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香港中環昃臣道8號立法會大樓
環境事務委員會秘書
余麗琼 女士

余女士：

<u>氣候變化顧問研究報告</u>

就環境事務委員會在 2010 年 9 月 22 日會議有關“香港應對氣候變化策略及行動綱領公眾諮詢”的跟進事宜，本署已經完成香港氣候變化顧問研究報告。現隨函附上 65 張載有顧問研究的行政摘要（中英文版）及研究報告（只有英文版）的光碟，供秘書處分發給各議員。

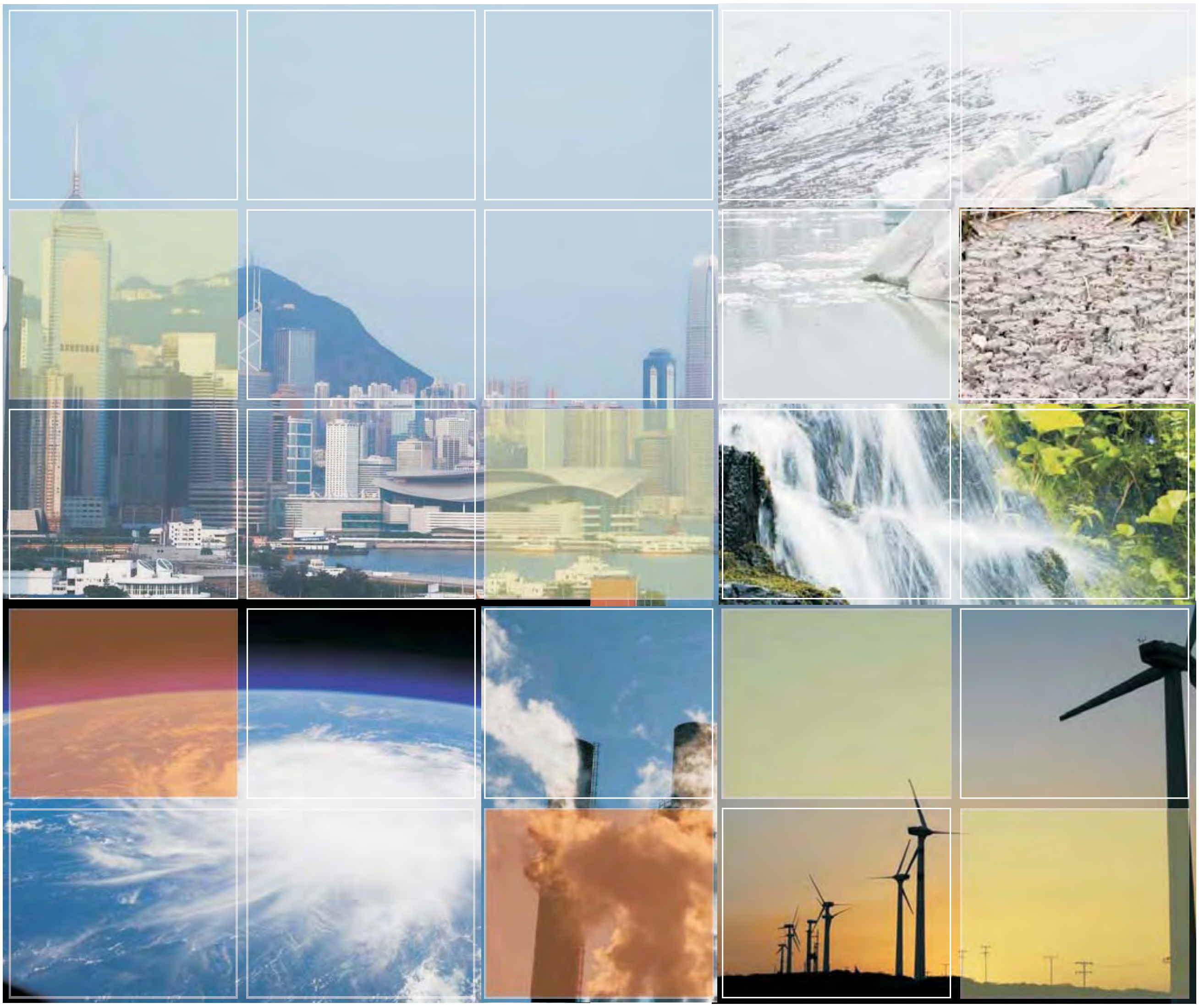
此外，亦附上3套印刷版的行政摘要及研究報告供秘書處作紀錄。

謝謝!

香港特別行政區政府
環境保護署署長
（王德威　　　　代行）

二○一○年十二月九日

行政摘要



環境保護署
Environmental Protection Department
The Government of the Hong Kong
Special Administrative Region

合約編號 *CE 45/2007 (EP)*
氣候變化項目研究

二零一零年十二月

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合約編號 CE 45/2007 (EP):
氣候變化項目研究

二零一零年十二月

檔案 0082487

香港環境資源管理顧問有限公司

批核： 溫志雄

簽署：

職位： 合伙人

日期： 二零一零年十二月三日

本報告由香港環境資源管理顧問有限公司，根據與顧客訂定之合約條款（其中包含本公司之通用合約條款），投入與顧客事先協定的資源，以適當的技巧細心謹慎撰寫。

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目錄

1 *概論：氣候轉變與香港*

背景

1.1 對於全球氣候變化的現象，各國已有廣泛共識，認爲必須通過國際間共同採取行動來避免對社會和下一代構成重大危機。

1.2 「聯合國氣候變化框架公約」（以下簡稱「公約」）於 1994 年 3 月生效，是一個整合各個締約政府在應對氣候變化挑戰的全面綱領。京都議定書（以下簡稱「議定書」）是基於該公約而簽定的國際協議書，旨在規範各個工業化國家（附件 I 國家），按照「共同但有區別的責任」的原則來控制溫室氣體排放量。該議定書於 1997 年 12 月通過，並於 2005 年 2 月生效，迄今已有 188 個國家和地區簽署。

1.3 中國是「公約」和「議定書」的締約方之一。根據該公約和議定書的規定，中國作爲非附件 I 締約方須履行下列責任：

- 收集和分享有關溫室氣體排放量、國家政策和最佳方法的資料；
- 實施全國性策略來處理溫室氣體排放，並適應預期的影響；及
- 與各方合作以準備適應氣候變化所帶來的影響。

1.4 中央政府在諮詢香港特區政府後，通知聯合國「公約」和「議定書」均適用於香港特別行政區，並於 2003 年 5 月起生效。香港特區政府於 2008/09 年度的「施政報告」中，承諾採取多種措施以及早準備應對氣候轉變所帶來的挑戰，其中包括：改善能源效益、採用潔淨燃料、減少依賴化石燃料，以及促使本港推行低碳經濟。在中央政府於 2009 年 11 月宣佈訂立國家自主行動目標後，香港特區政府亦爲 2020 年及以後的碳強度，積極考慮更進取的減碳目標。

目標

1.5 是次研究的整體目標，是要爲香港的氣候變化策略及措施提供基礎；以及提供所需資料，配合中央政府按照「聯合國氣候變化框架公約」要求進行國際間的溝通和合作。

1.6 是次研究的具體目標如下：

- 檢討和更新溫室氣體排放和清除**清單**，並推算未來趨勢；

- 評估各項減少溫室氣體排放量或增加其清除量的現有政策和措施，同時建議額外的政策和措施，並評估建議**減緩**措施的成本效益，以及在經濟、社會和環境方面的影響；

- 了解香港氣候變化可能造成的**影響**及其特點，並評估現有的應對策略和措施，以及建議額外策略和措施，以充分**適應**氣候變化；

- 就促進環保技術開發和應用，鼓勵探討氣候變化的科學研究和增加社會大眾**認識**，評估現有的及建議進一步的策略和措施。

方法

2.1 《聯合國氣候變化框架公約》之《京都議定書》要求已正式簽署議定書之非附件 I 締約方〔包括中國〕將溫室氣體排放清單作爲其國家信息通報的一部份。由於中國已經確認《京都議定書》，因此，香港特別行政區也需編寫溫室氣體清單。這份清單將會是中國提交予《聯合國氣候變化框架公約》的《締約方大會》的國家信息通報清單的一部份。

2.2 有關清單是遵從《締約方大會》的相關決定和國際間同意採用的方法而制訂。爲了進一步提高清單的準確性，在沒有香港的相關資料時，估算方法採用了最新版本的國際認可指引，即「2006 年政府間氣候變化專門委員會之國家溫室氣體清單指南」[1]。

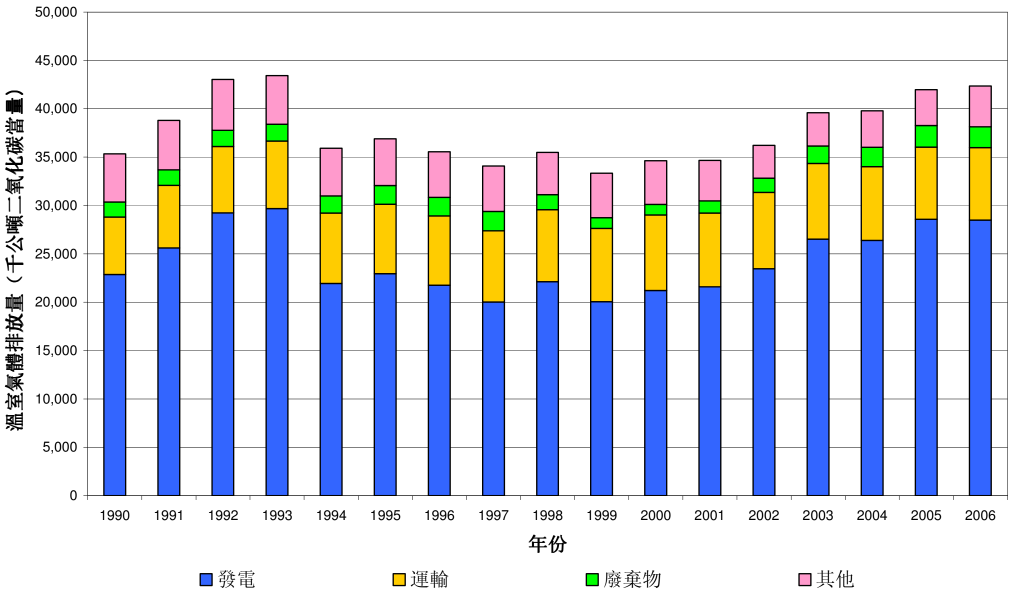
2.3 由於不同的溫室氣體會造成不同影響，因此，是次研究按照政府間氣候變化專門委員會指南和《締約方大會》的相關決定，以「全球增溫潛勢」(GWP) 來總括溫室氣體的排放情形。「全球增溫潛勢」是一種衡量特定溫室氣體對全球變暖的影响的尺度。這尺度是與同等重量的二氧化碳引致全球變暖的相對比率（其全球變暖潛能値爲１）。這是國際上被廣泛採用的方法，讓所有溫室氣體排放量都可以用二氧化碳當量（CO_2-e）的方式來表示。

香港溫室氣體排放的歷史趨勢（1990 至 2006 年）

2.4 *圖表 1* 展示了從 1990 年起，香港溫室氣體總排放量的趨勢。溫室氣體總排放量由 1990 年 3,530 萬公噸二氧化碳當量增加至 2006 年 4,230 萬公噸二氧化碳當量。 能源使用[2] 是主要溫室氣體排放的來源。在該段期間，能源使用排放出的溫室氣體平均佔每年總排放量約 93%。

2.5 *圖表 1* 和*圖表 2* 均展示了各個主要界別的排放量。從這些圖表可見，「發電」（約佔總排放量約 57 – 67%）和「運輸」（約佔總排放量 16 – 23%）是最具影響力的組別。除了在 1993 和 1994 年間由於從內地引入低碳核能取代本地燃煤發電廠的生產而有顯著跌幅之外，發電的排放量基本上一直在增加。

圖表1 *於1990-2006年期間各個主要界別的溫室氣體排放量*



圖表2　　　1990年至2006年按相關分組之香港溫室氣體排放量及其所佔百分比

年份	按界別細分之香港溫室氣體排放量（千公噸二氧化碳當量）[a]							按界別細分之香港溫室氣體排放量所佔百分比（%）						
	發電[b]	運輸	其他能源最終用途[c]	廢棄物	工業過程及產品使用	農業/林業及其他土地使用	合計	發電[b]	運輸	其他能源最終用途[c]	廢棄物	工業過程及產品使用	農業/林業及其他土地使用	合計
1990	22,900	5,940	4,620	1,550	215	141	35,300	64.7%	16.8%	13.1%	4.4%	0.6%	0.4%	100%
1991	25,600	6,470	4,360	1,600	638	123	38,800	66.0%	16.7%	11.2%	4.1%	1.6%	0.3%	100%
1992	29,200	6,870	4,500	1,660	651	100	43,000	68.0%	16.0%	10.5%	3.8%	1.5%	0.2%	100%
1993	29,700	6,970	4,200	1,750	724	87	43,400	68.4%	16.1%	9.7%	4.0%	1.7%	0.2%	100%
1994	21,900	7,270	4,030	1,770	830	77	35,900	61.1%	20.2%	11.2%	4.9%	2.3%	0.2%	100%
1995	23,000	7,180	3,810	1,940	935	85	36,900	62.2%	19.5%	10.3%	5.3%	2.5%	0.2%	100%
1996	21,800	7,170	3,680	1,900	952	86	35,500	61.2%	20.2%	10.3%	5.3%	2.7%	0.2%	100%
1997	20,000	7,340	3,590	2,000	1,060	75	34,100	58.7%	21.5%	10.5%	5.9%	3.1%	0.2%	100%
1998	22,100	7,430	3,330	1,550	977	70	35,500	62.4%	20.9%	9.4%	4.4%	2.8%	0.2%	100%
1999	20,100	7,570	3,470	1,120	1,020	85	33,300	60.2%	22.7%	10.4%	3.4%	3.1%	0.3%	100%
2000	21,200	7,800	3,450	1,110	977	78	34,600	61.2%	22.5%	10.0%	3.2%	2.8%	0.2%	100%
2001	21,600	7,640	3,220	1,250	862	85	34,700	62.3%	22.0%	9.3%	3.6%	2.5%	0.2%	100%
2002	23,400	7,890	2,800	1,490	503	82	36,200	64.8%	21.8%	7.7%	4.1%	1.4%	0.2%	100%
2003	26,500	7,810	2,830	1,800	538	74	39,600	67.0%	19.7%	7.1%	4.5%	1.4%	0.2%	100%
2004	26,400	7,640	3,060	1,990	636	67	39,800	66.3%	19.2%	7.7%	5.0%	1.6%	0.2%	100%
2005	28,600	7,480	2,770	2,220	867	74	42,000	68.1%	17.8%	6.6%	5.3%	2.1%	0.2%	100%
2006	28,500	7,480	2,730	2,140	1,380	74	42,300	67.4%	17.7%	6.5%	5.1%	3.3%	0.2%	100%

Notes:

(a)　千公噸二氧化碳當量的溫室氣體排放相等於一兆克二氧化碳當量。

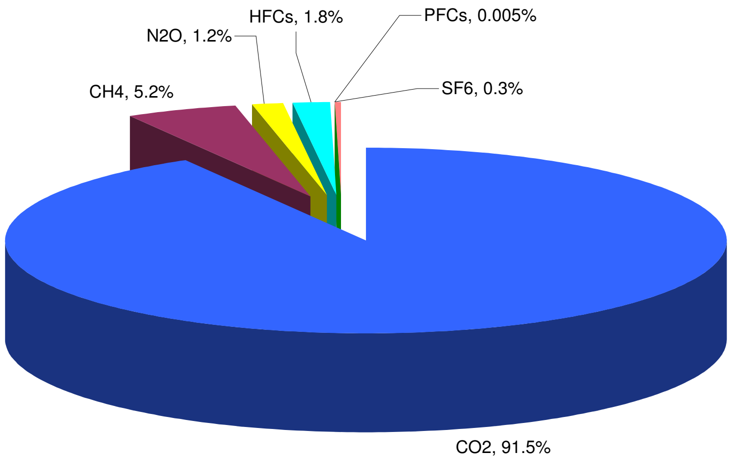
(b)　包括煤氣生產　–　佔能源生產的溫室氣體排放量約1%。

(c)　「其他能源最終用途」包括固體燃料的製造和其他能源工業，製造工業及建築，燃料的溢散排放和其他次要的組別。

2.6　除上述兩個組別以外，其次是「廢棄物」組別，平均佔每年總排放量約 4.5%。

2.7　在六種主要溫室氣體中，二氧化碳(CO_2)是最主要的一種，佔總排放量超過 90%。*圖表 3* 展示了 2005 年各類氣體排放的比例。

圖表3　2005年香港本地各溫室氣體排放比例



註：CO_2 – 二氧化碳；CH_4 – 甲烷；N_2O – 氧化亞氮；HFCs – 氫氟烴；PFC – 全氟碳；SF_6 – 六氟化硫

預估排放量（2005 至 2030 年）

2.8　倘若香港沒有控制溫室氣體排放的額外措施，預測排放量會按非線性形式，從 2005 年至 2030 年增加 7%。*圖表 4* 羅列了基本情況的一些主要指標和相關的估計排放量。

圖表4　主要指標：基準情形

	2005	2020	2030	2005-2020年總增長率 (%)	2005-2030年總增長率 (%)
人口（千人）	6,813	7,719	8,312	13	22
GDP (十億港元，按2005年物價計算) (1)	1,383	2,258	2,905	63	110
人均GDP（千港元）	203	293	349	44	72
一次性能源 (萬億焦耳) (2)	591,601	744,786	822,488	26	39
最終能源 (萬億焦耳) (3)	294,968	396,211	460,729	34	56
溫室氣體排放量 (百萬公噸二氧化碳當量)	42.0	46.1	44.8	10	7
一次性能源強度 (萬億焦耳／十億港元) (4)	428	330	283	-23	-34
最終能源強度 (萬億焦耳／十億港元)	213	175	159	-18	-26

	2005	2020	2030	2005-2020年總增長率 (%)	2005-2030年總增長率 (%)
人均碳排放量 (公噸二氧化碳當量）[5]	6.16	5.97	5.39	-3	-13
碳強度（千克／港元）	0.0304	0.0204	0.0154	-33	-49

附註：

(1) 各個GDP推測數值均基於可獲取的對經濟進行預測的假設。應予注意的，是從2014年起，各個假設增長率的不確定程度都較大。

(2) 一次性能源是指在大自然中發現的能源，尚未經過任何轉換或轉化過程。一次性能源的例子包括：煤、原油、陽光、風、河流、植物和鈾。

(3) 最終能源是指最終使用者因爲各種涉及能量的用途而所消耗的能量，例如升溫、煮食和驅動機器，但不包括非能量的用途，例如以煤油作爲溶劑。它與一次性能源的分別在於，後者包括在能源轉化和分配過程中所使用或消失的全部能量。

(4) 能源強度是量度一個國家的經濟能源效益的尺度。它以每單位GDP所使用的能源單位來表示。

(5) 是次研究的碳強度是以每單位GDP的總溫室氣體排放量計算。

3 *溫室氣體排放之減緩*

引言

3.1 一般意見認爲，若要扭轉氣候變化所帶來的最壞後果，必須減少溫室氣體的排放。根據本地的常見情況和不同界別的考慮，可以採取多種措施來減少排放量。其中包括直接減少特定源頭的排放量，以及廣泛地採用具能源效益的技術和方法。

減緩措施

3.2 由於香港所排放的溫室氣體中，有超過 90%來自能源供應、樓宇和運輸所用能源，以及來自堆填區。因此，這些界別有最大潛力協助進一步減緩溫室氣體排放問題。篩選有關政策和措施的主要標準包括：

- 技術可行性；
- 低成本或者零成本；
- 共同效益的最大化；
- 適合研發。

3.3 是次研究檢討了本地及國際上的溫室氣體減緩措施，並根據檢討結果和主要篩選標準，找出了下列各項可行措施，適合香港於 2030 年前考慮實施的可行性[3]。

(a) <u>樓宇及設備</u>

- 擴大《建築物能源效益守則》的適用範圍，並收緊該守則的現有規定，藉以改善商業樓宇主要電力設備的能源效益（例如照明和電梯）。推廣區域供冷或水冷式空調系統的使用，藉以提高空調效益，以及降低總熱傳送值[4] 標準，及推廣綠化屋頂等，藉以減少樓宇的用電需求；
- 擴大家用電器能源效益標準的適用範圍，並收緊有關標準；
- 透過良好的管理、採用資訊科技產品和智能樓宇環保管理系統，改善商業樓宇的能源效益。

(b) <u>運輸</u>

- 推廣使用另類燃料車輛，包括混合動力和電動車輛；

- 在車用汽油中加入乙醇 – 含有一定百分比乙醇的汽油；

- 在車用柴油中加入生化柴油 – 含有一定百分比生化柴油的車用柴油；

- 實施香港的「進口商車隊平均能源效益」標準[5]。

(c) <u>廢物</u>

- 發展綜合廢物管理設施和有機廢物處理設施，以便從都市固體廢物中回收可再生能源；

- 充分利用已回收的堆填區沼氣來產生能源；

- 充分利用從廢水處理過程中收集到的氣體來產生能源；

- 充分利用污泥處理來產生能源。

(d) <u>發電</u>

- 在本地使用更多天然氣發電；

- 增加使用可再生能源;

- 增加從內地輸入核電。

基準情形及減緩情形

3.4 是次研究主要通過對一系列假設情景進行定量分析來探討相關的減緩措施，以便支持相關政策方案的擬定。在分析過程中，採用了一個綜合能源、經濟和環境的模擬架構，即香港 MARKAL-MACRO 模型。這個模型不但包含了能源系統中各個階段的互動情況，亦可以對多種能源和技術進行分析；還可以評估經濟上的綜合影響。超過 60 個國家（包括中國）都採用了各國本身的 MARKAL-MACRO 模型來分析溫室氣體的減緩措施。

3.5 在模擬過程中設定了一個基準情形，以便對不同的政策方案或假設情景作出比較分析，藉此瞭解各方案的相對優、缺點。基準情形代表一個「如常運作」的情況。換言之，除了在 2005 年時已經存在和已作承諾的政策外，沒有增加任何額外措施。

3.6 此外，是次研究也設定了三個其他情景，以便評估它們對基準情景的影響：

- **情景 1（〝香港空氣質素指標〞情景）**包含了「香港空氣質素指標研究」[6]所建議的相關減緩措施，其中包括：更多使用天

然氣和可再生能源發電，推廣使用清潔能源的車輛，以及改善樓宇及設備的能源效益。

- **情景 2（加速方案）**是在假設情景 1 之上再加入額外的措施，藉以增加能源效益和減少能源需求，特別是在樓宇和運輸界別。在 2020 年以前充分利用本地的可再生能源，例如轉廢爲能設施。這個情形也假設香港和鄰近地區的電力系統繼續維持一定程度的結合。在 2020 年時，從內地輸入的電力數量與 2005 年相同。在 2030 年時，假設香港所使用的電力無論是在本地發電，還是從內地輸入，有 50%不會造成碳排放[7]。

- **情景 3（進取方案）**是基於假設情景 2，並加快結合香港和鄰近地區的電力系統。它假設在 2020 年時，香港每年會充分利用在有關能源合作備忘錄基礎上獲內地承諾提供的天然氣，以作發電之用。它亦假設在 2020 年時，香港會從內地輸入的核能，足以應付 50%的本地電力需求。

排放量減少與碳強度

3.7 每個假設情景和基準情景在規劃期間的溫室氣體減幅，均羅列於*圖表 5*，並在*圖表 6* 說明。

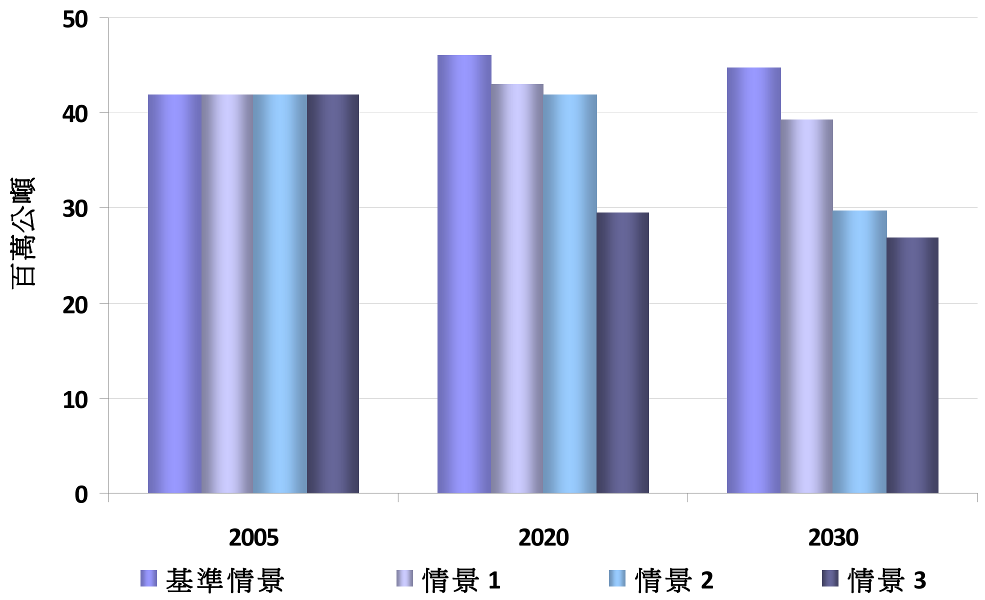
圖表5 *各個假設情景之香港溫室氣體排放量（百萬公噸二氧化碳當量）*

	2005	2020	2030	2020年與2005年比較	2030年與2005年比較
基準情景	42.0	46.1	44.8	10%	7%
情景1	42.0	43.0	39.3	2%	-6%
情景2	42.0	41.9	29.8	0%	-29%
情景3	42.0	29.5	26.8	-30%	-36%

3.8 在基準情景中，預測總碳排放量會隨時間而增加。至於情景 1，溫室氣體排放量在規劃期間雖然有所減少，但並非特別有效，只會減少 6%。模擬結果顯示，雖然專門處理空氣質素問題的策略能夠在減少溫室氣體方面帶來協同效應，但仍需實施更多有關措施。

3.9 情景 2 和 3 在規劃期間的排放量都大幅減少，其中以情景 3 最快達到減排目標。

圖表6 *各個假設情景之香港溫室氣體排放量（百萬公噸二氧化碳當量）*



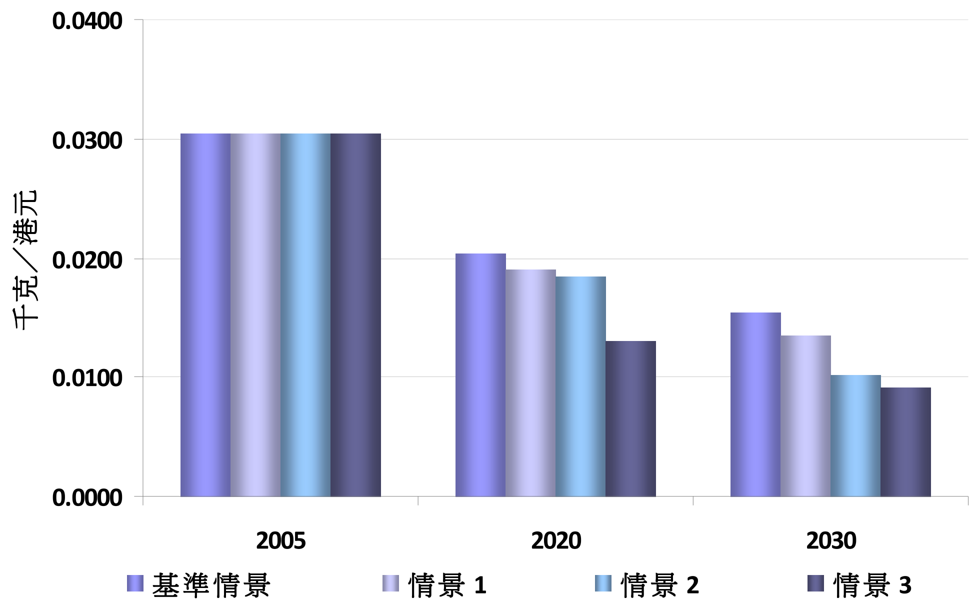
3.10 根據預測，基準情景中的本地生產總值（GDP）平均年增長率爲3.01%，而在各個假設情景中亦不會受到重大影響。造成這種現象有多個原因，包括促進能源效益的措施等，因而在長遠而言，節省了能源成本[(8)]。

3.11 按每單位 GDP 的溫室氣體排放量來表達的碳強度在 2020 年時，會比 2005 年時基本情況的水平減少 37%（情景 1）至 57%（情景 3）；在 2030 年時，會比 2005 年時基本情況的水平減少 56%（情景 1）至 70%（情景 3）。規劃期間的趨勢，均展示於*圖表 7* 和 *8*。

圖表7 *碳強度（每單位GDP之溫室氣體排放量，千克二氧化碳當量／港元）*

	2005	2020	2030	2020年與2005年比較	2030年與2005年比較
基準情景	0.0304	0.0204	0.0154	-33%	-49%
情景1	0.0304	0.0189	0.0135	-37%	-56%
情景2	0.0304	0.0185	0.0102	-39%	-66%
情景3	0.0304	0.0130	0.0091	-57%	-70%

圖表8　　*碳強度（每單位GDP之溫室氣體排放量，千克二氧化碳當量／港元）*



3.12 預測到 2020 年，情景 1、2 和 3 的人均碳排放量，會從 6.2 公噸分別減少至 5.6、5.4 和 3.8 公噸二氧化碳當量。到 2030 年時的相應預測數字則分別爲 4.7、3.6 和 3.2 公噸人均二氧化碳當量。

3.13 內地於 2009 年 11 月宣佈了一個與能源有關的碳強度自主目標，計劃於 2020 年時的碳強度水平比 2005 年減少 40%至 45%。在把 MARKAL-MACRO 模型和經濟預測的不確定性納入考慮後，預計情景 3 的碳強度會在 2020 時減少 54%至 60%(9)。

3.14 由於情景 3 能夠令碳強度大幅減少，所以是最可取的情況。若與其他假設情景相比，情景 3 在 2005 年至 2020 年間的溫室氣體排放量也有顯著減幅，而且，到 2030 年時比假設情景 2 的減幅更大。*圖表 9* 總結了可以協助情景 3 達到碳強度減幅的主要措施，以及在 2020 年和 2030 年時，這些措施的可能進展。

3.15 若要情景 3 的碳強度和溫室氣體排放量在 2020 年時達到預測減幅，便需要大幅和快速地重新調整發電燃料的組合，並對輸電基礎設施作出相應投資。由於這些基礎設施的規劃和建造，以及取得相應的能源供應，都需要一段時間才能完成，因此，若要確保在 2020 年時能夠達到國家的政策目標，必須及早實施這些措施。此外，也必須加快提高能源效益的步伐；這需要社會上不同界別的支持和參與，以及有利的經濟環境的配合。

圖表9　協助情景3達到碳濃度減幅的主要措施以及在2020年和2030年時這些措施的可能進展

措施	情景3		
樓宇及設備 (1)	2020		2030
擴大《建築物能源效益守則》適用範圍及收緊該守則的規定	所有新建商業樓宇主要電力設備的能源效益提高至多達50%		所有新建商業樓宇主要電力設備的能源效益提高至多達50%
推廣區域供冷或水冷式空調系統	全港多達20%的商業樓宇的空調效益，較使用一般空調機提高多達50%；		所有商業樓宇的空調效益，較使用一般空調機提高多達50%；
降低總熱傳送值標準及推廣綠化屋頂	所有新建商業樓宇的用電需求減少多達50%		所有新建商業樓宇的用電需求減少多達50%
擴大家用電器能源效益標準的適用範圍及收緊有關標準	在市面出售的所有電器的能源效益較2005年提高25%		在市面出售的所有電器的能源效益較2005年提高50%
透過良好的管理、採用資訊科技產品和智能樓宇環保管理系統，改善商業樓宇能源效益	25%現有商業樓宇的能源效益提高15%		所有現有商業樓宇的能源效益提高15%
運輸			
更廣泛地使用另類燃料的車輛	混合動力／電動或環保績效相若的車輛：30%在用私家車、15%巴士、15%貨車		混合動力／電動或環保績效相若的車輛：50%在用私家車、50%巴士、50%貨車
車用汽油混有10%乙醇 (E10)	所有車用汽油均混有10%乙醇		與2020年相同
車用柴油混有10%生化柴油 (B10)	所有車用柴油均混有10%生化柴油		與2020年相同
實施車隊平均能源效益標準	新車的能源效益較2005年市面車輛的平均能源效益提高20%		與2020年相同
廢物			
建設轉廢爲能設施	一座日處理達3,000公噸的綜合廢物管理設施；兩座有機廢物處理設施全面投入運作，總日處理達400公噸		有充足的綜合廢物管理設施處理全香港所有都市固體廢物；兩座有機廢物處理設施全面投入運作，總日處理達400公噸
利用堆填區氣體	充分利用回收到的堆填區沼氣		充分利用回收到的堆填區沼氣
利用廢水處理過程中所產生的氣體	充分利用		充分利用
利用污泥處理產生能源	一座污泥處理設施全面投入運作		一座污泥處理設施全面投入運作
發電	2005	2020	2030
燃煤發電	大約50%	不多於10%	0%
天然氣發電	大約25%	大約40%	大約50%
內地輸港核電	大約25%	大約50%	大約50%
可再生能源 (2)	少於1%	3%至4%	3%至4%

措施	情景3

附註：

(1) 是次研究的目的，是要評估各種減緩措施和情況對減少溫室氣體排放量的影響。有關各種減緩情況下的措施和假設，均以國際技術及政策的檢討結果爲依據。它們並非實行時必須要達到的目標，而只是一個參考範圍，以便推測不同假設可能造成的影響。在研究的稍後階段，必須對各項具體措施再作詳細的研究，考慮這些措施在香港實施的限制、不確定性和可行性。

(2) 可再生能源包括風能，以及堆填區沼氣、綜合廢物管理設施和有機廢物處理設施產生的能源。

背景

4.1 根據「政府間氣候變化專門委員會」第四次評估報告所述，在過去的一個世紀內，即從 1906 年至 2005 年期間，全球平均氣溫上升了 0.74 ℃（基於 100 年線性趨勢）。同時，預測未來二十年的氣溫，每十年會上升 0.2 ℃。根據該報告的評估結果，縱使在最樂觀的電腦氣候模擬情景中，到了 2100 年時，全球平均氣溫也會上升 1.8 ℃ 至 4.0 ℃。海平面上升是由氣候變化帶出的另一項重要影響。根據「政府間氣候變化專門委員會」第四次評估報告所述，衛星和潮汐數據顯示，從 1961 年起，全球平均海平面每年上升 1.8 毫米；而從 1993 年起，上升速度更達至每年 3.1 毫米。

對香港的影響

4.2 是項研究亦評估了氣候變化對香港的影響。此評估是根據「政府間氣候變化專門委員會」第四次評估報告的科學原理和香港天文台出版的刊物而擬定一些氣候情景，從而評估香港在氣候變化中可能受影響的地方。

4.3 在 120 多年前，香港天文台已開始有系統地觀察各種氣候變量。在這段期間觀察到多種天氣模式都出現了變化，特別是在過去 60 年間，外地所觀察到的多項主要氣候影響，在此期間本港同樣錄得這些變化。此外，氣候變化將會對香港經濟的多個界別和分組造成多種不同程度的影響。*圖表 10 和 11* 分別羅列了香港的氣候觀察結果，以及預計會出現的未來氣候變化情景之影響。

圖表10 *香港的氣候觀察結果（香港天文台）*

變量	**氣候變化觀察結果**
年平均溫度	每十年上升0.12 °C (1885-2009年)
平均每日溫差	每十年減少0.24 °C（1947-2009年）
在6至8月間的熱夜（即最低溫度 ≥ 28 °C）數目	每十年增加3.5晚（1947-2009年）
在12至2月間的寒冷（即最低溫度 ≤12 °C）日數	每十年減少2.3日（1948-2009年）
年降雨量	每十年上升51毫米（1947-2009年）
雷暴日數	每十年上升1.8天（1947-2009年）
暴雨（一小時雨量超過30毫米）日數	每十年上升0.4天（1947-2009年）
平均海平面（維多利亞港）	每十年上升26毫米（1954-2009年）

圖表11　　預計在2100年時之預估氣候因素變化（香港天文台）

變量	現況	影響	下限	上限	信度水平
十年平均年溫度（°C）	23.1	27.9	24.5	32.3	高
在6至8月間的熱夜數目	12.2	41.2	22.0	68.7	中－低
在6至8月間的酷熱日數（即最高溫度≥ 33 °C）	8.2	15.3	9.6	23.5	中－低
在12至2月間的寒冷日數（即最低溫度≤12 °C）	16.3	<1	<1	<1	中－低
年降雨量（毫米）	2383	2572	1763	3235	低
每年暴雨日數	6.1	6.5(*)	2.5(*)	8.3(*)	低
年降雨量<1282毫米的年份	2(#)	3.6(+)	未界定	未界定	低

註：

除特別註明外，在現況下的變量的參考期間爲1971-2000年，而影響、下限/上限的變量的參考期間爲2090-2099年。

*: 2070-2099年

#: 1885-2008年

*: 2010-2099年

以上預測會按最新科學數據及資料更新。

香港之主要脆弱範疇

4.4　是次研究根據上述預計未來的氣候情景，按照下列四個階段進行了脆弱性評估，務求找出主要界別的脆弱性：

1. **外界影響及敏感程度分析：**這個階段找出了各個界別的系統／受體可能會受到外界的影響（即背景氣候情況和變化），以及各個系統／受體對這些影響的敏感程度。

2. **識別潛在後果：**這個階段爲第一階段所找出的外界影響和敏感程度識別出潛在後果。

3. **氣候變化影響及脆弱性評估：**這個階段全面檢視了各個系統／受體在面對氣候變化的潛在影響時的脆弱程度，亦即各系統的受影響程度、它們對變化的敏感程度，以及它們的適應能力。

4. **找出「關鍵」脆弱範疇：**根據上述各階段的結果，找出香港主要的易受影響界別。

4.5　這是香港首個氣候變化脆弱範疇的全面評估。在對潛在風險最高的範疇進行評估時的依據包括：有關範疇的現有知識、從「政府間氣候變化專門委員會」第四次評估報告能夠取得的資料，以及顧問和專家的相關判斷。應予注意的，是在評估各個系統時，能夠取得的資料在質和量方面都各有不同。而且，第四次評估報告內的資料亦有不確定性和受局限的情況，因此脆弱範疇評估的結果也會受到相若影響。舉例而言，生物多樣化程度在面對氣候變化時的反應，其不確定程度會比其他受管理程度極高的系統，例

如建築環境和基礎設施等較高。當一個界別欠缺本地科學數據來配合以研究爲主的方法來評估該界別的脆弱程度和適應能力時，顧問公司都採用了專家的判斷來決定風險評級，例如「衞生健康」界別的風險評級。

4.6 評估結果顯示，下列八個主要界別受氣候變化影響的脆弱程度屬於「高」：

- 生物多樣性和自然保育；
- 建築環境和基礎設施；
- 商業和工業；
- 能源供應；
- 金融服務；
- 食物資源；
- 衞生健康；及
- 水資源。

氣候變化會對上述界別造成不同程度的影響。*圖表 12* 展示了各個「主要」脆弱界別的預計影響。

圖表 12 *「主要」脆弱界別的預計影響舉例*

「主要」脆弱界別	預計影響
生物多樣性和自然保育	• 氣候變化會令生物多樣性受損更多，而入侵的物種亦會增加集群定居 • 由於極端天氣的出現頻率及／或嚴重程度增加，林地和珊瑚群落受損 • 由於表面溫度增加，物種分布／出現／遷移模式有所變化
建築環境和基礎設施	• 海平面升高的幅度和速度都非常不確定 • 位於低窪地區／填海地區的發展項目對氣候變化都非常敏感 • 大雨和雷暴亦可能導致建築物地基鬆軟、雨水滲入建築結構的程度增加，以及損毀公用設施纜索和喉管 • 受水浸、山泥傾瀉、風害、風瀑潮、雷電等影響，可能會導致資產損失

「主要」脆弱界別	預計影響
商業和工業	• 本界別範圍廣泛，因此，行業內會感受到多種不同類型的影響 • 香港高度依靠國際貿易、金融市場、從境外入口主要產品和服務，因此我們需額外承受氣候變化對其他地方所引致的影響 • 因氣候變化對食物及水資源、運輸及基礎建設等其他方面的影響而變得更脆弱 • 保險費用增加
能源供應	• 電力供應中斷多半會帶來經濟和社會成本。此外，發電、供電及整體能源供應易受氣候變化影響 • 供應鏈沿線所受到的影響和氣候變暖的影響都非常不確定 • 因表面溫度上升，空調和冷凍的需求量會增加，可能會引致電力供應中斷或電力需求驟升 • 極端天氣事件的次數及／或嚴重程度增加，造成水浸、雷擊及山泥傾瀉的風險，令電纜及其他資產受損
金融服務	• 因通訊和電腦系統易受風暴、電力故障和電壓驟升的影響，令金融服務界別承受直接風險 • 因個人業務和投資的風險狀況有所改變，令此界別間接受到影響 • 部分金融服務環節，例如保險業，會受較大影響 • 這個界別可能會因爲其他範疇（例如基礎設施）受到影響而受影響
食物資源	• 極端天氣事件會減少農作物產量，令輸港食物減少，造成商品價格上升 • 溫度上升會令到害蟲數量和病害率增加，影響禽畜種類，並令入口數量下降，價格上升
衛生健康	• 預計氣候變化會對易受影響的人造成不同程度的影響 • 氣候變異會使慢性健康問題惡化，例如心血管和呼吸系統疾病 • 氣候變異可直接導致熱負荷、哮喘惡化及中暑 • 極端天氣事件的次數及／或嚴重程度增加，會引致更多意外和緊急情況，例如風暴、水浸、旱災及氣漩等 • 氣候變化可能引致傳染病傳播模式改變

「主要」脆弱界別	預計影響
水資源	• 未來降雨量若不確定，可能影響水源 • 水源供應可以是受制於實質環境或合約條件 • 雨量的分布變化和整個區域對食水的需求量上升，可能影響供水的持續性 • 表面溫度上升，令消費者對水的需求量增加 • 因海平面上升，可能導致淡水層鹽漬化

4.7 上述各界別的脆弱程度是由多種因素造成，其中包括：

- 會受廣闊的地域影響，因爲它們非常依賴入口，因此，不但會受到香港氣候變化的影響，還會受到世界其他地方的氣候變化影響。
- 對氣候因素高度敏感，所以必須倚賴中期至長期的穩定氣候或設定只能在氣候變化較少的情況下運作，。
- 這些界別受干擾的後果亦較嚴重，因爲香港很多社會經濟活動都依賴它們的產品／服務。
- 會受影響的時間較長，因爲要作出這些界別的投資／基建決定需較長的籌備時間。
- 依賴很多基礎設施，其中有很多潛在失靈的地方，因爲這些界別需要很多基礎設施的輔助，其中有很多範疇可能會受氣候變化的影響而失靈。
- 與其他界別的關係複雜，因爲它們與社區內的其他界別有廣泛聯繫。
- 未能應付現時發生的極端天氣情況，例如：香港在 2008 年 6 月 7 日受到暴雨和雷暴影響，令北大嶼山公路自 1997 年啓用以來首次受到山泥傾瀉堵塞，而在大澳的山泥傾瀉亦對交通，供水和電訊服務造成嚴重中斷，並令香港多個地方出現水浸。此外，在 2008 年 9 月當颱風黑格比襲港時亦令大澳受到海水淹浸。

4.8 在本報告的準備期間，「政府間氣候變化專門委員會」已在準備第五次評估報告，預計會於 2015 出版。多項工作都已經展開，包括爲進行影響、適應和脆弱性評估而擬訂新的假設情景。由於有關氣候變化的科學發展很快，因此，應該把脆弱性評估視爲一個動態過程，並應不時檢討和更新評估結果，特別是這類評估本身便存在高度的不確定性。

香港現時的適應能力

4.9 對於部份氣候變化所帶來的後果，香港已經具備相當不錯的適應能力。其中包括下列各項：

- 由保安局負責政府整體應變計劃，應付各項天災或緊急情況。

- 不同政府部門或服務供應商已制定監測或應急機制，處理山泥傾瀉、水浸、或針對受到惡劣天氣影響的危險建築物（包括招牌）、銀行服務、電訊服務、公共運輸服務、能源供應、主要糧食供應(如大米和小麥粉)等。

- 工務部門已在 1990 年制定指引，在相關的政府工務工程中考慮海平面可能每年上升 10 毫米，以應對氣候變化可能帶來的影響。

- 政府有爲市民提供緊急支援服務，援助受緊急事故、惡劣天氣影響的市民。

- 因應氣候變化和極端天氣事件，政府亦已設立不同的警告系統，例如熱帶氣旋、暴雨、酷熱天氣等警告系統。

- 透過監察計劃，有關部門密切監察生態或物種、害蟲例如白紋伊蚊、水資源等的情況。

這類政策可能需要加強，或者需要把啓動其他政策的氣候門檻降低。此外，亦應該考慮爲這類因應氣候情況而爲市民提供保護的政策和措施增加資源，以便能更好地回應氣候的變化。

適應方案

4.10 是次研究檢討了香港與及其他國際城市，包括倫敦、新加坡、東京和紐約等的現有適應政策和措施，藉以找出下列各項可以適應氣候變化的方案：

- 香港八個已知對氣候變化最脆弱的界別所需採取的行動。

- 可以爲決策提供所需資料的跨界別行動，例如研究等，以及能令市民更加了解氣候變化如何影響香港的活動和處理這些影響的適應行動。

- 設立跨部門組織，以確保各項制度安排和政府部門都在協調政府的應對氣候變化工作。同時，必須定期檢討這些制度安排，並視乎需要加以重整，以確保政府的決策已經考慮有關氣候變化的最新科學進展。

4.11 界別層面的氣候變化適應方案可以分爲下列各大類：

- **研究及調查** – 需要在多個範疇拓展有關各個脆弱界別的現有知識，包括：爲各種改善措施定立優先次序、找出本地的高風險範疇、更新過時的資料，以及評估和檢視各種潛在影響和效應。

- **監察** – 建造基礎監察制度，以便增加有關主要界別狀況的知識，同時加強檢討和修訂現有計劃。這類措施可以包括定期檢討各項監察計劃，並觀察和追踪相關的經濟、環境和社會指標的變化。

- **強化制度及提高能力** – 加強機構應對及適應氣候變化帶來不良影響的能力，其中包括：在現行管理架構中加入氣候變化的知識、評估發展策略上的潛在風險和機會，以及概述各個主要界別在運作上的所受到的潛在影響。

- **災難管理及應變計劃** – 改善負責應對緊急情況的各種規劃和各個系統。這些改善措施包括：強制擬訂緊急應變計劃的措施、擬訂應急計劃和檢討現行災難監察及應變系統。

- **教育及提升公眾意識** – 提高市民對氣候變化的認識，以令他們能夠採取適當行動來應對氣候變化的影響。這些措施包括：推廣氣候變化影響評估和相關知識、提供資料闡述氣候變化對各個行業和界別可能造成的影響，以及教導最易受影響的社群怎樣爲氣候變化作出最好的準備和回應。

*圖表13*羅列了特區政府及本港相關持份者可以採納的界別適應方案。

圖表13　香港受氣候變化影響之主要脆弱界別及適應方案例子

適應方案類別	主要脆弱界別	建議適應方案例子
(a) 研究及調查	• 生物多樣性和自然保育	• 爲風險最高的物種／生境／生態系統擬訂優先次序 • 訂立物種的下限數目，尤其是具有保育重要性的物種
	• 建築環境和基礎設施	• 找出可能受氣候影響的瀕危基礎設施 • 更新洪水風險地圖
	• 金融服務	• 檢視把保險公司在氣候風險管理方面所發揮的功能予以擴充的可能性，以及檢視保險業界和規管部門的法律角色 • 爲處於易受災害影響地方的各類基建及資產，探討提供氣候保險保障，並探討保險行業在處理氣候風險的法律職責

適應方案類別	主要脆弱界別	建議適應方案例子
	• 食物資源	• 檢視食物供應鍊可能受到的影響，食物危害及探討各個易受影響組別可能面對的影響
	• 衛生健康	• 探討易受影響組別健康及營養的影響
	• 水資源	• 評估水供應鍊各部份可能受到的影響
(b) 監察	• 生物多樣性和自然保育	• 定期檢討和修訂監察計劃
	• 能源供應	• 監察能源需求和供應模式的變化，藉此找出由氣候變化造成的趨勢
	• 食物資源	• 監測主要食品價格及令其波動的因素，並留意與香港主要食物進口地區有關氣候變化對農業影響所進行的研究
	• 衛生健康	• 建立監測系統，觀察極端氣溫對本地人口健康及食物安全的影響及不同群組的影響 • 建立監測系統，監測害蟲擴散對公共衛生的重大影響
(c) 強化制度及提高能力	• 建築環境和基礎設施	• 開發及使用氣候風險評估工具，篩檢未來發展項目，以盡可能減低氣候變化構成的潛在風險 • 定期更新及調整（如需要）建築物及基礎設施的建造相關守則及設計標準 • 制訂洪水及山泥傾瀉風險策略，以增強對極端天氣事件及海平面上升的適應能力
	• 商業及工業	• 發展一套評估香港工商界可能受氣候變化影響的工具
	• 能源供應	• 定期檢討能源需求和供應模式可能出現的變化 • 電力公司在定期檢討及預測能源供求時，考慮最新的氣候變化預測及相關影響 • 分散能源供應者及來源 • 為整個能源供應鏈所面對的氣候風險及挑戰，作出評估及採取行動，包括燃料來源、運輸供應、生產及分配電力的設施等環節所面對的風險
	• 金融服務	• 鼓勵公司向規管者／投資者披露氣候變化所帶來的金融風險，以及回應就這些風險所進行的行動。
	• 食物資源	• 為保障食物供應上妥善安排相關責任

適應方案類別	主要脆弱界別	建議適應方案例子
	• 水資源	• 從區域角度考慮氣候變化對水資源的影響 • 定期檢討香港的全面水資源管理策略
(d) 教育及提升公眾意識	• 建築環境和基礎設施	• 推廣綠化屋頂
	• 商業及工業	• 鼓勵工商界進行氣候影響評估
	• 金融服務	• 促使保險界和銀行界提高有關氣候變化的認識，並考慮相關的風險和商機，藉此檢視這兩個行業可能受到的影響
	• 食物資源	• 鼓勵業界作出持續運作規劃
	• 衞生健康	• 教導醫護界對相關疾病的知識
	• 水資源	• 提倡節約用水
(e) 災難管理和應變計劃	• 商業及工業	• 要求本港主要工商機構制訂計劃，在氣候變化可能引致的惡劣情況下維持正常運作
	• 能源供應	• 將氣候變化有關的風險和挑戰納入應變計劃
	• 食物資源	• 爲應付突發的糧食短缺，制定緊急應變管理計劃
	• 衞生健康	• 定期檢討預警及警報系統，監測系統和應急服務 / 應變計劃
	• 水資源	• 不時覆檢乾旱應變計劃

4.12 除了界別層面的適應方案之外，本報告亦建議了一些跨界別適應措施，包括進行氣候變化研究，以填補在氣候變化科學方面的主要數據不足，並廣泛地傳播有關氣候變化的課題，以促進市民大眾對社會上各種脆弱範疇及其適應措施的了解。

4.13 應予注意的，是這些方案都是基於目前對氣候變化的了解而擬訂，因此必須定期檢討，並按照科學的發展予以更新。特別是「政府間氣候變化專門委員會」已在準備第五次評估報告，預計會於 2015 出版。屆時，有關氣候變化對不同界別可能造成的影響，將會有更詳細的分析。所以，應該根據最新的發現擬定新的或修訂的應對策略。

4.14 若要實施各個建議適應方案，政府和其他相關持份者可能都需要付出額外成本。因此，建議在推行這些措施前，應該先評估其影響、可行性，以及成本和效益。

5 *配合活動*

5.1 是次研究檢討了香港現時有關氣候變化的研究和其他計劃，並建議考慮採取下列行動。

5.2 **研究** – 目前各界尚未清楚了解氣候變化對本地的影響；其中嚴重缺乏研究數據的範疇包括本地的海洋變化、生物多樣性和對人類健康的影響。因此更多政府和私人資金應投入到有關氣候變化的研究中，以彌補目前欠缺的主要數據。

5.3 **系統性的觀察** – 香港天文台現時正進行多項有關天氣的觀測。然而，其他政府部門例如環境保護署（環保署）和漁農自然護理署（漁護署）有需要加強對生物多樣性，以及對陸地和海洋環境進行長期監察，。

5.4 **技術轉移和提高能力** – 爲了減少溫室氣體排放量，香港可以專注於有關氣候變化的技術轉移以及提高有關的能力。政府亦可以鼓勵香港的清潔發展機制，以及協調和促進與氣候變化相關的技術轉移，例如電動車輛和樓宇能源效益技術等。此外，政府的支持更可以包括促進資訊分享、提供資助，或成立有關機構來爲減排方法進行認證。

5.5 **公眾認識** – 有需要引入更多教育和培訓計劃，以便增加公眾認識並鼓勵市民支持，及爲相關立法和投資形成共識。例如業界研討會等培訓可以鼓勵相關機構擬訂有關氣候變化的業務策略。此外，亦可在學校課程內納入有關氣候變化的題目，令年輕一代更加了解氣候變化的後果。同時，加強與非政府組織的合作也可以增加本港市民對氣候變化的認識。

5.6 **國際／區域合作** – 香港應該加強與國際和區域組織的合作，共同應對氣候變化。香港在多個範疇上都可以發揮作用，例如能源效益和能源研究；亦可以投資於綠色技術和碳交易市場上。香港應該與珠三角城市、世界各大城市和區域伙伴（亞太經合組織）持續合作，並參與處理氣候事宜的具體行動。此外，應鼓勵分享有關海洋變化的知識、相關研究的結果和水浸風險的應對策略。例如香港已經加入由鹿特丹帶領，並由上海、倫敦和紐約等城市參與的「連結三角洲城市」行動，分享有關管理三角洲的知識和技術。

5.7 **商業活動** – 由於在香港運作或由香港管理的公司尚未清楚氣候變化對其影響，因此大都沒有把有關問題作爲其業務計劃或風險管理的重點之一。爲了填補這方面的資訊缺失，政府及／或私營機構都應該資助更多研究，探討氣候變化對各行業的潛在影響。

6 總結

6.1 是次研究根據「2006 年政府間氣候變化專門委員會之國家溫室氣體清單指南」所闡述的最新方法，檢討和更新了香港的溫室氣體清單。

6.2 香港現正朝著低碳經濟的方向發展。爲了進一步減緩香港的溫室氣體排放量，是次研究建議一系列溫室氣體減排措施以作進一步分析。在情景 3（進取方案）中，減排措施能夠在 2020 年將香港的碳強度減少 54-60%；至 2030 年時，總碳排放量則減少約 36%。

6.3 這個策略的重點將要求：

(a) 實施減緩措施

- 運輸－透過改善能源效益和使用低碳燃料，例如從廢棄煮食油提鍊而成的生物柴油等，藉此減少道路運輸的碳足印；
- 廢物－充分利用堆填區沼氣作爲能源之一，並建造轉廢爲物設施；及
- 能源效益－廣泛地改善能源效益，特別是建築環境和電器的能源效益。

(b) 改變發電燃料的組合

- 大幅增加低碳或無碳燃料，例如天然氣和核能等在發電燃料組合中的比例。

6.4 由於這是一個跨界別的策略，而且需要迅速實施，因此必須取得所有界別的支持。

6.5 由於氣候變化是全球現象，因此，是次研究建議香港採取的行動雖然可以大幅減少溫室氣體排放量，卻未足以防止氣候變化。在未來的數十年間，預計香港仍會經歷氣候變化的情況。

6.6 這是香港首個氣候變化脆弱性的全面評估。在對潛在風險最高的範疇進行評估時的依據包括：有關範疇的現有知識、從「政府間氣候變化專門委員會」第四次評估報告內的資料，以及顧問和專家的相關判斷。應予注意的是，在評估各個系統時，能夠取得的資料在質和量方面都各有不同。而且，第四次評估報告內的資料亦有不確定和受局限的情況，因此脆弱性評估的結果也會受到相若影響。舉例而言，生物多樣化程度在面對氣候變化時的反應，其不確定程度會比其他受管理程度極高的系統，例如建築環境和

基礎設施等較高。當一個界別欠缺本地科學數據來配合以研究爲主的方法來評估該界別的脆弱程度和適應能力時，顧問公司都採用了專家的判斷來決定風險評級，例如「衞生健康」界別的風險評級。由於有關氣候變化的科學發展很快，因此，脆弱性評估視應被視爲一個動態過程，需要不時檢討和更新評估結果，特別是這類評估本身便存在高度的不確定性。

6.7 是次研究評估了本港的脆弱性。結果顯示，有八個主要界別受氣候變化影響的脆弱性屬於「高」，其中包括：

- 生物多樣性和自然護理；
- 建築環境和基礎設施；
- 商務和工業；
- 能源供應；
- 金融服務；
- 食物資源；
- 衞生健康；及
- 水資源。

6.8 爲了適應未來的氣候變化影響，是次研究建議了多項界別及跨界別的應對措施，以便作更深入考慮。然而，應該定期檢討各個適應方案，以確保它們仍然足以應付有關問題，並已考慮有關技術和方法的最新發展。

(1) http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

(2) 本報告內的「能源使用」指IPCC指南內的整個能源組別 (組別1)。

(3) 只列出可以量化的減緩措施。

(4) 「總熱傳送值」是量度一座樓宇外圍能量消耗量的數值。

(5) 這套標準會對所有進口至香港的新車訂定能源效益要求。

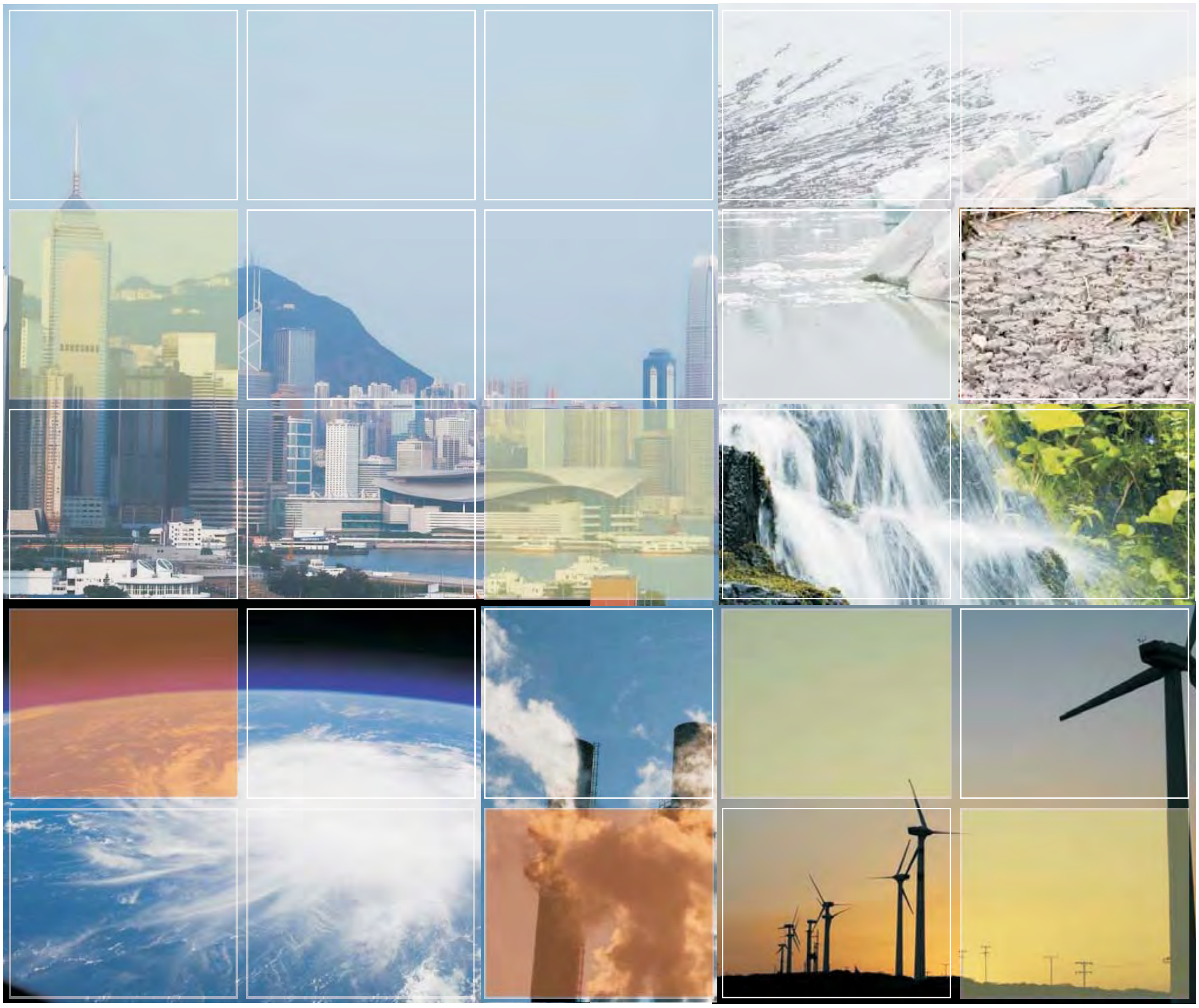
(6) 檢討香港空氣質素指標及發展長遠空氣質素管理策略－可行性研究，2009年7月。

(7) 這個數值不包括剩餘的燃煤發電廠的發電量。在不排放碳的電力中，有70%是輸入核能產生的電力。

(8) 基準情景中的本地生產總值（GDP）在各個假設情景中不會受到重大影響這一結論是在目前可獲信息的基礎上得到的。這個模型旨在提供宏觀的結果，具體措施的經濟影響應該在進一步的評估分析中獲得。特別要指出的是，有的措施需要大量的投資，而這些投資對一些特別領域產生的影響並沒有做具體的討論。因此，顧問建議在計劃實施任何一項政策的時候，應該對是項措施的影響作進一步的獨立評估。

(9) 全國碳強度目標是指與能源相關的每單位GDP二氧化碳排放量；而香港的本地碳濃度則是指每單位GDP的溫室氣體總排放量。香港會控制所有來源的溫室氣體排放量，包括非能源相關的碳排放量，例如堆填區的甲烷。因此，有關的碳濃度目標包括所有類別的溫室氣體排放量。

FINAL REPORT



Environmental Protection Department
The Government of the Hong Kong
Special Administrative Region

Agreement No. CE 45/2007 (EP)
A Study of Climate Change in Hong Kong - Feasibility Study

December 2010

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FINAL REPORT

Environmental Protection Department

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December 2010

Reference 0082487

For and on behalf of
ERM-Hong Kong, Limited

Approved by: Dr Andrew Jackson

Signed:

Position: Managing Director

Date: 3 December 2010

CONTENTS

APPENDICES

1 *OVERVIEW*

1.1 *BACKGROUND*

Climate change is a global phenomenon around which there is a broad consensus that international action is needed to prevent a material risk to society and, in particular, future generations.

The United Nations Framework Convention on Climate Change (hereafter referred to as "the Convention" or UNFCCC) is an overall framework for intergovernmental efforts to tackle the challenges posed by climate change and entered into force in March 1994. The Kyoto Protocol (the Protocol) is an international agreement linked to the Convention. The Protocol commits industralised countries (Annex I parties) to stabilize greenhouse gas (GHG) emissions under the principle of "common but differentiated responsibilities". The Protocol was adopted in December 1997, entered into force in February 2005 and has been ratified by 188 Parties to date.

Mainland China is a Party to the Convention and the Protocol. Under the Convention and the Protocol, and China as a non-Annex I Party is required to fulfill the following obligations -

- gathering and sharing information on GHG emissions, national policies and best practices;
- launching national strategies for addressing GHG emissions and adapting to expected impacts; and
- co-operating in preparing for adaptation to the impacts of climate change.

Following consultation with the Administration, the Central People's Government (CPG) notified the United Nations that the Convention and the Protocol were extended to the Hong Kong Special Administrative Region (SAR) with effect from May 2003. In the 2008/09 Policy Address, the Hong Kong SAR committed to making early preparations to meet the challenges of climate change through enhancing energy efficiency, using clean fuels, relying less on fossil fuels and promoting a low carbon economy. Following the announcement of a voluntary national target to reduce carbon intensity by the CPG in November 2009, the SAR Government is actively considering the adoption of a more aggressive target for reducing energy-related carbon intensity by 2020 and beyond.

1.2 *OBJECTIVES*

This study aims to provide the basis for additional strategies and measures for addressing climate change in Hong Kong, as well as necessary information to contribute to the CPG's national level communication under the UNFCCC.

Individual objectives of the study are summarised as follows-

- review and update the **inventories** of GHG emissions and removals and project future trends (*Section 2*).

- Evaluate existing and recommend additional policies and measures to reduce GHG, emissions or increase sinks of GHG, and assess their cost-effectiveness, economic, social and environmental implications of such **mitigation** measures (*Section 3*).

- Characterise the **impacts** of climate change in Hong Kong, and evaluate existing and recommend additional strategies and measures to facilitate adequate **adaptation** to climate change (*Section 4*).

- Evaluate existing and recommend further strategies and measures to promote the development and application of environmentally sound technologies and scientific research pertinent to, and public **awareness** of, climate change (*Section 5*).

The analyses summarised in the main body of this report is supported by a set of appendices that provide further information, as follows:

- *Appendix A: GHG Emissions Inventory.* This appendix provides further information on the methodologies used for the preparation of the inventory and the results for the period 1990 to 2006.

- *Appendix B: Mitigation Assessment.* This appendix documents the forecasted emissions for the period 2005 to 2030, the potential options for reducing emissions and the analysis of three alternate scenarios for emissions reduction.

- *Appendix C: Vulnerability and Adaptation Assessment*. This appendix summarises the findings of an assessment of the Hong Kong SAR's vulnerability to future climate change and the means of adapting to such change.

2 GREENHOUSE GAS EMISSIONS

2.1 INTRODUCTION

The Kyoto Protocol to the UNFCCC requires Non-Annex I parties which have ratified the Protocol to communicate a national (1) inventory of GHG emissions as part of their national communication. The Hong Kong SAR, as part of China which has ratified the Kyoto Protocol, is therefore also required to prepare a GHG inventory. This inventory will form part of China's inventory in its national communication which is to be submitted to the Conference of Parties (COP).

The inventory has been developed using internationally agreed and adopted methods, i.e. the *Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories*. The Guidelines include provision for the estimation of both sources of GHG emissions to the atmosphere and sinks, whereby GHGs are removed.

Different GHGs have differing impacts and Global Warming Potential (GWP) values are used to quantify the impact of GHG emissions in accordance with the IPCC Guidelines. The GWP is a measure of a particular GHG's contribution to global warming. The scale is a ratio of the contribution of global warming relative to that of the similar mass of carbon dioxide (which has a GWP of one). This approach is adopted internationally and allows the expression of all GHG emissions as carbon dioxide equivalents (CO_2-e).

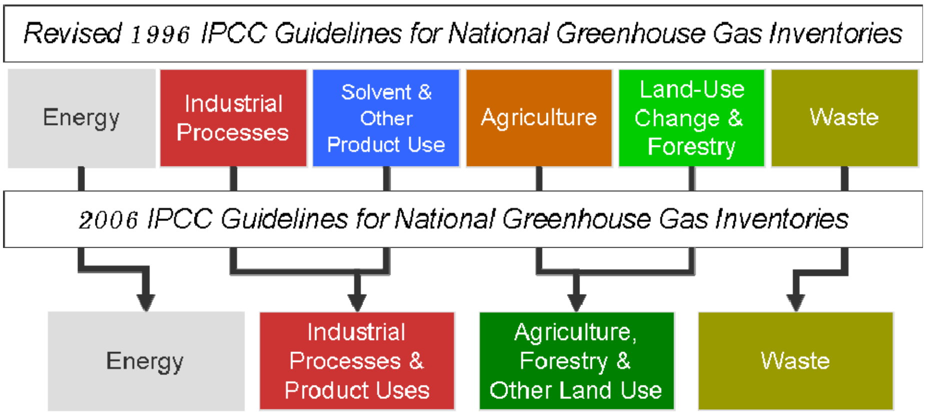
2.2 OVERVIEW OF ASSESSMENT METHODOLOGY

2.2.1 *Adoption of International Guidelines*

The estimation of emissions in this document follows the approach agreed internationally, including methods prescribed in the IPCC Guidelines. In particular, methods in the *2006 IPCC Guidelines* were employed to replace the corresponding methods in the revised *1996 IPCC Guidelines* as far as possible.

(1) For the sake of clarity in this report "national inventory" is used to refer to the inventory for China as a whole (ie including the HKSAR). "Domestic inventory" refers to the HKSAR inventory only.

Figure 2.1 *Differences in Categorisation of Sources and Sinks between the 2006 and Revised 1996 IPCC Guidelines*



Note: "Other" category not shown for both sets of Guidelines.

The Energy and Waste sectors remain as independent sectors under the *2006 IPCC Guidelines*; however, Industrial Processes and Solvent & Other Product Use are combined as Industrial Processes & Product Uses (IPPU) and Agriculture and Land-use Change & Forestry are combined as Agriculture, Forestry & Other Land Use (AFOLU) under the *2006 IPCC Guidelines.* Categorisation of sources and sinks also differs between the two versions of the *Guidelines* at the more disaggregated level.

2.2.2 *Calculation Methods*

Emissions and Removals

The estimation of emissions from a particular source combines information on the extent to which a human activity takes place, referred to as *Activity Data* (AD), with coefficients quantifying the emissions or removals per unit activity, referred to as *Emission Factors* (EF).

The basic equation for estimating GHG emissions (or removals) is, therefore:

$$Emissions\ (Removals) = AD \bullet EF$$

In addition to activity data and emission factors, this basic equation can incorporate other estimation parameters to reflect actual emissions or removals (1). A number of other approaches are also provided to reflect the characteristics of certain processes that emit or remove GHGs (2). For example, stock change methods are used in the AFOLU sector, estimating CO_2 emissions from changes in the carbon content of living biomass and dead organic matter pools over time.

(1) IPCC, 2006, "IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1: General Guidance and Reporting"

(2) The method for GHG emission estimation, in IPCC 2006 Guidelines, is categorised into 3 levels according to the level of methodological complexity or *tier*. Tier 1 is the basic method, Tier 2 intermediate, and Tier 3 most demanding in terms of complexity and data requirement. Tiers 2 and 3 are sometimes referred to as higher *tier* methods and are generally considered to be more accurate.

Global Warming Potential of GHGs

According to the IPCC Guidelines, the GWP is a measure of a particular GHG's contribution to global warming. The scale is a ratio of the contribution of global warming relative to that of the similar mass of carbon dioxide (which has a GWP of one), thus allowing the expression of all GHG emissions as carbon dioxide equivalents. A comparison of the GWPs adopted in the *Revised IPCC 1996 Guidelines* and the *2006 IPCC Guidelines* is shown in the *Table 2.1*.

Table 2.1 ***Comparison of 100-year GWP Estimates from the IPCC Guidelines***

Gas	1996 IPCC GWP	2006 IPCC GWP
Carbon Dioxide	1	1
Methane	21	23
Nitrous Oxide	310	296
HFC-23	11,700	12,000
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
Perfluoromethane (CF_4)	6,500	5,700
Perfluoroethane (C_2F_6)	9,200	11,900
Sulfur Hexafluoride (SF_6)	23,900	22,200

The GWPs presented in the *Revised 1996 IPCC Guidelines* were based on the findings of the *IPCC Second Assessment Report*, published in 1995 (IPCC, 1995) [(1)]. The *2006 IPCC Guidelines* were updated according to the findings of the *IPCC Third Assessment Report* (IPCC, 2001). A *Fourth Assessment Report* (IPCC, 2007) [(2)] was released, in 2007, which further updated the GWPs. Under the Kyoto Protocol, the Conference of the Parties decided that the GWPs calculated in the *Second Assessment Report* are to be used for converting GHG emissions into carbon dioxide equivalents, and the later findings should not be applied until the end of 2012. This is further validated by the UNFCCC Guidelines. Therefore, for the purpose of this inventory compilation, the GWPs defined in the *Revised 1996 IPCC Guidelines* will be used.

2.3 *EMISSIONS ESTIMATES, 1990 TO 2006*

This section provides an overview of the inventory of GHG emissions. The overview is presented in two stages, firstly by total GHG emissions (expressed as Gg $CO_{2\text{-}e}$), followed by a more detailed analysis of GHG emissions by gas and sector.

(1) Climate Change 1995: The Physical Science Basis, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

(2) Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

2.3.1 *Total GHG Emissions*

Table 2.2 summarises GHG emissions over the period 1990 to 2006, the emissions of $CO_{2\text{-}e}$ have risen from 35.3 million tonnes in 1990 to 42.3 million tonnes in 2006 (without Sector 3B) (1) . The Energy sector is the main contributor of GHG emissions, dominating the other three sectors. It is evident that emissions from electricity generation (accounting for about 57 to 67% of the total) and transport (about 16 to 23% of the total) are the most influential. Indeed, emissions from electricity generation generally were on the increase over the period, with the exception of a marked drop between 1993 and 1994 due to the introduction of low-carbon nuclear energy imports from Mainland China, in place of local generation by coal-fired power plants.

The Waste sector is the next most significant. The annual average share of GHG emissions from the Energy and Waste sectors from 1990 to 2006 was 93.0% and 4.5%, respectively. The IPPU and AFOLU sectors on average each contribute 2.2% and less than 1%, respectively. *Figure 2.2* and *Figure 2.3* show the trends in emissions by sector and gas type from 1990 to 2006.

(1) Sector 3B (Landuse) is excluded to be consistent with the UNFCCC GHG data reporting format.

Table 2.2 Detailed Breakdown of HK GHG Emissions by Concerned Sub-sector and its Percentage Share, from 1990 to 2006

Year	HK GHG Emissions by Sectors (kilotonnes CO_2-e)[a]							Percentage Share of HK GHG by Sectors (%)						
	Electricity Generation[b]	Transport	Other End Use of Fuel [c]	Waste	Industrial Process and Product Use	Agriculture, Forestry, Other Land Use (without 3B)	Total	Electricity Generation[b]	Transport	Other End Use of Fuel [c]	Waste	Industrial Process and Product Use	Agriculture, Forestry, Other Land Use (without 3B)	Total
1990	22,900	5,940	4,620	1,550	215	141	35,300	64.7%	16.8%	13.1%	4.4%	0.6%	0.4%	100%
1991	25,600	6,470	4,360	1,600	638	123	38,800	66.0%	16.7%	11.2%	4.1%	1.6%	0.3%	100%
1992	29,200	6,870	4,500	1,660	651	100	43,000	68.0%	16.0%	10.5%	3.8%	1.5%	0.2%	100%
1993	29,700	6,970	4,200	1,750	724	87	43,400	68.4%	16.1%	9.7%	4.0%	1.7%	0.2%	100%
1994	21,900	7,270	4,030	1,770	830	77	35,900	61.1%	20.2%	11.2%	4.9%	2.3%	0.2%	100%
1995	23,000	7,180	3,810	1,940	935	85	36,900	62.2%	19.5%	10.3%	5.3%	2.5%	0.2%	100%
1996	21,800	7,170	3,680	1,900	952	86	35,500	61.2%	20.2%	10.3%	5.3%	2.7%	0.2%	100%
1997	20,000	7,340	3,590	2,000	1,060	75	34,100	58.7%	21.5%	10.5%	5.9%	3.1%	0.2%	100%
1998	22,100	7,430	3,330	1,550	977	70	35,500	62.4%	20.9%	9.4%	4.4%	2.8%	0.2%	100%
1999	20,100	7,570	3,470	1,120	1,020	85	33,300	60.2%	22.7%	10.4%	3.4%	3.1%	0.3%	100%
2000	21,200	7,800	3,450	1,110	977	78	34,600	61.2%	22.5%	10.0%	3.2%	2.8%	0.2%	100%
2001	21,600	7,640	3,220	1,250	862	85	34,700	62.3%	22.0%	9.3%	3.6%	2.5%	0.2%	100%
2002	23,400	7,890	2,800	1,490	503	82	36,200	64.8%	21.8%	7.7%	4.1%	1.4%	0.2%	100%
2003	26,500	7,810	2,830	1,800	538	74	39,600	67.0%	19.7%	7.1%	4.5%	1.4%	0.2%	100%
2004	26,400	7,640	3,060	1,990	636	67	39,800	66.3%	19.2%	7.7%	5.0%	1.6%	0.2%	100%
2005	28,600	7,480	2,770	2,220	867	74	42,000	68.1%	17.8%	6.6%	5.3%	2.1%	0.2%	100%
2006	28,500	7,480	2,730	2,140	1,380	74	42,300	67.4%	17.7%	6.5%	5.1%	3.3%	0.2%	100%

Notes:

(a) 1 kilotonne CO_2-e in this table is equivalent to 1 Gg CO_2-e.

(b) Including towngas production – accounts for about 1% of GHG emissions as in the energy production sector

(c) Other End Use of Fuel covers manufacturing of solid fuels and other energy industries, manufacturing industries and construction, fugitive emissions from fuels and other minor sectors.

Figure 2.2 *Total HK GHG Emissions from 1990 to 2006, by Sector*

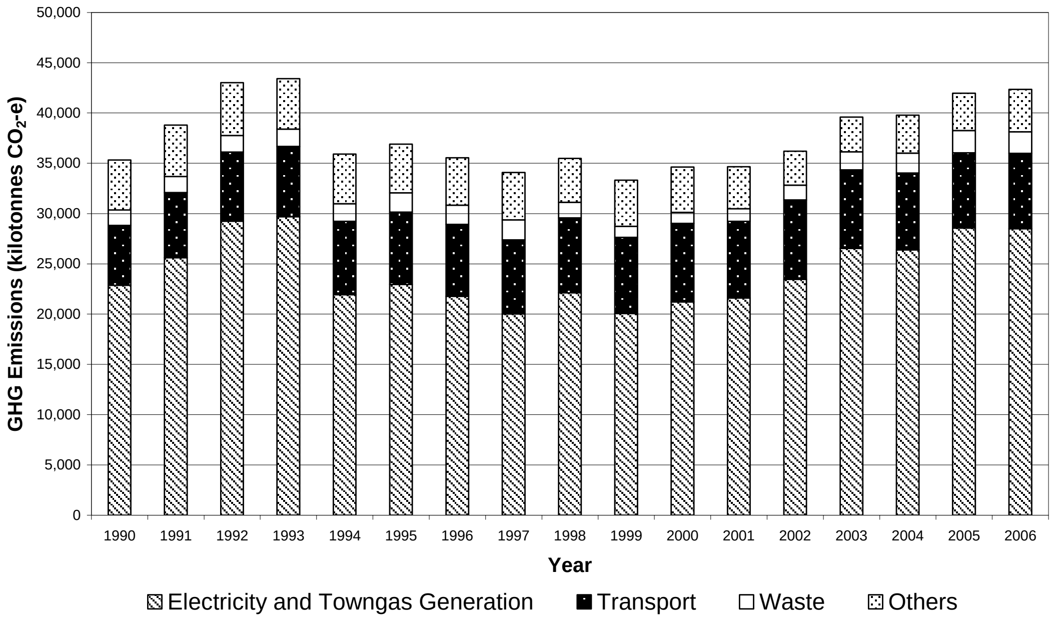
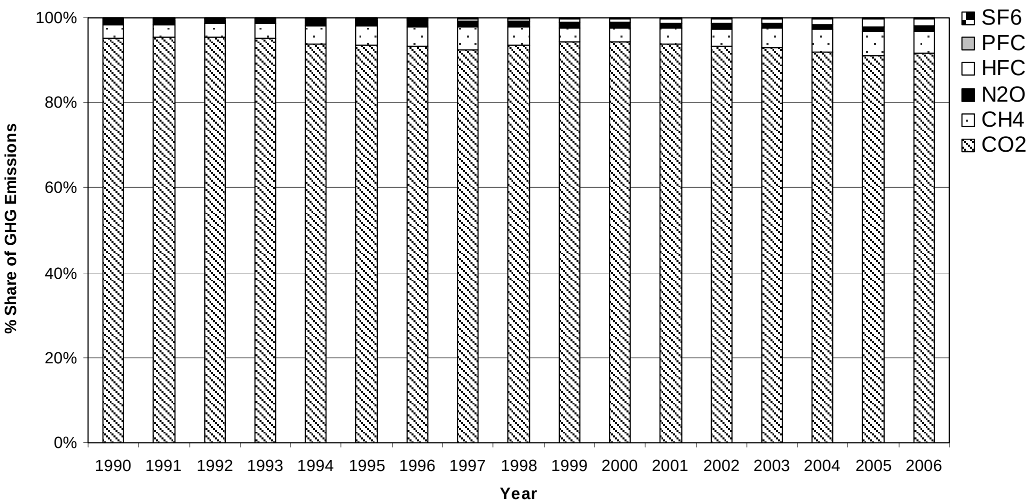


Figure 2.3 *Total HK GHG Emissions from 1990 to 2006, by Gas Type*



Prior to 1993, the total GHG emissions were gradually increasing but declined dramatically in the year 1994 largely due to the significant decrease in the emissions from the Energy sector as Hong Kong started to import nuclear power from mainland China.

It should be noted that all emissions from fuels for international aviation and marine travel and multilateral operations, in accordance with the Charter of the United Nations, are excluded from the total domestic inventory and reported separately as memo items. The inventory includes all domestic travel by air and sea, which is defined as all movements within the HKSAR.

2.3.2 *GHG Emissions by Gas and Sector*

Figure 2.3 shows the total emissions for each year, over the 17 year period, for each GHG. It can be seen that CO_2 is the dominant gas, accounting for at least 90% of total GHG emissions over the 17 years. CH_4 and N_2O contribute a maximum of approximately 5% and 2% of total, respectively, while the remaining gases have less than a 1% contribution each.

The emissions can be further disaggregated into the 2006 IPCC sectors - *Energy*, *Industrial Processes and Product Use (IPPU)*, *Agriculture Forestry and Land-Use Change (AFOLU)* and *Waste*. The GHG emissions by gas type for each sector are summarized in *Tables 2.3* and *2.4*.

Some of the principal observations on these data are summarised below.

- *Energy*: In the Energy sector, CO_2 is the most abundant GHG released into the atmosphere, followed by N_2O and CH_4. The GHG emissions released from the Energy sector increased consistently over the period studied, with the exception of a marked drop between 1993 and 1994, as noted previously.
- *IPPU*: GHG emitted from the IPPU sector are different in composition to the other sectors as they consist of CO_2, HFCs, PFCs, and SF_6 (all from product usage). Emissions of HFCs and PFCs were first documented in Hong Kong in 1995, whereas the CO_2 emissions were zero during the years 2002 to 2005 as a result of the temporary discontinuation of clinker production.
- *AFOLU*: A significant CO_2 removal is estimated from *Sector 3B – Land*. N_2O is the main GHG contributor and CO_2 is the smallest contribution in AFOLU without considering Sector 3B.
- *Waste*: There was a significant drop in GHG emissions from the Waste sector in 1999 and 2000 and then a gradual increase after 2000 for a number of reasons. Firstly the leachate treatment work (LTW) plants commenced operation in 1999 at the WENT landfill and the Tseung Kwan O (TKO) Stage I closed landfill. A large amount of LFG captured in the WENT landfill (at the rate of 4,400 m^3/hr) and the TKO Stage I closed landfill (at the rate of 1,300 m^3/hr) was utilized for the LTW operation as a source of energy. Secondly, LFG at the restored Shuen Wan landfill has been extracted and piped to Hong Kong and China Gas Company for utilization as a fuel since 1999, as a result, the net methane emissions in 1999 is significantly lower than the quantity emitted in the previous years. Finally, another LTW plant began to operate in 2000 at the NENT landfill and LFG was captured at a rate of 3,000 m^3/hr for utilisation in the LTW. As a result of the new LTWs starting operation, a significant drop of methane emissions from landfills is observed.

Table 2.3 GHG Emissions from Energy Sector, from 1990 to 2006

Year	HK GHG Emissions from Energy Sector ($GgCO_2$-e/year)			
	Domestic			
	CO_2	CH_4	N_2O	Total
1990	33,170	34	223	33,427
1991	36,190	37	218	36,445
1992	40,314	37	265	40,616
1993	40,547	39	273	40,860
1994	32,925	39	282	33,246
1995	33,621	41	288	33,950
1996	32,195	84	330	32,609
1997	30,484	109	366	30,959
1998	32,412	104	373	32,889
1999	30,610	112	373	31,095
2000	32,000	107	353	32,461
2001	31,981	111	357	32,450
2002	33,664	113	358	34,135
2003	36,764	93	314	37,172
2004	36,640	112	337	37,088
2005	38,378	114	322	38,814
2006	38,318	116	313	38,747

Table 2.4 *HK GHG Emissions from IPPU, AFOLU and Waste Sectors, from 1990 to 2006*

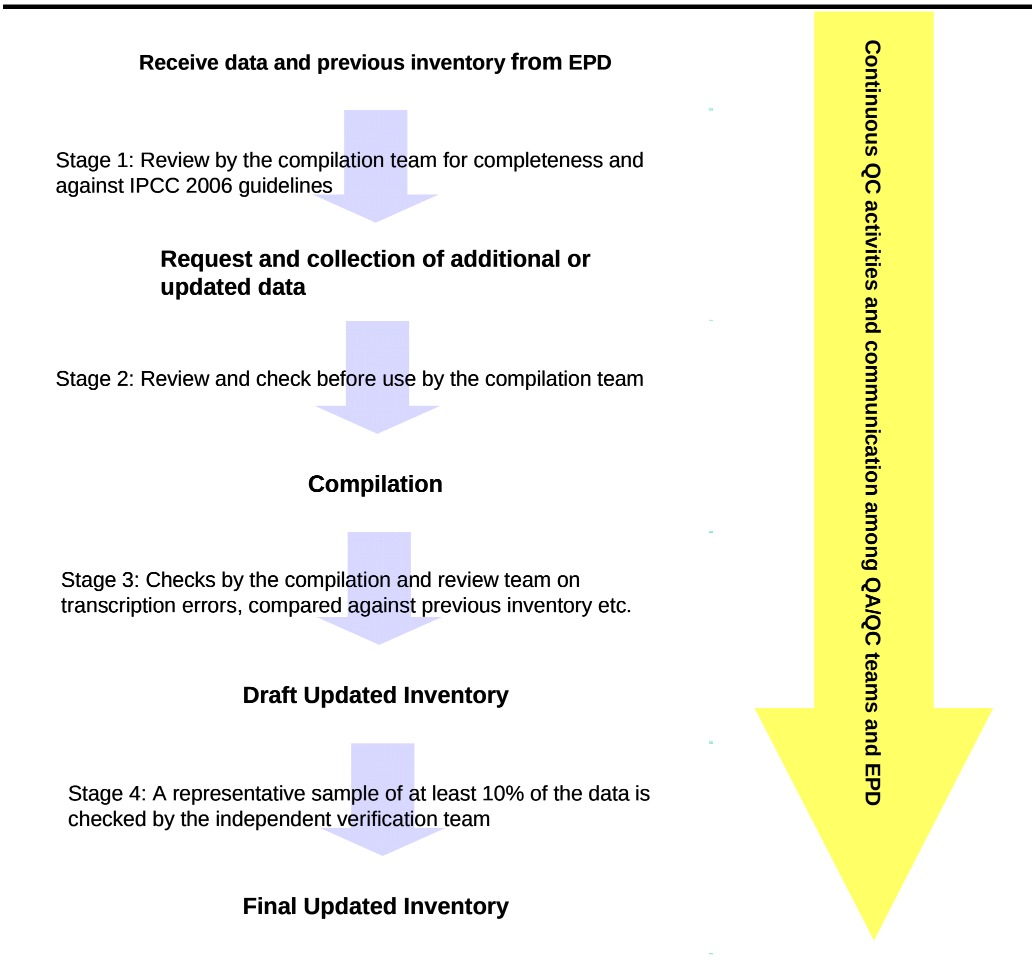
Year	HK GHG Emissions ($GgCO_2$-e/year)																
	IPPU					AFOLU								Waste			
						With Sector 3B				Without Sector 3B							
	CO_2	HFCs	PHCs	SF_6	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total
1990	113	0	0	102	215	-460	37	95	-328	9	37	95	141	338	1,058	152	1,548
1991	547	0	0	91	638	-459	29	84	-346	10	29	84	123	277	1,180	144	1,602
1992	544	0	0	108	651	-455	19	67	-368	14	19	67	100	228	1,284	144	1,656
1993	627	0	0	97	724	-461	18	62	-381	7	18	62	87	216	1,397	140	1,753
1994	703	0	0	127	830	-466	18	55	-392	3	18	55	77	127	1,502	141	1,769
1995	735	85	2	112	935	-455	19	52	-384	14	19	52	85	140	1,651	148	1,939
1996	724	113	2	112	952	-461	25	53	-383	8	25	53	86	137	1,614	150	1,902
1997	783	157	2	113	1,055	-467	26	48	-394	2	26	48	75	167	1,685	151	2,003
1998	689	191	3	95	977	-483	29	38	-416	3	29	38	70	32	1,389	127	1,548
1999	685	227	3	106	1,022	-408	34	40	-333	10	34	40	84	33	952	133	1,118
2000	599	283	4	91	977	-387	36	40	-311	2	36	40	78	34	955	125	1,114
2001	428	342	4	89	862	-368	38	44	-285	2	38	44	85	29	1,097	127	1,254
2002	0	390	2	112	503	-370	38	43	-289	1	38	43	82	29	1,328	131	1,488
2003	0	452	0	85	538	-383	31	41	-311	2	31	41	74	27	1,642	132	1,801
2004	0	541	2	93	636	-430	31	35	-364	2	31	35	67	26	1,836	133	1,995
2005	0	742	2	123	867	-412	31	42	-339	1	31	42	74	26	2,058	134	2,218
2006	535	739	0	108	1,383	-413	31	39	-344	5	31	39	74	21	1,989	133	2,142

2.3.3 *QA/QC and Uncertainty Analysis*

QA/QC

The emissions inventory was subjected to a series of checks to determine quality of the data, as illustrated in *Figure 2.4*. Further details of the process and the findings are presented in *Appendix A*.

Figure 2.4 Flowchart of the QA/QC Process



Uncertainty Analysis

A formal assessment of the uncertainty associated with the emissions estimates was undertaken in accordance with the recommendations of the *2006 IPCC Guidelines*. Details of the assessment methodology are presented in *Appendix A*.

The percentage uncertainty of the total inventory for 2005, excluding international transportation, is about 4.3% and the trend uncertainty is about 7.2%. When compared with the percentage uncertainty in the total inventory of other countries (eg New Zealand (20.7%) (1), Finland (15.9%) (2), US (-2 to

(1) Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990-2005 excluding LULUCF removals (following IPCC Tier1), Table A7.2. http://www.mfe.govt.nz/publications/climate/nir-jul07/html/tablea7-2.pdf

(2) *2006 IPCC Guidelines* Volume 1 chapter 3 table 3.4

7%) [1], UK (14-15%) [2] and Japan (3%) [3]), the level of uncertainty in is considered comparable.

2.4 *PROJECTED BASE CASE EMISSIONS, 2005 TO 2030*

This section provides an overview of the emissions estimates for the period 2005 to 2030 under the Base Case, i.e. in the absence of any additional measures or policies to restrict or limit GHG emissions. The Base Case is then used as the benchmark against which emissions under alternative control scenarios are compared.

2.4.1 *Methodology for Base Case Development*

The Base Case was developed in the Hong Kong MARKAL-MACRO (HKMM) model which provides energy supply-demand projections in a detailed and disaggregated pattern. Although the Base Case projects a "business as usual" energy system path by incorporating existing and planned measures and development programs into the model, it should not be taken as the prevailing energy market for the future in the absence of additional mitigation policies and measures. Rather, it provides a reference basis to evaluate impacts of additional alternative scenarios, representing recommended policies and measures, to provide useful insights into the future and the impacts of these scenarios. The uncertainties inherent in any long-term scenario (eg GDP projection, population growth, future energy prices) suggest that, it is most useful to focus only on the differences in the results between the mitigation scenarios and the Base Case rather than on the absolute numerical results in a single scenario. It is the differences, not the absolute results that reflect the impact of the additional technologies, policies and measures.

The Reference Energy System (RES) underlying the MARKAL-MACRO modelling system requires input data (actual and projected) from primary energy supply (eg diesel fuel imports), intermediate conversion and process (eg electricity generation), to end-use technologies (eg air conditioners) that satisfy energy service demands (eg space conditioning). Each element in the RES is characterized by three groups of data: technical (eg efficiency), economic (eg capital cost), and environmental (eg carbon emission coefficient). *Table 2.5* shows the six main data input categories, including the four energy system building blocks depicted in *Figure 2.5*: resources/primary energy supply, conversion & process technologies, end-use technologies, and demand for energy services. The other two categories are economic parameters of energy carrier/technology and emission factors associated with elements within the four building blocks.

(1) U.S. Greenhouse Gas Inventory Reports 1990-2006, Annex 7 http://www.epa.gov/climatechange/emissions/downloads/08_Annex_7.pdf

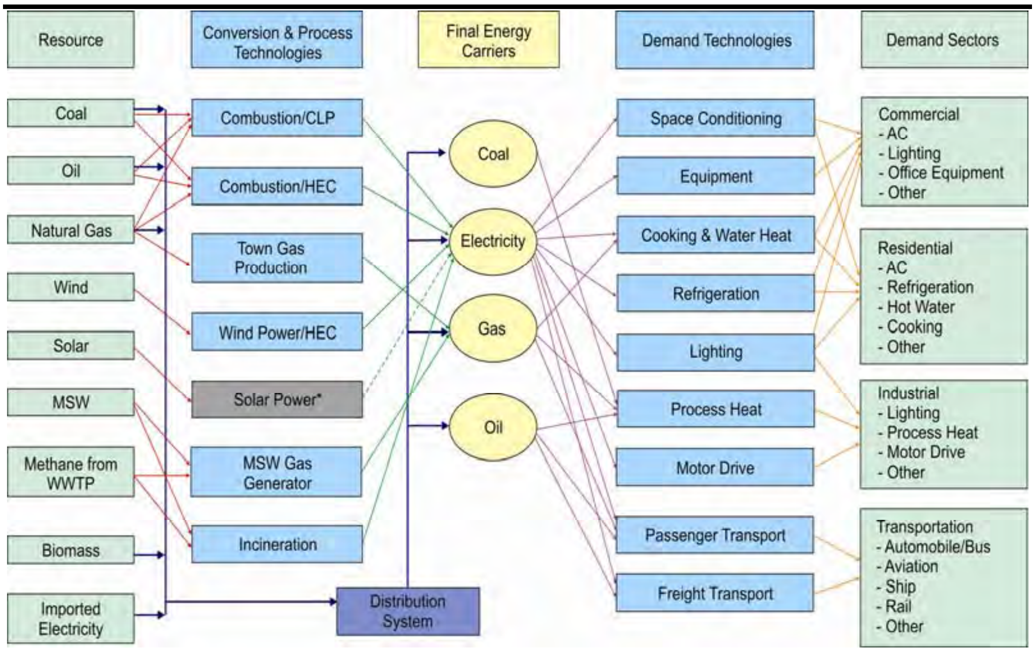
(2) UK NIR 2008 Annexes http://www.airquality.co.uk/archive/reports/cat07/0804161424_ukghgi-90-06_annexes_UNFCCCsubmission_150408.pdf

(3) National Greenhouse Gas Inventory Report of JAPAN (http://www-gio.nies.go.jp/aboutghg/nir/2008/NIR_JPN_2008_v4.0_E.pdf)

Table 2.5 *Data Category*

Data Category	Model Input
Demand for Energy Service; End-use Technologies	Demand Module
Conversion Technologies	Power Sector; Process
Primary Energy Supply	Resource
Price of energy carrier/technology	Price
Emission Factors	Emission Factors

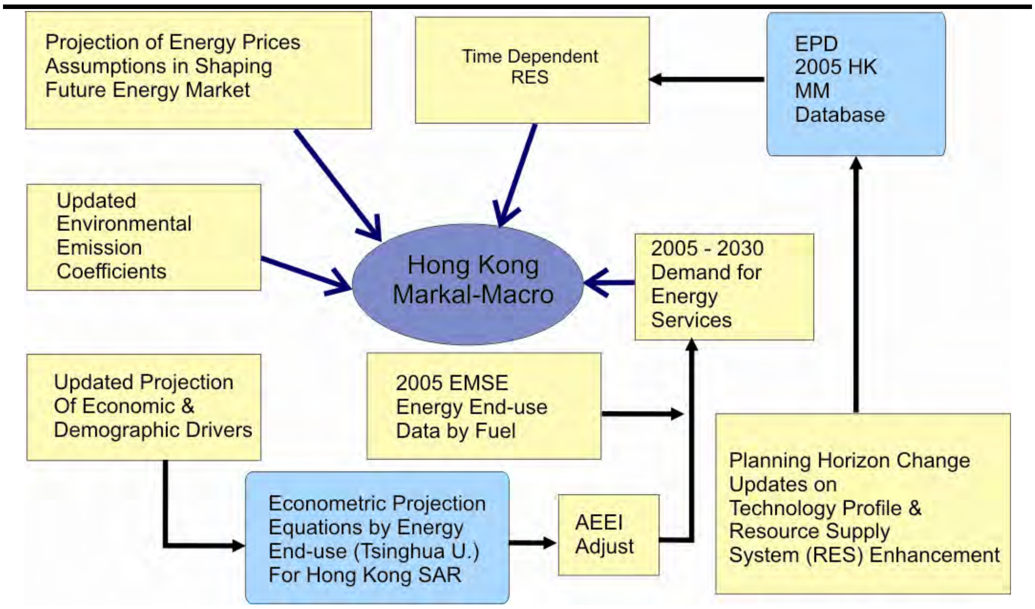
Figure 2.5 *HK Simplified RES*



Source: ERM and BNL.
Note: Technologies in gray boxes are those that can be developed in HK in the future.

Figure 2.6 depicts schematics of the interrelated tasks in the development of the Base Case. In general, Hong Kong specific historical energy demand-supply data were used to establish the base year (2005) RES in the Hong Kong MARKAL-MACRO model.

Figure 2.6 HKMM Baseline Dataflow



Source: ERM and BNL.

2.4.2 *Base Case Results*

If there were no additional measures to control the emission of GHGs, emissions from Hong Kong are projected to increase, albeit in a non-linear manner, by 7% over the period 2005 to 2030. The major indicators for the Base Case derived from the HKMM model results are summarized in *Table 2.6*.

Table 2.6 Major Indicators: Base Case

	2005	2020	2030	Total Growth 2005-2020 (%)	Total Growth 2005-2030 (%)	Annual Growth 2005-2030 (%)
Population (Thousand)	6,813	7,719	8,312	13	22	0.80
GDP (Billion 2005 HK$) (1)	1,383	2,258	2,905	63	110	3.01
Per Capita GDP (Thousand HK$)	203	293	349	44	72	2.20
Primary Energy (TJ) (2)	591,601	744,786	822,488	26	39	1.33
Final Energy (TJ) (3)	294,968	396,211	460,729	34	56	1.80
GHG Emissions (Million Tonnes $CO_{2\text{-}e}$)	42.0	46.1	44.8	10	7	0.26
Primary Energy Intensity (TJ/Billion HK$) (4)	428	330	283	-23	-34	-1.64
Final Energy Intensity (TJ/Billion HK$)	213	175	159	-18	-26	-1.18
Carbon Emissions per Capita (Tonnes $CO_{2\text{-}e}$) (5)	6.16	5.97	5.39	-3	-13	-0.53
Carbon Intensity (kg $CO_{2\text{-}e}$/ HK$)	0.0304	0.0204	0.0154	-33	-49	-2.68

	2005	2020	2030	Total Growth 2005-2020 (%)	Total Growth 2005-2030 (%)	Annual Growth 2005-2030 (%)

Notes:

(1) The GDP projections are based on the best available working assumptions for future economic growth. It is noted that the growth rate working assumptions from 2014 onwards are subject to a large degree of uncertainty.

(2) Primary energy is energy found in nature that has not been subjected to any conversion or transformation process. Examples of primary energy resources include coal, crude oil, sunlight, wind, running rivers, vegetation, and uranium.

(3) Final energy refers to the amount of energy consumed by final users for all energy purposes such as heating, cooking and driving machinery, but excludes non-energy usages such as using kerosene as solvent. It differs from primary energy in that the latter includes all energy used or lost in the energy transformation and the distribution process.

(4) Energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP.

(5) Carbon intensity in this study is calculated as total GHG emissions per unit GDP.

The total primary energy consumption in the Base Case is projected to grow at an annual rate of 1.33% during the period 2005 to 2030, while the final energy demand is projected to grow at an annual rate of 1.80%. Compared to the projected 3.01% annual growth rate in GDP [1] over the same period, the decoupling trend between GDP and primary energy consumption implied in the annual growth rates is consistent with the historical data reported by the Census and Statistics Department (C&SD). The projected values in GDP, final energy demand and primary energy consumption imply that the final energy intensity will decrease from 213 TJ/Billion HK$ in 2005 to 159 TJ/Billion HK$ in 2030. The primary energy intensity, currently among one of the lowest in the world, will further decrease from 428 TJ/Billion HK$ to 283 TJ/Billion HK$ during the same period.

The annual growth rate of total carbon emissions (0.26% per year between 2005 and 2030) is projected to decouple from primary energy growth, which increases at an annual rate of 1.33% over the same period. In comparison, the total carbon emission grew at an annual rate of 1% during the period 1990 to 2006. The relatively low carbon emission growth rate projected is mainly due to the scheduled decommissioning of coal-fired power plant units in Hong Kong by 2030. The phase-out of existing coal-fired power plants and the assumption in the Base Case that they are replaced with high efficiency combined cycle gas turbines are the main factors that limit the carbon emission growth in Hong Kong. As a result, Hong Kong’s carbon emission per GDP output, already one of the lowest in the world, is projected to continuously decrease from 0.0304 kg CO_{2-e} per HK$ in 2005 to about 0.0154 kg CO_{2-e} per HK$ in 2030. In terms of carbon emissions per capita, the model projects a very slight decrease (-0.53% per year for the period 2005 to 2030), based on the population growth rate provided by C&SD.

(1) The GDP projection and impact evaluated by the models is on the basis of real terms.

3 MITIGATION OF EMISSIONS

3.1 INTRODUCTION

The reduction of emissions of GHGs is widely acknowledged as being essential to averting the worst consequences of climate change. Contingent upon the prevailing local conditions and the sectors of concern, a wide range of measures is potentially available to reduce emissions. Emission reductions can be achieved by both reducing emissions from particular sources directly and through the widespread adoption of energy efficient technologies and practices.

The analysis of mitigation measures undertaken in the study utilises predominantly quantitative analyses of a set of scenarios to support the development of policy options. An integrated energy-economic-environmental modelling framework, the Hong Kong MARKAL-MACRO model, has been selected as the primary tool for this assessment. MARKAL represents the energy/environment system, captures the interactions between the various stages of the energy system and enables a wide range of energy resources and technologies to be analysed. MACRO is a macroeconomic model which is integrated with MARKAL to enable the aggregate economic consequences to be assessed. The solutions of the integrated model maximize social utility while assuring the least life-cycle costs in the energy system that meets the end-use service demands. More than 60 countries (including China) use country-specific MARKAL-MACRO models for GHG mitigation analysis. Further details of the model and its application are presented in *Appendix B*.

3.2 MITIGATION MEASURES

This study has approached the analysis of climate change mitigation measures on a sectoral basis. It focuses on four sectors that are main emission contributors in Hong Kong: electricity generation, buildings and appliances, transport and waste. *Table 2.2* and *Figure 2.2* demonstrate theses sectors' contribution to Hong Kong GHG emissions in 2005. As over 90% of Hong Kong's GHG emissions arise from the energy supply, use of energy in buildings and transport, and from landfills, the greatest potential for Hong Kong to further mitigate its GHG emissions lies within these sectors.

Key criteria for the selection of the policies and measures to be analysed were as follows:

- technical feasibility;
- no- or low-cost;
- maximising co-benefits;
- suitable for research, development and demonstration (RD&D).

Based on a local and international policy review, and with consideration of the key selection criteria, the study identified and shortlisted the following measures that were considered potentially suitable and feasible for implementation in the HKSAR before 2030 (1).

Building and Appliance Sector

- Expanding the scope and tightening the requirements of the Building Energy Codes (BEC) to achieve energy efficiency improvements of major installations (e.g lighting and lifts) in commercial buildings, expanding the use of district cooling systems (DCS)/water-cooled air conditioning systems (WACS) to reduce energy needs for cooling, and tightening the Overall Thermal Transfer Value (OTTV) (2) standards and promoting extensive use of green roofing, etc to reduce energy demands;

- Expanding the scope and tightening the requirements of the energy efficiency and performance standard of electrical appliances for domestic use;

- Improving the energy efficiency of commercial buildings through good housekeeping, information technology (IT) products or intelligent Building Environmental Management Systems (BEMS).

Transport Sector

- Widening the use of motor vehicles running on alternative fuel, including hybrid and electric vehicles (EVs);

- Introducing ethanol into the motor fuel mixture - petrol to be blended with a certain percentage of ethanol;

- Introducing biodiesel into the motor fuel mixture – diesel to be blended with a certain percentage of biodiesel;

- Implementation of a Hong Kong "Importers' Average Fleet Efficiency" standard (3).

Waste Sector

- Development of the Integrated Waste Management Facilities (IWMFs) and Organic Waste Treatment Facilities (OWTF) to recover renewable energy from municipal solid waste (MSW);

- Full utilization of the recovered landfill gas to produce energy;

- Full utilization of gas captured from wastewater treatment;

(1) Only quantifiable mitigation measures are listed.

(2) An OTTV is a measure of the energy consumption of a building envelop.

(3) The standard will set energy efficiency requirements for all new vehicles imported in Hong Kong.

- Full utilization of sludge treatment with energy recovery.

Electricity Generation

- Using more natural gas to generate electricity locally;
- Increasing the share of renewable energy (RE) in the overall fuel mix;
- Increasing the import of nuclear generated electricity from Mainland China.

3.2.1 *Buildings and Appliances*

End-use efficiency improvement to reduce the electricity generation output, which is applied on the demand-side, is among the most cost-effective of GHG emission control measures. The proportional contribution of various sources of GHG emissions in Hong Kong shows the potential significance of end use efficiency, particularly in electrical end uses.

Efficiency improvements in the end-uses have the potential to reduce peak loads, thereby reducing generation plant capacity requirements. This would bring economic benefits in addition to those associated with electrical energy and fuel savings, further off-setting the cost of investment in the more efficient equipment and thereby reducing the GHG emission reduction cost.

Many current technologies allow building energy consumption to be reduced through better thermal envelopes, improved design methods and building operations, more efficient equipment, and reductions in demand for energy services. Emerging areas for energy savings in commercial buildings include the application of controls and information technology to continuously monitor, diagnose and communicate faults in commercial buildings ("intelligent control"), and systems approaches to reduce the need for ventilation, cooling and dehumidification. Advanced windows, passive solar design, techniques for eliminating leaks in buildings, energy efficient appliances, and controlling standby and idle power consumption as well as solid-state lighting are also important in both residential and commercial sectors. Occupant behavior, including avoiding unnecessary operation of equipment and adaptive rather than invariant temperature standards for cooling, is also a significant factor in limiting building energy use (1).

Air conditioning and lighting are the most significant end-uses in Hong Kong. There are a range of technical options available for reducing the energy required to provide air conditioning services. These include using more efficient components (such as chillers) in central systems, more efficient packaged and room units, expanding the use of district cooling/water-cooled air conditioning system (WACS), and reducing the heat load on air conditioning plant by, for example, reducing the internal and external heat loads in buildings.

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

In order to promote the use of more energy efficient air-conditioning systems in Hong Kong, a pilot scheme for the use of fresh water for non-domestic air-conditioning in selected areas commenced in June 2000. In view of the support from the property owners and the environmental benefits, the Government decided to keep promoting the scheme in 2008 (1).

Lighting is a major end use. A survey of 80 studies show that efficient lighting technologies are among the most promising GHG-abatement measures in buildings in almost all countries, in terms of both cost-effectiveness and potential savings. There are many well known options to improve lighting efficiency available in the market, ranging from simple substitution of luminaries to the re-design of lighting systems. Lighting design, particularly commercial lighting design, is a complex and specialised field in its own right. Capturing efficiencies (and often simultaneous cost and employee productivity benefits) through better design is very building-specific.

Energy standards specifically aimed at appliances and equipment are widespread. Canada, Korea, Japan, the EU, the US and Singapore have all promoted such policies. Hong Kong's Voluntary Energy Efficiency Labelling Scheme (EELS), introduced in 1995, has been amended several times (most recently on 17 April 2008) and now covers 18 types of household and office appliances, including 10 types of electrical appliances (refrigerators, washing machines, compact fluorescent lamps, dehumidifiers, electric clothes dryers, room coolers, electric storage water heaters, television sets, electric rice-cookers and electronic ballasts, hot / cold bottled water dispensers), 7 types of office equipment (photocopiers, fax machines, multifunction devices, laser printers, LCD monitors, computers), domestic gas instantaneous water heaters. The *Energy Efficiency (Labelling of Products) Ordinance* of 9 May 2008 provides for a Mandatory Energy Efficiency Labelling Scheme (EELS) which currently covers room air conditioners, refrigerating appliances, and Compact Fluorescent Lamps (CFL).

Multiple obstacles exist and make it difficult to adopt more efficient technologies and realize the energy efficiency improvement potential in Hong Kong as rapidly as desired. These barriers include:

- availability of technology;
- higher costs of getting reliable information on energy efficient technology;
- limitations inherent in building designs;
- mixture of building ownership;
- allocation of costs and benefits associated with capital expenditure, i.e., the owners bear the cost while the tenants get the benefit;

(1) http://www.devb.gov.hk/en/publications_and_press_releases/publications/environmental_report/2008_environmental _report/2008_er_full_er/index.html

- cash flow constraints of some Small and Medium-sized Enterprises (SMEs) in relation to the initial investment cost; and
- lack of an appropriate portfolio of policies and programs.

The following measures may be considered by the Government to overcome these constraints:

- implement a mandatory scheme that sets energy efficiency targets for different types of buildings under the Building Energy Codes;
- use guidelines, training workshops and public campaigns to enhance the understanding of the stakeholders on the importance of building energy efficiency improvement and the mandatory scheme;
- financial support in the form of an environment fund, tax incentives and a loan funding scheme from power companies which could be used to encourage the enhancement of energy efficiency in buildings;
- implement the mandatory scheme in phases, with the priority focused on new buildings and the common areas of the buildings where the building owners/property managers have control and then extend the coverage to the tenant area in the long run;
- expand the scope and tighten the energy efficiency standards over time.

Consumer behaviour, including avoiding unnecessary operation of equipment and adaptive rather than invariant temperature standards for cooling, is also a significant factor in limiting building energy use. Information and education are important to promote climate-friendly consumer behaviour and thus help reduce energy demand.

3.2.2 Road Transportation

Transport is distinguished from other energy-using sectors by its predominant reliance on a single fossil resource and by the infeasibility of capturing carbon emissions from transport vehicles. It is also important to view GHG-emission reduction in conjunction with local air pollution, traffic management and energy security. Solutions therefore have to take into consideration of transportation problems as a whole, not just GHG emissions.

Mitigation measures includes vehicle efficiency improvement, alternate vehicle and fuel types (hybrid petrol-electric vehicles and petrol to bio-fuel blended petrol), as well as other policy options.

<u>Vehicle Efficiency Improvement</u>

Improved vehicle efficiency measures, leading to fuel savings, in many cases have net benefits, but the market potential is much lower than the economic potential due to the influence of other consumer considerations, such as performance. A major risk to the potential for future reductions in CO_2

emissions from the use of fuel economy technologies is that they can be used to increase vehicle power and size rather than to improve the overall fuel economy and cut carbon emissions. The preference of consumers for power and size has consumed much of the potential for GHG mitigation reduction achieved over the past two decades (1).

Alternative Vehicle and Fuel Types

Various forms of vehicle fuel switching measures are potentially feasible in Hong Kong, and include the following.

- *Diesel to LPG:* The Hong Kong SAR Government has already committed to changing taxis from diesel to LPG, principally as a measure to improve urban air quality. That measure and its associated policy instrument are included here to show the effect of the measure on GHG emissions. LPG could also be used for other small- to medium-sized diesel vehicles.

- *Bio-Fuel Mixtures*: The introduction of bio-fuels by mixing with traditional petro-fuels is a way of reducing net GHG emissions. Bio-fuels are considered GHG emission neutral, since the emission of CO_2 from the consumption of the fuels has already been off-set by the absorption of atmospheric CO_2 during the growth of the source crops. The GHG emission reduction possible is therefore a direct function of the proportion of fuel that can be substituted with bio-fuel. It is possible to mix a small proportion of bio-fuel such as methanol or ethanol with existing petrol, or biodiesel with diesel, without any change to existing engines (2). The introduction of biofuel such as adding ethanol to petrol could be more readily effected. No additional infrastructure or change to vehicle engines is required if, for example, all petrol is required to include a 10% bio-ethanol. Hence, it is assumed that biofuel can be introduced but some form of government support or regulation would be needed to encourage or require its use. Specifically, biodiesel produced from waste cooking oil should be considered.

- *Electric Vehicles:* Electricity produced from any primary energy source, with the exception of coal, is likely to offer significant CO_2 savings compared with petrol and diesel. Electric-powered cars could become increasingly prevalent in the future – for example, plug-in hybrids, running partly on electricity, could be commercial in a few years' time.

- *Hydrogen Vehicles:* Hydrogen produced from low-carbon sources can offer large carbon savings compared with petrol and diesel. In the short term, the scope to reduce the carbon intensity of the fuel mix through hydrogen is limited by the lack of availability and high cost of low-carbon hydrogen (except in special cases such as from intermittent electricity generation at

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007

(2) Julia King, The King's Review of low carbon cars, 2007, http://www.hm-treasury.gov.uk/king (accessed Sep 3 2009)

times of day when there is no other use for that power) along with the lack of available vehicles and supply infrastructure.

- There may also be scope for future innovative *future fuel developments* to contribute to CO_2 reductions from fuels.

Policy Instruments

A range of transport-focused policy instruments with potential for controlling GHG emissions were considered and include the following:

- *Road Pricing*: a road pricing scheme is usually used to overcome local traffic congestion problems. It may be expected to have some impact on GHG emissions, but the relationships are not straight-forward and are specific to particular schemes, geographical locations, local economic and transport sector conditions. Feasibility studies conducted previously conclude that the case for introducing road pricing in Hong Kong is considered weak [(1)] . From overseas experience, a road pricing scheme that aims to relieve traffic congestion can only be implemented equitably and effectively in the presence of alternative routes with adequate capacity for motorists to by-pass the charging zone. In the case of Hong Kong, such an alternative route is the Central-Wanchai Bypass (CWB) which will not be in place before 2017. While the case for road pricing implementation in Hong Kong as a measure to combat GHG emissions has yet to be established, there is a possibility that the measure could remain under consideration in the long term.

- *Replacement of Goods Vehicles*: the main target vehicle groups for replacement are old, inefficient vehicles and heavy goods vehicles. It is a practice which has been implemented in Hong Kong as well as in many other jurisdictions. The HKSAR Government from 1 April 2007 to 31 March 2010 offered a time-limited one-off grant to vehicle owners to replace their pre-Euro and Euro I diesel commercial vehicles with Euro IV compliant vehicles [(2)]. Internationally, the State of California has several programs intended to phase out polluting or inefficient vehicles such as incentives for voluntary retirement of high emitting passenger cars and light- and medium-duty trucks as well as incentives to retrofit old polluting school buses [(3)]. While Canada has committed CA$92 million over four years beginning in 2009 to create incentives for Canadians to trade in vehicles made in 1995 or earlier which do not meet today's emission standards for newer, more efficient vehicles [(4)].

- Emission reduction from *off-road vehicles and equipment:* electrification of vehicles and equipment operated at the airport and the ports has the

(1) According to the Transport and Housing Bureau (THB) of Hong Kong Government.

(2) http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/old_diesel_com_veh_replace_prog.html#special_arrangement

(3) http://www.arb.ca.gov/ba/fininfo.htm

(4) http://www.ec.gc.ca/cleanair-airpur/Sustainable_Transportation/Vehicle_Scrappage_Program-WSF8711200-1_En.htm

potential to reduce GHG emissions from these sources. The electrification of port yard equipment is currently being considered by other jurisdictions and could be feasible for consideration in Hong Kong. The California Air Resources Board, California Climate Action Registry, and South Coast Air Quality Management District are considering the development of a protocol for the electrification of truck stops which would establish a standard methodology in determining greenhouse gas emission reduction from the use of electric power as opposed to a diesel-powered engine on a truck for idling purposes (1). As a port initiative, the Port of Long Beach is considering "Green-Container" Transport Systems which will involve broadening the use of electrification (from "green energy" sources) in port-related sources (2).

- Implementation of the Hong Kong "*Importers' Average Fleet Efficiency*" *Standard.* This Study examined a standard whereby the average imported vehicle efficiency should be 20% higher than the 2005 market average efficiency by 2015. This is an alternative to introducing an environmental tax on high emitting vehicles and its implementation cost would be relatively low.

- Given the positive effects of higher population densities on *public transport use, walking, cycling* and CO_2 emissions, further improved integrated spatial planning is an important policy element in the transportation sector.

- *Vehicle Information and Driver Education Programmes*: driving style affects fuel consumption and emissions. Information about opportunities to reduce vehicle fuel consumption could cover the vehicles themselves and driving style and habits. Vehicle energy labelling and driver education programmes should be considered.

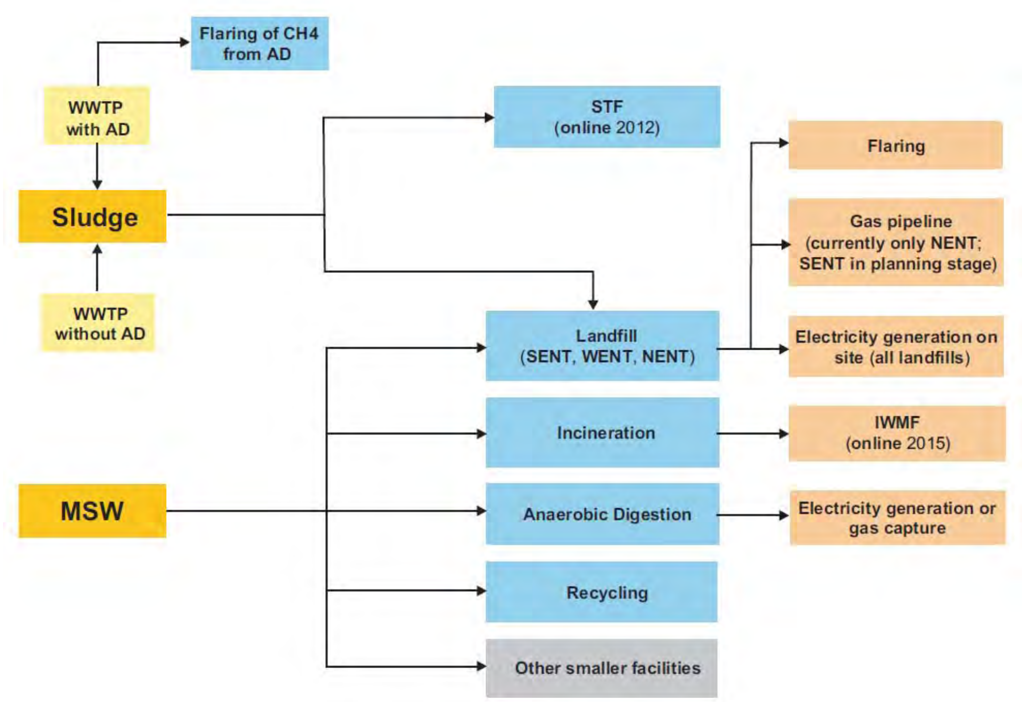
3.2.3 Waste

Figure 3.1 summarises the waste and wastewater management strategy in Hong Kong. Waste management is relevant from a climate change mitigation perspective as the anaerobic decomposition of organic material at landfill sites leads to the emission of methane (CH_4). A reduction in the amount of waste landfilled will reduce emissions.

(1) http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6344

(2) http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3468

Figure 3.1 *Waste and Wastewater Management in Hong Kong*



The most relevant climate change mitigation measure in the waste sector in Hong Kong is the recovery and utilisation of landfill gas in operating and closed/restored landfills. The recovered landfill gas, which essentially consists of CO_2 and CH_4, can then either be utilised as an alternative energy source on-site or off-site, or flared as an alternative way of reducing emissions. At present, all three strategic landfills have been utilising landfill gas for energy production and/or for Towngas production [(1)]. It is proposed that the landfill gas recovery rate would become higher, and there will be full utilisation of the landfill gas in the alternative mitigation scenarios.

With landfills expected to be exhausted earlier than first envisaged, the Government promulgated a policy framework in late 2005 with a view to manage Hong Kong's municipal solid waste in a sustainable manner. One element of the framework is the development of Integrated Waste Management Facilities (IWMF) that would adopt advanced incineration as the core waste treatment technology. The advanced technology, which is much cleaner than that of the incinerators previously operated in Hong Kong, involves high temperature combustion and allows for considerable power generation while reducing pressure on landfill sites substantially. The first phase of the IWMF would have a capacity of 3,000 metric tons per day and is planned to be commissioned by 2015 [(2)].

At present, all dewatered sewage sludge generated by sewage treatment works is disposed of at landfills in Hong Kong. This practice is not considered sustainable from both environmental and technical perspectives.

(1) All three strategic landfills have been partially utilising landfill gas for energy production and NENT has also been using landfill gas for Towngas production.

(2) http://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/WFdev_IWMF.html

In 2009, the Director of Environmental Protection (DEP), with the support of the Secretary for the Environment, proposed to design and construct the Sludge Treatment Facilities (STF). The capacity of the currently planned STF is 2,000 tonnes per day. Depending on the actual sewage sludge arisings in future, future upgrading of the STF capacity or even a new STF may be required [1] .

EPD is also planning to develop large scale Organic Waste Treatment Facilities (OWTF) to recycle organic waste from institutions, commercial and industrial establishments. Operation of the OWTF would reduce disposal of organic waste to landfills and produce useful products including compost and renewable energy. The first phase of OWTF would have a 200 metric tonnes per day capacity and is planned to be commissioned by the mid 2010's. The second phase is of a similar capacity and its commissioning is anticipated in late 2010's.

In addition to GHG mitigation, improved sanitation and waste management provide a wide range of public health and environmental co-benefits.

3.2.4 Energy Supply

Hong Kong has a diverse energy supply resource mix. Electricity is generated locally from coal and natural gas and a substantial quantity of nuclear electricity is imported from Guangdong. Reticulated consumer gas supplies are in the form of town gas manufactured from naphtha and natural gas.

Increasing the import of nuclear generated electricity from Mainland China, using more natural gas to generate electricity locally, and increasing the share of renewable energy would help Hong Kong to reduce carbon emissions. The potential for adverse effects in the long term, such as reduction in the overall energy supply security and reliability in Hong Kong, would need to be carefully considered before abandoning coal-fired electricity generation and converting the reticulated supply network to natural gas.

- Natural Gas

In August 2008, a Memorandum of Understanding (MOU) was signed between the HKSAR Government and the Central Government for the supply of nuclear electricity and natural gas to Hong Kong for the coming two decades. The MOU provides an opportunity to draw natural gas from three sources: first, from new gas fields planned to be developed in the South China Sea; second, from the second east-west gas pipeline bringing gas from Turkmenistan; and third, from a Liquefied Natural Gas (LNG) terminal to be located in the Mainland.

(1) http://www.legco.gov.hk/yr08-09/english/fc/pwsc/papers/p09-16e.pdf

- Nuclear

If Hong Kong is to expand its electricity import capacity from the Mainland and within the SAR itself, it needs not only to enhance the existing Nuclear Transmission Network (NTS), but also to build new transmission infrastructure between Hong Kong and the Mainland. Actual project costs are uncertain and will be subject to final network design and construction methods. The project lead time after a decision to proceed with such a project would be more than 8 years to allow for planning, design, permitting, construction and commissioning.

- Renewable Energy

New energy infrastructure investments, upgrades of energy infrastructure, and policies that promote energy security, can, in many cases, create opportunities to achieve GHG emission reductions (1). Renewable energy, such as large scale wind and solar, requires significant initial investment and operational costs.

In 2005 the First Sustainable Development Strategy the Government set a target of 1 to 2% renewable energy in electricity use by 2012. In addition to the IWMF being planned, both CLP and HEC are currently planning to develop off-shore wind farms.

- Overall Considerations

Hong Kong may import more nuclear electricity from Mainland China and more natural gas to generate electricity locally. The marginal electricity prices of both natural gas and nuclear electricity are higher than that of coal, and the natural gas price is expected to increase rapidly in this region (2) . Although the impact from fuel price changes on Hong Kong's aggregate GDP growth is small, the change of fuel mix will influence the future electricity tariff.

Further challenges are likely to be presented by both the increased import of natural gas and nuclear power. Generation and network infrastructure takes a long time to implement, requiring the resolution of a range of engineering issues, permitting processes and liaison with stakeholders. Continued engagement between industry and different stakeholder groups is needed to enable the development of feasible engineering options that meet the required programme.

Climate change policy objectives and other policies such as improving air quality should be well integrated to avoid wasteful investments and adverse effects on electricity supply reliability. Utilities need to plan effectively on the basis of asset lives which span more than two decades. Clear emission

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

(2) "Natural Gas in China Market Evolution and Strategy", IEA, June 2009.

reduction targets at least for 2020 and 2030 are necessary for practical planning and sustainability assessment.

3.3 ALTERNATIVE SCENARIOS

Following a review of local and international practices and policies that can contribute to the reduction of GHG emissions, three alternate Scenarios were developed. Each Scenario represents a set of measures which, working together, deliver varying degrees of emissions reduction over differing timescales. *Table 3.1* summarises some of the key measures included within each Scenario and their possible progress. It should be noted that the Scenarios were developed for the purpose of analyzing the effectiveness of alternate packages of practices and policies and hence to inform a decision on the likely ranges of emissions reduction that may be viable in Hong Kong. There remains a degree of uncertainty both as to the practices and policies that will ultimately be adopted and the degree to which they are effective. The degree of uncertainty is greater in the 2020 to 2030 time period than in the period up to 2020 and hence the policies and measures assumed for the purposes of this analysis may well be subject to change.

Table 3.1 Key Scenario Assumptions

Measures	Scenario 1 (2005-2030)	Scenario 2 (2005-2030)	Scenario 3 (2005-2030)
Buildings and Appliances (1)			
Expanding the scope and tighten the requirements of the Building Energy Codes	0.6% energy saving of total energy consumption by 2015	Up to 50% energy saving of major installations in all new commercial buildings by 2020	Up to 50% energy saving of major installations in all new commercial buildings by 2020
Expanding the use of district cooling system (DCS)/water-cooled air conditioning system (WACS)	0.5% saving in total energy consumption by 2020	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2030	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2030
Reducing energy demand in new buildings through e.g. tightening the overall thermal transfer value (OTTV) standards and promoting wider adoption of green roofing	N/A	Up to 50% cooling demand reduction in all new commercial buildings by 2020	Up to 50% cooling demand reduction in all new commercial buildings by 2020
Expanding the scope and tightening the energy efficient electrical appliance standards for domestic use	0.3% energy saving of total energy consumption by 2015	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level; Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level; Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level
Improving energy efficiency from Building Environmental Management System	N/A	Up to 15% energy efficiency improvement in up to 25% of existing commercial buildings by 2020; Up to 15% energy efficiency improvement in all existing commercial buildings by 2030	Up to 15% energy efficiency improvement in up to 25% of existing commercial buildings by 2020; Up to 15% energy efficiency improvement in all existing commercial buildings by 2030
Transport			
Wider use of motor vehicles running on alternative fuel	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV
Petrol blended with 10% Ethanol (E10)	N/A	All petrol to be blended with 10% of ethanol by 2020	All petrol to be blended with 10% of ethanol by 2020
Diesel blended with 10% Biodiesel (B10)	N/A	All diesel to be blended with 10% of biodiesel by 2020	All diesel to be blended with 10% of biodiesel by 2020
Implementation of "Importers' Average Fleet Efficiency" standard	N/A	New vehicles will be 20% more energy efficient than the 2005 market average by 2020	New vehicles will be 20% more energy efficient than the 2005 market average by 2020
Waste			
Construction and operation of waste-to-energy facilities	N/A	One IWTF with a treatment capacity of 3,000tonnes/day by 2020; Sufficient IWMFs to treat all MSW in HK by 2030. Two OWTFs operating at a total capacity of 400 tonnes per day by 2020.	One IWTF with a treatment capacity of 3,000tonnes/day by 2020; Sufficient IWMFs to treat all MSW in HK by 2030. Two OWTFs operating at a total capacity of 400 tonnes per day by 2020.
Utilization of landfill gas as energy source	N/A	Full utilization of recovered landfill gas	Full utilization of recovered landfill gas
Utilization of gas generated from wastewater treatment	N/A	Full utilization	Full utilization

Measures	Scenario 1 (2005-2030)	Scenario 2 (2005-2030)	Scenario 3 (2005-2030)
Utilization of sludge treatment with energy recovery	N/A	One sludge treatment facility operating at full capacity	One sludge treatment facility operating at full capacity
Energy Supply			
Use of coal in electricity generation	All power plants retire according to their expected life	All power plants retire according to their expected life	Accounting for less than 10% of fuel mix in 2020; zero in 2030
Use of natural gas in electricity generation	Natural gas makes up the balance of the share of the overall fuel mix, after taking account of RE, nuclear import and remaining coal	Natural gas makes up the balance of the share of the overall fuel mix, after taking account of RE, nuclear import and remaining coal	Making full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation (2)
Import of nuclear generated electricity	Maintained at the same level as in 2005	Maintained at the same level as in 2005 until 2020; meeting 35% of the local demand for electricity 2030	Nuclear electricity imported from the Mainland to meet 50% of the local demand for electricity from 2020 (2)
Renewable energy (RE) (3)	Meeting 4% of the local demand for electricity by 2020; 6% by 2030	Meeting 4% of the local demand for electricity by 2020; 15% by 2030	Meeting 3-4% of the local demand for electricity by 2020; 4% in 2030

Notes

(1) The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy reviews. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages, taking into account limitations, uncertainties and practicability of the measures within Hong Kong's local context.

(2) Assumptions provided by the Government.

(3) RE includes wind energy, and energy recovered from landfill gas (LFG), Integrated Waste Management Facilities (IWMF) and Organic Waste Treatment Facilities (OWTF). Scenarios 1 and 2 include RE imported from the Mainland, although the availability of this additional amount of RE sources in the neighbouring areas which may be able to supply electricity to Hong Kong in a technically feasible and cost-effective manner is subject to further studies.

3.3.1 *Scenario 1*

Scenario 1 (the 'AQO Scenario') includes relevant mitigation measures proposed in the AQO Study (1), including the increased use of natural gas and renewable energy sources for electricity generation, wider use of road vehicles using clean fuels, and enhanced energy efficiency in the building and appliance sector. It required some refinement of the AQO policy options for the following reasons.

- The AQO Study options were considered individually rather than in combination and thus not compatible with MARKAL-MACRO (MM), which is a dynamic macroeconomic model and considers measures in an integrated manner.
- For a number of options examined in the AQO Study, the required input parameters and assumptions for the HK MM model were not available. In these cases ERM and BNL have made assumptions based upon our understanding of the particular policy or measure (as implemented internationally) and/or the technology in question.
- Some measures proposed in the AQO Study were not assessed in the HKMM model either because they are not associated with GHG reduction or because they are not considered to be commercially viable within the necessary timeframe.

Specifically, Scenario 1 assumes the following.

Building and Appliance Sector (2)

- Annual 0.6% energy saving in total energy consumption in Hong Kong from energy efficiency improvement through mandatory implementation of Building Energy Code (BEC) by 2015.
- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.
- 0.5% energy saving in total energy consumption in Hong Kong from district cooling system by 2020.
- 0.3% energy saving of total energy consumption in Hong Kong from energy efficiency improvements in electrical appliances for domestic use by 2015.

Transport Sector

- Wider use of hybrid, electric powered, and biodiesel vehicles:

(1) Review of Air Quality Objectives and Development of a Long Term Air Quality Strategy for Hong Kong, July 2009.

(2) All energy saving information is based on the AQO Study assumptions.

- Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs
- Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs

Electricity Generation

- All power plants will retire according to their expected life.
- RE is to meet 4% of the local demand for electricity by 2020 and 6% by 2030 (including RE generated locally or imported from the Mainland) (1).
- Import of nuclear power maintained at the same level as in 2005.
- Apart from electricity generated by RE, nuclear, and remaining coal, all other local electricity consumption is from natural gas by 2030.

3.3.2 *Scenario 2*

Scenario 2 (the 'Accelerated Scenario') builds upon Scenario 1 and includes additional efforts on measures to increase energy efficiency and reduce energy demand, particularly in the building and transport sectors. Local sources of renewable energy such as waste-to-energy facilities are utilised by 2020. This scenario also assumes a certain level of integration of the power system between Hong Kong and its neighbouring areas. Electricity imported from Mainland China in 2020 is the same as that in 2005. In 2030, the scenario assumes, as a stress test, the notion that 50% of the electricity demand could be met by sources from the Mainland with no associated carbon emissions [(2)]. Specifically, Scenario 2 assumes the following.

Building and Appliance Sector

- Up to 50% energy saving of major installations in all new commercial buildings through measures such as expanding the scope, and tightening the requirements of the Building Energy Codes by 2020.
- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.
- Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; up to 50% energy efficiency improvement in all commercial buildings through measures such as expanding the use of district cooling system (DCS) and water-cooled air conditioning system

(1) In 2005 the First Sustainable Development Strategy sets a target of 1~2% RE in electricity use by 2012.

(2) This excludes remaining coal power plant generation. Among the electricity with no associated carbon emissions, 70% is from import of nuclear generated electricity.

(WACS). Energy efficiency improvement is compared with that of the regular air conditioning system.

- Up to 50% cooling demand reduction by 2020 in all new commercial buildings from measures such as new overall thermal transfer value (OTTV) standards and extensive green roofing.

- Appliances sold in the market in 2020 will be up to 25% more energy efficient; appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level by expanding the scope and tightening energy efficient electrical appliance standards.

- Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings by 2020; up to 15% energy efficiency improvement in all existing commercial buildings from improving energy efficiency from Building Environmental Management System by 2030.

Transport Sector

- Wider use of hybrid and electric powered vehicles (EV):
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs.
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs.

- Petrol blended with 10% ethanol by 2020 (E10) (1).

- Diesel blended with 10% biodiesel by 2020 (B10) (2).

- Implementation of the Hong Kong "Importers' Average Fleet Efficiency" standard by 2020 - new vehicles will be 20% more energy efficient than the 2005 market average.

Waste Sector

- Waste-to-energy facility:
  - One IWMF with a treatment capacity of 3,000 tonnes/day by 2020.
  - Sufficient IWMFs to treat all MSW in HK by 2030.
  - Two OWTFs operating at full capacity of 400 tonnes per day by 2020.

(1) All petrol contains a mixture of 10% ethanol by volume. Blends of ethanol above 10% are assumed to need engine modification.

(2) B5 Biodiesel, is comprised of a "blend" of 10% Biodiesel and 90% petroleum diesel. Blends biodiesel above 10% might need engine modification.

(5) The current conclusion that GDP and its growth will not be materially affected in the alternative scenarios against the Base Case is made based on the currently available information. The economic modelling is at a macro scale, and the detailed economic impact of individual measure should be subject to further assessment at a later stage. In

- Full utilization of the recovered landfill gas.
- Full utilization of gas generated from waste water treatment.
- One sludge treatment facility operating at full capacity by 2020.

Electricity Generation

- All power plants retire according to their expected life.
- Import of nuclear power maintained at the same level until 2020; approximately 50% of local electricity consumption by 2030 is from sources in the Mainland with no associated carbon emissions.
- Apart from electricity generated by RE, nuclear, and remaining coal, all other local electricity consumption is from natural gas by 2030.

3.3.3 Scenario 3

Scenario 3 (the 'Aggressive Scenario') builds upon Scenario 2 and accelerates the integration of the power system in Hong Kong with its neighbouring areas. It assumes that Hong Kong would make full use of the natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation for electricity generation. It also assumes that nuclear electricity imported from the Mainland would be able to meet 50% of the local demand for electricity from 2020. Specifically, Scenario 3 assumes the following.

Building and Appliance Sector

- Up to 50% energy saving of major installations in all new commercial buildings through measures such as expanding the scope, and tightening the requirements of the Building Energy Codes by 2020.
- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.
- Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; up to 50% energy efficiency improvement in all commercial buildings through measures such as expanding the use of DCS and WACS. Energy efficiency improvement is compared with that of the regular air conditioning system.
- Up to 50% cooling demand reduction by 2020 in all new commercial buildings from measures such as new OTTV standards and extensive green roofing.

- Appliances sold in the market in 2020 will be up to 25% more energy efficient; appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level by expanding the scope and tightening energy efficient electrical appliance standards.

- Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings by 2020; up to 15% energy efficiency improvement in all existing commercial buildings from improving energy efficiency from Building Environmental Management System by 2030.

Transport Sector

- Wider use of hybrid and electric powered vehicles (EV):
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs.
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs.

- Petrol blended with 10% ethanol by 2020 (E10).

- Diesel blended with 10% Biodiesel by 2020 (B10).

- Implementation of the Hong Kong "Importers' Average Fleet Efficiency" standard by 2020 - new vehicles will be 20% more energy efficient than the 2005 market average.

Waste Sector

- Waste-to-energy facility:
  - One IWMF with a treatment capacity of 3,000 tonnes/day by 2020.
  - Sufficient IWMFs to treat all MSW in HK by 2030.
  - Two OWTFs operating at full capacity of 400 tonnes per day by 2020.

- Full utilization of the recovered landfill gas.

- Full utilization of gas generated from wastewater treatment.

- One sludge treatment facility operating at full capacity by 2020.

Electricity Generation

- 10% coal penetration in 2020, and zero in 2030.

- Making full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation for electricity generation.

- Nuclear electricity imported from the Mainland would be able to meet 50% of the local demand for electricity from 2020.

- Local RE sources are sufficient to meet 3-4% of local electricity consumption in 2020, and 4% in 2030.

- No primary energy source accounts for more than around 50% of Hong Kong's total electricity supply.

3.4 SCENARIO ANALYSIS

This section evaluates the impact and cost-effectiveness of the three alternative scenarios by comparing the key model outputs with the Base Case. The key criteria used for evaluating the policies and measures in subsequent sections by the HKMM model are categorized in the three basic types of costs and benefits:

- **Energy:** effects on energy flow and technological activities, such as oil and gas imports, electricity generation capacity mix, etc.

- **Environmental:** effects on GHG emissions and local air pollutants.

- **Economic:** effects on GDP and marginal abatement cost of carbon.

3.4.1 *Carbon Emissions Abatement and GDP Impact*

Table 3.2 shows that the total annual carbon emission in 2030 falls to 39.3 million tonnes CO_{2-e} for Scenario 1, 29.8 million tonnes CO_{2-e} for Scenario 2, and 26.8 million tonnes CO_{2-e} for Scenario 3, down from 44.8 million tonnes CO_{2-e} projected for the Base Case. The reduced emissions in 2030 are 6%, 29% and 36% below the 2005 carbon emission level for Scenarios 1, 2 and 3, respectively. In the Base Case emissions were predicted to be 7% above the 2005 level by 2030.

Table 3.2 GHG Emissions in Hong Kong by Scenario (Million Tonnes CO_{2-e})

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	42.0	46.1	44.8	10%	7%
Scenario 1	42.0	43.0	39.3	2%	-6%
Scenario 2	42.0	41.9	29.8	0%	-29%
Scenario 3	42.0	29.5	26.8	-30%	-36%

Results of Scenario 1 show that although co-benefits from measures targeted at improving air quality are found to be large, and may help to offset mitigation costs, they alone are unlikely to provide sufficient incentives to achieve an aggressive GHG emission reduction target.

Scenarios 2 and 3 deliver substantive reductions in emissions over the planning period, with Scenario 3 achieving reductions most rapidly due to the earlier introduction of more imported electricity into Hong Kong.

As shown in *Table 3.3*, the GDP is projected to grow at an annual average growth rate of 3.01% in the Base Case from 2005 to 2030, and it is not predicted to be materially affected under the alternative scenarios. This is attributable to a variety of factors including energy efficiency measures, which will generate long-term savings in energy costs (5) .

Table 3.3 ***GDP in Hong Kong by Scenario (Billion 2005 HK $)***

	2005	2020	2030	2020 vs. 2005 Annual average growth rate	2030 vs. 2005 Annual average growth rate
Base Case	1,383	2,258	2,905	3.32%	3.01%
Scenario 1	1,383	2,263	2,916	3.34%	3.03%
Scenario 2	1,383	2,264	2,928	3.34%	3.05%
Scenario 3	1,383	2,270	2,947	3.36%	3.07%

3.4.2 *Carbon Intensity*

In 2005, the carbon intensities in Hong Kong, both in terms of GHG emissions per GDP value or on a per capita basis were among the lowest in the world's developed economies [1] . As shown in *Table 3.4* and *Figure 3.2*, the intensity against GDP in 2030 is projected to decrease to 0.0154, 0.0135, 0.0102, and 0.0091 kg $CO_{2\text{-}e}$ / HK$GDP by 2030 in the Base Case, Scenario1, Scenario 2, and Scenario 3, respectively, from the current level of over 0.0304 kg $CO_{2\text{-}e}$ / HK$GDP. It should be noted that Scenario 3 outperforms the Mainland target of reducing energy related carbon intensity of 40% to 45% by 2020 [2].

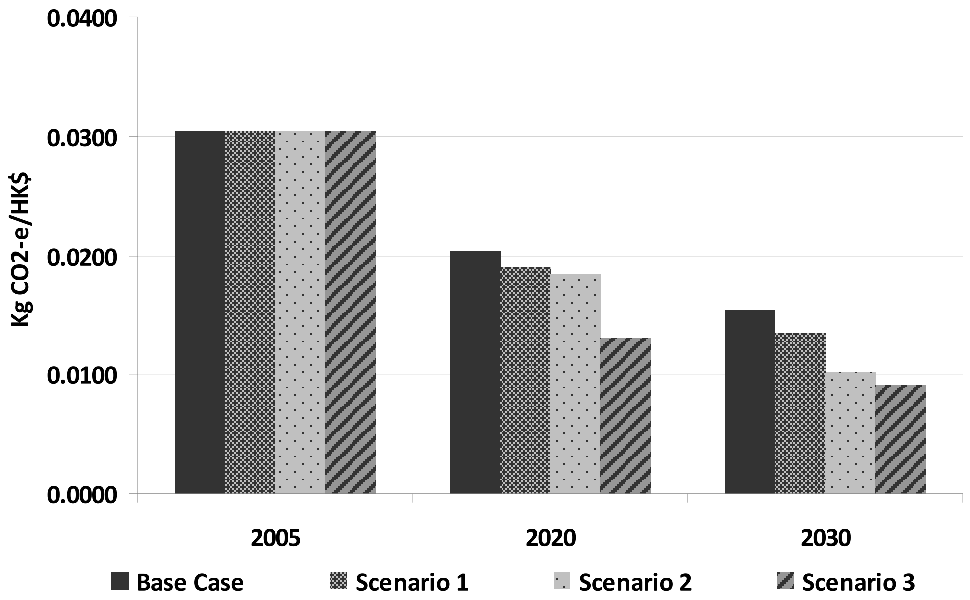
(1) http://www.iea.org/country/maps/world/co2_pop.htm; http://www.iea.org/country/maps/world/co2_gdp.htm (accessed on Oct 8 2009)

(2) The national carbon intensity target refers to the energy related CO2 per GDP value, while carbon intensity presented in this Study refers to total GHG emissions per GDP value. Hong Kong will control GHG emissions from all sources, including non-energy related carbon emissions such as methane from landfills, and thus the carbon intensity target includes all types of GHG emissions.

Table 3.4 ***Carbon Intensity (GHG Emissions per unit GDP in kg CO_2-e / HK$)***

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	0.0304	0.0204	0.0154	-33%	-49%
Scenario 1	0.0304	0.0189	0.0135	-37%	-56%
Scenario 2	0.0304	0.0185	0.0102	-39%	-66%
Scenario 3	0.0304	0.0130	0.0091	-57%	-70%

Figure 3.2 ***Carbon Intensity (GHG Emissions per unit GDP in kg CO_2-e / HK$)***

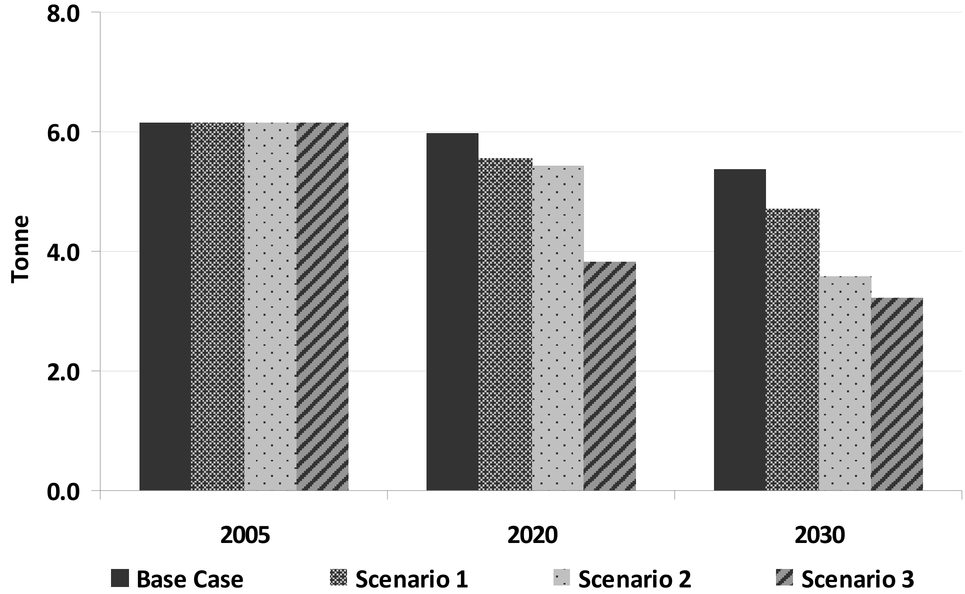


As shown in *Table 3.5* and *Figure 3.3*, carbon emissions per capita are predicted to fall from 6.2 tonnes to 5.6, 5.4, and 3.8 tonnes $CO_{2\text{-}e}$ for Scenarios 1, 2 and 3, respectively by 2020. The corresponding projected figures for 2030 are 4.7, 3.6, and 3.2 tonnes $CO_{2\text{-}e}$ per capita, respectively. Except for Scenario 3, both measures of carbon intensity are projected to drop at a faster rate between 2020 and 2025 in all cases because most of the existing coal-fired power plant units are scheduled to decommission during this period.

Table 3.5 ***Carbon Emissions per Capita (Tonne CO_2-e)***

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	6.16	5.97	5.39	-3%	-13%
Scenario 1	6.16	5.57	4.72	-10%	-23%
Scenario 2	6.16	5.43	3.58	-12%	-42%
Scenario 3	6.16	3.83	3.23	-38%	-48%

Figure 3.3 Carbon Emissions per Capita (Tonne CO_2-e)



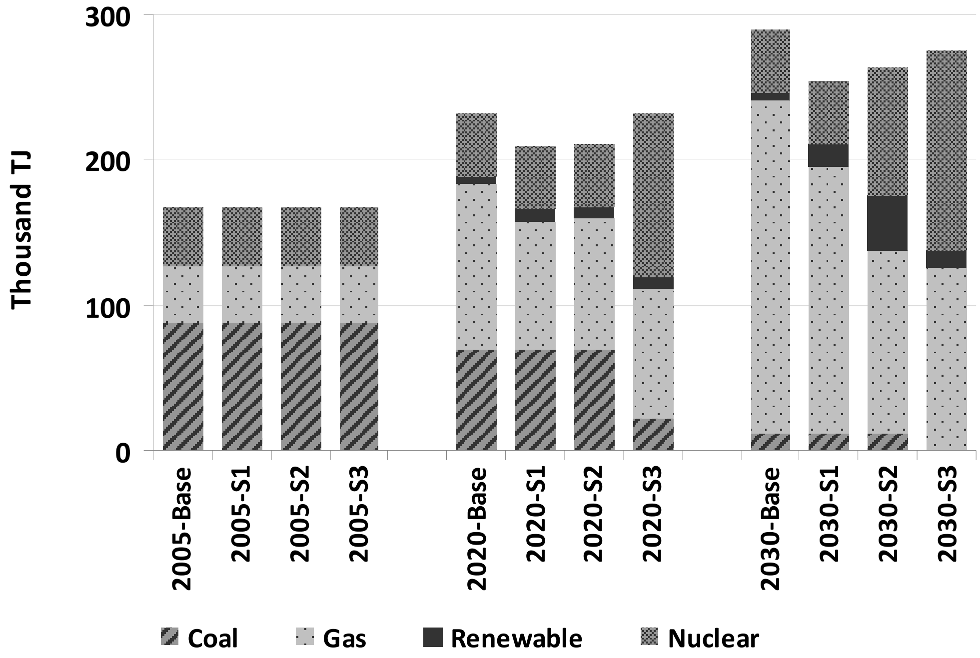
3.4.3 *Electricity Output*

In Hong Kong, electricity is the dominant energy carrier, accounting for more than 50% of the final energy use in 2005. This market share is projected to increase to over 60% in 2030 in the Base Case. The future may see two contradicting trends: on the one hand, more efficient end-use devices reduce electricity demand, whereas new electricity-using devices such as electric cars may be introduced to replace conventional gasoline vehicles, as assumed in the three mitigation Scenarios, thereby increasing the electricity use in the transportation sector.

Figure 3.4 presents the electricity output by source as well as the fuel mix in 2020 and 2030 for the different scenarios. In 2005, coal has the largest share and generates about 50% of electricity in Hong Kong. Under the Base Case, natural gas will progressively replace coal and generate approximately 80% of the electricity in 2030.

Under Scenario 3, no coal will be used for electricity generation in 2030. Natural gas used for electricity generation doubles in 2020, and almost triples in 2030, compared to the quantity used in 2005. Electricity from natural gas is projected to grow to 46% of the total. Electricity from renewable energy is expected to grow from less than 1% in 2005 to 4% of the total in 2030. Electricity from nuclear sources in the Mainland China in 2030 is expected to be more than three times the quantity used in 2005. It is projected to account for approximately half of the electricity usage beginning in 2020.

Figure 3.4 Electricity Output by Source (Thousand TJ)



The use of renewable resources, such as wind, reduces carbon emissions but is more costly than conventional electricity generation. The higher cost of electricity tends to lower those energy service demands requiring high electricity intensity devices to meet them. On the other hand, imports of natural gas in the future are projected to be more costly than at present, which may make electricity generated by gas-fired generation in Hong Kong more expensive than the nuclear electricity imports from Mainland China.

3.4.4 *Reduction in Other Air Pollutants from Power Generation*

There is a potentially large and diverse range of co-effects from climate change mitigation policies, which lower the net costs of emission reductions and thereby may strengthen the incentives to reduce emissions. Many recent studies have demonstrated significant benefits of carbon-mitigation strategies on human health, mainly because they also reduce other emissions, for example, SO_2, NO_x and particulate matter. This is projected to result in improvements to air quality and the prevention of some premature deaths due to air pollution. Quantification of mortality risks remains controversial, and hence a large range of benefits estimates can be found in the literature (1).

In the HKMM model, we have built in the emission coefficients for SO_2, NOx, and PM_{10} for power plants. Based on the projected fuel use by the sector to meet demand at market equilibrium, the model is able to account for the total emissions for these air pollutants, as shown in *Tables 3.6, 3.7* and *3.8*.

(1) IPCC, Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

Table 3.6 *Sulphur Dioxide from Electricity Generation (Thousand Tonnes)*

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	61.5	11.1	4.3	-82%	-93%
Scenario 1	61.5	11.0	4.1	-82%	-93%
Scenario 2	61.5	11.0	3.8	-82%	-94%
Scenario 3	61.5	5.0	0.6	-92%	-99%

Table 3.7 *Nitrogen Oxides from Electricity Generation (Thousand Tonnes)*

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	42.2	34.6	24.3	-18%	-42%
Scenario 1	42.2	32.7	20.4	-23%	-52%
Scenario 2	42.2	34.4	15.5	-19%	-63%
Scenario 3	42.2	16.8	10.6	-60%	-75%

Table 3.8 *Particulates (PM10) from Electricity Generation (Thousand Tonnes)*

	2005	2020	2030	2020 vs. 2005	2030 vs. 2005
Base Case	1.9	0.9	0.6	-52%	-70%
Scenario 1	1.9	0.9	0.5	-55%	-75%
Scenario 2	1.9	0.9	0.4	-55%	-80%
Scenario 3	1.9	0.4	0.2	-78%	-88%

Compared with the Base Case for the year 2005, the results show that in 2030:

- Sulphur dioxide emissions reduce by over 90% in all Scenarios by 2030;
- By 2030 nitrogen oxides emissions reduce by 52%, 63%, and 75% in Scenarios 1, 2, and 3, respectively;
- PM10 emissions reduce by 75%, 80%, and 88% in Scenarios 1, 2, and 3, respectively, by 2030 (1).

These estimates should be used for indicative purposes only and have the following limitations:

- The estimates are based on the average emission rates for the existing assets and are not responsive to the change due to future decommissioning of individual units.
- The exact operation and fuel use of each unit in the future cannot be reliably determined.

3.4.5 *Scenario Analysis by Mitigation Sectors*

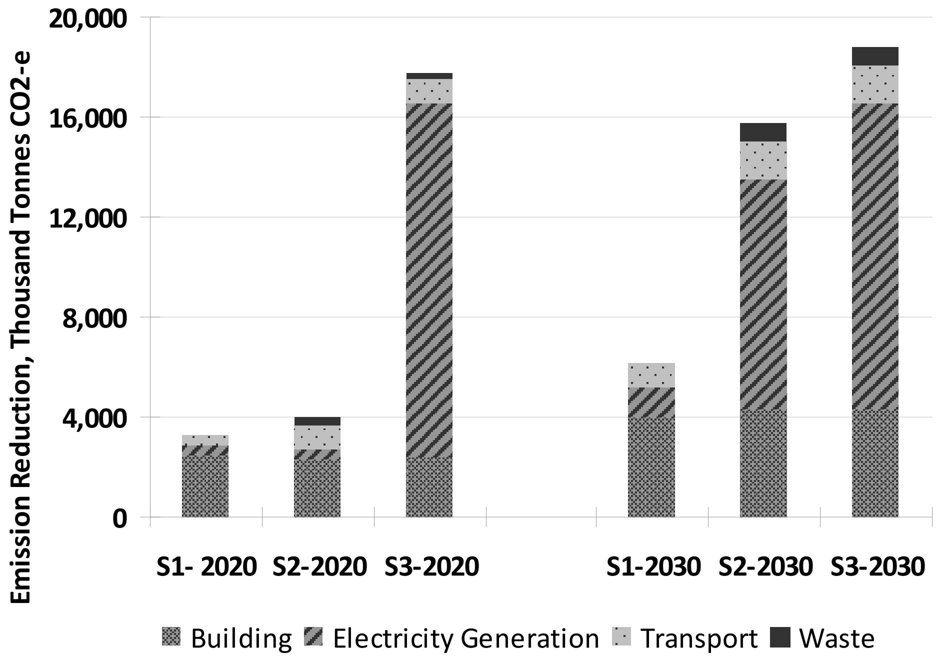
This section evaluates the carbon abatement potentials in particular sectors (i.e. building, transport, electricity generation, and waste) for all three alternative scenarios. This is achieved by performing a static comparative analysis on the MARKAL Model results obtained under partial equilibrium of

(1) The air emission reductions in Scenario 1 are not directly comparable with those in the AQO study due to several factors including 1) different modelling approaches were adopted; 2) the AQO study assumes 50% nuclear and 50% natural gas will be used to generate electricity by 2030, which is different from the assumptions in Scenario 1.

the energy market. Carbon emissions and associated energy system costs for each sector in all three scenarios are compared to the Base Case to evaluate each sector's abatement potential.

Figure 3.5 presents the carbon emission reduction potentials in 2020 and 2030 for Scenarios 1, 2 and 3 relative to the Base Case.

Figure 3.5 ***Carbon Abatement Potential by Sector by Scenario (Tonne CO_2-e)***



It is important to note that the abatement potentials calculated for each sector are not to be used to estimate the total system abatement potential. This is due to the fact that static comparative analysis does not catch the potential offsets (or synergies) among sectors and various sub-sectors. For example, a reduction in electricity demand in the buildings sector also reduces the size of the electricity market and hence, the abatement potential of the supply group. Another limitation of the static comparative analysis arises from that fact that mitigation measures in one sector may require the synergy provided from measures in another sector. For example, in the transportation sector in Scenario 3, the measures to switch all passenger cars and taxis to electric vehicles would increase electricity supply. This increase would result in a net increase in carbon emissions unless it is met by renewable or imported nuclear electricity instead of the gas combined cycles (a synergy required from the supply sector).

3.4.6 *Limitations and Challenges of the HKMM Modelling Methodology*

The HKMM model developed for this study represents the detailed energy and environmental system of the HKSAR, which facilitates the evaluation of GHG abatement potentials under various mitigation scenarios. The model measures the impact of alternative energy system development pathways determined under each scenario on economic growth, in terms of GDP changes. Even though the model's results and analysis presented in this section exhibit its diverse capability in achieving the objectives of the study, there are limitations and challenges to the approach that need further attention to refine and expand its current structure/approach. We outline the main limitations and challenges below.

- The current structure of HKMM confines the analysis of GHG mitigation impacts strictly within the Hong Kong SAR. A better coordination of joint analysis and implementation of these measures can be accomplished in a multi-regional MARKAL model framework.

- The embodied energy and GHG that are crucial to the manufacture and transportation of various consumer and industrial products and materials (eg cement) imported to the HKSAR are not considered in the HKMM. Additional mitigation measures (eg imports of green products and conservation of material use) need to be addressed to expand the abatement potential in Hong Kong SAR and beyond.

- Not all economic benefits can be reflected in the Model. For instance, green jobs can be created when renewable energy plants are built, but it is difficult to quantify and forecast the associated economic benefit. Also, the assessment doesn't quantify the energy reduction potential from changes of consumer habits.

- The impact of mitigation measures on consumer inflation and business costs is not quantified in the Model. In the short and medium term, inflation and business costs may be affected by the energy prices and investment costs. However, they are also influenced by a variety of factors such as relative elasticity of wages, interest rates, and growth rate of money supply.

- Normal climate conditions were assumed in the energy use projection. Should the prevailing temperatures change as a consequence of climate changes, the final energy demand might be different. For example, higher temperatures implies higher energy demands for cooling and hence an increase in carbon emissions.

- The assumptions and model outputs are not accurate projections for the future. The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy review. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages.

3.5 *SCENARIO 3 MEASURES AND POSSIBLE PROGRESS*

To deliver a substantive reduction in carbon intensity, implementing Scenario 3 is preferred. As compared with other Scenarios, Scenario 3 could also deliver substantive reduction in GHG emissions in absolute terms between 2005 and 2020 and would deliver more GHG reduction than Scenario 2 by 2030. *Table 3.9* presents key measures to support the achievement of carbon intensity reduction under Scenario 3 and possible progress of these measures by 2020 and 2030.

Meeting the predicted levels of reduction in carbon intensity and GHG emissions under Scenario 3 by 2020 will require a significant and rapid rebalancing of the fuel mix in the electricity sector and associated investments in the transmission infrastructure. Given the time needed to plan and construct such infrastructure, as well as securing energy supplies, early adoption of these measures is required to deliver the 2020 national target. Accelerating the pace of energy efficiency gains is also necessary and will require support and participation from all sectors of the economy, as well as a favourable economic environment.

Table 3.9 Key Measures to Support Achievement of Carbon Intensity Reduction under Scenario 3 and the Possible Progress of these Measures by 2020 and 2030

Measures	**Scenario 3**		
Buildings and Appliances (1)		**2020**	**2030**
Expanding the scope and tighten the requirements of the Building Energy Codes (BEC)		Up to 50% energy saving of major installations in all new commercial buildings	Up to 50% energy saving of major installations in all new commercial buildings
Expanding the use of district cooling system (DCS)/water-cooled air conditioning system (WACS)		Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners	All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners
Reducing energy demand in new buildings through e.g. tightening the overall thermal transfer value (OTTV) standards and promoting wider adoption of green roofing		Up to 50% cooling demand reduction in all new commercial buildings	Up to 50% cooling demand reduction in all new commercial buildings
Expanding the scope and tightening the energy efficient electrical appliance standards for domestic use		Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level	Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level
Improving energy efficiency through good housekeeping, information technology products or intelligent Building Environmental Management System		Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings	Up to 15% energy efficiency improvement in all existing commercial buildings
Transport			
Wider use of motor vehicles running on alternative fuel		Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% goods vehicles	Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV
Petrol blended with 10% Ethanol (E10)		All petrol to be blended with 10% of ethanol	Same as 2020
Diesel blended with 10% Biodiesel (B10)		All diesel to be blended with 10% of biodiesel	Same as 2020
Implementation of importers' average fleet efficiency standards		New vehicles will be 20% more energy efficient than the 2005 market average	Same as 2020
Waste			
Construction and operation of waste-to-energy facilities		One IWMF with a treatment capacity of 3,000 tonnes/day; two OWTFs operating at a total capacity of 400 tonnes per day	Sufficient IWMFs to treat all MSW in HK; two OWTFs operating at a total capacity of 400 tonnes per day
Utilization of landfill gas as energy source		Full utilization of recovered landfill gas	Full utilization of recovered landfill gas
Utilization of gas generated from wastewater treatment		Full utilization	Full utilization
Utilization of sludge treatment with energy recovery		One sludge treatment facility operating at full capacity	One sludge treatment facility operating at full capacity
Energy Supply	**2005**	**2020**	**2030**
Use of coal in electricity generation	ca 50%	≤10%	0%
Use of natural gas in electricity generation	ca 25%	ca 40%	ca 50%
Import of nuclear generated electricity	ca 25%	ca 50%	ca 50%
Renewable energy (RE) (2)	<1%	3% to 4%	3% to 4%

Notes:

(1) The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy reviews. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages, taking into account limitations, uncertainties and practicability of the measures within Hong Kong's local context.

(2) RE includes wind energy, and energy recovered from landfill gas (LFG), Integrated Waste Management Facilities (IWMF) and Organic Waste Treatment Facilities (OWTF).

4 VULNERABILITY AND ADAPTATION TO A CHANGING CLIMATE

4.1 BACKGROUND

Atmospheric carbon dioxide (CO_2) has been maintained, by the carbon cycle, at 200 to 300 parts per million (ppm) over the last 400,000 years (1), and at 260–280 ppm for the 10,000 years between the end of the last glacial maximum and the start of the industrial era c.1750 (2). Human activities have interfered with this balance since the 1700s by releasing greenhouse gases (GHGs) into the atmosphere through a variety of activities including: the combustion of fossil fuels, land-use changes, agricultural activities and the use of CFCs in refrigeration systems.

The current atmospheric CO_2 concentration is 387ppm (3), up almost 40% since the industrial revolution and the highest for at least the last 650,000 years. Observations indicate that this atmospheric concentration is increasing every year (*Figure 4.1*), similar to the other GHGs.

At present, about 49 billion tonnes of GHGs is emitted globally each year (4), mostly through the combustion of coal, oil and gas for energy. Between 1970 and 2004, global emissions of GHGs, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), weighted by their global warming potential (GWP), have increased by 70% (5) (24% between 1990 and 2004) (6). By 2030, atmospheric concentrations of CO_2 are likely to be 60% higher than they would be without human interference (7).

(1) Mayor of London, 2008: The London Climate Change Adaptation Strategy. Draft Report (August 2008).

(2) Denman, K.L., G. Brasseur, A. Chidthaisong, P. Ciais, P.M. Cox, R.E. Dickinson, D. Hauglustaine, C. Heinze, E. Holland, D. Jacob, U. Lohmann, S Ramachandran, P.L. da Silva Dias, S.C. Wofsy and X. Zhang, 2007: Couplings Between Changes in the Climate System and Biogeochemistry. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

(3) NOAA, Mauna Loa Observatory carbon dioxide dataset. Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/)

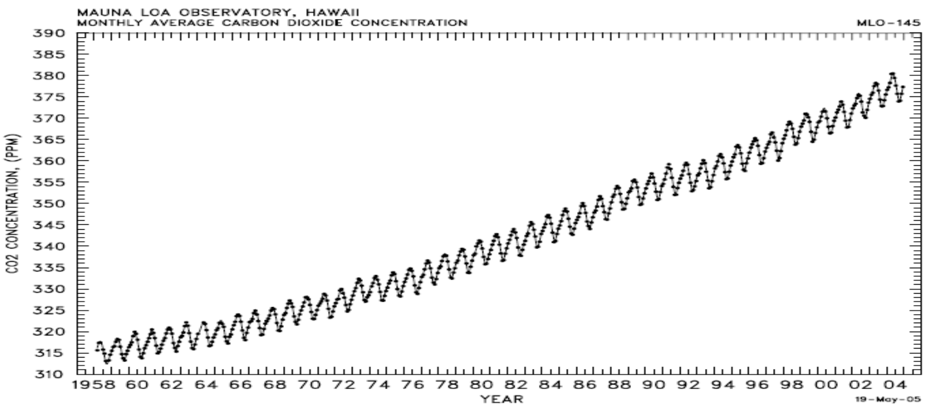
(4) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.), IPCC, Geneva, Switzerland.

(5) Weighted by their global warming potential (GWP)

(6) IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marqu

(7) Dupont, Alan. and Pearman, Graeme, 2006: Heating up the Planet – Climate Change and Security, Sydney Lowy Institute, 143 pp.

Figure 4.1 Recent Historic Atmospheric CO_2 Concentrations



Source: Keeling and Whorf, 2005 (1)

According to the Fourth Assessment Report (AR4) of the IPCC, during the past century the global average temperatures have risen by 0.74 °C between 1906 and 2005 (100-year linear trend). For the next two decades, 0.2 °C of warming per decade is projected. AR4 also assessed that even under the most optimistic climate modelling scenarios the average global temperature will rise by 1.8°C to 4.0°C by 2100. Sea level rise is another anticipated impact resulting from climate change. AR4 reports that satellite data show that the global average sea level has risen at 1.8mm per annum since 1961 and at 3.1 mm per annum since 1993.

4.2 *CLIMATE CHANGE IN HONG KONG*

A climate change vulnerability assessment for Hong Kong has been carried out using scenarios that are based upon the science in the IPCC AR4 and publications by the Hong Kong Observatory (HKO). HKO began making systematic observations of climatic variables more than 120 years ago. There are observable changes in many weather patterns, including many key impacts that have been observed within the last 60 years, which also correspond to the changes experienced by many global climatic systems observed over the same period.

Climate change will exert many, albeit very different, impacts, on various sectors and sub-sectors of the Hong Kong economy. *Tables 4.1* and *4.2* summarise some of the major observed climatic changes in Hong Kong and the key impacts of projected future climate change scenarios, respectively.

(1) Keeling, C.D., and T.P. Whorf, 2005: Atmospheric CO2 records from sites in the SIO air sampling network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy

Table 4.1 Observed Climate Changes in Hong Kong (HKO)

Variable	Observed Change
Annual mean temperature	+0.12 °C per decade (1885-2009)
Mean diurnal range	-0.24 °C per decade (1947-2009)
Hot nights (minimum temperature ≥ 28 °C) in June - August	+3.5 nights per decade (1947-2009)
Cold days (minimum temperature ≤ 12 °C) in December - February	-2.3 days per decade (1948-2009)
Annual rainfall	+51 mm per decade (1947-2009)
Thunderstorms days	+1.8 days per decade (1947-2009)
Heavy rain days (hourly rainfall > 30 mm)	+0.4 days per decade (1947-2009)
Mean sea level (Victoria Harbour)	+26 mm per decade (1954-2009)

Table 4.2 Projected Change in Climatic Factors by 2100 (HKO)

Variable	Current Conditions	Impact	Lower Bound	Upper Bound	Level of Confidence
Decadal mean annual temperature	23.1 °C	27.9 °C	24.5 °C	32.3 °C	High
Hot nights in June - August	12.2	41.2	22.0	68.7	Medium to Low
Very hot days (maximum temperature ≥ 33 °C) in June – August	8.2	15.3	9.6	23.5	Medium to Low
Cold days in December - February	16.3	<1	<1	<1	Medium to Low
Annual rainfall (mm)	2383	2572	1763	3235	Low
Heavy rain days	6.1	6.5(*)	2.5(*)	8.3(*)	Low
Years with annual rainfall < 1282 mm	2(#)	3.6(+)	Not defined	Not defined	Low

Notes:

Unless otherwise specified, the reference period for current conditions is 1971-2000 while that for impact, lower/upper bound is 2090-2099.

*: 2070-2099

#: 1885-2008

+: 2010-2099

Projected figures may be revised as scientific data and information are updated.

4.3 UNCERTAINTIES IN CLIMATE CHANGE SCIENCE

The subject of climate change is relatively new and the science is constantly evolving. There are considerable scientific uncertainties associated with lack of information and disagreement about what is known or even knowable embedded in the current state of climate change science. It is worth noting that climate *projections* should not be misinterpreted as climate *predictions.* The scientific community adopts the term *projections* (and not *predictions*) when describing future changes in climate as *projections* involve assumptions in parameters, e.g. future socio-economic and technological developments, and are therefore subject to substantial uncertainty.

The IPCC AR4 currently represents the best available international consensus on the likely impacts of climate change, upon which the current vulnerability analysis for Hong Kong is based. Nonetheless, ERM has noted areas where the risks are such that a watching brief needs to be maintained on the latest science to ensure that appropriate responses are developed. These include[(1)]:

- "Real World" Environmental Uncertainty; Inherent and Natural Internal Variability: natural external factors (e.g. solar output, volcanic activity) or future choices made by societies.

- Data Uncertainty: e.g. measurement error, incomplete or insufficient data due to limited temporal and spatial resolution, extrapolation based on uncertain data.

- Knowledge Uncertainty: e.g. lack of knowledge regarding future emissions, uncertainties about sea level rise.

- Model Uncertainty: e.g. model choice and structure, model input values, model parameters or model output variables and values

Uncertainties may arise from a variety of sources and ranking or estimating their magnitude often relies on expert, subjective judgement. Therefore, any climate change adaptation strategies should be flexible enough to be effective in the context of a degree of uncertainty and be able to accommodate and assimilate new evidence as it arises.

4.4 *HONG KONG CLIMATE CHANGE VULNERABILITY ASSESSMENT*

4.4.1 *Sector Coverage*

The vulnerability of following sectors of Hong Kong to climate change was assessed in this Study:

- Agriculture
- Aquaculture
- Biodiversity and Nature Conservation
- Built Environment and Infrastructure
- Business and Industry
- Energy Supply
- Financial Services
- Food Resources
- Human Health
- Leisure and Tourism
- Water Resources

(1) Willows, R.I., and R.K. Connell, (Eds.), 2003: Climate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.

4.4.2 *Framework for Vulnerability Assessment*

A framework based upon best practice identified through an international literature review was used for assessing the vulnerability for each of the sectors and associated systems (i.e. sub-sectors), and hence the determination of key vulnerable sectors. The framework of this assessment involves four main stages:

1. Exposure and Sensitivity Analysis

This stage identified the exposure (i.e. the background climate conditions and their changes) that could impact on systems/receptors in each of the sectors as well as the sensitivity of the systems/receptors to such exposures. Climate change scenarios developed from local studies by the HKO and international studies such as the IPCC AR4 were used for this assessment. The assessment included a review of the level of confidence with respect to the exposure and sensitivity of the sector in Hong Kong as well as identifying the sources of such uncertainties.

2. Identification of Potential Consequences

This stage identified the potential consequences of the exposure and sensitivities identified under stage 1, i.e. who and what will be affected, as well as the level of confidence in such assessment and the source of associated uncertainties.

3. Climate Change Impacts and Vulnerability Assessment

This stage provided an overview of how vulnerable each system/receptor was to the potential impacts associated with the changing climate, i.e. how exposed is this system to the impact, how sensitive are they to the change, and what is their capacity to adapt.

4. Selecting 'Key' Vulnerabilities

Based upon the preceding stages ERM identified key vulnerable sectors in Hong Kong. Some of the criteria / elements that were considered when identifying key vulnerabilities include magnitude, timing, persistence and reversibility of impacts, likelihood of impacts and vulnerabilities, and confidence in those estimates, potential for adaptation, distributional aspects of impacts and vulnerabilities, and importance of the vulnerable system(s) to Hong Kong.

4.4.3 *Uncertainties and Limitations of Vulnerability Assessment*

This is the first comprehensive assessment of vulnerability to climate change in Hong Kong. It has been carried out based upon the current state of knowledge and the information available in the IPCC AR4 as well as consultant's and health expert's judgments so as to make an assessment of the potential areas of greatest risk. It should be acknowledged that the quality and quantity of information available to make the assessment vary between systems. Moreover, there are uncertainties and limitations associated with the information in AR4 and hence the outcome of the vulnerability assessment. For instance, there is higher uncertainty in how biodiversity will respond to changing climatic conditions when compared to some other highly managed systems such as the built environment and infrastructure. Where there is a lack of "local" scientific data to support the research-driven approach to assess the vulnerability and adaptation of a particular sector, ERM has exercised expert judgement to determine the risk rankings of this sector, for example, the risk rankings under Human Health sector.

At the time of preparing this report, IPCC is preparing the Fifth Assessment Report (AR5) due for publication in 2015. Much work is being undertaken, including the development of new scenarios for impacts, adaptation and vulnerability (IAV) assessments. With the rapid evolution in the climate change science, the vulnerability assessment should be considered as a dynamic process and the findings of the assessment should be regularly reviewed and updated, particularly given the high-levels of uncertainty inherent in an exercise of this nature. It should be noted that this vulnerability assessment provides a high-level "screening" of the key vulnerabilities that are currently considered critical.

4.5 *KEY VULNERABILITIES IN HONG KONG*

Based on the future climate scenario outlined in *Table 4.2*, an assessment was undertaken to identify the key sectoral vulnerabilities. Eight key sectors were identified as having a "high" vulnerability to climate change impacts, namely: Biodiversity and Nature Conservation; Built Environment and Infrastructure; Business and Industry; Energy Supply; Financial Services; Food Resources; Human Health, and Water Resources. Examples of projected impacts to key vulnerable sectors are summarised in *Table 4.3*. Further description of projected impacts is provided in *Appendix C*.

Table 4.3 Examples of Projected Impacts for 'Key' Vulnerable Sectors

'Key' Vulnerable Sectors	Examples of Projected Impacts
Biodiversity and Nature Conservation	• Climate change can increase loss of biodiversity and increase colonisation of invasive species • Damage to woodlands, coral communities due to increase in frequency and/or severity of extreme weather • Change in species distribution patterns due to increase in surface temperatures
Built Environment and Infrastructure	• Very high uncertainties in the magnitude and rate of sea level rise • Developments located on low-lying areas / reclaimed land are highly sensitive to climate change • Heavy rain, thunderstorm and extreme weather leading to the damage of building foundations, increased risk of rain penetration of building fabric, and damage to utilities cabling and pipes • Potential asset damage because of flooding, landslides, wind damage, storm surge, and lightning strike, etc.

'Key' Vulnerable Sectors	Examples of Projected Impacts
Business and Industry	• Heavy reliance on international trade, financial markets, imports of key products and services exposing Hong Kong to climate change impacts beyond its boundaries and increasing its vulnerability • Vulnerable to climate change impacts on other areas such as food and water resources, transportation and infrastructure, etc. • Higher insurance costs
Energy Supply	• Interruptions in power supply are likely to result in economic and social costs. Also, electricity generation, supply and primary energy supply are vulnerable to climatic disruptions • High uncertainties in impacts along the supply chain and effects of warmer climate • Increased demand from air conditioning and refrigeration due to increase in surface temperatures leading to supply interruptions and power spikes • Risk of flooding, lightning strike, landslides, causing damage to power lines and other assets
Financial Services	• Direct risk relating to vulnerability of telecommunications and computer systems to storms, power failure and spikes • Indirect exposure in terms of changes to the risk profile of individual business and their investments • Some segments of financial services likely to be more exposed, e.g. insurance • Sector may be vulnerable to impacts on other areas i.e. infrastructure
Food Resources	• Extreme weather reducing agricultural outputs at sources of food imported to Hong Kong and pushing up commodity prices • Rise in temperature and increased incidence of pests and diseases affecting poultry and livestock species and resulting in more expensive and lower availability of imports
Human Health	• Climate change expected to disproportionately affect vulnerable groups • Chronic health conditions such as cardio-vascular and respiratory diseases may be aggravated by climatic variables • Thermal stress, exacerbation of asthma and heat stroke may be caused directly by climatic variables • More accidents and emergency situations may result from increased frequency and/or intensity of extreme weather, such as storms, floods, droughts and tropical cyclones, etc. • Changes in some infectious disease transmission patterns are a likely consequence of climate change
Water Resources	• Uncertainties in future rainfall levels could affect water availability • Water availability may be constrained by physical or contractual reasons • Changing distribution pattern of rainfall and rising regional demand for freshwater may impact on the sustainability of water supply • Increased consumer demand for water due to increase in surface temperatures • Possible salinization of freshwater aquifers due to sea level rise

Their vulnerability is due to a number of factors including:

- Broad geographical exposure, i.e. they are highly depending on imports such that they are vulnerable to potential climate change impact not only in Hong Kong but also in other parts of the world.

- High sensitivity to climatic factors, i.e. they are dependant upon a stable climate over time or designed to operate/function within a small window of climatic variation.

- The consequences of disruption to these sectors are also high, i.e. many socio-economic activities of Hong Kong are relying on the products / services provided by these sectors.

- Broad temporal exposure, i.e. investment / infrastructure decisions in these sectors require a long lead time.

- Reliance upon extended infrastructure with multiple potential failure points, i.e. they are building on an extensive infrastructure in which there may be many potential areas to fail under the impact of climate change.

- Complex inter-relationships with other sectors, i.e. they are widely connected with other sectors in the community.

- Failure to cope with extreme weather events occurring today, e.g. on 7 June 2008 Hong Kong was affected by heavy rainstorms and squally thunderstorms, resulting in the blockage of North Lantau Highway by landslides for the first time since the commencement of operation in 1997, and serious disruption in transportation, water supply and telecommunication to Tai O by landslides, and serious flooding in various parts of Hong Kong. Furthermore, there was a sea flooding incident of Tai O during the passage typhoon Hagupit in September 2008.

4.6 EXTANT ADAPTIVE CAPACITY IN HONG KONG

As with other cities in the world, Hong Kong is vulnerable to climate change because of the agglomeration of people and assets in a small area. Hong Kong's vulnerability is compounded by its dependence on imported food, water, energy and other products that are required for it to thrive. Hong Kong, however, possesses significant adaptive capacity and has many systems in place which could be used to adapt to the physical impacts of climate change, examples include the following.

- With regards to the emergency response, the Security Bureau (SB) co-ordinates the planning of Government's overall response to major emergencies. The Government has developed the "Emergency Response System" and "Contingency Plan for Natural Disasters" to respond to the emergency situations and handle the natural disasters (including those results from severe weather conditions). When there is an emergency or natural disaster, the Government will trigger these systems such that the emergency response measures can be implemented speedily and efficiently. The Emergency Monitoring and Support Centre (EMSC) is activated when major emergencies or natural disasters happen or are likely to happen. It monitors the response of the emergency and support services, and provides support to these services and takes appropriate actions during Rescue, Recovery and Restoration Phases.

- Various government departments and public utilities service providers have monitoring and emergency responses mechanisms in place to respond to certain climate change impacts, including

- The Geotechnical Engineering Office (GEO) of Civil Engineering and Development Department (CEDD), in consultation with HKO, issue Landslip Warnings when numerous landslips are expected to alert the public as well as relevant parties so that they can take necessary precautions to ensure safety.

- The GEO recently launched the Landslip Prevention and Mitigation Programme (LPMitP) to dovetail with the Landslip Preventive Measures (LPM) Programme which was completed in April 2010.

- Drainage Services Department (DSD) has operated the Emergency and Storm Damage Organisation to ensure that floods and other emergency situations could be dealt with speedily. When Red or Black Rainstorm Warning or Typhoon Warning Signal No. 8 or above is issued, the Emergency Control Centre will put into operation immediately. Also, DSD will closely monitor the water levels of river streams and flooding conditions of flood prone areas in Hong Kong and work with HKO and Home Affairs Department (HAD) to remind the residents living at coastal and low-lying areas about the flood risks resulting from the rainstorms.

- Buildings Department (BD) will activate the Emergency Control Centre when Tropical Cyclone Warning Signal No. 8 is issued or in times of heavy rainfall and other disasters. It co-ordinates professional services to deal with dangerous buildings, landslides, dangerous scaffolding and advertising signs.

- The Hong Kong Monetary Authority (HKMA) has established an emergency response plan to handle the issues that will affect banking stability in Hong Kong. HKMA anticipates that emergency response plans will also be developed by the banking institutions in order to ensure their normal operation. Such response plans will normally form part of the organisation's continuity plan and it will include arrangements for backup services and methodology for service reactivation.

- The Office of the Telecommunications Authority (OFTA) has an emergency response team that operates throughout the year and maintains close contacts with the telecommunications operators, relevant governments and overseas bodies so as to obtain the latest information about the emergencies (including the incidents resulting from the extreme weather events).

- The Transport Department (TD) has established the Emergency Transport Co-ordination Centre (ETCC) to closely monitor the traffic and public transport services throughout the year. The centre also has developed contingency plans for the traffic and public transport service disruption due to extreme weather events such as typhoons, rainstorms, flooding and landslides, etc. and coordinates with various Government departments such as Hong Kong Police Force (HKPF), Highways Department (HyD) and public transport service providers to implement the contingency plans and to disseminate the contingency measures and real time traffic conditions to the public through mass media.

- The power companies have developed emergency response plans to handle the issues on power systems (e.g. power outage) due to bad weather. These plans are subject to periodic review by the power companies and the Government is monitoring it through legislative means.

- According to the Reserved Commodities Ordinance and its subsidiary Regulations (Cap. 296), rice is classified as a reserved commodity under the regulation. The Government operates the Rice Control Scheme to ensure a stable supply of rice and the stockholders have to keep a reserve stock sufficient for consumption by the population for a reasonable period (at present 15 days) to cater for emergencies or any short term shortage of supply. About 70% of wheat flour is imported from Mainland China. The Trade and Industry Department (T&ID) monitors the import quantity of wheat flour periodically and will liaise with relevant authorities in Mainland China to increase the supply quantity if necessary.

- The Works Departments developed guidelines in 1990, in which relevant government works projects should consider the rate of mean sea level rise may increase at 10 mm per year so as to address the potential impacts from climate change.

- In the event of a Typhoon signal No. 8 or above, a landslip warning or a Red or Black rainstorm warning, Home Affairs Department and the Department Emergency Co-ordination Centre (DECC) will be activated for the provision of emergency support services. An emergency hotline manned round the clock for the provision of weather reports, information and assistance to the public will also be available. Temporary shelters to people in need in event of cold or prolonged hot weather are also provided. Meals, blankets and mattresses are provided to shelter-seekers at a number of widely-publicized locations.

- In view of the climate change impacts and potential increase of extreme events in the coming years, HKO periodically review the Tropical Cyclone, Rainstorm and Very Hot Weather Warning systems so as to fulfil the needs of the society and citizens.

- The Centre for Health Protection (CHP) and Central Health Education Unit (CHEU) of the Department of Health (DH) provides health advice in relation to climate change, such as advice to the elderly in extreme weather (heat/cold stress).

- The Labour Department (LD) has a Code of Practice that seeks to provide advice and practical guidelines on work arrangements in times of typhoons and rainstorms, in particular when Typhoon Warning Signal No. 8 or above or Black Rainstorm Warning is in force (e.g. Guide on Safety at Work in times of Inclement Weather, Code of Practice in times of Typhoons and Rainstorms). With regards to prevent heat stroke at work, LD has developed guidance, including Prevention of Heat Stroke at Work in a Hot Environment, Risk Assessment for the Prevention of Heat Stroke at Work, to raise the awareness of the employers and employees about heat stroke and instil them with practical skills to prevent heat stroke.

- Various programmes are in place to monitor certain climate change impacts on various species and resources, including

- The Agriculture, Fisheries and Conservation Department (AFCD), through its territory-wide survey programme, is identifying and monitoring the important components of biological diversity in Hong Kong. The information collated from the programme is used to study the climate change impacts to the flora and fauna species in Hong Kong. Through the Baseline Ecological Monitoring Programme and Waterbirds Survey at Mai Po Inner Deep Bay Ramsar Site, AFCD monitors and conserves the ecological value of this important wetland.

- The Department of Health (DH) coordinates the public health information and disease surveillance system in order to monitor the communicable diseases and collate the epidemiological data. Also, DH maintains close contact with Food and Environmental Hygiene Department (FEHD) so as to obtain the climate related vector-based data (e.g. Ovitrap Index) and food safety monitoring information from FEHD and take appropriate remedial measures accordingly.

- The Water Supplies Department (WSD) is implementing Total Water Management Programme and one of the objectives of the programme is to prepare for the changes brought on by climate change and potential reduction of rainfall. WSD periodically reviews and continuously monitors the water resources in Hong Kong and take appropriate actions to ensure the stable supply of water to Hong Kong society.

- AFCD monitors the supply and wholesale price of major food items and provides the information to the public periodically for reference. Also, AFCD strives to increase the sources of food supply and diversify the types of food so as to ensure the stable supply of food to Hong Kong.

- The Centre for Food Safety (CFS) of FEHD carries out risk assessment, risk management and risk communication to ensure food safety in Hong Kong, including research on food safety topics that are important to public health, food surveillance and sampling at the import, wholesale and retail levels, import control on high risk food items, monitor the food safety incidents in and outside Hong Kong through the Food Incidents Monitoring Mechanism and communicate with the trade and public about the food safety issues.

- In addition to the mandatory *Third Party Risks Insurance*, building owners and owners' corporations are advised to purchase *Property-All-Risks Insurance* (property insurance), which covers losses or damages to the common properties of the building due to fire or other risks e.g. flooding.

- The Hong Kong Exchanges and Clearing Limited (HKEx) has developed procedures and guidance for emergencies, including the exchanges and clearing arrangements under Typhoon and Black rainstorm as well as the exchanges and clearing rules and process for various HKEx departments.

- The Education Bureau (EDB) has held workshops aimed at improving teachers' understanding of climate change, and climate change is included in the curriculum. The HKO has provided an educational package for distribution in schools that aims to raise awareness and understanding of climate change and the associated impacts. AFCD has carried out a series of education programmes at Hong Kong Wetland Park, including seminars and bird watching competition, to encourage public participation in wetland conservation.

- There are a number of policies and measures, mainly implemented by the AFCD to protect and conserve biodiversity. There are measures that aim to protect endangered species of animals and plants by regulating all activities involving the listed species, to protect wild animals from human disturbances as well as conservation programmes for species that are of ecological importance, such as the Chinese White Dolphin.

- The Drainage Services Department (DSD) implements flood prevention projects (including eight Stormwater Drainage Master Plan (DMP) Studies) to improve the drainage systems for the whole territory, in particular in the low-lying flood plains of the North and Northwest New Territories, to relieve flooding problems and to raise the flood protection level.

It is, however, likely that some such policies may need to be enhanced, or that the climatic thresholds which trigger other policies may need to be made more conservative. Furthermore, the resources allocated to the implementation of policies and measures to protect and respond to climatic events may need to be increased to better respond to climate change. The following sections present the options identified to ensure that any such necessary changes can take place in a timely manner.

4.7 *PROPOSED ADAPTATION OPTIONS*

Based on the findings of vulnerability assessment, it is evident that several sectors in Hong Kong are vulnerable to climate change impacts. Therefore, adaptation measures, including available options, should be developed to minimise the risk brought about by climate change.

4.7.1 *Approach to Developing Climate Change Adaptation Options for Hong Kong*

The identification of climate change adaptation options for Hong Kong was based upon the following:

- General principles of international best practice (tenets of which include 'Sustainable', 'Inclusive', 'Flexible and regularly revised', 'Pro-active', 'Based upon the precautionary principle');

- A comprehensive review of overseas adaptation policies and measures, which included initiatives at the national, sub-national (i.e. jurisdictions in federally organised countries) and municipal levels; and,

- A detailed review of existing institutions in Hong Kong, i.e. legislative policies and measures currently in place in the public sector which offer adaptive resilience.

4.7.2 *Framework for Adapting to Climate Change in Hong Kong*

A review of existing adaptation policies and measures adopted in Hong Kong as well as other world cities, including London, Singapore, Tokyo and New York City, was performed and identified the following recommended government frameworks for adapting to climate change.

- Sectoral-level actions in the eight most vulnerable sectors identified for Hong Kong.

- Cross-sectoral activities such as research activities to inform government decision making and activities to raise awareness of Hong Kong's vulnerabilities to climatic change, as well as possible adaptation actions to address them.

- Cross-departmental bodies to monitor and co-ordinate government action to ensure consistency across government decision-making.

The following sections highlight the proposed adaptation options for Hong Kong. It should be noted that the options presented in this Report are based upon current understanding of climate change projections and will need to be periodically reviewed and updated as the science evolves. IPCC is preparing its AR5 due for publication in 2015. More detailed analysis on the possible impacts of climate change on different sectors would then be available and hence new or updated adaptation strategies should be developed based on the updated findings. Moreover, implementation of proposed adaptation options is likely to lead to additional compliance costs to both the Government and the other concerned stakeholders. Hence, the implications, feasibility and costs and benefits of these measures should be evaluated before adoption.

4.7.3 Major Categories of Sectoral-Level Adaptation Options

The sectoral-level climate change adaptation options can be classified into the following major categories:

- **Research & investigation** – efforts to expand current knowledge regarding vulnerable sectors is needed in a number of areas and includes: establishing priorities for improvement measures, identifying local high risk areas, updating outdated information, assess and examine potential impacts and effects.

- **Monitoring** – creation of monitoring infrastructure which enhances knowledge pertaining to the status of key sectors, as well as enhancement of current efforts for the purpose of reviewing and revising current programs. Such measures could include periodic review of monitoring programmes, observe and closely track changes in economic, environmental and social indicators.

- **Institutional strengthening & capacity building** – enhance the ability of institutions to respond and adapt to adverse impacts brought about by climatic changes. Such strengthening could include: incorporating climate change knowledge into current management framework, assess potential risks and opportunities in development strategies, outline potential impacts on the operations of key sectors.

- **Disaster management & emergency planning** – improvement of the planning and systems which are responsible for responding to emergencies. Such enhancements could include: mandating emergency planning measures, development of contingency plans and reviewing current disaster monitoring and response systems.

- **Education & public awareness** – increase the level of public awareness amongst the population such that they can take appropriate actions to combat climate change impacts. This could include promotion of climate change impact assessments and knowledge, providing information on the likely implications of climate change on various industries and sectors, and educating vulnerable communities on how best to prepare and respond to climate change.

Table 4.4 highlights some sectoral-level adaptation options that the SAR Government and relevant stakeholders in Hong Kong could take.

Table 4.4 Examples of Climate Change Adaptation Options for Key Vulnerable Sectors in Hong Kong

Category of Adaptation Options	Key Vulnerable Sectors	Examples of Proposed Adaptation Options
(a) Research & Investigation	• Biodiversity and Nature Conservation	• To establish priorities for species/ habitats/ ecosystems most at risk • To develop a baseline of species, especially for those of conservation importance
	• Built Environment and Infrastructure	• To identify at-risk infrastructure that are likely to be vulnerable to climate impacts • To update flood risk maps
	• Financial Services	• To examine the potential for expanding the role of insurers in climate risk management, examine legal roles of insurance industry • To examine the insurance coverage on climate risks for infrastructure and assets located in hazard-prone areas and vulnerable assets, and the legal implications of the insurance industry in dealing with climate risks
	• Food Resources	• To examine the impacts on food supply chain and food hazards, and research effects on vulnerable groups
	• Human Health	• To research health and nutrition effects on vulnerable groups
	• Water Resources	• To assess the impacts along the water supply chain
(b) Monitoring	• Biodiversity and Nature Conservation	• To review and revise monitoring programmes periodically
	• Energy Supply	• To monitor for changes in energy demand and supply patterns to identify trends caused by climate change
	• Food Resources	• To monitor prices of major food stuff and factors that could lead to fluctuations in prices, and climate change agricultural impact studies for Hong Kong's key food importers

Category of Adaptation Options	Key Vulnerable Sectors	Examples of Proposed Adaptation Options
	• Human Health	• To set up monitoring programmes to observe health and food safety implications of extreme temperatures on local population and associated impacts on different groups of population • To set up monitoring programmes on proliferation of pests with public health significance
(c) Institutional Strengthening and Capacity Building	• Built Environment and Infrastructure	• To develop and use climate risk assessment tool for screening future development projects to minimise potential risks posed by climate change and variability • To regularly update and adjust, if necessary, construction-related codes, guidelines and design standards for buildings and infrastructure • To develop flood and landslip risk strategies for increasing adaptive capacity to extreme weather and sea level rise
	• Business and Industry	• To develop a Hong Kong business assessment tool for climate change impacts
	• Energy Supply	• To review likely changes in energy demand and supply patterns periodically • Power companies to consider the latest available climate change scenarios and associated impacts during regular review and forecasts of energy demand and supply • To diversify fuel sources and fuel suppliers • To assess and act on the climate risks and challenges along the energy supply chain, including those at fuel sources and associated logistics and at the generation and distribution assets themselves
	• Financial Services	• To encourage companies to disclose to regulators/investors the financial risks from climate change, and actions being taken to respond to those risks
	• Food Resources	• To allocate responsibility for security of food supply

Category of Adaptation Options	Key Vulnerable Sectors	Examples of Proposed Adaptation Options
	• Water resources	• To consider climate change and variability in the regional context and their impact on water resources • To periodically review HK's Total Water Management Strategy
(d) Education and Public Awareness	• Built Environment and Infrastructure	• To promote green roofs
	• Business and Industry	• To promote business climate impact assessments
	• Financial Services	• To examine the implications on the insurance and banking industries by engaging them to consider risks and opportunities with climate change through awareness raising
	• Food Resources	• To encourage business continuity planning
	• Human Health	• To educate the medical community on related diseases
	• Water Resources	• To promote water conservation
(e) Disaster Management & Emergency Planning	• Business and Industry	• To request essential operations to prepare business continuity plan for possible threats arising from climate change
	• Energy Supply	• To incorporate climate change-related risks and challenges in contingency planning
	• Food Resources	• To develop an emergency response management plan to deal with unforeseen food shortages
	• Human Health	• To periodically review warning, alert and monitoring systems, as well as emergency services and contingency plans
	• Water Resources	• To review drought contingency plans as desirable from time to time

4.7.4 *Cross-sectoral Climate Change Adaptation Measures*

In addition to sectoral level adaptation options, some cross-sectoral adaptation measures are proposed as follows:

- Climate change research activities – This could include the development of Hong Kong climate change projections (e.g. sea level rise, the marine environment changes and extreme weather events) to support further sector-level research on impacts and vulnerabilities.

- Education and public awareness – This could include the mass communication of climate change topics, in particular, the causes and potential impacts on ecosystems, climate variability and concepts such as risk and uncertainty so as to enhance the public understanding of vulnerabilities and the associated adaptation measures.

4.7.5 *Coordination and Review of Institutional Arrangement*

To ensure that institutional arrangements and Government departments are coordinating their climate change response and adaptation efforts, institutional arrangements need to be periodically reviewed and aligned as necessary to ensure co-ordination between different departments and that the Government is making decisions that is informed by the latest climate change science.

5 SUPPORTING ACTIVITIES

5.1 REVIEW OF CURRENT ACTIVITIES

A desktop review of Hong Kong's current research activities and other support programmes and plans in relation to climate change was undertaken and the following section summarises the key findings.

5.1.1 *Policy Integration – Mitigation and Adaptation*

One of the major Government initiatives to address climate change is the establishment of Interdepartmental Working Group on Climate Change (IWGCC), which consists of five bureaux and sixteen departments. The IWGCC is responsible for the coordination of the Government's work in response to climate change and is in charge of developing and promoting measures for the reduction of GHG emissions, as well as facilitation of adaptation to climate change.

5.1.2 *Technology Transfer and Capacity Building*

Technology is likely to play a central role in both reducing GHG emissions and adapting to climate change. The Government aims to promote Hong Kong as a knowledge-based economy by directly supporting high quality research, development and transfer of new technologies to various industrial sectors in Hong Kong. Together with the technology transfer arms of CUHK, CityU, HKUST and HKU there are at least six distinct organisations focused directly on technology transfer. Some focus areas of these organisations include: Research and Development (R&D), technological infrastructure, adoption of international standards and transfer of new technology to industry. The Government also has mechanisms and policies promoting cooperation between Hong Kong and the Mainland. For example, technology collaboration and development agreements have been signed between the HKSAR Government and the Mainland's Ministry of Science and Technology.

In terms of capacity building, the Government has provided funding for the Technology Development Branch (TDB) and the Environmental Management Division (EMD) of the Hong Kong Productivity Council (HKPC). They assist local enterprises to enhance productivity through technology transfer. The Vocational Training Council (VTC) is another institution that provides capacity building resources to raise the latent potential of Hong Kong's workforce.

5.1.3 *Climate Change Research and Systematic Observations*

Hong Kong's universities and the HKO have conducted research focused on a wide range of disciplines associated with climate change, including climate systems, environmental systems, the human environment and social science based research. Research on climatic systems includes atmospheric, meteorological and oceanographic studies. There have also been a number of studies related to environmental systems such as ecological, terrestrial and hydrological studies. Studies on the human environment focusing on such topics as the built environment, human health and energy have also been undertaken.

In terms of the systematic observations and monitoring efforts, the HKO is the key government entity for meteorological data collation and analysis. In order to track weather information the HKO operates more than 70 Automated Weather Stations (AWS) and two manned weather stations distributed throughout Hong Kong. The key weather variables that are tracked include: oceanographic, surface, terrestrial and upper air observations.

5.1.4 Information on Education, Training and Public Awareness

The Government, non-government organisations (NGOs), universities and private sector have all contributed to raising levels of public awareness on climate change. Activities such as in the form of forums, public lectures, workshops, formal classroom training and media campaigns (including publications and internet campaigns) have been held in Hong Kong. A wide range of climate change related topics have been covered, including for example reducing energy consumption and the use of RE. These programmes focus on raising awareness amongst employees, business partners, and the general public regarding climate change impacts and the actions necessary to combat climate change. Local universities, the HKO and other organisations have provided technical training on several climate change related topics (e.g. climate modelling and carbon auditing).

Large scale public awareness campaigns conducted in Hong Kong include: the Government's "I Love Green, I Love Hong Kong"; WWF's "Climateer Ambassador's"; and HSBC's "Climate Change Partnership". In addition to general public awareness campaigns, some of Hong Kong's universities also offer specifically focused academic concentrations or courses on climate change (e.g. HKU's undergraduate minor in global climate change and HKUST's "Climate Change Risk, Mitigation and Adaptation").

5.1.5 Information and Networking

In accordance with the principles of "One Country, Two Systems" and the relevant provisions of the Basic Law, Hong Kong is eligible under the Clean Development Mechanism (CDM) . In addition, Hong Kong has also been active in establishing the foundations of cooperation on climate change through international agreements and organisation such as C40 Cities - Climate Leadership Group (C40) and Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development. The SAR has committed to tackling global climate change issues through strengthened economic cooperation, energy efficiency, environmental protection, scientific research and sustainable development.

5.2 SUMMARY OF QUESTIONNAIRE SURVEY FINDINGS ON LOCAL RESEARCH ACTIVITIES

Apart from the desktop review of local research activities under *Section 5.1*, ERM undertook a questionnaire survey with local universities, institutes, business organisations and NGOs to identify existing research activities, programmes and plans as well as core competencies and interests in areas related to climate change.

5.2.1 *Questionnaire Survey Process*

The online questionnaire survey forms were developed for two major groups of stakeholders, namely "Business and NGOs" and "Universities and Research Institutes". The survey was conducted between August 2009 and February 2010 and over 600 local stakeholders had been invited to provide responses to the online questionnaire survey. Also, to enhance the survey response rate, two rounds of email reminder and one round of phone call reminder had been made with the stakeholders during the survey period. 39 (including 26 business organisations and 13 NGOs) and 18 valid responses with verifiable contact information of the stakeholders were received from "Business and NGOs" and "Universities and Research Institutes" groups respectively. The following sections provide the summary of key survey findings. Whilst the questionnaire survey did not provide statistically significant responses from the stakeholders, it did gather their views and perceptions on climate change in Hong Kong.

5.2.2 *Business Organisations Group*

Although 72% of respondents indicated that have implemented or are planning initiatives/programmes that are concerned with climate change, of which 22% of this group indicated that >75% of their organisation's programme and activities are explicitly concerned with this topic. With regards to research activities, identification of technologies that facilitate mitigation is the most common research activity, followed by the policy research to facilitate adaptation. Some of these research programmes are carried out through collaboration with other local NGOs or local businesses including small and medium enterprises (SMEs). With regards to the technology transfer, most respondents indicated that such activities are carried out with overseas countries (including Mainland China and Macau) for mitigation technologies. For education, training and public awareness activities, they are typically carried out with primary or secondary schools or through housing exhibitions. In order to further promote and facilitate the development and implementation of climate change activities/programmes, most respondents commented that financial incentives are the most important factor for consideration.

5.2.3 *NGOs Group*

About 85% of respondents revealed that they have implemented or are planning initiatives/programmes that are concerned with climate change, of which about 36% of this group indicated that >75% of their organisation's initiatives /programmes are explicitly concerned with climate change. These programmes mainly receive funding from donations or sponsors. With regards to the research activities, their key activities are those related to education and public awareness and promoting technologies to facilitate mitigation. Some of these activities are undertaken through collaboration with local tertiary education institutes. Unlike the Business Group's responses, most respondents indicated that their technology transfer activities are carried out with local transfer of mitigation technologies and these activities are carried out with local NGOs, local tertiary institutions or SMEs. With regards to the education, training and public awareness activities, these are carried out with primary or secondary schools or through public workshops and seminars. Similar to Business Group's responses, they consider that financial support is the most important factor to promote and facilitate the implementation of climate change initiatives/programmes.

5.2.4 *Universities and Research Institutes Group*

About 40% of the respondents indicated that their research activities are explicitly concerned with climate change, of which about 50% of these respondents indicated that they have been involved with climate change research in and/or systematic observations in the past 12 months. Most of the research activities are related to climate change impacts and vulnerability and human responses to climate change. Some of these research activities are carried out through collaboration with local or overseas tertiary institutes and it is funded by the University Grants Committee (UGC)/Research Grants Council (RGC) or other private funds. About half of the respondents indicated that they will have research activities and/or systematic observations that are explicitly concerned with climate change in the next 12 months and these activities will focus on systematic observations and human responses to climate change. With regards to the key factors required to promote and facilitate the development and implementation of climate change research programmes, most respondents considered that financial incentive is their most important concern, followed by the interest/demand from prospective students.

5.3 *IDENTIFICATION OF ADDITIONAL SUPPORTING STRATEGIES AND MEASURES*

Following the review of current activities, the following additional initiatives are recommended for consideration.

Research - Although research in Hong Kong is often of high quality, there is currently a limited focus on climate change related issues, technologies and impacts. There is a need for the development of localised emission factors and activity data so that GHG inventories can be more accurately calculated. More development in regional and local climate modelling is necessary to better predict the affects of climate change on Hong Kong. There is a need for additional research in a number of areas: oceanographic data (concerning sea level rise), biodiversity issues (e.g. terrestrial and aquatic species composition, indigenous flora and fauna) and the potential affects on human health (e.g. the affects of climate change on disease outbreak or increased susceptibility). More Government and private funding should be directed towards climate change research to fill key data gaps.

Systematic Observations - The HKO currently conducts a number of weather observations, however, there are needs to enhance the long-term ecological monitoring efforts being undertaken by other Government departments such as Environmental Protection Department (EPD) and Agriculture, Fisheries and Conservation Department (AFCD). Hence, there is a need to regularly observe species composition, forests and biodiversity through additional terrestrial and aquatic monitoring.

Technology Transfer and Capacity Building – To further reduce GHG emissions, the Government should focus on technology transfer for climate change related applications and capacity building. The Government could encourage more Clean Development Mechanism (CDM) projects in Hong Kong and coordinate the promotion of transfer of climate change related technologies, such as electric vehicles and building energy efficiency technologies. The four Hong Kong Universities with technology transfer branches should also be given assistance in focusing technology development for GHG emissions reduction in key areas: the built environment, transport and the power sector. There is also a need to increase the number of people with professional qualifications and experience in carbon auditing, carbon footprinting and GHG inventory development and verification. Providing or subsidising the attainment of qualifications and certification (e.g. Certified Carbon Auditor Professional) in these areas should be considered.

Public Awareness – Many small and medium enterprises (SMEs) have been slow to implement GHG emission reduction, energy efficiency and climate change adaptation measures, hence there is a need for Government resources to encourage their participation. Industry seminar training that incorporates adaption of climate change contingency plans into their business models, comprehensive green business development strategies, supply chain management and green procurement should all be considered as potential topics. Also, there is a need to train experts in key climate change topics (e.g. vulnerability and adaptation). Inclusion of climate change topics in school curriculum (e.g. inclusion of climate change study as part of secondary school curriculum and study of global warming as part of undergraduate degrees) would raise the awareness levels amongst younger generation on climate change impacts.

Public awareness campaigns on a number of issues would also help in raising the level of awareness amongst Hong Kong's citizens and these include climate change science, current actions in Hong Kong to combat climate change, changes in individual's behaviour to reduce power consumption and waste generation, low-carbon/green business development and potential public savings garnered from adherence to energy efficient building codes. These issues should be presented through interactive media such as websites as well as through the traditional media such as newspapers. Moreover, the Government could enhance the current efforts with various NGOs in organising these campaigns so as to raise the level of public engagement.

International/Regional Cooperation – Currently collaboration is limited to a small number of organisations and is lacking in areas such as energy efficiency and energy research, investment in green technologies and carbon markets. Many of Hong Kong's key resources providers (e.g. Thailand for rice) are at risk from climate change which has implications for the SAR. Increased participation (APEC economies) could also include specific actions to address climate related issues. Moreover, sharing of knowledge on oceanic changes and associated research into flood risk strategies should also be encouraged. For example, Hong Kong has joined the 'Connecting Delta Cities' initiative which is led by Rotterdam and includes other cities such as Shanghai, London, and New York, to share knowledge.

Policy Measures – This Study has presented a number of options which could be further developed for the HKSAR Government to create a comprehensive climate change strategy. See *Sections 3* and *4.7*.

Business Activities - As the extent of climate change impacts on businesses operating in or managed from Hong Kong is not well characterised, relatively few businesses have made it a focus of business planning or risk management. More funded research from the government and/or private sectors on potential impacts on businesses should be encouraged to address this information gap and to enable the private sector to make informed decisions for managing this source of business risk.

6 *STAKEHOLDER ENGAGEMENT PROCESS*

In order to provide an opportunity for public participation and to gather the views of a variety of stakeholders, ERM has applied various engagement approaches to inform the stakeholders about the study, its key findings and to invite their comments. These approaches include the establishment of a dedicated internet site for stakeholders and the conduct of a series of technical workshops.

6.1 *DEDICATED STUDY WEBSITE FOR STAKEHOLDERS*

ERM has established and maintained a project internet website (http://www.climatechange.com.hk/) throughout the study to facilitate communication with stakeholders. The website is open to everyone and has been used to provide information about the study objectives, workshop activities and to invite input/comments from interested sectors of the community via the dedicated email address (enquiry@climatechange.com.hk). Moreover, all materials from the workshops (see *Section 6.2*), including presentation materials, briefing papers and summary reports, have been posted on the website. As of November 2010, the website has been accessed by the general public more than 9,200 times since it was launched in early July 2008.

6.2 *CONDUCT OF TECHNICAL WORKSHOPS*

In order to inform the stakeholders on the study's progress and to gather their views/comments on the findings, ERM has conducted five public workshops. An overview of each of the workshops is provided in the following sections.

6.2.1 ***Public Workshop on Climate Change Study***

A half-day public workshop was held at the Exhibition Hall of the Hong Kong Productivity Council on 18th July 2008. The purpose of the workshop was to present the aims and objectives of, and our approach to, the Study. Representatives of stakeholder groups including NGOs, academic institutions, business community bodies and professional associations were invited and over 70 attendees participated in the workshop. During the workshop an overview of climate change, the current state of the science, major global and local challenges, and a brief description of the approach to the Study and key tasks were presented. A record of the discussions and the views and queries of the attendees was made. Some of the key questions and comments raised by the stakeholders are summarised in *Box 6.1*.

Box 6.1 Selected Stakeholder Queries and Feedback

- How is the GHG emissions inventory of Hong Kong defined?
- How do the NGOs feed their own research findings or other information into this Study?
- Will this Study also focus on the poor communities in developing countries in adapting to climate impacts?
- If you just look at Hong Kong under this Study, losing a species in Hong Kong may be acceptable but not from the regional point of view. Therefore, this Study should have a more strategic vision and look at impacts to biodiversity in South China.
- This study will inform policy options. How much control does the Government have on this Study and what is the role of Government in this Study?
- Are you setting an emission reduction target and recommending a certain reduction measures? If you recommend certain measures, how do you do modelling studies to ensure that the targets are met?
- If the V&A assessment is not based on accurate information, I am worried that the relevancy and adequacy of the policy options recommended.

6.2.2 Mitigation Assessment Workshops

Two public workshops on the mitigation assessment were carried out during the Study period.

The first workshop was held on 25th September 2008 at the Main Conference Room of ERM's Hong Kong office. It was divided into four separate sessions, namely Buildings and Appliances, Power Supply, Transport and Waste and each session had about 20 attendees from various stakeholder groups. During the workshop, a review of existing policies and measures, both in Hong Kong and overseas, that help to reduce greenhouse gas emissions, as well as an overview of other initiatives aimed at mitigating emissions was presented. In addition, a list of policies and measures (e.g. mandatory implementation of carbon/energy audits in buildings, change of energy/fuel mix, congestion charging, and waste-to-energy facilities etc) that could potentially be implemented in Hong Kong was also discussed in order to seek technical input from the attendees, as well as to collect their views and comments. *Box 6.2* presents some of the views and comments from the stakeholders.

Box 6.2 Selected Stakeholder's Views and Comments

Building and Appliances

- Older buildings account for the majority of the building stock in Hong Kong, so targeting any energy efficiency performance improvements on this group of buildings could be expected to result in a bigger impact than a focus on constructing new carbon neutral buildings. Thus, it should be useful to have policy differentiation between new buildings and existing building to promote energy efficiency.
- Emissions associated with the use of air-conditioning and lighting are significant contributors. These areas deserve more attention as overseas experience suggests a potential energy saving of 20% in these areas.

Power Supply

- It was suggested that a greater share of gas and nuclear is desirable. Key concerns will be access to adequate gas supplies in the future and siting new nuclear capacity.
- Consumers need to be educated so that they are responsible for GHG emissions as well as the power companies.

Transport

- There are competing routes between buses and the MTR; measures could be taken to reduce multiple routes or combine some similar bus routes.
- The technology for electric vehicles exists and there is an opportunity for Hong Kong to develop the expertise and skills that can then be transferred to mainland China. There could be regional co-operation to produce electric vehicles and to promote their use. Hong Kong should considering creating the infrastructure for their use.

Waste Management

- Various comments were made about the need for more public information on the Waste-to-Energy (WtE) project and associated technologies in Hong Kong and the use of different terminology (i.e. gasification compared with incineration) to gain public acceptance of WtE.
- In general, it was acknowledged that, considerations for waste minimisation, waste management, waste strategy and implementation all originate from the waste problem in Hong Kong (not GHGs). Hence, if waste is well managed, the GHG emissions associated with the waste will be taken care of as well.

The second workshop was held on 30th September 2010 at the Main Conference Room of ERM's Hong Kong office. Two half-day workshop sessions were arranged and about 25 attendees participated in each session. The purpose of the workshop was to present the findings of the mitigation assessment and to gather the stakeholders views and feedback on these findings. *Box 6.3* presents some examples of queries and feedback from the stakeholders.

Box 6.3 Selected Stakeholder's Queries and Feedbacks

- What is the amount of GHG emission reduction achieved from demand side and fuel mix revamp respectively?
- What are processes and procedures involved in the import of nuclear energy into Hong Kong? Also, which parties would be involved in the decision making process?
- Offsetting the carbon emissions in Hong Kong should be carried out, rather than proposing actions and targets to combat climate change in the public consultation document.
- Will China's carbon intensity reduction target have any binding effect to the proposed Hong Kong target?
- What are the mitigation measures for domestic buildings?
- Is there any road map for the 10-year plan since the proposed regulation on Building Energy Codes (BEC) is still being discussed in the Legislative Council (LegCo) and the BEC is still currently a voluntary programme?
- The point-to-point supply of electricity to Hong Kong should be enforced to ensure that the electricity supplied to Hong Kong is generated from clean sources.
- How do we capture gas from landfill and produce energy? What is the efficiency of landfill gas capture? For waste water treatment, will gas be fully utilized? How about biogas from untreated water or those from illegal discharge?

6.2.3 Vulnerability and Adaptation Assessment Workshops

Two public workshops on vulnerability and adaptation assessment were held during the Study period.

The first workshop was held on 19th December 2008 at the Main Conference Room of ERM's Hong Kong office. Two half-day workshop sessions were arranged and over 20 attendees from various stakeholder groups participated in each session. The purpose of the workshop was to present the preliminary findings of the Study including the likely climate change impacts on Hong Kong, identification of key sectors most vulnerable to climate change, discussions on present-day adaptive capacity and constraints on adaptation, and potential adaptation options to be adopted in the future. The stakeholder's input and their views and feedback were also sought. *Box 6.4* presents some examples of the views and comments received.

Box 6.4 Selected Stakeholder Views and Comments

- There is very limited research on climate change related impacts of on biodiversity in Hong Kong. There could potentially be many impacts but it was felt that these currently rely on expert judgement. Hence, proposals for any specific adaptive measures would require more local research across different taxa as different species will respond differently to climate change. More information is needed in order to identify appropriate actions.
- Along with developing contingency plans, it would be necessary to factor in climate change to the architectural and engineering stages of new building development, as well as investing in research and development into building design and materials, such as passive ventilation and thermal mass.
- Gas supply in Hong Kong relies primarily on pipelines. There have been concerns over pipeline security so alternative delivery routes may need to be investigated.
- Many sectors are correlated and interconnected so it is difficult to isolate one sector from another. For instance, the financial services sector is highly interlinked with infrastructure, communications and the transport network.
- Hong Kong imports a significant quantity of food from Mainland China and the Pearl River Delta. Authorities from both sides need to cooperate and work together to examine the potential impacts induced by climate change.
- There are interlinkages between the Human Health sector and others. For instance, this sector is highly linked to the infrastructure people live in. Hence, building standards may help to improve housing design, natural ventilation and the maintenance of buildings, which in turn may help to improve living conditions for those who live in crowded conditions.
- At the moment, Hong Kong has a reliance on imports of water from Dongjiang. Greater flexibility needs to be incorporated into the contract terms so that the supply adheres to the demand in Hong Kong. Water quality needs to be maintained in the future.
- Adaptation to climate change should not be seen as a substitute for mitigation. Instead, mitigation and adaptation should be considered together.

The second workshop was held on 24th February 2010 at the Main Conference Room of ERM's Hong Kong office. Two half day workshop sessions were arranged and over 20 attendees from various stakeholder groups participated in each session. The aims of the workshop were to present the Study findings on vulnerability and adaptation assessment and seek the stakeholder's views and feedbacks on these findings. *Box 6.5* summarises some examples of the stakeholder's key views and comments.

Box 6.5 Stakeholder Views and Feedbacks

- Many aspects of marine aquaculture in Hong Kong are already very stressed due to environmental factors, and predictions that sea level rise will cause the collapse of various eco-systems have been made, e.g. mariculture done in very shallow water due to the already high mortality rates.
- Current building codes were often made on the assumption that weather conditions were static and unchanging, so the effect of extreme weather events is not reflected in current building code. It was recommended that climactic changes, historical and international data, especially for older buildings, be incorporated in adaptation measures for future versions, e.g. the influence of standards for the building envelope and debris input on sewage systems, floods, and transport.
- An increase in temperature would cause an increase in the demand for energy. Substantial increases in energy pricing would create a large burden on poorer groups of the population. A concern was raised that the issue here is not energy availability, but affordability. It might be necessary to create an energy policy assessing energy affordability for vulnerable groups.
- Due to limited operating life and a lack of long-term operating outlook, many small and medium sized businesses tend to not fully consider the effects of climate change.
- There is a need for a contingency plan should an interruption in the food supply occur or if prices rise significantly for basic foodstuff.
- There is a need for more government regulation and detailed plans regarding labour insurance and reaction plans to extreme weather.
- As the potential impacts associated with changes in average sea level carry enormous ramifications, it is important to consider the most accurate and up-to-date scientific findings when assessing responsive measures.
- To facilitate stakeholders' gauging how they would be affected and what adaptation actions should be considered and taken, information on vulnerabilities and adaptation strategies should be available to the public.

7 *CONCLUSION*

The Study has reviewed and updated Hong Kong's GHG inventories based on the latest methodologies in the *2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories.*

Hong Kong is moving along a path to a low carbon economy. The total primary energy consumption in the Base Case is projected to grow at an annual rate of 1.3% during the period 2005 to 2030, while the final energy demand is projected to grow at an annual rate of 1.8%. Compared to the projected 3.01% annual growth rate in GDP (1) over the same period, the decoupling trend between GDP and primary energy consumption implied in the annual growth rates is expected to continue. The annual growth rate of total carbon emissions, 0.24% per year between 2005 and 2030, is projected to decouple from primary energy growth. In comparison, the total carbon emission grew at an annual rate of 1.1% during the period 1990 to 2006 while GDP grew at an annual rate of 4.18%. The relatively low carbon emission growth rate projected is mainly due to the reduced utilisation of coal-fired power plant units by 2030.

To further mitigate Hong Kong's GHG emissions, our recommended approach will further reduce Hong Kong's carbon intensity by 54% to 60% by 2020 and, by 2030, will reduce carbon emissions per capita by approximately 50% and the total quantity of emissions by 40%, compared with the 2005 level. The cornerstones of this strategy will need:

(a) implementing mitigation measures

- transport - reducing the carbon footprint of road transportation through improving energy efficiency and the use of low carbon fuels, such as biodiesel derived from waste cooking oil;
- waste - maximising utilisation of landfill gas as a source of energy and building waste-to-energy facilities; and
- energy efficiency - widespread improvements in energy efficiency, in particular in the built environment and in electrical appliances.

(b) revamping the fuel-mix for electricity generation

- a significant increase in the proportion of low- or zero-carbon fuel such as natural gas and nuclear energy in the fuel mix for electricity generation.

Meeting the predicted levels of reduction in carbon intensity and GHG emissions under Scenario 3 by 2020 will require a significant and rapid rebalancing of the fuel mix in the electricity sector and associated investments

(1) The GDP projection and impact evaluated by the models is on the basis of real terms.

in the transmission infrastructure. Given the time needed to plan and construct such infrastructure, as well as securing energy supplies, early adoption of theses measures is required to ensure that the 2020 national policy target can be met. The cross-sectoral nature of this strategy and the speed with which it needs to be implemented requires support from all sectors of the community.

As climate change is a global phenomenon, the actions recommended to be taken in Hong Kong whilst substantially reducing GHG emissions, will not be sufficient to prevent climate change from occurring. In the coming decades Hong Kong can expect to experience increases in climatic instability. To address the risks presented by these changes, our assessment of vulnerabilities in Hong Kong has identified eight key sectors as having "high" vulnerability to climate change impacts, namely: Biodiversity and Nature Conservation; Built Environment and Infrastructure; Business and Industry; Energy Supply; Financial Services; Food Resources; Human Health, and Water Resources. To adapt to future climate change impacts, sectoral and cross-sectoral adaptation measures have been recommended for further consideration. This is the first comprehensive assessment of vulnerability to climate change in Hong Kong. It has been carried out based upon the current state of knowledge and the information available in the IPCC AR4 as well as consultant's and expert's judgments so as to make an assessment of the potential areas of greatest risk. It should be acknowledged that the quality and quantity of information available to make the assessment vary between systems. Moreover, there are uncertainties and limitations associated with the information in AR4 and hence the outcome of the vulnerability assessment. For instance, there is higher uncertainty in how biodiversity will respond to changing climatic conditions when compared to some other highly managed systems such as the built environment and infrastructure. Where there is a lack of local scientific data to support the research-driven approach to assess the vulnerability and adaptation of a particular sector, ERM has exercised expert judgement to determine the risk rankings, for example, the risk rankings under Human Health sector. With the rapid evolution in the climate change science, the vulnerability assessment should be considered as a dynamic process and the findings of the assessment should be regularly reviewed and updated, particularly given the high-levels of uncertainty inherent in an exercise of this nature.

As with other cities in the world, Hong Kong is vulnerable to climate change because of the agglomeration of people and assets in a small area. Hong Kong's vulnerability is compounded by its dependence on imported food, water, energy and other products that are required for it to thrive. Hong Kong possesses significant adaptive capacity and has many systems in place which could be used to adapt to the physical impacts of climate change. Nevertheless, a review of existing adaptation policies and measures adopted in Hong Kong as well as other world cities, including London, Singapore, Tokyo and New York City was performed to identify the following recommended frameworks for adapting to climate change:

- Sectoral-level actions in the eight most vulnerable sectors identified for Hong Kong.

- Cross-sectoral activities such as research activities to inform government decision making and activities to raise awareness of Hong Kong's vulnerabilities to climatic change, as well as possible adaptation actions to address them.

- Cross-departmental bodies to monitor and co-ordinate government action to ensure consistency across government decision-making.

Due to the limitation and uncertainty in the current assessment, it is recommended that the assessment of vulnerability to climate change is periodically reviewed and updated so as to take into account the latest scientific findings. Adaptation options should be reviewed in parallel to ensure that they remain adequate and take into consideration developments of climate change science and technologies.

Appendix A

GHG Emissions Inventory

CONTENTS

PART I – INTRODUCTION AND OVERVIEW OF GREENHOUSE GAS EMISSION INVENTORY

1.1 INTRODUCTION AND TASK OBJECTIVES

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) requires Non-Annex I parties which have ratified the Protocol to communicate a national [1] inventory of Greenhouse Gas (GHG) emissions as part of their national communication. The Hong Kong Special Administrative Region (hereafter referred to as HK), as part of China which has ratified the Kyoto Protocol, is therefore also required to prepare a GHG inventory. This inventory will then form part of China's inventory in its national communication to be submitted to the Conference of Parties (COP) in 2010.

A HK GHG inventory methodology was originally developed under the *Greenhouse Gas Emission Control Study* (*Agreement No. CE 58/98*) in 2000 (hereafter called the *GHG Study 2000*) and has since been maintained by the Environmental Protection Department (EPD). This inventory followed the *Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (hereafter called "*Revised 1996 IPCC Guidelines*", IPCC 1997).

Since the preparation of this inventory the Intergovernmental Panel on Climate Change (IPCC) has published the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter called "*2006 IPCC Guidelines*", IPCC 2006) as well as other good practice guidelines. The *2006 IPCC Guidelines* and these good practice guides update the *Revised 1996 IPCC Guidelines* and provide methodologies intended to assist countries in estimating their GHG emissions to fulfil their obligations under the Kyoto Protocol.

In response to the methodological update and the need for Hong Kong to contribute to China's national communication to the COP in 2010, the inventory has been updated with reference to the requirements specified in the latest UNFCCC Guidelines for the preparation of national communications from non-Annex I countries. The objectives are as follows:

1. To **review and analyse the current methodologies** of the Hong Kong GHG Inventory developed through previous consultancy studies based on the *Revised 1996 IPCC Guidelines*. The review will cover the six gases specified in the Kyoto Protocol;

2. To **analyse and discuss** the basis of the methods, availability of data, sources of emission factors and activity data, data gaps and uncertainties,

For the sake of clarity in this appendix "national inventory" is used to refer to the inventory for China as a whole (ie including the HKSAR). "Domestic inventory" refers to the HKSAR inventory only.

taking into account the guidance on the possible use of different methods, as set out in the *Revised 1996 IPCC Guidelines;*

3. To **recommend, with full justification, necessary amendments to the current methodologies** used in compiling the GHG Inventories for Hong Kong, with a view to reducing uncertainties. The recommended methodologies will be in full compliance with the relevant guidelines issued by the IPCC, including the *2006 IPCC Guidelines*;

4. To prepare the "**Review Report on GHG Inventory Compilation Methodologies**" presenting the findings of the work undertaken in Items 1 to 3;

5. To **update the inventory of GHG** emissions by sources and removals by sinks for each year from 1990 to 2006, according to the agreed methodologies;

6. To quantitatively **estimate the uncertainties** in the data used to compile the inventory of GHG emissions and removals for the year 2005, the combined uncertainties associated with the 2005 GHG emission inventory, and the trend estimate (using 1990 as the base year) based on the IPCC methodologies; and

1.2 DESCRIPTION OF THE METHODOLOGIES AND DATA SOURCES BETWEEN 1996 AND 2006 IPCC GUIDELINES

The HK inventory covers sources of GHGs and removals by sinks that have resulted from anthropogenic activities. These originate from a large number of processes as well as diffuse sources. Emissions are not usually monitored, thus are estimated using models and applying methodologies developed for this purpose.

The previous HK GHG Inventories have been compiled for the years 1990 to 2006, using methodologies developed through consultancy studies, consistent with the *Revised 1996 IPCC Guidelines.* Where the *Revised 1996 IPCC Guidelines* did not adequately describe the situation in the HKSAR or in instances where the available data did not allow the IPCC methods to be used, alternative methods were employed.

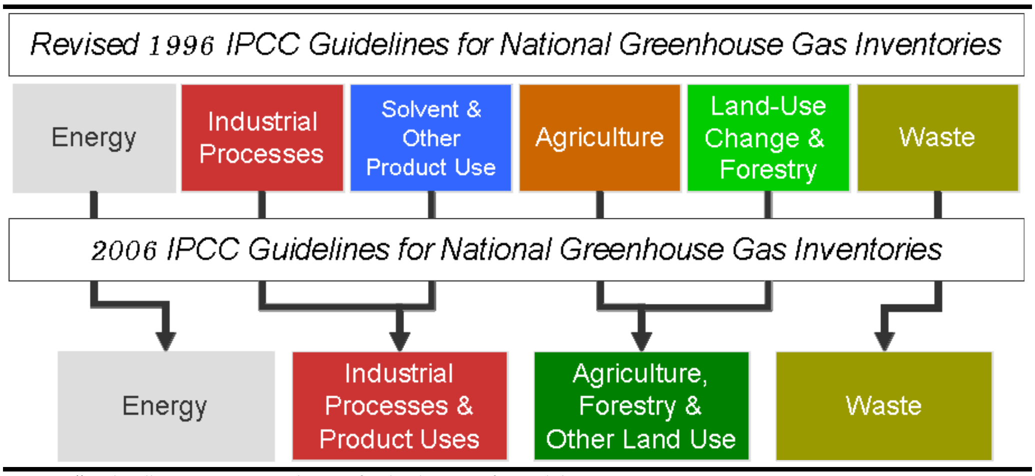
These inventories have now been updated to take into account the methodologies specified in the *2006 IPCC Guidelines* as far as possible. While these methodologies are based on the same principles as the *Revised 1996 IPCC Guidelines,* three key differences exist - the categorisation of sources and sinks, the methodologies, and data requirements.

The Guidelines are internationally accepted and are designed to allow countries to determine their GHG emissions. As data availability varies significantly between countries, the Guidelines have been designed in such a way to allow a variety of calculation methodologies to be followed, depending on data availability. This is called using a 'Tier' system, with the Tiers generally increase in complexity and accuracy as they increase. The complexity of the Tiers is usually consistent for the same gas and source sector, however, they may be different between different gases and sectors. It is common practice to use the most sophisticated Tier level that the available data allows. The following sections discuss these further.

1.2.1 *Categorization of Sources and Sinks*

The differences in the categorisations (1) of GHG sources and sinks between the two guidelines are summarised in *Figure 1.1.*

Figure 1.1 Differences in Categorisation of Sources and Sinks between the 2006 and Revised 1996 IPCC Guidelines



Note: *"Other" category not shown for both sets of Guidelines.*

From *Figure 1.1*, it can be seen that the Energy and Waste sectors remain as independent sectors under the *2006 IPCC Guidelines*. However, Industrial Processes and Solvent & Other Product Use are combined as Industrial Processes & Product Uses (IPPU) and Agriculture and Land-use Change & Forestry are combined as Agriculture, Forestry & Other Land Use (AFOLU) under the *2006 IPCC Guidelines*. The latter integration removes the distinction between the two categories in the *Revised 1996 IPCC Guidelines*, and promotes consistent use of data between them, especially for more detailed estimation methods.

Categorisation of sources and sinks also differs between the two versions of the *Guidelines* at the more disaggregated level. Comparison of the categorisation schemes proposed by the *Revised 1996 IPCC Guidelines* and the *2006 IPCC Guidelines* at the sub-sectoral level is presented in *Table 1.1*. The group 1A2 Fuel Combustion Activities in the Manufacturing Industries and Construction, for example, now contains 13 sub-groups, up from 6 sub-groups in the *Revised 1996 IPCC Guidelines*.

(1) The term 'difference in categorisation' is widely used in this appendix. As the estimation of GHG inventory can be distinguished into four levels: sector level, sub-sector level, activity level and data level, the term 'difference in categorisation' could be used in any level depending on the focused level. For this section, it is referred to the difference between 'sectors' identified by the *Revised 1996 IPCC Guidelines* and *2006 IPCC Guidelines*.

Table 1.1 Differences in Categorization of Sources and Sinks between the Revised 1996 IPCC Guidelines and 2006 IPCC Guidelines

Revised 1996 IPCC Guidelines	*2006 IPCC Guidelines*
1 ENERGY	
1A Fuel Combustion Activities	1A Fuel Combustion Activities
1A1 Energy industries	1A1 Energy industries
1A2 Manufacturing industries & construction	1A2 Manufacturing industries & construction
1A3 Transport	1A3 Transport
1A4 Other sectors	1A4 Other sectors
1A5 Non-specified	1A5 Non-specified
1B Fugitive Emissions from Fuels	1B Fugitive Emissions from Fuels
1B1 Solid fuels	1B1 Solid fuels
1B2 Oil and natural gas	1B2 Oil and natural gas
	1B3 Other emissions from energy production
	1C Carbon Dioxide Transport and Storage
	1C1 Transport of CO_2
	1C2 Injections & storage
	1C3 Other
2 INDUSTRIAL PROCESSESS	**2 INDUSTRIAL PROCESSES & PRODUCT USE**
2A Mineral Industry	2A Mineral Industry
2A1 Cement production	2A1 Cement production
2A2 Lime production	2A2 Lime production
2A3 Limestone & dolomite use	2A3 Glass production
2A4 Soda ash production & use	2A4 Other process uses of carbonates
2A5 Asphalt roofing	2A5 Other
2A6 Road paving with asphalt	
2A7 Other	
2B Chemical Industry	2B Chemical Industry
2B1 Ammonia production	2B1 Ammonia production
2B2 Nitric acid production	2B2 Nitric acid production
2B3 Adipic acid production	2B3 Adipic acid production
2B4 Carbide production	2B4 Caprolactam, glyoxal and glyoxylic acid production
2B5 Other	2B5 Carbide production
	2B6 Titanium dioxide production
	2B7 Soda ash production
	2B8 Petrochemical & carbon black production
2E Production of Halocarbons and Sulphur Hexafluoride	2B9 Fluorochemical production 2B10 Other
2E1 By-Product Emissions	
2E2 Fugitive Emissions	
2E3 Other (please specify)	
2C Metal Industry	2C Metal Industry
2C1 Iron & steel production	2C1 Iron & steel production
2C2 Ferroalloys production	2C2 Ferroalloys production
2C3 Aluminum production	2C3 Aluminum production
2C4 SF_6 used in aluminium and magnesium foundries	2C4 Magnesium production 2C5 Lead production
2C5 Other	2C6 Zinc production
	2C7 Other

Revised 1996 IPCC Guidelines	*2006 IPCC Guidelines*
	2D Non-Energy Products from Fuels and Solvent Use
	2D1 Lubricant use
	2D2 Paraffin wax use
	2D3 Solvent use
	2D4 Other
	2E Electronics Industry
	2E1 Integrated circuit or semiconductor
	2E2 TFT flat panel display
	2E3 Photovoltaics
	2E4 Heat transfer fluid
	2E5 Other
2F Consumption of Halocarbons and Sulphur Hexafluoride	2F Product Uses as Substitutes for Ozone Depleting Substances
2F1 Refrigeration and air conditioning	2F1 Refrigeration and air conditioning
2F2 Foam Blowing	2F2 Foam blowing agents
2F3 Fire Extinguishers	2F3 Fire protection
2F4 Aerosols	2F4 Aerosols
2F5 Solvents	2F5 Solvents
2F6 Other	2F6 Other applications
2G Other	2G Other Product Manufacture and Use
	2G1 Electrical equipment
	2G2 SF_6 and PFCs from other product uses
	2G3 N_2O from product uses
	2G4 Other
2D Other Production	2H Other
2D1 Pulp and paper	2H1 Pulp and paper industry
2D2 Food and drink	2H2 Food and beverages industry
	2H3 Other
3 SOLVENT & OTHER PRODUCT USE	
3A Paint Application	
3B Degreasing & Dry Cleaning	
3C Chemical Products, Manufacture & Processing	
3D Other	
4 AGRICULTURE; AND 5 LAND-USE CHANGE & FORESTRY	**3 AGRICULTURE, FORESTRY, AND OTHER LAND USE**
4A Enteric Fermentation	3A Livestock
4B Manure Management	3A1 Enteric fermentation
	3A2 Manure management
5A Change in Forest and other Woody Biomass Stocks	3B Land
5A1 Tropical forests	3B1 Forest land
5A2 Temperate forests	3B2 Cropland
5A3 Boreal forests	3B3 Grassland
5A4 Grasslands/tundra	3B4 Wetlands
5A5 Other	3B5 Settlements
	3B6 Other land
5B Forest and Grassland Conversion	
5B1 Tropical forests	
5B2 Temperate forests	
5B3 Boreal forests	
5B4 Grasslands/tundra	
5B5 Other	

Revised 1996 IPCC Guidelines	*2006 IPCC Guidelines*
5C Abandonment of Managed Lands	
5C1 Tropical forests	
5C2 Temperate forests	
5C3 Boreal forests	
5C4 Grasslands/tundra	
5C5 Other	
	3C Aggregate Sources and Non-CO_2 Emissions Sources on Land
4F Field Burning of Agricultural Residues	3C1 Emissions from biomass burning
4F1 Cereals	
4F2 Pulse	
4F3 Tuber and root	
4F4 Sugar cane	
4F5 Other	
5D CO_2 Emissions and Removals from Soil	3C2 Liming
	3C3 Urea application
	3C4 Direct N_2O emissions from managed soils
	3C5 Indirect N_2O emissions from managed soils
	3C6 Indirect N_2O emissions from manure management
4C Rice Cultivations	3C7 Rice cultivations
4C1 Irrigated	
4C2 Rainfed	
4C3 Deepwater	
4C4 Other	
4G Other (Agriculture)	3C8 Other
4D Agricultural Soils	
4E Prescribed Burning of Savannas	
5E Other (Land-Use & Land-Use Change)	
	3D Other
	3D1 Harvested wood products
	3D2 Other
6 WASTE	**4 WASTE**
6A Solid Waste Disposal on Land	4A Solid Waste Disposal
6A1 Managed waste disposal on land	4A1 Managed waste disposal sites
6A2 Unmanaged waste disposal sites	4A2 Unmanaged waste disposal sites
6A3 Other	4A3 Uncategorised waste disposal sites
	4B Biological Treatment of Solid Waste
6C Waste Incineration	4C Incineration and Open Burning of Waste
	4C1 Waste incineration*
	4C2 Open burning of waste
6B Wastewater Handling	4D Wastewater Treatment and Discharge
6B2 Domestic and commercial wastewater	4D1 Domestic wastewater treatment & discharge
6B1 Industrial wastewater	4D2 Industrial wastewater treatment & discharge
6B3 Other	
6D Other	4E Other

1.2.2 *Methodology*

In general, both guidelines follow the same methodological approach, whereby they combine information on the extent to which a human activity takes place, referred to as *Activity Data* (AD), with coefficients quantifying the emissions or removals per unit activity, referred to as *Emission Factors* (EF).

The basic equation for estimating GHG emissions (or removals) is, therefore:

$$Emissions\ (Removals) = AD \bullet EF$$

In addition to activity data and emission factors, this basic equation can incorporate other estimation parameters to reflect actual emissions or removals (1). A number of other approaches are also provided to reflect the characteristics of certain processes that emit or remove GHGs (2). For example, stock change methods are used in the AFOLU sector, estimating CO_2 emissions from changes in the carbon content of living biomass and dead organic matter pools over time. The *2006 IPCC Guidelines* also provide more complex modelling approaches for higher degrees of accuracy.

The key conceptual differences between the *Revised 1996 IPCC Guidelines* and the *2006 IPCC Guidelines* by sector are as follows.

Energy

- ***Treatment of CO_2 capture and storage***: emissions and removals associated with CO_2 capture and storage are covered by the new *Guidelines*, including fugitive losses from CO_2 capture and transport stages, and losses from carbon dioxide stored underground. Amounts of CO_2 captured from the combustion of biofuels, and subsequently injected into underground storage are included in the inventory as a negative emission.

- ***Methane from abandoned coal mines***: A methodology for estimating these emissions is included in the *2006 IPCC Guidelines*.

Industrial Processes & Product Uses (IPPU)

New GHGs from industrial processes: Additional GHGs identified in the *IPCC Third Assessment Report* (IPCC, 2001) (3) are included where anthropogenic sources have been identified. These gases include nitrogen trifluoride (NF_3), trifluoromethyl sulphur pentafluoride (SF_5CF_3), and halogenated ethers. However, these gases do not need to be reported as part of the national inventory; subsequently, the preparation of the inventory will not include these three gases.

- ***Non-energy uses of fossil fuels***: Emissions from non-energy uses of fossil fuels are now reported under Industrial Processes and Product Use (IPPU), rather than in Energy. A method has been introduced for

(1) IPCC, 2006, "IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1: General Guidance and Reporting"

(2) The method for GHG emission estimation, in IPCC 2006 Guidelines, is categorised into 3 levels according to the level of methodological complexity or *tier*. Tier 1 is the basic method, Tier 2 intermediate, and Tier 3 most demanding in terms of complexity and data requirement. Tiers 2 and 3 are sometimes referred to as higher *tier* methods and are generally considered to be more accurate.

(3) Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

checking the completeness of carbon dioxide emission estimates from the non-energy uses.

- ***Actual emissions of fluorinated compounds***: The potential emissions approach used as a Tier 1 method in the *Revised 1996 IPCC Guidelines* is replaced by actual emission estimation methods in the *2006 IPCC Guidelines*.

Agriculture, Forestry & Other Land Use (AFOLU)

- ***Managed land is used as a proxy for identifying anthropogenic emissions by sources and removals by sinks:*** In most AFOLU sectors anthropogenic GHG emissions by source and removals by sinks are defined as those occurring on managed land.

- ***Consolidation of previously optional categories***: Emissions by sources and removals by sinks associated with all fires on managed land are now estimated, removing the previous optional distinction between wildfires and prescribed burning. This is consistent with the concept of managed land as a proxy for identifying anthropogenic emissions by sources and removals by sinks, as discussed above. Wildfires and other disturbances on unmanaged land cannot, in general, be associated to an anthropogenic or natural cause, and hence are not included in the *2006 IPCC Guidelines*, unless the disturbance is followed by a land-use change. In this case, the land affected by disturbance is considered to be managed, and all the GHG emissions by sources and removals by sinks associated with the fire and other events are now estimated, irrespective of whether they are of natural origin or not. Carbon dioxide emissions and removals associated with terrestrial carbon stocks in settlements and managed wetlands, which were previously optional, have been incorporated into the main guidance.

- ***Emissions from managed wetlands***: The *2006 IPCC Guidelines* now contain methods to estimate CO_2 emissions due to land use change in wetlands.

Waste

- ***Harvested wood products (HWP)***: The *2006 IPCC Guidelines* provide detailed methods that can be used to include HWP in GHG inventories.

- ***Revised methodology for methane from landfills:*** The previous Tier 1 method, based on the maximum potential release of methane in the year of placement, has been replaced by a simple first order decay model that provides the option to use data available from the UN and other sources. This approach includes regional and country-specific defaults on waste generation, composition and management, and provides a consistent basis for estimating GHG emissions across all tiers. This gives a more accurate time series for estimated emissions and should avoid the situation in which the use of landfill gas apparently exceeds the amount generated in a particular year.

- ***Carbon accumulation in landfills***: This is provided as an output from the decay models, and can be relevant for the estimation of HWP in AFOLU.

- ***Biological treatment and open burning of waste*:** Guidance on estimation of emissions from composting and biogas facilities has been included.

Global Warming Potential of GHGs

Another key difference between the *Revised 1996 IPCC Guidelines* and the *2006 IPCC Guidelines* is the Global Warming Potential (GWP) values defined. According to the IPCC Guidelines, the GWP is a measure of a particular GHG's contribution to global warming. The scale is a ratio of the contribution of global warming relative to that of the similar mass of carbon dioxide (which has a GWP of one), thus allowing the expression of all GHG emissions as carbon dioxide equivalents. A comparison of the GWPs adopted in the *Revised IPCC 1996 Guidelines* and the *2006 IPCC Guidelines* is shown in the *Table 1.2*.

The GWPs presented in the *Revised 1996 IPCC Guidelines* were based on the findings of the *IPCC Second Assessment Report*, published in 1995 (IPCC, 1995) [1]. The *2006 IPCC Guidelines* were updated according to the findings of the *IPCC Third Assessment Report* (IPCC, 2001). A *Fourth Assessment Report* (IPCC, 2007) [2] was released, in 2007, which further updated the GWPs. Under the Kyoto Protocol, the Conference of the Parties decided that the GWPs calculated in the *Second Assessment Report* are to be used for converting GHG emissions into carbon dioxide equivalents, and the later findings should not be applied practically until the end of 2012. This is further validated by the UNFCCC Guidelines. Therefore, for the purpose of this inventory compilation, the GWPs defined in the *Revised 1996 IPCC Guidelines* will be used.

(1) Climate Change 1995: The Physical Science Basis, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

(2) Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)

Table 1.2 *Comparison of 100-year GWP Estimates from the IPCC Guidelines*

Gas	1996 IPCC GWP	2006 IPCC GWP
Carbon Dioxide	1	1
Methane	21	23
Nitrous Oxide	310	296
HFC-23	11,700	12,000
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
Perfluoromethane (CF_4)	6,500	5,700
Perfluoroethane (C_2F_6)	9,200	11,900
Sulfur Hexafluoride (SF_6)	23,900	22,200

1.2.3 *Data*

Data available for the estimation of GHG emissions and removals dictate the choice of calculation methodologies. The HK inventories have been compiled from a combination of local specific data and IPCC methodologies and emission factors. The more complex the methodology, the more accurately emissions are calculated though this is often dependent on the availability of data. Furthermore, the additional complexity also ensures that emissions from the past are reflected in the inventory, as well as current ones. A key example of the significance of this is in the calculation of emissions through solid waste disposal, where landfills will continue to generate emissions for decades following their closure, thus making past waste disposal actions as significant as current ones.

The existing and new HK inventories have been prepared using a mix of sources of activity data that is predominantly derived from official statistical agencies and from the Environmental Protection Department (EPD). Some of the key data sources include:

- ***Energy sector*** – Electrical & Mechanical Services Department's (EMSD's) Energy End-Use Database; Hong Kong Energy Statistics; Hong Kong Annual Digest of Statistics; EPD – Air Policy Group; Census and Statistics Department (C&SD); Electrical and Mechanical Services Department (EMSD); Civil Aviation Department (CAD); Transport Department; Marine Department; EPD – Waste Group and other GHG contributors.

- ***IPPU sector*** – Key industrial process industries; key HK providers (eg fire protection equipment, SF_6) and EPD.

- ***AFOLU sector*** – Agriculture, Fisheries and Conservation Department (AFCD) and EPD.

- ***Waste sector*** –EPD; A Policy Framework for the Management of Municipal Solid Waste in Hong Kong; EPD Waste Disposal Plan for Hong

Kong; Annual Municipal Solid Waste Reports and Drainage Services Department (DSD).

The source of each activity datum and emission factor used in the GHG emission calculation is provided in the detailed worksheets.

Having compared the required data for the *Revised 1996 IPCC Guidelines* and *2006 IPCC Guidelines*, it is found that there will be three possible data scenarios for the data requirements of the updated inventories:

- New data
- Different categorisation
- Ready to go

New Data

In the case of a major change in the calculation methodology, new sets of data will be required. An example is in the IPPU sector where new data for calculating GHG emissions from fluorinated substitutes for ozone depleting substances are required. *Table 1.3* presents the data requirement for this example.

Table 1.3 Differences in Data Required for Tier 1 Emissions Estimation Methods for Fluorinated Substitutes for Ozone Depleting Substances in the Revised 1996 IPCC Guidelines and 2006 IPCC Guidelines

Revised 1996 IPCC Guidelines	***2006 IPCC Guidelines***
Tier 1a Production Imports Exports Destruction	Tier 1a Production Imports Exports Destruction Composite emission factor
Tier 1b Production Imports Exports Destruction Quantity of chemical imported in HFC/PFC containing products Quantity of chemical exported in HFC/PFC containing products	Tier 1b Annual sales of new chemical Total charge of new equipment Original total charge of retiring equipment

Different Categorisation

As briefly discussed in *Section 1.2.1*, the *Revised 1996 IPCC Guidelines* categorise activities/sources differently from the *2006 IPCC Guidelines* in certain cases. The new data requirements are consequently different from the existing requirements in terms of categorisation. It is noted that in this scenario the methodologies used in calculating GHG emissions remain unchanged. An example can be found in the Energy sector where

Manufacturing Industries and Construction in the *Revised 1996 IPCC Guidelines* is categorised into 5 different sub-sectors; while it is categorised into 13 different sub-sectors under the *2006 IPCC Guidelines*. From this example, an entirely new data input may not be required, but the existing data may have to be rearranged to match the new categorisation.

Ready to Go

In the case where the *2006 IPCC Guidelines* are identical to the *Revised 1996 IPCC Guidelines* or where the data required are similar, the existing data can be used in the *2006 IPCC Guidelines* without any modification or adjustment.

1.3 OVERVIEW OF THE INVENTORIES

1.3.1 Introduction

This section provides an overview of the findings of the updated inventory of HK GHG emissions. The overview is presented in two stages, firstly by total GHG emissions (expressed as $GgCO_2e$), followed by a more detailed analysis of GHG emissions by gas and sector.

1.3.2 Total GHG Emissions

Tables present a comparison of emissions from 1990 to 2006 (with and without Sector 3B (Land)[1], using the *Revised 1996* and *2006 IPCC Guidelines* methodologies. *Table 1.4* shows that the Energy sector is the main contributor of GHG emissions, dominating the other three sectors. The Waste sector is the next most significant. The annual average share of GHG emissions from the Energy and Waste sectors from 1990 to 2006 was 93.0% and 4.5%, respectively. The IPPU and AFOLU sectors on average each contribute 2.2% and less than 1% respectively. *Figures* show the trend in total GHG emissions in Hong Kong by major sectors and gas types from 1990 to 2006. The emissions of CO_2-e have risen from 35.3 million tonnes in 1990 to 42.3 million tonnes in 2006.

[1] Sector 3B (Landuse) is excluded in the presentation of the overall inventory to be consistent with the UNFCCC GHG data reporting format.

Table 1.4 Comparison of HK GHG Emissions, by sector, using Revised 1996 and 2006 IPCC Guidelines Methodologies, from 1990 to 2006 [(a)]

Year	IPCC 2006 ($GgCO_2e$ /year)							IPCC 1996 ($GgCO_2e$ /year) [(d)]				
	Energy	IPPU	AFOLU		Waste	Total (With Sector 3B)	Total (Without Sector 3B)	Energy	IPPU	AFOLU	Waste	Total
			All Sectors except Sector 3B	Sector 3B								
1990	33,427	215	141	-469	1,548	34,861	35,330	34,188	258	46	4,808	39,300
1991	36,445	638	123	-469	1,602	38,339	38,807	37,231	691	40	4,963	42,925
1992	40,616	651	100	-469	1,656	42,556	43,024	41,375	695	32	5,162	47,264
1993	40,860	724	87	-468	1,753	42,956	43,424	41,668	767	30	5,418	47,883
1994	33,246	830	77	-469	1,769	35,454	35,922	34,154	876	28	5,629	40,687
1995	33,950	935	85	-469	1,939	36,440	36,909	34,882	985	27	5,808	41,702
1996	32,609	952	86	-469	1,902	35,080	35,549	33,578	1,024	30	5,842	40,474
1997	30,959	1,055	75	-469	2,003	33,624	34,093	31,932	1,128	29	5,678	38,767
1998	32,889	977	70	-487	1,548	34,999	35,485	33,935	1,046	27	5,460	40,468
1999	31,095	1,022	84	-418	1,118	32,902	33,319	32,154	1,098	31	5,272	38,555
2000	32,461	977	78	-389	1,114	34,241	34,630	33,765	1,066	31	4,663	39,525
2001	32,450	862	85	-370	1,254	34,280	34,650	33,841	918	33	4,720	39,512
2002	34,135	503	82	-371	1,488	35,837	36,208	35,721	552	32	4,886	41,191
2003	37,172	538	74	-385	1,801	39,199	39,585	38,112	579	28	5,061	43,780
2004	37,088	636	67	-432	1,995	39,355	39,787	38,238	676	25	5,080	44,019
2005	38,814	867	74	-412	2,218	41,560	41,973	38,491	901	27	5,410	44,829
2006	38,747	1,383	74	-418	2,142	41,928	42,346	38,621	1,475	26	5,311	45,433
AGR [(e)]	0.9%	12.3%	-3.9%	-0.7% [(e)]	2.1%	1.2%	1.1%	0.8%	11.5%	-3.5%	0.6%	0.9%

Notes:

(a) Information Item (excluded from total inventory) = CO_2 from burning of landfill gas onsite or offsite. Note that flaring of LFG is not required to be reported in the inventory according to the 2006 IPCC Guidelines therefore it is not included.

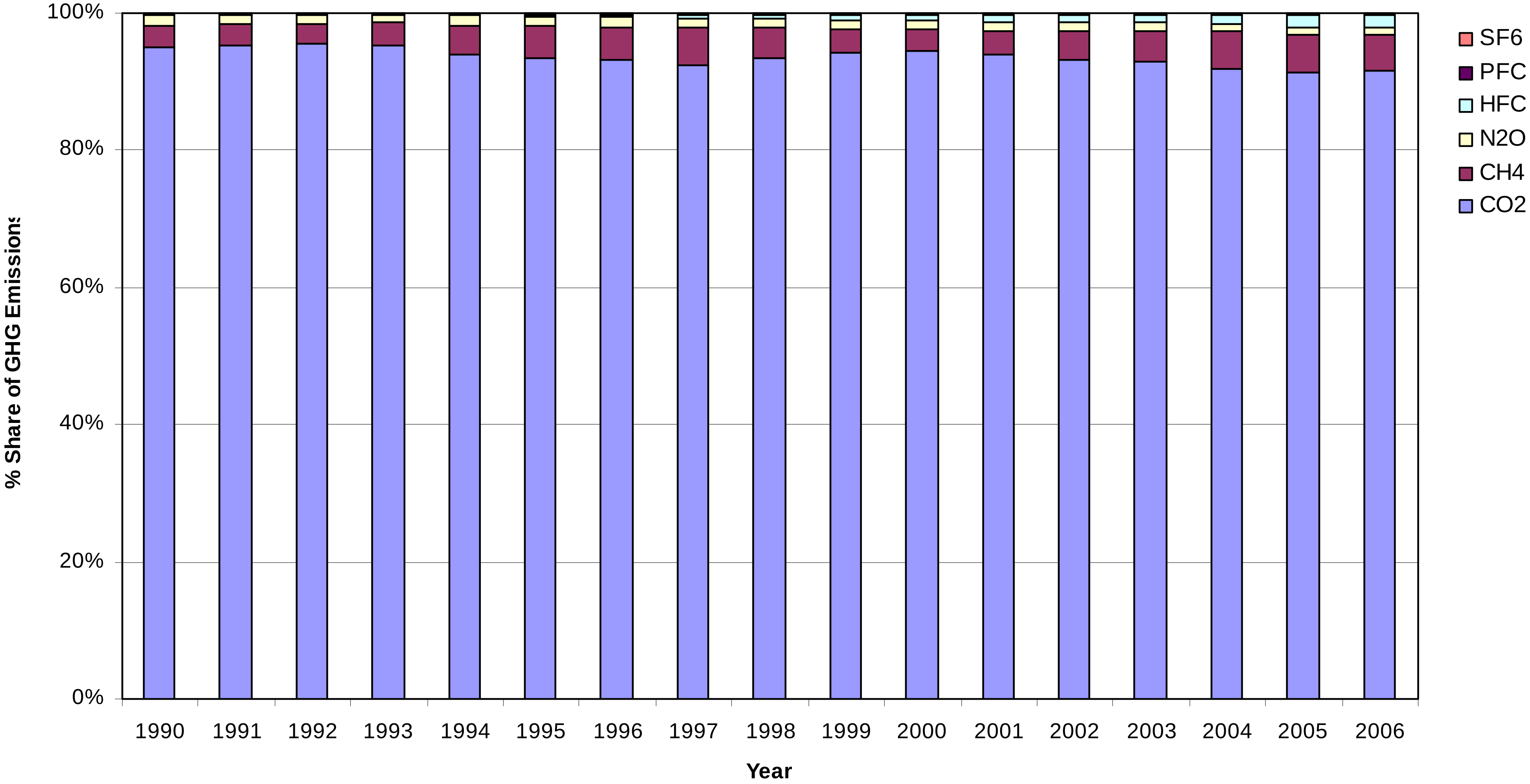
(b) International aviation and navigation as memo items are excluded from the inventory.

(c) The results are extracted from EPD's GHG Inventories as of March 2008.

(d) AGR = Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0}\right]^{\frac{1}{t}} - 1$ where t is the number of years in the study period.

(e) The negative AGR in Sector 3B represents decline in carbon removal over the study period.

Figure 1.2 *Total HK GHG Emssions from 1990 to 2006, by Gas Type*



From *Table 1.4,* prior to 1993, the total GHG emissions in HK were gradually increasing but declined dramatically in the year 1994. After 1994, the total GHG emissions continued on an upward trend. The dramatic decline in the emissions between 1993 and 1994 is largely due to the significant decrease in the emissions from the Energy sector as Hong Kong started to intake nuclear power from mainland China in 1994. The GHG emissions from the Energy sector during 1993 to 1994 period reduced from 40,860 GgCO_2e to 33,246 GgCO_2e (as shown in *Table 1.4*).

According to *2006 IPCC Guidelines*, CO_2 emission from burning of biomass should be reported as an Information Item (1) separately from the HK Inventory. In Hong Kong, landfill gas (LFG) generated in some active strategic landfills and closed landfills are captured and utilized as fuel for operating onsite power generator or leachate treatment plant. Since LFG is regarded as a biomass fuel, CO_2 emission from utilization of LFG as fuel is not reported in the HK Inventory.

Besides utilisation as fuel, LFG is also recovered for flaring which is not required to be included in the inventory according to the *2006 IPCC Guidelines*, as discussed in Vol.5, page 3.18, '*Emissions from flaring are however not significant, as the CO_2 emissions are of biogenic origin and the CH_4 and N_2O emissions are very small, so good practice in the waste sector does not require their estimation*.' As such, LFG flared in HK is not reported.

It should be noted that all emissions from fuels for international aviation and marine travel (1A3di and 1A3ai) and multilateral operations in accordance with the Charter of the United Nations, are excluded from the total domestic inventory and reported separately as memo items. This is similar to the approach in the *Revised 1996 IPCC Guidelines*. The inventory includes all domestic travel by air and sea, which is defined as all movements within the HKSAR.

The IPPU sector has the highest average annual rate of increase at 12.3% over the 17 year period. The Energy and Waste sectors have only a 0.9% and 2.1% annual average rate of increase, respectively. AFOLU is the only sector which removes carbon (negative GHG emissions) and carbon removal in this sector has declined by 0.7% over the study period) .

From a comparison perspective, the GHG emissions calculated using the *2006 IPCC Guidelines* methodologies in the Energy and IPPU sectors are similar to the GHG emissions calculated using the *Revised 1996 IPCC Guidelines* methodologies, as shown in *Table 1.4*.

(1) In the *2006 IPCC Guidelines*, 'information item' includes CO_2 emissions resulting from combustion of biogenic materials (eg CO_2 from waste-to-energy applications) which is not included in the national totals, but are recorded as an information item for cross-checking purposes and avoid double-counting. In the IPPU sector when the total emissions from the gases are calculated, the quantity transferred to the energy sector should be noted as an information item under IPPU source category and reported in the relevant energy sector source category to avoid double counting.

A considerable difference in GHG emissions between the two methodologies is observed in the emissions from the Waste sector. Using the *2006 IPCC Guidelines* methodologies, GHG emissions from the Waste sector are lowered significantly by an average of approximately 65 -70%, compared to the emissions calculated using the *Revised 1996 IPCC Guidelines* methodologies, also shown in *Table 1.4*.

The rationale behind the changes in all of the sectors is further explored in *Part II* of *Appendix A*.

Table 1.5 and *Figure 1.2* show the total emissions for each year, over the 17 year period, for each GHG. It can be seen that CO_2 is the dominant gas, accounting for more than 90% of total GHG emissions over the 17 years. CH_4 and N_2O contribute a maximum of 5% and 2% of total, respectively, while the remaining gases have less than a 1% contribution each.

Table 1.5 Comparison of HK GHG Emissions by Gas, using 2006 IPCC Guidelines Methodologies, from 1990 to 2006

Year	IPCC 2006 ($GgCO_2e$ /year)								
	CO_2		CH_4	N_2O	HFC	PFC	SF_6	Total	
	With Sector 3B	Without Sector 3B						With Sector 3B	Without Sector 3B
1990	33,161	33,630	1,129	470	-	-	102	34,861	35,330
1991	36,555	37,024	1,246	447	-	-	91	38,339	38,807
1992	40,631	41,100	1,341	476	-	-	108	42,556	43,024
1993	40,930	41,398	1,454	475	-	-	97	42,956	43,424
1994	33,289	33,758	1,559	478	-	-	127	35,454	35,922
1995	34,041	34,510	1,710	489	85	1.8	112	36,440	36,909
1996	32,596	33,065	1,723	533	113	1.9	112	35,080	35,549
1997	30,967	31,436	1,820	565	157	2.3	113	33,624	34,093
1998	32,649	33,136	1,523	538	191	2.5	95	34,999	35,485
1999	30,921	31,338	1,098	547	227	2.6	106	32,902	33,319
2000	32,247	32,636	1,099	518	283	3.7	91	34,241	34,630
2001	32,070	32,440	1,246	529	342	3.5	89	34,280	34,650
2002	33,323	33,694	1,479	532	390	1.6	112	35,837	36,208
2003	36,408	36,793	1,767	487	452	0.5	85	39,199	39,585
2004	36,236	36,668	1,979	504	541	2.0	93	39,355	39,787
2005	37,992	38,404	2,203	499	742	1.9	123	41,560	41,973
2006	38,462	38,880	2,135	484	739	0.2	108	41,928	42,346

1.3.3 *GHG Emissions by 2006 IPCC Sectors*

This section provides an overview of the HK GHG emissions from 2006 IPCC sectors - *Energy*, *Industrial Processes and Product Use (IPPU)*, *Agriculture Forestry and Land-Use Change (AFOLU)* and *Waste*. The GHG emissions by gas type of each sector are summarized in *Tables 1.6* and *1.7*. A detailed analysis of the contribution of each sector is presented in *Part II* of *Appendix A*.

Table 1.6 ***HK GHG Emissions from Energy Sector, using 2006 IPCC Guidelines Methodologies, from 1990 - 2006***

Year	HK GHG Emissions from Energy Sector ($GgCO_2e$/year)			
	CO_2	CH_4	N_2O	Total
1990	33,170	34	223	33,427
1991	36,190	37	218	36,445
1992	40,314	37	265	40,616
1993	40,547	39	273	40,860
1994	32,925	39	282	33,246
1995	33,621	41	288	33,950
1996	32,195	84	330	32,609
1997	30,484	109	366	30,959
1998	32,412	104	373	32,889
1999	30,610	112	373	31,095
2000	32,000	107	353	32,461
2001	31,981	111	357	32,450
2002	33,664	113	358	34,135
2003	36,764	93	314	37,172
2004	36,640	112	337	37,088
2005	38,378	114	322	38,814
2006	38,318	116	313	38,747

Table 1.7 HK GHG Emissions from IPPU, AFOLU and Waste Sectors, using 2006 IPCC Guidelines Methodologies, from 1990 - 2006

Year	HK GHG Emissions ($GgCO_2e$/year)																
	IPPU					AFOLU								Waste			
						With Sector 3B				Without Sector 3B							
	CO_2	HFCs	PHCs	SF_6	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total	CO_2	CH_4	N_2O	Total
1990	113	0	0	102	215	-460	37	95	-328	9	37	95	141	338	1,058	152	1,548
1991	547	0	0	91	638	-459	29	84	-346	10	29	84	123	277	1,180	144	1,602
1992	544	0	0	108	651	-455	19	67	-368	14	19	67	100	228	1,284	144	1,656
1993	627	0	0	97	724	-461	18	62	-381	7	18	62	87	216	1,397	140	1,753
1994	703	0	0	127	830	-466	18	55	-392	3	18	55	77	127	1,502	141	1,769
1995	735	85	2	112	935	-455	19	52	-384	14	19	52	85	140	1,651	148	1,939
1996	724	113	2	112	952	-461	25	53	-383	8	25	53	86	137	1,614	150	1,902
1997	783	157	2	113	1,055	-467	26	48	-394	2	26	48	75	167	1,685	151	2,003
1998	689	191	3	95	977	-483	29	38	-416	3	29	38	70	32	1,389	127	1,548
1999	685	227	3	106	1,022	-408	34	40	-333	10	34	40	84	33	952	133	1,118
2000	599	283	4	91	977	-387	36	40	-311	2	36	40	78	34	955	125	1,114
2001	428	342	4	89	862	-368	38	44	-285	2	38	44	85	29	1,097	127	1,254
2002	0	390	2	112	503	-370	38	43	-289	1	38	43	82	29	1,328	131	1,488
2003	0	452	0	85	538	-383	31	41	-311	2	31	41	74	27	1,642	132	1,801
2004	0	541	2	93	636	-430	31	35	-364	2	31	35	67	26	1,836	133	1,995
2005	0	742	2	123	867	-412	31	42	-339	1	31	42	74	26	2,058	134	2,218
2006	535	739	0	108	1,383	-413	31	39	-344	5	31	39	74	21	1,989	133	2,142

Energy

In the Energy sector, CO_2 is the most abundant GHG released into the atmosphere, followed by N_2O and CH_4 as shown in *Table 1.6*. The GHG emissions released from the Energy sector increased consistently over the period studied, with the exception of a marked drop between 1993 and 1994 due to a considerable increase in the amount of energy imported from China. Detailed explanation is presented in *Section 2.2* .

IPPU

GHG emitted from the IPPU sector are different to the other sectors as they consist of CO_2, HFCs, PFCs, and SF_6 (all from product usage). HFCs and PFCs were first documented to be emitted in HK in 1995, whereas the CO_2 emissions were zero during the years 2002 to 2005 as a result of the temporary discontinuation of clinker production.

AFOLU

The calculations show that a significant CO_2 removal estimated from Sector 3B – Land. N_2O is the main GHG contributor and CO_2 is the smallest contribution in AFOLU without considering Sector 3B. Detailed analysis of these trends is presented in *Section 2.4.*

Waste

There has been a significant drop of GHG emissions from Waste sector in 1999 and 2000 and then gradually increased after 2000 for a number of reasons. Firstly the leachate treatment work (LTW) plants commenced operation in 1999 at the WENT landfill and the Tseung Kwan O (TKO) Stage I closed landfill. A large amount of LFG captured in the WENT Landfill (at the rate of 4,400 m^3/hr) and the TKO Stage I closed landfill (at the rate of 1,300 m^3/hr) was utilized for the LTWs' operation. Secondly, LFG at the restored Shuen Wan landfill has been extracted for utilization as a fuel since 1999, as a result, the net methane emissions in 1999 is significantly lower than the quantity emitted in the previous years. Finally, another LTW began to operate in 2000 at the NENT landfill and LFG was captured at a rate of 3,000 m^3/hr for LTW's utilisation. As a result of operation commencement of the new LTWs began operation, a significant drop of methane emissions from landfills is observed. Further analysis is presented in *Section 2.5*.

1.4 QUALITY ASSURANCE AND QUALITY CONTROL

Quality control (QC) is "*a system of routine technical activities to assess and maintain the quality of the inventory as it is being complied.*" (1). It is designed to check and ensure data integrity, correctness and completeness; to identify and address errors and omissions; and to document all QC activities. In relation to this inventory updating task (referred as 'the task' hereafter), the primary

(1) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1, Chapter 6

goal of the QC activities are to ensure that correct data and parameters are selected and applied in the emission calculations for each sector.

Quality assurance (QA) on the other hand, is "*a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process*"[1]. The objective of QA here is to ensure the accuracy of calculations and identify any mistakes or errors.

Both QA and QC activities have been carried out throughout the inventory compilation task to ensure the over quality of the updated inventory. This section presents details of the QA/QC approach, key findings and conclusions of the QA/QC activities.

QA/QC Approach

There are three teams involved in the QA/QC activities:

<u>QC– The Compilation Team</u>

The compilation team is involved at all stages of the task and continuously check the data. It consists of technical experts who are experienced in compiling inventories with a good understanding of the IPCC guidelines requirements. At the initial stage, the team reviewed data and the previous inventory provided by the EPD, compared against the *2006 IPCC Guidelines* and made requests for additional or updated data. Having examined the data, the team compiled the inventory and produced an initial updated inventory, which they then revised into the final updated inventory.

<u>QC – The Review Team</u>

The review team works closely and maintains constant communication with the compilation team and the EPD, team members are therefore aware of the rationale for data selection and processing (if any). As such, the team is responsible to ensure the correct data and/or parameters are used and calculated according to the final decisions as agreed among all parties. The team reviews the inventory calculations and provides feedback to the compilation team throughout its development process.

<u>QA – The Independent Verification Team</u>

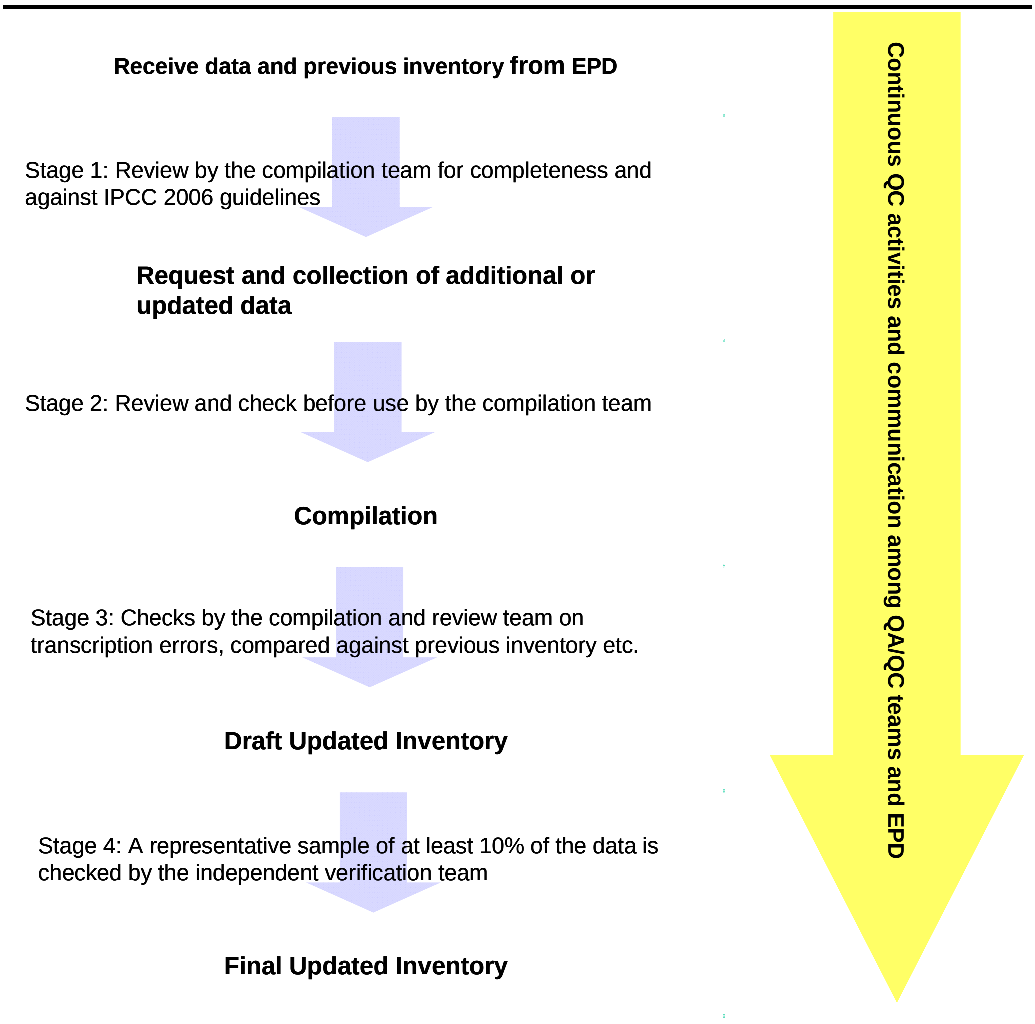
This team is independent of the compilation and review teams and has not been directly involved in the data compilation/ development process. The team is engaged at the final stage of the QA/QC process to verify calculations in the updated inventory, identifies any errors and/or miscalculations and then advises its findings to the compilation team.

QA/QC Process

QA/QC has been an integral element of the inventory updating task and continuously implemented at all stages of the task. *Figure 1.3* illustrates the

QA/QC activities carried out at each stage and involvement of the QA/QC teams.

Figure 1.3 *Flowchart of the QA/QC Process*



Stage 1 Review of initial data and previous inventory by the EPD

The compilation team reviews the previous inventory compiled following the *1996 IPCC Guidelines* and source data provided by the EPD, which are then compared against the *2006 IPCC Guidelines*. The team also examines data nature, checks data completeness, identifies data gaps and additional data needed to update the inventory. Next, data gaps and changes in the categorisation of data are proposed and discussed. Requests for additional and update data are made to the EPD and other relevant parties.

Stage 2 Checks and Review Prior to Compilation

Having gathered all available data, the compilation team goes through the entire set of data. The team communicates with the review team and the EPD to decide how data is processed and to clarify major assumptions to be made. Compilation begins once the selection of data and the calculation methodology is agreed.

Methodology and categorisation to be adopted are cross-checked by the compilation team, key deviations are documented and reported for each sector in *Part II* of Appendix A.

Stage 3 Checks and Review During Compilation

QC is carried out simultaneously with the compilation process by the review and compilation teams. Once emissions have been completed for a sector or category, the output is reviewed for its trend and compared with emissions estimates in the previous inventory. This is to identify outliers and any significant departures from the previously inventory, re-checks are then performed to explain any differences. Key observations (eg a sudden drop in emissions from the Energy sector) are noted and explained for each sector in *Part II* of Appendix A.

Prior to delivering the draft updated inventory, the review team checks a sample of data and parameters to ensure that the correct inputs have been used to calculate the emissions. Priority is given to significant sector (eg Energy) and categories with major changes from the previous inventory.

Stage 4 Final Verification and Review

The draft updated inventory is provided to the independent verification team, a representative sample of at least 10% of the data is checked. The team primarily checks for transcription and calculation errors. Findings are communicated to the review and compilation teams in order to correct any miscalculation identified and to produce the final updated inventory.

Checks are performed on selected emissions calculation spreadsheets for all sectors (Energy, IPPU, AFOLU and Waste). As recommended by the *2006 IPCC Guidelines*, priority was given to those sectors with most changes, therefore more checks have been done on the Energy and Waste sectors. More samples were also chosen from these sectors because they have the greatest contribution to GHG emissions and therefore a greater potential influence in the total emission values.

Conclusions and Key Findings

In general there are two types of error that can occur in this task, (i) using the wrong data/ parameter sources for calculations and (ii) miscalculation with wrong formula and/or values. The QA/QC approach for this task aims at identifying both types of error for the entire inventory updating process, starting from initial data review and data gathering up to the fine-tuning of the draft updated inventory.

The QA/QC also involves various parties working closely with the EPD, which compiled the data originally, to better understand the nature and background of the data. The compilation team compiles the updated inventory, reviews data source and self-checks its work; the review team double-checks data inputted into the updated inventory to ensure it matches with the most updated decisions; and finally the independent verification team checks for transcription and calculation errors.

The comprehensive QA/QC approach seeks to eliminate errors/ mistakes throughout the process. Throughout the development of the updated inventory, the number of errors spotted has significantly reduced from one stage to the next, thus the QA/QC approach is considered effective. Findings from the independent verification team as well as errors noted during QA/QC and specific findings are discussed in the following sections.

Independent Verification

No errors and inconsistencies were detected from the representative sample of data chosen from all sectors.

Common Errors

Given the size of the inventory and the numerous changes made in the inventory compilation process, data sources or parameters selected for calculations sometimes did not match with the latest approach adopted. This was most common in the Energy and Waste sectors as new data arrived at different timeframes and decisions were revised continuously. The review team recognized this type of error as all decisions and changes were communicated between the compilation and review team.

Specific Error

When compared with the previous inventory, an unexpectedly high N_2O emission was noted in *Manure Management* (Division 3A2) under the AFOLU sector. A further study into the cause shows that an underestimation of number of animals had occurred in the *GHG Study 2000*.

1.5 UNCERTAINTY ANALYSIS

Introduction

The GHG inventory's estimates of emissions and removals are inevitably different from the true underlying value for many reasons, for example sampling error and biases. The degree of the potential difference is quantified through uncertainty analysis which relies upon the quality and quantity of data as well as an understanding of the underlying processes and methods.

Uncertainty analysis is a tool for estimating and reporting uncertainties associated with annual estimation of emissions and trend over the study period, as referred in the *2006 IPCC Guidelines*. It is *good practice* to take all causes of uncertainties into consideration to assess the level of accuracy of the inventory. In general, there are eight causes [1] of uncertainty in estimating emissions and removals:

- Lack of completeness
- Modelling uncertainty
- Lack of data
- Lack of representativeness of data
- Statistical random sampling error
- Measurement error
- Misreporting or misclassification, and
- Missing data

In this section, uncertainties are quantified from the above mentioned causes, taking into consideration various assumptions and with reference to the *2006 IPCC Guidelines* as well as expert judgment.

Uncertainty Analysis Approach and Methodology

The structural approach to estimating inventory uncertainty is:

- determining uncertainties in individual variables applied in the inventory;

- combining the component uncertainties with the total inventory;

- determining the uncertainty in the trend (ie in the total inventory overtime); and

- identifying significant sources of uncertainty in the inventory with a view to prioritising data collection and efforts to improve the accuracy level of the inventory.

Quantitative uncertainty analysis is performed by estimating the 95% confidence interval of the emissions and removals estimates for individual categories and for the total inventory. In the *2006 IPCC Guidelines*, there are two approaches recommended to combine uncertainties from several categories to determine the percentage uncertainty in the total inventory and the trend uncertainty: (i) propagation of error and, (ii) Monte Carlo simulation.

Propagation of Error (Approach 1)

The propagation of error (hereafter referred as '*Approach 1*') estimates uncertainty in individual categories in the total inventory and in trends between the base year and the year of interest (ie year *t*).

(1) 2006 IPCC Guidelines, Volume 1, Chapter 3.10

Approach 1 assumes that distribution is normal and there are, in general, no correlations between the set of activity data and the set of emission factors (EFs) or both.

Approach 2, however, is a Monte Carlo analysis which is ideal for detailed category-by-category assessment of uncertainty. It is most suitable for data with large uncertainities, non-normal distribution and where the algorithms are complex functions and/or there are correlations between some of the activity sets, emissions factors, or both.

After comparing data availability and nature against requirements as discussed above, Approach 1 is considered more appropriate to be employed in this study. This is primarily because of the insufficient data to perform the Monte Carlo simulation.

The Approach 1 analysis estimates uncertainties by using the error propagation equation in two steps. First, the *Equation 1.1* approximation is used to combine emission factor, activity data and other estimation parameter ranges by category and GHG. Second, the *Equation 1.2* approximation is used to arrive at the overall uncertainty in national emissions and the trend in national emissions between the base year and the current year.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + ... + U_n^2} \qquad \text{Eq.1}$$

Where

U_{total} = *the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage);*

Un = *the percentage uncertainties associated with each of the quantities*

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + (U_2 \bullet x_2)^2 + ... + ((U_n \bullet x_n)^2}}{|x_1 + x_2 + ... + x_n|} \qquad \text{Eq.2}$$

Where

U_{total} = *the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total (ie mean) and expressed as a percentage). This term "uncertainty" is thus based upon the 95 percent confidence interval;*

x_n *and* U_n = *the uncertain quantities and the percentage uncertainties associated with them, respectively.*

Uncertainties in the HK inventory are quantified for the year 2005 (year *t*) and the core outcomes of this analysis are:

- Total percentage uncertainty in the total inventory, and
- Trend uncertainty.

The trend uncertainty is estimated using the estimated sensitivity of the calculated difference of emissions between the base year (1990) and the year of interest (2005) to an incremental (i.e., 1%) increase in one or both of these values for that source category. There are two types of sensitivities that are used in this study:

- Type A sensitivity which highlights the effect on the difference between the base and the current year emissions caused by a 1% change in both, and

- Type B sensitivity which highlights the effect caused by a change to only the current year's emissions.

Once calculated, the two sensitivities are combined using the error propagation equation to estimate overall trend uncertainty. The total (overall) percentage uncertainty in the total inventory is calculated by the combined uncertainty equation and the weighed average in every category of the total GHG emissions in 2005. The sum of the calculated value of each category is represented by the total percentage uncertainty.

Uncertainty Analysis of the Total Inventory

The percentage uncertainty of the total inventory for 2005, excluding international transportation, is about 4.3% and the trend uncertainty is about 7.2%.

When compared with the percentage uncertainty in the total inventory of other countries (eg New Zealand (1), Finland (2), US (3), UK (4) and Japan (5)), the level of uncertainty in this study is considered similar.

In terms of sectoral uncertainty, the percentage uncertainty from the Energy sector is the major contributor to the total uncertainty because it is also the largest contributor to the total emissions.

The other sectors (Waste, IPPU and AFOLU) have much less impact to the total percentage uncertainty, mainly as a result of their considerably smaller share of total GHG emissions.

(1) Uncertainty calculation for the New Zealand Greenhouse Gas Inventory 1990-2005 excluding LULUCF removals (following IPCC Tier1). http://www.mfe.govt.nz/publications/climate/nir-jul07/html/tablea7-2.pdf

(2) *2006 IPCC Guidelines* Volume 1 chapter 3

(3) U.S. Greenhouse Gas Inventory Reports 1990-2006, Annex 7 http://www.epa.gov/climatechange/emissions/downloads/08_Annex_7.pdf

(4) UK NIR 2008 Annexes http://www.airquality.co.uk/archive/reports/cat07/0804161424_ukghgi-90-06_annexes_UNFCCCsubmission_150408.pdf

(5) National Greenhouse Gas Inventory Report of JAPAN (http://www-gio.nies.go.jp/aboutghg/nir/2008/NIR_JPN_2008_v4.0_E.pdf)

CONTENTS

PART II – HONG KONG GREENHOUSE GAS INVENTORY, 1990 TO 2006

2.1 INTRODUCTION

This section of the report aims to provide a more technical and detailed analysis of the GHG emissions from different sectors and the approach used for the compilation of the inventory of Hong Kong's GHG emissions. Each sector, from 1990 to 2006, is discussed individually, providing further information on data collection and any assumptions that have been made using the methodology defined in the *2006 IPCC Guidelines.* A comparative analysis of the inventory between the *GHG Study 2000*, which followed the methodology from the *Revised 1996 IPCC Guidelines*, is also included in this section. The inventories are presented based on the sector classification in the *2006 IPCC Guidelines* - Energy, IPPU, AFOLU, and Waste.

2.2 ENERGY

2.2.1 Introduction

In the *2006 IPCC Guidelines,* the GHG emissions from the Energy sector have been divided into three sub-sectors:

- *Fuel Combustion Activities (Sector 1A);*
- *Fugitive Emissions from Fuels (Sector 1B);* and
- *Carbon Dioxide Transport and Storage (Sector 1C).*

Emissions from fuel combustion activities are defined as "the emissions from the intentional oxidisation of materials within an apparatus that is designed to raise heat and provide it either as heat or as mechanical work to a process or for use away from the apparatus" [(1)], whereas fugitive emissions are defined as "the intentional or unintentional release of GHG which may occur during the extraction, processing and delivery of fossil fuel to the point of final use" [(2)].

The emissions from the new Sector 1C, *Carbon Dioxide Transport and Storage Activities* are not included as this technology process is not available in HK. As mentioned in the previous chapter, all emissions from fuels for *International Aviation and Marine Travel (1A3di and 1A3ai)* and multilateral operations pursuant to the Charter of UN are also excluded from the inventory and reported separately as memo items. This is similar to the approach in the *Revised 1996 IPCC Guidelines*.

(1) 2006 IPCC Guideline for National Greenhouse Gas Inventories Volume 2 page 2.7

(2) 2006 IPCC Guideline for National Greenhouse Gas Inventories Volume 2 page 4.6

In this study, Sub-sector *1A - Fuel Combustion Activities* contributes almost all of the GHG emissions (more than 99%) while sub-sector *1B - Fugitive Emissions* is found to account for only less than 0.1% of the total GHG emission released from the Energy sector. The *Energy Industries* division (1A1), is the main contributor within the sub-sector (1A) accounting for almost 70% of the total emissions of the Energy sector. *Transport* (1A3), also within sub-sector 1A, is the second largest GHG emitter in this sector with a share of approximately 20% of total emission of the Energy sector.

Of the total GHG emissions released from the Energy sector each year, CO_2 has by far the highest average percentage share among the GHGs, accounting for more than 98% every year from 1990-2006 of the sector's emissions, whereas N_2O and CH_4 on average only account for about 2% altogether. This percentage share of GHG emissions released from the Energy sector is consistent over the study *Figure 2.1* and *Table 2.1* indicate that GHG emissions from the Energy sector increased dramatically from 1990 to 1993 (33,427 $GgCO_2e$/year to 40,860 $GgCO_2e$/year) , followed by a sudden drop to 33,246 $GgCO_2e$ in year 1994, representing a decrease of almost 20% in one year. This decrease in the Energy sector was attributed specifically to a reduction in electricity production in Hong Kong, which was subsidised through the import from China.

From 1994 to 2006, there is a slight growth in the total emissions from the Energy sector for both CO_2 emissions and the total emissions, which would imply it is from the greater demand for Energy within Hong Kong. Natural gas was used for power generation in late 1995 and this slows down the increase in CO_2 emissions.

Figure 2.1 *GHG Emissions of the Energy Sector 1990-2006, by GHG Gas*

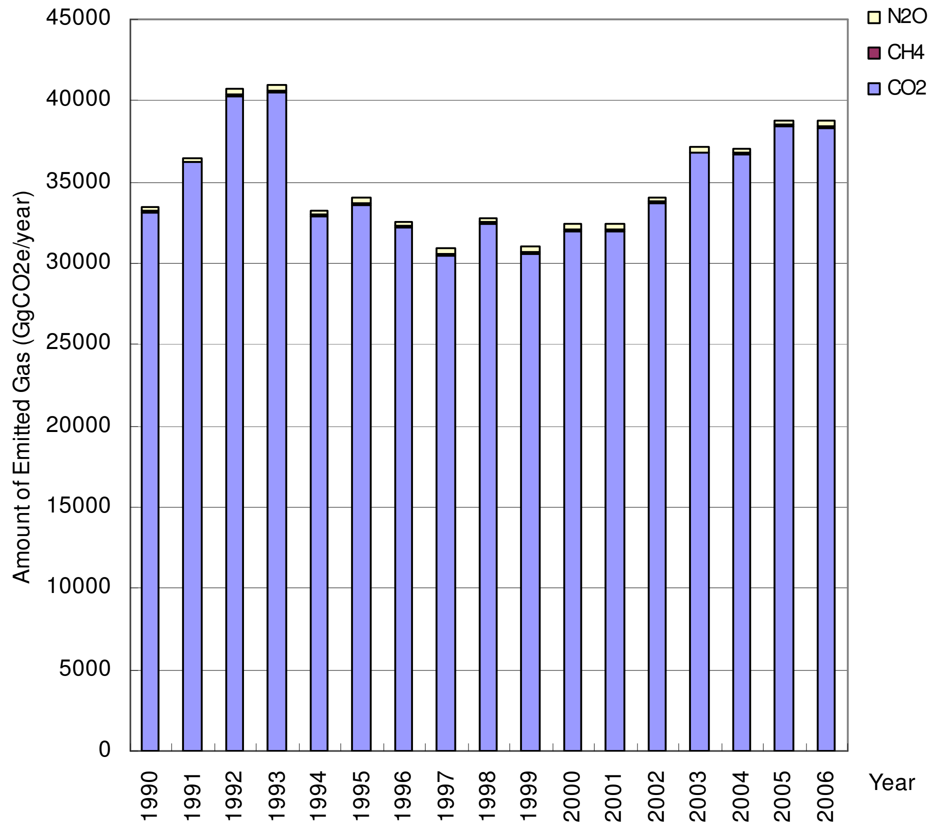
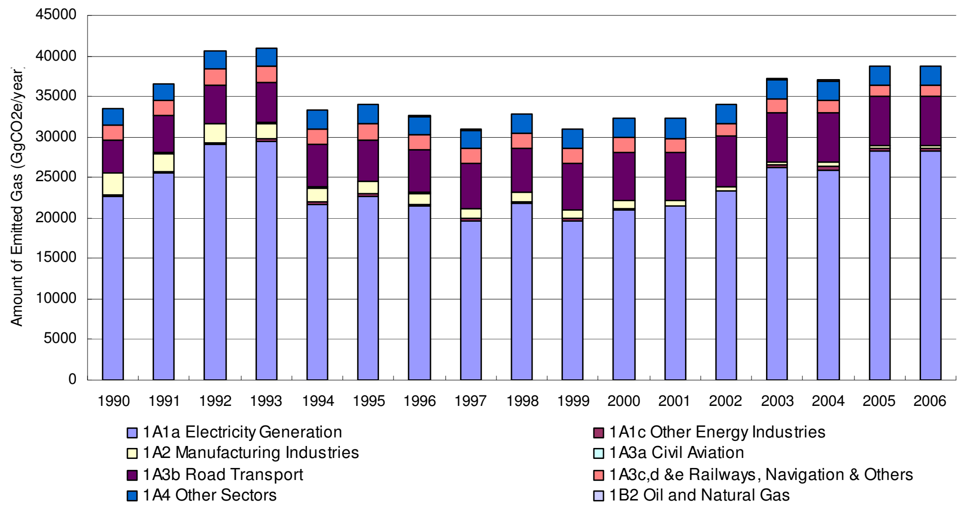


Figure 2.2 *GHG Emissions of the Energy Sector 1990-2006, by sub-sector*



2.2.2 *Fuel Combustion Activities (Sector 1A)*

The *Fuel Combustion Activities (1A)* sub-sector had the highest percentage contribution amongst other sub-sectors within the Energy sector, accounting for more than 99% of the total emissions of the Energy sector, as shown in *Table 2.2*. Combustion activities include both stationary and mobile combustion activities which represent almost all fuel combustion activities in HK.

The *Fuel Combustion* sub-sector consists of 4 divisions, specifically *Energy Industries (1A1), Manufacturing Industries and Construction (1A2), Transport (1A3), Other Sectors (1A4), and Non-Specified (1A5)* (1). The detailed summary of the amount of GHG emissions released from the Fuel Combustion categories is shown in *Table 2.2*.

The *Energy Industries* (1A1) division contributes the most GHG emissions in the Energy sector, accounting for more than 65% of the total GHG emissions released from the Energy sector. This is followed by *Transport (1A3)* which accounts for about 20%. The amount of GHG emissions from 1A2 and 1A4 divisions are significantly lower than other divisions and accounted for an average of about 3% and 7% of the total GHG emissions from the Energy sector respectively.

It is noted that despite being the largest contributor of GHG emissions in the Energy sector, the *Energy Industries* division (1A1a), has only a relatively slow annual GHG emission growth rate (roughly 1%) . *Fugitive emissions (1B)* on the other hand, has the highest AGR of almost 14%. It is followed by the *Other Energy Industries* division *(1A1c)* which had an average growth of about 4%. The overall annual growth rate of the Energy sector is relatively low compared to the annual growth rate in other sectors. Moreover, all divisions have a positive annual growth rate, except the *Manufacturing Industries and Construction* division *(1A2)* and the combined AGR of *Railways, Navigation and Others (1A3c, 1A3d and 1A3e)* which decreased annually at a rate of 12 % and 2% respectively.

This implies that even though the amount of fuel consumption in this sector has been increased, which aligns with the increase in population in Hong Kong and energy demand, the type of fuel that is being consumed in this division has changed from those with a relatively low thermal efficiency (eg coke and gas oil) to fuels with higher thermal efficiencies (eg natural gas and LPG). Natural gas was used for power generation in late 1995 and this slows down the increase in CO_2 emissions.

Energy Industries (1A1)

The majority of the emissions from *Fuel Combustion Activities* are associated with fuel combustion activities in power plants. The CO_2 emissions from

(1) In this study, division 1A5 (military aviation) is neglected as there is an insufficient data.

these plants have been estimated from the fuel consumed by each plant and the fuel carbon content, irrespective of the combustion technology or emissions control technology in place. The fuel carbon content for all of Energy sector fuels are specific to Hong Kong and not based on IPCC default values. These are derived from the calorific values of the different fuel types, ie, coal, oil and natural gas.

For all of the fuels, with the exception of those consumed to produce electricity, and those consumed for gas production, the most recent fuel properties data available for Hong Kong were used. These were mostly collected from a survey carried out in 2001 and the same value was used in 2005 as would have been used for other years.

In general, specific net calorific value (NCV) is used for the emission estimation. Should only specific gross calorific values (GCVs) for coal, heavy oil, industrial diesel oil and natural gas were available for the year 2005, they would be converted to NCVs according to *2006 IPCC Guidelines*.

Landfill gas (LFG) in HK is utilised for power generation and operating leachate treatment works (on-site use) and gas production. In addition to the three strategic landfills (SENT, NENT and WENT), LFG from five closed landfills (Shuen Wan, Jordan Valley, Tseung Kwan O Stage I/II/III, Gin Drinkers Bay and Pillar Point Valley) has also been utilised. LFG is considered in this sub-sector, under *Other Energy Indsutries (1A1c)*.

Under the *2006 IPCC Guidelines*, LFG is considered a type of biomass gas fuel (Volume 2, Table 1.1) and CO_2 emissions from the utilisation of LFG should be reported as an information item and not included in the inventory total. IPCC default NCV values and emission factors are used for the calculation of GHG emissions from LFG utilization for onsite electricity generation as no site-specific information is available. A site-specific CO_2 emission factor of gas production and default CH_4 and N_2O emission factors are used for LFG utilization for gas production. CH_4 and N_2O emitted from the utilisation of LFG to generate electricity has been included in the total inventory.

Table 2.1 Detailed GHG Emissions from the Energy Sector for 1990-2006

Year	Energy Sector GHG Emissions ($GgCO_2e$/year)									
	1A Fuel Combustion							1A Total	1B Fugitive Emissions	Total (1A & 1B) [(a) (b)]
	1A1 Energy Industries		1A2 Manufacturing Industries and Construction	1A3 Transport			1A4 Other Sectors		1B2 Oil and Natural Gas	
	1A1a Electricity Generation	1A1c Other Energy Industries[(b)]		1A3a Civil Aviation (Domestic)	1A3b Road Transport	1A3c,d&e Railways, Navigation (Domestics)& Others				
1990	22,688	181	2,632	26	4,050	1,865	1,974	33,417	9	33,427
1991	25,420	194	2,322	27	4,554	1,888	2,029	36,435	10	36,445
1992	29,008	236	2,274	25	4,736	2,107	2,219	40,605	11	40,616
1993	29,425	261	1,972	25	4,992	1,953	2,219	40,847	12	40,860
1994	21,660	279	1,790	25	5,260	1,988	2,231	33,233	13	33,246
1995	22,655	298	1,499	25	5,136	2,024	2,299	33,935	15	33,950
1996	21,456	311	1,353	37	5,237	1,892	2,266	32,552	57	32,609
1997	19,709	320	1,240	29	5,522	1,786	2,272	30,878	82	30,959
1998	21,815	316	1,036	23	5,508	1,900	2,214	32,812	78	32,889
1999	19,738	318	1,026	15	5,705	1,850	2,359	31,011	85	31,095
2000	20,970	238	958	18	5,985	1,797	2,416	32,382	79	32,461
2001	21,491	101	672	23	5,915	1,699	2,469	32,370	80	32,450
2002	23,369	80	397	22	6,231	1,634	2,326	34,058	77	34,135
2003	26,288	245	335	17	6,194	1,598	2,439	37,116	56	37,172
2004	26,027	358	594	22	6,130	1,489	2,395	37,015	73	37,088
2005	28,207	362	314	21	6,134	1,321	2,382	38,741	73	38,814
2006	28,201	337	315	22	6,129	1,327	2,343	38,673	73	38,747
AAGR[(c)]	1.4%	3.9%	-12.4%	-1.0%	2.6%	-2.1%	1.1%	0.9%	13.7%	0.9%

Notes:

(a) May not sum to total due to rounding.

(b) The total represents the total emissions in the Energy Sector excluding landfill gas' (LFG) CO_2 emissions, which is an information item according to the *2006 IPCC Guidelines*

(c) Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0}\right]^{\frac{1}{t}} - 1$ where t is the number of years in the study period

Table 2.2 Detailed Percentage Share of GHG Emissions from the Energy Sector, for 1990-2006

Year	Energy Sector GHG Emissions (% of Total)									
	1A Fuel Combustion							1A Total	1B Fugitive Emissions	Total (1A & 1B) (a) (b)
	1A1 Energy Industries		1A2 Manufacturing Industries and Construction	1A3 Transport			1A4 Other Sectors		1B2 Oil and Natural Gas	
	1A1a Electricity Generation	1A1c Other Energy Industries(b)		1A3a Civil Aviation	1A3b Road Transport	1A3c,d&e Railways, Navigation & Others				
1990	68%	0.5%	7.9%	0.1%	12%	6%	6%	99.97%	0.03%	100%
1991	70%	0.5%	6.4%	0.1%	12%	5%	6%	99.97%	0.03%	100%
1992	71%	0.6%	5.6%	0.1%	12%	5%	5%	99.97%	0.03%	100%
1993	72%	0.6%	4.8%	0.1%	12%	5%	5%	99.97%	0.03%	100%
1994	65%	0.8%	5.4%	0.1%	16%	6%	7%	99.96%	0.04%	100%
1995	67%	0.9%	4.4%	0.1%	15%	6%	7%	99.96%	0.04%	100%
1996	66%	1.0%	4.1%	0.1%	16%	6%	7%	99.82%	0.18%	100%
1997	64%	1.0%	4.0%	0.1%	18%	6%	7%	99.74%	0.26%	100%
1998	66%	1.0%	3.2%	0.1%	17%	6%	7%	99.76%	0.24%	100%
1999	63%	1.0%	3.3%	0.0%	18%	6%	8%	99.73%	0.27%	100%
2000	65%	0.7%	3.0%	0.1%	18%	6%	7%	99.76%	0.24%	100%
2001	66%	0.3%	2.1%	0.1%	18%	5%	8%	99.75%	0.25%	100%
2002	68%	0.2%	1.2%	0.1%	18%	5%	7%	99.78%	0.22%	100%
2003	71%	0.7%	0.9%	0.0%	17%	4%	7%	99.85%	0.15%	100%
2004	70%	1.0%	1.6%	0.1%	17%	4%	6%	99.80%	0.20%	100%
2005	73%	0.9%	0.8%	0.1%	16%	3%	6%	99.81%	0.19%	100%
2006	73%	0.9%	0.8%	0.1%	16%	3%	6%	99.81%	0.19%	100%
AVR(c)	68%	0.7%	3%	0.1%	16%	5%	7%	99.85%	0.2%	100%

Notes:

(a) May not sum to total due to rounding.

(b) The total represents the total emissions in the Energy Sector excluding landfill gas' (LFG) CO_2 emissions, which is an information item according to the 2006 IPCC Guidelines

(c) Average = average of 1990-2006

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Transport (1A3)

As the *Transport* division (1A3) contributes the second largest portion of GHG emissions in the Energy sector a closer look at the GHG emissions has been taken. *Tables 2.3* presents the detailed breakdown of GHG emitted from this sector during the period of 1990 to 2006.

Similar to the overall Energy sector, CO_2 has the largest quantity and percentage share of the GHG emissions in this sub-sector.

Within the *Transport* division (1A3), non-manufacturing fuel use has been added to the *Off-road* section (1A3eii), which originally included airport and terminal off-road fuel use. It is assumed that all 'non-manufacturing' fuel uses classified in the HK Energy End-Use Database (EEUDB) are off-road vehicle fuel usage, mainly by the construction industry and includes the mining and quarrying industries. This additional information provides a more comprehensive coverage of major off-road fuel use identified in Hong Kong.

Further breakdown of the *Transport* division is presented in *Tables 2.3* and *2.4*. All sub-sectors' GHG emissions have been reducing from 1990 to 2006, except *1A3b Road Transportation*, which has an average growth rate of about 2.6%. Due to its significant contribution in this division's GHG emissions, the overall emissions of the 1A3 *Transport* division have had an average growth rate of about 1.4%.

Table 2.3 Detailed Breakdown of GHG Emissions from the Transport Divisions (1A3), for 1990-2006

Year	GHG Emissions ($GgCO_2e$/year)					
	1A3 Transport Activities					
	1A3a Domestic Aviation	1A3b Road Transportation	1A3c Railways	1A3d Domestic Water-borne Navigation	1A3e Other Transport (Off-road)	Total [(a)]
1990	26	4,050	6	1,193	665	5,941
1991	27	4,554	6	1,207	675	6,469
1992	25	4,736	6	1,275	827	6,868
1993	25	4,992	5	1,122	826	6,970
1994	25	5,260	5	1,038	944	7,273
1995	25	5,136	5	1,012	1,006	7,184
1996	37	5,237	5	927	960	7,166
1997	29	5,522	4	771	1,011	7,337
1998	23	5,508	4	816	1,081	7,431
1999	15	5,705	4	838	1,008	7,570
2000	18	5,985	3	958	836	7,800
2001	23	5,915	3	824	871	7,637
2002	22	6,231	3	774	857	7,887
2003	17	6,194	4	883	711	7,810
2004	22	6,130	3	901	584	7,642
2005	21	6,134	3	772	547	7,476
2006	22	6,129	3	838	487	7,478
AGR[(b)]	-1.0%	2.6%	-5.0%	-2.2%	-1.9%	1.4%

Notes:

(a) May not sum to total due to rounding.

(b) Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0} \right]^{\frac{1}{t}} - 1$ by t is the study period

Table 2.4 Percentage Share of GHG Emissions from Each Sub-division of Transport Divisions (1A3), for 1990-2006

Year	% Share of GHG Emissions in 1A3 (%)					
	1A3 Transport Activities					
	1A3a Domestic Aviation	**1A3b Road Transportation**	**1A3c Railways**	**1A3d Domestic Water-borne Navigation**	**1A3e Other Transport (Off-road)**	**Total[(a)]**
1990	0.4%	68%	0.11%	20%	11%	100%
1991	0.4%	70%	0.09%	19%	10%	100%
1992	0.4%	69%	0.08%	19%	12%	100%
1993	0.4%	72%	0.08%	16%	12%	100%
1994	0.3%	72%	0.07%	14%	13%	100%
1995	0.3%	71%	0.07%	14%	14%	100%
1996	0.5%	73%	0.07%	13%	13%	100%
1997	0.4%	75%	0.05%	11%	14%	100%
1998	0.3%	74%	0.05%	11%	15%	100%
1999	0.2%	75%	0.05%	11%	13%	100%
2000	0.2%	77%	0.04%	12%	11%	100%
2001	0.3%	77%	0.04%	11%	11%	100%
2002	0.3%	79%	0.04%	10%	11%	100%
2003	0.2%	79%	0.05%	11%	9%	100%
2004	0.3%	80%	0.04%	12%	8%	100%
2005	0.3%	82%	0.04%	10%	7%	100%
2006	0.3%	82%	0.04%	11%	7%	100%
AVR [(b)]	0.3%	75.1%	0.1%	13.2%	11.2%	100%

Notes:
(a) May not sum to total due to rounding.
(b) Average from 1990-2006.

2.2.3 *Fugitive Emission (Sector 1B)*

The *Fugitive Emissions* sub-sector consists of 3 sources of emissions represented in the following divisions: *Fugitive emission from solid fuels (1B1), from oil and natural gas systems (1B2)*, and from *other energy production (1B3)* [(1)].

In this study, the GHG emissions within the *Fugitive Emissions* sub-sectors (1B1) has been excluded as there is no coal mining and handling in Hong Kong. Emissions for 1B2 – *Oil and Natural Gas Systems*, are estimated only for the distribution of gas produced. The GHG emissions released from the *Fugitive Emissions* sub-sector accounts for less than 0.1% of the total GHG emissions released from the Energy sector. An annual average growth rate of approximately 14% is observed, as shown in *Table 2.1*. The small share of the GHGs released from this division is mainly the result of the lack of natural resources (eg the lack of production of oil and gas) and mining industry in Hong Kong.

(1) In this study, division 1B1 and 1B3 are neglected as there is no such sector in HK.

2.3 IPPU

2.3.1 Introduction

The IPPU sector is the second smallest contributor to the total GHG emissions, after the AFOLU sector.

Emissions from the IPPU sector are mainly from sub-sectors other than 2F and 2G and from the use of substitutes for *Ozone Depleting Substances* (ODSs) (Sector 2F), as presented in *Tables 2.5 and 2.6*. Sub-sectors other than 2F and 2G contribute all CO_2 emissions in the IPPU sector, and the use of ODSs substitutes contributes all HFCs and PFCs in the HK inventory. The share by each GHG and by sub-sector in the IPPU sector is shown in *Figures 2.3* and *2.4.*

The sub-sectors from which GHG emissions occur in Hong Kong are: *2A - Mineral Industry; 2F - Product Uses as Substitutes for Ozone Depleting Substances;* and *2G - Other Product Manufacture and Use.*

Figure 2.3 ***GHG Emissions of the IPPU Sector 1990-2006, by GHG Gas***

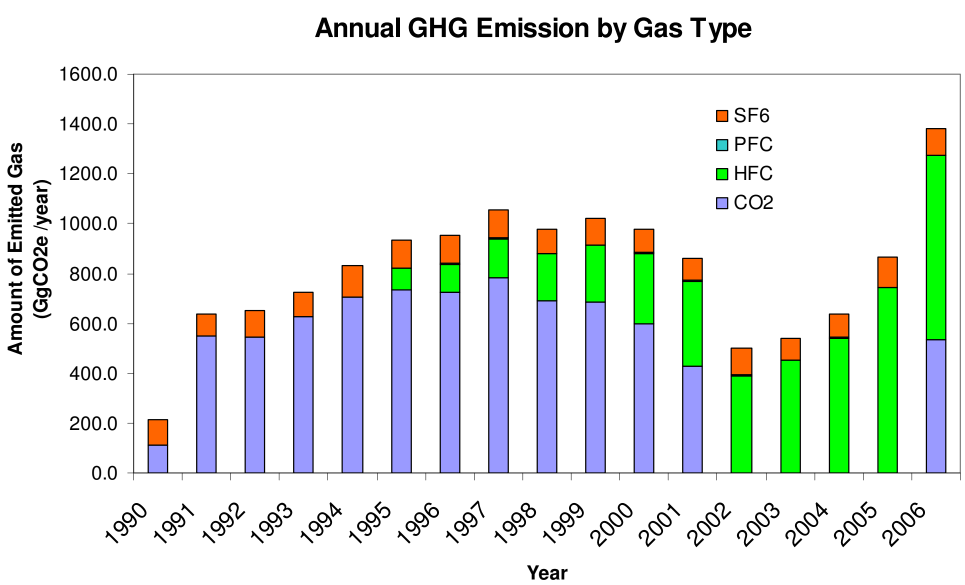

Figure 2.4 GHG Emissions of the IPPU Sector 1990-2006, by sub-sector

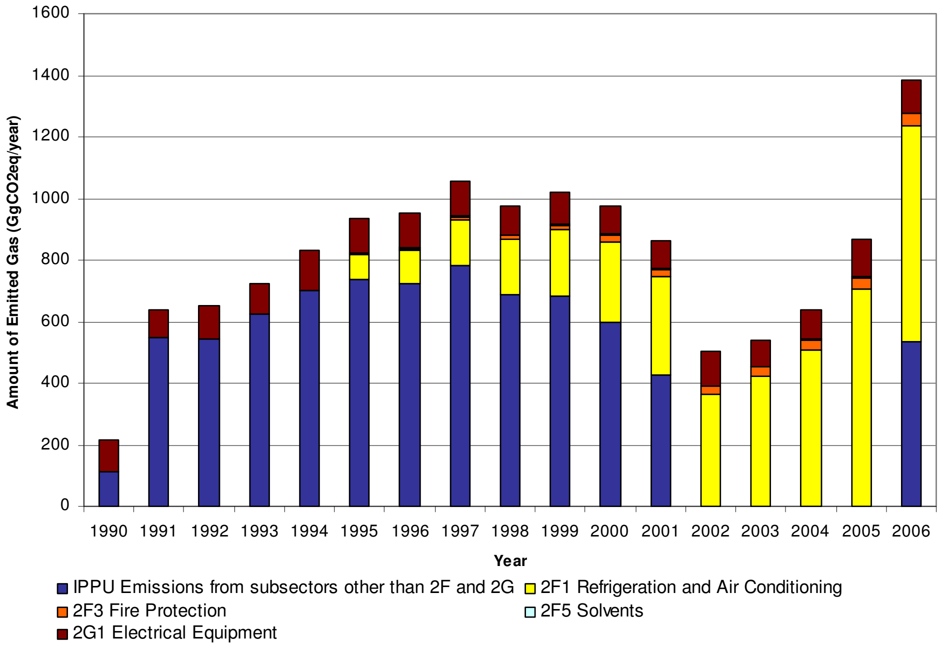

Table 2.5 GHG Emissions of the IPPU Sector from 1990-2006

Year	GHG Emissions ($GgCO_2e$/year)						
	2 IPPU						Total (a)
	2A Mineral Industry	2F Product Uses as Substitutes for ODS				2G Other Product Manufacture and Use	
		2F1 Refrigeration and Air Conditioning	2F3 Fire Protection	2F5 Solvents	2F Total	2G1 Electrical Equipment	
1990	113	0	0	0	0	102	215
1991	547	0	0	0	0	91	638
1992	544	0	0	0	0	108	651
1993	627	0	0	0	0	97	724
1994	703	0	0	0	0	127	830
1995	735	85	1	2	87	112	935
1996	724	109	4	2	115	112	952
1997	783	149	8	2	159	113	1055
1998	689	179	12	3	194	95	977
1999	685	213	15	3	230	106	1022
2000	599	261	22	4	287	91	977
2001	428	317	25	4	345	89	862
2002	0	362	28	2	392	112	503
2003	0	422	30	0.5	453	85	538
2004	0	508	33	2	543	93	636
2005	0	707	36	2	744	123	867
2006	535	701	38	0.2	739	108	1383
AGR(b)	10%	21%	44%	-19%	21%	0%	12%

Notes:

(a) May not sum to total due to rounding.

(b) Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0}\right]^{\frac{1}{t}} - 1$ by t is the study period

Table 2.6 Detailed Percentage Share of GHG Emissions of the IPPU Sector from 1990-2006

Year	% Share of GHG Emissions						
	2 IPPU						Total % [a]
	2A Mineral Industry	2F Product Uses as Substitutes for ODS				2G Other Product Manufacture and Use	
		2F1	2F3	2F5	2F Total	2G1	
		Refrigeration and Air Conditioning	Fire Protection	Solvents		Electrical Equipment	
1990	53%	0%	0%	0%	0%	47%	100%
1991	86%	0%	0%	0%	0%	14%	100%
1992	83%	0%	0%	0%	0%	17%	100%
1993	87%	0%	0%	0%	0%	13%	100%
1994	85%	0%	0%	0%	0%	15%	100%
1995	79%	9%	0%	0%	9%	12%	100%
1996	76%	11%	0%	0.2%	12%	12%	100%
1997	74%	14%	1%	0.2%	15%	11%	100%
1998	70%	18%	1%	0.3%	20%	10%	100%
1999	67%	21%	1%	0.3%	23%	10%	100%
2000	61%	27%	2%	0.4%	29%	9%	100%
2001	50%	37%	3%	0.4%	40%	10%	100%
2002	0%	72%	5%	0.3%	78%	22%	100%
2003	0%	78%	6%	0.1%	84%	16%	100%
2004	0%	80%	5%	0.3%	85%	15%	100%
2005	0%	82%	4%	0.2%	86%	14%	100%
2006	39%	51%	3%	0.01%	53%	8%	100%
AVR [b]	53%	29%	2%	0.2%	31%	15%	100%

Notes:
(a) May not sum to total due to rounding.
(b) Average from 1990 to 2006

2.3.2 *Mineral Industry (Sector 2A)*

Cement Production (Sector 2A1)

Cement production is the main contributor to HK's GHG inventory in the IPPU sector. There was a temporary halt in clinker production, a process that produced CO_2 in cement manufacture, between 2002 and 2005 even though cement production continued which explains the significant reduction of GHG emissions from 2002 to 2005

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2.3.3 *Product Used as Substitutes for Ozone Depleting Substances (Sector 2F)*

This sector contributes almost 30% of the total emissions in the IPPU sector, and is the sole emitter of HFCs and PFCs.

Refrigeration and Air Conditioning (Sector 2F1)

Sector 2F1 is further classified into *Refrigeration and Stationary Air Conditioning (2F1a)* and *Mobile Air Conditioning (2F1b)*. To simplify the calculation of the emissions, this is separated into a total of 6 sub-application domains or categories, which are (1):

1. Domestic (i.e., household) refrigeration;

2. Commercial refrigeration including different types of equipment, from vending machines to centralized refrigeration systems in supermarkets;

3. Industrial processes including chillers, cold storage, and industrial heat pumps used in the food, petrochemical and other industries;

4. Transport refrigeration including equipment and systems used in refrigerated trucks, containers, reefers, and wagons;

5. Stationary air conditioning including air-to-air systems, heat pumps, and chillers for building and residential applications; and

6. Mobile air-conditioning systems used in passenger cars, truck cabins, buses, and trains.

The first five RAC (Refrigeration and Air Conditioning) systems in the list above represent sub-sector 2F1a while the last RAC system in the represent sub-sector 2F1b. According to the *2006 IPCC Guidelines* (2), if the activity data available are disaggregated at the sub-application level (the 6 RAC areas), at least a Tier 2 approach could be used to calculate for the emissions. Using the data collected over past years for the previous inventories, some emissions

(1) 2006 IPCC Guidelines, Volume 3 IPPU, Chapter 7, page 7.43

(2) 2006 IPCC Guidelines, Volume 3 IPPU, Chapter 7, page 7.46, Figure 7.6: Decision tree for actual emissions from the refrigeration and air conditioning (RAC) application.

could be considered a Tier 2a (Emission factor) approach, while some emissions could be considered a Tier 3 approach.

For the Tier 2a approach for Refrigeration and Air Conditioning, the total emissions are the sum of four types of emissions [(1)], which are:

1. $E_{containers}$ = Emissions related to the management of refrigerant containers and transfers from large bulk containers down to smaller capacity containers and remaining refrigerants left in the containers
2. E_{charge} = Emissions related to the charging of new equipment during the connecting and disconnecting the refrigerant container to and from the equipment
3. $E_{lifetime}$ = Emissions from the banked refrigerants in existing systems during operation, accounting for average annual leakage and average annual emissions during servicing
4. $E_{end-of-life}$ = Emissions at system disposal

2.4 AFOLU

2.4.1 Introduction

According to *2006 IPCC Guidelines*, Agriculture, Forestry and Other Land Use sector comprises of three (3) main sub-sectors as follows:

- Livestock (3A);
- Land (3B); and
- Aggregate Sources and non-CO_2 Emissions Sources on Land (3C).

Unlike other sectors, the AFOLU sector overall contributes to carbon removal mainly due to the gain in carbon stock from sub-sector *3B1 Forestland*. GHG emissions of the AFOLU sector over the years broken down by gas and by sub-sector are shown in *Figures 2.5* and *2.6*. Detail GHG emissions by sub-sectors in the AFOLU sector are also presented in *Tables 2.7* and *2.8*.

Hong Kong has flooded land however its GHG emissions has not been calculated under Sub-sector 3B4 Wetland. This is because there is no guidance for the calculation of CO_2, CH_4 and N_2O emissions in the *2006 IPCC Guidelines*.

(1) 2006 IPCC Guidelines, Volume 3 IPPU, Chapter 7, page 7.49, Equation 7.10

Figure 2.5 *GHG Emissions of the AFOLU Sector 1990-2006, by GHG Gas*

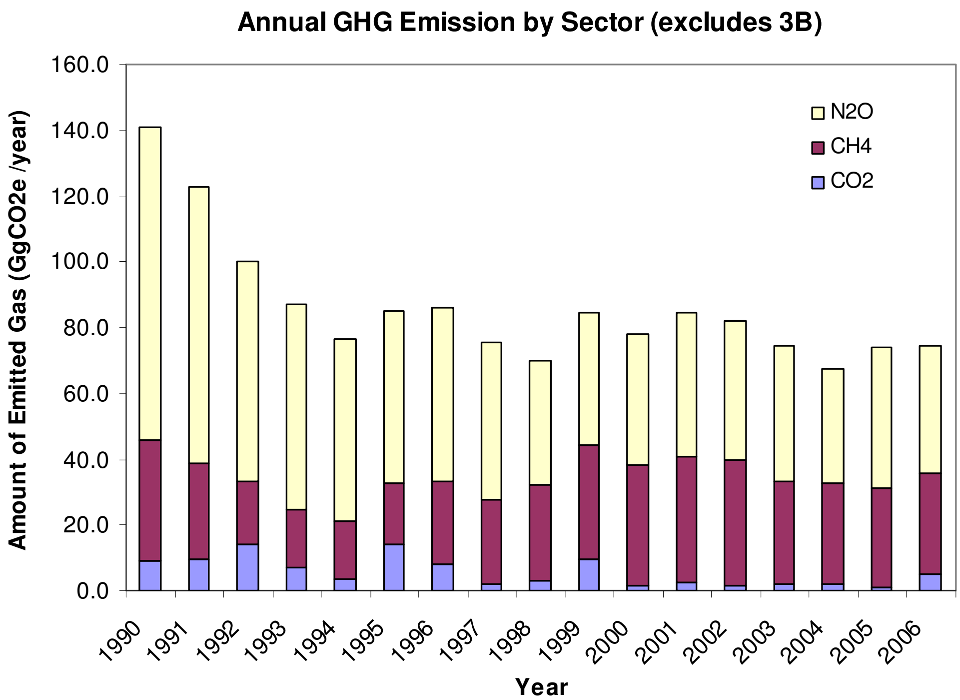


Figure 2.6 *GHG Emissions of the AFOLU Sector 1990-2006, by sub-sector*

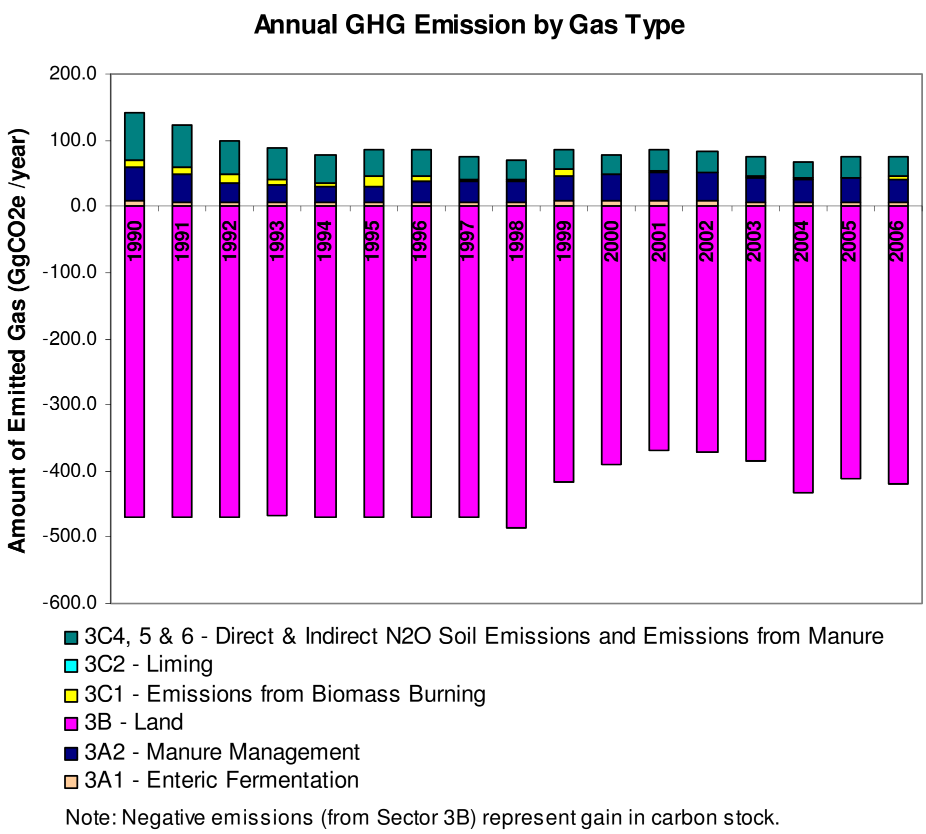


Table 2.7 Detailed GHG Emissions from AFOLU Sector from the year 1990-2006

Year	GHG Emissions ($GgCO_2e$/year)							
	3 AFOLU						Total(c)(d)	Total excludes 3B(c)
	3A		3B Land (d)	3C				
	3A1 Enteric Fermentation	3A2 Manure Management		3C1 Emissions from Biomass Burning	3C2 Liming	3C4 + 3C5 +3C6(a)		
1990	8.3	51.5	-468.9	9.7	0.03	71.3	-328.1	140.9
1991	7.2	41.9	-468.6	10.3	0.03	63.2	-346.0	122.6
1992	5.5	28.9	-468.6	14.9	0.03	50.8	-368.3	100.2
1993	5.1	26.8	-468.2	7.6	0.03	47.6	-381.1	87.2
1994	4.7	26.0	-468.8	3.5	0.02	42.4	-392.2	76.6
1995	5.0	25.5	-469.0	14.8	0.02	39.5	-384.1	84.9
1996	5.8	32.4	-469.1	8.6	0.02	39.3	-383.1	86.0
1997	6.1	32.1	-469.3	1.9	0.02	35.3	-393.9	75.4
1998	6.8	30.6	-486.5	3.2	0.01	29.5	-416.4	70.2
1999	8.0	37.0	-417.6	10.4	0.01	29.1	-333.1	84.5
2000	8.3	39.2	-389.0	1.8	0.01	28.6	-311.0	78.0
2001	8.8	41.7	-369.8	2.5	0.01	31.7	-285.1	84.7
2002	7.5	42.9	-371.4	1.5	0.01	30.2	-289.3	82.1
2003	6.3	36.6	-385.1	2.2	0.01	29.3	-310.8	74.3
2004	6.7	34.3	-431.8	2.3	0.01	24.1	-364.3	67.4
2005	6.5	36.6	-412.4	0.9	0.01	29.9	-338.6	73.9
2006	6.5	35.0	-418.3	5.4	0.01	27.5	-343.9	74.4
AGR (b)	-1%	-2%	-1%	-4%	-10%	-6%	0%	-4%

Notes:

(a) *3C4 Direct N_2O Emissions from Managed Soil; 3C5 Indirect N_2O Emissions from Managed Soil; 3C6 Indirect N_2O Emissions from Manure Management.*

(b) Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0}\right]^{\frac{1}{t}} - 1$ where t is the number of years in the study period.

(c) May not sum to total due to rounding.

(d) The negative AGR in Sector 3B represents decline in carbon removal over the study period.

Table 2.8 Detailed Percentage Share of GHG Emissions (Source) from the AFOLU Sector from Year 1990-2006

Year	% Share of GHG Emissions (%)						
	3 AFOLU [(a)]						% Total
	3A		3B Land [(b)]	3C			
	3A1 Enteric Fermentation	3A2 Manure Management		3C1 Emissions from Biomass Burning	3C2 Liming	3C4 + 3C5 +3C6 [(a)]	
1990	6%	37%	-	7%	0.02%	51%	100%
1991	6%	34%	-	8%	0.03%	52%	100%
1992	6%	29%	-	15%	0.03%	51%	100%
1993	6%	31%	-	9%	0.03%	55%	100%
1994	6%	34%	-	5%	0.03%	55%	100%
1995	6%	30%	-	17%	0.02%	47%	100%
1996	7%	38%	-	10%	0.02%	46%	100%
1997	8%	43%	-	3%	0.02%	47%	100%
1998	10%	44%	-	5%	0.02%	42%	100%
1999	9%	44%	-	12%	0.01%	34%	100%
2000	11%	50%	-	2.4%	0.01%	37%	100%
2001	10%	49%	-	3%	0.01%	37%	100%
2002	9%	52%	-	1.8%	0.01%	37%	100%
2003	8%	49%	-	3%	0.01%	39%	100%
2004	10%	51%	-	3%	0.01%	36%	100%
2005	9%	49%	-	1.2%	0.01%	41%	100%
2006	9%	47%	-	7%	0.01%	37%	100%
Avg	8%	42%	-	7%	0.02%	44%	100%

Note:

(a) 3C4 Direct N_2O Emissions from Managed Soil; 3C5 Indirect N_2O Emissions from Managed Soil; 3C6 indirect N_2O Emissions from Manure Management.

(b) *3B Land* has been excluded as there is no net emissions, instead, it is a net carbon sink.

In terms of the percentage share of GHG emissions from the AFOLU sector (excluding Sector 3B), division 3C has the highest share, accounting for an average of more than half of the AFOLU sector. N_2O is the most important GHG contributing to the GHG Inventory in the AFOLU sector using the *2006 IPCC Guidelines.*

As shown in *Figure 2.6, Division 3B (Landuse)* annually removes on average more than 400 $GgCO_2e$ which is way more than the GHG emissions from the entire AFOLU sector, therefore overall the AFOLU sector is a net carbon remover with negative GHG emissions. Division 3B is also the only net carbon remover in the inventory.

2.4.2 *Livestock (Sub-sector 3A)*

The Livestock sub-sector is further divided into *Enteric Fermentation* (division 3A1) *and Manure Management* (division 3A2).

Enteric Fermentation (Division 3A1)

The only GHG from this sector is methane (CH_4), occurring from the animals' enteric fermentation. The emissions are calculated as a product of the number of animals and the enteric fermentation emission factor for each type of animal.

Manure Management (Division 3A2)

The GHGs emitted from this division are methane (CH_4) and nitrous oxide (N_2O). The calculation method used for calculating the CH_4 emissions is the same as for *Enteric Fermentation*, emission factors were also updated in the same manner.

For N_2O emissions, there are two types of activities as identified by the *2006 IPCC Guidelines* under this sub-sector, the *Direct and Indirect N_2O Emissions from Manure Management*.

2.4.3 Land (Sub-sector 3B)

In the *2006 IPCC Guidelines*, the GHG emissions from land converted to other land is not included in the inventory due to the insufficient availability of data, and of the six land type categories, GHG emissions were only calculated from forest land, cropland and wetlands as these are the only land types present in Hong Kong.

2.5 WASTE

2.5.1 *Introduction*

According to *2006 IPCC Guidelines,* the GHG emissions from the Waste sector are separated into four (4) sub-sectors as follows:

- *Solid Waste Disposal Sites (4A);*
- *Biological Treatment of Solid Waste (4B);*
- *Incineration and Open Burning of Waste (4C)*; and
- *Wastewater Treatment and Discharge (4D).*

GHG emissions generated from the Waste sector include methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O). *Tables 2.9* and *2.10* present the total GHG emissions from the Waste sector in units of Gg CO_2e by gas and sub-sector.

Figures 2.7 and *2.8* summarise the overall GHG emissions from the waste sector. It should be noted that there is a significant decrease of almost 30% of GHG emissions from 1998 to 1999. This rapid decrease is mainly due a significant increase in CH_4 recovery in 1998-1999 which greatly reduced CH_4 emissions by recovering 34 Gg more CH_4 in 1999 when compared to 1998.

Following the significant decrease in emissions in 1999, there was considerable growth of emissions from 2001 to 2003, with the greatest percentage increase from 2001 to 2002. Although domestic waste quantities slightly reduced in 2002, many other waste types grew including commercial waste (+13.1%) and special waste (+38.4%) [1].

(1) Information from 2002 MSW Report.

Figure 2.7 *GHG Emissions of the Waste Sector 1990-2006, by GHG Gas*

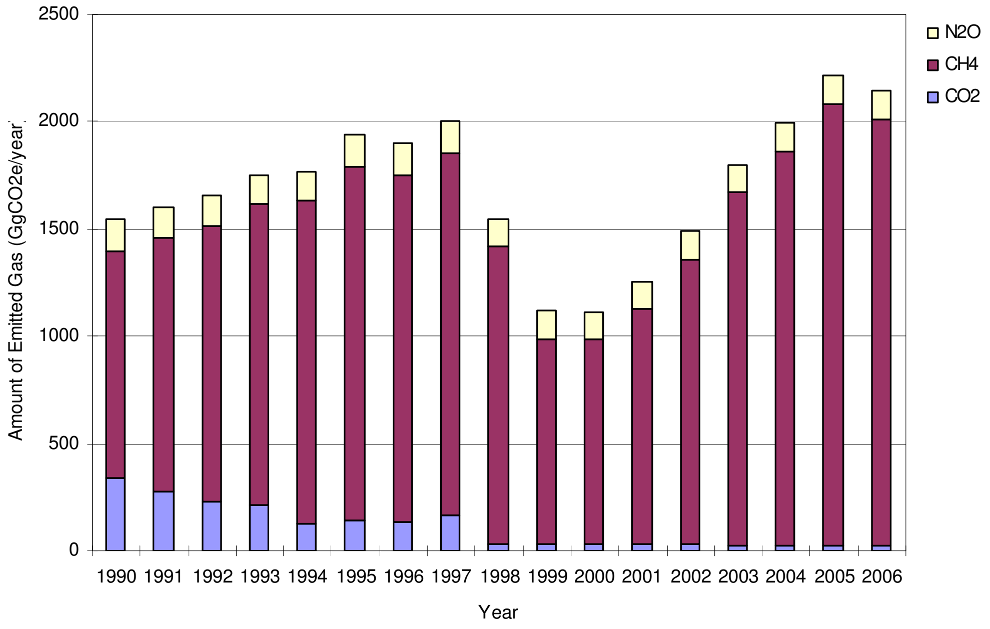
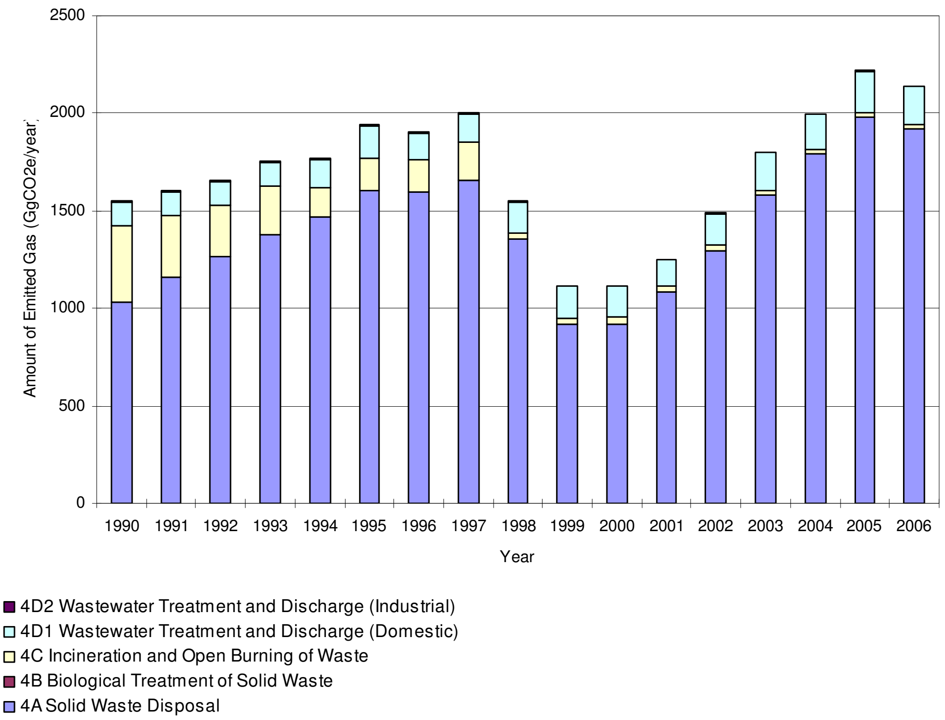


Figure 2.8 *GHG Emissions of the Waste Sector 1990-2006, by sub-sector*



Direct CO_2 emissions from the Waste sector came entirely from the waste incineration activities. Generally, the amount of CO_2 emissions from the incineration of waste are related to two (2) parameters i.e. quantity of waste incinerated and its composition. It can be observed from *Table 2.9* that CO_2 emissions from the Waste sector can be observed to have decreased at a rate of 17%. It should be noted that there were no MSW incineration in Hong Kong after 1997; since then the Chemical Waste Treatment Centre (CWTC) has been the major incineration facility in Hong Kong and incinerates certain types of chemical waste. Clinical waste from hospitals is also continually incinerated in Hong Kong. Emissions from the incineration of MSW have, therefore, only been included in the inventory from 1990 to 1997, while from 1993 emissions from the CWTC have been included in the inventory. There were no data available for the incineration of hospital waste, however, these emissions can be regarded as minor and thus have been excluded from the inventory.

Furthermore, the composition of this MSW in each year up to 1997 was not available; therefore it was assumed to be identical to the composition of MSW sent to landfills in the same year.

Table 2.9 Detailed GHG Emissions from the Waste Sector, from the Year 1990-2006

Year	GHG Emissions ($GgCO_2e$/year)						
	4 Waste						Total[a]
	4A Solid Waste Disposal	4B Biological Treatment of Solid Waste	4C Incineration and Open Burning of Waste	4D Wastewater Treatment and Discharge			
				4D1	4D2	4D Total [a]	
1990	1,034	0	388	119	7	126	1,548
1991	1,158	0	318	118	7	125	1,602
1992	1,266	0	266	118	7	125	1,656
1993	1,380	0	249	118	7	125	1,753
1994	1,469	0	149	144	7	151	1,769
1995	1,607	0	163	162	7	169	1,939
1996	1,600	0	160	135	7	142	1,902
1997	1,659	0	191	146	7	153	2,003
1998	1,352	0	32	162	2	164	1,548
1999	915	0	33	168	2	170	1,118
2000	922	0	34	156	2	158	1,114
2001	1,085	0	29	138	2	140	1,254
2002	1,297	0	29	160	2	161	1,488
2003	1,580	0	27	192	1	194	1,801
2004	1,791	0	26	177	1	178	1,995
2005	1,980	0	26	211	1	213	2,218
2006	1,921	0	21	200	1	200	2,142
AGR [b]	4%	0%	-17%	3%	-15%	3%	2%

Notes:

(a) May not sum to total due to rounding.

(b) Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0}\right]^{\frac{1}{t}} - 1$ where t is the number of years in the study period

Table 2.10 Detailed Percentage Share of GHG Emissions from the Waste Sector from the Year 1990-2006

Year	% Share of GHG Emissions						
	4 Waste						Total
	4A Solid Waste Disposal	4B Biological Treatment of Solid Waste	4C Incineration and Open Burning of Waste	4D Wastewater Treatment and Discharge (a)			
				4D1	4D2	4D Total	
1990	67%	0%	25%	8%	0%	8%	100%
1991	72%	0%	20%	7%	0%	8%	100%
1992	76%	0%	16%	7%	0%	8%	100%
1993	79%	0%	14%	7%	0%	7%	100%
1994	83%	0%	8%	8%	0%	9%	100%
1995	83%	0%	8%	8%	0%	9%	100%
1996	84%	0%	8%	7%	0%	7%	100%
1997	83%	0%	10%	7%	0%	8%	100%
1998	87%	0%	2%	10%	0%	11%	100%
1999	82%	0%	3%	15%	0%	15%	100%
2000	83%	0%	3%	14%	0%	14%	100%
2001	87%	0%	2%	11%	0%	11%	100%
2002	87%	0%	2%	11%	0%	11%	100%
2003	88%	0%	1%	11%	0%	11%	100%
2004	90%	0%	1%	9%	0%	9%	100%
2005	89%	0%	1%	10%	0%	10%	100%
2006	90%	0%	1%	9%	0%	9%	100%
Average	83%	0%	7%	9%	0%	10%	100%

Note:
(a) 4D1 Domestic Wastewater; 4D2 Industrial Wastewater.

Tables 2.10 and *Figure 2.8* indicate that *4A Solid Waste Disposal* is the main contributor of GHGs within the Waste sector, accounting for more than 80% of total emissions of the Waste sector each year. Other divisions under the Waste sector such as *4D Wastewater Treatment and Discharge* and *4C Incineration and Open Burning of Waste*, are the second and third largest GHG emitters, with an average contribution of 10% and 7% to this sector's GHG emissions, respectively.

Emissions from all divisions within the Waste sector except for *4C Incineration and Open Burning of Waste* have grown over the inventory period. This correlates with the increasing waste quantity generated during the same period of time as a result of population growth. In contrast, emissions from *4C Incineration and Open Burning of Waste* declined rapidly from 1990 to 2006, with a sudden reduction of more than 80% of emissions in 1997-1998. The decline is due to the closure of MSW incinerators in Hong Kong. The last MSW incinerator was closed in 1997 and since 1998, only clinical waste from hospitals and chemical waste are incinerated in Hong Kong.

2.5.2 *Waste Mapping*

A number of emission factors and calculation parameters of the Waste sector are waste type-specific in accordance with the *2006 IPCC Guidelines*. It is therefore essential to match the EPD's waste classification with the IPCC's waste categorization to determine appropriate parameters to be applied in each waste type, especially when Hong Kong-specific parameters are not available. Information collected from the Municipal Solid Waste (MSW) Monitoring Reports and from the EPD has been used in the waste categorization matching based on the nature of each waste type, as shown in *Table 2.11*.

Table 2.11 Waste Mapping of EPD and IPCC's Waste Categorization

EPD's Waste Categorization	IPCC's Waste Categorization
Municipal Solid Waste (MSW)	
Bulky waste	Inert waste
Glass	Inert waste
Metals	Inert waste
Paper	Paper
Plastics	Inert waste
Putrescibles	Food waste
Textiles	Textiles
Wood/ Rattan	Wood and straw
Household Hazardous Wastes (HHW)	Inert waste
Others	Inert waste
Landfill Construction Waste	
Inert portion	Inert waste
Non-inert portion	10% of non-inert portion is classified as Garden waste
Special Waste	
Abattoir waste	Food waste
Animal carcasses and kernel waste	Food waste
Chemical waste other than asbestos waste	Inert waste
Dewatering sewage sludge	Sewage sludge
Dewatered dredged materials	Inert waste
Dewatered waterworks sludge	Inert waste
Grease trap waste	Food waste
Livestock waste	Food waste
Sewage works screening	Inert waste
Asbestos waste	Inert waste
Clinical waste	Clinical waste
Condemned goods	Inert waste
Waste tyres	Inert waste
Incinerator ash	Inert waste
CWTC Stabilised residue	Inert waste
Excremental	Food waste
Pulverized rejects	Inert waste

2.5.3 Solid Waste Disposal (Sector 4A)

GHG generated from solid waste disposal sites (SWDS) is the largest source of GHG emissions in the Waste sector, on average accounting for more than 80% over the 17 year period. CH_4 is the only GHG gas emitted from this sub-sector.

The First Order Decay (FOD) method adopted in this sub-sector following the *2006 IPCC Guidelines* is based on the assumption that CH_4 generation potential of waste disposed in a certain year will decrease gradually throughout the following decades. The FOD model is built on an exponential factor that describes the fraction of degradable material which is degraded into CH_4 and CO_2 each year. A key input of the model is the amount of degradable organic matter (DOC_m) in waste disposed into SWDS. This is estimated based on information on disposal of different waste categories (municipal solid waste (MSW), sludge, industrial and other waste) and the different waste types/material (food, paper, wood, textiles, etc.) included in these categories, or alternatively as mean DOC in bulk waste disposed.

The FOD method requires solid waste disposal data (amounts and composition) to be collected by default for 50 years from the first year of disposal at each site. Data in HK only dated back to 1970 and only one landfill (Gin Drinkers Bay Landfill) is known to operate in the 1970s. Emissions from SWDS are therefore calculated from 1970 using the FOD method. The earliest MSW information available is from the *1986 MSW Monitoring Report*, data prior to 1986 are obtained from the *GHG Study* 2000 which is extrapolated from data since 1986.

Construction and demolition (C&D) waste data for landfills has been revised and adopted in this inventory. The revised C&D waste data has taken into account the surge of inert C&D material being disposed to landfills due to the temporary closure of public filling facilities during 1990-1995.

A detailed breakdown of CH_4 contribution of each waste type in the 4A *Solid Waste Disposal* division is presented in *Table 2.12*. Food and Paper waste are the largest contributors to CH_4 emissions in this division, accounting for more than half of the division's total GHG emissions. These two types of waste defined by IPCC's waste categorisation include paper, putriscibles, abattoir waste, animal carcasses and kernel waste, grease trap waste, livestock waste and excremental waste under EPD's categorisation.

Table 2.12 Detail Breakdown of CH_4 Emissions by Waste Types Disposed in Solid Waste Disposal Sites for the Year 1990-2006

Year	CH_4 Emission (Gg)									
	SWDS Waste (4A)							Total SWDS Waste Emissions[a]	Methane Recovered	Net Methane Emissions[b]
	Food	Garden	Paper	Wood	Textile	Sludge	Clinical			
1990	19.5	1.4	22.4	3.8	5.5	2.0	0.0	54.7	0.0	49.3
1991	23.1	1.7	24.2	4.0	6.0	2.2	0.1	61.3	0.0	55.2
1992	25.4	1.9	26.0	4.3	6.6	2.7	0.1	67.0	0.0	60.3
1993	27.7	2.1	28.3	4.6	7.2	3.0	0.1	73.0	0.0	65.7
1994	27.8	2.3	32.1	5.0	7.6	2.8	0.1	77.7	0.0	70.0
1995	30.2	2.5	35.5	5.4	8.0	3.4	0.2	85.0	0.0	76.5
1996	31.2	2.6	38.2	5.9	8.0	2.9	0.1	89.0	4.3	76.2
1997	32.7	2.8	41.2	6.5	8.2	3.0	0.1	94.5	6.7	79.0
1998	34.4	2.9	45.1	7.0	8.3	3.5	0.1	101.2	29.7	64.4
1999	39.6	2.9	49.9	7.3	8.2	4.4	0.1	112.4	64.0	43.6
2000	46.6	3.1	54.4	7.6	8.2	4.9	0.1	125.0	76.3	43.9
2001	51.3	3.2	59.0	8.1	8.3	5.3	0.1	135.3	77.9	51.7
2002	57.8	3.2	62.6	8.3	8.3	6.3	0.1	146.6	78.0	61.8
2003	61.4	3.1	66.1	8.6	8.2	9.5	0.1	157.0	73.4	75.3
2004	64.3	3.1	69.4	8.9	8.2	11.9	0.1	165.9	71.2	85.3
2005	65.9	3.1	72.6	9.2	8.1	13.7	0.1	172.7	68.0	94.3
2006	67.2	3.1	75.6	9.5	8.1	15.2	0.1	178.9	77.3	91.5

Notes:

(a) May not sum to total due to rounding.

(b) Net Methane Emissions = (Total SWDS Waste Emissions – Methane Recovered) x (1-Methane Oxidisation Factor)

2.5.4 Biological Treatment of Solid Waste (Sector 4B)

4B Biological Treatment of Solid Waste mainly comprises two types of treatment - composting and the anaerobic digestion at biogas facilities. Hong Kong's GHG emissions in this sector only come from composting. Since HK's major source of composting is from manure composting at pig farms, which has already been accounted in the *AFOLU Livestock* (3A), no emissions has been estimated and reported under *4B Biological Treatment of Solid Waste*.

2.5.5 Incineration and Open Burning of Waste (Sector 4C)

The GHG emissions from *4C Incineration and Open Burning of Waste* are the third largest emission source in the Waste sector. Emissions from this source gradually decreased over the period due to the drop in the quantity of waste incinerated. As discussed previously no municipal solid waste had been incinerated from 1998 onwards. Incineration of MSW has only been included in the inventory from 1990 to 1997 and from 1998 onwards this division included emissions from chemical waste incineration in Hong Kong, which is of a much smaller quantity. Although clinical waste continues to be incinerated in HK (since 1998), the emissions have not been incorporated due to the lack of both default and Hong Kong-specific emission factors.

2.5.6 Wastewater Treatment and Discharge (Sector 4D)

GHG emissions from the *4D Wastewater Treatment and Discharge* sub-sector are the second largest emission source in the Waste sector. This sector includes two categories - *Domestic Wastewater Treatment and Discharge (4D1)* and *Industrial Wastewater Treatment and Discharge (4D2)*. GHG emissions from this sub-sector include only CH_4 and N_2O. CH_4 was emitted from both domestic and industrial treatment while N_2O only emitted from only domestic wastewater treatment.

As shown in *Table 2.9*, the GHG emissions in the *Wastewater Treatment and Discharge* sub-sector mostly come from *Domestic Wastewater* (4D1), which contribute more than 80% of emissions for the sub-sector on average. From *Tables 2.13* and *2.14*, it can also be concluded that the N_2O emissions dominate GHG emissions in sub-sector *4D Wastewater Treatment and Discharge*, comprising roughly 80% of total GHG emissions in this sub-sector from 1990 to 2006.

Table 2.13 GHG Emissions in 4D Wastewater Treatment and Discharge, by Gas from 1990 to 2006

Year	GHG Emissions ($GgCO_2e$/year)		Total
	CH_4	N_2O	
1990	21	105	126
1991	20	106	126
1992	16	109	125
1993	16	109	125
1994	32	119	151
1995	43	126	169
1996	14	128	142
1997	25	128	153
1998	37	127	164
1999	36	133	170
2000	33	125	158
2001	12	127	140
2002	30	131	161
2003	62	132	194
2004	45	133	178
2005	78	134	213
2006	68	133	200
AGR (b)	8%	2%	3%

Notes:

(a) May not sum to total due to rounding.

(b) Average Annual Growth Rate is calculated as $AGR = \left[\frac{value_t}{value_0}\right]^{\frac{1}{t}} - 1$ where t is the number of years in the study period.

Table 2.14 Percentage Share of GHG Emissions, in 4D Wastewater Treatment and Discharge sub-sector, by Gas from 1990 to 2006

Year	% Share		Total
	CH_4	N_2O	
1990	17	83	100
1991	16	84	100
1992	13	87	100
1993	13	87	100
1994	21	79	100
1995	25	75	100
1996	10	90	100
1997	16.	84	100
1998	23	77	100
1999	21	79	100
2000	21	79	100
2001	9	91	100
2002	19	81	100
2003	32	68	100
2004	25	75	100
2005	37	63	100
2006	34	66	100
Average	22	78	100

2.6 KEY CATEGORY ANALYSIS AND RECOMMENDATIONS

2.6.1 Key Category Analysis

Key Category Analysis (KCA) has been carried out to identify influential GHG emission sources. This allows better allocation of resources on the identified key categories for the reduction of the uncertainty in the inventory in a cost-effective manner.

KCA is carried out using the Approach 1 Level Assessment methodology stated in the *2006 IPCC Guidelines*. Key categories are identified for 2005 data using a pre-determined cumulative emissions threshold. Key categories are those that, when summed together in descending order of magnitude, add up to 95 percent of the total emissions. Key categories are identified in *Table 2.15*.

Table 2.15 Key Category Analysis (KCA)

IPCC Category Code	IPCC Category[(a)]	Greenhouse Gas	2005 Estimate ($GgCO_2eq$)	Level Assessment	Cumulative Total of Level Assessment
1A1	**Energy Industries**	**CO2**	**28,423.43**	**0.68**	**0.68**
1A3	**Transport**	**CO2**	**7,267.08**	**0.17**	**0.86**
1A4	**Energy - Other sectors**	**CO2**	**2,373.79**	**0.06**	**0.92**
4A	**Solid Waste Disposal**	**CH4**	**1,979.63**	**0.05**	**0.96**
2F	Consumption of halocarbons and sulphur hexafluoride	HFCs	742.38	0.02	0.98
3B	Land	CO2	-412.45	-0.01	0.97
1A2	Manufacturing industries and construction	CO2	313.22	0.01	0.98
1A3	Transport	N2O	178.96	0.00	0.98
1A1	Energy Industries	N2O	140.27	0.00	0.99
4D	Wastewater Treatment and Discharge	N2O	134.12	0.00	0.99
2F	Consumption of halocarbons and sulphur hexafluoride	SF6	122.75	0.00	0.99
4D	Wastewater Treatment and Discharge	CH4	78.41	0.00	0.99
1B2	Oil and natural gas	CH4	72.93	0.00	1.00
3A	Livestock	CH4	30.54	0.00	1.00
1A3	Transport	CH4	30.12	0.00	1.00
3C	Aggregate Sources and Non-CO2 Emissions Sources on Land	N2O	29.98	0.00	1.00
4C	Incineration and Open Burning of Waste	CO2	25.50	0.00	1.00
3A	Livestock	N2O	12.49	0.00	1.00
1A4	Energy - Other sectors	CH4	5.84	0.00	1.00
1A1	Energy Industries	CH4	5.37	0.00	1.00
1A4	Energy - Other sectors	N2O	2.25	0.00	1.00
2F	Consumption of halocarbons and sulphur hexafluoride	PFCs	1.93	0.00	1.00
3C	Aggregate Sources and Non-CO2 Emissions Sources on Land	CO2	0.84	0.00	1.00
1A2	Manufacturing industries and construction	N2O	0.66	0.00	1.00
1B2	Oil and natural gas	CO2	0.08	0.00	1.00
1A2	Manufacturing industries and construction	CH4	0.07	0.00	1.00
3C	Aggregate Sources and Non-CO2 Emissions Sources on Land	CH4	0.03	0.00	1.00
		Total	**41,560**	**1.00**	**-**

Note:
(a) Key categories are in bold.

2.6.2 *Recommendations*

This section provides recommendations on approaches to increase the accuracy level of the GHG inventory and reduce the degree of uncertainty. The recommendations are established based on the key categories identified in the KCA in order to maximise cost-effectiveness of effort spent to reduce uncertainty. The recommendations are also supplemented with the observations made during the compilation of the GHG inventory.

General Recommendations

Any changes in data collection and documentation should be documented in the data management system which is maintained by the currently designated team in the EPD and communicated to all relevant parties.

The following recommendations are also made for key categories which have significant contribution to the overall emissions inventory.

Energy – 1A1 Energy Industries, 1A3 Transport and 1A4 Others

Most of the approaches employed in this sector are Tier 2, which require a significant quantity of site-specific data. In contrast, a Tier 1 approach (i.e. using default values provided in the *2006 IPCC Guidelines)* has been employed in some divisions (eg for water-borne navigation and fugitive emissions) due to the lack of Hong Kong-specific data. To improve the accuracy of the GHG inventory, the *2006 IPCC Guidelines* suggest that site-specific data should be used wherever possible, ie Tier 2 should be adopted for this sector.

The uncertainty analysis of the Energy sector indicates that the combined percentage uncertainty varies with the type of GHG emission and the source of emission factor adopted. While the emission factor uncertainties fluctuated depending on availability of site-specific data, activity data uncertainties were consistently very low. This is most likely to be the result of a very well-managed data collection system within the Energy sector, in particular those of the power companies. In addition, most of the activity data were gathered from surveys, which is a more reliable and accurate data source when compared to extrapolated data. This well-managed data collection methodology and system should therefore be maintained, especially for major GHG contributors such as sector 1A1a (Main Activity Electricity and Heat Production). To further improve accuracy, a dynamic annual data collection system is recommended. Data should also be collected in a format which can be easily applied to other categories to enhance data consistency and to reduce errors arising from data conversion activity, such as unit conversion.

General recommendations for 1A1, 1A3 and 1A4 in Energy sector:

- Obtain fuel properties data, including density, NCV and carbon content for different fuel types on an annual basis for all fuel types consumed in Hong Kong.

Specific Recommendations for sub-categories in 1A3 Transport:

1A3a Civil Aviation

The Tier 3A methodology is proposed for future estimation of international aviation emissions following the decision made in the *2006 IPCC Guidelines* and given the availability of flight schedules from CAD.

In the Tier 2 method currently adopted calculates emissions generated during the Landing/Take-Off (LTO) cycle and cruise phases of flight. This methodology therefore utilizes information of aircraft total fuel consumption and the number of LTO cycles by aircraft type.

The proposed Tier 3A method is a more detailed approach based on actual flight movement data. It takes into account the LTO cycle and cruise emissions for different flight distances. Details on the origin (departure) and destination (arrival) airports and aircraft type are needed to use in Tier 3A.

For HK's inventory, this Tier 3A will require:

- Flight schedule by aircraft type (for the number of flight and aircraft type to each destination);
- Flight distance or destination of each flight schedule;
- Emission factors for cruising and LTO (referenced from CORINAIR Guidebook which is updated annually [1]).

Figure 2.9 is extracted from the *2006 IPCC Guidelines* and indicates data requirements for each tier.

Figure 2.9 ***Data Requirements for Different Tiers of Civil Aviation***

TABLE 3.6.2
DATA REQUIREMENTS FOR DIFFERENT TIERS

Data, both Domestic and International	Tier 1	Tier 2	Tier 3A	Tier 3B
Aviation gasoline consumption	X			
Jet Fuel consumption	X	X		
Total LTO				
LTO by aircraft type		X		
Origin and Destination (OD) by aircraft type			X	
Full flight movements with aircraft and engine data				X

1A3b Road Transportation

As fuel-use efficiency technology improves over time (ie less fuel is consumed per km driven), fuel consumption per km (litre per km) should be regularly (annually) updated in order to reflect true vehicle emissions.

(1) EMEP/CORINAIR Emission Inventory Guidebook - 2007, prepared by the UNECE/EMEP Task Force on Emissions Inventories and Projections.

1A3d Water-borne Navigation

The following should be considered:

- segregating marine energy-use data from its "Marine and Others" category in the Energy End-Use Database;

- providing energy use data for marine vessels that carry passengers; and

- documenting major vessel types included in "Marine and Others" and identifying gaps in other marine vessels fuel use.

The inventory compiler is recommended to obtain NRT data by destination through vessel movement information. At the moment this information is available at the Marine Department.

1A3e Other Transportation

It is recommended that energy data for the construction industry should be separated from the Non-manufacturing sector in the Energy End-Use Database, and that these data are to be included in the Off-road emissions calculation.

IPPU

No key categories have been identified in the IPPU sector, however the *Electronic Industry* (sub-sector 2E) may potentially be an emission source in HK. It is a new category in the *2006 IPCC Guidelines* and its potential contribution in GHG emissions remains unknown. Investigation into the significance of this sector is recommended, to explore data availability and to determine the Tier level to be selected. For inventory compilation, 'process type' (p) and 'gases' (i) used in this industry should be surveyed.

AFOLU

No key categories have been identified in the AFOLU sector and removals from this sector are minor compared to the overall total for Hong Kong thus the balance between time investment and significance of improvement to the overall inventory should be carefully considered.

Waste - 4A Solid Waste Disposal

The categorisation of the MSW that is disposed to landfill is different to that specified by the *2006 IPCC Guidelines*. It is understood that the existing categorization system has been in place for a long period of time and therefore it is practical to continue using this system. To ensure that conversion from EPD to IPCC's categorisation is appropriate, it is recommended that the conversion method should be clearly documented and made known to all relevant staff.

The *2006 IPCC Guidelines* categories are:

- Food Waste;
- Garden and Park Waste;
- Paper;
- Wood and Straw;
- Textiles;
- Nappies;
- Sewage Sludge;
- Clinical Waste; and
- Inert Waste.

To upgrade from the current Tier 2 method to a Tier 3 method, the key parameters i.e. half-life time ($t_{1/2}$), degradable organic carbon (DOC) for each waste type, fraction of DOC that can be decomposed (DOC_f) and methane generation potential (L_o) are required. Such data are difficult to collect or calculate. However, results from uncertainty analysis suggest that, due to their significant contribution towards the total uncertainty in the inventory, an upgrade of the Tier level should be considered if more data are available.

2.7 *OVERALL CONCLUSIONS*

This study presents the updated GHG inventory for HK from the year 1990 to 2006. The calculations of the GHG inventory are carried out in accordance with the *2006 IPCC Guidelines* as far as possible.

The results show that the quantity of GHG emissions estimated following *2006 IPCC Guidelines* is lower than that estimated following the *Revised 1996 IPCC Guidelines.* The Waste sector is the main reason of this drop in emissions. The Energy sector continues to be the main contributor of GHG emissions in HK accounting for more than 90% on average, followed by the Waste sector.

In terms of GHG composition of the overall inventory, CO_2 is by far the dominant gas, with an average proportion of more than 90%. CH_4 and N_2O contribute significantly less for less than 10% in total, while the remaining gases have just less than a 1% contribution each.

The annual growth rate of the total HK GHG emissions over the 17 year period is about 1%. Prior to 1993, the total GHG emissions in HK were gradually increasing at a stable annual rate and declined dramatically in 1994 largely due to the drop in the Energy sector emissions, as discussed in *Section 2.2*. After 1994, the total GHG emissions continued on an upward trend, increasing by approximately 1% annually. The IPPU sector has the highest average annual rate of increase, while the Energy and Waste sectors also grow, but at a much slower rate. AFOLU is the only carbon removing sector where the GHG emission figures are negative.

Appendix B

Mitigation Assessment

CONTENTS

1 PROPOSED POLICIES AND MEASURES

1.1 CRITERIA FOR SELECTION OF POLICIES AND MEASURES

If Hong Kong were to adopt a mitigation objective for GHG, it would be setting out to contribute to the international response to climate change and to achieving the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC). There are four distinct mechanisms by which Hong Kong might establish a mitigation objective:

- establishing an emission reduction target, which could take several forms, as discussed below;
- introducing certain specific policies and measures;
- specifying levels of performance for the emission intensity or the energy intensity of the economy as a whole or certain individual sectoral components; or
- introducing a system of economic instruments, such as carbon taxes, to provide incentives for the adoption of mitigation measures.

Key criteria for the selection of the policies and measures to be analysed were as follows:

- **Technical feasibility -** measures in the mitigation scenarios are based on international technology and policy reviews. Detailed feasibility studies for individual measures are required at a later stage, taking into account their limitations, uncertainties and practicability if proposed for adoption within Hong Kong's local context.

- **No- or low-cost measures** – measures that will limit the total and per metric ton cost of emission control in Hong Kong to below some accepted threshold. The emphasis of these approaches is to minimise costs associated with the achievement of some level of emission reduction.

- **Maximising co-benefits** - measures that provide collateral benefits by simultaneously reducing emissions of other air pollutants or achieving environmental benefits in other media. For example, a measure that reduces coal use for electricity generation would also reduce emissions of sulphur dioxide.

- **Suitable for research, development, and demonstration (RD&D)** – measures that might be suitable for investment in research, development and demonstration, but are not presently at the stage of widespread commercial application in Hong Kong. Promising medium- to long-term technologies such as some forms of renewable energy or electric vehicles are examples of such measures.

Classification of the different measures into these four categories can assist decision-making by providing a context of likely effects and implementation requirements. There are several other attributes of policies and measures that need to be borne in mind when assessing their desirability for inclusion in a climate-change response strategy.

- **The distribution of burdens and benefits across the various segments of society**. All other things being equal, a desirable response strategy might strive to distribute the burdens of cost and implementation, as well as the environmental and collateral benefits, as evenly as possible across affected individuals and strata of society. This may ease the concerns of parties who are required to take abatement measures, by demonstrating that they are not being "singled out" by Government for action. Thus, it may facilitate the success of the programme.

- **Other effects of the policies and measures, including the secondary environmental and wider socio-economic effects**. Some measures may be successful at reducing GHG emissions from one sector by shifting the burden to another sector. For example, introduction of electric vehicles reduces emissions from the combustion of petrol in vehicles but may increase emissions from the combustion of fossil fuels in power stations. Socio-economic issues might arise when the burden of cost falls inequitably on the poorer segments of society or causes unemployment to rise.

- **Ease of implementation**. Measures can seem to have attractive cost-effectiveness attributes but may be difficult to implement, monitor, and/or enforce. Related issues include questions of whether measures can be introduced under existing legislation and what pressures might result from forces outside Hong Kong.

1.2 ASSESSMENT OF MITIGATION MEASURES

An assessment of the economic, social and environmental implications of these measures has been undertaken. Further explanation of the methodology and quantitative output are provided in *Sections 2 and 3.* This section discussed the proposed mitigation measures qualitatively by sector. It provides discussions of the opportunities and potentials for GHG mitigation, as well as institutional/social barriers that have to be removed for their effective implementation. The impacts of some mitigation policies and options are not readily quantifiable. This is particularly true in the aviation and marine sectors. Other measures such as RD&D and general supportive programs have an intangible impact on their sector.

1.2.1 Buildings and Appliances

End-use efficiency improvement to reduce the electricity generation output, which is applied on the demand-side, is among the most cost-effective of GHG emission control measures. The proportional contribution of various sources of GHG emissions in Hong Kong shows the potential significance of end use efficiency, particularly in electrical end uses.

Efficiency improvements in the end-uses have the potential to reduce peak loads, thereby reducing generation plant capacity requirements. This would bring economic benefits in addition to those associated with electrical energy and fuel savings, further off-setting the cost of investment in the more efficient equipment and thereby reducing the GHG emission reduction cost.

Many current technologies allow building energy consumption to be reduced through better thermal envelopes, improved design methods and building operations, more efficient equipment, and reductions in demand for energy services. Emerging areas for energy savings in commercial buildings include the application of controls and information technology to continuously monitor, diagnose and communicate faults in commercial buildings ("intelligent control"), and systems approaches to reduce the need for ventilation, cooling and dehumidification. Advanced windows, passive solar design, techniques for eliminating leaks in buildings and dusts, energy efficient appliances, and controlling standby and idle power consumption as well as solid-state lighting are also important in both residential and commercial sectors. Occupant behavior, including avoiding unnecessary operation of equipment and adaptive rather than invariant temperature standards for cooling, is also a significant factor in limiting building energy use[1].

Air conditioning and lighting are the most significant end-uses in Hong Kong. There are a range of technical options available for reducing the energy required to provide air conditioning services. These include using more efficient components (such as chillers) in central systems, more efficient packaged and room units, expanding the use of district cooling/water-cooled air conditioning system, and reducing the heat load on air conditioning plant by, for example, reducing the internal and external heat loads in buildings.

In order to promote the use of more energy efficient air-conditioning systems in Hong Kong, a pilot scheme for the use of fresh water for non-domestic air-conditioning in selected areas commenced in June 2000. In view of the support from the property owners and the environmental benefits, the Government decided to keep promoting the scheme in 2008 [2].

Lighting is a major end use. A survey of 80 studies show that efficient lighting technologies are among the most promising GHG-abatement measures in buildings in almost all countries, in terms of both cost-effectiveness and potential savings. There are many well known options to improve lighting efficiency available in the market, ranging from simple substitution of luminaries to the re-design of lighting systems. Lighting design, particularly commercial lighting design, is a complex and specialised field in its own right. Capturing efficiencies (and often simultaneous cost and employee productivity benefits) through better design is very building-specific.

Energy standards specifically aimed at appliances and equipment are widespread. Canada, Korea, Japan, the EU, the US and Singapore have all promoted such policies. Hong Kong's Voluntary Energy Efficiency Labelling Scheme (EELS), introduced in 1995, has been amended several times (most recently on 17 April 2008) and now covers 18 types of household and office appliances, including 10 types of electrical appliances (refrigerators, washing machines, compact fluorescent lamps, dehumidifiers, electric clothes dryers, room coolers, electric storage water heaters, television sets, electric rice-cookers and electronic ballasts, hot / cold bottled water dispensers), 7 types of office equipment (photocopiers, fax machines, multifunction devices, laser printers, LCD monitors, computers), domestic gas instantaneous water heaters. The *Energy Efficiency (Labelling of Products) Ordinance* of 9 May 2008 provides for a Mandatory Energy Efficiency Labelling Scheme (EELS) which currently covers room air conditioners, refrigerating appliances, and Compact Fluorescent Lamps (CFL).

Multiple obstacles exist and make it difficult to adopt more efficient technologies and realize the energy efficiency improvement potential in Hong Kong as rapidly as desired. These barriers include:

- availability of technology;
- higher costs of getting reliable information on energy efficient technology;
- limitations inherent in building designs;
- mixture of building ownership;
- allocation of costs and benefits associated with capital expenditure, i.e., the owners bear the cost while the tenants get the benefit;
- cash flow constraints of some Small and Medium-sized Enterprises (SMEs) in relation to the initial investment cost; and
- lack of an appropriate portfolio of policies and programs.

The following measures may be considered by the Government to overcome these constraints:

- implement a mandatory scheme that sets energy efficiency targets for different types of buildings under the Building Energy Codes;
- use guidelines, training workshops and public campaigns to enhance the understanding of the stakeholders on the importance of building energy efficiency improvement and the mandatory scheme;
- financial support in the form of an environment fund, tax incentives and a loan funding scheme from power companies which could be used to encourage the enhancement of energy efficiency in buildings;

- implement the mandatory scheme in phases, with the priority focused on new buildings and the common areas of the buildings where the building owners/property managers have control of, and then extend the coverage to the tenant area in the long run.

- expand the scope and tighten the energy efficiency standards gradually

Consumer behaviour is not modelled or quantified in *Section 3,* as it is difficult to accurately predict its effect on energy consumption or carbon emissions in advance. However, consumer behavior, including avoiding unnecessary operation of equipment and adaptive rather than invariant temperature standards for cooling, is also a significant factor in limiting building energy use[3]. Information and education are important to promote climate-friendly consumer behaviour and thus help reduce energy demand.

1.2.2 Road Transportation

Transport is distinguished from other energy-using sectors by its predominant reliance on a single fossil resource and by the infeasibility of capturing carbon emissions from transport vehicles. It is also important to view GHG-emission reduction in conjunction with local air pollution, traffic management and energy security. Solutions therefore have to take into consideration of transportation problems as a whole, not just GHG emissions[4].

Mitigation measures includes vehicle efficiency improvement, alternate vehicle and fuel types (hybrid petrol-electric vehicles and petrol to bio-fuel blended petrol), as well as other policy options.

Vehicle Efficiency Improvement

Improved vehicle efficiency measures, leading to fuel savings, in many cases have net benefits, but the market potential is much lower than the economic potential due to the influence of other consumer considerations, such as performance. A major risk to the potential for future reductions in CO_2 emissions from the use of fuel economy technologies is that they can be used to increase vehicle power and size rather than to improve the overall fuel economy and cut carbon emissions. The preference of consumers for power and size has consumed much of the potential for GHG mitigation reduction achieved over the past two decades[5].

Alternative Vehicle and Fuel Types

Various forms of vehicle fuel switching measures are potentially feasible in Hong Kong, and include the following.

- *Diesel to LPG:* The Hong Kong SAR Government has already committed to changing taxis from diesel to LPG, principally as a measure to improve urban air quality. That measure and its associated policy instrument are included here to show the effect of the measure on GHG emissions. LPG could also be used for other small- to medium-sized diesel vehicles.

- *Bio-Fuel Mixtures*: The introduction of bio-fuels by mixing with traditional petro-fuels is a way of reducing net GHG emissions. Bio-fuels are considered GHG emission neutral, since the emission of CO_2 from the consumption of the fuels has already been off-set by the absorption of atmospheric CO_2 during the growth of the source crops. The GHG emission reduction possible is therefore a direct function of the proportion of fuel that can be substituted with bio-fuel. It is possible to mix a small proportion of bio-fuel such as methanol or ethanol with existing petrol, or biodiesel with diesel, without any change to existing engines[6]. The introduction of biofuel such as adding ethanol to petrol could be more readily effected. No additional infrastructure or change to vehicle engines is required if, for example, all petrol is required to include a 10% bio-ethanol. Hence, it is assumed that biofuel can be introduced but some form of government support or regulation would be needed to encourage or require its use. Specifically, biodiesel produced from waste cooking oil should be considered.

- *Electricity Vehicles:* Electricity produced from any primary energy source, with the exception of coal, is likely to offer significant CO_2 savings compared with petrol and diesel. Electric-powered cars could become increasingly prevalent in the future – for example, plug-in hybrids, running partly on electricity, could be commercial in a few years' time.

- *Hydrogen Vehicles:* Hydrogen produced from low-carbon sources can offer large carbon savings compared with petrol and diesel. In the short term, the scope to reduce the carbon intensity of the fuel mix through hydrogen is limited by the lack of availability and high cost of low-carbon hydrogen (except in special cases such as from intermittent electricity generation at times of day when there is no other use for that power) along with the lack of available vehicles and supply infrastructure.

- There may also be scope for future innovative *future fuel developments* to contribute to CO_2 reductions from fuels.

<u>Policy Instruments</u>

A range of transport-focused policy instruments with potential for controlling GHG emissions were considered and include the following:

- *Road Pricing*: a road pricing is usually used to overcome local traffic congestion problems, to create a revenue stream for highway infrastructure investment projects or to implement a 'user-pays' or 'cost-reflective pricing' philosophy. The technology now exists to allow road pricing to be administered automatically and hence it is often called electronic road pricing (ERP). Road pricing schemes may be expected to have some impact on GHG emissions, but the relationships are not straight-forward and are specific to particular schemes, geographical locations, local economic and transport sector conditions. Furthermore, the results could potentially be either positive or negative, since some effects (such as reduction of engine idling during congestion) will tend to reduce GHG emissions, but others (such as increased driving distances to by-pass critical areas) will tend to increase GHG emissions.

From the transport perspective, feasibilities studies conducted previously conclude that the case for introducing road pricing in Hong Kong is considered weak[7]. From overseas experience, a road pricing scheme that aims to relieve traffic congestion can only be implemented equitably and effectively in the presence of alternative routes with adequate capacity for motorists to by-pass the charging zone. In the case of Hong Kong, such an alternative route is the Central-Wanchai Bypass (CWB) which will not be in place before 2017. While the case for road pricing implementation in Hong Kong as a measure to combat GHG emissions has yet to be established, there is a possibility that the measure could remain under consideration in the long term.

- *Replacement of Goods Vehicles*: the main target vehicle groups for replacement are old, inefficient vehicles and heavy goods vehicles. It is a practice which has been implemented in Hong Kong as well as in many other jurisdictions. The HKSAR Government from 1 April 2007 to 31 March 2010 offered a time-limited one-off grant to vehicle owners to replace their pre-Euro and Euro I diesel commercial vehicles with Euro IV compliant vehicles[8]. Internationally, the State of California has several programs intended to phase out polluting or inefficient vehicles such as incentives for voluntary retirement of high emitting passenger cars and light- and medium-duty trucks as well as incentives to retrofit old polluting school buses[9]. While Canada has committed CA$92 million over four years beginning in 2009 to create incentives for Canadians to trade in vehicles made in 1995 or earlier which do not meet today’s emission standards for newer, more efficient vehicles[10].

- Emission reduction from *off-road vehicles and equipment:* electrification of vehicles and equipment operated at the airport and the ports has the potential to reduce GHG emissions from these sources. The electrification of port yard equipment is currently being considered by other jurisdictions and could be feasible for consideration in Hong Kong. The California Air Resources Board, California Climate Action Registry, and South Coast Air Quality Management District are considering the development of a protocol for the electrification of truck stops which would establish a standard methodology in determining greenhouse gas emission reduction from the use of electric power as opposed to a diesel-powered engine on a truck for idling purposes[11]. As a port initiative, the Port of Long Beach is considering “Green-Container” Transport Systems which will involve broadening the use of electrification (from “green energy” sources) in port-related sources[12]. The Port of Long Beach had also previously requested proposals for electrification of rubber tired gantry cranes[13]. Another case is the Port of Seattle, Port of Tacoma, and Vancouver Port Authority who published the Northwest Ports Clean Air Strategy in 2007 which considers the electrification of lift equipment as an efficiency improvement[14].

- Implementation of the Hong Kong "*Importers' Average Fleet Efficiency*" *Standard.* This Study examined a standard whereby the average imported vehicle efficiency should be 20% higher than the 2005 market average efficiency by 2015. This is an alternative to introducing an environmental tax on high emitting vehicles and its implementation cost would be relatively low.

- Given the positive effects of higher population densities on *public transport use, walking, cycling* and CO_2 emissions, further improved integrated spatial planning is an important policy element in the transportation sector.

- *Vehicle Information and Driver Education Programmes*: driving style affects fuel consumption and emissions. Information about opportunities to reduce vehicle fuel consumption could cover the vehicles themselves and driving style and habits. Vehicle energy labelling and driver education programmes should be considered.

Measures such as vehicle efficiency improvement, alternative vehicle and fuel types are quantified and analysed under *Section 3*.

1.2.3 Marine Transportation

At present, no comprehensive international requirements exist to address CO_2 emissions from ocean-going ships. Under the Kyoto Protocol, there are no national GHG emission caps for the aviation and marine sectors as they cannot be fully controlled by one jurisdiction. Sectoral targets and the participation of multinational corporations are crucial to curb the carbon emissions in these two sectors.

Shipping

Shipping is more efficient per tonne of $CO_{2\text{-}e}$ per km than air or road transport; however, recent research has found that total CO_2 emissions from ocean going ships are double those from aviation, and will continue to increase in line with the projected growth of trade. The 2020 emissions from shipping are expected to be 75% higher than at present due to increased trade volumes[15].

The *Second IMO GHG Study 2009*[16] provides technological, operational, and policy options for emissions reduction. These measures may not be implemented unless coordinated policies are established to support their adoption. An overall assessment of the potential of these options to achieve a reduction in CO_2 emissions is shown in *Figure 1.1*.

Figure 1.1 *Assessment of Potential Reductions of CO_2 Emissions from Shipping by using Known Technology and Practices*

DESIGN (New ships)	Saving of CO_2/tonne-mile	Combined	Combined
Concept, speed and capability	2% to 50%+	10% to 50%+	25% to 75%+
Hull and superstructure	2% to 20%		
Power and propulsion systems	5% to 15%		
Low-carbon fuels	5% to 15%*		
Renewable energy	1% to 10%		
Exhaust gas CO_2 reduction	0%		
OPERATION (All ships)			
Fleet management, logistics and incentives	5% to 50%+	10% to 50%+	
Voyage optimization	1% to 10%		
Energy management	1% to 10%		

Source: IMO, *Second IMO GHG Study 2009*
Note: + Reductions at this level would require reductions of operational speed.
* CO_2 equivalent, based on the use of LNG.

In addition to the *Environmental Shipping Index*, Mitigation options proposed in this Study include:

- *Better routing and timing for ships*

According to the *IPCC Fourth Assessment Report*, the short-term potential for operational measures to reduce emissions ranged from 1-40%.

- *Environmental Tax on Shipping*

An environmental tax on shipping has been implemented by various ports through initiatives such as incentives or differentiated dues and could possibly be considered for application in Hong Kong.

Ports

Shoreside power has the potential to reduce the carbon emissions; however, although some ports have begun to install the necessary infrastructure power, and large ships are being built to accommodate it, there is no international standard regulating the voltage or physical design of this technology. The US and some countries provide power at 60Hz, while Europe and many other countries provide 50 Hz. Also, there is no global standard for a connector that would easily handle 6,600 volts on a container ship and 11,000 for a cruise ship. In practical terms, the switch to 6,600 volts from the standard 440 volts generated by a container ship is a significant change that requires a converter, a cable management system, and a synchroniser to enable a smooth power transfer from dock to ship[17].

In HK, there is a proposal for development of an onshore support power supply at the cruise terminal at Kai Tak. The HK Tourism Commission has included the provision of on-shore support power supply to cruise vessels during berthing as a condition in the development of the cruise terminal[18]. Similar to the EVs, the use of shore power can contribute to carbon emission abatement only if the electricity generation in Hong Kong is from less carbon intensive sources such as nuclear and RE.

The HKSAR Government may seek to lead a process of deliberation including the relevant departments and private sector stakeholders. Regional collaboration should also be explored. In view of cross-ownership and cross-management between the terminal operators in Hong Kong and Shenzhen, there are opportunities to extend the deliberation process to not only the terminals in each city but to the ports in the region as a whole.

If any of the proposed potential mitigation measures for the marine sector is to be further explored for implementation in the future, its feasibility applicability and cost-effectiveness have to be considered in further detail, having regard to, amongst other things, the international nature of the industry and the socio-economic context of Hong Kong. Consultation of the stakeholder groups should also be conducted.

1.2.4 Aviation

The fuel efficiency of civil aviation can be improved by a variety of means, including technology and operational measures.

Technology

Technology development might offer a 20% improvement in fuel efficiency over 1997 levels by 2015, with a 40-50% improvement likely by 2050[19]. As civil aviation continues to grow at around 5% each year, such improvements are unlikely to keep carbon emissions from global air travel from increasing. The introduction of biofuels could mitigate some of aviation's carbon emissions, if biofuels can be developed to meet the demanding specifications of the aviation industry. Both the costs of such fuels and the emissions from their production process are uncertain at this time[20].

Operational Measures

Energy use by aircraft operations can be optimized by minimizing taxiing time, flying at optimal cruise altitudes, flying minimum-distance great-circle routes, and minimizing holding and stacking around airports. From a global perspective, the GHG-reduction potential of such strategies has been estimated at 6-12%[21].

As Hong Kong is an aircraft and fuel importer, the proposed mitigation measures are more focused on the operation and management side within the boundaries of the HKSAR only.

- Energy efficiency improvement of ground support equipment.

Hong Kong Airport Services Limited (HAS)[22] has taken to improve the energy efficiency and reduce carbon emissions of ground support equipment.

- Emission trading scheme for aviation sector.

A trading scheme for the aviation sector would have the potential to reduce emissions. The geographical scope (routes and operators covered), the amount of allowances to be allocated to the aviation sector and the coverage of non-CO_2 climate impacts will be key design elements in determining the effectiveness of any emission trading scheme. Emission charges or trading should lead to an increase in fuel costs that can be expected to have a positive impact on engine efficiency[23].

As not all airlines have the necessary data or tracking methodologies in place, there are costs associated with carbon measurement, reporting and verification under a trading scheme. Hong Kong should closely follow international developments in the sector and is not in the position to implement an emission trading scheme for the aviation sector on its own.

- Rationalization of flight paths.

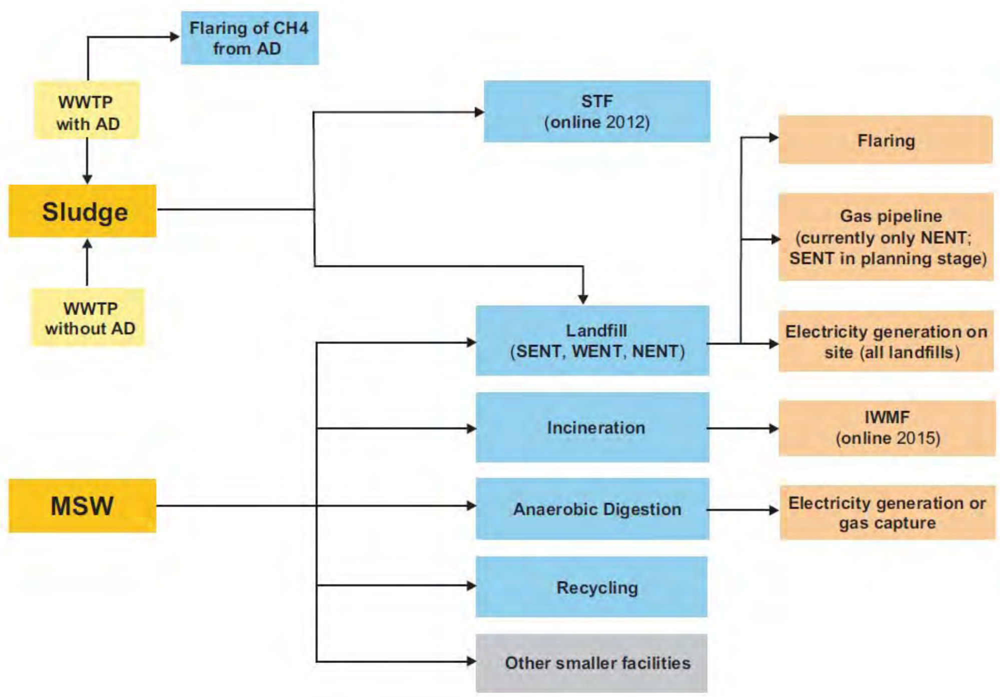
Available data were not sufficient to estimate the potential emission reductions available from the rationalization of flight paths in Hong Kong. Flight path designation is a complex process involving various considerations, most notably aviation safety.

It should be noted that the overall climate impact of aviation is considered to be much greater than the impact of CO_2 emissions alone. As well as emitting CO_2, aircraft contribute to climate change through the emission of NO_x, which is particularly effective in forming the GHG ozone when emitted at cruise altitudes. These effects are estimated to be about two to four times greater than those of aviation's CO_2 alone, even without considering the potential impact of cirrus cloud enhancement which some consider to be a contributing factor. The environmental effectiveness of future mitigation policies for aviation will depend on the extent to which these non-CO_2 effects are also addressed[24].

1.2.5 Waste

Figure 1.2 summarises the waste and wastewater management strategy in Hong Kong. Waste management is relevant from a climate change mitigation perspective as the anaerobic decomposition of organic material at landfill sites leads to the emission of methane (CH_4). A reduction in the amount of waste landfilled will reduce emissions.

Figure 1.2　　*Waste and Wastewater Management in Hong Kong*



The most relevant climate change mitigation measure in the waste sector in Hong Kong is the recovery and utilisation of landfill gas in operating and closed/restored landfills. The recovered landfill gas, which essentially consists of CO_2 and CH_4, can then either be utilised as an alternative energy source on-site or off-site, or flared as an alternative way of reducing emissions. At present, all three strategic landfills have been utilising landfill gas for energy production and/or for Towngas production[25]. It is proposed that the landfill recovery rate would become higher, and there will be full utilisation of the landfill gas in the alternative mitigation scenarios.

With landfills expected to be exhausted earlier than first envisaged, the Government promulgated a policy framework in late 2005 with a view to manage Hong Kong's municipal solid waste in a sustainable manner. One element of the framework is the development of Integrated Waste Management Facilities (IWMF) that would adopt advanced incineration as the core waste treatment technology. The advanced technology, which is much cleaner than that of the incinerators previously operated in Hong Kong, involves high temperature combustion and allows for considerable power generation while reducing pressure on landfill sites substantially. The first phase of the IWMF would have a capacity of 3,000 metric tons per day and is planned to be commissioned by 2015[26].

At present, all dewatered sewage sludge generated by sewage treatment works is disposed of at landfills in Hong Kong. This practice of sludge disposal at landfill is not considered sustainable from both environmental and technical perspectives. In 2009, the Director of Environmental Protection (DEP), with the support of the Secretary for the Environment, proposed to design and construct the Sludge Treatment Facilities (STF). The capacity of the currently planned STF is 2,000 tonnes per day. Depending on the actual sewage sludge arisings in future, future upgrading of the STF capacity or even a new STF may be required[27].

EPD is also planning to develop large scale Organic Waste Treatment Facilities (OWTF) to recycle organic waste from institutions, commercial and industrial establishments. Operation of the OWTF would reduce disposal of organic waste to landfills and produce useful products including compost and renewable energy. The first phase of OWTF would for 200 metric tonnes per day capacity and is planned to be commissioned by the mid 2010's. The second phase is of a similar capacity and its commissioning is anticipated in late 2010's.

Mitigation measures in the waste sector are quantified and analysed under *Section 3*. In addition to GHG mitigation, improved sanitation and waste management provide a wide range of public health and environmental co-benefits.

1.2.6 Energy Supply

Hong Kong has a reasonably diverse energy supply resource mix. Electricity is generated locally from coal and natural gas and a substantial quantity of nuclear electricity is imported from Guangdong. Reticulated consumer gas supplies use town gas manufactured from naphtha and natural gas.

Increasing the import of nuclear generated electricity from Mainland China, using more natural gas to generate electricity locally, and increasing the share of renewable energy would help Hong Kong to reduce carbon emissions. However, the potential for adverse effects in the long term, such as reduction in the overall energy supply security and reliability in Hong Kong, would need to be carefully considered before completely abandoning coal-fired electricity generation and converting the reticulated supply network to natural gas.

- Natural Gas

In August 2008, a Memorandum of Understanding (MOU) was signed between the HKSAR Government and the Central Government for the supply of nuclear electricity and natural gas to Hong Kong in the coming two decades. The MOU opens the opportunity to draw natural gas from three sources: first, from new gas fields planned to be developed in the South China Sea; second, from the second east-west gas pipeline bringing gas from Turkmenistan; and third, from a Liquefied Natural Gas (LNG) terminal to be located in the Mainland.

If all of the gas supply to Hong Kong were to pass through a single point somewhere in the network, it would be possible for a single catastrophic event to interrupt supply and hence to disrupt electricity generation. If, as could be the case in Hong Kong, an increased proportion of future electricity generation was reliant on the same gas supply as the gas network supplying consumers, the provision of the two major energy forms to end users could then be simultaneously affected.

- Nuclear

If Hong Kong is to expand its electricity import capacity from the Mainland and within the SAR itself, it needs not only to enhance the existing Nuclear Transmission Network (NTS), but also to build new transmission infrastructure between Hong Kong and the Mainland. Actual project costs are uncertain and will be subject to final network design and construction methods. The project lead time after a decision to proceed with such a project would be more than 8 years to allow for planning, design, permitting, construction and commissioning.

Currently, the import electricity price is based on a commercial negotiation and, as such, the future imported electricity price is unknown and uncertain.

Renewable Energy

New energy infrastructure investments, upgrades of energy infrastructure, and policies that promote energy security, can, in many cases, create opportunities to achieve GHG emission reductions[28]. Renewable energy, such as large scale wind and solar, as well as the waste-to-energy opportunities discussed above, requires significant initial investment and operational costs.

In 2005 the First Sustainable Development Strategy the Government set a target of 1 to 2% renewable energy in electricity use by 2012. In addition to the IWMF being planned, both CLP and HEC are currently planning to develop off-shore wind farms. *Box 1.1* provides a cost and environmental benefit estimation for CLP's off-shore wind farm.

Box 1.1 CLP Off-shore Wind Farm

The investment cost of CLP's off-shore wind farm is about HK$80-100 Million per 3MW turbine[29]. This is on par with other wind farms and less than the cost of solar[30]. According to the CLP offshore wind stakeholder consultation website[31], the Project would also provide benefits to local air quality since the wind farm will produce clean energy and would offset emissions from fossil fuels. Every year of operation of the project would offset approximately:

- 343,000 - 383,000 tonnes of CO_2;
- 54 - 60 tonnes of SO_2;
- 394 - 440 tonnes of NOx; and
- 14 - 16 tonnes of particulate matter.

Overall Considerations

Quantitative analysis for electricity generation is provided under *Section 3*. Hong Kong may import more nuclear electricity from Mainland China and more natural gas to generate electricity locally. The marginal electricity prices of both natural gas and nuclear are higher than that of coal, and the natural gas price is expected to increase rapidly in this region[32]. Although the impact from fuel price changes on Hong Kong's aggregate GDP growth is small, the change of fuel mix will influence the future electricity tariff.

Further challenges are likely to be presented by both the increased import of natural gas and nuclear power. Generation and network infrastructure takes a long time to implement, requiring the resolution of a range of engineering issues, permitting processes and liaison with stakeholders. Continued engagement between industry and different stakeholder groups is needed to enable the development of feasible engineering options that meet the required programme.

Climate change policy objectives and other policies such as improving air quality should be well integrated to avoid wasteful investments and adverse effects on electricity supply reliability. Utilities need to plan effectively on the basis of asset lives which span more than two decades. Clear emission reduction targets at least for 2020 and 2030 are necessary for practical planning and sustainability assessment.

1.2.7 Carbon Tax, Cap and Trade

General economic instruments that apply across the various sectors of the economy and are not specific to particular GHG emission reduction measures may be implemented in addition to, or more likely as an alternative to, government policy instruments targeting particular measures. This approach is characteristic of a laissez faire philosophy of governance and economic management.

The general economic instruments relevant to the control of GHG emissions are emission taxes or levies (referred to here as "taxes") and a cap-and-trade permit system, referred to here as "permits." These two alternative approaches both seek to send economic signals to decision-makers to limit their GHG emissions. The effects of emission tax and cap and trade could be the same as they approach the problem from opposite ends. In the HKMM model, emission tax was selected for analysis and consideration as a non-measure-specific, cross-sectoral policy instrument.

Each approach is applicable to a particular policy context. The characteristics of these two alternative approaches are shown in *Table 1.1*.

Table 1.1 Key Characteristics of Emission Taxes and Tradable Permits

Variable	**No Generic GHG Economic Instruments**	**Emission Levies or Taxes**	**Tradable Permits**
Quantity of Emissions	Completely unconstrained, the indirect result of other economic decisions	Reduced according to the level of the tax and the extent to which emitters are price elastic	Directly controlled by a cap, so an emission target must be met, subject to the scope of the constraint and the effectiveness of enforcement
Cost / Price / Market Value of GHG Emissions	No economic value, because unconstrained – no scarcity	Determined directly by the tax level	Determined by the costs of abatement and the laws of supply-and-demand in the market
Broad Policy Context	No change, business-as-usual economics with direct government planning and intervention	Require a definite position to be taken on emission cost adder – may be perceived as the imposition of a direct economic penalty	Requires a definite position to be taken on the quantity of emissions allowed – more likely to be perceived as primarily an environmental action
Issues	Which measures to select and promote, which policy instruments to select to promote them, how to implement	How to determine the correct level of tax or levy; assignment of liability (upstream versus downstream, point of emission versus point of end use); Tax adjustment based on a regular basis in view of environmental outcomes; Use of revenues (retained versus recycled)	Assignment of liability (upstream versus downstream, point of emission versus point of end use); Allocation (auctioning, grandfathering, or mix); Use of revenues (retained versus recycled)
Implementation		Long planning period, including the consultation with stakeholders	Long planning period, including the consultation with stakeholders and the development of the trading scheme

1.2.8 General Support Measures

The success of any climate change policy cannot be achieved without support measures, such as public awareness raising and education. They help to change lifestyle and behaviour patterns, overcome barriers to particular Government actions, and enhance the success of policies.

The aims of these support measures are to:

- inform all members of society of the importance of the climate change issue and why the Hong Kong SAR Government has decided to take action;

- inform all members of society of what the goals and components of the Government's policy are and how individuals and organisations can help achieve them;

- advise consumers of the economic benefits that they can avail themselves of by adjusting their purchasing habits, as well as the environmental benefits that would accrue to society at large if they would change their habits;

- develop and enforce laws and regulations that can effectively achieve the aims of the Government's policy; and

- improve the effectiveness with which Government can administer the strategy and monitor its progress.

The first three items can be termed as education and information, while the last two are institutional measures. They can be considered as a foundation or as social infrastructure on which to build other measures and policies.

<u>Education and Information</u>

Education and information may be considered as providing a foundation on which to build other measures. The provision of information and the use of communication strategies and educational techniques can encourage a change in personal behavior. It will be easier to implement measures and policy instruments for a general GHG emission control policy if the wider community and business sector understand the issues and the thinking behind the policy responses.

A public education programme could include the development of printed, visual and multi-media materials for schools, colleges, businesses, or organisations, the development of a dedicated website or TV programme devoted to climate change topics and the production of leaflets and other promotional materials for vendors and distributors of energy-efficient appliances, products, and materials.

Education and training are likely to influence people's behaviour patterns and make them more likely to adopt appropriate actions in response to more specific options to mitigate climate change across different sectors. According to the IPCC AR4, changes in occupant behaviour, cultural patterns and consumer choice and use of technologies can result in considerable reductions in CO_2 emissions related to energy use in buildings. Transport Demand Management, which includes urban planning (that can reduce the demand for travel) and provision of information and educational techniques (that can reduce car usage and lead an efficient driving style) can support GHG emissions mitigation. In industry, management tools that include staff training, reward systems, regular feedback, and documentation of existing practices can help overcome organization barriers, reduce energy use, and GHG emissions[33].

Education programmes are expected to have short lead time, possibly one year to at most 18 months to plan and develop. However, estimating quantitatively the effectiveness of public awareness and education policies is also difficult. Most analysts agree that these programmes enhance the effectiveness of other measures and as such are important components of a comprehensive climate change strategy, but that it is not possible to quantify emission reductions or the extent to which other measures and policy instruments would have been less successful without the general publicity. However, a comparative back-calculation can be made from the cost and a comparative cost per unit of emission reduction to the minimum impact that would be needed to justify the cost. For instance, if the cost of a public awareness programme is HK$1 million and leads to emission reductions of 20,000 tonnes $CO_{2\text{-}e}$, and if the emissions reduction is not attributable to other factors, it implies a unit cost of the education programme is HK$50 per tonne of $CO_{2\text{-}e}$ reduction.

Institutional Measures

Institutional measures could include the establishment of new focal points in Government to administer the climate change policy, to co-ordinate the various arms of Government charged with implementing its component elements, to monitor its success over time, to develop and enforce the necessary implementing laws and regulations, and to review and update the policies.

The implementation of the proposed measures and policies is affected by a number of factors, including:

- the availability of the required infrastructure and conditions;
- the availability of funding; and
- the status of the required technologies.

In general, there are four generic phases for the implementation of each measure or policy.

- *Planning and Approval*. This refers to the internal government procedures for deciding on the details of the proposed measures or policies. These may include liaising with various government departments and relevant public bodies. This also includes the time required to carry out feasibility studies, where appropriate. This phase ends when approval is obtained and the measures or policies are adopted.

- *Development*. Once approval is obtained, the next phase requires the design and preparatory work for the implementation of the measures or policies. In the case of new facilities or infrastructure this phase will include the construction and the commissioning of the facilities. In the case of regulation or incentive schemes, this will include the time required for drafting and enacting the regulations, as well as the time for consultation, where appropriate.

- *Full Implementation*. This refers to the time when the measures and policies will start to make the expected impacts on the reduction of GHG emissions.

- *Monitoring, Audit and Evaluation.* This refers to the measurement of carbon stock, GHG emissions, and socio-economic and environmental benefits and costs that occur as a result of the implementation[34].

Inventories and indicators provide a macro-level assessment of the success of an overall policy but do not enable policy makers to decide the extent to which individual policy instruments have contributed towards emerging trends. In most cases it requires the establishment of a counter-factual: what would have happened in the absence of the policy. For some emission sources of non-CO_2 GHGs, the emission control measure involves the capture or direct measurement of the gas. For example, landfill methane capture can be directly measured, even if the total aggregate emissions for the HKSAR cannot. Establishing a counter-factual for other measures is less straightforward. For example, when evaluating the improvements in energy efficiency in specific industry groups, the difficulties include:

- obtaining energy use data at the level of the individual industry;

- separating out efficiency changes from other changes, eg in product lines;

- identifying which efficiency improvements result from responses to policy and which are simply business as usual and reflect some autonomous level of energy efficiency improvement.

Achieving the targeted emission reductions is the primary objective regardless of which measures result in the reductions. However, because most measures impose costs both on industry, consumers and the public purse, it is useful to know where the most cost-effective reductions are occurring and if some measures perform better than others.

In order to assess the effectiveness and costs of particular policy instrument, a review process might involve one or more of the following elements:

- development of industry level indicators of energy and/or emission intensity;
- development of a business as usual baseline for sectors or industry groups targeted by policy against which future energy use or emission rates or intensities can be compared;
- surveys of sectors to identify penetration rates of specific technologies and industry estimates of investments and behavioural changes in response to policy

Once decisions have been made regarding the introduction of a policy in Hong Kong an interdepartmental process will need to be established for its ongoing review. This should include the monitoring data in the form of an inventory and indicators, and a process for its review.

There are a number of reasons why cost-effective, energy-efficiency measures might not be taken up. For example:

- lack of information - building owners or occupiers may not have access to information about the energy efficiency of a building or an appliance in an understandable form, for example, in a way that shows the impact of an energy-efficient appliance on their electricity bill.
- lacks of incentives - developers find it difficult to recoup the added costs of energy-efficient features in a building, as these enhancements are not recognised or credited in the selling price or rental received. Similarly, landlords have little incentive to include energy-efficient appliances in apartments, because rental values do not increase as a result.

Overcoming these barriers requires policy instruments that provide information, or enforce particular actions, eg, through the use of energy-efficiency standards or building codes. However, introducing these measures is not cost-free, and the energy savings need to be offset against the costs of the programme, as well as the costs of the technologies themselves. In general, these programme costs are not included in our cost estimates. Including these costs may reduce the net benefits of some of the measures or transform some that are presently estimated to be zero or negative cost measures into positive cost measures. In other instances, the existence of cost-effective measures may be time dependent. For example, if significant energy savings are available, it might be expected that eventually energy service companies will advise firms of their discovery. Thus, the savings may be limited in time[35].

1.2.9 Research, Development, and Demonstration (RD&D)

Climate change mitigation will involve increased expenditures at all stages of the technology development process, ranging from research and development upstream to demonstration, deployment, and ultimately diffusion downstream. Most importantly, empirical evidence suggests that most emerging low carbon energy technologies are subject to sizeable "learning effects", *ie* their costs fall as experience accumulates through cumulative production[36]. For example, learning rates – the percentage reduction in unit investment costs for each doubling of cumulative investment – in the order of 10% to 20% have typically been reported for wind and solar power technologies. In that context, significant technology deployment costs may have to be incurred before low-carbon technologies can become competitive at market prices. However, wide uncertainties remain surrounding the magnitude and even the nature of learning effects, and their policy implications are far from obvious[37].

A cost-effective approach to addressing climate change should not only tend towards marginal abatement cost equalisation across current economic activities, but also help shape future economic activities so that marginal abatement costs will be lowered. This can be achieved through efficient R&D, innovation and diffusion of GHG emissions-reducing technologies. Technological progress will be needed both to:

- bring down the cost of available or emerging emission-reducing technologies; and

- expand the pool of available technologies and their mitigation potential.

A number of measures have been identified in this study as promising options to reduce GHG emissions in Hong Kong out to 2030 and beyond, but which are not viable commercial options today. This may be because they are too expensive, the technology is not yet fully commercialised in Hong Kong, or simply that the technology has not yet been commercialised anywhere in the world to any great extent. It is not likely that some of these technologies will have significant application in Hong Kong in the near term under market forces alone. However, with Government support and incentives, costs might be reduced or offset and the level of consumer comfort rise such that they could make a notable contribution in the longer term.

There are many examples of how Government could invest in the future of clean technologies. At the level of fundamental research into advanced technologies with potential in Hong Kong, Government could provide research grants to local universities. Government could support the demonstration of advanced technology options by, for example, promoting the use of hybrid cars or installing photovoltaic systems in schools. Cost-sharing of demonstration programmes or provision of low-interest loans for innovative technology installations are ways to provide financial inducements for investors to assume the risks associated with first-of-a-kind projects.

Another option is for Government to demonstrate new technologies in the facilities it owns. It could, for example, convert Government transport vehicles to clean fuels, further improve the air conditioning and lighting energy efficiency in Government buildings, finance some carbon neutral programmes. One advantage of programmes such as these is that they demonstrate Government's commitment to climate change action and may thereby encourage similar initiatives from the private sector.

Speeding up the emergence and deployment of low-carbon technologies will ultimately require increases in – and reallocation of – the financial resources channelled into energy-related RD&D. The actual expenditure on energy-related RD&D in Hong Kong is not available. The total R&D expenditure of Hong Kong has also increased from 0.43% of the GDP in 1998 to 0.77% of the GDP in 2007, with the business sector's share rising from 29% in 1998 to 50% in 2007[38]. The R&D expenditure as a ratio to GDP and the portion of R&D expenditure invested by the private sector are low when compared to those of the neighboring and comparator economies such as Korea, Taiwan, Singapore and the Mainland.

It is not possible to measure the cost-effectiveness of RD&D measures. Costs can be estimated readily beforehand, but the effects cannot. This is because the ultimate penetration of any path-breaking innovation hinges on a series of additional incremental innovations and learning gains, which are largely unpredictable ex-ante[39]. The eventual investment and commercial penetration of new technologies happens long after the RD&D activity and because the relationship between the RD&D and the final outcome is highly uncertain. In other words, it is practically impossible to estimate to what extent the GHG emission reduction effect is attributable to RD&D. Given that the effectiveness part of the cost-effectiveness equation is difficult to assess, even *ex-post,* cost-effectiveness is practically impossible to estimate *ex-ante*. Therefore, these measures are discussed separately and not included in the HKMM model.

Price Incentive to Stimulate RD&D

Pricing GHG emissions increases expected returns from RD&D in low-carbon technologies. In the presence of learning effects, it also reduces expected cumulative deployment costs needed for existing climate-friendly technologies to become competitive. The effects of emission pricing on expected returns are likely to be largest for technologies, such as CCS, which would yield no private financial gain otherwise as they affect only the carbon intensity of energy (GHG emissions per unit of energy) but not energy efficiency (number of units of energy per unit of output). More broadly, emission pricing gives emitters a continuing incentive for emissions-reducing RD&D and technology deployment, the so-called "dynamic efficiency" of price-based mechanisms. However, the credibility of the price signal also matters since investments in RD&D and/or deployment of emerging technologies entail sunk costs. In practice, empirical evidence has found private energy-related RD&D and innovation at the company level to be responsive to past fluctuations in energy prices[40], while the fairly strong correlation until recently between fluctuations in oil price and public R&D spending suggests that governments also respond to price incentives.

1.2.10 *Water Management, Energy Use, and Carbon Emissions*

Hong Kong has enjoyed a secure and stable supply of water from the Dongjiang River in Guangdong Province, which is capable of meeting 70% to 80% of Hong Kong's raw water supply needs as well as an ultimate supply of up to 1,100 million cubic metres which could meet the projected demand up to 2030. Despite the assured supply of water from the Mainland, Hong Kong has a responsibility to contribute to water conservation in the region. In aspiring to sustainable development, the Total Water Management Strategy was promulgated in 2008 to better prepare Hong Kong for uncertainties such as acute climate change and low rainfall and so to enhance the SAR's role as a good partner to other municipalities in the Pearl River Delta[41].

The Strategy suggests that through various measures, water consumption can be reduced by 236 mcm from the projected 1,315 mcm by 2030 (compared with currently around 1,000mcm). If the water conservation target can be achieved, the carbon emissions are expected to be reduced by around 0.4% of the total, assuming other factors remain unchanged[42].

1.2.11 *Carbon Leakage and Interactions with Other Government Policy Objectives*

"Carbon leakage" is a phenomenon whereby emitters relocate from an economy with a GHG emission tax or cap to a location where they are free from that cost burden. Carbon leakage operates through two distinct channels: a competitiveness effect, and an energy-intensity effect that may also lead to increased emissions outside the participating countries. The energy-intensive effect would arise because abatement in participating countries would reduce demand for fossil fuels worldwide, pushing their price down. This may lead non-participating countries to produce and consume more energy-intensive products than they otherwise would as these become cheaper.

This may not be as significant an issue in Hong Kong as it would be in economies with substantial energy-intensive industries, which could choose to relocate to locations without limits on GHG emissions. Much of Hong

Kong's manufacturing sector relocated its productive capacity to Mainland China during the 1980s and so there are very limited large, energy-intensive industries in Hong Kong today. However, there are still some sectors of the economy that may be susceptible to the phenomenon of carbon leakage, for example, electricity generation and local or coastal shipping.

An increase in electricity prices as a result of GHG emission control policies would be unlikely to cause companies in Hong Kong to relocate. However, policy instruments such as a GHG emission tax or a GHG emission cap may act as driver for the generation facilities themselves to relocate outside of Hong Kong, depending on the size of the cost adder due to the tax or cap relative to the overall financial position. The existence of either a GHG emission tax or a GHG emission cap affecting the electricity generation industry in Hong Kong could have a significant influence both on where plants are located and on the competitive position of Hong Kong-based plants relative to competing plants in Mainland China if there was not a similar constraint on generators in Mainland China. Thus the imposition of a tax or a cap in Hong Kong could simply move GHG emissions off Hong Kong's inventory without reducing emissions either for the PRC as a whole or globally. This effect would likely be exacerbated if wholesale (generation supply) competition was introduced to the Hong Kong and southern China electricity sector while a tax or cap was applied in Hong Kong, but not in Mainland China.

2 METHODOLOGY AND ANALYTICAL APPROACH

This section describes the Hong Kong MARKAL-MACRO (HKMM) model, the development of the Base Case.

2.1 QUANTITATIVE APPROACH

An integrated energy-economic-environmental modelling framework is an essential tool for carrying out quantitative analysis of climate change mitigation. The Hong Kong MARKAL-MACRO model has been selected as the primary tool for this assessment, since it is uniquely suited to the framework listed in the *Reporting on Climate Change: User Manual for the Guidelines on National Communications from non-Annex I Parties*[43]. More than 60 countries (including China) use country-specific MARKAL-MACRO models for GHG mitigation analysis, which enables simple comparison of cross-country results on a consistent basis.

2.1.1 Overview of MARKAL-MACRO Model

MARKAL-MACRO model is an integration of a bottom-up MARKAL model and a top-down MACRO module. MARKAL provides a framework to evaluate resource and technology options within the context of the entire energy/environment system. It captures the market interactions among fuels to be used for power generation (eg competition between LNG and coal) and other processes to meet end-use demands. It explicitly tracks the vintage structure of all capital stocks in the economy that produces, transports, transforms or uses energy. In MARKAL, the entire energy system is represented as a network, based on the Reference Energy System (RES) concept, which depicts all possible flows of energy from resource extraction, through energy transformation, distribution and transportation, to end-use devices that satisfy the demands of useful energy services. The solution algorithm evaluates all resource and technology options within the context of the entire energy system and reaches a least-cost solution at partial equilibrium of the energy sector. The model evaluates each of the available energy technologies by looking at the type and amount of fuel consumed, capital and operating costs, availability constraints and capital stock turnover. The model also evaluates the cost and availability of domestic and imported energy resources, including all of the intermediate processing and conversion costs and efficiencies, as well as and other assumptions such as electric generation reserve requirements and environmental constraints.

The top-down component MACRO is a one-sector neoclassical growth model based on the maximization of a utility function subject to a national budget constraint. National output is produced by a single sector, represented by a nested production function with constant elasticity of substitution between three inputs (Labour, Capital and Energy). The linkage between MARKAL and MACRO is formulated at the level of demands for energy services. In MARKAL these demands are specified exogenously in the reference case, and are then endogenously altered by the model for alternative scenarios. MARKAL-MACRO uses a different approach: the demands are variables of the model that are aggregated to become the Energy input into the MACRO production function, alongside Labour and Capital. Merging these two components results in a new model that captures the characteristics of an inter-temporal general equilibrium model, while retaining the rich technological details of MARKAL. The equilibrium is based on the assumption of perfect foresight and competitive markets in the sense of neo-classical economic theory. The solutions of the integrated model maximize social utility while assuring the least life-cycle costs in the energy system that meets the end-use service demands for each sector. A detailed description of the model can be found at the website of the Energy Technology and Systems Analysis Program[44] operated by the International Energy Agency.

2.1.2 *Development of Hong Kong MARKAL-MACRO Model*

The overall approach to developing the Base Case is to update the existing HKMM model using the latest energy and economic information available. The 2009 version of the model developed for this assessment involves a comprehensive update in data input and enhancement in energy system configuration built in an earlier version of the model[45,46]. To establish the Base Case, all parametric values and assumptions (technical, environmental, and economic) required in the model were updated based on the latest available data and trends for shaping the future Hong Kong energy markets (2005 – 2030). The model solution attains an inter-temporal general equilibrium that provides optimal energy demand-supply balances and development path, the associated environmental emissions and economic costs (eg the impact on GDP).

2.1.3 *Base Case and Development*

For the purpose of measuring the energy-environmental-economic impact of the mitigation scenarios formulated in the Climate Change Mitigation Assessment (the Study), it is necessary to develop a Base Case. The Base Case developed in the Hong Kong MARKAL-MACRO (HKMM) model provides energy supply-demand projections in a detailed and disaggregated pattern. This is required to model the individual mitigation measures at the end-use/technology level. The fuel and technology specific flows in the energy system also facilitate more accurate accounting of their associated environmental emissions. *Annex A* provides a description of how the Base Case is formulated. It also identifies the data resources and major assumptions used.

Although the Base Case projects a "business as usual" energy system path by incorporating existing and planned measures and development programs into the model, it should not be taken as the prevailing energy market for the future in the absence of additional mitigation policies and measures. Rather, it provides a reference basis to evaluate impacts of additional alternative scenarios, representing recommended policies and measures, to provide useful insights into the future and the impacts of these scenarios. The uncertainties inherent in any long-term scenario (eg GDP projection, population growth, future energy prices) suggest that, it is most useful to focus only on the differences in the results between the mitigation scenarios and the Base Case rather than on the absolute numerical results in a single scenario. It is the differences, not the absolute results that reflect the impact of the additional technologies, policies and measures.

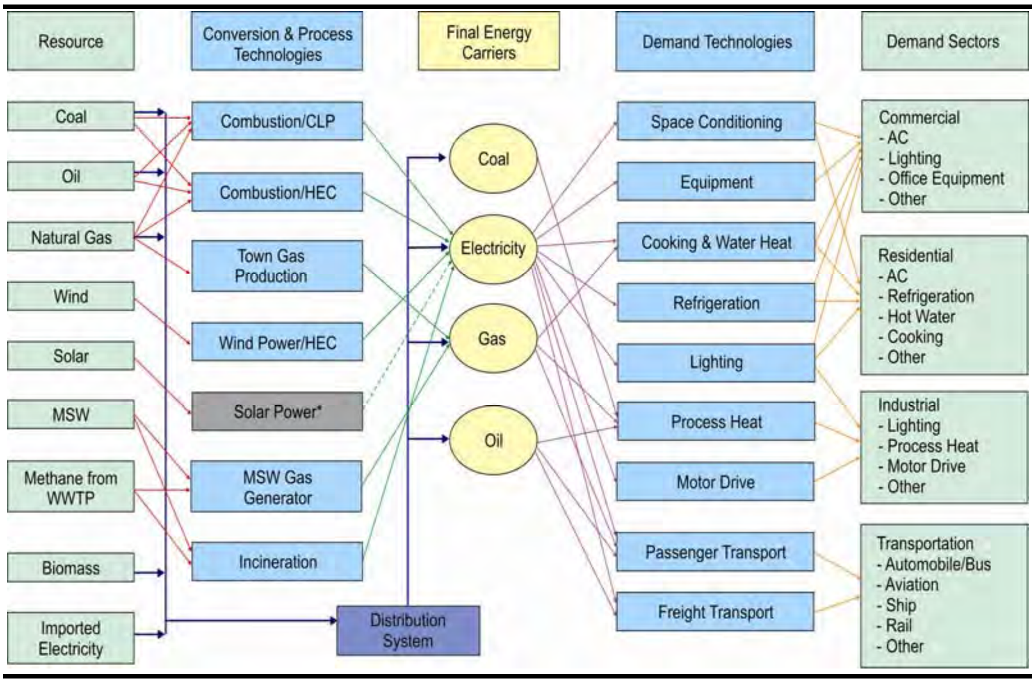
2.1.4 Base Case Energy System Data Input and Organization

The Reference Energy System (RES) underlying the MARKAL-MACRO modelling system requires input data (actual and projected) from primary energy supply (eg diesel fuel imports), intermediate conversion and process (eg electricity generation), to end-use technologies (eg air conditioners) that satisfy energy service demands (eg space conditioning). Each element in the RES is characterized by three groups of data: technical (eg efficiency), economic (eg capital cost), and environmental (eg carbon emission coefficient). *Table 2.1* shows the six main data input categories, including the four energy system building blocks depicted in *Figure 2.1*: resources/primary energy supply, conversion & process technologies, end-use technologies, and demand for energy services. The other two categories are economic parameters of energy carrier/technology and emission factors associated with elements within the four building blocks.

Table 2.1 Data Category

Data Category	**Model Input**
Demand for Energy Service; End-use Technologies	Demand Module
Conversion Technologies	Power Sector; Process
Primary Energy Supply	Resource
Price of energy carrier/technology	Price
Emission Factors	Emission Factors

Figure 2.1 *HK Simplified RES*

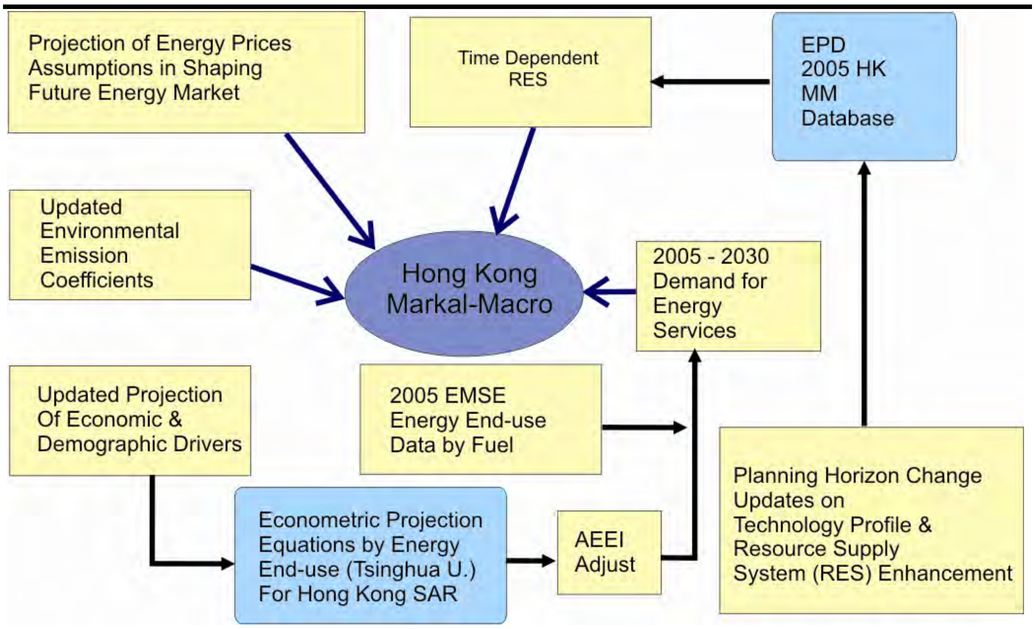


Source: ERM and BNL.
Note: Technologies in gray boxes are those that can be developed in HK in the future.

2.1.5 *Development of the Hong Kong Base Case*

Figure 2.2 depicts schematics of the interrelated tasks in the development of the Base Case. In general, Hong Kong specific historical energy demand-supply data were used to establish the base year (2005) RES in the Hong Kong MARKAL-MACRO model. The base year RES provides a balanced stance (partial equilibrium) based on which future energy-environmental-economic scenarios can be formulated. If no Hong Kong specific data are available, data can be taken from many existing MARKAL databases in the world community as a starting point.

Figure 2.2 HKMM Baseline Dataflow



Source: ERM and BNL.

Annex A details the structure of different modules, the sources of data, and key assumptions for the projections. It should be noted that there are uncertainties inherent in the input data and projections used to develop the Base Case. In considering the results of modelling analysis, it is most useful to focus on the differences between the scenarios representing the situation with and without (Base Case) the additional technologies, policies and measures selected for the study, rather than on the absolute numerical results for either scenario. This approach minimizes the significance of these uncertainties.

Please note that the Hong Kong MARKAL-MACRO model accounts for energy related CO_2 emissions. Other carbon emissions from non-energy sources are estimated outside the Model based on historical trend and their driving factors. The energy related CO_2 emissions and other carbon emissions under different sectors are added up to derive the total carbon emissions (CO_{2}-$_{e}$).

2.2 BASE CASE RESULTS

The major indicators for the Base Case derived from the HKMM model results are summarized in *Table 2.2*.

Table 2.2 Major Indicators: Base Case

	2005	2010	2015	2020	2025	2030	Annual Growth 2005-2030(%)	Total Growth 2005-2020 (%)	Total Growth 2005-2030 (%)
Population (Thousand)	6,813	7,094	7,391	7,719	8,035	8,312	0.80	13	22
GDP (Billion 2005 HK$ Exchange Rate) (1)	1,383	1,596	1,911	2,258	2,567	2,905	3.01	63	110
Per Capita GDP (Thousand HK$)	203	225	259	293	320	349	2.20	44	72
Primary Energy (TJ) (2)	591,601	631,258	678,823	744,786	770,817	822,488	1.33	26	39
Final Energy (TJ) (3)	294,968	306,121	348,700	396,211	432,533	460,729	1.80	34	56
Carbon Emissions (Million tonnes $CO_{2\text{-}e}$)	42.0	42.8	44.1	46.1	42.6	44.8	0.26	10	7
Primary Energy Intensity (TJ/Billion HK$) (4)	428	395	355	330	300	283	-1.64	-23	-34
Final Energy Intensity (TJ/Billion HK$)	213	192	182	175	168	159	-1.18	-18	-26
Carbon Emissions per Capita (Tonnes $CO_{2\text{-}e}$) (5)	6.16	6.04	5.97	5.97	5.30	5.39	-0.53	-3	-13
Carbon Intensity (kg $CO_{2\text{-}e}$/ HK$)	0.0304	0.0268	0.0231	0.0204	0.0166	0.0154	-2.68	-33	-49

Notes:

(1) The GDP projections are based on the best available working assumptions for future economic growth. It is noted that the growth rate working assumptions from 2014 onwards are subject to a large degree of uncertainty.

(2) Primary energy is energy found in nature that has not been subjected to any conversion or transformation process. Examples of primary energy resources include coal, crude oil, sunlight, wind, running rivers, vegetation, and uranium.

(3) Final energy refers to the amount of energy consumed by final users for all energy purposes such as heating, cooking and driving machinery, but excludes non-energy usages such as using kerosene as solvent. It differs from primary energy in that the latter includes all energy used or lost in the energy transformation and the distribution process.

(4) Energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP.

(5) Carbon intensity in this study is calculated as total GHG emissions per unit GDP.

2.2.1 *Energy and Energy Intensities*

The total primary energy consumption in the Base Case is projected to grow at an annual rate of 1.33% during the period 2005-2030, while the final energy demand is projected to grow at an annual rate of 1.80%. Compared to the projected 3.01% annual growth rate in GDP[47] over the same period, the decoupling trend between GDP and primary energy consumption implied in the annual growth rates is consistent with the historical data reported by the Hong Kong Census and Statistics Department (C&SD). During the period 1997-2007, C&SD's data show that primary energy consumption grew at 2.1% per year when the annual growth rate in GDP was 3.8% in real terms. The projected values in GDP, final energy demand and primary energy consumption imply that the final energy intensity will decrease from 213 TJ/Billion HK$ in 2005 to 159 TJ/Billion HK$ in 2030. The primary energy intensity, currently among one of the lowest in the world, will further decrease from 428 TJ/Billion HK$ to 283 TJ/Billion HK$ during the same period.

2.2.2 *Carbon Emissions and Intensities*

The annual growth rate of total carbon emissions (0.26% per year between 2005 and 2030) is projected to decouple from primary energy growth, which increases at an annual rate of 1.33% over the same period. In comparison, the total carbon emission grew at an annual rate of 1% during the period 1990–2006, as reported in ***Appendix A: Update of GHG Inventory***. The relatively low carbon emission growth rate projected is mainly due to the scheduled decommissioning of coal-fired power plant units in Hong Kong by 2030. The phase-out of existing coal-fired power plants and the assumption in the Base Case to replace them with high efficiency combined cycle gas turbines are the main factors that limit the carbon emission growth in Hong Kong. As a result, Hong Kong's carbon emission per GDP output, already one of the lowest in the world, is projected to continuously decrease from 0.0304 kg CO_{2-e} per HK$ in 2005 to about 0.0154 kg CO_{2-e} per HK$ in 2030. In terms of carbon emissions per capita, the model projects a very slight decrease (-0.53% per year for the period 2005-2030), based on the population growth rate provided by C&SD.

2.2.3 *Sensitivity of MARKAL Model Output to GDP Projections*

The model outputs might be different should deviations occur for key assumptions. Sensitivity of Base Case MARKAL Model outputs to GDP projections are discussed under this section.

Figure 2.3 shows the percent change in final energy demand while *Figure 2.4* depicts the percent change in carbon emissions under different GDP projection paths, ranging from 5% above to 5% below their respective values in the Base Case for each period. In absolute terms, these deviations represent significant differences from the Baseline GDP in dollar amounts over time. The Hong Kong MARKAL output from these sensitivity runs indicate that the percent changes in final energy demand and carbon emissions are linearly proportional to the percentage change in GDP in a converging pattern. Since this study focuses on the differences in the model results between the mitigation scenarios and the Base Case (ie, the impact of additional technologies, policies and measures), the uncertainties inherent in the long-term GDP projections have only a minimal impact on the general conclusions that can be drawn from the Study.

Figure 2.3 *Final Energy Demand Change by GDP Projection*

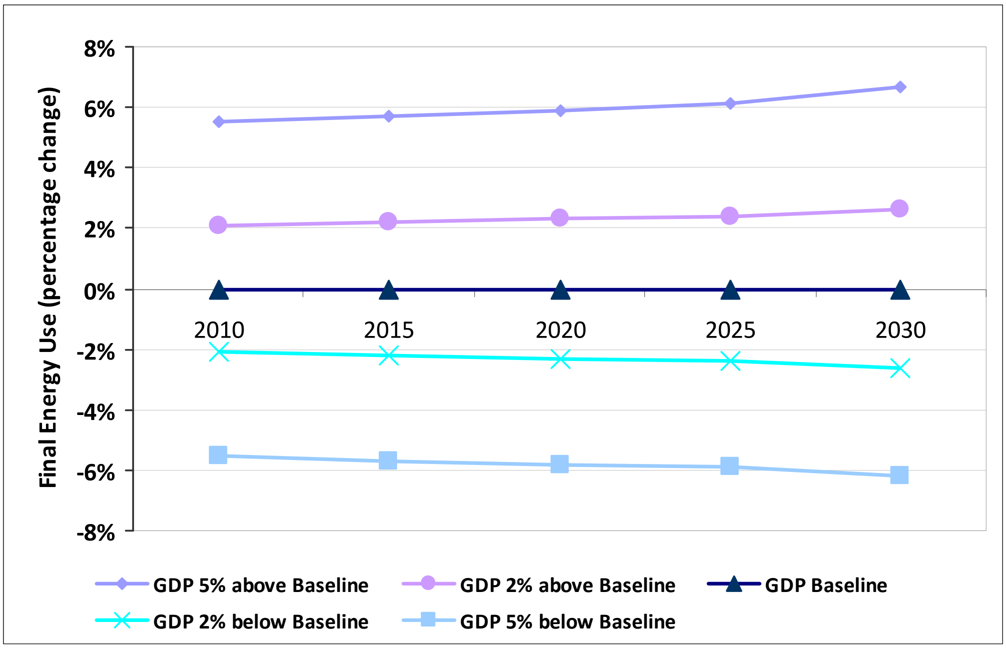
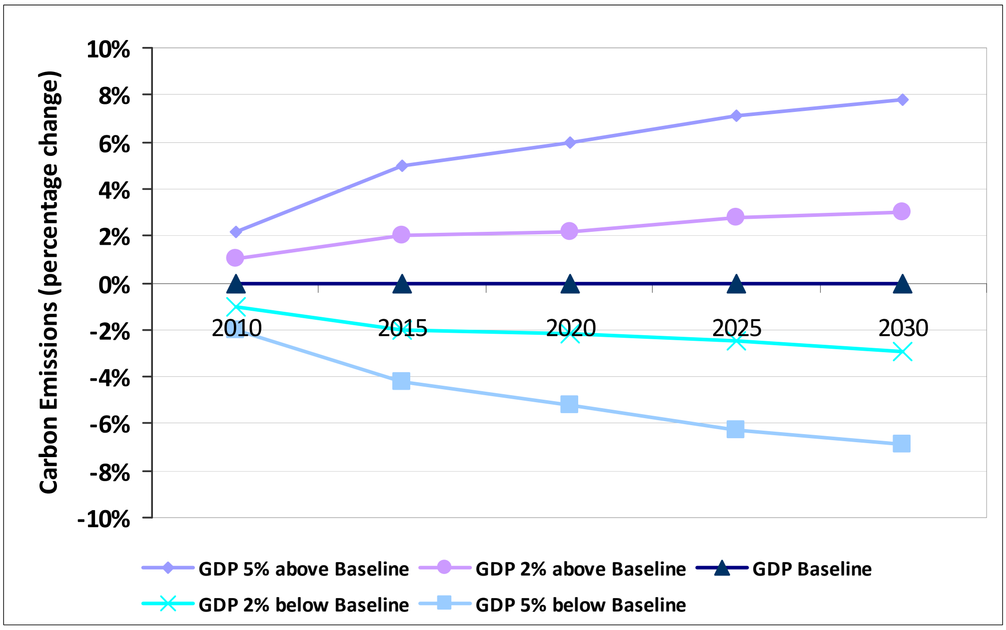


Figure 2.4 *Carbon Emissions by GDP Projection*



3 SCENARIO FORMULATION AND ANALYSIS

The Study examined three scenarios in the mitigation analysis: Scenarios 1 to 3. These three scenarios were formulated by incorporating specific policy targets and market penetration rates for measures selected in four sectors (Buildings, Transport, Electricity Generation, and Waste), as described in the *Table 3.1*[48]. It should be noted that the Scenarios were developed for the purpose of analyzing the effectiveness of alternate packages of practices and policies and hence to inform a decision on the likely ranges of emissions reduction that may be viable. There remains a degree of uncertainty both as to the practices and policies that will ultimately be adopted and the degree to which they are effective. The degree of uncertainty is greater in the 2020 to 2030 time period that in the period up to 2020 and hence the policies and measures assumed for the purposes of this analysis may well be subject to change.

3.1 ALTERNATIVE SCENARIO ASSUMPTIONS

Scenario 1 (the 'AQO Scenario') includes relevant mitigation measures proposed in the AQO Study[49], including the increased use of natural gas and renewable energy sources for electricity generation, wider use of road vehicles using clean fuels, and enhanced energy efficiency in the building and appliance sector. It required some refinement of the AQO policy options for the following reasons.

- The AQO Study options were considered individually rather than in combination and thus not compatible with MARKAL-MACRO (MM), which is a dynamic macroeconomic model and considers measures in an integrated manner.

- For a number of options examined in the AQO Study, the required input parameters and assumptions for the HKMM model were not available. In these cases ERM and US's Brookhaven National Laboratory (BNL, the model developer) have made assumptions based upon our understanding of the particular policy or measure (as implemented internationally) and/or the technology in question.

- Some measures proposed in the AQO Study were not assessed in the HKMM model either because they are not associated with GHG reduction or because they are not considered to be commercially viable within the necessary timeframe.

Specifically, Scenario 1 assumes the following.

Building and Appliance Sector[50]

- Annual 0.6% energy saving in total energy consumption in Hong Kong from energy efficiency improvement through mandatory implementation of Building Energy Code (BEC) by 2015.

- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.

- 0.5% energy saving in total energy consumption in Hong Kong from district cooling system by 2020.

- 0.3% energy saving of total energy consumption in Hong Kong from energy efficiency improvements in electrical appliances for domestic use by 2015.

Transport Sector

- Wider use of hybrid, electric powered, and biodiesel vehicles:

  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% heavy goods vehicles (HGVs) and light goods vehicles (LGVs)

  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs

Electricity Generation

- All power plants will retire according to their expected life.

- RE is to meet 4% of the local demand for electricity by 2020 and 6% by 2030 (including RE generated locally or imported from the Mainland)[51].

- Import of nuclear power maintained at the same level as in 2005.

- Apart from electricity generated by RE, nuclear, and remaining coal, all other local electricity consumption is from natural gas by 2030.

3.1.1 Scenario 2

Scenario 2 (the 'Accelerated Scenario') builds upon Scenario 1 and includes additional efforts on measures to increase energy efficiency and reduce energy demand, particularly in the building and transport sectors. Local sources of renewable energy such as waste-to-energy facilities are utilised by 2020. This scenario also assumes a certain level of integration of the power system between Hong Kong and its neighbouring areas. Electricity imported from Mainland China in 2020 is the same as that in 2005. In 2030, the scenario assumes, as a stress test, the notion that 50% of the electricity demand could be met by sources from the Mainland with no associated carbon emissions[52]. Specifically, Scenario 2 assumes the following.

Building and Appliance Sector

- Up to 50% energy saving of major installations in all new commercial buildings through measures such as expanding the scope, and tightening the requirements of the Building Energy Codes by 2020.

- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.

- Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; up to 50% energy efficiency improvement in all commercial buildings through measures such as expanding the use of district cooling system (DCS) and water-cooled air conditioning system (WACS). Energy efficiency improvement is compared with that of the regular air conditioning system.

- Up to 50% cooling demand reduction by 2020 in all new commercial buildings from measures such as new overall thermal transfer value (OTTV) standards and extensive green roofing.

- Appliances sold in the market in 2020 will be up to 25% more energy efficient; appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level by expanding the scope and tightening energy efficient electrical appliance standards.

- Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings by 2020; up to 15% energy efficiency improvement in all existing commercial buildings from improving energy efficiency from Building Environmental Management System by 2030.

Transport Sector

- Wider use of hybrid and electric powered vehicles (EV):
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs.
  - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs.

- Petrol blended with 10% ethanol by 2020 (E10)[53].

- Diesel blended with 10% biodiesel by 2020 (B10)[54].
- Implementation of the Hong Kong "Importers' Average Fleet Efficiency" standard by 2020 - new vehicles will be 20% more energy efficient than the 2005 market average.

Waste Sector

- Waste-to-energy facility:
  - One IWMF with a treatment capacity of 3,000 tonnes/day by 2020.
  - Sufficient IWMFs to treat all MSW in HK by 2030 (projected to be 10,300 tonnes/day in 2030).
  - two OWTFs operating at full capacity of 400 tonnes per day[55].
- Full utilization of the recovered landfill gas.
- Full utilization of gas generated from waste water treatment.
- One sludge treatment facility operating at full capacity by 2020.

Electricity Generation

- All power plants retire according to their expected life.
- Import of nuclear power maintained at the same level until 2020; approximately 50% of local electricity consumption by 2030 is from sources in the Mainland with no associated carbon emissions[56].
- Apart from electricity generated by RE, nuclear, and remaining coal, all other local electricity consumption is from natural gas by 2030.

3.1.2 Scenario 3

Scenario 3 (the 'Aggressive Scenario') builds upon Scenario 2 and accelerates the integration of the power system in Hong Kong with its neighbouring areas. It assumes that Hong Kong would make full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation, for electricity generation in 2020. It also assumes that nuclear electricity imported from the Mainland in 2020 would be able to meet 50% of the local demand for electricity. Specifically, Scenario 3 assumes the following.

Building and Appliance Sector

- Up to 50% energy saving of major installations in all new commercial buildings through measures such as expanding the scope, and tightening the requirements of the Building Energy Codes by 2020.

- 0.011% energy saving in total energy consumption in Hong Kong from energy efficiency improvements in street lighting and traffic signals by 2020.

- Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; up to 50% energy efficiency improvement in all commercial buildings through measures such as expanding the use of DCS and WACS. Energy efficiency improvement is compared with that of the regular air conditioning system.

- Up to 50% cooling demand reduction by 2020 in all new commercial buildings from measures such as new OTTV standards and extensive green roofing.

- Appliances sold in the market in 2020 will be up to 25% more energy efficient; appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level by expanding the scope and tightening energy efficient electrical appliance standards.

- Up to 15% Energy efficiency improvement in up to 25% of existing commercial buildings by 2020; up to 15% energy efficiency improvement in all existing commercial buildings from improving energy efficiency from Building Environmental Management System by 2030.

<u>Transport Sector</u>

- Wider use of hybrid and electric powered vehicles (EV):
    - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2020: 30% private cars, 15% buses, 15% HGVs and LGVs.
    - Penetration rates of hybrid/EV or other vehicles with similar environmental performance by 2030: 50% private cars, 50% buses, 50% HGVs and LGVs.

- Petrol blended with 10% ethanol by 2020 (E10).

- Diesel blended with 10% Biodiesel by 2020 (B10).

- Implementation of the Hong Kong "Importers' Average Fleet Efficiency" standard by 2020 - new vehicles will be 20% more energy efficient than the 2005 market average.

<u>Waste Sector</u>

- Waste-to-energy facility:
    - One IWMF with a treatment capacity of 3,000 tonnes/day by 2020.

  - Sufficient IWMFs to treat all MSW in HK by 2030 (projected to be 10,300 tonnes/day in 2030).

  - Two OWTFs operating of 400 tonnes per day by 2020.

- Full utilization of the recovered landfill gas.

- Full utilization of gas generated from wastewater treatment.

- One sludge treatment facility operating at full capacity by 2020.

Electricity Generation

- 10% coal penetration in 2020, and zero in 2030.

- Making full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation for electricity generation.

- Nuclear electricity imported from the Mainland would be able to meet 50% of the local demand for electricity from 2020.

- Local RE sources are sufficient to meet 3-4% of local electricity consumption in 2020, and 4% in 2030.

- No primary energy source accounts for more than around 50% of Hong Kong's total electricity supply.

3.1.3 *Cross-sectoral Measure - Carbon Tax*

Analysis in the Study applies a carbon tax schedule from HK$500/tonne to HK$5,000/tonne of carbon (ie approximately US$17 to US$175/tonne $CO_{2\text{-}e}$) to the three mitigation scenarios. By introducing progressively higher carbon taxes and recording the quantity of abated emissions from the MARKAL-MARCO model output, marginal abatement cost (MAC) curves can be generated for different portfolios of policies and measures specified in the different scenarios.

Table 3.1 Alternative Scenario Assumptions

Measures	Scenario 1 (2005-2030)	Scenario 2 (2005-2030)	Scenario 3 (2005-2030)
Buildings and Appliances (1)			
Expanding the scope and tighten the requirements of the Building Energy Codes	0.6% energy saving of total energy consumption by 2015	Up to 50% energy saving of major installations in all new commercial buildings by 2020	Up to 50% energy saving of major installations in all new commercial buildings by 2020
Expanding the use of district cooling system (DCS)/water-cooled air conditioning system (WACS)	0.5% saving in total energy consumption by 2020	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2030	Up to 20% of all commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2020; All commercial buildings will be up to 50% better in refrigeration performance compared with buildings using regular air conditioners by 2030
Reducing energy demand in new buildings through e.g. tightening the overall thermal transfer value (OTTV) standards and promoting wider adoption of green roofing	N/A	Up to 50% cooling demand reduction in all new commercial buildings by 2020	Up to 50% cooling demand reduction in all new commercial buildings by 2020
Expanding the scope and tightening the energy efficient electrical appliance standards for domestic use	0.3% energy saving of total energy consumption by 2015	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level; Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level	Appliances sold in the market in 2020 will be up to 25% more energy efficient, compared with 2005 level; Appliances sold in the market in 2030 will be up to 50% more energy efficient, compared with 2005 level
Improving energy efficiency from Building Environmental Management System	N/A	Up to 15% energy efficiency improvement in up to 25% of existing commercial buildings by 2020; Up to 15% energy efficiency improvement in all existing commercial buildings by 2030	Up to 15% energy efficiency improvement in up to 25% of existing commercial buildings by 2020; Up to 15% energy efficiency improvement in all existing commercial buildings by 2030
Transport			
Wider use of motor vehicles running on alternative fuel	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV	2020: Hybrid/EV or other vehicles with similar performance: 30% private cars, 15% buses, 15% HGV and LGV 2030: Hybrid/EV or other vehicles with similar performance: 50% private cars, 50% buses, 50% HGV and LGV
Petrol blended with 10% Ethanol (E10)	N/A	All petrol to be blended with 10% of ethanol by 2020	All petrol to be blended with 10% of ethanol by 2020
Diesel blended with 10% Biodiesel (B10)	N/A	All diesel to be blended with 10% of biodiesel by 2020	All diesel to be blended with 10% of biodiesel by 2020
Implementation of "Importers' Average Fleet Efficiency" standard	N/A	New vehicles will be 20% more energy efficient than the 2005 market average by 2020	New vehicles will be 20% more energy efficient than the 2005 market average by 2020
Waste			

Measures	Scenario 1 (2005-2030)	Scenario 2 (2005-2030)	Scenario 3 (2005-2030)
Construction and operation of waste-to-energy facilities	N/A	One IWTF with a treatment capacity of 3,000tonnes/day by 2020; Sufficient IWMFs to treat all MSW in HK by 2030. Two OWTFs operating at a total capacity of 400 tonnes per day by 2020.	One IWTF with a treatment capacity of 3,000tonnes/day by 2020; Sufficient IWMFs to treat all MSW in HK by 2030. Two OWTFs operating at a total capacity of 400 tonnes per day by 2020.
Utilization of landfill gas as energy source	N/A	Full utilization of recovered landfill gas	Full utilization of recovered landfill gas
Utilization of gas generated from wastewater treatment	N/A	Full utilization	Full utilization
Utilization of sludge treatment with energy recovery	N/A	One sludge treatment facility operating at full capacity	One sludge treatment facility operating at full capacity
Energy Supply			
Use of coal in electricity generation	All power plants retire according to their expected life	All power plants retire according to their expected life	Accounting for less than 10% of fuel mix in 2020; zero in 2030
Use of natural gas in electricity generation	Natural gas makes up the balance of the share of the overall fuel mix, after taking account of RE, nuclear import and remaining coal	Natural gas makes up the balance of the share of the overall fuel mix, after taking account of RE, nuclear import and remaining coal	Making full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation (2)
Import of nuclear generated electricity	Maintained at the same level as in 2005	Maintained at the same level as in 2005 until 2020; meeting 35% of the local demand for electricity 2030	Nuclear electricity imported from the Mainland to meet 50% of the local demand for electricity from 2020 (2)
Renewable energy (RE) (3)	Meeting 4% of the local demand for electricity by 2020; 6% by 2030	Meeting 4% of the local demand for electricity by 2020; 15% by 2030	Meeting 3-4% of the local demand for electricity by 2020; 4% in 2030

Notes

(1) The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on international technology and policy reviews. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages, taking into account limitations, uncertainties and practicability of the measures within Hong Kong's local context.

(2) Assumptions provided by the Government.

(3) RE includes wind energy, and energy recovered from landfill gas (LFG), Integrated Waste Management Facilities (IWMF) and Organic Waste Treatment Facilities (OWTF). Scenarios 1 and 2 include RE imported from the Mainland, although the availability of this additional amount of RE sources in the neighbouring areas which may be able to supply electricity to Hong Kong in a technically feasible and cost-effective manner is subject to further studies.

3.2 MITIGATION SCENARIO ANALYSIS

This section evaluates the impact and cost-effectiveness of the three alternative scenarios by comparing their key model output with the Base Case.

The key criteria used for evaluating the policies and measures in subsequent sections by the HKMM model are categorized in the three basic types of costs and benefits:

- **Energy:** effects on energy flow and technological activities, such as oil and gas imports, electricity generation capacity mix, etc.
- **Environmental:** effects on GHG emissions and local air pollutants.
- **Economic:** effects on GDP and marginal abatement cost of carbon.

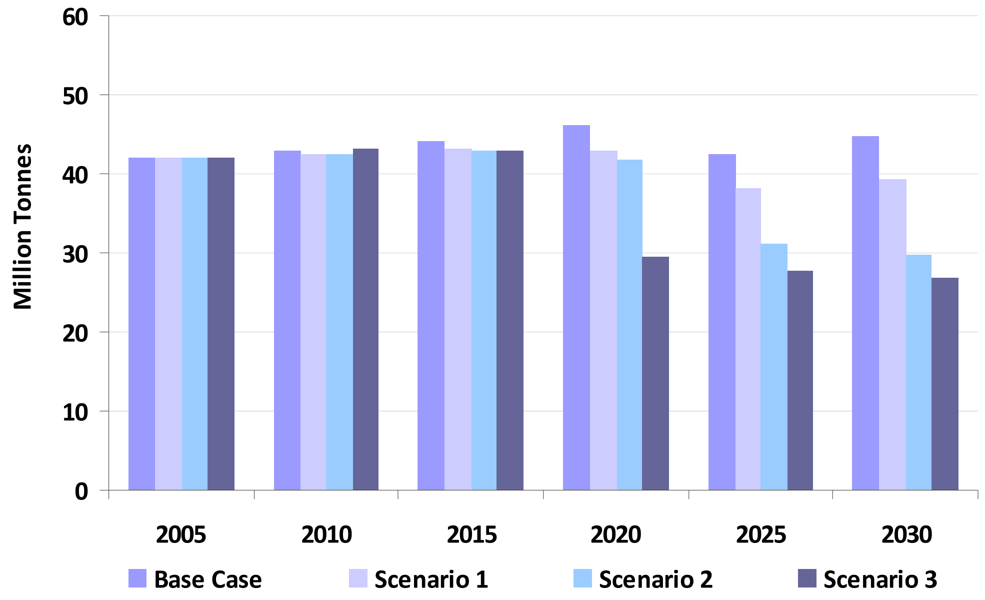
3.2.1 *Carbon Emissions Abatement and GDP Impact*

Table 3.2 and *Figure 3.1* show that the total annual carbon emission in 2030 falls to 39.3 million tonnes CO_{2-e} for Scenario 1, 29.8 million tonnes CO_{2-e} for Scenario 2, and 26.8 million tonnes CO_{2-e} for Scenario 3, down from 44.8 million tonnes CO_{2-e} projected for the Base Case. The reduced emissions in 2030 are 6%, 29% and 36% below the 2005 carbon emission level for Scenarios 1, 2 and 3, respectively. In the Base Case emissions were predicted to be 7% above the 2005 level by 2030.

Table 3.2 Carbon Emissions in Hong Kong by Scenario (Million Tonnes CO_{2-e})

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	42.0	42.8	44.1	46.1	42.6	44.8	10%	7%
Scenario 1	42.0	42.6	43.1	43.0	38.3	39.3	2%	-6%
Scenario 2	42.0	42.4	42.9	41.9	31.0	29.8	0%	-29%
Scenario 3	42.0	43.3	43.0	29.5	27.8	26.8	-30%	-36%

Figure 3.1 ***Carbon Emissions in Hong Kong by Scenario (Million Tonnes CO_{2-e})***



Results of Scenario 1 show that although co-benefits from measures targeted at improving air quality are found to be large, and may help to offset mitigation costs, they alone are unlikely to provide sufficient incentives to achieve an aggressive GHG emission reduction target.

In Scenarios 1 and 2, most of the GHG emissions reductions are achieved after 2020. This is mainly due to the fact that most of coal-fired power plant units are assumed to be decommissioned between 2020 and 2025. In Scenario 3, however, most of the GHG emission abatement is achieved between 2015 and 2020 as about half of the electricity is from nuclear sources by 2020.

The GDP is projected to grow at an annual average growth rate of 3.01% in the Base Case, and it is not predicted to be materially affected under the alternative scenarios. The annual average GDP growth rate for the period 2005 to 2030 is 0.02, 0.03, and 0.06 percentage points higher than that under the Base Case for Scenario 1, 2 and 3 respectively. These additional GDP increases are attributable to the low carbon intensities and low cost (no regret) mitigation measures included in the demand sectors (ie buildings and transport) as well as the lower energy costs in the alternative scenarios when compared with the Base Case.

3.2.2 Carbon Intensity

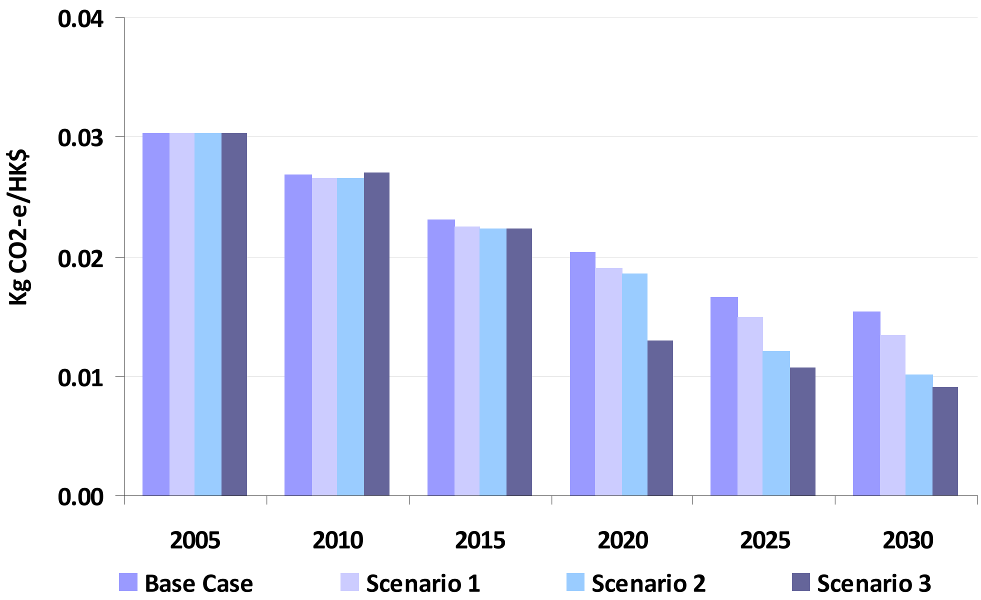
In 2005, the carbon intensities in Hong Kong, both in terms of GHG emissions per GDP value or on a per capita basis are among the lowest in the world's developed economies[58]. As shown in *Table 3.3* and *Figure 3.2*, the intensity against GDP in 2030 is projected to decrease to 0.0154, 0.0135, 0.0102, and 0.0091 kg CO_{2-e} /HK$ GDP by 2030 in the Base Case, Scenario1, Scenario 2, and Scenario 3, respectively, from the current level of 0.0304 kg CO_{2-e} /

HK$GDP. Taking into account the uncertainties of the MARKAL-MACRO model and the projection in economic output, Scenario 3 can be expected to deliver a carbon intensity reduction of 54% to 60% by 2020[59].

Table 3.3 *Carbon Intensity (GHG Emissions per unit GDP in kg CO_{2-e}/HK$)*

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	0.0304	0.0268	0.0231	0.0204	0.0166	0.0154	-33%	-49%
Scenario 1	0.0304	0.0266	0.0225	0.0190	0.0149	0.0135	-37%	-56%
Scenario 2	0.0304	0.0265	0.0224	0.0185	0.0120	0.0102	-39%	-66%
Scenario 3	0.0304	0.0271	0.0224	0.0130	0.0107	0.0091	-57%	-70%

Figure 3.2 *Carbon Intensity (GHG Emissions per unit GDP in kg CO_{2-e}/HK$)*

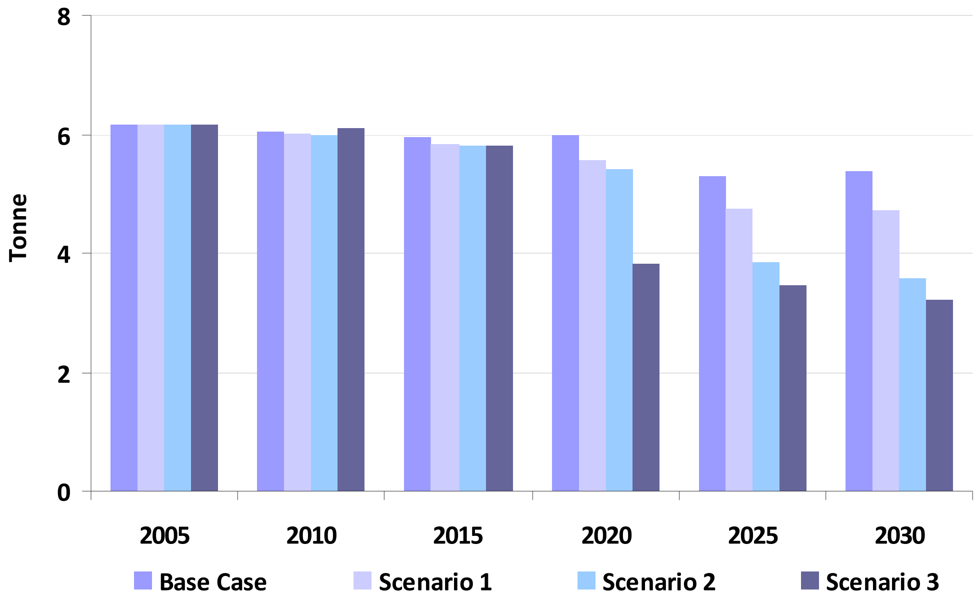


As shown in *Table 3.4* and *Figure 3.3*, the intensity of carbon emissions per capita in 2030 is projected to decrease to 5.39, 4.72, 3.58, and 3.23 tonnes CO_{2-e} in the Base Case, Scenario 1, Scenario 2, and Scenario 3, respectively, from the current level of 6.16 tonnes CO_{2-e}. Except for Scenario 3, both measures of carbon intensity are projected to drop at a faster rate between 2020 and 2025 in all cases because most of the existing coal-fired power plant units are scheduled to decommission during this period.

Table 3.4 *Carbon Emissions per Capita (Tonne CO_{2-e})*

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	6.16	6.04	5.97	5.97	5.30	5.39	-3%	-13%
Scenario 1	6.16	6.00	5.83	5.57	4.76	4.72	-10%	-23%
Scenario 2	6.16	5.98	5.80	5.43	3.86	3.58	-12%	-42%
Scenario 3	6.16	6.10	5.81	3.83	3.46	3.23	-38%	-48%

Figure 3.3 Carbon Emissions per Capita (Tonne CO_{2-e})



3.2.3 *Final and Primary Energy Demand*

Table 3.5 and *Figure 3.4* present the HKMM output of final energy demand. These values represent the energy used by various end-use devices (eg air conditioning systems and passenger cars) in the demand sectors defined in the model.

Table 3.5 Final Energy Demand (TJ)

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Commercial								
Base Case	106,222	121,193	150,122	179,315	204,768	229,371	69%	116%
Scenario 1	106,222	121,210	148,575	171,884	193,711	219,557	62%	107%
Scenario 2	106,222	121,484	149,178	172,255	195,029	222,558	62%	110%
Scenario 3	106,222	125,667	151,104	189,068	208,572	233,738	78%	120%
Residential								
Base Case	52,857	56,049	61,143	70,218	76,031	81,103	33%	53%
Scenario 1	52,857	55,435	58,853	62,771	68,302	72,140	19%	36%
Scenario 2	52,857	55,207	59,447	63,112	68,241	78,765	19%	49%
Scenario 3	52,857	56,527	59,776	67,550	71,238	79,581	28%	51%
Transportation								
Base Case	111,866	111,577	121,929	131,826	137,753	137,879	18%	23%
Scenario 1	111,866	109,782	118,351	124,894	126,216	121,580	12%	9%
Scenario 2	111,866	109,778	118,675	125,734	127,473	123,695	12%	11%
Scenario 3	111,866	110,041	118,969	127,353	128,899	124,711	14%	11%
Industrial								
Base Case	24,023	17,301	15,506	14,851	13,981	12,376	-38%	-48%
Scenario 1	24,023	17,034	15,494	14,638	13,824	12,410	-39%	-48%
Scenario 2	24,023	17,057	15,514	14,716	13,833	14,165	-39%	-41%
Scenario 3	24,023	17,999	15,683	17,885	15,926	15,252	-26%	-37%
Total								
Base Case	294,968	306,121	348,700	396,211	432,533	460,729	34%	56%
Scenario 1	294,968	303,461	341,273	374,187	402,053	425,686	27%	44%
Scenario 2	294,968	303,526	342,814	375,817	404,576	439,184	27%	49%
Scenario 3	294,968	310,234	345,533	401,857	424,636	453,282	36%	54%

Figure 3.4 ***Final Energy Demand by Scenario (Thousand TJ), 2005-2030***

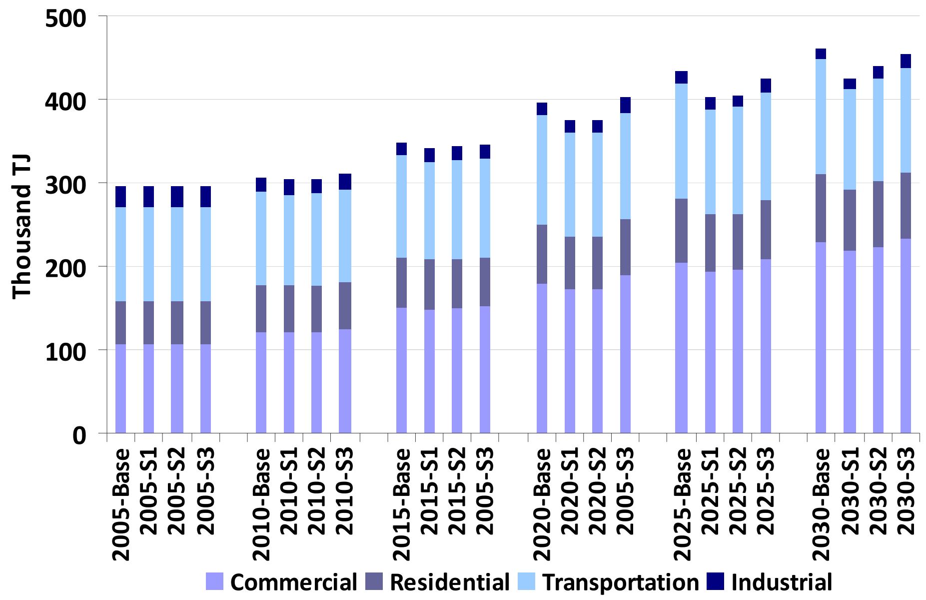


Table 3.5 and *Figure 3.4* show that the projected final demand grows more slowly in the alternative scenarios relative to the Base Case, especially in Scenarios 1 and 2, as the overall end-use efficiencies improve due to the market penetration of demand-side mitigation measures. In Scenario 3, it is projected that the energy cost will be lower than that in other scenarios. As a result, it will stimulate more economic activities not related to the energy supply sector and thus boosts the final energy demand.

Among the demand sectors, the final energy demand in the commercial sector is projected to grow at the fastest rate between 2005 and 2030 in all cases, followed by residential, transportation and the industrial sector.

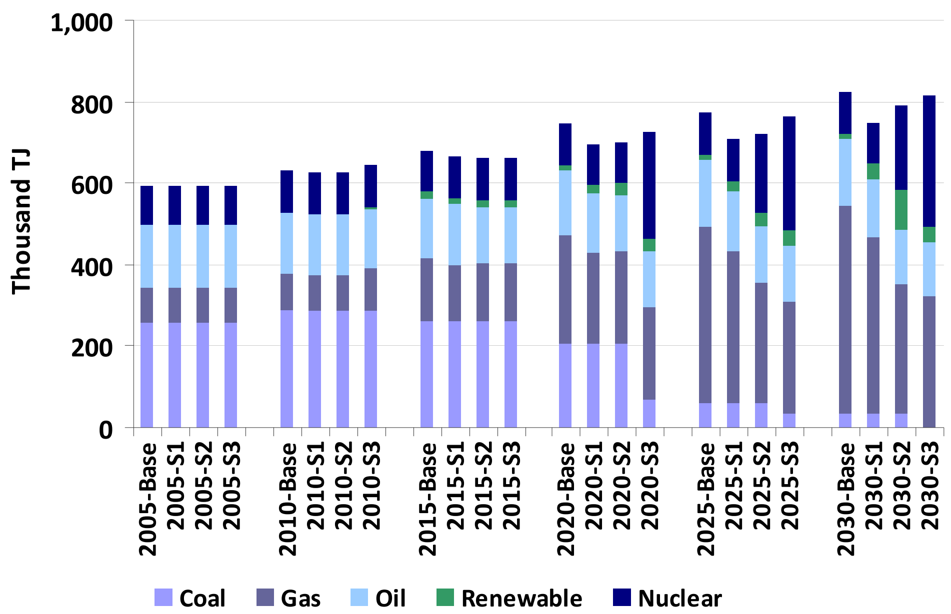
Table 3.6 and *Figure 3.5* presents the HKMM output of primary energy demand. These values represent the energy from different sources such as gas, oil, coal, renewable and nuclear electricity import.

Table 3.6 ***Primary Energy Demand (TJ)***

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Gas								
Base Case	85,732	89,776	155,174	266,099	433,244	509,361	210%	494%
Scenario 1	85,732	85,732	135,634	220,549	372,718	433,816	157%	406%
Scenario 2	85,732	85,898	141,954	227,009	295,440	317,569	165%	270%
Scenario 3	85,732	101,062	142,861	227,109	274,574	321,178	165%	275%
Oil								
Base Case	153,548	150,328	146,769	156,758	162,605	162,634	2%	6%
Scenario 1	153,548	149,366	150,727	147,631	148,017	142,640	-4%	-7%
Scenario 2	153,548	149,177	136,661	136,712	137,963	132,932	-11%	-13%
Scenario 3	153,548	149,514	137,095	137,414	139,033	133,017	-11%	-13%

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Coal								
Base Case	258,018	287,591	261,746	206,551	59,388	34,770	-20%	-87%
Scenario 1	258,018	287,591	261,746	206,551	59,388	34,770	-20%	-87%
Scenario 2	258,018	287,591	261,746	206,551	59,388	34,770	-20%	-87%
Scenario 3	258,018	287,591	261,746	67,830	34,770	45	-74%	-100%
RE								
Base Case	1,867	2,165	13,736	13,980	14,182	14,325	649%	667%
Scenario 1	1,867	2,165	13,762	21,005	24,990	35,584	1025%	1806%
Scenario 2	1,867	2,183	17,994	29,045	35,028	98,022	1456%	5151%
Scenario 3	1,867	2,183	18,004	29,128	35,361	38,024	1460%	1937%
Nuclear								
Base Case	92,436	101,398	101,398	101,398	101,398	101,398	10%	10%
Scenario 1	92,436	101,398	101,398	101,398	101,398	101,398	10%	10%
Scenario 2	92,436	101,398	101,398	101,398	194,758	205,157	10%	122%
Scenario 3	92,436	101,398	101,398	263,921	278,303	321,755	186%	248%
Total								
Base Case	591,601	631,258	678,823	744,786	770,817	822,488	26%	39%
Scenario 1	591,601	626,252	663,267	697,134	706,511	748,209	18%	26%
Scenario 2	591,601	626,247	659,752	700,716	722,577	788,450	18%	33%
Scenario 3	591,601	641,748	661,105	725,402	762,041	814,018	23%	38%

Figure 3.5 ***Primary Energy Demand by Scenario (Thousand TJ), 2005-2030***



Currently, coal has the largest share in the total primary energy supply. This share is expected to drop sharply beginning in 2025 when almost all coal-fired power plants are scheduled to have been decommissioned. Except in Scenario 3, natural gas is projected to account for the largest share in all cases due to the increased use of combined cycle gas turbines for electricity generation. In Scenario 3, the nuclear electricity import from China is projected to account for approximately 40% of the total primary energy consumption beginning in 2020[60].

Except for Scenario 3, it is assumed that all power plants retire according to their expected life. In Scenario 3, electricity from coal-fired power plants accounts for approximately 10% of the total electricity demand in 2020, and no coal-fired power units will be used in 2030. As coal will be replaced by RE or nuclear sources, carbon emissions and intensities are predicted to be further reduced in Scenario 3.

3.2.4 Energy Intensity

The three mitigation scenarios represent a progressively increasing use of low carbon energy sources on the supply side (including electricity generation) and more efficient end-use devices on the demand side. As a result, both primary energy consumption and final energy use decrease relative to the Base Case. *Table 3.7* and *Figure 3.6* depict the decreasing trend of the primary energy intensity relative to the GDP. In general, this intensity is lower in the alternative scenarios according to their level of market penetration of more efficient energy technology/devices.

Table 3.7 Primary Energy Intensity (TJ per Billion HK$)

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	428	395	355	330	300	283	-23%	-34%
Scenario 1	428	392	347	308	275	257	-28%	-40%
Scenario 2	428	392	345	309	280	269	-28%	-37%
Scenario 3	428	401	344	319	293	276	-25%	-35%

Figure 3.6 Primary Energy Intensity (TJ per Billion HK$)

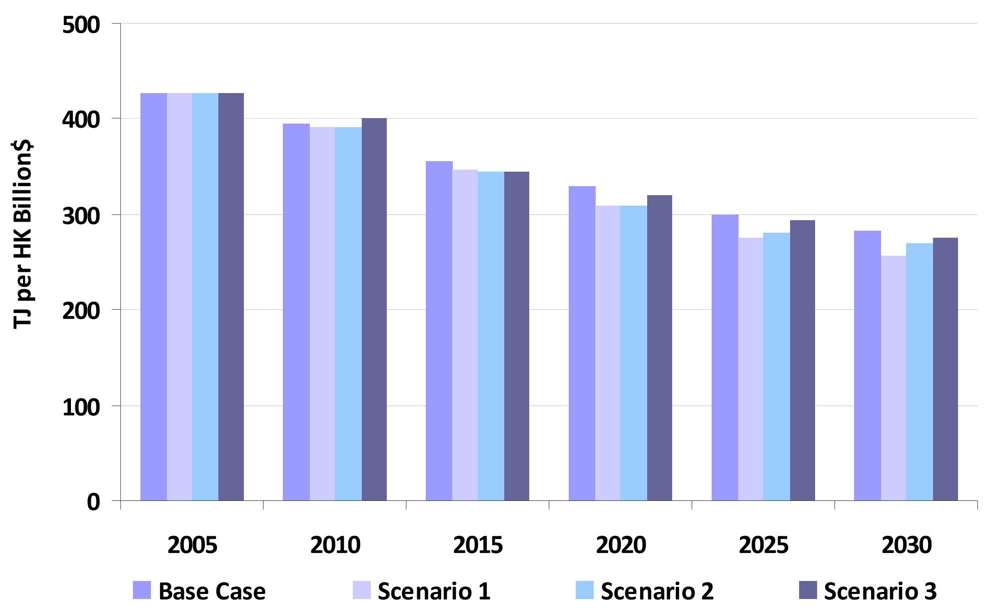


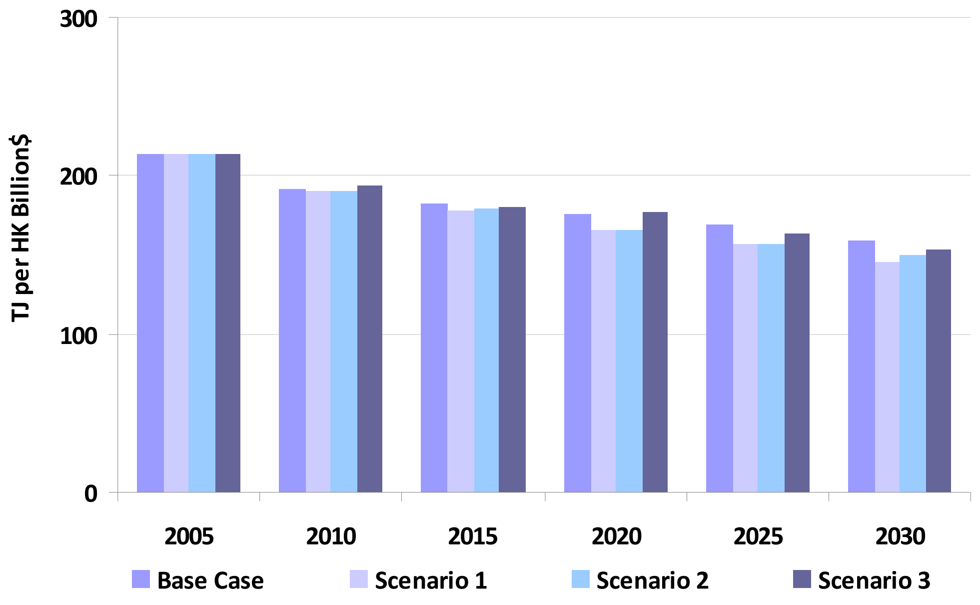
Table 3.8 and *Figure 3.7* d epict a similar trend for final energy use. The energy intensity in Scenario 3 is higher than that of Scenarios 1 and 2. Again, this is attributable to the lower marginal energy costs and thus higher energy demand in Scenario 3 as discussed in Section 3.2.3.

The ratio of the final energy intensity to the primary energy intensity represents the overall energy system efficiency in converting primary energy resources to useful energy for end-uses, which improves from about 50% in 2005 to approximately 56% in 2030 for all cases[61].

Table 3.8 ***Final Energy Intensity (TJ per Billion HK$)***

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	213	192	182	175	168	159	-18%	-26%
Scenario 1	213	190	178	165	156	146	-22%	-32%
Scenario 2	213	190	179	166	157	150	-22%	-30%
Scenario 3	213	194	180	177	163	154	-17%	-28%

Figure 3.7 ***Final Energy Intensity (TJ per Billion HK$)***



3.2.5 *Electricity Output*

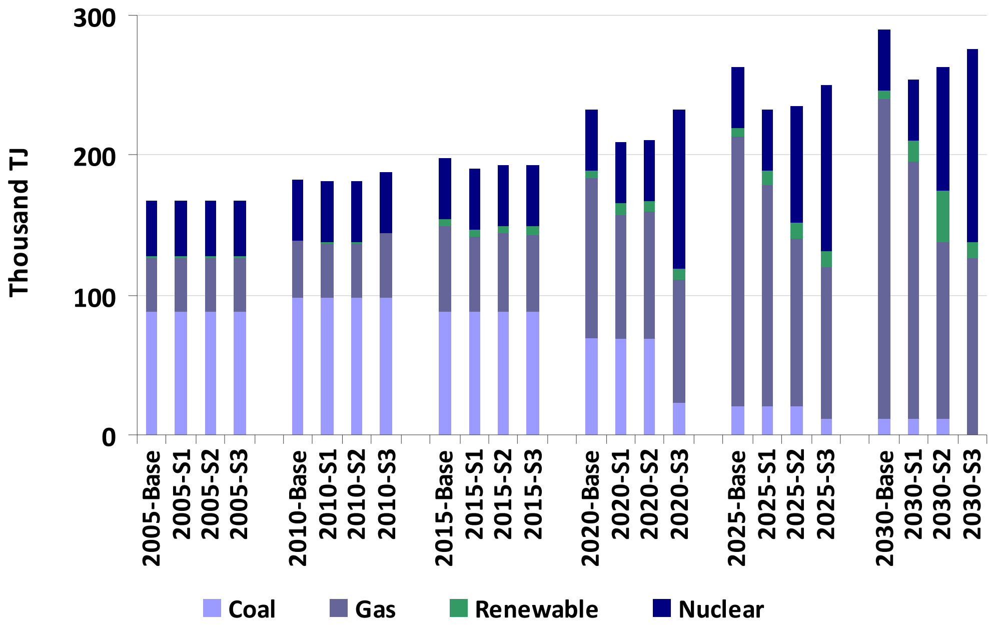
In Hong Kong, electricity is the dominant energy carrier, accounting for more than 50% of the final energy use in 2005. This share is projected to increase to over 60% in 2030 in the Base Case. The future may see two opposing trends: on the one hand, more efficient end-use devices reduce electricity demand, whereas new electricity-using devices such as electric cars may be introduced to replace conventional gasoline vehicles, as assumed in the three mitigation Scenarios, thereby increasing the electricity use in the transportation sector.

Table 3.9 and *Figure 3.8* present the electricity output by source as well as the fuel mix in 2020 and 2030 for different scenarios. In 2005, coal has the largest share and generates about 50% of electricity in Hong Kong. Under the Base Case, natural gas will progressively replace coal and generate approximately 80% of the electricity in 2030. In the Base Case, the use of natural gas will be 5 times greater in 2030 than that in 2005 for electricity generation. Under Scenario 3, no coal will be used for electricity generation in 2030. Natural gas used for electricity generation doubles in 2020, and almost triples in 2030, compared to the quantity used in 2005. Electricity from natural gas is projected to grow to 40% of the total. Electricity from renewable energy produced locally is expected to grow from less than 1% in 2005 to 4% of the total in 2030. Electricity from nuclear sources in the Mainland China in 2030 is expected to be more than three times the quantity used in 2005. It is projected to account for approximately half of the electricity usage beginning in 2020.

Table 3.9 Electricity Output by Source (TJ)

	2005	2010	2015	2020	2025	2030	Fuel mix in 2020	Fuel mix in 2030
Natural Gas								
Base Case	39,148	40,994	61,936	114,274	193,716	228,701	49%	79%
Scenario 1	39,148	39,148	53,640	88,280	158,516	183,962	42%	72%
Scenario 2	39,148	39,224	56,461	90,796	121,036	125,573	43%	48%
Scenario 3	39,148	46,147	56,000	87,905	108,599	125,957	38%	46%
Coal								
Base Case	87,656	97,801	87,501	69,080	19,936	11,811	30%	4%
Scenario 1	87,656	97,801	87,501	69,080	19,936	11,811	33%	5%
Scenario 2	87,656	97,801	87,501	69,080	19,936	11,811	33%	4%
Scenario 3	87,656	97,801	87,501	22,811	11,811	0	10%	0%
RE								
Base Case	778	902	5,253	5,354	5,439	5,498	2%	2%
Scenario 1	778	902	5,264	8,364	10,069	14,607	4%	6%
Scenario 2	778	902	5,253	7,954	10,532	37,631	4%	14%
Scenario 3	778	902	5,253	7,954	10,639	11,898	3%	4%
Nuclear								
Base Case	39,604	43,444	43,444	43,444	43,444	43,444	19%	15%
Scenario 1	39,604	43,444	43,444	43,444	43,444	43,444	21%	17%
Scenario 2	39,604	43,444	43,444	43,444	83,444	87,899	21%	33%
Scenario 3	39,604	43,444	43,444	113,077	119,239	137,856	49%	50%
Total								
Base Case	167,186	183,142	198,134	232,152	262,535	289,454		
Scenario 1	167,186	181,295	189,849	209,169	231,965	253,824		
Scenario 2	167,186	181,371	192,659	211,274	234,948	262,915		
Scenario 3	167,186	188,295	192,198	231,747	250,288	275,711		

Figure 3.8 Electricity Output by Source (Thousand TJ)



3.2.6 *Reduction in Other Air Pollutants from Power Generation*

There is a potentially large and diverse range of co-effects from climate change mitigation policies, which lower the net costs of emission reductions and thereby may strengthen the incentives to reduce emissions. Many recent studies have demonstrated significant benefits of carbon-mitigation strategies on human health, mainly because they also reduce other airborne emissions, for example, SO_2, NO_x and particulate matter. This is projected to result in the prevention of some premature deaths due to air pollution. Quantification of mortality risks remains controversial, and hence a large range of benefits estimates can be found in the literature[62].

In the HKMM model, we have built in the emission coefficients for SO_2, NO_x, and PM_{10} for power plants. Based on the projected fuel use by the sector to meet demand at market equilibrium, the model is able to account for the total emissions for these air pollutants, as shown in *Table 3.10*, *Table 3.11, and Table 3.12.*

Table 3.10 Sulphur Dioxide from Electricity Generation (Thousand Tonnes)

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	61.5	60.0	19.2	11.1	4.8	4.3	-82%	-93%
Scenario 1	61.5	60.0	19.2	11.0	4.6	4.1	-82%	-93%
Scenario 2	61.5	60.0	19.2	11.0	4.5	3.8	-82%	-94%
Scenario 3	61.5	60.0	19.2	5.0	3.8	0.6	-92%	-99%

Figure 3.9 Sulphur Dioxide from Electricity Generation

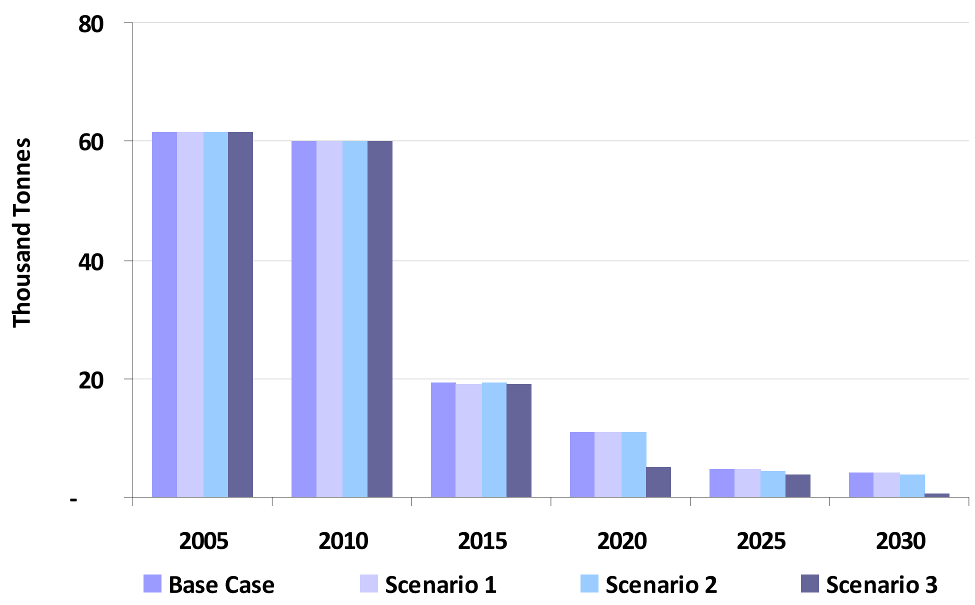


Table 3.11 Nitrogen Oxides from Electricity Generation (Thousand Tonnes)

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	42.2	44.4	38.0	34.6	24.5	24.3	-18%	-42%
Scenario 1	42.2	44.3	37.2	32.7	21.4	20.4	-23%	-52%
Scenario 2	42.2	44.3	37.4	34.4	18.2	15.5	-19%	-63%
Scenario 3	42.2	44.6	37.5	16.8	14.1	10.6	-60%	-75%

Figure 3.10 Nitrogen Oxides from Electricity Generation

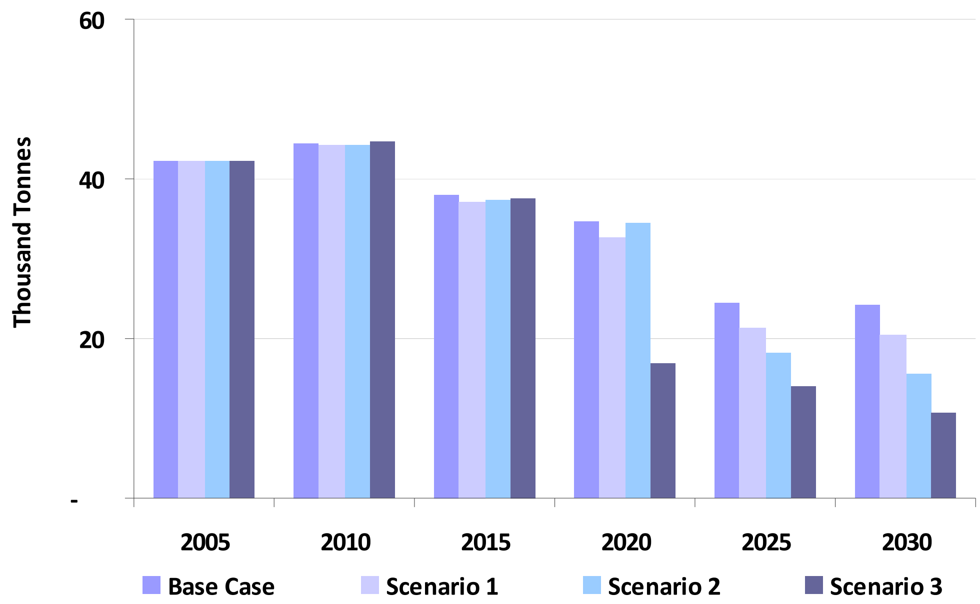
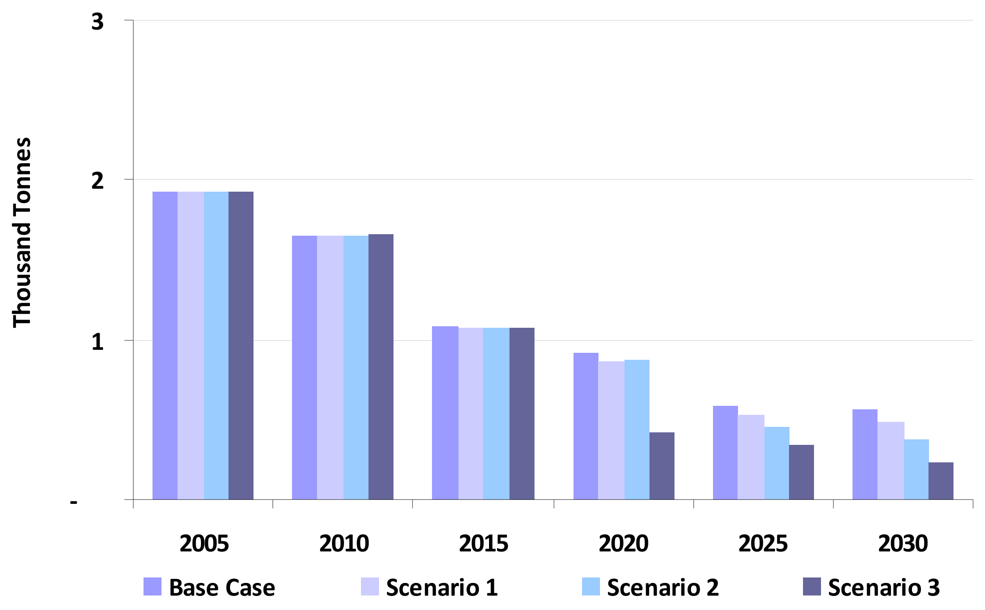


Table 3.12 Particulates (PM10) from Electricity Generation (Thousand Tonnes)

	2005	2010	2015	2020	2025	2030	2020 vs. 2005	2030 vs. 2005
Base Case	1.9	1.7	1.1	0.9	0.6	0.6	-52%	-70%
Scenario 1	1.9	1.6	1.1	0.9	0.5	0.5	-55%	-75%
Scenario 2	1.9	1.6	1.1	0.9	0.5	0.4	-55%	-80%
Scenario 3	1.9	1.7	1.1	0.4	0.3	0.2	-78%	-88%

Figure 3.11 Particulates (PM_{10}) from Electricity Generation



Compared with the Base Case for the year 2005, the results show that in 2030:

- Sulphur dioxide emissions reduce by 93%, 94%, and 99% in Scenarios 1, 2, and 3, respectively;
- Nitrogen oxides emissions reduce by 52%, 63%, and 75% in Scenarios 1, 2, and 3, respectively;
- PM_{10} emissions reduce by 75%, 80%, and 88% in Scenarios 1, 2, and 3, respectively[63].

These estimates should be used for indicative purposes only and have the following limitations:

- The estimates are based on the average emission rates for the existing assets and are not responsive to the change due to future decommissioning of individual units.
- The exact operation and fuel use by each unit in the future cannot be reliably determined.

3.2.7 *Carbon Tax*

The marginal abatement cost curves compare mitigation scenarios with the Base Case and quantify benefits of mitigation policies and measures in terms of their relative emission control costs. For this purpose, we applied a carbon tax schedule ranging from HK$500/tonne to HK$5,000/tonne of carbon to all the three scenarios (HK$5,000/tonne of carbon is close to US$175/tonne $CO_{2\text{-}e}$[64]). This range encompasses the range of historical and projected prices of carbon credits traded in the international market. The tax rate represents the marginal cost of reducing carbon at the corresponding carbon emission level obtained at the market equilibrium.

Marginal Abatement Cost Curves

The marginal abatement cost (MAC) curves characterize the cost related response of an energy market to attain a specific carbon emission target. Lower MAC curves imply that higher abatement potential can be achieved at a lower cost. On the other hand, higher MAC curves are associated with scenarios in which technologies to reduce carbon (through efficiency improvement or fuel substitution) are not available or costly.

MAC curves in *Figure 3.12* and *Figure 3.13* depict the carbon emissions reduction potential for various levels of carbon tax in 2030, in an attempt to bring down 2030 emissions to below the 2005 level. It clearly shows that the marginal cost of reducing carbon at a given level below the 2005 emission is the lowest in Scenario 3. The same costs for Scenarios 1 and 2 lie in between that of the Base Case and Scenario 3. It should be noted here that the extension of the MAC curve for the Base Case might never reach the abatement potentials achieved in the mitigation scenarios, indicating that such abatement goals are either technically unfeasible or economically unsustainable under the definition of the Base Case.

The stiffness of the slopes shown in these MAC curves reflect the rigidity of the energy system represented in the Base Case and the mitigation scenarios, while responding to further carbon emission reductions from their initial equilibrium positions (ie no carbon tax), since most of the mitigation policies and measures proposed in this study are defined with fixed market penetration, energy targets, or market shares. Further reduction potentials from these initial positions (shown in *Figure 3.12* and *Figure 3.13*) are largely generated from economic feedback on reduction in energy service demands and hence, affecting GDP due to increased energy cost with carbon taxes. Also, as the energy cost is lower in alternative scenarios, the effect of applying a tax on carbon is further reduced. The initial equilibrium positions of these MAC curves provide key information for Hong Kong SAR Government to formulate and adopt mitigation policies and measures, and decide on reduction targets.

Figure 3.12 MAC Curves- % Difference in 2030 Emissions from 2005 Levels

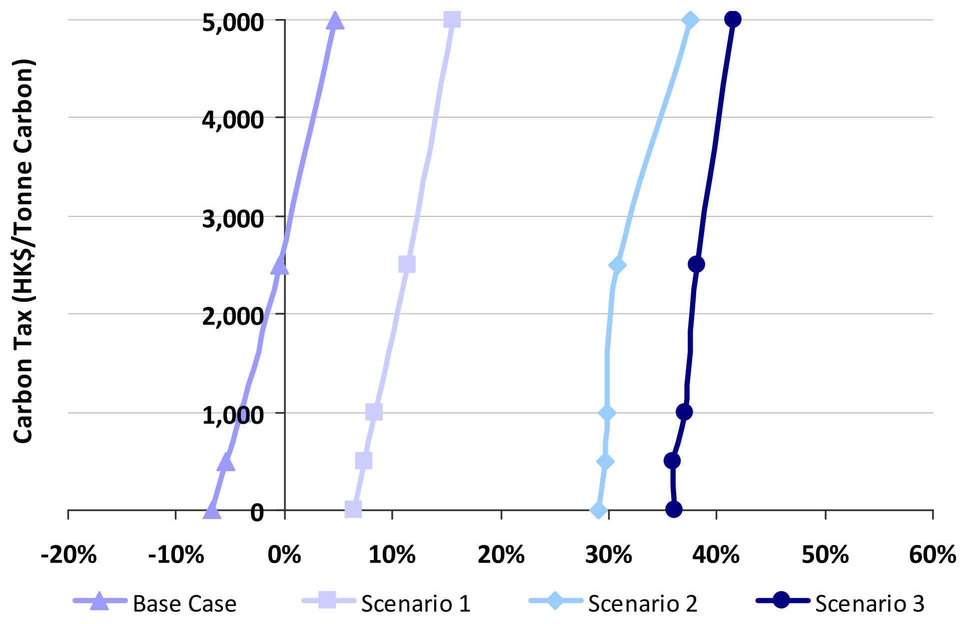
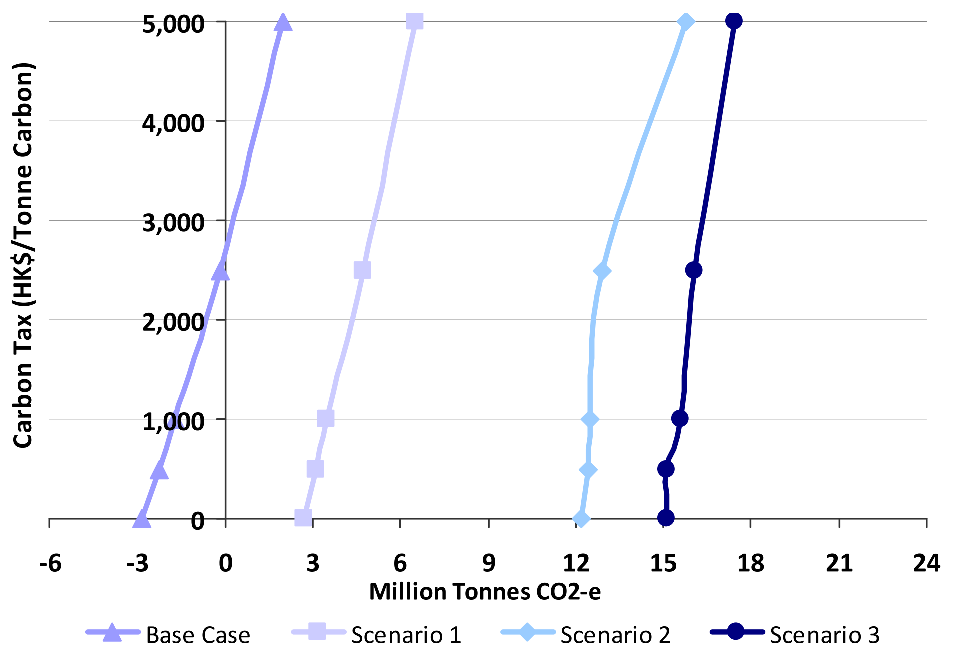


Figure 3.13 MAC Curves- Emission Reduction in 2030 from 2005 Levels (Million Tonnes $CO_{2\text{-}e}$)



3.2.8 *Scenario Analysis by Mitigation Sectors*

This section evaluates the carbon abatement potentials and costs of mitigation in particular sectors (ie building, transport, electricity generation, and waste) for all three alternative scenarios in addition to those in the Base Case. This is achieved by performing a static comparative analysis on the MARKAL Model results obtained under partial equilibrium of the energy market. Carbon emissions and associated energy system costs for each sector in all three scenarios are compared to the Base Case to evaluate each sector's abatement potential and the average cost per metric tonne of carbon emissions to realize this potential[65]. *Figure 3.14* presents the carbon emission reduction potentials in 2020 and 2030 for Scenarios 1, 2 and 3 relative to the Base Case. *Table 3.13* details the emission reduction potentials and average costs in 2030 by mitigation group.

Figure 3.14 ***Additional Carbon Abatement Potential by Sector by Scenario (Thousand Tonnes CO_{2-e})***

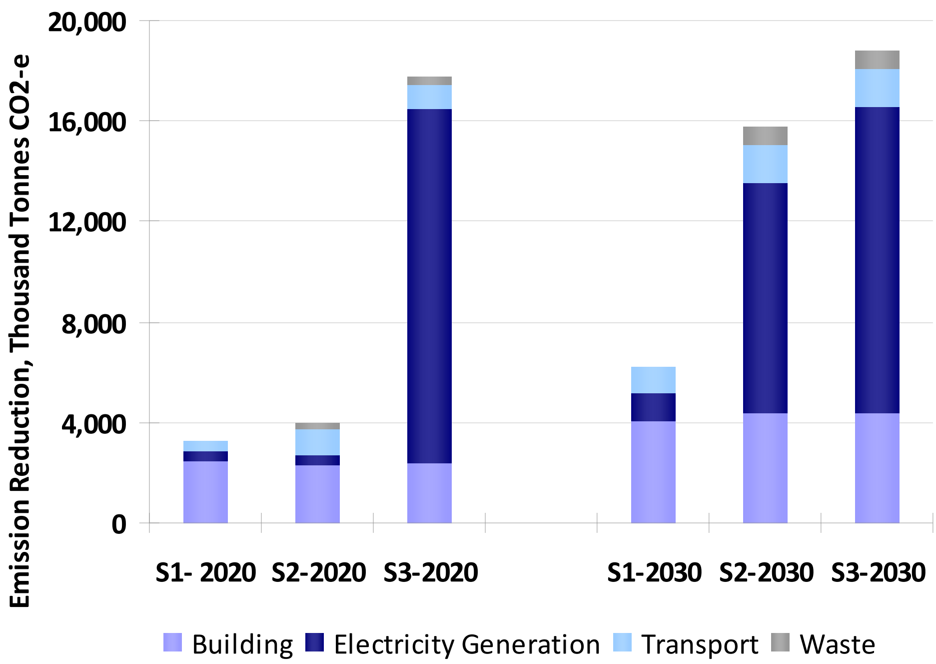


Table 3.13 ***Additional Carbon Abatement Potentials and Average Costs by Sector by 2030***

	Scenario 1		Scenario 2		Scenario 3	
	Cost (HK$/tonne CO_{2-e})	Potential (Thousand tonnes CO_{2-e})	Cost (HK$/tonne CO_{2-e})	Potential (Thousand tonnes CO_{2-e})	Cost (HK$/tonne CO_{2-e})	Potential (Thousand tonnes CO_{2-e})
Buildings	-487	4,039	-505	4,351	-505	4,351
Energy Supply	-303	1,159	-150	9,200	-167	12,244
Transport	-1,226	983	-1,007	1,517	-1,007	1,517
Waste	0	0	-747	725	-749	725

By 2030, the additional abatement potential in the buildings sector is projected to reach 4,039 thousand tonnes CO_{2-e} in Scenario 1 and 4,351 thousand tonnes CO_{2-e} in Scenarios 2 and 3, at average reduction costs per tonne CO_{2-e} of HK$-487 and HK$-505 respectively (benefits), compared with the Base Case. Most measures proposed in the building sector are "no regret" policies. The energy generation sector shows the largest abatement potential, estimated to reduce 9,200 thousand tonnes CO_{2-e} in Scenario 2 and 12,244 thousand tonnes CO_{2-e} in Scenario 3. As the energy cost in the Base Case is higher than that of the energy systems in alternative scenarios, accelerated use of more renewable technologies and imports does not result in higher abatement costs. The transport sector abatement potential is estimated at 983 and 1,517 thousand tonnes CO_{2-e} in Scenarios 1 and 2, respectively. However, this relatively modest potential can be realized at great benefit (negative costs) of HK$1,226, and HK$1,007 per tonne CO_{2-e}.

It is important to note that the abatement potentials calculated for each sector are not to be used to estimate the total system abatement potential. This is due to the fact that static comparative analysis does not catch the potential offsets (or synergies) among sectors and various sub-sectors. For example, a reduction in electricity demand in the buildings sector also reduces the size of the electricity market and hence, the abatement potential of the supply group. Another limitation of the static comparative analysis arises from that fact that mitigation measures in one sector may require the synergy provided from measures in another sector. For example, in the transportation sector in Scenario 3, the measures to switch all passenger cars and taxis to electric vehicles would increase electricity supply. This increase would result in a net increase in carbon emissions unless it is met by renewable or imported nuclear electricity instead of the gas combined cycles (a synergy required from the supply sector).

While the relative cost (or benefit) of abatement potential by sector calculated in this section provides a general guidance for prioritizing program implementation, the absolute quantities presented here are not to be used without careful interpretation from the perspective of policy making.

3.2.9 Limitations and Challenges of the HKMM Modelling Methodology

The HKMM model developed for this study represents the detailed energy and environmental system of the HKSAR, which facilitates the evaluation of GHG abatement potentials under various mitigation scenarios. The model measures the impact of alternative energy system development pathways determined under each scenario on economic growth, in terms of GDP changes. Even though the model's results and analysis presented in this section exhibit its diverse capability in achieving the objectives of the study, there are limitations and challenges to the approach that need further attention to refine and expand its current structure/approach. We outline the main limitations and challenges below.

- The current structure of HKMM confines the analysis of GHG mitigation impacts strictly within the Hong Kong SAR. A better coordination of joint analysis and implementation of these measures can be accomplished in a multi-regional MARKAL model framework.

- The embodied energy and GHG that are crucial to the manufacture and transportation of various consumer and industrial products and materials (eg cement) imported to the HKSAR are not considered in the HKMM. Additional mitigation measures (eg imports of green products and conservation of material use) need to be addressed to expand the abatement potential in Hong Kong SAR and beyond.

- Not all economic benefits can be reflected in the Model. For instance, green jobs can be created when renewable energy plants are built, but it is difficult to quantify and forecast the associated economic benefit. Also, the assessment doesn't quantify the energy reduction potential from changes of consumer habits.

- The impact of mitigation measures on consumer inflation and business costs is not quantified in the Model. In the short and medium term, inflation and business costs may be affected by the energy prices and investment costs. However, they are also influenced by a variety of factors such as relative elasticity of wages, interest rates, and growth rate of money supply.

- Normal climate conditions were assumed in the energy use projection. Should the prevailing temperatures change as a consequence of climate changes, the final energy demand might be different. For example, higher temperatures implies higher energy demands for cooling and hence an increase in carbon emissions.

- The assumptions and model outputs are not intended to represent very accurate projections. The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatement. Measures and assumptions in mitigation scenarios are based on an international technology and policy review. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at a later stage.

3.3 *CONCLUSION*

The Study examines three scenarios for the mitigation analysis quantitatively.

Scenario 1 (the 'AQO Scenario') includes relevant mitigation measures proposed in the AQO Study, including the increased use of natural gas and renewable energy sources for electricity generation, wider use of road vehicles using clean fuels, and enhanced energy efficiency in the building and appliance sector.

Scenario 2 (the 'Accelerated Scenario') builds upon Scenario 1 and includes additional efforts on measures to increase energy efficiency and reduce energy demand, particularly in the building and transport sectors. Local sources of renewable energy such as waste-to-energy facilities are utilised by 2020. This scenario also assumes a certain level of integration of the power system between Hong Kong and its neighbouring areas. Electricity imported from Mainland China in 2020 is the same as that in 2005. In 2030, the scenario assumes that approximately 50% of the electricity used has no associated carbon emissions[66], and is either locally produced or imported from the Mainland.

Scenario 3 (the 'Aggressive Scenario') builds upon Scenario 2 and accelerates the integration of the power system in Hong Kong with its neighbouring areas. It assumes that Hong Kong would make full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation, for electricity generation in 2020. It also assumes that nuclear electricity imported from the Mainland in 2020 would be able to meet 50% of the local demand for electricity.

Details of GHG emissions reduction measures in each of the scenarios are set out in *Section 3.1*. Results for the Base Case and three alternative scenarios are detailed under *Section 3.2*. Due to the uncertainties of the projections, key results are presented in ranges in *Table 3.14*.

Table 3.14 Summary Table for Base Case, Scenarios 1, 2 and 3

	Base Case		Scenario 1		Scenario 2		Scenario 3	
	2020	**2030**	**2020**	**2030**	**2020**	**2030**	**2020**	**2030**
Fuel Mix – Electricity Output (%)(1)								
Natural Gas	46-52%	76-82%	39-45%	69-75%	40-46%	45-51%	35-41%	43-49%
Coal	27-33%	1-7%	30-36%	2-8%	30-36%	1-7%	7-13%	0-3%
RE	0-5%	0-5%	1-7%	3-9%	1-7%	11-17%	0-6%	1-7%
Nuclear	16-22%	12-18%	18-24%	14-20%	18-24%	30-36%	46-52%	47-53%
Carbon Emission Reduction - Compared with 2005 (%)(1)	7-13% Increase	4-10% Increase	1% reduction - 5% increase	3-9%	3% reduction - 3% increase	26-32%	27-33%	33-39%
Carbon Intensity Reduction– Compared with 2005 (%)(1)	30-36%	46-52%	34-40%	53-59%	36-42%	63-69%	54-60%	67-73%

Note:
(1) Based on -3%/+3% from the outputs

The low carbon intensities in Hong Kong SAR provide significant potential in abating carbon emissions from the energy sector with a very small impact on the SAR's economic growth. These reduced emission levels in 2030 amount to 3-9%, 26-32% and 33-39% % below the 2005 carbon emission level for Scenarios 1, 2 and 3 respectively, whereas 2030 emissions are 4-10% above the 2005 level in the Base Case. GDP is project to grow at an annual average growth rate of 3.01% in the Base Case, and it is not predicted to be materially affected under the alternative scenarios[67]. The findings of the Mitigation Assessment indicate that it is possible to achieve the National Target (reduction of 40% - 45% of CO_2 per unit of GDP by 2020) by the implementation of the mitigation measures recommended in Scenario 3.

In the power sector, the use of coal currently contributes to more than half of the total carbon emission from the energy sector. This provides a good potential in reducing carbon emissions as the coal-fired units are decommissioned progressively over the next 20 years. The building sector in Hong Kong consumes more than half of the final energy – a significant market potential in which low cost policies and measures are available to reduce energy use with net economic benefits. Implementation of energy demand side measures may require new or updated legislation, on matters such as energy efficiency standards for buildings, electrical appliances, motor fuel standards etc.

The Study also discussed mitigation policies and options that are not readily quantifiable. They can help to further reduce carbon emissions. Further studies should be carried out to establish the technical feasibility and cost-effectiveness of these options for the implementation within HKSAR.

[1] IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[2] http://www.devb.gov.hk/en/publications_and_press_releases/publications/environmental_report/2008_environmental _report/2008_er_full_er/index.html

[3] IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[4] IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[5] IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[6] Julia King, *The King's Review of low carbon cars, 2007 (*http://www.hm-treasury.gov.uk/king (accessed Sep 3 2009))

[7] According to Transport and Housing Bureau.

[8] http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/old_diesel_com_veh_replace_ prog.html#special_arrangement

[9] http://www.arb.ca.gov/ba/fininfo.htm

[10] http://www.ec.gc.ca/cleanair-airpur/Sustainable_Transportation/Vehicle_Scrappage_Program-WSF8711200-1_En.htm

[11] http://www.polb.com/civica/filebank/blobdload.asp?BlobID=6344

[12] http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3468

[13] http://www.polb.com/economics/contractors/rfq_rfp/proposals.asp

[14] http://www.portseattle.org/downloads/community/environment/NWCleanAirStrat_200712.pdf

[15] http://www.stwr.org/climate-change-environment/co2-output-from-shipping-twice-as-much-as-airlines.html (accessed Oct 9 2009)

[16] International Marine Organization, *Second IMO GHG Study*, 2009.

http://www.imo.org/includes/blastDataOnly.asp/data_id%3D26046/4-7.pdf (accessed in Oct 17 2009)

[17] Galbraith V., Curry L., Loh C., "Green Harbours: Hong Kong and Shenzhen, Reducing Marine and Port-related emissions", 2008.

[18] Agreement No CE 57/2006 (EP) Review of Air Quality Objectives and Development of a Long Term Air Quality Strategy for Hong Kong - Feasibility Study, Final Report, 2009

19 Wickrama, U.K., Henderson, S.C., Vedantham, A., et al. (1999) Chapter 9 Aircraft Emissions: Current Inventories and Future Scenarios. *Aviation and the Global Atmosphere. Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press

20 IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

21 IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

22 HAS is a wholly owned subsidiary of Cathay Pacific airways at Hong Kong International Airport (HKIA).

23 IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

24 IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

25 All three strategic landfills have been partially utilising landfill gas for energy production and NENT has also been using landfill gas for Towngas production.

26 http://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/WFdev_IWMF.html

27 http://www.legco.gov.hk/yr08-09/english/fc/pwsc/papers/p09-16e.pdf

28 IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

29 CLP's presentation on 2 July 2009 "CLP's Proposed Offshore Wind Farm – A World Landmark Renewable Energy Project"

30 http://www.house-energy.com/Wind/Costs-Wind.htm#; http://www.wind-energy-the-facts.org/en/part-3-economics-of-wind-power/chapter-2-offshore-developments/

31 http://www.hongkongoffshorewind.com/TheProject.html

32 "Natural Gas in China Market Evolution and Strategy", IEA, June 2009.

33 IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

34 Lawrence Berkeley National Laboratory, *Best Practices Guide: Monitoring, Evaluation, Reporting, Verification, and Certification of Climate Mitigation Projects*, 2000.

35 OECD, *The Economics of Climate Change Mitigation: Policies and Options for the Future*, Economics Department Working Paper No. 658, 2008.

36 IEA, *Experience Curves for Energy Technology Policy*, Paris, 2000.

37 OECD, *The Economics of Climate Change Mitigation: Policies and Options for the Future*, Economics Department Working Paper No. 658, 2008.

38 http://www.info.gov.hk/gia/general/200901/09/P200901090139.htm

[39] Stern, N., *The Economics of Climate Change: The Stern Review*, 2007.

[40] Johnstone, N., I. Hascic and D. Popp, "Renewable Energy Policy and Technological Innovation: Evidence Based on Patent Counts", *NBER Working Paper* No. 13760, 2008.

[41] http://www.devb.gov.hk/en/secretary/press/press20090622.htm

[42] As the local carbon emission factor of water is not available, average emission factor from the Carbon Trust was used to estimate the reduced emissions (emission factor is around 0.271 kg CO2/m3 for water, and 0.476 kgCO2/m3 for wastewater). 236 million m3 * (0.271+0.476) = 176,292 tonnes CO2-e, which is approximately 0.4% of total emissions in 2030.

[43] UNFCCC, *Reporting on Climate Change: user manual for the guidelines on national communications from non-Annex I Parties*, 2003. http://unfccc.int/files/essential_background/application/pdf/userman_nc.pdf (accessed Oct 9 2009)

[44] www.etsap.org

[45] *Operation and Development of the Hong Kong MARKAL-MACRO Model Instruction Order 01: Updating HKMM, Version 1.0*, January 13, 2005, Tsinghua University

[46] Energy Environment Economy Research Institute, Tsinghua University, for Environmental Protection Department, HKSAR, *Operation and Development of the Hong Kong MARKAL-MACRO Model Instruction Order 01: Updating HKMM, Version 1.0*, 2005.

[47] The GDP projection and impact evaluated by the models is on the basis of real terms.

[48] The purpose of the Study is to assess the impacts of various mitigation measures and scenarios on GHG emission abatements. Measures and assumptions in mitigation scenarios are based on some international technology and policy reviews. They are not implementation targets, but provide an envelope within which the impacts of alternative assumptions can be inferred. Detailed feasibility studies for individual measures are required at later stages, taking into account limitations, uncertainties and practicability of the measures within Hong Kong's local context.

[49] Review of Air Quality Objectives and Development of a Long Term Air Quality Strategy for Hong Kong, July 2009.

[50] All energy saving information is based on the AQO Study assumptions.

[51] In 2005 the First Sustainable Development Strategy sets a target of 1~2% RE in electricity use by 2012. The assumption made for 2020 and 2030 does not reflect the actual availability of RE in the neighbouring areas for consumption in Hong Kong.

[52] This excludes remaining coal power plant generation. Among the 50% electricity with no associated carbon emissions, 35% is from import of nuclear generated electricity.

[53] All petrol contains a mixture of 10% ethanol by volume. Blends of ethanol above 10% are assumed to need engine modification.

[54] B10 Biodiesel, is comprised of a "blend" of 10% Biodiesel and 90% petroleum diesel. Blends biodiesel above 10% might need engine modification.

[55] OWTFs have not been modelled in the HKMM.

[56] According to the report "中国2050年低碳情景和低碳发展之路." released by the Energy Research Institute of NDRC in 2009, the ratio of no carbon emissions electricity from renewable sources (except hydropower) and nuclear power will be around 3:7 at national level by 2030. While this ratio will be used as assumption in this modelling exercise, it is not suggesting that the ratio is valid for Hong Kong's neighbouring areas which may be supplying additional electricity to Hong Kong in a technically feasible and cost-effective manner.

[58] http://www.iea.org/country/maps/world/co2_pop.htm; http://www.iea.org/country/maps/world/co2_gdp.htm (accessed on Oct 8 2009)

[59] The national carbon intensity target refers to the energy related CO_2 per GDP value, while the domestic carbon intensity for Hong Kong refers to total GHG emissions per GDP value. Hong Kong will control GHG emissions from all sources, including non-energy related carbon emissions such as methane from landfills, and thus the carbon intensity target includes all types of GHG emissions.

[60] The fossil fuel equivalent of electricity generated from renewable technologies and nuclear power (imports from China) is based on a thermal efficiency of 43%. This is based on the assumption that the alternative way to generate this electricity in Hong Kong.

[61] There are exceptional cases in which reduction in final energy use results in an increase in primary energy consumption. For example, the conversion of all passenger cars and taxis to electric in Scenario 3 in 2030 reduces about 2 energy units of liquid fuels for one additional unit of electricity in terms of final energy, but it will require more than 2.5 units of primary energy resources to generate that unit of electricity. This explains the increase in primary energy intensity in Scenario 3.

[62] IPCC, *Climate Change 2007 Mitigation*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[63] The air emission reductions in Scenario 1 are not directly comparable with those in the AQO study due to several factors including 1) different modelling approaches were adopted; 2) the AQO study assumes 50% nuclear and 50% natural gas will be used to generate electricity by 2030, which is different from the assumptions in Scenario 1.

[64] In the international carbon market, the price is projected to be around US$100/tonne CO2e in 2030.

[65] This approach is broadly similar to the method used in generating the McKinsey abatement cost curve.

[66] This excludes remaining coal power plant generation. Among the 50% electricity with no associated carbon emissions, 35% is from import of nuclear generated electricity.

[67] The current conclusion that GDP and its growth will not be materially affected in the alternative scenarios against the Base Case is made based on the currently available information. The economic modelling is at a macro scale, and the detailed economic impact of individual measure should be subject to further assessment at a later stage. In particular, some of the measures would require substantial investments, the costs of which and the resultant impacts on specific areas of the economy (e.g. electricity tariff) have not been assessed in detail. The consultants suggest that the Government should conduct a more detailed independent assessment when comprehensive information is available and when the Government proposes to pursue any of the proposed measures.

Annex A

Development of the Base Case

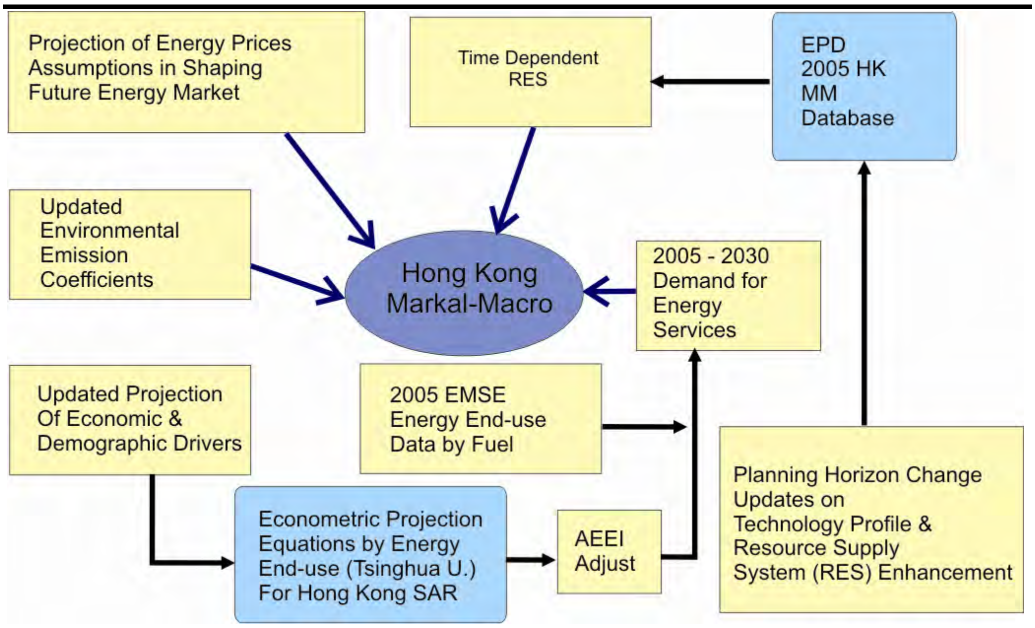
In Hong Kong MARKAL-MACRO Model

1 DEVELOPMENT OF THE BASE CASE

1.1 DEVELOPMENT OF THE BASE CASE

Figure 1.1 depicts schematics of the interrelated tasks in the development of the Base Case. In general, Hong Kong specific historical energy demand-supply data were used to establish the base year (2005) RES in the Hong Kong MARKAL-MACRO model. The base year RES provides a balanced stance (partial equilibrium) based on which future energy-environmental-economic scenarios can be formulated. If no Hong Kong specific data are available (characteristics of a specific technology, existing or future); they can be taken from many existing MARKAL databases in the world community as a starting point.

Figure 1.1 HKMM Baseline Dataflow



Source: ERM-HK and BNL.

The following sections detail the structure of different modules, the sources of data input, and key assumptions for projections. It should be noted that there are uncertainties inherent in the input data and projections used to develop the Base Case. In considering the results of modeling analysis, it is most useful to focus on the differences between the scenarios representing the situation with and without (Base Case) the additional technologies, policies and measures selected for the study than on the absolute numerical results for either scenario. This approach minimizes the significance of these uncertainties on the impact of alternative scenarios measured against the Base Case developed here.

1.2 DEMAND MODULE

The energy market represented in the RES of the Hong Kong MARKAL-MACRO is driven by demand for energy services. The demand for energy service breakdown is required in order to evaluate mitigation measures that may apply to very specific energy services. Projections of these demands determine the quantity and mix of the final energy used by end-use technologies to meet them. The energy consumed by the end-use technologies in turn determines the energy supply systems, creating a balance in the energy market. *Section 1.2.1* to *Section 1.2.3* describe the approach and assumptions of the projections, while *Section 1.2.4* and *Section 1.2.5* explain the detailed input data characterizing individual end-use technologies.

1.2.1 Input of 2005 Energy End-use Data

To establish the base year (2005) energy service demand (DM) in MARKAL, the detailed energy end-use by fuel type reported by EMSD (1) were obtained. It should be noted that the EMSD End-use data only considers the local energy use, and energy consumption for international and regional transportation in marine and aviation sectors is not included in the base case.

1.2.2 Energy Service Demand

In the HKMM model, the level of an energy service demand (DM) is the summation of the energy services provided by all end-use technologies (DMD) servicing that demand. Thus, for a given energy service demand DMi, where quantities of fuels, Di are used by DMDi at Ei (the relative efficiency of DMDi), then DMi equals the summation of the product Ei*Di, over i (the set of all DMDi servicing DMi).

DMi = (Σ Ei*Di)/i

It should be noted that the energy service demands are not the same as the end-use energy and they should not be compared directly against the end-use data. The energy service demands represent the need for which energy is used to provide (ie a person demands light to illuminate their home at night, rather than electricity). They use a mix of units and the values that cannot be added. The units include: Terajoules (TJ) of direct energy, Terajoules (TJ) of useful energy, and Terra Lumen-seconds, etc.

1.2.3 Projections of Energy Service Demand

The Base Case (2005-2030) is driven by the projected energy service demand (DM) in the Model (2). This involves the insertion of the latest or updated projection values (2010-2030) of the explanatory variables (drivers) into the

(1) Hong Kong Energy End-use Data 2008, EMSD. Energy use breakdown by fuel type information for residential, industrial, and commercial sectors were provided by EMSD in October 2008.

(2) The projections of these energy service demands utilize the econometric equations estimated in the *Operation and Development of Hong Kong MARKAL-MACRO Model Instruction Order 02: Energy Projection* , Tsinghua University.

energy end use projection equations. Future energy service demands will be derived based on these projection results and used as the demand side input required by the Hong Kong MARKAL-MACRO model. The projected values of the key drivers are depicted in *Table 1.1*. Since there are discrepancies between the 2005 energy service demand derived (with 2005 actual data) and their corresponding values projected for 2005 from the econometric equations, we applied the period by period growth rates implied in these projections to the values for the base year calibration.

Table 1.1 Projected Divers for the Econometric Equations in Energy Service Demand Projections

Category	Unit	2005	2010	2015	2020	2025	2030	Source
Population	Million	6,813,200	7,094,000	7,391,400	7,718,600	8,034,800	8,311,700	C&SD data and projection. [1]
GDP Aggregate	Million 1990HK$	1,077,030	1,240,649	1,487,772	1,758,389	1,999,160	2,261,866	C&SD data and projection. [2]
Floor Space								
Domestic	Thousand Units	2,197	2,302	2,398	2,504	2,607	2,697	2005 data from C&SD 2006 Annual Digest of Statistics; growth rate from HK 2030 Study Working Paper.
Retail	Thousand sq.m	9,522	9,724	9,733	9,743	9,753	9,763	2005 data from C&SD 2006 Annual Digest of Statistics; growth rate from HK 2030 Study Working Paper.
Office	Thousand sq.m	9,770	11,660	12,255	12,880	13,537	14,227	2005 data from C&SD 2006 Annual Digest of Statistics; growth rate from HK 2030 Study Working Paper.
Industrial	Thousand sq.m	17,468	14,846	14,048	13,292	12,577	11,900	2005 data from C&SD 2006 Annual Digest of Statistics; growth rate from HK 2030 Study Working Paper.
Electricity Price	1990 HK$/kWh	0.739	0.761	0.741	0.750	0.757	0.764	CLP and HEC's Operating Statistics; 2009-2013. Development Plan; US EIA Energy Projection Index. [3]

Notes:

1. 2005 Population and projections are from C&SD website
http://www.statistics.gov.hk/stat_table/population/D5320182BXXXXXXXXB.xls

2. 2005 to 2008 data are from the C&SD website and converted to 1990 HK dollars based on deflator of GDP.
According to the Government announcement in May 2009, the 2009 GDP growth rate is projected to be -4.5%.
According to EABFU/ FSO's estimation in 2009, the GDP growth rates are expected to be 3.5% between 2010 and 2013, 4% between 2014 and 2017; 3% between 2018-2021; and 2.5% between 2022 and 2030.

3. Electricity price is the weighted average of CLP and HEC's electricity tariff. The projection is based on EPD's advice. It is assumed that the basic tariff will stay the same, and the electricity price will fluctuate based on the fuel price projection.

There are inherent uncertainties in the long term projection of transportation fuel use. Factors including number of cars that are allowed in HK's limited space and consumer's desire to own automobiles cannot be easily captured by the econometrically determined equations. The Hong Kong vehicle kilometers travelled (VKT) data from 2002 to 2007 show that with a slow growth rate the VKT are quite stable in recent years. Transportation energy end use data from EMSD also suggest a similar trend. It is then instructive to choose different AEEI factors to evaluate the energy service demand for the transportation sector.

The "Working Paper on Traffic Forecasts Approach and Assumptions" in the AQO Review Study [(1)] provides projections of vehicle fleet sizes for private vehicles, taxis, and goods vehicles (2011 to 2030). The road network assumptions used in the study was sourced from committed government highway development plan, recommendations from various planning studies and advices from the Transport Department. As the fleet sizes of goods vehicles and private vehicles are closely related with their respective VKT and energy consumption, higher AEEI factors were adopted for them and the projected growth rates for energy service demand have been adjusted to be in line with the projected vehicle fleet sizes [(2)] .

1.2.4 *Input Future Efficiencies of Existing Demand Devices*

For some selected sector/devices, we assume there are efficiency improvements due to on-going efficiency improvement programs and autonomous efficiency improvements in these devices over time. On average, it is assumed that these efficiencies will improve 10% by 2030 over the current stocks.

1.2.5 *Input Investment Costs*

The investment and O&M costs for demand devices reported in *"Operation and development of Hong Kong MARKAL-MACRO Model Instruction Order 01: Updating HKMM"* were updated to 2005 Hong Kong dollars. For new technologies not included in that data base, we applied their relative cost factor reported in the world market (eg USDOE EIA data base) to obtain these costs.

1.3 *POWER SECTOR*

The power sector in the HKMM is modeled based on the detailed operating statistics reported by CLP and HEC. On a plant by plant basis, their actual generation, fuel use, thermal efficiencies, and other related parameters in 2005

(1) EPD, Review of Air Quality Objectives and Development of a Long Term Air Quality Strategy for Hong Kong – Feasibility Study, August 2007. It was circulated to both Transport Department and Planning Department for their agreement.

(2) The AQO review study doesn't provide the projection for buses. It also projects that the fleet size of taxis will keep the same from 2011 to 2030. Energy service demand of buses and taxis were not adjusted in the study as historical energy use data show that they have been growing.

were input to the model to construct the electricity/power supply side in the base year energy market. For future years between 2010 and 2030, we assumed that all existing power plants will continue to operate within their designed specifications, as defined by the value of these parameters for this period (1) . The following assumptions were made with regard to Hong Kong's future energy market:

- Assumption 1: electricity import from the mainland holds at the current level;
- Assumption 2: CLP and HEC will build all new power plants within the SAR to meet future increase in electricity/power demand. These power plants are assumed to be mainly natural gas fired technologies, with limited wind; and
- Assumption 3: system transmission efficiency stays at the current level of 92% throughout the planning period.

1.4 *PROCESS*

In MARKAL-MACRO, the Process is defined as a technology which converts one energy form to another (except electricity). Examples of common process are refineries and coal gasifiers. For Hong Kong SAR, town gas production from naphtha is the only operating process identified in the model.

The key assumption is that the production capacity stays unchanged in the planning horizon.

1.5 *RESOURCE*

The Hong Kong SAR imports almost all of its energy resources from outside the region. Production of indigenous resources is limited to the solid waste the region generates and limited potential in solar and wind power. Quantities of municipal solid waste (MSW) disposed and sewage sludge production in 2005 and their projections to 2030 are provided by the EPD. First Order Decay Model (FOD) introduced in the IPCC Guideline 2006 was adopted to derive the methane generation (2).

1.6 *PRICE*

As a price taker, Hong Kong SAR's energy import prices in the future depend on their movements in the world market. In Hong Kong MARKAL-MACRO, the 2005 prices were extrapolated to 2030 using projected prices for crude oil (USDOE EIA 2009) as a reference indicator for oil products and gas (*Table 1.2)*.

(1) The investment and O&M costs for the power plants reported in *Operation and development of Hong Kong MARKAL-MACRO Model Instruction Order 01: Updating HKMM" (Tsinghua Study)* were converted to 2005 dollars. In the absence of local information, assumptions and parameters in the "Assumptions to the Annual Energy Outlook"1 provided by the US EIA (Energy Information Administration) were used for future generation investment and fixed O&M costs.

(2) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/IPCC_Waste_Model.xls

Table 1.2 ***Key assumptions: world reference price indicators for oil and gas (US$/Barrel)***

(2007 US$/barrel)	2005	2010	2015	2020	2025	2030
Imported Crude Oil	51.81	48.99	96.77	114.50	116.06	124.36

Source: 2009 US EIA Projection.
http://www.eia.doe.gov/oiaf/servicerpt/stimulus/aeostim.html

Table 1.3 presents the imported fuel prices in 2005 and their projections through 2030 in Hong Kong SAR. It is assumed that the import electricity price from PRC will stay at the 2005 level.

Table 1.3 ***Imported Fuel and Electricity Prices – HKSAR (Thousand 2005 HK$/TJ)***

Fuel [1]	2005	2010	2015	2020	2025	2030
Black Coal	14.09	13.33	26.33	31.15	31.57	33.83
Pipeline Natural Gas[2]	33.56	60.18	118.88	140.66	142.57	152.77
Electricity -PRC[3]	214.00	214.00	214.00	214.00	214.00	214.00

Sources:
1. 2005 imported fuel prices (except for LNG and Ethanol) are from Hong Kong Energy Statistics - 2005, page 24
2. Natural Gas in China Market ecolution and strategy, IEA, June 2009. It suggests that the LNG price would be USD 17.5 per Mbtu for an oil price of USD 100 per barrel
3. Imported electricity price is the estimation based on the Government press release http://www.info.gov.hk/gia/general/200909/22/P200909220194.htm

1.7 EMISSION FACTORS

In the Hong Kong MARKAL-MACRO model, a set of carbon emission coefficients is incorporated to track the carbon emissions released from fuel use in the RES for current and future years. These carbon emission coefficients are provided by the EPD and power companies. Parallel to these coefficients, emission coefficients of SOx, NOx, and PM_{10} are also being developed for the power sector to evaluate the co-benefit of GHG mitigation.

2 SENSITIVITY OF MARKAL MODEL OUTPUT TO GDP PROJECTIONS

The Base Case solution in the MARKAL model depends on the projected energy service demand. As GDP projection is a major driver to these energy service demand projections and it might vary through the years, further analysis is added in this section to examine the sensitivity of the model solutions to changes of these basic drivers. Two higher (2% and 5%) and two lower (2% and 5%) GDP projections were assumed in comparison to their corresponding values in the baseline for the period between 2010 and 2030. Alternative GDP projections were used to drive the econometric equations and their respective future energy service demands were obtained as input of Hong Kong MARKAL model.

Table 2.1 shows the final energy use change while *Table 2.2* depicts the change of carbon emissions under different GDP projections, compared with the baseline.

Table 2.1 Final Energy Use Change by GDP Projection

	Change of Final Energy Use (%)				
GDP Projection	**2010**	**2015**	**2020**	**2025**	**2030**
5% above baseline	5.50%	5.70%	5.90%	6.10%	6.68%
2% above baseline	2.10%	2.20%	2.30%	2.40%	2.65%
Baseline	0.00%	0.00%	0.00%	0.00%	0.00%
2% below baseline	-2.10%	-2.20%	-2.30%	-2.40%	-2.62%
5% below baseline	-5.50%	-5.70%	-5.80%	-5.90%	-6.17%

Table 2.2 Carbon Emissions Change by GDP Projection

	Change of Carbon Emissions (%)				
GDP Projection	**2010**	**2015**	**2020**	**2025**	**2030**
5% above baseline	2.20%	5.00%	6.00%	7.10%	7.80%
2% above baseline	1.00%	2.00%	2.20%	2.80%	3.00%
Baseline	0.00%	0.00%	0.00%	0.00%	0.00%
2% below baseline	-1.00%	-2.00%	-2.20%	-2.50%	-2.90%
5% below baseline	-2.00%	-4.20%	-5.20%	-6.30%	-6.90%

It should be noted that 2-5% GDP deviations from the Baseline projection represent significant dollar amount in absolute magnitude over time. Since this study focuses on the differences of the model results between the mitigation scenarios and the Base Case (i.e., the impact of additional technologies, policies and measures), the uncertainties inherent in the long-term GDP projections have minimal impact on the general conclusions drawn from this approach.

Annex B

Abbreviations

Abbreviations

AQO	Air Quality Objectives
BEC	Building Energy Codes
CCS	Carbon Capture and Storage
CFL	Compact Fluorescent Lamps
C&SD	Census and Statistics Department
DCS	District Cooling System
EEDI	Energy Efficiency Design Index
EELS	Energy Efficiency Labelling Scheme
EEOI	Energy Efficiency Operational Indicator
EMSD	Electrical and Mechanical Services Department
EPD	Environmental Protection Department
ERP	Electronic Road Pricing
EV	Electric Vehicle
GDP	Gross Domestic Product
GFA	Gross Floor Area
GHG	Greenhouse Gas
HGV	Heavy Goods Vehicle
HKMM	Hong Kong MARKAL-MACRO
HKSAR	Hong Kong Special Administrative Region
ICF	International Compensation Fund
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IWMF	Integrated Waste Management Facilities
LCD	Liquid Crystal Display

LGV	Light Goods Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MAC	Marginal Abatement Cost
METS	Maritime Emissions Trading Scheme
MOU	Memorandum of Understanding
MSW	Municipal Solid Waste
NTS	Nuclear Transmission Network
NGV	Natural Gas Vehicle
OTTV	Overall Thermal Transfer Value
OWTF	Organic Waste Treatment Facilities
RD&D	Research, Development, and Demonstration
RE	Renewable Energy
RES	Reference Energy System
SEMP	Ship Efficiency Management Plan
SME	Small and Medium-sized Enterprise
STF	Sludge Treatment Facilities
TJ	Terajoule
UNFCCC	United Nations Framework Convention on Climate Change
WACS	Water-cooled Air Conditioning System
WtE	Waste-to-Energy

Appendix C

Vulnerability and Adaptation Assessment

CONTENTS

1 INTERNATIONAL BEST PRACTICE FOR CLIMATE CHANGE IMPACT AND ADAPTATION ASSESSMENT

This section provides an overview of the current best practice regarding methodological approaches for assessing the potential impacts of future climate change and evaluating appropriate adaptation strategies and measures. It is primarily based on international literature including the *UNFCCC User Manual* [(1)], *IPCC Technical Guidelines* [(2)], the *UNFCCC Handbook* [(3)] and the *UNEP Handbook* [(4)].

A review of the literature indicates that approaches are being continually developed to reflect current knowledge. Furthermore, there is no single preferred method as "*methodologies, approaches and/or guidelines to be used in the V&A assessment will depend on the national circumstances… with respect to the availability of data, and technical, financial and human resources* [(1)]".

The general framework for conducting a climate change impacts and adaptation analysis as defined by the UN and IPCC involves the following steps:

- Definition of the problem;
- Selection of the method;
- Testing the method;
- Selection of scenarios;
- Definition of the environmental and socio-economic baseline;
- Assessment of biophysical and socio-economic impacts;
- Assessment of autonomous adjustments and evaluation of adaptation strategies.

Each of these steps is explained in more detail in the following sections.

1.1 DEFINITION OF THE PROBLEM

As presented in the *IPCC Technical Guidelines*, the *UNFCCC Handbook* and the *UNEP* Handbook, this involves asking the following questions:

Table 1.1 *Climate Change Impacts and Adaptation Assessment*

Question	Description	In the Present Study
Goals of the assessment	Study objectives	• To characterise the impacts of climate change in Hong Kong • To evaluate existing and recommend additional strategies and measures to facilitate adequate adaptation to climate change

Question	Description	In the Present Study
Assessment boundary	Geographic boundary	Hong Kong SAR boundary
	Depth of the assessment	Literature review of relevant studies published by Government departments, international and national authorities, and the scientific community
Exposure unit to be studied	Scope of the assessment	The socio-economic and natural systems in Hong Kong
Time frame	Time horizon for study	Around 18 months
	Time frame of projections / impacts	Up to 2100
	Timeframe of adaptation strategies / measures	Up to 2030

1.2 SELECTION OF THE METHOD

Predicting future impacts is one of the major goals of climate change impact assessment. There is a wide range of different methods and approaches available, such as quantitative modelling, empirical study, expert judgement and experimentation, as well as stakeholder involvement. Since each of these has its own strengths and weaknesses, the use of a combination of approaches in different parts of the assessment or at different stages of the analysis is recommended by the *UNEP Handbook*. Geographic information systems and remote sensing are amongst other tools that may be also used.

1.2.1 *Quantitative Models*

Where the variables can be expressed in quantitative terms and where feasible, the use of models is desirable to enable sensitivity analysis, for example, to be carried out. Climate impact studies often involve the use of biophysical models, socio-economic models and integrated system models. Many of the models are simple cause and effect models but the reality is a complex interactive system. This complexity is being addressed by an on-going effort to develop integrated systems models.

It is important to keep in mind that although the model results generated may look very precise, there are underlying assumptions in the climate change and socio-economic scenarios, in addition to those inherent in the models. As a result numerical quantitative data generated by these models should be treated as informed estimations rather than the definitive 'answer'. Models that address only one sector or aspect of a system may simulate that sector or aspect well but may be unable to incorporate interactions from related sectors or other aspects of the system. For these reasons, the choice of models should be conducted by experienced modellers who have detailed foreknowledge of the problems likely to be encountered.

Given the timeframe, scope and available data the present study has not undertaken any detailed quantitative modelling. However, this study serves as an important step in identifying the current knowledge gaps and uncertainties, and hence the areas where further more detailed research would be especially valuable in responding to climate change in Hong Kong.

1.2.2 *Empirical Studies*

Empirical observations of the interactions of climate and society and natural systems are commonly achieved through analogue methods, such as historical events, historical trends, and regional or spatial analogues of present climate. These enable questions to be asked about how stakeholders adapt or have adapted in the past.

Case studies have been included in this study to illustrate the need for a holistic response in the event of an unexpected crisis, and to illustrate that such crises can have consequences for the broader economy. The IPCC notes that whilst the consequences of climate change will be greater in low income countries "*no matter what the degree of preparedness is, projections suggest that some future extreme events will be catastrophic because of the unexpected intensity of the event and the underlying vulnerability of the affected population. The European heatwave in 2003 and Hurricane Katrina are examples*" (5).

1.2.3 *Expert and stakeholder judgement and participation*

Expert judgement and opinions enable a relatively rapid assessment of the current state of knowledge concerning the likely impacts of climate change, especially in preliminary or pilot studies to assist with the design of such studies. Policy analysis may also incorporate decision-making support systems that combine dynamic simulation with expert judgement.

In this vulnerability and adaptation assessment independent expert judgement has been utilised. For example, local and overseas health experts have been consulted to guide the analysis for human health, and engineers have provided support in areas including the built environment and infrastructure, as well as water resources.

1.2.4 *Remote Sensing and GIS*

Data about features located on the earth's surface is collected by remote sensing from aircraft and satellites, and is analysed to provide useful information. Remote sensing can very effectively be used in combination with Geographic Information System (GIS), which allows the analysis of geographically referenced data in complex ways. One of the main limitations to this method is that effective use of GIS requires substantial data sets, which for some features, often needs to be regularly updated.

GIS has been applied in this climate change impact and vulnerability assessment to indicate areas of the territory that are more likely to be at risk in a changing climate and to illustrate the distribution of various features including infrastructure, population density and ecosystems across the Hong Kong SAR.

1.3 *TESTING THE METHOD*

The selection of the assessment methods should be tested in preparation for the main evaluation tasks. Feasibility studies, data acquisition and compilation, and model testing may be useful in evaluating the methods. This present vulnerability and adaptation assessment serves as a feasibility study to provide information on the effectiveness of alternative approaches, of models, of data acquisition and monitoring, and of research collaboration.

1.4 *SELECTION OF SCENARIOS*

Climate change impacts are estimated as the difference between conditions (both environmental and socio-economic) expected to exist over the period of analysis in the absence of, and with, climate change. Studies may elect to analyse several different climate change scenarios where the science is uncertain regarding the direction and/or magnitude of future trends.

1.4.1 Climatological Scenarios

The climatological baseline should be consistent with the present-day or recent average climate in the study region; it should be of sufficient duration to encompass a range of climatic variations; it should cover a period for which data on all climatological variables are abundant, adequately distributed and readily available; and, it should include data of sufficient quality for use in evaluating impacts. The standard WMO baseline period (1961-90) should be adopted in assessments where appropriate.

The climate change scenarios used for impact assessment should be consistent with the broad range of global warming projections based on higher atmospheric concentrations of GHGs and regional variability. The scenarios should not violate the basic laws of physics, i.e. they should be physically plausible. The scenarios should also cover a sufficient number of variables on a spatial and temporal scale to enable impacts assessment. Lastly, the scenarios should, to a reasonable extent, reflect the potential range of future regional climate change.

1.4.2 Socio-Economic Scenarios

There is tremendous uncertainty about future socio-economic conditions. Socio-economic scenarios are scenarios of the state and size of the population and economy. Scenarios are often based on a combination of expert judgement, extrapolation of trends, international comparisons and model runs; simple extrapolation should be avoided. Socio-economic scenarios may comprise of a wide range of elements as illustrated in *Table 1.2*.

Table 1.2 *Examples of Indicators*

Economy	Demography	Environment
GDP	Population	Land
Relative importance of sectors	Age structure	Water
Imports and exports	Education	Air
Unemployment	Health	Biota
Comparative advantages	Gender	Principal and unique resources
Technology	Religion	Quantity and quality
Infrastructure		
Institutions		

Socio-economic scenarios are developed to identify what socio-economic variables are most likely to be more or less vulnerability to climate change. Multiple scenarios (at least three) should be used as a single scenario for future developments may transmit a false sense of certainty to the study's audience. The use of multiple scenarios enables a better understanding of the system under consideration and is in fact a sensitivity analysis. Baseline scenarios may be developed beyond the middle of this century and even up to approximately the end of the century. This allows the scenarios to be on the same scale as typical climate change scenarios. However, socio-economic scenarios covering such long periods of time tend to have very low credibility.

IPCC Special Report on Emissions Scenarios

The future evolution of human society, technological development, and the global economy is largely unpredictable over long time horizons. Projecting future climate is complicated by the fact that it will also be influenced by emissions of GHGs which we, (and those that have yet to be born) have yet to emit. The IPCC *Special Report on Emissions Scenarios* (6) outlines a range of plausible descriptions of alternative futures based on different assumptions regarding population growth, socio-economic and technological change and other factors, known as A1, A2, B1 and B2, and within A1, there are a further three sub-scenarios A1FI, A1T and A1B, making a total of six emissions scenarios. The characteristics of these emissions scenarios are summarized in *Table 1.3*. The projected trends of global GHG emissions under the various emissions scenarios and their associated temperature increase are shown in *Figure 1.1*.

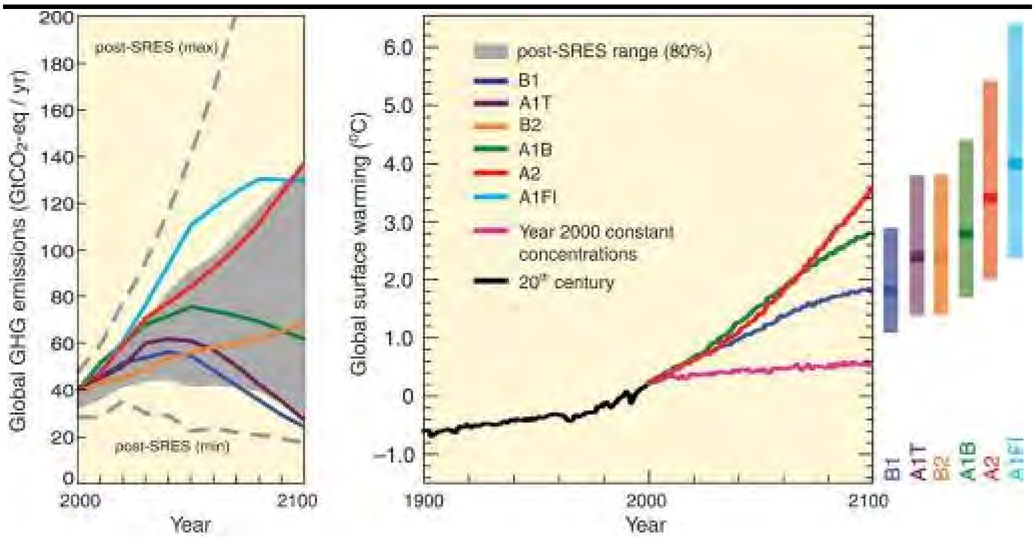
Table 1.3 ***SRES Emissions Storylines***

A1 (A1FI, A1T and A1B)
Rapid economic growth, low population growth. Rapid introduction of new more efficient technologies. Convergence in regional differences in per capita income. The A1 scenario has 3 alternative future energy use storylines: fossil fuel intensive A1FI, the non-fossil fuel (nuclear and renewable) A1T, and A1B which is a balance between the two.
A2
A very heterogeneous world, fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower.
B1
A convergent world with low population growth. Rapid changes toward a service /

A1 (A1FI, A1T and A1B)
information economy. Reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to sustainability.

B2
Emphasis is on local solutions to development and sustainability. Moderate population growth, intermediate economic development, less rapid and more diverse technological change.

Figure 1.1 ***SRES Emissions Scenarios in terms of CO_2 Emissions and Likely Future Temperature Rises***



IPCC, 2007 (7)

The IPCC is currently in the process of updating its SRES emissions scenarios to incorporate actual emissions pathways over the last decade and to update socio-economic and technical projections. A watching brief is thus advised in this area.

1.4.3 *Climate Change Scenarios*

Three generic types of climate change scenarios have been used in climate change impacts research: scenarios based on outputs from GCMs, synthetic scenarios and analogue scenarios.

Global Climate Models (GCMs)

While climate change in the past can be reconstructed from paleo-climatic evidence (from tree ring and ice core data, for example) and instrumental data (historic records), scientists attempt to make forecasts of future climate change through the construction and use of global climate models (GCMs). GCMs are mathematical representations of atmosphere, ocean, ice cap and land surface processes based on physical laws and physically-based empirical relationships. GCMs have quite a coarse resolution as they estimate changes for meteorological variables for grid boxes that are typically 3-4° latitude / longitude, i.e. 250 km in width and 600 km in length. Coupled ocean-atmosphere GCMs are the most advanced. These complex GCMs mimic how the Earth's atmosphere is affected by different factors that can influence the weather such as the carbon cycle, variations in solar intensity, volcanic emissions and anthropogenic GHG emissions. GCMs have evolved considerably over time and they are often validated by testing their ability to recreate the observed climate record. Although it should be stressed that ability to recreate the historic climatic record is not necessarily indicative of accuracy in projecting future climatic trends.

Both equilibrium experiments and transient experiments are two types of GCM runs that can be useful for impact assessments. Equilibrium experiments concerns with the difference between the simulation of current ($1 \times CO_2$) and future ($2 \times CO_2$ or occasionally $4 \times CO_2$) climates, i.e. a scenario of how climate may change with an effective doubling (or quadrupling) of atmospheric CO_2 concentrations. Both the current and future climates are assumed by modellers to be in equilibrium (i.e. stationary) but this is an oversimplification as Earth's climate is never in equilibrium.

In a transient experiment, a coupled GCM simulates current climate ($1 \times CO_2$) and future climate as it responds to a steady increase in GHG concentrations beyond $1 \times CO_2$ concentrations. This model is typically run for 100 years or more into the future. As computing power increases with time, transient experiments become less expensive to run and output from these has been used more frequently in climate change impact studies.

Synthetic Scenarios

Synthetic scenarios (also known as arbitrary scenarios) are based on incremental changes in meteorological variables such as temperature and precipitation. For instance, temperature increases of 2°C and 4°C can be combined with precipitation changes of +10% or -20% or no change in precipitation to create a synthetic scenario. Incremental changes are usually combined with a baseline daily climate database to yield an altered 30-year record of daily climate.

Analogue Scenarios

In analogue scenarios, past warm climates are used as a scenarios of future climate (temporal analogue scenario), current climate in another (usually warmer) location as a scenario of future climate in the study area (spatial analogue scenario). Temporal analogue scenarios may come from the instrumental record (weather observations) or the paleoclimatic record.

Temporal analogues of global warming were not contributed by anthropogenic emissions of GHGs while spatial analogues are unlikely to be plausible scenarios of future climate change. For these reasons, these types of scenarios should only be used under two conditions:

- The limitations of this approach should be clearly explained, pointing out that analogue scenarios may not be accurate representations of GHG induced climate change; and,

- Other approaches such as synthetic or GCM-based scenarios are also used in the same study to ensure that a broader range of climate changes is included in the scenarios.

Each of the above options has their own advantages and disadvantages (*Table 1.4*), and none of these fully satisfies all scenario selection conditions described earlier in this *Section*. As a result, the use of a combination of scenarios based on outputs from GCMs and synthetic scenarios is recommended as they allow for a wider range of potential climate change at the regional level and are easier to construct and apply.

The choice of creating climate change scenarios should depend on the available resources, as well as how quickly the scenarios are needed by impacts researchers. Despite the evolving techniques in climate change scenario construction; fundamental uncertainty about regional climate change remains, including uncertainties such as the magnitudes and even the direction of change of many important variables, particularly extreme weather/climate events. Precipitation is another area which has proved difficult to model over the long time horizons used in climate change impact assessments. It is crucial to bear in mind that climate change scenarios only help us to understand the potential implications of climate change and the vulnerability of human and natural systems to this change; they are not predictions of the future.

Table 1.4 Advantages and Disadvantages of Different Types of Climate Change Scenarios

Scenario Types	Advantages	Disadvantages
Global Climate Models (GCMs)	• GCMs are the only tool that can provide the best information on how global and regional climate may change as a result of increasing atmospheric concentrations of GHGs for a large number of climate variables (e.g. temperature, precipitation, pressure, wind, humidity, solar radiation) in a physically consistent manner.	• Although GCMs accurately represent global climate, their simulations of current regional climate are often inaccurate. • The GCM output on a geographic and temporal scale produced are not fine enough for many impact assessments due to the uniform climate changes projected in grid boxes several hundred kilometers across. • A single GCM, or even several GCMs, may not represent the full range of potential climate changes in a region. • The influence of a number of climatic variables and features i.e. water vapour, have yet to be modeled and incorporated in a quantitative manner into GCMs.
Synthetic Scenarios	• Synthetic scenarios are easy to use and transparent to policy makers and other readers of impact studies. • Synthetic scenarios can capture a wide range of potential climate changes. • They help to identify the relative sensitivities of sectors to changes in specific meteorological variables by changing individual variables independently of each other. • Different studies can use the same set of scenarios to compare sensitivities. • They are inexpensive, quick and easy to construct, and generally require few computing resources.	• They may not be physically plausible; particularly if uniform changes are applied over a very large area or if assumed changes in variables are not physically consistent with each other. It is therefore important to not arbitrarily select changes in variables that are not internally consistent with each other. • These scenarios may not be consistent with estimates of changes in average global climate. Nevertheless, this limitation can be overcome by using the outputs of GCMs to guide the development of synthetic scenarios.
Temporal analogue scenarios	• The use of instrumental record as the basis for a climate change scenario is advantageous as climate change data is available on a daily and local scale and at a finer temporal and spatial resolution than those based on GCMs. • The advantage of using paleoclimatic data over instrumental data for scenario construction is that temperature fluctuations in the distant past compared to current climate tend to be greater than those within the instrumental record, so they may be more consistent with potential changes in average global temperature in this century.	• The primary drawback is that these scenarios are not based on human-induced increases in GHGs. • For scenarios that are based on instrumental records, complete instrumental records for the period in question may not exist in many countries. • The collection or collation the relevant paleoclimatic data for scenario construction for the required region may be a costly and time-consuming exercise. Furthermore, paleoclimatic data is generally available only for seasonal changes in temperature and precipitation, and is not available in many locations, particularly in tropical areas. • Temporal analogue scenarios (except those from millions of years ago, which have very low resolution of data) tend to be at the low end or even below the range of potential future climate warming.

Scenario Types	Advantages	Disadvantages
Spatial analogue scenarios	• These scenarios can be used to examine how social and natural systems have adapted to different climates, therefore are particularly helpful in examining the potential for adaptation. • They provide an often graphic means of communicating the broad significance of climate change to the public. • They can also introduce changes in spatial and temporal variability. • They can enable approximate or relative costs of impacts to be more easily inferred although geographic differences in asset values and clustering have to be understood.	• Due to geographical and other differences, the future climate in the study area is unlikely to be the same as the current climate in another location, even with a similar average annual temperature. Hence, the level of detail available from an analogue site may give a false sense of precision. • Extensive continental or global climate data sets are necessary to search for an analogue region, and such data sets may not be easy to obtain.

1.4.4 *Other Environmental Factors*

The environmental baseline presents the present state of other non-climatic environmental factors that affect the exposure unit, such as groundwater levels, soil pH, elevation, the extent of wetlands etc.

The present state of all the non-environmental factors, including geographical (e.g. land use), technological (e.g. pollution control), managerial (e.g. forest rotation), legislative (e.g. air quality standards), economic (e.g. commodity prices), social (e.g. population), or political (e.g. land tenure) that influence the exposure unit is described by the socio-economic baseline.

The present study has adopted the climatological data made available by the Hong Kong Observatory for local conditions. Where such information is not available, the global or regional averages provided in the IPCC AR4 WGI report have been used. Socio-economic variables such as population and GDP data have been obtained from the Census and Statistics Department (C&SD). The baseline conditions of each of the sectors within present day Hong Kong are summarized.

1.5 *ASSESSMENT OF BIOPHYSICAL AND SOCIO-ECONOMIC IMPACTS*

Impacts are estimated as the differences over the study period between the environmental and socio-economic baseline conditions (without climate change) and conditions projected to exist with climate change. Assessments may include:

- Qualitative description – which requires the experience and interpretive skills of the analyst, especially the analyst's ability to consider all factors of importance and their interrelationships;
- Indicators of change – certain regions, activities or organisms that are intrinsically sensitive to climate may provide an early or accurate indication of effects due to climate change.
- Compliance to standards – which may provide a reference or an objective against which to measure the impacts of climate change.
- Costs and benefits – quantitative estimates should be given to the extent possible and expressed in economic terms. This approach can also examine the costs or benefits of "doing nothing" in mitigation.
- Geographical analysis – the spatial variation in impacts is of concern to policy makers operating at regional, national or internal scales as they may have policy and planning implications.
- Dealing with uncertainty – uncertainties pervade all levels of a climate impact assessment, from the projection of future GHG emissions to

evaluation of adaptation strategies. Both the uncertainty analysis and risk analysis attempt to account for these uncertainties.

1.6 *ASSESSMENT OF AUTONOMOUS ADJUSTMENTS AND EVALUATION OF ADAPTATION STRATEGIES*

Two broad types of response to climate change can be identified: while mitigation attempts to deal with the causes of climate change, adaptation refers to any adjustment, whether passive, reactive or anticipatory, that can respond to anticipated or actual consequences (both adverse and positive) associated with climate change.

The framework for the evaluation of adaptation strategies generally involves the following stages:

- Define the objectives: Any analysis of adaptation must be guided by some agreed overall goals and evaluation principle, commonly the promotion of sustainable development and the reduction of vulnerability. The definition of specific objectives, derived from public involvement, by legislation etc, will be needed.

- Specify the climatic impacts of importance: Climatic events that are expected to cause damage need to be specified so that the most appropriate adaptation options can be identified.

- Identify the adaptation options: A list of possible adaptive responses that might be employed to cope with the effects of climate is to be compiled in this stage. Existing practices or those previously adopted, along with new or possible alternative strategies should be considered.

- Examine the constraints: Constraints (e.g. legal, financial, social) should be examined including how they might affect the range of feasible choices available.

- Quantify measures and formulate alternative strategies: This stage assesses the performance of each adaptation measure with respect to the stated objectives under different climatic scenarios using simulation models, if appropriate data and analytical tools exist. Uncertainty analysis and risk assessment are also considered in this step.

- Weight objectives and evaluate trade-offs: This evaluation step involves weighing the objectives according to assigned preferences and then comparing between the effectiveness of different strategies in meeting these objectives, as well as the associated trade-offs.

- Recommend adaptation measures: The outcome of the evaluation process should provide policy advisers and decision makers with information on the best available adaptation strategies that covers some of the assumptions and uncertainties involved in the evaluation procedure and the rationale used.

2.1 CLIMATE CHANGE WITHIN A REGIONAL CONTEXT

The GCMs used to project the future climate scenarios are designed for planetary level analysis, and the resolution is rather "coarse". Therefore, ERM supplemented the data available from international studies with those from regional and local sources.

Table 2.1 provides an overview of the observed and projected changes at the global and regional level for East Asia. Some regional projections produced by the PRECIS model for China are also included. PRECIS, developed at the Hadley Centre of the UK Met Office, is a regional climate modeling system and is used to generate high-resolution climate change projections for many regions of the world.

Table 2.1 High Level Overview of Global and Regional Climate Change and Climate

Observed Changes in the Past	Projected Changes in Future
Temperature will continue to rise…	
Global:	
• Average surface temperature increased by 0.74°C between 1906 and 2005 and has risen at a rate of 0.13°C per decade in the last 50 years (IPCC, 2007).	• Global: temperature is *likely* to rise by 1.1-6.4 °C at 2090-99 relative to 1980-99 (IPCC, 2007).
Regional:	
• In China, annual average air temperature increased by 0.5-0.8°C in last 100 years. Most of the warming was observed over the last 50 years [(8)]. • More significant warming in western, eastern and northern China [(8)]. • Most significant temperature increase occurred in winter, and 20 consecutive warm winters were observed nationwide during 1986-2005 [(8)].	• *Likely* that warming is above the global mean in East Asia (IPCC, 2007), and that warming tends to be largest in winter. • Nationwide annual mean air temperature to increase by 1.3-2.1°C (2020) and 2.3-3.3°C (2050) cf. [(8)] • Warming magnitude to increase from south to north in China, particularly in northwestern and northeastern China [(8)].
Temperature extremes	
Global:	
• Warmer and fewer cold days/nights were *very likely* (IPCC, 2007). • Warmer and more frequent hot days/nights over most land areas were *very likely* (IPCC, 2007). • *Likely* that warm spells/heat wave frequency increased over most land areas (IPCC, 2007).	• Warmer and fewer cold days and nights are *virtually certain* (IPCC, 2007). • Warmer and more frequent hot days/nights over most land areas are *virtually certain* (IPCC, 2007). • *Very likely* that warm spells/heat waves frequency will increase over most land areas (IPCC, 2007).

Observed Changes in the Past	Projected Changes in Future
Regional:	
	• *Very likely* that summer heat waves/hot spells in East Asia will be of longer duration, more intense and more frequent (IPCC, 2007). • Fewer very cold days in East Asia is *very likely* (IPCC, 2007).
Precipitation patterns will change…	
Global:	
• Precipitation has increased significantly in eastern North and South America, northern Europe, northern and central Asia between 1900 and 2005; drying occurred in the Sahel, the Mediterranean, southern Africa and parts of southern Asia (IPCC, 2007).	• Precipitation *very likely* to increase at high latitudes in the 21st century, but *likely* to decrease in most subtropical land regions (IPCC, 2007).
Regional:	
• For China, no obvious trend of change in annual precipitation in the past 100 years; considerable variation among regions (8). There is an increasing trend in precipitation in the western and southern part of China, but a decreasing trend in northern and north-eastern China. • Annual precipitation decreased gradually since 1950s (average rate of 2.9 mm/decade, with northern China being most severe (8).	• Average increases of precipitation over China relative to the reference period 1961-90 is projected to be 4.5% for 2011-40, 8% for 2041-70 and 13% for 2071-2100 (Personal Communications (9). Both winter and summer precipitations are *very likely* and *likely*, respectively, to increase in East Asia (IPCC, 2007). • Nationwide precipitation increase is projected for the next 50 years by 2-3% (2020) and 5-7% (2050), with southeastern coastal regions being the most significant (8).
Precipitation extremes	
Global:	
• *Likely* that frequency of heavy precipitation events has increased over most areas (IPCC, 2007). • *Likely* that area affected by droughts increased in many regions since 1970s (IPCC, 2007).	• *Very likely* that frequency of heavy precipitation events has increased over most areas (IPCC, 2007). • *Likely* that area affected by droughts to increase (IPCC, 2007).
Regional:	
• Drought in northern and north-eastern China, and flood in the middle and lower reaches of the Yangtze River and south-eastern China have become more severe (8). • Annual precipitation in most years since 1990 has been larger than normal, with the precipitation pattern being a dipole, corresponding to frequent disasters in the North and flood in the South (8).	• *Very likely* that frequency of intense precipitation events in East Asia will increase (IPCC, 2007). • The arid area in China is to become larger and the risk of desertification might increase (8).
Sea level will change…	
Global:	
• Global mean sea level has risen at an average rate of 1.8 mm per year (the rise is consistent with warming) between 1961 and 2003. The rate increased to 3.1 mm per year in the period 1993-2003 (IPCC, 2007). • Rate of sea level change varies by region (IPCC, 2007).	• Global mean sea level to rise by 0.18-0.59 m at 2090-99 relative to 1980-99 (excluding future rapid dynamical changes in ice flow). It is *very likely* that average rate of sea level rise during the 21st century exceeds the 1961-2003 average rate (IPCC, 2007). • Sea level rise during the 21st century will not be geographically uniform (IPCC, 2007).

Observed Changes in the Past	Projected Changes in Future
Regional:	
• Rate of sea level rise along China's coasts during the past 50 years was 2.5 mm/year [8].	• Sea level along China's coasts to continue to rise [8].
The magnitude and/or frequency of some weather extremes will change…	
Tropical cyclones	
Global:	
• Intense tropical cyclone activity in the North Atlantic has increased since 1970s, but there is limited evidence elsewhere. However, there is no clear trend in the annual numbers of tropical cyclones (IPCC, 2007).	• Globally, it is expected that peak wind intensities and mean and peak precipitation intensities in future tropical cyclones to increase; the number of relatively weak tropical cyclones may decrease but the numbers of intense tropical cyclones is to increase. Total number of tropical cyclones globally to decrease (IPCC, 2007).
Regional:	
• Whether tropical cyclone activity in the western North Pacific has increased remains unclear (Yeung, 2006 [10]).	• Whether tropical cyclone activity in the western North Pacific will increase in a warmer world remains uncertain (Yeung, 2006 [10]). • An increase in the number of tropical cyclones is expected when the current quiet phase changes to an active phase in the western North Pacific (Yeung, 2006 [10]). • *Likely* that extreme rainfall and winds associated with tropical cyclones will increase in East Asia (IPCC, 2007).

IPCC 2007 references refer to IPCC AR4 (2007) [11]

2.2 *CLIMATE CHANGE IN HONG KONG*

The climate change vulnerability assessment for Hong Kong has been carried out using scenarios that are based upon the science in the IPCC AR4 and publications by the Hong Kong Observatory. *Table 2.2* presents a high-level overview of the observed changes in past climate of Hong Kong and climate change projections for future climate. The precautionary principle has been adopted in this Study by using the IPCC SRES [a] A1FI (ie the high) emissions scenario in the assessment as this storyline most accurately portrays the world's actual historic GHG emissions.

(a) More information on the IPCC SRES emission scenarios is available at http://www.grida.no/publications/other/ipcc_sr/.

Table 2.2 Baseline Climatic Conditions and Climate Change Scenarios for Hong Kong

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
Temperature and Extreme Temperatures								
Decadal mean annual temperature °C	23.1 (1980-1999)	A rising trend of 0.12°C per decade has been observed by the HKO over the past 124 years.	27.9 (a) (+4.8)	24.5 (b) (+1.4)	32.3 (c) (+9.2)	**Local**. Hong Kong Observatory, Leung *et al*., 2007a (12)	High, this study was conducted using AR4	Low. No information on diurnal range or seasonality of temperature increases.
Mean daily diurnal range °C	4.5 (1971-2000)	There is a decreasing trend of 0.28°C per decade (1947-2002). This is likely to reduce as nights get warmer.	n/a	n/a	n/a	**Local**. Hong Kong Observatory, Leung *et al*., 2004 (13)	n/a	Medium-High. More research is needed in this area.
Hot nights (d) (no. days in JJA)	Annual: 13.1; JJA: 12.2 (1971-2000)	Increasing trend of 1.5 nights per decade from 1885-2008 (14). A rising tend has already been observed, up from 8 nights per year in the 1960s to 15 nights per year in the period 1980-99.	41.2(a) by 2090-99	22.0 by 2090-99	68.7 by 2090-99	**Local**. Hong Kong Observatory, Leung *et al*., 2007a (12) Hong Kong Observatory, Wong and Mok, 2009 (15)	Medium	Medium. Mean temperature data are used for generating the regression relationships as gridded projected minimum and maximum temperature data in most models used in AR4. The lower bound assumes no further urbanization occurs post 2006, the upper assumes current rates.
Very hot days (e) (no. days in JJA)	Annual: 9.8;	There is no clear observed trend regarding very hot days	15.3(a) by 2090-99	9.6 by 2090-99	23.5 by 2090-99	**Local**. Hong Kong Observatory, Leung *et al*., 2007a (12)	Low-Medium	Medium-High. Mean temperature data are

(a) Average of the scenarios as well as of the two situations regarding urbanization

(b) The lower end of the projection range with "urbanization frozen at 2006"

(c) The upper end of the projection range with "constant urbanization rate"

(d) Hot nights are defined as those with a minimum. temperature of 28°C or above

(e) Very hot days are defined as those with a daily maximum temperature of 33°C or above

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
	JJA: 8.2 (1971-2000)	in Hong Kong.				Hong Kong Observatory, Wong and Mok, 2009 (16)		used for generating the regression relationships as gridded projected minimum and maximum temperature data in most models used in AR4. HKO is beginning to study extreme temperature projections using higher temporal resolution model data (daily) and more statistically superior downscaling techniques. The study for extreme temperature events is expected to be completed in 2010.
Cold days [a] (no. days in DJF)	Annual: 18.6; DJF: 16.3 (1971-2000)	Decreasing trend of 1.2 days per decade from 1885-2008 (14). The number of cold days in Hong Kong has fallen dramatically in recent years from a norm of 21 in the 1960s, to under 15 per year by 1999. This trend is likely to continue, with annual mean no. of cold days decreasing to	< 1	< 1	< 1	**Local**. Hong Kong Observatory, Leung *et al*., 2007a (12) Hong Kong Observatory, Wong and Mok, 2009 (15)	Medium	Medium. Mean temperature data are used for generating the regression relationships as gridded projected minimum and maximum temperature data in most models used in AR4.

(a) Cold days are defined as those with a minimum temperature of 12°C or below

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
		< 1 c. 2030-49						The lower bound assumes no further urbanization occurs post 2006, the upper assumes current rates.
The Water Cycle								
Average annual rainfall (mm)	2382.7 (1971-2000)	A rising trend of about 25 mm (~1.1%) per decade between 1885 and 2008 has been observed.	2572.0 (+248) by 2090-2099 Negative anomaly before 2040s; a rising trend in the latter part of 21st century.	1763.1 (-560.9) by 2090-2099	3235.3 (+911.3) by 2090-2099	**Local**. Hong Kong Observatory, Lee *et al*., 2008 (17) **Regional**. NCC of CMA for Guangdong (http://www.ipcc.cma.gov.cn/cn/MapSys/)	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. The ability of global climate models at forecasting rainfall is low, particularly at regional level. There is a wide data spread between scenarios. 73% of model runs indicate a positive rainfall trend in the 21st century.
Annual rain days (no. days per year)	104 (1971-2000)	A decreasing trend of 0.12 days/year is observed in the period 1947-2007	142.1 by 2070-2099	120.7 by 2070-2099	152.1 by 2070-2099	**Local**. Hong Kong Observatory, Wu *et al*., 2006 (18)	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. There is no information on seasonality of precipitation. HKO will extend the study using higher temporal resolution model data (daily) from IPCC
Frequency of heavy rain (a) (no. days per year)	6.1 (1971-2000)	Increasing trend of 0.2 days per decade from 1885-2008 (statistically significant at 5%	6.5 by 2070-2099	2.5 by 2070-2099	8.3 by 2070-2099	**Local**. Hong Kong Observatory, Wu *et al*., 2006 (18) Hong Kong Observatory, Wong and Mok,	Low. The skills of global climate models in	High. This assessment is based on available IPCC AR4 monthly

(a) Heavy rain is defined as days where hourly rainfall exceeds 30mm, which is one of the criteria for issuing an amber rainstorm warning

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
		level) [14]. Observed rising trend from 4.8 to 6.8 from 1947 to 2002 (not statistically significant at 5% level).				2009 [15]	forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	projection data. There is no information on seasonality of heavy rain days. HKO will extend the study using higher temporal resolution model data (daily) from IPCC.
Extreme Rainfalls of Different Durations								
Extreme Rainfalls of Different Durations	n/a	An Analysis of Effects of Climate Change on Stormwater Drainage System" reveals that the long-term trends of annual total and extreme rainfall of different durations are increasing. The percentage increase in these trends is less high for longer rainfall durations. For example, for those rainfall durations of less than or equal to 30 min., the percentage changes of annual maxima are substantially higher than the data for rainfall events from 60 min. to 24 hours as well as the annual total.	n/a	n/a	n/a	**Local:** Drainage Services Department, R&D Report no. 1036	Low.	Medium. More research is needed in this area.
Annual Extreme Rainfall								
Annual maximum 1-hourly rainfall	n/a	An increasing trend of 1.7 mm per decade between 1885 and 2008.	n/a	n/a	n/a	**Local**. Hong Kong Observatory, Wong and Mok, 2009 [14]	Low	High. There is currently no information on seasonal variability.

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
		Return values for fixed return periods (10-year, 20-year, 50-year, 100-year) increased by 1.1 mm per decade between 1885 and 2008. Return period of ≥100 mm shortened from 37 years (1900) to 18 years (2000).						
Annual maximum 2-hourly rainfall	n/a	An increasing trend of 2.1 mm per decade between 1885 and 2008. Return values for fixed return periods (10-year, 20-year, 50-year, 100-year) increased by 1.8 mm per decade between 1885 and 2008. Return period of ≥150 mm shortened from 32 years (1900) to 14 years (2000).	n/a	n/a	n/a	**Local**. Hong Kong Observatory, Wong and Mok, 2009 (14)	Low	High. There is currently no information on seasonal variability.
Annual maximum 3-hourly rainfall	n/a	An increasing trend of 1.7 mm per decade between 1885 and 2008 (trend is marginally insignificant at 5% level). Return values for fixed return periods (10-year, 20-year, 50-year, 100-year) increased by 2.0 mm per decade between 1885 and 2008. Return period of ≥200 mm shortened from 41 years (1900) to 21 years (2000).	n/a	n/a	n/a	Local. Hong Kong Observatory, Wong and Mok, 2009 (14)	Low	High. There is currently no information on seasonal variability.

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
Extreme Annual Rainfall								
Years with extremely low annual rainfall [(a)]	2 (1885-2008)	n/a	3.6 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al*., 2008 [(17)]	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. This assessment is based on available IPCC AR4 monthly projection data.
Years with extremely high annual rainfall [(a)]	3 (1885-2008)	According to the findings of the report entitled "An Analysis of Effects of Climate Change on Stormwater Drainage System", the long-term trend of rainfall is moving upwards. The percentage changes of annual trend of rainfall data generally decrease with an increase in duration. For durations less than or equal to 30 min., the percentage changes of annual maxima are substantially higher than the data for 60 min. to 24 hours as well as the annual total. This indicates the intensity of short rainfall duration is likely to become more extreme than long rainfall duration.	9.7 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al*., 2008 [(17)]	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. This assessment is based on available IPCC AR4 monthly projection data.

(a) Extremely low annual rainfall is defined as years where rainfall is less than 1282mm p/a

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
Mean number of occurrences of two consecutive of extremely dry years	No occurrence since 1885	n/a	0.4 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al.*, 2008 (17)	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. This assessment is based on available IPCC AR4 monthly projection data.
Mean number of occurrences of two consecutive of extremely wet years	No occurrence since 1885	n/a	1.8 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al.*, 2008 (17)	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. This assessment is based on available IPCC AR4 monthly projection data.
Mean number of occurrences of alternative extremely dry and extremely wet year	No occurrence since 1885	n/a	0.4 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al.*, 2008 (17)	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. This assessment is based on available IPCC AR4 monthly projection data.
Mean number of years of the occurrence of annual rainfall	n/a	n/a	6.9 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al.*, 2008 (17)	Low. The skills of global climate models in forecasting	High. This assessment is based on available IPCC AR4 monthly projection data.

(a) Extremely high annual rainfall is defined as years where rainfall exceeds 3187mm p/a

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
above 3343 mm (record high)							rainfall vary widely and the confidence in model estimates is usually low at the regional level.	
Mean number of years of the occurrence of annual rainfall below 901 mm (record low)	n/a	n/a	0.8 in the 21st century	n/a	n/a	**Local**. Hong Kong Observatory, Lee *et al*., 2008 (17)	Low. The skills of global climate models in forecasting rainfall vary widely and the confidence in model estimates is usually low at the regional level.	High. This assessment is based on available IPCC AR4 monthly projection data.
Run-off levels	n/a	The IPCC has high confidence that by mid-century, annual river runoff & water availability are projected to decrease, however no local observations are available.	n/a	n/a	n/a	**International**, IPCC 2007 (19)	Low	High. More research is needed in this area (a)
Evaporation (mm)	1343.4 (1971-2000)	A decrease in global solar radiation reduced the annual total evaporation by 40% from the 1960s to 2002. This is a decline of 184mm per decade.	n/a	n/a	n/a	**Local**. Hong Kong Observatory, Leung *et al*., 2004b (13)	Low	High. More research is needed in this area.
Extreme Weather Events								
Thunderstorm frequency (no. days per year)	37.1 (1971-2000)	Thunderstorms are a common occurrence in Hong Kong between April and September. The annual number of days with a thunderstorm has been increasing at a rate of 1.7 days	55.3	n/a	n/a	**Local**. Hong Kong Observatory, Leung *et al*., 2004b (13)	Low	High. More research is needed in this area. The estimated impact has been obtained by mapping the currently observed linear trend

(a) Actual run-off levels are location dependent and therefore any international research is likely to be of limited value to the Hong Kong situation, except where this relates to general design approaches e.g. greening of catchments.

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
		per decade from 1947 to 2002, and is linked to the increase in heavy rainfall days.						forwards.
Tropical cyclone (TC) frequency [(a)] (annual number)	2.4 (1971-2000)	Tropical cyclones threaten Hong Kong during the summer months. Recently a decline in the number of typhoons occurring in the South China Sea has been observed from an average annual frequency of 5.5 from 1961-90, to 3.7 a year from 1996-2005, probably due to interdecadal variations. Fewer TCs occur in El Nino years. No significant trends in the annual numbers of typhoons passing within 100, 200 and 300 km of HK from 1961 to 2008 [(14)].	n/a	n/a	n/a	**Local.** Hong Kong Observatory, Leung *et al.*, 2007b [(21)]	n/a	High. Globally there is a great deal of uncertainty in this area. There is a broad suggestion that TCs frequency may decrease, but their range and severity may increase (likely acc. to AR4). More research is needed in this area.
Average annual incidence of category 4 and 5 tropical cyclones	0.2	Recent decline in severity of TCs affecting Hong Kong has been observed. In 1961-90, 1.9 TCs a year would be cat4-5, from 1996-2005 only 0.2 were. The recent decline appears to be due to interdecadal variations. No significant trends in the	n/a	n/a	n/a	**Local.** Hong Kong Observatory, Leung *et al.*, 2007b [(21)] Hong Kong Observatory, Wong and Mok, 2009 [(15)] **International**, IPCC 2007 [(22)]	Low	High. Poor statistical dataset due to low frequency of such events in Hong Kong.

(a) Tropical cyclone frequency defined as the annual number of tropical cyclones landing over the South China coast within 300km of Hong Kong. Category 4-5 is defined as 1-minute of maximum sustained wind ≥ 114 knots

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
		annual numbers of typhoons of any intensity passing within 100, 200 and 300 km of HK from 1961 to 2008 [14].						
ENSO / monsoon activity	Neutral in late 2008	For an El Niño year or the year following onset of El Niño, Hong Kong tends to be wetter. The annual number of tropical cyclones is predominantly less (more) than normal for El Niño (La Niña) onset year and the year after onset. During El Niño (La Niña) winters, the winter monsoon over southern China tends to be weak (strong), Hong Kong tends to have higher (lower) mean winter temperatures and there is an increase in the occurrence frequency of higher (lower) daily mean temperatures.	n/a	n/a	n/a	**International**, IPCC 2007 [22] **Local.** Hong Kong Observatory, Lam (1993) [23], Leung and Leung (2002) [24], Wu and Leung (2008) [25],	n/a	High. More research needed in this area. Models suggest a weakening of the ENSO-monsoon relationship in a future warmer climate, although this may not be applicable for Hong Kong.
Sky Conditions								
Cloud amount (%)	Annual: 67.4% (1971-2000)	Increasing at an annual rate of 1.8% per decade over the period 1961 – 2001	n/a	n/a	n/a	**Local**. Hong Kong Observatory, Leung *et al.*, 2004 [20]	n/a	n/a. More research is needed in this area.
Global solar radiation (MJ/m^2)	Annual: 13.23 (1971-2000)	Has decreased by 26% (1964 – 2002) at a rate of $1MJ/m^2$ per decade.	n/a	n/a	n/a	**Local**. Hong Kong Observatory, Leung *et al.*, 2004 [20]	n/a	n/a. More research is needed in this area.
Sea Conditions								
Sea level rise / SLR (mm)	Rising at 2.4-2.7 mm per year	Currently rising at 2.4 mm per year for the period 1954-2007 at North Point / Quarry Bay,	Not defined	260-590 mm	Not defined	**Local**, Hong Kong Observatory, Wong *et al.*, 2003 [26] **Regional,** Huang 2004 [27]	Very Low. There are numerous uncertainties (see	High. More research is needed in this area (including assessing

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
	depending on location	and at an average rate of 2.7 mm per year for the period 1963-2007 at Tolo Harbour.				**International**, IPCC 2007 (22) There is no international consensus on upper bound and most likely SLR by 2100. The IPCC AR4 projections are used in this study for identifying the lower bound of likely SLR, but should not be construed as the most likely or upper bound, as they are incomplete.	*Section 2.3*). The upper bound could be considerably higher should ice sheet melt at Greenland / Antarctic occur in a rapid nonlinear fashion. Emerging scientific studies suggest that SLR could be in the order of 500–2000 mm by 2100.	the rapid melt seen at the North Pole for the last 2 summers) (a). The IPCC recently stated that it failed to include the contribution from dynamic ice flow (at the Arctic and Antarctic) into its SLR projections. This means that effectively there is no upper bound estimate.
	Rising at 2.4 mm/year at South Sea, China	The sea level at South Sea has risen by 72 mm over the last 30 years	Sea level will raise by 470 mm at the area near Pearl River Delta, China	Raise by 310 mm	Raise by 560.mm	**Regional:** Regional, National Oceanography Bureau of CPG, 2009	Very low as they lack of long term monitoring data and research in this area.	High as most of the researches are based on computer modelling to predict the impact of global climate change on ocean and coastal areas.
Sea Surface Temperatures	Rising	The global mean temperature increase for the 0- to 300-metre layer was 0.31C (1950-90)	n/a	n/a	n/a	**International,** Levitus *et al*., 2000 (28)	Low	High. More research and measurement needed.
Acidity (pH) of Seawater	8.104	Between 1751 - 1994 surface ocean pH is estimated to have decreased from approx 8.179 to 8.104, as increasing	7.824 (-0.28)	7.964 (-0.14)	7.754 (-0.35)	**International,** Orr *et al*., 2005 (29)	Low. Feedback mechanisms are poorly understood.	High. Concern that uptake of CO_2 by the ocean appears to have slowed suggesting

(a) Sea level rise is a global issue and there is much ongoing international research in this area. Therefore, it is considered that sea level rise projections relevant to Hong Kong are likely to emerge from such international research.

Climatic Hazard	Current Conditions	Observed Change	Impact by 2100	Lower Bound	Upper Bound	Source and Nature of Study (i.e. local, regional, international)	Confidence	Uncertainties
		atmospheric CO_2 lowers oceanic pH and carbonate ion concentrations					Impact could be much higher.	saturation.

2.3 *UNCERTAINTIES IN CLIMATE CHANGE SCIENCE*

The subject of climate change is relatively new and the science is constantly evolving. There are considerable scientific uncertainties associated with lack of information and disagreement about what is known or even knowable embedded in the current state of climate change science. It is important to remember that climate *projections* should not be misinterpreted as climate *predictions.* The scientific community adopts the term *projections* (and not *predictions*) when describing future changes in climate as *projections* involve assumptions in parameters, e.g. future socio-economic and technological developments, and are therefore subject to substantial uncertainty.

The IPCC AR4 currently represents the best available international consensus on the likely impacts of climate change, upon which the current vulnerability analysis for Hong Kong is based. Nonetheless, ERM has noted areas where the risks are such that a watching brief needs to be maintained on the latest science to ensure that appropriate responses are developed.

Some of the key uncertainties that are inherent in climate change science and impact assessment should be kept in mind during the consideration of likely impacts and when devising adaptive responses. These include [30]:

2.3.1 *"Real World" Environmental Uncertainty; Inherent and Natural Internal Variability*

Many environmental processes, including the weather and climate which are variable over all spatial and temporal scales, can only be described probabilistically (pure "risk"). In addition to human activities, climate change may also be associated with natural variability, i.e. natural external factors (e.g. solar output, volcanic activity) and/or natural internal variation of the climate system. Uncertainty due to natural variability also include future choices made by societies, business or individuals that affect the social and economic environment in which climate adaptation decisions are taken and implemented, as well as variability in stock markets, social and some ecological systems.

2.3.2 *Data Uncertainty*

Data uncertainty may arise due to:

- Measurement error, both random and systematic (e.g. bias);
- Incomplete or insufficient data due to limited temporal and spatial resolution (e.g. accurate long term observational data are lacking, particularly in the developing world and oceanic data); and,
- Extrapolation based on uncertain data.

Data uncertainty can be particularly acute when attempting to determine the risk associated with extreme events as they are rare and the consequences may also be more uncertain.

2.3.3 *Knowledge Uncertainty*

The available theoretical and empirical knowledge is unlikely to provide complete, sufficient or even partial understanding of the problem a decision-maker may face. Knowledge uncertainty also includes uncertainty about the future. "Ignorance" should be acknowledged in circumstances where there is a chronic lack of knowledge.

- Future emissions: The SRES scenarios make no assumptions about future fossil fuel supplies, but assume that the supply of conventional fossil fuels will be able to keep up with demand which contradicts expert opinion from the energy modelling sector.

- Uncertainties regarding sea level rise (SLR) projection: The rate and magnitude of future SLR remain one of the largest areas of uncertainties in climate change impact assessments worldwide due to our limited understanding of many of the oceanic processes and the role of oceans in climate change. Although the SLR projections in IPCC AR4 take into account the increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, this rate could change in the future, hence the projections have not captured the full effects of changes in ice sheet flow. Some studies published since the IPCC AR4 indicated that sea levels could potentially rise by substantially more than the levels predicted in AR4. Hence in this study, the IPCC's figures are presented as the lower bound of SLR projections. This area deserves more attention and regular review on the latest scientific developments regarding SLR, as well as the range of alternative SLR figures that have recently emerged in the scientific literature.

- Atmospheric inertia: The inertia of the climate system delays the responses in the atmosphere to both external and internal forces. "*Even if all greenhouse gas emissions could be stopped today, the immense inertia in the Earth's climate systems means that changes to our climate for the rest of the century are unavoidable* [31]". Committed climate change indicates that there could be another 0.6°C in temperature rise and changing weather patterns for the next 40 years from emissions already emitted [11].

- Uncertainties regarding dangerous / run-away climate change: There are increasingly concerns that "dangerous"[31] warming (2°C exceeding pre-industrial levels) may instigate a number of positive feedback mechanisms, whereby natural tipping points are exceeded and self reinforcing, run-away warming is initiated [31]. Most GCMs do not yet include the effect any warming might have on the positive feedback loops. The tipping point of catastrophic climate change may be approaching sooner, and at a lower atmospheric concentration of GHGs than was previously thought. Examples of such feedback mechanisms, which could all trigger further warming, are illustrated in *Table 2.3*.

Table 2.3 Climate Change Positive Feedback Mechanisms

Feedback Mechanism	Status c.2008	Source
Release of methane from previously frozen deposits i.e. permafrost, methane hydrates.	Already occurring in Northern Siberia and North America	*International Siberian Shelf Study* 2008 (32)
The die-back of tropical forests and the release of their embodied carbon through forest fires.	Already occurring in the Amazon.	Lancaster University, University of East Anglia, 2008 (33)
Change to the albedo balance of the polar regions, as sea ice is reduced, and allowing oceans to absorb more warmth.	Already occurring in the Arctic and Antarctic	*Scientific American*, 2004 (34)
Higher CO_2 levels in the atmosphere reduce the ocean's ability to store CO_2 by increasing the acidity of the ocean and harming plankton and crustaceans.	Already occurring (particularly in the Southern Ocean).	*Science*, 2007 (35)

Whether climate as a whole is now approaching a tipping point is difficult to judge at present. ERM recommends that adopting the precautionary principle is appropriate in these circumstances.

- Atmospheric sensitivity to GHG and saturation thresholds: The sensitivity of the planet to increased atmospheric GHG concentrations and the rate with which the climate could change remains uncertain. The impacts of climate change could be considerably worse than that stated in the IPCC AR4.

2.3.4 *Model Uncertainty*

Model uncertainty is a particular example of knowledge uncertainty. Models may be conceptual or heuristic (learning by trial and error). Other technical models describe data (statistical models), known processes (e.g. environmental systems models), assess risks (risk assessment and stochastic process models) and impacts (impact and valuation models), examine the influence of decision on future (decision models) and study the influence of the future social / environmental systems on the outcomes of decisions. The sources of uncertainty arise from:

- Model choice and structure: Many aspects and physical processes of the climate system, such as the roles played by clouds, aerosols, the oceans etc, are yet to be fully understood and quantified in GCMs. Secondly, there is no "right" or "wrong" in climate change projections. It is not possible to determine whether one GCM is more accurate/reliable than the other as different GCMs, with different characteristics, produce different climate change patterns. Lastly, a GCM that can reasonably reproduce the observed trends and patterns does not necessary imply its capability in accurately simulating the future climate.

- Model input values: The values of the variables needed as inputs to models may be uncertain, as described by a range as a fuzzy set, or taken from a probability distribution of potential values for use in a quantitative Monte Carlo-based risk model.

- Model parameters: Parameter values may be known with high confidence in some of the models that are based on fundamental understanding of the underlying physical processes. However, these are estimated from limited data of uncertain quality through the process of model or parameter-fitting for many climate forecasting, downscaling and impact assessment models used in climate impact risk assessments.

- Model output variables and values: Uncertainty and sensitivity analysis are used to determine the consequences of model uncertainties for model output variables. Uncertainty propagates through the impact assessment process. It is essential in developing or using a particular model that important assumptions are identified and assessed for their possible consequence for any analysis, and that subsequent users are aware of their limitations when arriving at their decision.

The IPCC also has its limitations: The IPCC's schedule for producing reports requires a deadline for submissions up to two years prior to the report's final release in order to reach consensus agreement from all signatory governments to the UNFCCC. This is a limitation especially in an area of science where our understanding is rapidly changing, as expressed by the IPCC themselves. Some of the recent research omitted from IPCC AR4 includes the shutdown of the thermohaline circulation (the Gulf Stream), disintegration of the West Antarctic and Greenland ice sheets, and widespread bleaching of coral reefs.

The findings of the IPCC have been used as the basis for the climate change scenarios in this study as it is the best available international consensus; however it is recommended that a watching brief is kept on the latest scientific development.

2.3.5 *Recognising and Dealing with Uncertainty*

Uncertainties may arise from a variety of sources for a particular outcome or decision and categorizing these, and ranking or estimating their magnitude often relies on expert, subjective judgement. There is not always a "right" categorization, and acknowledging the presence of uncertainty is more important than assigning a category.

Science cannot and will not be able to prove any statement with absolute certainty and confidence. Any climate change adaptation strategies should be flexible enough to be effective in the face of variability, the reasonable worst case scenario, as well as any new evidence as it arises. In order to avoid the development of considerable maladaptation in infrastructure, we should not wait for 100% consensus to emerge on any aspect in the academic record of climate change. Furthermore, as highlighted in the *Stern Review* (2006) [36], an early proactive approach against climate change will be less expensive and more effective than a reactionary, retrospective or emergency response.

2.4 *SECTOR COVERAGE*

The sectors covered within this assessment and the assumptions regarding the baseline conditions of each of the sectors within present day Hong Kong are summarized in *Table 2.4*.

Table 2.4 Sectoral Baseline

Sector	Characteristics of the Sector Being Assessed	Significance to Hong Kong				Present Vulnerability
		GDP	Employment (workforce)	Distribution of Infrastructure	Socio-cultural Importance	
Agriculture	Including poultry production, pig husbandry, dairy farming and cattle husbandry, and fruit, flower and vegetable growing.	<1%	4,870 (0.1%)	Sector centered in the New Territories and Lantau Island with ~ 2,550 farms and 800 ha.	High	Low
Aquaculture (including fisheries)	Including marine capture fisheries, marine aquaculture, inland pond aquaculture, and oyster culture.	<1%	10,888 [(a)] (0.3%)	Offshore, coastal and rural regions of the New Territories. Oyster culture is centered on Deep Bay	High	Medium
Biodiversity / Nature Conservation	Including terrestrial, aquatic and marine biodiversity, and nature conservation	n/a	>1,830 (0.1%)	Across the territory although nature conservation efforts are concentrated at designated sites such as country and marine parks.	Low-medium	High
Built Environment and Infrastructure	Including construction and maintenance, building stock, transport infrastructure, communications infrastructure, drainage and sewage infrastructure	n/a	287,900 (7.9%)	Hong Kong's steep slopes are poorly suited to development. Infrastructure and building stock is concentrated on flat coastal strips (often reclaimed).	Medium	High
Business and Industry	Including: trading and logistics, manufacturing, professional services and producer services	41.18%	1,418,000 (39.1%)	Distributed across the territory centered on major commercial and logistics centres (i.e. ports and airport)	High	High
Energy Supply	Including electricity generation, electricity distribution and transmission, primary fuel imports and supply	2-3% (direct)	12,400 (0.3%)	Infrastructure across the territory, fuel and 20% electricity from outside Hong Kong. 4 plants located in Hong Kong in Lamma, Tuen Mun and Lantau.	High	High

(a) This figure does not include the approximate 4,700 mainland deckhands that are employed in Hong Kong.

Sector	Characteristics of the Sector Being Assessed	Significance to Hong Kong				Present Vulnerability
		GDP	Employment (workforce)	Distribution of Infrastructure	Socio-cultural Importance	
Financial Services (including insurance)	Including: banking, financial trading, brokerage and speculation, asset management, insurance, reinsurance and other financial services	15.9%	192,700 (5.3%)	Centred on Yau Tsim Mong, Kowloon City, Wan Chai and Central and Western Districts. Global assets and sensitivities.	High	High
Food Resources (agriculture, aquaculture and imports from the mainland / overseas)	Including agriculture, aquaculture and fisheries in Hong Kong, overseas food imports and food wholesale and retail trade	n/a	14,392 (0.4%)	Retail distributed across the Territory. Importers concentrated in the port warehouse districts in Kwai Tsing District, important import origins include Mainland China and Thailand	Medium	High
Human Health	Healthcare infrastructure, also changes to mortality and morbidity re accidents, chronic health conditions, air water and vector borne diseases and impacts on external infrastructure i.e. water	n/a	50,232 (1.4%)	Distributed across the territory, although focusing on the major centres of population	High	Medium
Leisure and Tourism (including cultural heritage assets)	Hotels, tourist attractions and services, transport	3.2%	193,800 (5.3%)	Tourism attractions and accommodation are focussed either side of Victoria Harbour. Key transport nodes include the cruise ship terminals in Tsim Sha Tsui and the airport at Chek Lap Kok, the Macau Ferry Terminal and road/rail links with the Mainland	Medium/High	Medium

Sector	Characteristics of the Sector Being Assessed	Significance to Hong Kong				Present Vulnerability
		GDP	Employment (workforce)	Distribution of Infrastructure	Socio-cultural Importance	
Water Resources	Including local yield and treatment, and Dongjiang imports	2-3% direct	4,463 [(a)] (0.1%)	Distribution network located across the territory, reservoirs primarily in the New Territories. Imported component comes from the Dongjiang in Guangdong, via the Shenzhen reservoir and the Dongshen supply line	Medium	High

(a) Employment figures for the Water Resources sector only cover the local Hong Kong employment sector and do not include jobs on the Mainland associated with providing Hong Kong's water supply.

ERM has conducted this study by subdividing the vulnerability assessment into economic sectors as per the *Study Brief*. Some other climate change adaptation studies have carried out the assessment by climate change impact type (e.g. heatwaves, flooding); others have chosen a geographic method of ordering their findings. The IPCC notes that there is no "*single preferred method*" providing analysis follows the key steps identified as best practice [37], as all approaches have their inherent strengths and weaknesses.

It should be noted that there is some overlap between the delineations of these sectors, and that some sectors have a natural symbiosis with others, as a result none of the sectors should be considered in isolation. Additionally, one sector's adaptation response could aggravate another sectors capacity to respond if response strategies are formulated without adequate cross-sectoral consultation. Vulnerability assessments and adaptation responses for all sectors should be considered in a holistic manner with broad stakeholder consultation.

2.5 HONG KONG CLIMATE CHANGE VULNERABILITY ASSESSMENT

The following sections outline the framework that was used for the vulnerability assessment for each of the systems (ie the sub-sectors), hence the determination of key vulnerable sectors. This framework follows the best practice identified in the international literature review and involves four main stages as follows:

2.5.1 *Exposure and Sensitivity Analysis*

This section introduces the exposure (i.e. the background climate conditions and their changes) that impact on a system/receptor for each of the sectors. The earlier introduction on certainty of climate change scenarios will be used to focus the assessment. This section also examines the sensitivity (i.e. the responsiveness) of a system/receptor to climatic influences i.e. what are the impacts (primary and secondary i.e. direct and indirect) that may affect the system, and what is the probability of this occurring. This includes a review of the level of confidence with respect to the exposure and sensitivity of the sector in Hong Kong; the sources of uncertainties will also be identified.

2.5.2 *Identification of Potential Consequences*

This section identifies the potential impact upon addressing the elements of exposure and sensitivity in the above section i.e. who and what will be affected. This includes a review of confidence with respect to the potential impacts in Hong Kong; the sources of uncertainties will also be identified.

2.5.3 *Climate Change Impacts and Vulnerability Assessment*

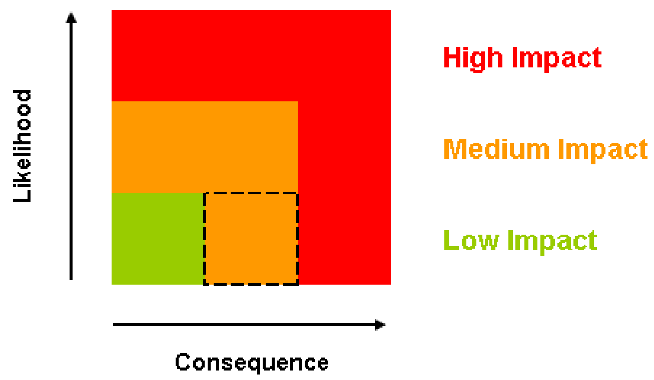
This section provides an overview on how vulnerable each system is to the potential impacts associated with the changing climate i.e. how exposed is this system to the impact, how sensitive are they to the change, and what is their capacity of the system/receptor to adapt.

The vulnerability of a system is influenced by its *sensitivity*, which in turn determines the impacts; it also depends on its *adaptive capacity*. The definition of "vulnerability" used in this assessment is that defined by the IPCC.

Climate Change Impact

Climate change impact is defined in this Study as the product of the likelihood and the consequence of a consequence occurring, including an assessment of its magnitude. In addition, impacts are assigned as high (H), medium (M) or low (L). Our methodology in assigning these terms is illustrated below:

Figure 2.1 Methodology for Defining Impacts



As per international best practice, and in line with the precautionary principle, ERM has taken a precautionary approach to defining impacts, hence a high consequence event, with a low likelihood of occurrence is still defined as a high impact. The highlighted square in *Figure 2.1*, whilst having a low likelihood of occurring, has been assigned to medium impact as the consequences of it occurring are medium.

Following international literature, the definitions of likelihood used in this Study are based on a combination of probability and frequency of an impact occurring, as illustrated in *Table 2.5*.

Table 2.5 Defining Likelihood

Likelihood	Definition
High	Likely (a) to occur several times a year
Medium	Likely to occur on an annual basis
Low	Likely to occur on a decadal basis

(a) Likely here refers to the IPCC's definition of 'likely' i.e. more than 60% probability

Consequence is a definition of the severity of the given impact should it occur (*Table 2.6*). These are based upon best practice in risk management i.e. the ALARP (as low as reasonably practicable) model and Hong Kong risk guidelines, and draw upon those used from literature review.

Table 2.6 Defining Consequence

Consequence	Definition
High	Likely[1] to cause: • Serious loss of life and limb (over 100 affected) • Creation of large number of permanent or temporary climate change refugees (over 5,000 people) • Permanent loss or irreversible change to ecosystem or majority of component species • Permanent loss of majority of sector revenue • Destruction or serious damage to key assets • Serious interruption to sector activities for over 1 month
Medium	Likely to cause: • Some loss of life and limb (over 10 affected) • Creation of permanent or temporary climate change refugees (<5000 people) • Permanent loss or irreversible change to some component species within ecosystem • Permanent loss of minority of sector revenue, temporary loss of majority of sector revenue • Damage to key assets • Interruption to sector activities for over 1 week
Low	Likely to cause: • Risk of non life threatening injury • Creation of temporary climate change refugees (0-500) • Temporary damage, reversible change to ecosystem, loss of small number of component species • Temporary loss of minority of sector revenue • Minor damage to assets • Minor interruption to sector activities for < 1 week

Adaptive Capacity

Resilience is an important concept in understanding vulnerability. When a system (e.g. a community or society) is exposed to a hazard, it may resist or change in order to reach and maintain an acceptable level of functioning and structure.

Resilience in human-ecological systems is characterised by [(38)]:

- The amount of disturbance a society can absorb and still remain within the state of domain of attraction;

- The degree to which the society is capable of self-organisation or adjustment; and,

- The degree to which the society can build and increase the capacity for learning and adaptation.

Societies have inherent capacities to adapt to climate change. Adaptive capacity can reduce the likelihood and magnitude of adverse climate change impacts, as well as exploit beneficial opportunities. It is also a necessary condition for the design and implementation of effective adaptation strategies.

A system requires time to realise its adaptive capacity as adaptation, hence adaptive capacity represents *potential* adaptation, i.e. a high level of adaptive capacity only reduces a system's vulnerability to future hazards (e.g. anticipated future storms, extreme rainfall events) or to continuous hazards (e.g. increases in mean temperatures over decades), to which the system can adapt reactively. In contrast, current levels of vulnerability are determined by existing adaptations resulting from the past realization of adaptive capacity [39].

Climate change vulnerability assessments have facilitated our understanding of adaptive capacity. The indicators selected for vulnerability assessments often provide important insights on the factors, processes and structures that influence adaptive capacity. The term "adaptive capacity" is used to cover a multitude of factors, but to date, there is little agreement as to what these factors should be. Some dimensions of adaptive capacity are generic (such as education, income, health), while others are specific to particular climate change impacts (such as drought, heatwaves). Some studies argue on the usefulness of indicators of generic adaptive capacity and the robustness of the results.

The table below presents some of the elements that may be considered when assessing the adaptive captive of a system.

Table 2.7 Elements Used for Assessing Adaptive Capacity [40]

• Economic development / resources • Technology • Innovation, i.e. the development of new strategies or technologies • Existing anticipatory [a] / autonomous [b] / planned adaptation [c] • Infrastructure • Information, skills and management • Governance structures • Equity • Human capital	• Social capital (made up of the networks and relationships between individuals and social groups that facilitate economic well-being and security) • Values • Perceptions • Customs • Income • Traditions • Level of cognition / education

The definitions of adaptive capacity adopted in this Study are illustrated in *Table 2.8* and are based upon the recent World Bank definitions of adaptive capacity outlined in the Climate Resilient Cities project [38]. It may be difficult to evaluate the adaptive capacity for some sectors. Evidence and experience

(a) Adaptation that takes place before impacts of climate change are observed.

(b) Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.

(c) Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

from the past may be used to guide judgement and priority assessment in this aspect. It should be emphasized that "*[E]even societies with high adaptive capacity remain vulnerable to climate change, variability, and extreme events*" (38).

Table 2.8 Defining Adaptive Capacity

Adaptive Capacity	Definition
High	• Low sensitivity (high tolerance) to change • High likelihood and significance of autonomous adaptation • Planned adaptation may not be necessary, or is no/low cost • Low risk of maladaptation
Medium	• Medium sensitivity (tolerance) to change • Moderate likelihood and significance of autonomous adaptation • Planned adaptation is low cost / win-win • Moderate risk of maladaptation
Low	• High sensitivity (low tolerance) to change • Low likelihood or significance (where it occurs) of autonomous adaptation. • Planned adaptation may not be feasible, or is financially prohibitive. • High risk of maladaptation.

2.5.4 Selecting "Key" Vulnerabilities

Policy processes can be informed by scientific analysis but substantial scientific uncertainties and value judgements are inherent in the assessment of key vulnerabilities. Therefore, the determination of which impacts of climate change are potentially "key" and what is "dangerous" is a dynamic process. *Table 2.9* shows some of the criteria / elements that may be considered when identifying key vulnerabilities. These provide a basis for determining the priorities for action and/or management in Hong Kong.

Table 2.9 Criteria Used for Identifying Key Vulnerabilities (41)

Factual / Objective Elements	Normative / Subjective Elements
• Magnitude of impacts • Timing of impacts • Persistence and reversibility of impacts	• Likelihood of impacts and vulnerabilities, and confidence in those estimates • Potential for adaptation • Distributional aspects of impacts and vulnerabilities • Importance of the vulnerable system(s)

Magnitude

Both the scale (e.g. the area or number of people affected) and the intensity (e.g. the degree of damage caused) of an impact affect its magnitude. Large magnitude impacts are more likely to be evaluated as "key". Some of the metrics that have been used to describe the magnitude of climate impacts include:

- Monetary units, e.g. welfare, income, revenue losses, costs of anticipating and adapting to certain biophysical impacts, estimates of people's willingness to pay to avoid (or accept as compensation for) certain climate impacts

- Non-monetary indicator, e.g. number of people affected, morbidity and mortality, forced migration, species extinction numbers or rates.

Timing

An adverse impact that is expected to happen soon is more likely to be evaluated as “key”. Those occurring in the distant future which are caused by nearer-term events or forcings, such as the disintegration of the West Antarctic ice sheet, may also be considered “key”. More significant impacts may also include those occurring suddenly (and surprisingly), as opposed to those occurring gradually – i.e. the rate at which impacts occur. In addition, very rapid change in a non-linear system can exacerbate other vulnerabilities (e.g. human vulnerability to disease may be influenced by impacts on agriculture and nutrition).

Persistence and Reversibility

Persistent or irreversible impacts are more likely to be considered “key”. The emergence of near-permanent drought conditions and intensified cycles of extreme flooding that were previously regarded as “one-off” events are some examples of impacts that are persistent. Irreversible impacts (at least on time-scales of many generations) include the loss of unique cultures and the extinction of species.

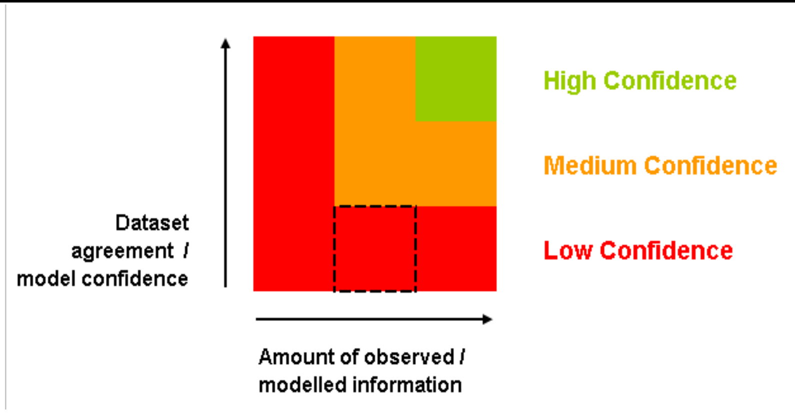
Likelihood and Confidence

Uncertainty of climate change and the associated impacts are often characterized by the likelihood of impacts and our confidence in their assessment. Likelihood represents the probability of an outcome having occurred or occurring in the future while confidence is the subjective assessment that any statement about an outcome will prove correct.

In the vulnerability assessment, confidence levels are attached to the projected climate change for Hong Kong and the identified potential consequences to indicate the level of confidence in the “correctness” of a result. This method of assigning confidence levels follows that adopted by the United Kingdom (UK) Marine Climate Change Impacts Partnership (MCCIP), which is based upon the framework used by the IPCC and that adopted by the UK Climate Impact Programme (UKCIP).

Qualitative assessment of both the amount and consistency of the available information leads to an overall confidence rating of high, medium or low. A high confidence denotes that the available evidence is high in both the quantity and agreement of information available. As per international best practice, a low confidence is assigned if **either** is insufficient due to a high degree of uncertainty.

Figure 2.2 Methodology for Defining Confidence Statements



The square highlighted in *Figure 2.2* represents a hypothetical topic where there is a "moderate" amount of information but where the agreement between different sources of information is "low". This square falls into the red area which gives us an overall confidence rating of "low".

Confidence estimates have been assigned to the potential climate scenarios and the possible resultant impacts for Hong Kong as illustrated in *Table 2.2* and *Table 2.11*, respectively.

Potential for Adaptation

"Key" vulnerabilities generally involve those impacts that have lower availability and feasibility of effective adaptation. For instance, there is relatively little scope for adaptation to loss of land resulted from sea-level rise, and there are no realistic options for preserving many endemic species in areas that become climatically unsuitable. The adaptive capacity of human systems is likely to be constrained when key assets are long lived and, once in place, cannot be readily modified or adjusted. In addition, any system may be overwhelmed by sufficiently rapid and extreme changes. Adaptation assessments should consider the technical feasibility of certain adaptations, the availability of required resources, the costs and side-effects of adaptation, the knowledge about those adaptations, their timeliness, the (dis-)incentives for adaptation actors to actually implement them, and their compatibility with individual or cultural preferences.

Distribution

Equity issues are often raised when concerning distributional impacts of climate change. "Key" impacts and vulnerabilities tend to be those that are highly heterogeneous or which have significant distributional consequences. Factors such as income, gender, age, regional/national/sectoral groupings and others may be considered.

Importance of the vulnerable system(s)

Different people and groups of society may value the significance of impacts and vulnerabilities on human and natural systems differently. In this assessment, the significance of a system is determined by considering elements that include workforce, contribution to GDP, geographic distribution, socio-cultural importance, as well as (but are not limited to) other factors such as ecological importance / value, ecosystem services, interdependencies.

2.5.5 *Remarks*

This vulnerability assessment aims to identify the potential key vulnerable areas. This assessment does not, however, attempt to order the vulnerabilities by priority or severity as "*no single metric can adequately describe the diversity of key vulnerabilities, nor determine their ranking*" [40]. The vulnerabilities are determined by considering the elements identified in *Table 2.9*, upon which the prime criteria for "key vulnerability" are based; this assessment has also taken into account the discussions with, and amongst, the stakeholders during the *Vulnerability and Adaptation Assessment Workshop*.

The categories of High (H), Medium (M), and Low (L) assigned in this assessment are indicative and are presented for illustrative purposes only. It should also be noted that this climate change impacts and vulnerability assessment is based upon the current knowledge and understanding of climate change science and the associated consequences, as well as the data and information available (in particular, with reference to the local situation) during the time of the assessment. Such an assessment should be reviewed on a regular basis in order to take into account updated data and information (on the science, the methodology, for example) as they become available. Furthermore, detailed sectoral climate change impact assessments are encouraged to identify specific receptors that can potentially be impacted and their vulnerabilities.

2.6 CLIMATE CHANGE IN HONG KONG – SECTORAL IMPACTS AND VULNERABILITY

2.6.1 *Hong Kong Climate Change Vulnerability Assessment*

An overview of the exposure units and the receptors that may be sensitive, and the sensitivity (or responsiveness) of a receptor to climate change, along with the climatic and non-climatic drivers that may have an influence on these, are illustrated in *Table 2.10*. The full exposure and potential consequences for each of the sectors are detailed in *Annex A*.

Table 2.10 Exposure and Sensitivity of the Sectors

Sector	Exposure and Sensitivity
Agriculture	• Increase in surface temperature; • Changes in frequency and/or severity of extreme weather events; • Changes in precipitation patterns; • Decreased global solar radiation; • Sea level rise; • Changes to soil moisture levels; • Changes to planting, transplanting and harvesting timetables; • Impacts on agricultural production; • Impacts on assets and infrastructure; and, • Health and safety of workforce.
Aquaculture	• Increase in sea surface temperatures; • Potential change in ocean currents; • Ocean acidification; • Changes in frequency and/or severity of extreme weather events; • Changes in precipitation patterns; • Sea level rise; • Onset of hypoxic conditions; • Changes in species distribution and breeding patterns, marine productivity; • Changes in capture fisheries operations; • Changes in species selection; • Changes in fish pond water levels; • Coastal flooding / inundation of low lying coastal areas; • Impacts on assets and infrastructure; and, • Health and safety of workforce.
Biodiversity / Nature Conservation	• Increase in surface and sea surface temperatures; • Changes in frequency and/or severity of extreme weather events; • Changes in precipitation patterns; • Ocean acidification; • Onset of hypoxic conditions; • More frequent hyposaline events; • Changes in terrestrial and marine species distribution/occurrence; • Changes to Montane habitat; • Changes in Hong Kong ecological communities; • Wash out of streams; • Increased risk of storm damage to woodlands; and • Changes in the size of intertidal habitats and sedimentation rates due to sea level rise.
Built Environment and Infrastructure	• Increase in surface temperatures; • Changes in frequency and/or severity of extreme weather events; • Changes in precipitation patterns; • Sea level rise; • Impacts on the building stock and slope stability; • Impacts on transport, communication and drainage (including stormwater drainage, sewerage systems and wastewater treatment facilities) infrastructure; and, • Health and safety of workforce, building occupants and tenants.

Sector	Exposure and Sensitivity
Business and Industry	• Increase in surface temperature; • Changes in precipitation patterns; • Changes in frequency and/or severity of extreme climate / weather events; • Sea level rise; • Reduced visibility (or at least the perception of poor air quality); • Impacts on manufacturing facilities in the Pearl River Delta Economic Zone (PRDEZ) and locally; • Allocation of public funds to disaster management and adaptation; and, • Impacts on supply chain, assets and infrastructure; and, • Health and safety of workforce.
Energy Supply	• Increase in surface temperature; • Changes in precipitation patterns; • Changes in frequency and/or severity of extreme climate / weather events; • Sea level rise; • Impacts beyond the HKSAR border at the origins of imports and impacts on its supplier trading partners; • Knock-on socio-economic consequences in the Broader economy; • Electricity production, increased import insecurity due to rising international demand and increased national stockpiling, rising prices; • Logistical delays to international cargo transportation; • Increased competition for electricity in the region; • Changes in electricity demand and supply patterns; • Impacts on assets and infrastructure (e.g. electricity generation and transmission, and those associated with fuel distribution); and, • Health and safety of workforce.
Financial Services	• Increase in surface temperature; • Changes in precipitation patterns; • Changes in frequency and/or severity of extreme climate / weather events; • Sea level rise; • Changes to water resources; • Impacts on telecommunications networks; • Impacts on insurers and reinsurers; • Changes to the risk profile of individual businesses; • Implications for business operations, investments, insurance, corporate pension funds and corporate reputation; • Changes in market demand for goods and services; • Impacts on assets and infrastructure; and, • Health and safety of workforce.
Food Resources	• Changes in surface temperature; • Changes to soil moisture levels; • Changes in frequency and/or severity of extreme climate / weather events; • Changes in precipitation patterns; • Decreased global solar radiation; • Sea level rise; • Changes to water resources; • Impacts on agricultural production at the origins of food imports, notably China and Thailand; • Impacts on supply chain, assets and infrastructure; and, • Health and safety of workforce.

Sector	Exposure and Sensitivity
Human Health	• Increase in surface temperature; • Changes in precipitation patterns; • Changes in frequency and/or severity of extreme climate / weather events; • Decreased global solar radiation; • Changes in the survival of some pathogens and disease patterns; • Changes in respiratory, vector-borne, water-borne and food-borne diseases; • Impacts on health and external infrastructure; and, • Health and safety of workforce and the general population.
Leisure and Tourism	• Increase in surface temperature; • Changes in precipitation patterns; • Changes in frequency and/or severity of extreme climate / weather events; • Reduction in visibility; • Sea level rise; • Impacts on Hong Kong's competitors; • Impacts on tour operators, tourist attractions, assets and infrastructure; and, • Health and safety of workforce.
Water Resources	• Increase in surface temperature; • Changes in precipitation patterns; • Increase in evaporation; • Changes to water resources; • Changes in frequency and/or severity of extreme climate / weather events; • Sea level rise; • Impacts on water quantity and quality; • Impacts on water supply chain, assets and infrastructure; and, • Health and safety of workforce.

2.6.2 *Uncertainties and Limitations of Vulnerability Assessment*

Based on the detailed evaluation of individual sectors and the assessment as in *Section 2.6*, *Table 2.11* summarises the vulnerabilities for each of the systems assessed. This is the first comprehensive assessment of vulnerability to climate change in Hong Kong. It has been carried out based upon the current state of knowledge and the information available in the Fourth Assessment Report (AR4) of IPCC as well as consultant's and expert's judgments so as to make the best possible assessment of potential areas of greatest risk. It should be acknowledged that the quality and quantity of information available to make the assessment vary between systems. Moreover, there are uncertainties and limitations associated with the information in AR4 and hence the outcome of the vulnerability assessment. For instance, there is high uncertainty in fisheries and biodiversity compared to some other highly managed systems such as engineered slopes. The gradings in *Table 2.11* are derived based on various prime criteria for "Key" Vulnerability such as Distribution, Timing, Importance, Magnitude as well as the Consultant and their expert's opinion while *Table 2.12* provides further details on rationales behind the assessment for each system presented in the *Table 2.11.* The sources of uncertainties and areas for further research from this vulnerability assessment are further illustrated under *Section 2.6.3.*

There are many areas in climate change that lack of or do not have sufficient "local" scientific information at the time of preparing the vulnerability assessment, for example, information on the health impacts to the sub-tropical regions like Hong Kong is not extensive. Where there is a lack of "local" scientific data to support a research-driven approach to assessing the vulnerability and adaptation of a particular sector, ERM has exercised expert judgement to determine the risk rankings of this sector, for example, the risk rankings under Human Health sector in *Table 2.11*. At the time of preparing this report, IPCC is preparing the Fifth Assessment Report (AR5) due for publication in 2015. Much work is being undertaken, including the development of new scenarios for impacts, adaptation and vulnerability (IAV) assessments. With the rapid evolution in the climate change science, the vulnerability assessment should be considered as a dynamic process and the findings of this risk based assessment should be regularly reviewed and updated.

As shown in *Table 2.11*, the key vulnerabilities, represented as "High (H)" vulnerability, have been identified. This vulnerability assessment highlights the current priorities for adaptation research and supplementary action; the adaptation options for theses areas are discussed in *Section 6* of this Report.

It should be noted that this vulnerability assessment provides a high-level "screening" of the key vulnerabilities that are currently considered critical. More detailed and focused assessments using more sophisticated methodology (e.g. modelling) are likely to be needed for identifying specific vulnerabilities.

Table 2.11 Vulnerabilities of the Sectors

		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
		Climate Change Impacts			**Potential for Adaptation**				
	Systems	**Adverse Implications**	**Potential to Benefit**	**Confidence**	**Present Day Capacity**	**Adaptive Capacity**	**Importance**	**Prime Criteria for "Key" Vulnerability**	**Vulnerability**
A	**Agriculture**								
A1	Poultry Production	M	L	L/M	M/H	M/H	M	Magnitude, Importance	L/M
A2	Pig Husbandry	M	L	L/M	M/H	M/H	L/M	Magnitude, Importance	L/M
A3	Diary Farming / Cattle Husbandry	M	L	L/M	M/H	M/H	L	Magnitude	L/M
A4	Fruit, Flower and Vegetable Production	M/H	L	L/M	M	M	L	Persistence, Irreversibility, Magnitude, Timing, Importance	M
B	**Aquaculture & Fisheries**								
B1	Marine Capture Fishery	H	Uncertain	L	M	L	L	Persistence, Irreversibility, Magnitude, Timing, Confidence	M
B2	Marine Culture Fishery	H	Uncertain	L	M	L	L	Persistence, Irreversibility, Magnitude, Timing, Confidence	M
B3	Inland Pond Aquaculture	M/H	L	L	M/H	L/M	L	Persistence, Irreversibility, Magnitude, Timing, Confidence	L/M
B4	Oyster Culture Fishery	M/H	L	L	M/H	L/M	L	Magnitude, Timing, Confidence	L
C	**Biodiversity & Nature Conservation**								
C1	Terrestrial / Aquatic Ecosystems and Biodiversity	H	L	L/M	L	L	H	Persistence, Irreversibility, Magnitude, Timing, Low Adaptive Capacity, Confidence, Importance	H
C2	Marine Ecosystems and Biodiversity	H	Uncertain	L	L	L	H	Persistence, Irreversibility, Magnitude, Timing, Low Adaptive Capacity, Confidence, Importance	H
D	**Built Environment & Infrastructure**								
D1	Building Stock	H	L	L/M	M/H	L	H	Distribution, Magnitude, Timing, Low Adaptive Capacity, Importance, Irreversibility, Confidence	H
D2	Transport Infrastructure	H	L	L	M/H	L	H	Magnitude, Timing, Low Adaptive Capacity, Importance, Irreversibility,	H

	Systems	(i) Climate Change Impacts: Adverse Implications	(ii) Climate Change Impacts: Potential to Benefit	(iii) Confidence	(iv) Potential for Adaptation: Present Day Capacity	(v) Potential for Adaptation: Adaptive Capacity	(vi) Importance	(vii) Prime Criteria for "Key" Vulnerability	(viii) Vulnerability
								Confidence	
D3	Communications Infrastructure	H	L	L	M/H	L/M	H	Magnitude, Timing, Low Adaptive Capacity, Importance, Irreversibility, Confidence	M/H
D4	Stormwater Drainage Systems	H	L	L/M	M	L	H	Magnitude, Timing, Low Adaptive Capacity, Importance, Persistence, Irreversibility, Confidence	H
D5	Sewerage Systems	H	L	L	M/H	L	H	Magnitude, Timing, Low Adaptive Capacity, Importance, Persistence, Irreversibility, Confidence	H
D6	Slope Stability	H	L	M	M	L/M	H	Distribution, Timing, Persistence, Importance	H
E	**Business & Industry**								
E1	Trading and Logistics	M	L/M	L/M	M	M	H	Distribution, Magnitude, Timing, Confidence, Importance	H
E2	Manufacturing (Hong Kong)	M	L/M	L/M	M	M	M	Distribution, Timing, Confidence	M
E3	Manufacturing (Pearl River Delta)	M/H	L/M	L	L/M	L/M	M/H	Distribution, Timing, Confidence, Lower Adaptive Capacity	M/H
E4	Professsional and Producer Services	M	L/M	L/M	M	M	M/H	Distribution, Timing, Confidence	M
F	**Energy Supply**								
F1	Electricity Generation	M/H	L/M	L/M	M/H	M	H	Magnitude, Timing, Importance	H
F2	Electricity Transmission and Distribution	M	L	L	M/H	M	H	Magnitude, Timing, Importance, Confidence	H
F3	Primary Fuel Imports and Supply	M/H	L	L	M/H	L/M	H	Magnitude, Timing, Importance, Confidence	H
G	**Financial Services**								
G1	Banking	M/H	L/M	L	L/M	L/M	H	Distribution, Magnitude, Timing, Confidence, Importance	H
G2	Insurance	M/H	L/M	L/M	L/M	M	H	Distribution, Magnitude, Timing, Confidence, Importance	H

	Systems	(i) Climate Change Impacts: Adverse Implications	(ii) Climate Change Impacts: Potential to Benefit	(iii) Confidence	(iv) Potential for Adaptation: Present Day Capacity	(v) Potential for Adaptation: Adaptive Capacity	(vi) Importance	(vii) Prime Criteria for "Key" Vulnerability	(viii) Vulnerability
G3	Other Financial Services	M/H	L/M	L	L/M	L/M	H	Distribution, Magnitude, Timing, Confidence, Importance	M/H
H	**Food Resources**								
H1	Food Imports	H	L	L	M	L	H	Distribution, Magnitude, Confidence, Importance	H
H2	Food Wholesale and Retail	M	L	L/M	M	L/M	H	Distribution, Confidence, Importance	M
I	**Human Health**								
I1	Accidents / External Health Stresses	M/H	L	L/M	M/H	M	M/H	Distribution, Timing, Importance	H
I2	Air Quality and Respiratory Disease	M/H	L	L/M	M	L/M	H	Distribution, Magnitude, Timing, Importance	M/H
I3	Chronic Health Conditions	M/H	L	L/M	M	L/M	H	Distribution, Magnitude, Timing, Importance	H
I4	General Communicable Diseases	M/H	L	M	M/H	M	H	Distribution, Timing, Persistence, Irreversibility, Importance	H
I5	Vector Borne Disease	M/H	L	L/M	M/H	M	H	Distribution, Timing, Persistence, Importance	H
I6	Water Borne Disease	M/H	L	L/M	M/H	M	H	Distribution, Magnitude, Timing, Irreversibility, Importance	M/H
I7	Food Borne Disease	M	L	M	M/H	M	H	Distribution, Timing, Irreversibility, Importance	M
I8	Health Infrastructure	M	L	L/M	M/H	L/M	H	Distribution, Magnitude, Timing, Persistence, Importance	M/H
I9	External Infrastructure	M	L	L	M/H	L/M	H	Distribution, Magnitude, Timing, Importance, Confidence	M
I10	Occupational Health and Safety	M/H	L	M	M/H	M	H	Distribution, Timing, Irreversibility, Importance	M/H
J	**Leisure & Tourism**								
J1	Hotels	M	L	L/M	M/H	L/M	M/H	Distribution, Magnitude, Timing, Importance	M/H
J2	Tourist Attractions / Tourism	M	L	L/M	M/H	M	M/H	Distribution, Magnitude, Timing,	M

		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
		Climate Change Impacts			Potential for Adaptation				
	Systems	**Adverse Implications**	**Potential to Benefit**	**Confidence**	**Present Day Capacity**	**Adaptive Capacity**	**Importance**	**Prime Criteria for "Key" Vulnerability**	**Vulnerability**
	Services							Importance	
K	**Water Resources**								
K1	Impounding and Service Reservoirs	M/H	L	L	M/H	L/M	M	Distribution, Magnitude, Timing, Importance	M/H
K2	External Supply from Dongjiang	H	L	L	M/H	L	H	Distribution, Magnitude, Timing, Importance	H

Table 2.12 Sector Vulnerability Assessment Explanation

Agriculture

A(i)
- The majority of the potential consequences arising from climate change are likely to be negative (e.g. rising commodity prices and falling production), and these could occur on an annual basis.

A(ii)
- Few beneficial climate change effects are anticipated in the sub-tropics.

A(iii)
- Little is known about how local agriculture could be impacted by climate change, e.g. from an increased atmospheric CO_2 concentrations, the thermal tolerance of plant and livestock species, changes to pest and animal disease distribution.
- Local agriculture could have an important role in enhancing Hong Kong's future food security but its potential to contribute requires further investigation.

A(iv)
- Farmers may suffer from present day weather and extreme events but are generally capable of recovering in a relatively short time period.

A(v)
- Agriculture is particularly sensitive to changes in the climate. However, agriculture is one of the highly managed sectors that has relatively high potential to adapt through selection of new breeds, changes to planting / transplanting / harvesting timetables, use of new cultivars and climate controlled greenhouses etc.
- [A4(v)] Arable land may be more susceptible to flooding or loss of land as a result of sea-level rise, relocation may be less flexible.

A(vi)
- This sector accounts for a minority of the local food demand although it could strategically be valuable in terms of local food security. This sector may also have an importance from the historical and socio-cultural perspective.
- Local poultry production [A1] and pig husbandry [A2] satisfies around 45% and 20% of local demands, respectively.

A(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

The agriculture sector in general is highly managed and has higher potential for adaptation, and therefore the impacts reduced. Poultry production and pig husbandry have significance in meeting local demands and impacts on these may have wider repercussions. Impacts on arable land may be more severe as low-lying land may suffer from re-occurring flooding events or permanent land loss and relocation may be more difficult. As adaptive capacity for arable farmers may be lower compared to others, the potential impacts could be more significant.

Aquaculture & Fisheries

B(i)
- The majority of the potential consequences arising from climate change are likely to be negative (e.g. changes in species distribution / occurrence), and that could occur on an annual basis.
- The impacts on marine capture fishery [B1] and marine culture fishery [B2] could potentially be greater due to lack of clear understanding of the potential changes in the marine environment and therefore the lack of preparedness.

B(ii)
- There is currently no information on the potential to benefits from climate change to the marine environment.

B(iii)
- Very high uncertainties in the future marine environment (e.g. ocean acidification, future changes in ocean currents, salinity levels) and the associated impacts.
- The socio-economic significance of this sector to Hong Kong is not apparent.

B(iv)
- This sector may suffer from present day weather and extreme events (e.g. impacts on fishing operations) but are generally capable of recovering in a relatively short time period.
- Marine capture fishery [B1] and marine culture fishery [B2] are more dependant and sensitive to extreme weather events and others such as overfishing.

B(v)
- The potential to adapt is uncertain. Some aquaculture operations and species operating at the limits of heat tolerance may have limited adaptive capacity.
- Due to the uncertainties in the future marine environment, human interventions in marine capture fishery [B1] and marine culture fishery [B2] are likely to be more difficult, and that these sectors may be less easily managed.

B(vi)
- This sector accounts for a relatively small proportion of the local food demand

although it could strategically be valuable in terms of local food security. This sector, however, has an importance from the historical and socio-cultural perspective.

B(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

Overall, the aquaculture and fishery sector has relatively low economic importance. Very little is known about the future marine environment and this contributes to the uncertainties in predicting the potential consequences on this sector. Nevertheless, the anticipated magnitude and rate of changes are expected to negatively impact the marine food chain and therefore marine species occurrence and distribution, especially for species that are at the edge of their thermal tolerance limits. Some impacts or effects on the marine capture or culture species and operations may be persistent (e.g. the extent and frequency of hypoxia events) or irreversible (e.g. loss of fish diversity, species extinction), and this may affect fisheries operations. Potential for human intervention in inland pond aquaculture is higher and thereby minimising the impact. The potential loss of mudflats due to sea-level rise may affect oyster culture operations, however, the significance of oyster farm aquaculture is relatively low.

Biodiversity & Nature Conservation

C(i)
- Increasing loss of biodiversity and colonisation of invasive species are expected, and these could occur on an annual basis.

C(ii)
- There is currently little information on the potential to benefits from climate change to the terrestrial or marine environment.

C(iii)
- Knowledge of the full extent of Hong Kong's ecosystems and biodiversity is incomplete and much of the baseline data / information are missing.
- Very high uncertainties in climate change impacts on Hong Kong's ecosystems and biodiversity, such as the implications of seasonal changes and in particular those on marine ecosystems and biodiversity.

C(iv)
- Local biodiversity is already under substantial pressures from human activities, such as urban development, hill fires, pollution and introduction of foreign species.

C(v)
- Ecosystems and biodiversity is highly sensitive to climate change and autonomous adaptation is unlikely to take place given the rate of change.
- Despite conservation efforts that aim to limit non-climate stress on species and habitats, real adaptation options to preserve some or many of Hong Kong's endemic species and habitats are likely to be limited.

C(vi)
- Ecosystems, biodiversity and ecosystem services have intrinsic values that cannot easily be quantified in monetary term.

C(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

Hong Kong has a variety of endemic species and is disproportionally rich in biodiversity. Many ecosystems are already under intense human-induced stresses; losses of biodiversity have been documented and extirpations are a continuing threat. Many of the ecosystems are highly sensitive to climate change (e.g. coral reefs) and are likely to have limited inherent capacity to adapt to the anticipated magnitude and rate of change. Some changes may be persistent (e.g. a prolonged period of wet or dry conditions, reoccurring drought or flooding events) and some consequences may be irreversible (e.g. the extinction of species). There are limited realistic options for preserving many endemic species in areas that become climatically unsuitable and these species may be replaced by better suited or invasive species as an outcome of natural selection. Prediction of the potential consequences of climate change to this sector is constrained by the high uncertainties in the future conditions, in particular, of the marine environment. In addition, many of the species and habitats have not been well studied or understood.

Built Environment & Infrastructure

D(i)
- Damage to buildings, assets and infrastructure could have very significant implications for individuals, sectors / industries and social activities and increased

risk to human life is likely.

• Insurance industry may withdraw coverage in some high risk areas and for climate induced damages and/or increase premiums.

• A majority of the potential consequences are likely to occur on an annual basis and the consequences could potentially be significant to the broader economy (e.g. serious interruption to activities and serious damage to key assets).

• [D6] The increase in frequency and severity of extreme rainstorms events brought about by climate change could have significant adverse implications and consequences on slope safety in Hong Kong, e.g. the increase in possible damage to buildings, infrastructures, public facilities, and potential risks to the public.

D(ii)
- Given the long term impact of planning decisions, Hong Kong could potentially benefit from early attention and adaptation planning. However, flat land is at a premium in Hong Kong for conventional development.

D(iii)
- Very high uncertainties in the magnitude and rate of sea level rise and the associated flood risk (areas at risk and the degree of risk)
- There are relatively lower uncertainties in some areas / systems, e.g. loss of thermal comfort and increased use of mechanical cooling are expected with warmer temperatures [D1]; studies on the impacts of climate change on the drainage systems are emerging [D4]; The adverse effects of climate change on slope safety in Hong Kong are uncertain and relevant risk management strategies have not yet established [D6].

D(iv)
- Relatively few buildings and infrastructure suffer from damages from present day weather such as extreme weather events and flooding.
- [D4] Stormwater drainage systems are already challenged under present day conditions e.g. existing rainfall patterns.

• [D6] Although most of the sub-standard high-risk man-made slopes have been dealt with under the GEO's LPM programme which was completed in Apr 2010, there are still significant landslide risks associated with the remaining sub-standard and old technology man-made slopes, and natural hillside catchments of which their susceptibility to rain-induced failures is sensitive to effects of climate change.

D(v)
- Developments located on low-lying areas / reclaimed land on either side of Victoria Harbour are prone to flooding and storm surges, and therefore are highly sensitive to climate change.
- There is relatively little scope for adaptation to loss of land resulted from sea-level rise.
- High risk of mal-adaptation due to the long investment and planning decisions. Buildings, assets and infrastructure tend to be long lived.
- [D3] The "hardware" of communications infrastructure is relatively less extensive compared to other systems e.g. the building stock and transport infrastructure, and may therefore be more capable of adapting.
- [D6] The stability of natural hillsides is particularly sensitive to severe rainfall conditions. GEO's studies have shown that the number of natural terrain landslides would increase exponentially with rainfall intensity. The scale of failures and mobility of debris flows would also increase significantly with rainfall intensity. For man-made slopes, there could be more frequent, large scale erosion and wash-out type failures due to increase in frequency of short duration heavy precipitation.

D(vi)
- The built environment and infrastructure provide much of the key infrastructure upon which economic and social activities within Hong Kong depends.

D(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

The built environment is essential for the city of Hong Kong. Buildings and infrastructure have long investment decisions and asset lives. Once built, the buildings and infrastructures have low potential for adaptation and some impacts could be irreversible, e.g. there is little scope for adapting existing development against loss of land in low-lying or reclaimed areas in the latter half of this century. There are substantial uncertainties in the magnitude and rate of change in future sea-levels and storm surges events, in particular, and this further limits the level of preparedness. Uncertainties in the mechanisms of sea-level changes, for example, imply that sea-level rise may not be linear, and this could result in significant negative impacts across the territory's coastal development. Infrastructures at most risk is unknown. Some groups (e.g. the less wealthy population, and smaller businesses and corporates) may be more susceptible to impacts as they cannot afford to relocate or have difficulties to recover from major events. Changes in rainfall patterns may bring about prolonged periods of heavy rainfall, which may challenge drainage and sewerage infrastructure. The increase in frequency and severity of extreme rainstorm events will significantly increase the number, scale and mobility of rain-induced landslides on both natural hillsides and man-made slopes posing higher landslide risks to the public.

Communication infrastructure may have relatively high potential for adaptation as they are relatively less extensive and have relatively less resource implications, compared to say the building stock or transport infrastructure.

Business & Industry

E(i)
- This sector may be vulnerable to impacts on other areas such as infrastructure, and also international supply chains (e.g. the shipping industry) due to its global coverage. Impacts or disruption on this sector could potentially have significant adverse implications on the broader economy (e.g. employment and contribution to GDP), and these could occur on an annual basis.
  • [E3] Impacts on the PRD region could potentially be more severe due to lower availability in resource and technology which help businesses to cope with or recover from challenges.

E(ii)
- Climate change could bring about new business opportunities and service areas.

E(iii)
- The business and industry sector is very broad and a wide range of impacts could be felt across the sector. The types and extent of impacts on different industries require further investigation.
  • [E3] Climate change impacts on the PRD region require further investigation; their implications on the supply chain for Hong Kong businesses and operations are also areas of concern.

E(iv)
- The recent financial crisis suggests that some industries or services may already be vulnerable to non-climate risks.
- [E3] Electricity supply problems do hamper business operations in the PRD.

E(v)
- Different segments of the sector each have differing risks and opportunities, which suggest varying capabilities of adapting.
- [E3] Manufacturing in the PRD region may be less capable of absorbing disturbance due to resource and technological constraints.

E(vi)
- This sector is an integral part of the territory’s self image and international reputation. It has significant contribution to Hong Kong's employment and GDP, in particular trading and logistics [E1].
- [E3] There has been an increased trend in off-shoring manufacturing activities to the Mainland and particularly the Pearl River Delta Economic Zone. Impacts on this area could significantly affect the businesses and operations in Hong Kong.

E(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

The business and industry sector (trading and logistics, in particular) has significant economic importance for Hong Kong and in terms of employment and impacts on this sector could potentially have implications for the whole economy. Due to the diverse nature of this sector, differential impacts (both risks and opportunities) are expected to be felt across different segments of this sector, which require further investigation. This sector is sensitive to impacts on other areas locally and overseas, such as those along the supply chain (the supply of raw materials, manufacturing), impacts on international trade partners and financial markets, disruption in transport or communication infrastructures resulted from extreme weather events etc, and some of these impacts could occur rapidly and unexpectedly. Climate change impacts on manufacturing in the PRD may be less capable of coping with disturbances and recover from these events due to resource and technical constraints.

Energy Supply

F(i)
- Any interruptions in power supply are likely to result in significant economic and social costs, and these could occur on an annual basis, e.g. from prolonged periods of hot weather and extreme high temperatures in the summer.
- [F2] Impacts on the transmission and distribution may be more localised and the implications may be confined to certain areas.

F(ii)
- Electricity demand for heating in winters may be reduced.

F(iii)
- High uncertainties in impacts along the supply chain [F3] and effects of warmer climate on transmission infrastructure [F2] in the sub-tropics.
- [F1] Uncertainties in future energy demand and supply patterns.

F(iv)
- Few power supply interruptions have occurred in the past.

F(v)
- [F3] Long term planning could be possible to reduce vulnerabilities along the international supply chain. Short term capacity may be limited due to the infrastructure currently in place, long term purchase agreements etc.

F(vi)
- This sector enables virtually all socio-economic activities in Hong Kong and is vital for Hong Kong population's lives and livelihoods.

F(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

Energy supply and infrastructure is fundamental for all activities in Hong Kong and any supply interruptions are likely to result in significant social and economic costs. Demand for energy is partly associated with climate and climate change is expected to change demand patterns. Reliability of power supply may be challenged by unexpected accelerated demand growth. Warmer climate and changes in extreme weather events could potentially affect production and transmission efficiencies. Little is known about how climate change could impact the supply chain of primary fuel imports and supply, and also on the transmission and distribution infrastructures.

Financial Services

G(i)
- This sector may be vulnerable to impacts on other areas such as infrastructure (notably the landmark waterfront assets), and also international supply chains due to its global coverage. Impacts or disruption on this sector could potentially have significant adverse implications for the broader economy (e.g. employment and contribution to GDP), and these could occur on an annual basis.

G(ii)
- Climate change could bring about new business opportunities and service areas.

G(iii)
- The climate change risks and opportunities this sector may face require further investigation.
- Many of the data (e.g. insurance claims) and findings of research carried out by insurers and re-insurers, for example, are highly sensitive and are not available in the public domain.

G(iv)
- The recent financial crisis suggests that this sector may already be vulnerable to non-climate risks.

G(v)
- Different segments of the sector each have differing risks and opportunities, which suggest varying capabilities of adapting.
- [G2] Many insurers and re-insurers are already exploring potential business opportunities and identifying climate change impacts and risks they may face. Its role in climate risk management suggests that the insurance industry has relatively higher adaptive capacity.

G(vi)
- Financial services is a very important prestige sector for Hong Kong, as well as an important element of the territory's international reputation and self image. It is also a significant contributor to Hong Kong's employment and GDP.

G(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

The financial services sector is very important for Hong Kong economically and in terms of employment. This sector, in particular the insurance and banking industry, may suffer from sudden and unexpected climate impacts both locally and overseas. The time taken for the maturation of asset values against which loans and pensions are secured or derivatives traded could heighten its vulnerability. Differential risks and opportunities are expected to be felt across different segments of this sector.

Larger corporates are more capable of adapting, through the purchase of (more expensive) insurance to spread the costs, for example. Few studies have been carried out to investigate the risks and opportunities corporates may face under climate change. Because of this, they have limited preparedness to minimise the impacts, which could potentially be severe - this could have wider repercussions on the territory.

Food Resources

H(i)
- Extreme weather events could reduce agricultural outputs at sources of food imported to Hong Kong (namely Mainland China and Thailand), and rising commodity prices could be resulted. These could occur on an annual basis especially during the wet season or the summer months.
- Impacts on local wholesale and retail [H2] may be relatively easier to manage and therefore their severity minimised.

H(ii)
- The implications of increased atmospheric CO_2 concentrations on agricultural outputs, as well as the net effects of climate change, are currently unclear.

H(iii)
- [H1] Very high uncertainties in the vulnerability of Hong Kong's key food producer partners, namely Thailand and China, to climate change, and also the implications of the wholesale and retail industry.
- High uncertainties in how the vulnerable groups (e.g. the less wealthy communities) in Hong Kong could be impacted.

H(iv)
- Food supply in Hong Kong is sensitive to weather events, e.g. the impacts of rainstorm on vegetable imports.

H(v)
- Although agricultural production at source is sensitive to climate change, this sector is likely to have the capacity to adapt. However, Hong Kong may suffer from international vulnerabilities and have limited capacity to adapt due to its heavy reliance on food imports, in particular on few key trade partners.
- Impacts on local wholesale and retail [H2] may be easier to manage and therefore its vulnerability reduced.

H(vi)
- Hong Kong is not self-sufficient in its food supply and relies heavily on imports.

H(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

The food resources sector provides an essential service for humans. Food imports may be affected by climate change impacts at sources of agricultural production and also the impacts along the supply chain. Hong Kong's over-reliance upon a few key food producer partners makes it particularly vulnerable - for instance, the implications for Hong Kong could be severe should rice production in Thailand be impacted by floods or drought. Falling agricultural production elsewhere may raise commodity prices, thereby most notably affecting the poor. Lower availability of food and increase prices could have knock-on effects on the wholesale and retail industry, although these impacts require further investigation. Larger businesses are likely to be able to cope with any disturbance.

Human Health

I(i)
- The majority of the potential consequences arising from climate change are likely to be negative, and these could occur on an annual basis.
- More accidents and emergency situation [I1] could result from increased frequency and/or intensity of extreme weather events.
- Cardio-respiratory related morbidity and mortality [I3] may become more significant in general with the anticipated aging population.
- New / non-endemic and vector-borne diseases [I4 and I5] could pose particular threat to Hong Kong.

I(ii)
- Reduced cold harvesting of vulnerable populations is expected.

I(iii)
- Uncertainties in climate change impacts in the sub-tropics.
- Climate change is expected to disproportionally affect the vulnerable groups such as the aged, sick and poor. How these groups could be impacted requires further investigation.
- [I9] Human vulnerability to diseases may be aggravated by impacts on agriculture,

fisheries, nutrition etc. These relationships have not been well studied.

I(iv)
- Hong Kong has world leading facilities and services in protecting and maintaining the population's health. Despite these, some impacts are inevitable although the scale / magnitude of events will be reduced.
- [I2 and I3] Respiratory diseases and chronic health conditions may be less "manageable" or "controllable" due to factors such as air quality issues.

I(v)
- The aging population in Hong Kong may be more susceptible to cardio-respiratory morbidity and mortality [I2 and I3] and these may be less easy to manage compared to other areas (having sufficient resources to deal with accidents and emergency situations). Also, the adaptive capacities of health and external infrastructure [I8 and I9] may partly be determined by impacts on other areas.

I(vi)
- The health of the local population plays a significant role in enabling GDP growth and maintenance - although quantifying its value into monetary terms is a difficult and subjective exercise.

I(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

All aspects of human health are important. Climate change may alter disease / pathogen patterns temporarily or permanently (e.g. warmer temperatures may increase the likelihood of occurrence of food borne diseases and heat stress), and may give rise to new emerging diseases, as well as accidents or emergency situations. The impacts of communicable diseases (such as vector borne diseases) are likely to be reduced owing to the increased preventive, monitoring, surveillance and reactive measures in these areas. Food borne diseases tend to be isolated or localised events should they occur. On the other hand, should water supplies be contaminated, the implications could be more significant, although the likelihood of such events is rather low. Vulnerable groups of the population may be particularly impacted: the sick and aged may be weaker in defending against diseases or recovering from injuries. In particular, with an aging population, mortalities and morbidity of cardio-respiratory diseases may become more significant. There are high uncertainties in the potential implications of impacts on external systems and infrastructure (e.g. food supplies, energy demand and supply patterns, environmental migration).

Leisure & Tourism

J(i)
- This sector may be vulnerable to impacts on other areas such as infrastructure, business and retail sectors. Impacts on physical and environmental assets (e.g. infrastructure) are likely to be more severe than those on tourism services.
- In general, impacts on this industry could potentially have significant adverse implications for the broader economy (e.g. employment and contribution to GDP).

J(ii)
- Some tourism operators may benefit from new business opportunities such as new tourist locations.

J(iii)
- Uncertainties in the economic impact of climate change on Hong Kong's tourism industry.
- Uncertainties in tourist climate preference and destination loyalty and how future tourism will operate in a changing climate.

J(iv)
- Overall, this sector has been shown to be capable of recovering from major negative events such as SARS, H1N1 and terrorism activities.

J(v)
- Climate is one of the factors that determine the suitability of locations for a wide range of tourist activities. The dynamic nature of the tourism industry suggests that it is capable of adapting to future climate. However, assets that have longer investment decisions may have lower adaptive capacity - e.g. hotels or resorts located at / near the waterfront may be more vulnerable to flooding or storm surges.

J(vi)
- Tourism is one of the four key industries in the Hong Kong economy.

J(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

Tourism is an important industry for Hong Kong. Impacts on this sector may have implications for the wider economy. This sector is sensitive to the climate and environment. It may also be particularly susceptible to sudden and unexpected events such as new emerging disease (e.g. SARS, H1N1), although the tourism industry is generally able to recover. Like other infrastructure, hotels and some tourist attractions tend to have long investment decisions and some may be located near the waterfront and they may be less capable of adapting to flooding, sea-level rise and storm surges, for instance. Larger corporate and tourism operators are likely to have higher capability of adapting.

Water Resources

K(i)
- Although the average annual rainfall is projected to increase, the annual distribution of rainfall may change. This, together with rising demand in the Mainland, may have implications for the sustainability of the water supply both locally and in Guangdong.
- [K2] Potential increases in incidence of flood along the Dongjiang catchment area could give rise to contamination from industrial pollutants, for example.

K(ii)
- Few beneficial climate change effects are anticipated.

K(iii)
- Very high uncertainties in future rainfall amount and distribution.
- High uncertainties in future indigenous demand in Guangdong which could lead to water stress in Dongjiang and have implications for the supply to Hong Kong.

K(iv)
- Water shortages and water restrictions have occurred in the past but these events are rare in recent decades.

K(v)
- Despite the Total Water Management Strategy, a significant proportion of Hong Kong's water is imported and this limits its adaptive capacity. In particular, water supply from Dongjiang [K2] may have lower adaptive capacity due to other non-climate stresses such as rising indigenous demand resulted from economic growth and indirect impacts from flooding or extreme weather events.

K(vi)
- Virtually all social and economic activities and natural resources in Hong Kong are dependent on water availability.
- [K2] Imported water accounts for a majority (70-80%) of the raw water in Hong Kong.

K(viii)
- The relative vulnerability is determined primarily by considering the criteria listed in Column (vii) of Table 3.11.

The water resources sector provides an essential service for humans; many sectors and other natural resources are dependent on water availability. The supply of water is dependent upon rainfall amount and distribution, the future changes of these (e.g. the fluctuation in rainfall amount) are difficult to project. Water availability in Hong Kong may be constrained by physical or contractual reasons, and this could have wider repercussions for the population's lives and livelihoods. Imported water from Dongjiang, which constitutes a majority of Hong Kong's water supply, may be particularly vulnerable due to the anticipated increased competition for water from the region and indirect impacts (e.g. contamination from flooding events), as well as the limited direct control the local government may have on this. Vulnerable groups of the population may be particularly affected should water resources be impacted in terms of quantity and quality.

2.6.3 Uncertainties and Further Research

The sources of uncertainties and keys areas identified for further research from this vulnerability assessment for each of the sectors are illustrated in *Table 2.13*.

Table 2.13 Uncertainties and Areas for Further Research of Each Sector

Sector	Uncertainties and Key Areas for Further Research
Agriculture	• Research into the local climate change impacts on this sector. • Examination into the role of local agriculture in Hong Kong's future food security.
Aquaculture	• Forward planning and adaptation strategies for the sector are likely to be very difficult for this sector as research into the local climate change scenarios and the associated impacts are needed. • Warming of local sea surface temperatures and any affects on the ocean current regime of the South China Sea are largely unknown. • The implication of ocean acidification on marine fishes, in particular fish reproduction and stock replenishment, is largely unknown. • There is high uncertainty in climate change related (e.g. from an increase in precipitation and the associated increases in freshwater discharges of the Pearl River) changes in salinity levels of Hong Kong western waters. • There is little data on the number of people who depend upon this sector both officially, unofficially and on a casual basis for either their income, or as a major source of protein.
Biodiversity / Nature Conservation	• Research into the local climate change impacts on this sector, in particular, the marine environment (e.g. sea surface temperatures, changes in the ocean current regime of the South China Sea, ocean acidification) and the effects of seasonality on the impacts of terrestrial / aquatic ecology. • Considerable data gaps are present in our understanding of Hong Kong's biodiversity baseline.
Built Environment and Infrastructure	• Future global average and extreme sea level rise is a critically important area of research for scientists worldwide as the associated impacts are obviously highly dependent on the quantum of the actual rise which eventually transpire. • Research into the changes in local sea levels and storm surges under future climate conditions • The Drainage Master Planning (DMP) Studies by DSD would be a first point of reference for the further research into the limitations of the existing of storm water drainage systems, and how they would be impacted as climate changes. Areas for further research would be identified from any gaps in the coverage of the existing DMPs. • A schedule of the cope level of coastal infrastructure for Hong Kong is not readily available. • Research into implications of effects of Climate Change on Slope Safety, as well as their associated adaptation strategies and mitigation measures, is necessary.
Business and Industry	• As this sector is a very broad delineation, detailed climate change impact assessments may need to be carried out, perhaps at the trade association level, to ascertain the risks to individual business sectors within Hong Kong. • Manufacturing in the PRD region which could impact on the supply chain deserves further investigation.

Sector	Uncertainties and Key Areas for Further Research
Energy Supply	• Elevation modelling of key generation capacity within Hong Kong to ensure continuance of supply in the future under a range of climate changed and sea level rise scenarios. • Examination of the impacts of warming on transmission infrastructure in the sub-tropics as most of the research done in this field has been carried out by temperate countries.
Financial Services	• Many of the findings of the research carried out by insurers and reinsurers, for example, are highly sensitive and are not publicised. This lack of transparency is a major component of the sectors' risk. Where this information is made available, there is a disconnect for businesses to implement recommendations to boost their adaptive capacity where financial reward is not visible in the short. Research is necessary to understand how best to bridge this incentive gap and how to translate the urgency expressed scientifically into an urgent business response whilst there is still time to respond in an anticipatory manner.
Food Resources	• More research is needed into the implications of increased atmospheric CO_2 concentrations on agricultural outputs, as well as the net effects of climate change. • The vulnerability of key food producer partners to climate change should be investigated by Hong Kong. • Building resilience at key food resource "nodal" points should also be a research priority.
Human Health	• The health impacts of climate change resulted from causal processes are difficult to quantify, such as health risks due to the social, demographic, and economic disruptions of climate change (e.g. from changes in agricultural yields, disruption to fisheries, loss of livelihoods and population displacement). • Few studies have been carried out to investigate the societal impacts in Hong Kong, such as on vulnerable groups (ie the poor, sick and aged).
Leisure and Tourism	• The tourism industry generally has relatively high adaptive capacity. Hence, adaptation options deserve further research in order to further enhance resilience. • The United Nation's World Tourism Organisation (UNWTO) attempted to assess qualitatively the most at-risk tourism destinations as a result of climate change by 2100 (42). However, systematic regional level assessments are needed for a definitive statement on the net economic or social impacts and they found insufficient information for some regions to complete the exercise, with East Asia being one of them. • There are considerable uncertainties associated with tourist climate preference and destination loyalty and how future tourism will operate in a changing climate. Understanding the potential long-range shifts in tourist demand requires more information on how tourists perceive environmental impacts related to travel and their willingness to pay to reduce this impact, tourists' views on the impacts of global climate change at destinations (e.g. perceptions of coral bleaching, reduced biodiversity etc), and tourist climate preferences and key thresholds (e.g. "what is too hot for a beach holiday").
Water Resources	• There are considerable uncertainties associated with future climate, in particular the rainfall patterns in Hong Kong, the level of annual and decadal variations and precipitation extremes. • Other areas for further research include assessing the impacts of climate change on the sector in the light of more extreme sea level rise projections to assess resilience under a reasonable worst case scenario.

2.6.4 *Conclusion*

Several features of Hong Kong's geography, demographics and economy make it vulnerable to climate change, namely:

(i) According to international literature, the city is located in a region of Asia that is already prone to vector borne diseases and extreme weather events (e.g. typhoons), and is vulnerable to future sea level rise, loss of water supplies, the resulting food insecurity and environmental displacement of population;

(ii) Hong Kong is located in the PRD with a significant proportion of low-lying high asset value reclaimed land (including key infrastructure such as the airport);

(iii) Hong Kong is vulnerable to climate change beyond its borders due to its heavy reliance on imports of water, food, and both primary energy sources and electricity;

(iv) The territory depends on highly complex infrastructure (particularly mass transit systems) which has multiple potential failure points;

(v) The territory's economy is highly dependant on international trade and logistics, and the financial sector, which are highly vulnerable to climate change; and

(vi) Urban areas are inherently vulnerable due to the density of people, and high concentration of key infrastructure and high asset values (31).

Sectors that are potentially more vulnerable to the physical impacts of climate change have been identified for prioritisation as key areas where the Government may need to work with stakeholders to develop an effective adaptation response. The key vulnerabilities are summarised as follows.

Biodiversity and Nature Conservation

Biodiversity can be highly adaptable but the rate of climate change may be beyond some species' abilities to adapt. The biodiversity sector is already highly vulnerable to external stress and is globally considered to be amongst the most climate sensitive of sectors, due to the innate lack of planned adaptive capacity internally and the limitations of human attempts to assist planned adaptation for wider ecosystems.

Biodiversity in Hong Kong is a highly interconnected system. It also has complex interrelationships with many other sectors within Hong Kong. The loss of one type of species or habitat could potentially disrupt whole food chains and ecosystem services. This could have significant wider repercussions for Hong Kong's economy and society as it provides key ecosystem services (e.g. mitigation of air pollution, carbon sequestration, rainfall catchments) upon which they depend. Therefore, Hong Kong's resilience to climate change is, in many ways, only as strong as the resilience of Hong Kong's ecosystems.

Despite the uncertainties (such as the lack of information on the future changes in seasonal climate and the marine environment), changes and loss of biodiversity are anticipated under the current projected climate change. Both terrestrial and aquatic flora and fauna are considered highly vulnerable with low adaptive capacity. Invasive species are also likely to profit in a climate-disturbed environment. Intertidal areas are likely to be impacted, with resulting losses in biodiversity such as seagrasses. Hard coral communities are highly vulnerable to ocean acidification, sea temperature increases etc. Very limited measures have been identified currently that could prevent their loss that are technologically viable.

Biodiversity in Hong Kong may be affected by climate change impacts overseas (e.g. in the case of migrant birds should higher latitudes become warmer). Improvements in the adaptive capacity of Hong Kong's biodiversity require national and international efforts, alongside strong leadership and commitment of resources by the Hong Kong SAR Government.

Built Environment and Infrastructure

The built environment and infrastructure provide much of the key infrastructure upon which economic and social activity within Hong Kong depends. As a result any interruptions within this sector may have considerable widespread consequences across the territory. The sector's vulnerability is heightened by the predominance of extensive interconnected infrastructure with multiple failure points. The resilience of key functional nodes including sewerage treatment plants, major transport routes and interchange stations needs to be guaranteed to ensure systemic robustness.

Some sections of the existing storm water drainage systems are already challenged under existing rainfall and sea level conditions. The potential increase in frequency and/or intensity of rainfall, together with future sea levels, could impact the entire drainage infrastructure and is therefore considered to be highly vulnerable. Areas which are currently prone to flooding are likely to suffer more frequent and severe flooding events. Furthermore, new areas where flooding events are rare, or have never previously occurred, may become prone to regular flooding in the future.

This sector is exposed over a long temporal time range with investment decisions that may have implications for many decades. The potential to design in mal-adaptation and constrain future adaptation options is significant unless the possible climate change impacts are considered at the design stage. This is however a highly complex process and there is a risk of over and under engineering future infrastructure given the considerable uncertainties in climate change science, in particular future sea levels, storm return periods etc.

The sector's vulnerability is complicated by the wide number, type and range of actors operating. Interlinkages between subsectors are not always clearly defined and that some issues can fall between multiple stakeholders. Although it is likely that autonomous adaptation may occur (e.g. in the selection of different road surfacing materials), adaptation to rapid changes may be constrained by purchasing procedures and materials specifications currently in place.

A major uncertainty in this area of concern is the magnitude of the upper bound values of sea level rise. This is particularly significant considering the substantial amount of development in low lying coastal areas and on reclaimed land in Hong Kong. Any decision making to be carried out in the shorter term should be flexible enough to allow for regular reviews and adjustments to incorporate any new developments in the climate change science, as is ongoing in other parts of the world. A range of sea level rise scenarios should be considered. An understanding of the longer term risks is also crucial to prevent resources being spent on infrastructure which may have to be abandoned before the end of its useful life. It is important that the latest scientific developments are kept under regular review to ensure sufficient and timely measures to be implemented into the short, medium and long term future. Mechanisms are needed to transfer the latest findings from the scientific community to decision makers such as those designing policy and engineering guidance for Hong Kong. These mechanisms may include an interface body, placements to enable researchers to work in policy-making environments or expert meetings and debate to communicate scientific information to decision makers. Building up the resilience of this sector will benefit from cooperation between the local government, and national and international actors.

Business and Industry

The economic contribution of the business and industry sector in Hong Kong is highly significant and any negative implications here are likely to have wider consequences for Hong Kong society. It is dependent upon myriad complex interdependencies with other sectors within the territory and overseas (e.g. food resources, infrastructure and foreign investment), which must be resilient if the city is to continue to attract businesses. This sector may be affected by knock on impacts from other sectors. The city's reliance on international trade, financial markets and on imports of key products and services makes it vulnerable to climate change associated impacts beyond its boundaries. Many of the required adaptation responses must be taken by external parties and are outside of the direct control of the Hong Kong SAR Government.

Past performance is not necessarily indicative of future reliability and complacency should be avoided through continued vigilance. Hong Kong's business and industry sector is already impacted by weather events, e.g. seasonal purchasing, prices of raw materials. This vulnerability is heightened as the sector is exposed over a wide geographic area globally with long and often complex supply chains, particularly for the logistics and international trade sub-sector. Some businesses will also be exposed over a long temporal range due to long term investment decisions and infrastructure renewal cycles. Diversification in private sector supply chains is not a given as most businesses choose suppliers on the basis of lowest cost rather than resilience to business interruption, contributing to significant vulnerability.

There is a high degree of correlation between the economic performances of Hong Kong and the PRD in the medium term. The offshoring of essential elements of the supply chain, e.g. many manufacturing activities, to the PRD region potentially reduces the adaptive capacity and resilience of this sector as climate change impacts in one region are likely to translate to losses and business continuity issues in the other, certainly for the short term. However, the present Study is confined to the assessment of the impacts and vulnerabilities within the Hong Kong SAR political boundary.

Energy Supply

The energy supply sector in Hong Kong is of primary significance and is considered highly vulnerable as it underlies virtually all local economic activities. It is interlinked with many other sectors within the territory and overseas. The energy supply sector needs to be considered alongside other sectors, namely built infrastructure, water resources, human health and food resources.

Although the system is currently able to cope with climatic variability without interruption by large, future demand is linked to the weather as is transmission capacity, adapting to rapid changes is likely to be constrained by purchasing procedures and materials specifications currently in place and supply interruptions in the future should not be dismissed. Resilience of key functional nodes such as generation plant, primary fuel import infrastructure, major substations needs to be guaranteed to ensure systemic robustness. There are some key international vulnerabilities including imports of raw materials and commodities for engineering, construction and maintenance.

Hong Kong has no significant primary energy reserves and imports all of its gas, oil and coal requirements, it is therefore highly vulnerable to climatic disruption further up the supply chain. This is particularly acute with minimal diversification within the primary fuel supply chains, i.e. Singapore for oil products and Indonesia for coal. Hong Kong has relatively low adaptive capacity should production or transportation at either of these locations be disrupted.

The energy sector is exposed over a long temporal time range with investment decisions that may have implications for 50+ years or so. The potential to design in mal-adaptation and constrain future adaptation options is significant unless climate change impacts are considered at the design stage. This highly complex process requires the incorporation of the latest science into investment decisions, e.g. future sea level rise, storm return periods etc, and in which there is considerable uncertainty and risk of over and under engineering future infrastructure.

Building up the resilience within this sector will require cooperation between the Hong Kong SAR Government, and national and international actors. Many of the most significant actions have to be taken by private sector actors, although clear guidance from the Government will be needed.

Financial Services

The financial services sector is perceived to be highly vulnerable and of significant economic importance for Hong Kong due to it reliance upon extensive interconnected infrastructure. It contains a number of disconnected actors with a wide range of objectives; the sector invests in long international supply chains and is vulnerable to failures therein; and, it is already vulnerable to climatic extremes.

This sector is both spatially and temporally exposed to climate change due to its global coverage and the time taken for the maturation of asset values against which loans and pensions are secured. The concentration of the sector's most significant assets in a small geographic locale within Hong Kong, namely the high value harbour-side real estate, elevates the sector's collective vulnerability from future impacts including sea level rise and storm surge without adaptation. Reputationally, the financial services sector is also vulnerable due to the importance its clients place on the qualities of foresight, forward planning and risk management.

In addition, the sector is also considered vulnerable attitudinally – it has, traditionally, limited capacity to understand and "price in" environmental externalities and considerations in the absence of regulatory or market drivers. Its vulnerability is exacerbated by the lack of transparency and knowledge of climate change vulnerability in the wider business community. At present, many financial services actors view climate change to be beyond the time horizon of their investment decisions. Long-term investors are more likely to incorporate climate change in making their investment decisions, while short-term investors may not incorporate such issues. The financial services community is beginning to embark on review of the consequences of climate change on their investment and their environmental liabilities.

The insurance sector can be particularly vulnerable due to its role in protecting the assets of others from unexpected and potentially catastrophic events such as extreme weather events (e.g. in the case of Hurricane Katrina in 2005). Firms are likely to be vulnerable to both the direct and indirect impacts of climate change, and the interconnectedness of the global financial system implies that climate change may impact upon actors far from the actual impact.

Within Hong Kong, the financial sector contains relatively few large corporate actors many of which do not have the flexibility to respond to rapid events. This could be seen as potentially limiting the number of key nodal points which, should they fail, could cause systemic repercussions. However, it should be noted that the financial services sectors have shown a rapid response to other financial variations and demonstrated responsiveness to crises in the past.

Food Resources

The food resources sector has intrinsic importance in providing Hong Kong with an essential resource in which it is not self sufficient. The sector should also be prioritised due to its importance for maintaining the population's health and complex interrelationships with other sectors, such as its vulnerability to indirect climate change impacts from international trade and logistics, energy supply, business and industry, and water resources.

Hong Kong's reliance on a broad geographic region for its food to some extent provides resilience. However, large scale climate change impacts (e.g. a widespread drought) could induce large scale system failure. Hong Kong's food resources sector may be vulnerable to long international supply chains, which may be slow to adapt to climate change and may be increasingly stressed should climatic change result in rising commodity prices, falling production and the increasing need for humanitarian food aid. The overreliance on one or two countries for the bulk of some of its most important food resources (e.g. Thailand provides 90% of Hong Kong's rice) may heighten vulnerability; diversification could be important to reduce this risk.

Temporally, this sector is primarily influenced by agricultural timescales and investment decisions are made annually. Agricultural commodities available on the international markets are usually more costly than advance purchase contracts. Many food processors, wholesalers and supermarkets only purchase on the spot markets when supply chains fail and inventories run low. The perishable nature the products suggests high stock turnover and low stockpiling.

Furthermore, the sector's reliance upon just in time (JIT) delivery mechanisms and low inventory "in-house" to reduce costs make it vulnerable to any unforeseen disruptions to international trade routes (Hong Kong port and airport, in particular), and would have only a short contingency period before stocks run low. Any interruption to one transport mode either road, rail, sea or air could lead to increased pressure on others; increased costs and decreased availability, potentially increased loss of perishable cargoes and associated financial losses may result.

The Hong Kong SAR Government has some freedom of action on this sector, and can guide adaptation with only moderate national and international collaboration. Nevertheless, it will require significant collaboration with actors from the private sector and those in the region.

Human Health

Hong Kong's health sector underlies all socio-economic activities and is essential in enabling economic growth and maintenance, although this is difficult to calculate directly.

Hong Kong can be seen to have world leading facilities and services in healthcare, public health initiatives, education, infrastructure and economic development. The excellent systems currently in place do offer significant resilience in the face of climate change. Compared to other regions of the world, Hong Kong has proven itself to be able to deal rapidly with quick-onset health incidents and emergencies, e.g. avian influenza and swine flu pandemic. The lessons learned from the SARS episode, suggest that Hong Kong has considerably enhanced its adaptive capacity in this regard. However it is important to avoid complacency. Whilst the worst health impacts of climate change are anticipated in the developing world, "*economic development is an important component of adaptation, but on its own will not insulate the world's population from disease and injury due to climate change (very high confidence)*" [(43)]. Past excellence is not necessarily indicative of future success; some future extreme weather events could be catastrophic because of the unexpected intensity of the event and the underlying vulnerability of the affected population, including the European heatwave (2003) and Hurricane Katrina (2005) examples. Continued vigilance will be required to ensure the robustness of the healthcare sector in the light of the potentially new challenges.

Hong Kong has a highly evolved public health infrastructure and there are numerous bodies which could be used by the Government to respond to the risks to health posed by climate change. However systems with high degrees of complexity and a large number of actors could be at risk of inflexibility and delays in the decision making process in responding to emergencies. It is not clear from the information gathered for this Study whether climate change has been factored into accident and emergency or contingency planning. International best practice suggests that disaster response and emergency contingency planning should include reasonable worst case scenarios [(44)] and combinations of cumulative impacts regarding climate change. Climate change will be a paradigm shift from the historic climate; it is important that emergency and contingency plans continue to be regularly revised and that current resilience is not taken for granted.

Water Resources

The water resources sector provides a potable, reliable water supply, which enables all other economic activities in Hong Kong to operate. Any interruptions could have systemic repercussions, hence ensuring its robustness in the light of future climate change should be considered one of the highest priorities.

There are considerable uncertainties in future rainfall amount and distribution, which can have positive or negative implications on yield of raw water both locally and regionally, as well as limitations on a meaningful assessment of vulnerability.

Many adaptive measures on both the demand and supply side within Hong Kong have already been taken under the Total Water Management Strategy. The vulnerability of imported water resources from Guangdong is likely to be considerably greater than the local supply due to a combination of climate change impacts and rising indigenous demand. Despite the existing contract with the Dongjiang water authorities, the total imported water quantity available to Hong Kong may still be limited due to physical (e.g. water stress in Dongjiang) or contractual constraints (ie the daily and annual maximums). Water shortages in Hong Kong could occur unless demand is managed to be within supply capacity.

3 POTENTIAL ADAPTATION STRATEGIES AND MEASURES

3.1 ESSENTIAL PRINCIPLES OF CLIMATE CHANGE ADAPTATION

Scientists believe that some of the impacts of climate change impacts are inevitable, regardless of future global greenhouse gas emissions. In addition, the decisions we make today about infrastructure, health, water management, agriculture, biodiversity and housing will have lasting consequences. It is therefore important to begin planning now to adapt to impacts of climate change in the future.

The IPCC define vulnerability to climate change in AR4 as "*the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed as a result of climate change effects*" (45). Climate change adaptation aims to reduce the potential for adverse impacts of climate change and enhance any beneficial impacts to reduce vulnerability or enhance resilience in response to observed or projected changes in climate. Adaptation can involve a variety of forms, such as better education, training and awareness of climate change, and more technical measures, such as drought-resistant seeds and better coastal protection. The exact impacts of climate change remain uncertain, so focus is also placed on building adaptive capacity, maintaining well-being, protecting property or land, maintaining economic growth, or exploiting new opportunities (46). However, adaptation measures generally involve financial cost and do not prevent all adverse impacts.

The IPCC notes that adaptation to climate change is already occurring around the world, in both the public and private sector through policies, investments in infrastructure and technology, and behavioural change, albeit on a limited basis (47).

At present, adaptation measures are to address present day climatic extremes and seldom in response to projected future climate change scenarios. Examples of consideration of future climate change scenarios include incorporating projected sea level rise into the design of infrastructure, such as the Confederation Bridge in Canada, and coastal zone management in the United States and the Netherlands (48). Usually, adaptation initiatives are embedded within broader sectoral initiatives, such as coastal defence, sustainable development and disaster management.

Extremes, variability, and rates of climate change are all key variables to be considered when addressing vulnerability and adaptation, not simply changes in average climate conditions.

3.1.1 *Extant Adaptive Capacity and Understanding the Context for Adaptation*

The ability of human systems to adapt to and cope with climate change is not universally uniform. According to the IPCC, the vulnerability of a society to climate change is influenced by its level of development, physical exposures, resource availability, prior climatic experiences, management capabilities, and sociopolitical will [49]. However, it should be emphasised that high adaptive capacity does not necessarily equal successful adaptation. The IPCC notes that some future extreme events will be catastrophic regardless of a nation's preparedness because of the unexpected intensity of the event [50]. For example, the adaptive capacity in Western Europe is generally considered to be high, and the risks of warmer winters increasing the range of livestock diseases in the region has been well documented, yet many parts of Europe were still seriously affected by outbreaks of the Bluetongue virus in livestock in 2007. Examples of high adaptive capacity nations failing to prevent serious climate impacts include the well documented aftermath of Hurricane Katrina in the United States which led to significant loss of life, failure of flood defences, loss of essential services such as water, power and food supplies; the 2003 heatwave in Europe which caused considerable loss of life amongst vulnerable demographic groups such as the elderly; and the 2007 floods in the UK which caused serious failures in the provision of basic essential services such as food and water supplies and which caused serious disruption to many sectors including healthcare and transport. A report into the events in the UK concluded "*the experiences have highlighted a lack of contingency planning and information at strategic level as well as limited contingency and emergency arrangements at critical infrastructure level, for example water pumping stations*" [51] and "*it was recognised that the plans and processes in place were not adequate to meet the experience associated with this flooding event*" [52].

The capacity to adapt is not fixed, rather it is dynamic and influenced by economic and natural resources, social networks, entitlements, institutions, governance, human resources, and technology. Existing multiple stresses (ie economic recession, land degradation, etc) reduce adaptive capacity.

For biological and geophysical systems, adaptive potential is much less than in social and market systems because impacts are more direct and therefore appear more rapidly [53], and planned adaptation is not always possible. The majority of the predicted increase in key vulnerabilities is likely to be recorded first in biological systems. This does not mean that vulnerabilities will not occur in social and market systems; they depend on biological systems and, as ecosystems are effected by mounting stresses from climate change and concomitant factors such as habitat fractionation and the spread of plant diseases and pest infestations, the follow-on, second-order effects on human health and safety, livelihoods and prosperity, will be considerable (*ibid*).

Adaptive capacity is driven by factors operating at many different interlinked scales. Adaptive capacity at a local scale will be affected by national, regional or global scale processes. In Hong Kong, it may be that adaptation is constrained or encouraged by international processes, or the failure or success of trade partners and other international actors to adapt.

Adaptations at one scale can also create externalities at another by reducing the adaptive capacity of other actors. This is often found when broad assessments of the costs and benefits of adaptation are conducted at smaller scales; whilst adaptation may benefit some actors, it also has a negative effect on others.

Furthermore, whilst in some cases one adaptation measure can be sufficient to reduce individual vulnerability, it is more common for collective measures to be required [54], requiring wide ranging stakeholder consultation at different scales, i.e. from individuals, firms, and civil society, to local, regional, national and international governments / legislative bodies. The different scales of decision making are interrelated; for instance, individuals' decisions are likely to be constrained by national institutions, and national adaptation policies tend to be influenced by international processes such as the UNFCCC. Different adaptation actions can be influential at different spatial scales and involve actors and institutions with different spheres of influence.

Best practice recommends that policy makers strive to mainstream adaptation to climate change into national and sectoral development [55] [56] as development plans which do not address adaptation to climate change may result in a worsened socioeconomic situations [57].

3.1.2 Autonomous and Planned Adaptation

A distinction is generally made in the literature between planned adaptation and autonomous (or spontaneous) adaptation. According to the IPCC, planned adaptation is defined as a "*result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state*" [58], whereas autonomous adaptation does not constitute a conscious response to climatic stimuli. Adaptation can occur either in anticipation of change (anticipatory adaptation), or be a response to those changes (reactive adaptation) [59].

Biological systems adapt reactively, whereas people and societies adapt both reactively and anticipatory [60]. Human and natural systems will to some degree adapt autonomously to climate change, although the pace of projected climate change impacts may overwhelm autonomous adaptive strategies in some instances, i.e. terrestrial species migration. Evidence of past and current autonomous adaptations to climate change or variability has been reported widely, particularly in the ecological context [61], but such adaptations may not be sufficient to adapt to current and expected rates of climate change in the future and cannot be relied upon to be the primary defence against climate change. Planned adaptation can supplement autonomous adaptation, although there are more options and greater possibility for offering incentives in the case of adaptation of human systems than natural systems.

Most adaptation responses being implemented at present around the world are responding to climate change are reactive, i.e. based on observed climate trends and variability, for example increased use of artificial snow-making in the European Alps, water conservation measures in Australia, etc.

Planning adaptation that goes beyond autonomous and reactive adaptation is now seen as a priority by the signatories of the UNFCCC, particularly to avoid what is known as maladaptation (and the associated waste of capital and other resources) to climate change.

3.1.3 *Avoiding Maladaptation and Adaptation which Constrains Mitigation*

Adaptation to climate change must avoid inadvertent maladaptation. Maladaptation refers to adaptation measures that increase vulnerability instead of reducing it, usually as a result of the uncertainties in climate change projections and their broad temporal exposure.

The interplay between adaptation and mitigation options also needs to be considered in order to ensure that adaptation strategies do not hamper mitigation efforts or lock-in rising carbon emissions. One example of avoiding this dilemma would be to use passive cooling systems to adapt to rising temperatures rather than air conditioning systems with associated greenhouse gas emissions. The *Stern Review* (2006) suggested that the best adaptation measures are those that are also strong mitigation measures; they avoid the worst projected impacts of climate change, and hence the need to adapt to them.

3.1.4 *Managing Scientific Uncertainty*

Conventional decision-making analysis requires an understanding of possible outcomes, their probability of occurrence and the value each holds for the decision maker and other actors, in order to decide the way forward. Classic decision analysis implicitly assumes that research reduces uncertainty. In climate science, however, as our understanding has advanced through research over time, the amount of uncertainty (as measured by our ability to make specific predictions) has remained unchanged, or has even grown as processes or complications that had not previously been understood or anticipated are revealed. Therefore, research in understanding climate science, climate impacts and the likely effectiveness of various climate management policies and technologies may not be capable of reducing uncertainty immediately; and thus, key uncertainties may not be eliminated by research activities globally within the timescales of decision making. Certainly, the IPCC's series of four assessment reports have grown more pessimistic with regard to projected climate change impacts as research has progressed.

In the face of high uncertainty, the following decision making are most appropriate [(62)]:

1) *Resilient Strategies* – Attempt to identify the range of future scenarios that one might face, and then identify approaches that will work reasonably well across that range.

2) *Adaptive Strategies* – Choose strategies that can be modified to achieve better performance as one learns more about the issues at hand and how

the future is unfolding. This works best when there are no large non-linearities and in which the decision time scales are well matched to the changes being observed in the world.

Some analyses have explored sequential decision strategies in combination with the avoidance of key vulnerabilities or thresholds for global temperature change. These strategies allow for the resolution of key uncertainties in the future by incorporating the findings of future research, observations and/or improved modelling. The quantitative results of these analyses only carry low confidence as most studies represent the numerous uncertain values by a small number of discrete values only and/or employ arbitrary assumptions. Furthermore there is significant uncertainty as to what temperatures and emissions concentrations will produce or preclude which climate impacts. Many studies cited in the AR4 provide global mean temperature thresholds which would lead to a specific key impact – however such thresholds are not yet known precisely. Therefore deterministic studies alone cannot provide sufficient information for a full analysis of response strategies, and probabilistic approaches should be considered to enhance the literature in Hong Kong.

The IPCC reports that, even when the impacts of climate change are not yet discernable, and despite considerable uncertainties regarding the rate and magnitude of change, scenarios of projected impacts may be of sufficient concern to justify implementing some adaptation measures now [(63)]. In some cases, it could be more cost effective to implement adaptation measures early, particularly for infrastructure with long economic life [(64)], or if current activities may irreversibly constrain future adaption to the impacts of climate change. Single scientific papers rarely prove or disprove anything - they simply add to the mass of evidence we have on a given issue. Recent reviews suggest that a "wait and see" or reactive approach is often inefficient and could be particularly unsuccessful in addressing irreversible damages such as species extinction or unrecoverable ecosystem damages [(65) (,66)].

The IPCC's conclusion that *'all studies report the opinions of their authors' to be that the scientific uncertainty by itself does not provide justification for doing nothing today to mitigate potential climate damages* [('67)] could also be applied to adaptation measures.

Scientific Uncertainty – the Example of Sea Level Rise

Developing adequate and appropriate responses to potential sea level rise, an area of some of the most considerable scientific uncertainty, is one of the greatest challenges of adapting to climate change. With Hong Kong's extensive use of reclaimed land and its high population density along the coastal strip, this is likely to be an important threat requiring attention. International best practice advises policy makers involved with infrastructure development to keep a watching brief on the latest climate science and incorporate sufficient buffer in design briefs for infrastructure and land use planning to allow for sea level rise.

Examples of good practice in adaptation to rising sea levels are appearing around the world. The design of the Confederation Bridge in Canada, which provides a navigation channel for ocean going vessels with vertical clearance of 50m [68], recognised sea level rise as a principal concern by building the bridge one metre higher than required to accommodate sea level rise over its hundred year lifespan [69]. Deer Island sewage facility in Boston Harbour was designed to be at a higher elevation from sea level to avoid the potential future cost of constructing a protective wall around its perimeter and diverting the discharge pipe over the wall requiring extensive pumping equipment [70]. Other examples are the Konkan Railway in Western India [71]; a coastal highway in Micronesia [72], The Copenhagen Metro in Denmark [73] and the Thames Barrier in the United Kingdom [74] [75].

Although the SLR projections in IPCC AR4 take into account the increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, this rate could change in the future, hence the projections have not captured the full effects of changes in ice sheet flow. Due to considerable uncertainties and the need for clearer projections to assist with adaptation, modelling of sea level rise has been a particular area of focus in recent years and many studies have been published subsequent to the AR4 that have enriched understanding of the topic. Many of these studies indicate that sea levels could potentially rise by substantially more than those predicted in the AR4.

However, current "consensus" seems to be that, while multi-metre sea level rise may be unavoidable over the coming centuries, sea level rise this century is not likely to exceed 2 metres [76]. While a total sea level rise of about 2 metres by 2100 could occur under physically possible glaciological conditions but only if all variables are quickly accelerated to extremely high limits, more plausible but still accelerated conditions lead to total sea-level rise by 2100 of about 0.8 metres. These roughly constrained scenarios provide a "most likely" starting point for refinements in sea-level forecasts that include ice flow dynamics.

Some of the ranges of likely SLR from recent research are illustrated in the table below:

Table 3.1 *IPCC and Alternative SLR Projections*

SLR Projection Range	Reference
260mm to 590mm (2100)	IPCC Fourth Assessment Report (AR4)
800mm to 1,500mm [a]	Jevrejeva, S., A. Grinsted, J. C. Moore and S. Holgate (2006): Nonlinear trends and multi-year cycle in sea level records, Journal of Geophysical Research, 111, 2005JC003229. Presented at European Geosciences Union Annual Meeting in 2008

(a) This is Jevrejeva's own interpretation of her paper referenced in *Table 4.2*. Her comments to the European Geosciences Union Annual Meeting in 2008 were quoted by the BBC: '*But by the end of the century, we predict it will rise by between 0.8m and 1.5m. The rapid rise in the coming years is associated with the rapid melting of ice sheets*." (http://news.bbc.co.uk/1/hi/sci/tech/7349236.stm).

SLR Projection Range	Reference
500mm to 1,400mm above 1990 levels (2100)	Rahmstorf, S., 2007, A semi-empirical approach to projecting future sea-level rise, *Science*, 315, 368–70.
500mm above 1990 levels (2100) [a] 1420mm (2200) 7300mm (3000)	Institution of Mechanical Engineers, *Climate Change Adapting to the Inevitable?*, IMechE, London, UK, February 2009 using GENIE-1 and HadCM3L GCMs
1400mm (22nd Century)	Herberger, M., H. Cooley, P. Herrera, P. Gleick, E. Moore, 2009: *The Impacts of Sea Level Rise on the California Coast*, Pacific Institute, Climate Change Center, USA [b]
500mm to 600mm (2050), and 'multi-metre' (2100) [c]	Hansen, J.E. (2007): Scientific reticence and sea level rise, Environmental Research Letters, 2:2, 024002, doi:10.1088/1748-9326/2/2/024002. Discussed in Hansen, J.E. (2007): *Climate Catastrophe*. New Scientist, July 28,2007
800mm (most likely), up to 2,000mm (2100)	Pfeffer et al. (2008): Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise, Science, 321:5894, 1340-1343.

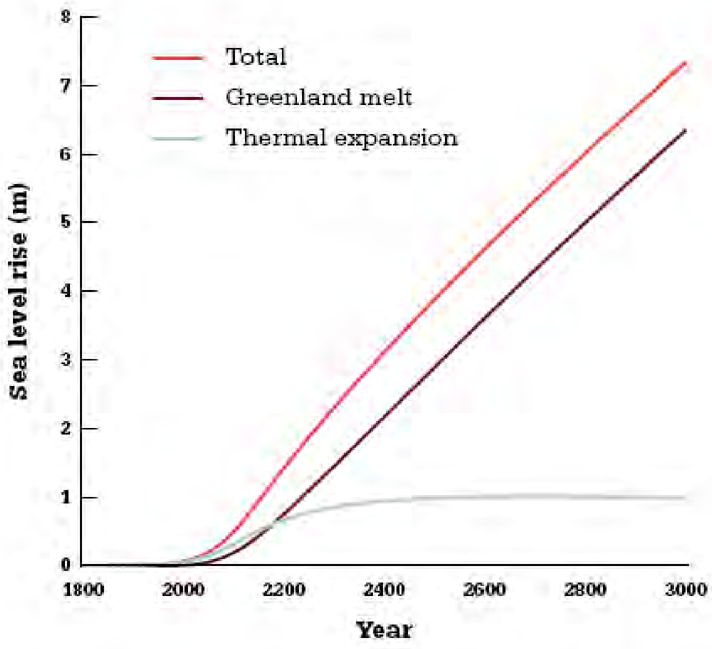
The UK Institution of Mechanical Engineers has recently published their professional opinion on how infrastructural development should best be tackled within a framework of uncertain science [77]. It points towards considering long term impacts (i.e. several hundred years) such as sea level rise, which will require revision and could lead to the construction of significant maladaptation. The likely long term changes to sea levels expected by the IMechE, and to which they recommend infrastructure is designed to, is illustrated in the figure below:

(a) Thermal expansion of the ocean is estimated to contribute 310mm of SLR and the melting of the Greenland icesheet is estimated to contribute 190mm, and the authors of the report note that this is likely to be an underestimate because the melting of smaller inland icecaps has been excluded.

(b) http://www.pacinst.org/reports/sea_level_rise/report.pdf

(c) This is inferred from the lines '*let us say that ice sheet contribution is 1cm for the decade 2005-15 and that it doubles each decade until the West Antarctic ice sheet is largely depleted. That time constant yields a sea level rise of the order of 5 m this century. Of course I cannot prove that my choice of a ten-year doubling time is accurate, but I am confident that it provides a far better estimate than a linear response for the ice sheet component of sea level rise under BAU forcing*.'

Figure 3.1 Sea Level Rise Projections



Source: IMechE, 2009

The IPCCAR4 (2007) "*does not assess the likelihood, nor provide a best estimate or an upper bound for sea level rise… Therefore the upper values of the ranges given are not to be considered upper bounds for sea level rise*". Therefore, in this study ERM has presented the IPCC's figures as the lower bound for our sea level rise projections. Also, prior to the achievement of consensus among various international parties on SLR, it is recommended that the Hong Kong Government should keep a watching brief on the latest scientific research on SLR with a view to updating the most likely and upper bound figures for SLR once available, and to bear in mind the range of alternative SLR figures that have recently emerged in scientific literature. It is also suggested that long term infrastructure developments are designed according to long term, reasonable worst case scenario projections.

Any decisions to be made in the shorter term should be flexible enough to allow for regular reviews and adjustments to incorporate any new climate change research findings, as is practiced in other parts of the world. A key date for a future review is around 2013, when the fifth assessment report from the IPCC is due to be published.

3.2 *BARRIERS TO ADAPTATION*

In the IPCC AR4, the following five barriers to climate change adaptation are defined:

- Physical and ecological
- Technological

- Financial
- Informational and cognitive
- Social and cultural

Despite an increased focus on adaptation (rather than mitigation) to climate change, there is less understanding of the feasibility, costs, limitations, effectiveness and likely extent of implementation of adaptation measures since much of the literature on climate change adaptation is qualitative rather than quantitative, which means that understanding of the likely future costs and benefits of adaptation into numeric and particularly economic terms is limited. For many locations, sectors and impacts there is insufficient quantitative information relevant for adaptation decisions to be made.

Whilst there are serious extant barriers to implementing adaptation measures, these constraints should not be considered insurmountable or an excuse for inaction. New planning processes are attempting to overcome these barriers at local, regional and national levels in both developed and developing countries, i.e. NAPAs (National Adaptation Programmes for Action) in the developing world and national adaptation policy frameworks in some developed countries such as Australia and the UK.

These barriers are discussed in more detail in the following paragraphs.

3.2.1 Physical and Ecological Barriers

There is increasing evidence from ecological studies that the resilience of socio-ecological systems to climate change will depend on the magnitude and rate of change experienced. There may be critical thresholds beyond which some systems may not be able to adapt without radically altering their functional state and system integrity. Regions already experiencing environmental and climatic difficulties, and those with degraded land and denuded ecosystem services are likely to experience reduced adaptive capacity. Additionally, the loss of what are termed 'keystone' species may impact the broader socio-ecological system, eventually influencing ecosystems services that humans rely on [78] .

Furthermore, evidence cited in the AR4 suggests that dramatic climate changes may lead to transformations of the physical environment that limit the possibilities for adaptive capacity, for example rapid sea level rise causing significant land loss in locations where land is at a premium, i.e. small island states and coastal settlements, where adaptation options are limited to either expensive coastal defences or managed retreat resulting in migration and relocation of infrastructure and population [79]. Whilst it is technically feasible for some such locations to adapt to as much as five metres of sea level rise, the resources to do so are so unevenly distributed that in reality this risk may be considered outside the risk of viable adaptation [80].

3.2.2 *Technological Barriers*

Technological innovation and technology transfer is often cited by policy makers as a key adaptive response to climate change. However, there are also potential limits to technological adaptation due to economically unfeasibility, or cultural inappropriateness, or unpopularity with the general public, i.e. waste water recycling as an alternative source of potable water.

Adaptations that are effective in one location may not be in others [81], or may not be equally transferable to all groups or individuals; furthermore this may create knock-on vulnerabilities for other places or groups, and may lead to an enhancement of existing inequalities [82].

Finally, as noted by the IPCC [83], decision makers under uncertainty, may inhibit the timely adoption of technological solutions to climate change. Whilst the desire for technological solution to climate change is often cited in the media, if this desire does not translate into effective investment, research and development, such adaptation solutions cannot be developed or adopted.

3.2.3 *Financial Barriers*

Adaptation to climate change may be constrained by the lack of adequate financial resources. Even in a wealthy society, lack of resources may limit the ability of low income groups within that society to afford proposed adaptation mechanisms such as insurance coverage. Even individuals and organisations who are not financially constrained often fail to purchase insurance against low probability / high loss events, perhaps because the trade offs are not fully understood [84].

Uncertainty in climate change science is also likely to raise actuarial uncertainty in risk assessments, placing upward pressure on insurance premiums and potentially a reduction in risk coverage. Physical adaptations to climate change including infrastructure developments, may be subject to higher insurance costs, or lower coverage, in the future [85] and this should be considered during the design and development of adaptation measures.

3.2.4 *Informational and Cognitive Barriers*

Adoption of adaptation responses to climate change can be limited by human cognition [86], primarily because there are significant uncertainties with regard to the impacts of climate change. However, even where there is certain knowledge, this does not necessarily lead to adaptation since providing scientifically sound evidence does not necessarily result in information assimilation, action and support for policies based on this evidence [87]. Contextual factors such as personal experiences and priorities and societal values, influence in this regard [88], for example, in societies where environmental issues are not traditionally considered important.

There is significant evidence that individuals can only respond to a limited number of issues at any one time [89] as concern about one type of risk increases, worry about others decreases. Individuals tend to prioritise the risks they face based on which they consider to be, rightly or wrongly, the most significant at a given point in time. As an illustration of this, there was considerable concern expressed at the COP14 (Conference of the Parties to the UNFCCC) / MOP4 (Meeting of the Parties to the Kyoto Protocol) at Poznan, Poland, in December 2008, that worries about the present negative global economic situation would reduce the focus on addressing climate change, an issue generally perceived to be a more medium to long term problem. Furthermore, this example illustrates that the human brain is not well evolved to deal with medium to long term problems, but rather is best able to process immediate external threats.

A lack of previous experience of negative climatic events, or experiencing adequate societal responses to past negative events (sufficient to prevent the worst impacts of a climatic event, i.e. a typhoon) may inhibit appropriate responses beyond an individual's cognition even though more serious climatic events may be projected for the future. The issue of climate change is complicated by the fact that the threat of climate change is not entirely external, peoples' own actions and behaviour, i.e. failure to reduce their own emissions, is a part of the problem.

Concern about climate change is relatively high in developed societies, although until recently it has been commonly perceived that populations in Europe viewed climate change as a more pressing concern than those in Hong Kong. However, a 2007 study by TNS and WWF Hong Kong found that public attitudes in Hong Kong had shifted dramatically in that year, with over 82% of its residents believing Hong Kong is vulnerable to the impacts of climate change (90). The study also found that Hong Kong's people were more concerned about climate change than those in Western European countries such as the UK and Germany. However, across the developed world, climate change is still not perceived to be a pressing personal priority sufficient to compel them to make serious lifestyle changes. This attitude-behaviour gap has been shown to be a significant barrier to implementing adaptation measures (91). Strong visceral reactions towards the risk of climate change are needed to provoke meaningful behavioural change (92).

A divergence between perceived and actual adaptive capacity can be problematic (93). Actors may overestimate their adaptive capacity due to their past ability to successfully meet climatic challenges; this may not accurately reflect their ability to deal with projected climate change impacts and could result in complacency and maladaptation. Conversely, actors which feel that climate change is likely to be overwhelmingly catastrophic may find attempts or the desire to adapt is paralysed by pessimism.

Studies suggest that perception of barriers to adaptation limits adaptive action, even where there are sufficient resources and capacity to adapt. Policymakers need to be aware of the barriers to adaptation and provide structural support to overcome them, and concurrently work toward fostering empowerment and action at the individual level. Research has shown that appealing to guilt or fear does not succeed in engaging on climate change issues, and does not motivate appropriate adaptive behaviour. Rather, climate change needs be made personally relevant through messages of practical advice on individual actions and by using local imagery.

3.2.5 *Social and Cultural Barriers*

Social and cultural constraints to climate change adaptation are not well documented [(94)]. Anthropological research indicates that the scale and novelty of climate change is not likely the sole determinant of degree of impact [(95)]. Societies alter their own environments and thus their own vulnerability. Different risk tolerances, different preferences about adaptation measures, etc. exist depending on the views of different groups and societies. Conflicting and diverse knowledge and priorities of climate change adaptation across different social and cultural groups are also likely to impede adaptation.

The most successful adaptation involves marginal changes to material circumstances rather than wholesale changes in location, cultural values or development paths.

Differential power and access to decision makers may promote adaptation responses by some, but constrain them for others [(96)]. Therefore the most effective adaptation strategies will be those that maximise community participation and consultation.

4 *HONG KONG – EXTANT ADAPTIVE CAPACITY*

4.1 *INTRODUCTION*

Hong Kong is sensitive to climate change due to its location in a densely populated region of the sub-tropics and due to a number of local geographic and demographic characteristics. As with all cities, Hong Kong is vulnerable because of the agglomeration of people and assets in a small area. In terms of unique locational risks, '*the physical location of Hong Kong, surrounded by water, on traditional typhoon tracks and with a dense urban setting, makes it particularly vulnerable to climate change*' [(97)]. Hong Kong's vulnerability is compounded by its dependence on imported food, water, energy and other products that are required for it to thrive.

However, Hong Kong also has comparatively high adaptive capacity due to:

- its relative wealth and access to finance and international goods;
- excellent international trade, communication and academic links;
- the Hong Kong population is by and large accepting of new ideas and willing to embrace change and best practice from around the world;
- the Hong Kong population values education and offers a world class workforce able to adapt to trends in the employment market;
- Hong Kong has world class healthcare facilities and the population is healthy, and recognizes the importance of identifying and responding to external health hazards;
- Hong Kong has high reliability of essential services i.e. electricity and water supplies;
- Highly advanced infrastructure and in situ emergency response protocols are already in existence;
- The process of approving and implementing legislation in Hong Kong is comparatively efficient and able to address long term issues.

Despite this, Hong Kong's adaptive capacity to climate change and associated resilience to climate change impacts may require improvement. The stock taking exercise undertaken by Government stakeholders illustrated that few sectors believe they are undertaking policies which build adaptive capacity for climate change as a by-product of other strategy aims and fewer still are actively considering climate change adaptation at present (only health, the built environment and water resources sectors). It may be that further policy measures either in existence, or planned for the future will assist in adapting to climate change, however these have not been identified to the study team by the relevant stakeholders to date.

Although, Hong Kong, like many highly developed societies may today be considered to be highly adaptive to climate variability and change, it is important to recognise that vulnerability is dynamic and likely to change in response to multiple processes including economic factors [(98)].

Whilst the impacts of climate change and the challenge of adapting to it are likely to be more problematic in developing countries due to resource constraints, it would be erroneous to assume that a highly developed city such as Hong Kong will face no barriers to adaptation. The IPCC notes evidence from Europe and other highly developed parts of the world, which suggests that high adaptive capacity many not automatically translate into successful adaptation to climate change and that complacency and overconfidence about infrastructural and systematic robustness, amongst wider society and governments in particular, in wealthy countries may itself become a barrier to adaptation [(99)].

The IPCC highlights that '*while the overall record of adaptation to climate change and variability in the past 200 or so years has been successful overall, there is evidence of insufficient investments in adaptation opportunities especially in relation to extreme events* [(100)]'. With regard to extreme events the insurance and reinsurance industry has recorded that monetary losses have been rising sharply whilst mortality (in developed nations) has been falling. This situation is only partly explained by rising asset prices. Adaptation via major improvements in understanding, forecasts and warnings has been successful to a point but further progress is constrained where local concern about extreme events has declined [(101)] (as the memory of specific disaster events fades) eliciting a reduced propensity to adopt proactive adaptation measures. Thus Hong Kong residents' ability to respond and adapt to climate change should not be assumed on the basis of past familiarity with extreme weather events or even on the basis of regular warnings. The IPCC notes that '*related to this lack of appreciation of possible risks is that governments and communities can still be taken by surprise when extreme events occur, even though scientific evidence of their potential occurrence is widely available*'.

Furthermore, despite high adaptive capacity and significant investment, numerous studies have shown that extreme events (particularly heat waves), continue to result in high levels of mortality and morbidity, and disruption to infrastructure and electricity supplies, in highly developed countries across Europe, North America and East Asia [(102)].

4.2 *EXISTING POLICIES AND MEASURES IN HONG KONG*

Within Hong Kong's legislation and contingency planning, there are numerous policies and measures which provide some degree of adaptive capacity to extreme weather events, and potentially subject in some cases to some degree of modification, to climate change. Notably, the Inter-departmental Working Group on Climate Change (IWGCC) was established, in 2007, to co-ordinate, develop and promote actions in reducing GHG emissions and adapting to climate change. The IWGCC is currently comprised of 5 bureaux and 16 departments. ERM undertook a detailed desktop review of legislative policies and measures currently in place in the public sector which offer adaptive resilience to Hong Kong in the face of climate change. These policies and measures are illustrated thematically by climate change impacts in *Annex B*; whilst an overview of these is provided in the subsequent sections. It should also be noted that this exercise covers only public sector legislation within Hong Kong and that private sector initiatives may also be in existence which offer additional adaptive capacity. It is worth noting that the vast majority of these policies and measures were not originally designed to explicitly address climate change.

4.2.1 *Adaptive Capacity to Respond to Extreme Temperatures / Heatwaves*

In Hong Kong, high temperatures exceeding 31 °C are not unusual especially during the afternoons of the summer months. The "urban heat island" effect intensifies the effects of high temperatures. Heatwaves do not have defined geographic boundaries (unlike floodplains), and they typically affect the whole of Hong Kong. It is not possible to prevent heatwaves from occurring but it is possible to improve how we prepare for them. This section discusses the management of Hong Kong's urban heat island and minimising the need for cooling in buildings. The policies and measures concerning human health that are associated with extreme temperatures are discussed in *Section 4.2.6*.

Urban heat island effect can be managed by increasing the area of green space cover through protecting existing green spaces and encouraging new opportunities for urban greening. The Hong Kong 2030 Strategy provides a framework for future developments in Hong Kong. The Planning Department (PlanD) has a *Hong Kong Planning Standards and Guidelines* that provides suggestions and guidelines including open space, air ventilation, landscaping and others. Micro-climate studies are carried out by the Housing Department (HD) to examine the climate characteristics of the housing estate site including wind speed, natural ventilation, solar heat gain and others. There are, however, no mandatory requirements that new and redevelopment projects need to address the urban heat island effect, such as to create breeze pathways that enhance natural ventilation, punctuate new development with green spaces, use low-albedo, permeable paving materials, and optimize the street width to allow for appropriate scale deciduous street trees.

High temperatures may cause buckling of railway lines and melting of road surfaces. The *Structures Design Manual for Highways and Railways* of the Highways Department (HyD) provides a range of suggested measures that include the use of materials and testing materials against heat stress.

Indoor temperature is dependent on the design of the building, its location and aspect. Warmer temperatures may lead to an increase in demand for energy intensive cooling such as air conditioning. Air conditioning is a common way to keep buildings cool in Hong Kong but this solution is unsustainable as it is energy intensive, contributes to greenhouse gas emissions and the waste heat generated can exacerbate the urban heat island effect. Development should be designed and constructed to avoid the need for extensive mechanical cooling as far as possible. The *Code of Practice for Overall Thermal Transfer Value in Buildings* aims to reduce heat transfer through the building envelope (in particular external walls and roofs of a commercial or hotel building), thus the electricity required for air conditioning. This does not apply to other buildings and private developments. Moreover, insulation is an important adaptation option but is not always considered during the design stage of a building in Hong Kong.

A comprehensive local review on the measures currently planned or already in operation by the Government that aim to mitigate climate change was provided under the Mitigation Assessment task of the study and these are not repeated here. The measures discussed such as energy supply, energy efficiency and conservation, renewables, are for Hong Kong's four major emission sectors, namely Energy Supply, Buildings and Appliances, Transport and Waste.

4.2.2 *Adaptive Capacity to Respond to Drought*

Hong Kong relies heavily on imported water. Periods of low rainfall has significantly impacted Hong Kong in the past. For instance, water supply was restricted to four hours every four days during the 1963 drought, and then in 1967 for a short period. For a period in 1977, the supply was limited to 10 hours a day; similar restrictions were again imposed in 1981 and early 1982.

A new agreement was signed in 2008 with the Dongjiang water authorities that allow some flexibility for variation of the quantity of water imported to Hong Kong for the period 2009-11, but does include daily and annual maximums which limit the total imported water quantity available to Hong Kong. Nevertheless, reduced availability of water resources in Hong Kong could potentially result during periods of low rainfall (1) if the quantity of imported Dongjiang water cannot be increased to compensate the reduced yield due to physical or contractual constraints; (2) the contractual obligations cannot physically be met due to water stress in Dongjiang. With regard to water use in Hong Kong, the *Total Water Management Programme* consists of a number of measures that aim to manage both water supply and water demand.

4.2.3 *Adaptive Capacity to Respond to Floods*

Hong Kong is prone to flooding from different sources of floodwater, including (1) from heavy rainfall overcoming the drainage system (surface water flooding); (2) from the sewers; and, (3) from the sea (tidal flooding).

Extreme Rainfall

Changes in the mean rainfall and frequency of extreme rainfall events will have an influence on Hong Kong's water supply; the latter may also give rise to flooding, landslips etc.

Flooding is not uncommon in Hong Kong especially during periods of heavy rainstorms and/or tropical cyclones. The Hong Kong Observatory (HKO) issues rainstorm warnings when heavy rain is expected. Preventive measures in Hong Kong include annual inspection of drains and watercourses especially before and during wet seasons to ensure their full operation in times of rainstorm, regular de-silting and dredging of tidal channels. The Government also has the authority to access private land to carry out maintenance works and to remove obstructions to watercourses under the Land Drainage Ordinance. There are other drainage improvement works, rural drainage rehabilitation schemes and flood protect scheme to raise flood protection level, to alleviate flooding problems and to reduce flooding hazards at various locations across the territory. The Drainage Services Department (DSD) implements flood prevention projects (including eight Stormwater Drainage Master Plan (DMP) Studies) to improve the drainage systems for the whole territory, in particular in the low-lying flood plains of the North and Northwest New Territories, to relieve flooding problems and to raise the flood protection level. All stormwater facilities in new developments have to be designed to withstand a severe flood event in accordance with the flood protection standards.

DSD has operated the Emergency and Storm Damage Organisation to ensure that floods and other emergency situations could be dealt with speedily. When Red or Black Rainstorm Warning or Typhoon Warning Signal No. 8 or above is issued, the Emergency Control Centre goes into operation immediately. Also, DSD will closely monitor the water levels of river streams and flooding conditions of flood prone areas in Hong Kong and work with HKO and Home Affairs Department (HAD) to remind the residents living at coastal and low-lying areas about the flood risks resulting from the rainstorms. Emergency situations that may threaten human lives and livelihoods along with Hong Kong's existing adaptive capacity to respond to these are described in more details in *Section 4.2.6*.

There are numerous ongoing and upcoming efforts, in particular by the DSD, to alleviate flood problems and to manage flood hazards Design standards, thresholds, etc are reviewed regularly and updated when necessary in order to ensure that drainage facilities are capable of dealing with changes in frequency and/or intensity of rainfall and extreme rainfall events. Climate change may also lead to new risks, such as in areas that were not prone to flooding in the past, and areas that may not have a comprehensive monitoring system. All these would require regular reviews and updates of the existing measures as well as continue monitoring.

Sewers

The whole of Hong Kong is covered by the 16 Sewerage Master Plan Studies, some of which are being reviewed to accommodate the changes in planned population.

Similar to the drainage infrastructure, design standards and hydraulic capacity for sewerage infrastructure may need regular reviews that incorporate the latest development in climate change science. There is currently limited research on the implications of climate change on sewerage infrastructure, such as on odour, the effects on hydraulic load of wastewater as stormwater enters sewerage systems in the event of heavy rainfall, the effects of hydraulic capacity of sewage treatment plant discharge systems under different sea-level rise scenarios etc.

Sea-Level Rise

Tidal information at various locations in the territory is provided by the HKO. The longest tidal records in Hong Kong is provided by North Point/Quarry Bay (NPQB) tide gauge station, which were built on reclaimed land and therefore settlement corrections would be necessary. Also, the Works Departments of the Government have developed guidelines in 1990, in which relevant government works projects should consider that the rate of mean sea level rise may increase at 10 mm per year so as to address the potential impacts from climate change.

Local / regional crustal movements are an important factor to be taken into account when considering future sea-level rise. For this reason, the Hong Kong Observatory (HKO) has started measuring vertical ground movement at tide gauge stations using satellite-based Global Positioning System techniques since 2004. This means that unfortunately, long term data does not exist for the period prior to 2004.

Projecting future sea-level rise is complex and has significant resource implications. The amount of future sea-level rise may also be influenced by regional ocean currents, as well as processes that may be unknown at present. There is also potential for synergetic impacts of storm surge coupling with sea level rises. Currently there is limited research that focuses on the issue of local sea-level rise, such as downscaling from global projections, research in factors that may contribute to or exacerbate the effects of sea-level rise, modelling / sensitivity studies on the potential impacts resulted from different scenarios of sea-level rise etc.

Development on reclaimed land may be particularly susceptible to flooding associated with sea-level rise and storm surges. Guidance and recommendations on reclamation design, covering design considerations, stability analysis, settlement assessment and monitoring are provided in *Port Works Design Manual: Part 3*. In line with drainage and sewerage infrastructure described above, the implications of climate change will need to be incorporated into the development and reviewing of design standards, thresholds, return periods etc. Victoria Harbour is protected from any new reclamation projects under the *Protection of the Harbour Ordinance*. However, this *Ordinance* only applies to Victoria Harbour, and reclamation can still take place in other parts of Hong Kong which will potentially raise the area at risk of flooding associated with sea-level rise.

4.2.4 Adaptive Capacity to Respond to High Winds and Gusts associated with Tropical Cyclones, Intense Monsoon and Severe Thunderstorms

Hong Kong typically experiences a few tropical cyclones every year, and they commonly occur during the months of May to November. Tropical cyclones activities in recent decades have not resulted in significant deaths, casualties and damages due to the high level of preparedness within the community.

In view of the climate change impacts and potential increase of extreme events in the coming years, HKO periodically review the Typhoon, Rainstorm and Very Hot Weather Warning systems so as to fulfil the needs of the society and citizens. Warnings will be issued for shipping when a tropical cyclone is within Hong Kong's area of responsibility. Whenever a threatening tropical cyclone comes within 800 km of Hong Kong, the HKO issues local warnings and advisory bulletins. This provides information on the warning signal, the latest position and expected movement of the centre of the tropical cyclone, wind strength, rainfall and sea level in the territory, as well as advice on precautionary measures so that the public can prepare for the tropical cyclone. The Labour Department (LD) has a *Code of Practice* that seeks to provide advice and practical guidelines on work arrangements in times of typhoons and rainstorms, in particular when Typhoon Warning Signal No. 8 or above or Black Rainstorm Warning is in force. There are also arrangements for Kindergartens, Day Schools and Evening Schools in periods of tropical cyclones and heavy persistent rain by the Education Bureau (EDB). Apart from tropical cyclones, the Strong Monsoon Signal is issued during episodes of strong or gale force gusty winds associated with surges of intense southwest (summer) or northeast (winter) monsoon. The Hong Kong Observatory may also issue thunderstorm warnings with information on violent gusts generated by intense squall lines.

The *Code of Practice on Wind Effects* of the Buildings Department (BD) provides general equations on calculating wind information that can be incorporated into building designs. Nevertheless, this does not apply to buildings of unusual shapes or where wind conditions are influenced by topography. The existing warning systems and the associated arrangements imply that Hong Kong is already in a position to cope with climate change influence on tropical cyclone activities and storms. In spite of these measures, intense tropical cyclones, i.e. those equivalent to Category 4 and 5 hurricanes, are rarely experienced in Hong Kong. Should tropical cyclones intensify as a result of climate change, relevant policies or measures may need to be reinforced to minimise the impacts.

4.2.5 *Adaptive Capacity to Respond to Landslips / Landslides*

Hong Kong has a hilly to mountainous terrain with steep slopes, and landslips in Hong Kong have impacted human lives and livelihoods in the past. For instance, the rainstorm of late July 1994 triggered a severe landslide at Kwun Lung Lau which led to 5 deaths and 3 serious injuries. The June 2008 extreme rainfall event causing 2,500 landslides on both man-made slopes and natural terrain in Hong Kong, and the extensive damage and loss of life resulting from landslide disasters triggered by typhoon Morakot on Taiwan in August 2009 are vivid reminders that adverse impacts of climate change on slope safety should not be underestimated, as the current adaptive capacity to respond to landslips/landslides may not be sufficient.

The GEO, in consultation with HKO, issue Landslip Warnings when numerous landslips are expected to alert the public as well as relevant parties so that they can take necessary precautions to ensure safety.

The GEO recently launched the Landslip Prevention and Mitigation Programme (LPMitP) to dovetail with the Landslip Preventive Measures (LPM) Programme which was completed in April 2010. The LPMitP is implemented on a rolling basis with the following annual output: (a) upgrade 150 government man-made slopes; (b) conduct safety-screening studies for 100 private man-made slopes; and (c) implement studies and necessary risk mitigation works for 30 natural hillside catchments.

In conjunction with LMPitP, the GEO controls the standard of new slopes by checking their design and construction, promotes regular maintenance of slopes by maintenance parties to prevent deterioration and provides public education to maintain public awareness of landslide risk.

The GEO promotes slope engineering practice by promulgating technical guidance documents. For example, the *Highway Slope Manual* provides a standard of good practice on slope engineering for project planning, design, construction and maintenance on highway slopes. Other key publications include Geotechnical Manual for Slopes, Guide to Soil Nail Design and Construction (Geoguide 7), etc.

4.2.6 *Adaptive Capacity to Respond to Health Impacts and Safety Concerns*

There are organisations and systems in place to safeguard the health of the population in Hong Kong; many of these may contribute to, or are synergistic to, adaptation to climate change. For instance, the Hong Kong Observatory (HKO) monitors the changing weather patterns and issues forecasts and warnings that allow the general public to prepare for severe weather conditions; the Department of Health (DH) of the Hong Kong SAR Government is an agency to execute health care policies and statutory functions, under which a Centre for Health Protection (CHP) has been established to strengthen the public health system in prevention and control of communicable diseases and other public health hazards; the Home Affairs Department (HAD), Security Bureau (SB) and Civil Aid Service (CAS) are some of the authorities involved as emergency situations or incidents arise; the Centre for Food Safety (CFS) and the Food and Environmental Hygiene Department (FEHD) address food safety while the Water Supplies Department (WSD) has measures to ensure the quality of water supply. The following sections provide an overview of the existing policies and measures in Hong Kong that may facilitate climate change adaptation of relevance to human health impacts and safety.

Heat Stress and Cold Stress

Heat stress and cold stress may result from periods of extreme temperatures, and the elderly population is particularly vulnerable. The relationship between cold and hot weather on the health of senior citizens in Hong Kong was recently studied jointly by the Hong Kong Observatory and the Senior Citizen Home Safety Association (SCHSA). The Observatory and SCHSA will continue their collaboration to ensure the safety of senior citizens in hot and cold weather conditions. When periods of cold or very hot weather are anticipated, health warnings are issued and communicated to the general public via the media so that they can take necessary precautions. The announcement of such warnings also activates the relevant government departments and voluntary agencies to provide emergency relief such as temporary shelters and distribution of blankets. A leaflet has been produced to promote heatstroke prevention at work place by the Occupational Safety and Health Branch of Labour Department (LD), which provides generic information for employers and employees. Employers are responsible for the occupational health and safety of all employees, including assessing the risk of heat stroke for those working in a hot environment. There are also guidelines that identify a range of potential health hazards and provide recommendations on preventive measures. Under the Elderly Health Service by the Department of Health (DH), elderly health centres were established to provide primary health care to the population aged over 65, as well as health visiting teams. Regarding weather extreme and the relevant health information/services for elderly, the Central Health Education Unit of the Department of Health (DH) has a pamphlet which includes health advice to the elderly in extreme weather (heat/cold stress). More specific guidance is also available from Elderly Health Service (EHS) of DH. Elderly Health Service has been using various channels to deliver relevant health messages and advice, targeting at both the elderly and their carers. This includes face-to-face health education by the Visiting Health Teams at various community settings, pamphlets, contributed articles to publications targeting at elderly readers, radio interviews, internet webpages, etc. To assist carers and volunteers, two Do-It-Yourself health education kits, comprising reading materials, presentation files and speaking notes, have been produced and made available for download from the internet.

In addition to the hot and cold weather warnings, the Hong Kong Observatory also provides information on ultraviolet (UV) radiation and issues advisory messages when the UV Index reaches 11 or above. Further, there is a fire danger warning system in place to warn against the risks of hill fires during episodes of low relative humidity in the dry season.

Air Pollution Related Morbidity and Mortality

Climate change will have an influence on both the sources and dispersion of air pollutants. Air pollution episodes will have the greatest impact on the elderly population and those with pre-existing cardio and/or respiratory conditions. In Hong Kong, the Air Pollution Index (API) provides information to the general public via the media so that necessary precautions can be taken. Warnings are issued to schools when API of a certain level has been detected or forecasted. To improve the air quality in Hong Kong, the Air Quality Objective (AQO) is currently under review and a long-term air quality management strategy is being developed.

Weather Disasters

The frequency and/or intensity of extreme weather events have been projected to increase as climate changes, which may raise the risk of weather-related disasters such as storms and floods.

Hong Kong has excellent warning systems for bad weather conditions as the Hong Kong Observatory (HKO) maintains a close watch on the weather. Early warnings (e.g. warnings for tropical cyclones, rainstorm, thunderstorm and landslip etc) are issued when severe weather conditions are predicted to affect Hong Kong so that general public can take precautionary measures.

Should there be an emergency situation or in the event of natural disasters, the Emergency Monitoring and Support Centre (EMSC) activates. The actions to be taken under an emergency situation are outlined in the *Emergency Response System: the policy, principles and operation of the Government's emergency response system*, which covers the rescue, recovery and restoration phase, as well as communication with the public. There is a *Contingency Plan for Natural Disasters* by the Security Bureau (SB), which lists out the roles and responsibilities of controlling authorities. The plan is updated annually and is tested regularly. The Civil Aid Service (CAS) also provides support to the emergency services and government departments. There is also guidance on the action to be taken by government departments, agencies and relevant organisations when emergency situation involving Hong Kong Residents arises outside of Hong Kong SAR. Buildings Department (BD) will activate the Emergency Control Centre when Tropical Cyclone Warning Signal No. 8 is issued or in times of heavy rainfall and other disasters. It co-ordinates professional services to deal with dangerous buildings, landslides, dangerous scaffolding and advertising signs. Transport Department (TD) has established the Emergency Transport Co-ordination Centre to closely monitor the traffic and public transport services throughout the year. The centre also has developed emergency response plans for the traffic and public transport service disruption due to extreme weather events such as typhoons, rainstorms, flooding and landslides, etc. and coordinates with various Government departments such as Hong Kong Police (HKP), Highways Department (HyD) and public transport service providers to implement the response measures and provides the real time traffic conditions to the public through mass media. The power companies have developed emergency response plans to handle the issues on power systems (e.g. power outage) due to bad weather. These plans are subject to periodic review by the power companies and the Government is monitoring it through legislative means. In the event of a Typhoon signal No. 8 or above, a landslip warning or a Red or Black rainstorm warning, Home Affairs Department (HAD) and the Department Emergency Co-ordination Centre (DECC) will be activated for the provision of emergency support services. An emergency hotline manned round the clock for the provision of weather reports, information and assistance to the public will also be available. Temporary shelters to people in need in event of cold or prolonged hot weather are also provided. Meals, blankets and mattresses are provided to shelter-seekers at a number of widely-publicized locations.

Diseases

The Department of Health (DH) coordinates the public health information and disease surveillance system in order to monitor the communicable diseases and collate the epidemiological data. There are a number of policies and measures in place that aim to prevent and control both infectious and non-communicable diseases. In the prevention and preparedness stage, there are programmes for on-going disease surveillance and monitoring, public education, awareness raising and information sharing among health professionals, as well as a Childhood Immunisation Programme. In the respond stage, there is a mechanism for emergency response to deal with outbreaks of infectious diseases (including in public hospitals) which involves centres for coordination and communications to both authorities and the general public. Further, there is an advisory group that provides advice to the Centre for Health Protection (CHP) on risk communication strategies and development of action plans. The group also reviews the CHP's existing risk communication measures. Also, DH maintains close contact with the Food and Environmental Hygiene Department (FEHD) so as to obtain climate related vector-based data (e.g. Ovitrap Index) and food safety monitoring information and take appropriate remedial measures accordingly.

The public sector has shown awareness in the potential changes in disease patterns associated with climate change as the Hong Kong Observatory (HKO) has analysed health surveillance data (such as mortality and Japan encephalitis) against weather information.

The water supplied in Hong Kong complies with the World Health Organisation (WHO) guidelines. The Water Supplies Department (WSD) has a number of measures including a multi-barrier approach to ensure the quality of drinking water is maintained in Hong Kong. These include hazard identification, risk assessment, monitoring and operational requirements, control measures and corrective actions covering events of flooding, power failure and water contamination that may be caused by adverse weather conditions. WSD not only ensures the quality of the supply of water, but also has a scheme to encourage proper maintenance of the fresh water plumbing system within premises. Notwithstanding these measures, water supply may be contaminated at source (i.e. in the Dongjiang water catchment area) which WSD may not have direct control over.

The Centre for Food Safety (CFS) of FEHD carries out risk assessment, risk management and risk communication to ensure food safety in Hong Kong, including research on food safety topics that are important to public health, food surveillance and sampling at the import, wholesale and retail levels, import control on high risk food items, monitor the food safety incidents in and outside Hong Kong through the Food Incidents Monitoring Mechanism and communicate with the trade and public about the food safety issues.

Apart from food safety, the Government also has regulations in place to maintain the stable supply of food into Hong Kong. Under the Reserved Commodities Ordinance and its subsidiary Regulations (Cap. 296), rice is classified as a reserved commodity under the regulation. The Government operates the Rice Control Scheme to ensure a stable supply of rice and the stockholders have to keep a reserve stock sufficient for consumption by the population for a reasonable period (at present 15 days) to cater for emergencies or any short term shortage of supply. About 70% of wheat flour is imported from Mainland China. The Trade and Industry Department (T&ID) monitors the import quantity of wheat flour periodically and will liaise with relevant authorities in Mainland China to increase the supply quantity if necessary.

4.2.7 Adaptive Capacity of Hong Kong's Economy

Climate change will result in differing risks and opportunities in different segments of the financial services sector although analysis of how climate change will affect the sector is still at an early stage. For example, the value of the assets that are vulnerable to climate change (such as those located at the waterfront or on reclaimed land) may depreciate. On the other hand, climate change may bring about new service areas and business opportunities.

The financial services sector is one of the Four Key Industries in the Hong Kong economy. While short-term investors may not take into account long-term climate change in their investment decision-making process, financial institutions may benefit from incorporating future climatic conditions into their decision making. The sector also has a role to aid identification of threats and opportunities to Hong Kong's economy such as in the advice they offer, the assets they invest in, the business continuity plan they develop etc, yet they are not required to do so.

Businesses, particularly the insurance industry, have a key role in climate risk management. In addition to the mandatory *Third Party Risks Insurance*, building owners and owners' corporations are advised to purchase *Property-All-Risks Insurance* (property insurance), which covers losses or damages to the common properties of the building due to fire or other risks e.g. flooding. This type of insurance has the potential to minimise the losses property owners may face, especially the waterfront properties alongside of Victoria Harbour (that are also amongst those with some of the highest asset values in Hong Kong), but it is not currently a mandatory requirement.

The Hong Kong Monetary Authority (HKMA) has established emergency response plan to handle the issues that will affect banking stability in Hong Kong. HKMA anticipates that the emergency response plan will also be developed by the banking institutions in order to ensure their normal operation. Such a response plan will normally form part of the organisation's continuity plan and it will include the arrangement for backup services and methodology for service reactivation.

The Hong Kong Exchanges and Clearing Limited (HKEx) has developed procedures and guidance for emergencies, including the exchanges and clearing arrangement under Typhoon and Black rainstorm as well as the exchanges and clearing rules and process for various HKEx departments.

The Office of the Telecommunications Authority (OFTA) has an emergency response team that operates throughout the year and maintains close contacts with the telecommunications operators, relevant governments and overseas bodies so as to obtain the latest information about the emergencies (including the incidents resulting from the extreme weather events).

4.2.8 *Adaptive Capacity of Hong Kong's Environment*

Hong Kong's Biodiversity

In addition to being a highly developed world city, Hong Kong is rich in biodiversity and has a variety of endemic and near endemic species. The territory also supports globally significant proportions of the population of a number of more widespread far-ranging species.

There are a number of policies and measures, mainly implemented by the Agriculture, Fisheries and Conservation Department (AFCD), to protect and conserve biodiversity. There are measures that aim to protect endangered species of animals and plants by regulating all activities involving the listed species, to protect wild animals from human disturbances as well as conservation programmes for species that are of ecological importance, such as the Chinese White Dolphin.

There is legislation to protect ecologically important areas from adverse development impact, and prevent development or incompatible land uses on ecologically sensitive sites. Country Parks, marine parks and marine reserves are some of the sites being regulated. The wetland in the Mai Po and Inner Deep Bay region is a significant Ramsar Site in Hong Kong. Through the Baseline Ecological Monitoring Programme and Waterbirds Survey at Mai Po Inner Deep Bay Ramsar Site, AFCD monitors and conserves the ecological value of the important wetlands.

The Agriculture, Fisheries and Conservation Department (AFCD) also works with NGOs, private sectors, communities, the academia and etc in research, surveys and awareness raising. In addition, the Environment and Conservation Fund (ECF) also supports educational activities, research, technology demonstration and other environmental and conservation related projects and activities.

Education and Public Awareness

Until relatively recently, environmental issues (e.g. biodiversity) were not a major concern for the majority of stakeholders in Hong Kong. Attitudes are changing and the population in Hong Kong is becoming increasingly aware of and values the unique biodiversity of the territory.

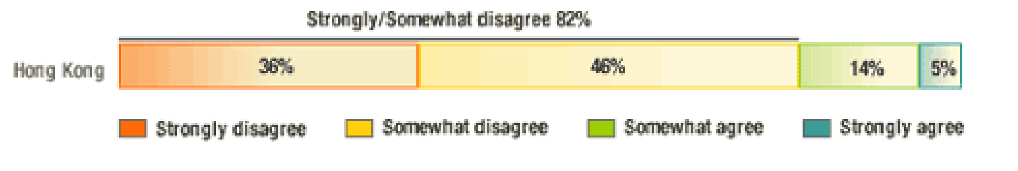
It is important to incorporate the subject of climate change into education curriculum as, in Hong Kong, there is often a misconception that climate change is equivalent to an air quality issue. The Education Bureau (EDB) has held workshops aimed at improving teachers' understanding of climate change, and climate change is included in the curriculum. The Hong Kong Observatory (HKO) has provided an educational package for distribution in schools that aims to raise awareness and understanding of climate change and the associated impacts. The Hong Kong Observatory is also actively engaged in activities that aim to promote public awareness. AFCD has carried out a series of education programmes at Hong Kong Wetland Park, including seminars and bird watching competition, to encourage public participation in wetland conservation.

4.3 PUBLIC PERCEPTION OF CLIMATE CHANGE AND ADAPTIVE CAPACITY IN HONG KONG

As noted in *Section 3.2.4* of this report, cognitive and socio-cultural attitudes to climate change are an important part of adaptive capacity. A recent survey conducted by the WWF and TNS in Hong Kong found that over 80% of people still feel threatened by climate change.

The results of this survey are illustrated below:

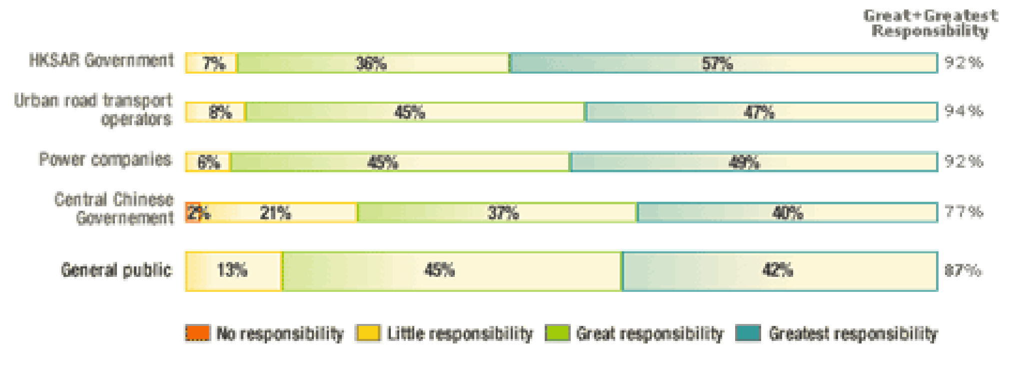
Figure 4.1 ***What Extent do you agree With the Statement: 'Hong Kong is safe from the impacts of Climate Change'?***



Source: TNS and WWF, 2007 [103]

In terms of assigning who should be responsible for adapting to, and mitigating the worst impacts of climate change, whilst over 90% of Hong Kong residents are willing to make some lifestyle changes themselves, the majority feel that the Hong Kong SAR Government has the most responsibility for addressing the issue.

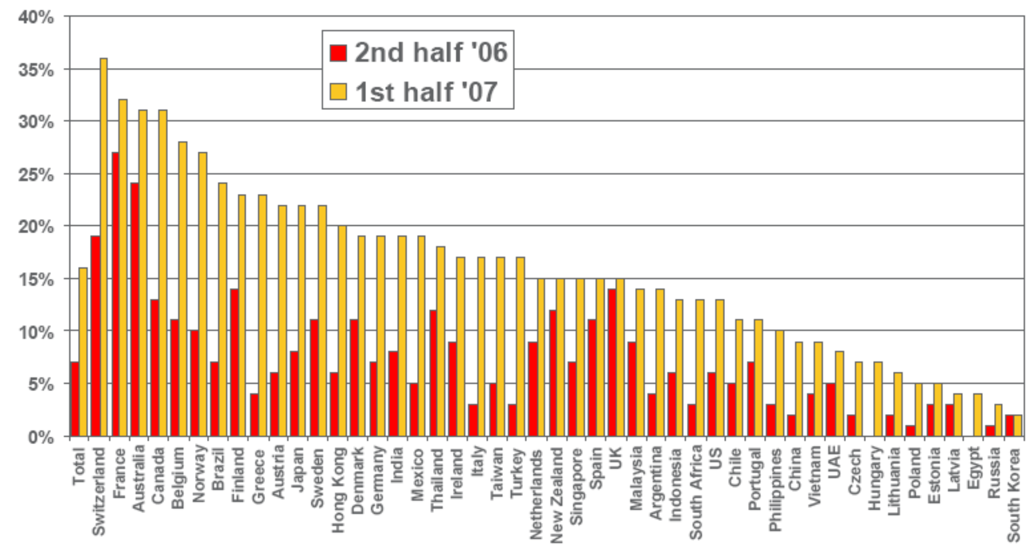
Figure 4.2 ***If Hong Kong was to take Action on Climate Change, What Responsibilities should each of the Following Have?***



Source: TNS and WWF, 2007 [104]

It is important to put Hong Kong's residents' opinions within an international context. It appears from international surveys that climate change has rapidly become an important concern for Hong Kong residents. The following figures obtained from an international survey conducted across 47 countries in 2007 [105], reveal that the population in Hong Kong are in the top 30% of those surveyed in terms of the degree to which they are concerned about climate change, representing a 14% increase in the percentage of those Hong Kong residents concerned about the issue over the previous six months.

Figure 4.3 International Concern about Climate Change



(Percentage of Respondents who felt Climate Change was their First or Second most Pressing Concern over the Next 6 Months). Source: Neilsen, 2007

Another international survey: the 2007 Synovate Global Omnibus survey on climate change which interviewed 14,220 respondents across 21 countries (USA, China, France, Germany, Hong Kong, Singapore, South Korea, Australia, India, Japan, Poland, Dubai, UK, Brazil, Italy, South Africa, Norway, Spain, Denmark, Russia and Canada), revealed that 76% of Hong Kong residents surveyed were concerned about climate change, which was considerably higher than the global average of 68% (106).

4.3.1 *Conclusions*

Hong Kong's residents are concerned about the impacts of climate change on the SAR, and this concern is increasing. Hong Kong however possesses significant adaptive capacity and has many systems in place which could be used to adapt to the physical impacts of climate change. It is however likely that some such policies may need to be up-scaled, or that the climatic thresholds which trigger other policies may need to be made more conservative. Furthermore the resources allocated to the implementation of policies and measures to protect and respond to climatic events may need to be increased as a result of climate change.

5 METHODOLOGY USED TO DEVELOP RECOMMENDATIONS FOR HONG KONG

5.1 ESSENTIAL PRINCIPLES FOR HONG KONG'S ADAPTIVE RESPONSE

The IPCC notes that '*it is clear, that there is no simple comprehensive response to the adaptation question, and that the answers are often very place specific and very nuanced and are likely to become more so as research advances.* [107]' Despite this, there are some best practice principles which need to be considered by Hong Kong in the development of its response to the impacts of climate change.

Based upon international best practice, it is recommended that the central tenets of Hong Kong's climate change adaptation strategy should be five-fold:

1. Sustainable
2. Inclusive
3. Flexible and regularly revised
4. Pro-active
5. Based upon the precautionary principle

These principles are described in more detail in the paragraphs below.

5.1.1 *Sustainable*

Firstly, all adaptive responses to climate change should be sustainable and should not compound the problem of climate change by exacerbating GHG emissions. Preference should be given to measures that yield complimentary benefits such as mitigating further GHG emissions, biodiversity protection, cost savings, cleaner air, increased human health etc. Synergistic measures that offer both mitigatory and adaptive benefits should be prioritised, as should measures which offer no-regrets and win-win solutions. Furthermore in the light of IPCC conclusions [108] that locations already suffering from environmental degradation will be more vulnerable to the impacts of climate change, it is vital that Hong Kong acts to secure the ecosystem services of its natural environment and seeks to redress and remedy extant environmental degradation.

5.1.2 *Inclusive*

Adaptation must be inclusive and informed. A well adapted society requires individuals and businesses to take action to increase their adaptive capacity and reduce their vulnerability, alongside government effort. Education of the public including publication of reasonable worst case scenarios for climate change is essential to illicit lasting behaviour change. An effective adaptation strategy requires a consultative, multi-stakeholder approach able to incorporate and respond to the views of all sections of society.

Any official body tasked with driving adaptation to climate change in Hong Kong will require input and/or representation from the public, private and NGO sectors and should be directed by independent scientific advice. Consultation and education are essential components of the multi-sectoral competency building needed to address climate change in Hong Kong.

5.1.3 *Flexible*

Incorporating flexibility and making use of the latest available science is vital. Hong Kong's adaptation strategy needs to be based upon and regularly updated via the latest climate change science. Relying upon superseded data and climate change projections could result in maladaptation. Because of the considerable uncertainties within climate change science, and because some of the science used in any vulnerability assessment conducted at present is incomplete i.e. sea level rise projections, it is recommended that Hong Kong's adaptation strategy is viewed as a 'roadmap' that will be continually updated to reflect developments in technology, actions already undertaken and, perhaps most significantly; changes in climate change science and observed climate change impacts.

5.1.4 *Proactive*

Adaptation should start as soon as practicable and as the literature review has shown it has been underway for several years in some other world cities around the world. Hong Kong needs to build on its existing adaptive policies and measures to ensure climate change is being appropriately addressed in a timely manner. The *Stern Review* has shown that early action will bring clear economic benefits by anticipating potential damages and minimizing threats to ecosystems, human health, economic development, property and infrastructure. The C40 Cities Climate Leadership group has acknowledged that most previous measures to deal with global warming have consisted of efforts to reduce the emission of carbon dioxide and other greenhouse gases, but with the various impacts of global warming now emerging there is a growing understanding that *urgent* adaptation measures are also required to minimize damages (109).

It is acknowledged that sufficient knowledge on the likely timing of climate change impacts is important when setting adaptation priorities. However, the exact level of change to any climatic variable is uncertain due to unknowns in the science, and due to the fact that climate change is not a 'fixed' entity - future emissions will depend on global mitigation action taken over the next few decades and hence a range of possible 'futures' exists. This is particularly the case for the longer time frames for which uncertainties are larger. A solutions orientated scenario based approach (similar to that used in London's TE2100 project) is recommended to deal with the inevitable uncertainties and to ensure that scientific uncertainties do not result in a lack of action.

5.1.5 *Precautionary Principle*

The precautionary principle needs to be central to Hong Kong's climate change adaptation strategy. International best practice dictates that it is vital to consider worst-case scenario measures, even if uncertainties are high (cases where the costs or the magnitude of the impacts in such scenarios would be unacceptable). To ensure that the latest science is used to shape Hong Kong's adaptation at all stages, close relationships with independent academic experts from the climate science, insurance, medical and engineering communities will need to be developed and used to inform policy and decision makers.

5.2 *CHECKLIST FOR POLICY MAKERS*

The policy recommendations have been developed in accordance with general principles of international best practice observed in the literature and policy review, which have been summarized into the following road map / flow chart [110] recommended for policy makers to use in assessing responses to the impacts of climate change:

- Economic Efficiency: Will the initiative yield benefits substantially greater than if the resources were applied elsewhere?
- Flexibility: Is the strategy reasonable for the entire range of possible changes in temperatures, precipitation, and sea level?
- Urgency: Would the strategy be successful if implementation were delayed ten or twenty years?
- Low Cost: Does the strategy require minimal resources?
- Equity: Does the strategy unfairly benefit some at the expense of other regions, generations, or economic classes?
- Institutional feasibility: Is the strategy acceptable to the public? Can it be implemented with existing institutions under existing laws?
- Unique or Critical Resources: Would the strategy decrease the risk of losing unique environmental or cultural resources?
- Health and Safety: Would the proposed strategy increase or decrease the risk of disease or injury?
- Consistency: Does the policy support other national state, community, or private goals?

- Private v. Public Sector: Does the strategy minimize governmental interference with decisions best made by the private sector?

5.3 *PACE AND TIMESCALES FOR ADAPTATION ACTION*

Both temporal and spatial scales are very important in thinking about adaptation. Much adaptation takes place in relation to short-term climate variability; however this may cause maladaptation to longer-term climatic trends.

The IPCC notes that it might be expected that the slower the rate of climate change the more likely it is that adaptation will be successful. For example, even a major rise in sea level may be accommodated and adjusted to by human societies if it happens very slowly over many centuries (111). However, slow incremental change can still involve considerable costs and people are likely to be less motivated to take precautionary action against gradual change and are thus likely face additional costs without some more dramatic stimulus. *'Paradoxically, therefore the full array of human adaptation potential is not likely to be brought to bear when all the market, social, psychological, market and institutional barriers to adaptation (*to gradual change*) are taken into account (112)'*.

One of the most fundamental issues facing decision makers is whether to implement responses today or defer preparation until the impacts are better understood and more close at hand. The fact that global warming might eventually necessitate a particular action does not necessarily imply that the action should be taken today. On the other hand, the likelihood of global warming is sufficiently well-established, and the time it takes to develop a response sufficiently long, that deferring all preparation could lead us to overlook opportunities to inexpensively prepare today and which may have other benefits in the interim (113). The view that it would be unwise to prepare for climate change until its eventuality and consequences are firmly established has been largely discredited in the international literature.

If policy responses are delayed, Hong Kong may be forced into reactive ad hoc adaptation as a response to increasingly frequent crises and disasters, which will prove much more costly and damaging to Hong Kong's society and economy.

For impacts where there is enough confidence in the forecasts, or where alternative benefits 'win-wins' can be postulated i.e. improved public health; it is recommended that adaptation must therefore start now. Furthermore competitive advantages could be gained for local companies if they choose to lead in adaptation strategies and technologies.

The IPCC notes (114) that '*a harmful impact is more likely to be considered 'key' by policy makers if it is expected to happen soon rather than in the distant future*'. In the international literature the disintegration of the Greenland and West Antarctic ice sheets are often cited as examples of key impacts and delayed irreversibility. It has been proposed that melting of ice shelves in the next 100 to 200 years may lead to gradual but irreversible deglaciation and a large sea level rise over a much longer time scale (in the order of 7 metres [115]), which is a timescale usually beyond that considered by policy makers, however adapting to lower, more short term estimates of sea level rise is likely to require significant reinvestment in the future as the ice shelves continue to melt. Debates over an appropriate rate of time preference for such events i.e. discounting, are widespread in the integrated assessment literature (*ibid*). The IPCC notes that '*major geophysical changes (*such as multi-metre sea level rise*) leave little room for human-managed adaptation. Fortunately these changes are likely to unfold relatively slowly, thus allowing more time for adaptation to their eventual impacts*. [116]' The UK Institution of Mechanical Engineers has recently published their professional opinion how infrastructural development should best be tackled within a framework of uncertain science [117] which points toward considering long term impacts (i.e. several hundred years) for impacts such as sea level rise rather than short term perspectives which will require revision and which could lead to the construction of significant maladaptation. It is therefore recommended that an adaptation strategy is adopted early with regular revisions as the science develops.

5.3.1 *Classifying Adaptive Reponses by Temporal Scales*

Knowing when to respond to climate change is as important and problematic as knowing the scale of the response needed. There are no definitive answers onto the 'timing' of specific climate change impacts and this means that flexible solutions will be needed to cope with this inherent uncertainty. Recommendations on the temporal scale of potential responses also consider the four-fold categorization identified by Titus [118]: i.e.:

1. No action today solutions – where least-cost quick-implementation solutions can be implemented as the problem emerges with existing technology and institutions;

2. Anticipatory actions – where it would be wise to take concrete measures today despite the scientific uncertainty;

3. Planning – where decision makers do not need to physically change what they are doing immediately, but where we need to change the legislative, fiscal, institutional or policy framework now so that people can respond to new information and priorities in a way that furthers social goals;

4. Research and education – actions which should begin now i.e. where it could potentially take decades to develop solutions and train people to carry them out, or where the need to take action has not been assessed sufficiently in the international or local literature.

Further information on the types of responses and actions which could be implemented under each of these categories are given in the following paragraphs below:

No Action Today

The urgency of responding to the impacts of climate change depends not only on the severity of a potential impact, but also the extent to which taking action today would diminish the ultimate cost of adaptation or allow us to avoid problems which will be unavoidable if policymakers wait before taking action. If the solution to a particular impact is well defined, based upon readily available extant technology and can be implemented quickly, there is little reason to take action decades in advance of the solution being needed. Examples of such a strategy would be changing the schedule for lowering reservoir water levels during flood periods to reflect future rainfall trends, farmers changing crops to other crops or varieties (already in existence) that reflect new climatic norms – both of which could be done relatively quickly but there is no need to do them today in advance of these impacts occurring. However before assigning any actions to this category it is important that all consequences of the impact on the system are understood, and that broader consequences and thresholds are appreciated. Therefore assigning potential adaptation responses to the 'no action today' category should be considered only after all eventualities have been considered, and any actions assigned to this category need to be reviewed regularly.

Anticipatory Action

There are a number of studies in the literature which identify adaptive responses that are appropriate to be undertaken today by either incorporating climate change projections into long term projects that are already underway, or by taking actions today that without climate change might not be necessary until later, if at all [(119)].

Incorporating climate change projections into projects with long time horizons or asset lifespans is one area of pressing concern for engineers and designers around the world. The rationale for designing according to the projections is that the outcome of projects initiated today may be altered by climate change, and that designing for the current climate and climatic extremes is not appropriate for assets which have long lifespans and will have to function in the future climate. Modifying plans to consider climate change is viewed by many experts to be an 'easy win' solution despite the considerable uncertainty regarding climate change projections as the cost of factoring climate change will often be a small percentage of total project costs, and by doing so would mean that the project would be better able to cope with present day extreme conditions, even if the projected warming does not materialise as expected. It is recommended that where there are major infrastructure projects currently at the planning stages in Hong Kong, that reasonable worst case scenario climate change impact projections are considered for the late stages of the projects useful life, and that these should be used to inform the design standards, as once the project is under construction or completed, it is usually more difficult and expensive to retrofit adaptive capacity.

For example, Titus *et al* (1987) examined the replacement of drainage systems in Charleston, South Carolina, and found that if they designed for the current 5-year storm, such a system might be insufficient to cope with sea level rise of one foot (0.30m) or if the severity of such a storm were to increase by 10%, necessitating a completely new system long before the end of the project's useful life. It was found that installing slightly larger pipes sufficient to accommodate climate change projections would only add an additional 5% to the original build costs. In such a case, designing for increases in precipitation might prove to be worthwhile if these changes occur and even if they do not, there would be some benefits because the system would provide protection during 10-year storm events. Similar situations are acknowledged by the study authors to exist around the world, and it is logical that many examples may exist in Hong Kong. It is our recommendation that when costing future projects with a lifespan of over 20-30 years that design specifications are drawn up both with and without adaptation to climate change projections, and that it is inherent on the project team to build to the adaptive design unless it is proven via conservative analysis that it is cheaper to adapt such designs in the future to climate change, than to build in adaptive capacity now. There needs to be a culture shift in planning and engineering toward the implicit assumption that climate adaptation is an essential part of business as usual design, as recommended by the UK's Institution of Mechanical Engineers and other professional bodies around the world.

Additionally, where the Government may be contemplating public works for which the economic justification is marginal, the prospect of sea level rise or climate change may convince decision makers to proceed. Constructing a project because of climate change will rarely be an 'easy' process as it requires a greater level of certainty than incorporating climate change into a project that would be undertaken anyway. Until recently the consensus has been that even if future impacts are certain, action on climate change is unnecessary unless the time it will take for the impacts to occur is no greater than the time it will take to design, approve and build the project. Thus only near term impacts and those whose solutions may take several decades to implement were deemed necessary of requiring remedial action today. However recent additions to the scientific literature raising the risk of non-linear warming and 'tipping points' suggest that our ability to project 'when' impacts may occur is less robust than previously assumed and that as a result where the decision has been only marginally toward the opinion that it is 'safe' to delay adaptive action, then it may instead be wise to err on the side of caution and include climate change adaptation. For example, in parts of the United States where it is projected that the climate may become drier, but where regional forecasts contain significant uncertainties and water resource managers are not yet sure that they will need more dams and reservoirs, in many instances the view has been taken that it would be wisest to purchase the necessary land today, otherwise the most suitable sites may be developed, making future construction more expensive and perhaps infeasible. Examples of this situation include Tocks Island National Park on the Delaware River.

Planning

Because of the future focussed nature of the profession, planners have to deal with significant uncertainty. Thus defining the legislative and policy framework i.e. how to respond to particular events should they occur – is often as important as taking concrete action. Although taking concrete action today in response to the impacts of climate change is necessary today for only a few types of problems – defining the rules of the game is needed to provide solutions for a much wider class of problems. Doing so increases flexibility, if the climate changes, Hong Kong will be better prepared, if it does not or changes in a manner different to the current projections, then preparation has not cost any significant capital outlay. Political feasibility for designing the framework for new future policy responses may be enhanced because it is easier to reach consensus when no one is immediately threatened. Moreover such planning reduces the risk to investors for although they continue to face uncertainty due to the uncertainty surrounding the degree of future climate change, planning can prevent that uncertainty from being compounded with additional uncertainty regarding how the Government may respond.

Research and Education

The fact that a particular problem may not require solutions for a few decades does not necessarily mean that society should not begin preparing today. For climate change, whilst the necessary solutions for some issues are available now, the need to implement others is decades away, for many others, very little work has been undertaken to systematically examine the costs and benefits. Investment in research and education is an essential element of adaptation which can commence today even if expenditure on immediate physical measures cannot be financially justified, or undertaken due to a lack of knowledge. The value of research into climate change adaptation is potentially the savings that it could make. Education is another critical component of adaptation for the medium and long term which can commence now without risk of maladaptation. Education is important for a number of reasons; there will be an increased need for personnel in some professions (i.e. hydrologists, coastal engineers etc), people in other professions will need to routinely consider the implications of climate change and it will take time to develop this familiarity, and an informed citizenry will be needed for the public expenditures and institutional changes that may be required.

5.3.2 Classifying Adaptive Responses by Function

Because the temporal scales of adapting to climate change contain significant uncertainties adaptation options will be prioritized under criteria which are based upon the methodology used by the draft adaptation strategy for London [120] and which is itself based upon the UK climate impact programme's range of methodological tools.

1. Prevention: actions which can reduce the probability of an impact occurring;

2. Preparation: actions taken to better understand the risk and develop an effective response;

3. Response: damage limitation actions taken in response to an event to reduce the consequences

4. Recovery: actions taken after an event to enable a return to normal, or a state of greater resilience than before the event

It is recommended that Category 1 'Prevention' actions should be the focus of a resilient adaptation response. However actions under all 4 headings will be needed in Hong Kong, as in any location seeking to increase their adaptive capacity. Category 4 'Recovery' actions should be considered ideally, after all other actions have been exhausted as it would be hoped that having to recover could be avoided by preventing an impact in the first place. However, not all impacts will be preventable, and not all impacts can be adapted to. Responses under each of the adaptation headings need to be developed in a synchronised manner, so that worst case scenarios can be averted where possible in the first instance, and responded to adequately should they occur. Additionally some events cannot be prevented and for these instances, effective response and recovery plans are the only adequate form of adaptation.

It can be seen that these criteria cover all three of the adaptation cornerstones identified by the IPCC by firstly reducing exposure, secondly reducing sensitivity and thirdly building intrinsic adaptive capacity by raising population wellbeing and education or designing insurance schemes.

5.3.3 Classifying Adaptive Responses by Location

Some geographical locations are more vulnerable than others to particular climate change hazards. It is recommended that adaptation is focussed initially at these locations [121].

Table 5.1 Most Vulnerable Locations by Impact

Impact	Particularly Vulnerable Locations
Rise in average temperatures (and increased risk of heatwaves)	Regions where average temperatures are already high Urban Centres where the UHI effect will exacerbate high temperatures Dwellings without access to, or unable to afford artificial cooling
Sea level rise, coastal flooding, storm surge	Coastal zones and islands Offshore locations
Drought, wildfire, subsidence	Locations where current demand for water almost matches / outstrips supply Locations where water quality is poor Regions prone to wildfire Subsidence prone soils
Increased seasonal precipitation and flooding	Regions with high rainfall Deltas, river floodplains, estuaries, low lying areas Mountainous and hilly areas Locations prone to landslips Urban areas where drainage is already challenged Contaminated environments (land or water)

Impact	Particularly Vulnerable Locations
	Densely populated areas
Possible increased storm intensity or frequency	Areas at risk of tropical and extra tropical storms Densely populated areas Areas where construction standards are poor
Human health	Areas with endemic / borderline endemic diseases that are influenced by climatic conditions Populations with reduced access to healthcare (due to financial, language, cultural constraints)

Source: London Accord, 2009

6 *CLIMATE CHANGE ADAPTATION OPTIONS FOR HONG KONG*

6.1 *INTRODUCTION*

A review of overseas approaches and existing institutions in Hong Kong suggests the need for the following government framework for adapting to climatic change:

- Sectoral-level actions in specific areas where Hong Kong is most vulnerable.
- Cross-sectoral activities such as research activities to inform government decision making and activities to raise awareness of Hong Kong's vulnerabilities to climatic change as well as possible adaptation actions to address them.
- Cross-departmental bodies to monitor and co-ordinate government action to ensure consistency across government decision-making.

The following sections highlights adaptation options that the Hong Kong SAR Government could take to address the identified "key" vulnerabilities, as well as to improve understandings of the science of the climate system, the impacts of climate change on society and possible responses to climate change. It should be noted that the options presented in this Report are based upon current understanding of climate change and will need to be periodically reviewed and updated as the science evolves. IPCC is preparing its AR5 due for publication in 2015. More detailed analysis on the possible impacts of climate change on different sectors would then be available and hence new or updated adaptation strategies should be developed based on the updated findings.

Implementation of proposed adaptation options is likely to lead to additional compliance costs on both the Government and the trades concerned. Hence, it is recommended that the Government should duly evaluate the implications, feasibility and costs and benefits of various measures before taking the matter forward. The methodology in assessing the economic aspects of the proposed adaptation options and its limitations are discussed in *Section 10*.

6.2 *SECTORAL CLIMATE CHANGE ADAPTATION OPTIONS*

This section presents some of the climate change adaptation options that aim to address key sectoral vulnerabilities in Hong Kong, as identified in the vulnerability assessment in *Section 2.6*, for the Hong Kong SAR Government to consider.

Table 6.1 Climate Change Adaptation Options for Biodiversity and Nature Conservation

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Research & Investigation							
BIO-R1	Establish priorities	Species / habitats / ecosystems most at risk	Due to resource limitations, priority species and habitats need to be established for more immediate actions. Priorities may include, but are not limited to: • Currently rare / threatened / endangered species • Species and ecological communities with narrow climatic ranges • Systems most sensitive to changes in climate or climate-driven processes • Habitats that have known concentrations of high biodiversity • Species that are endemic and of ecological significance; and, • Potential species extirpation and extinction under future climate.	• Develop methods and ecological criteria for identifying and mapping species and ecosystems at greatest risk from climate change. • Identify key indicator (climate-sensitive) species (including non-native / invasive species), populations and communities, and ecosystems (e.g. those in Montane habitats) that are particularly sensitive to changes in climate and the associated effects to track climate impacts in terrestrial, freshwater and marine ecosystems (e.g. changes in occurrence, distribution and health of these indicators). • Identify and determine actions to address most important gaps in the local knowledge and data (e.g. for the marine environment and on seasonality) that limit the ability of decision making.	Prepare	• AFCD • Academia • NGOs	Short Term[1]
BIO-R2	Research effects on non-native / invasive species	Non-native / invasive species	Non-native / invasive species could change in distribution and abundance as climate changes. Consequently, their risk on Hong Kong's biodiversity may also be altered.	• Research the effects (e.g. changes in distribution and abundance) of key invasive species / non-native species (*Option BIO-R1 - Establish priorities*) that may become invasive as climate changes, and pathways in which these species may affect local biodiversity.	Prepare	• AFCD • Academia	Short Term
Monitoring							
BIO-M1	Periodically review and revise monitoring	Incomplete knowledge of Hong Kong's	The establishment and maintenance of long term data sets (ie robust baseline and historical data sets) are essential for accurate monitoring, preventing loss of services, mitigating climate	• Review, and as necessary update, current biodiversity monitoring approaches to ensure they are adequate to track changes related to climatic changes.	Prepare	• AFCD • NGOs	Short Term

[1] Short term is generally now and/or within the next few years

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
	programmes	biodiversity	change impacts, as well as to underpin modelling and scenario work. Baseline assessments may include the extent of ecological services currently provided by natural ecosystems (eg, carbon sequestration, flood control, physical buffer, etc), existing threats and opportunities.	• As necessary, develop monitoring programmes for other areas of ecological importance or priorities (Option BIO-R1 – Establish priorities), such as SSSIs, conservation areas and montane habitats.	Prepare	• AFCD • NGOs	Medium / Long Term
BIO-M2	Surveillance for non-native species	Non-native / invasive species	Invasive species have gradual but persistent impacts upon biodiversity and ecosystems. There is evidence that climate change is already increasing the impact of alien invasive species on biodiversity overseas. Hong Kong's biodiversity is considered to be highly vulnerable to climate change. Invasive species may pose an increased threat to the local terrestrial, marine and freshwater biodiversity under future climate.	• Establish and/or adapt existing surveillance programs for the arrival of non-native species that may threaten to become invasive as climate changes by methods such as early identification, prevention and protection of areas.	Prepare	• AFCD	Short Term
				• As necessary, control any alien species that threaten to become invasive as a result of climate change at an early stage in their establishment or spread by methods such as direct removal or containment..	Respond	• AFCD	Medium / Long Term
				• As necessary, monitor the success of control programs for selected widespread invasive species.	Prepare	• AFCD	Medium / Long Term
Institutional Strengthening & Capacity Building							
BIO-I1	Incorporate climate change into existing management framework	Future climate and variability	Climate change may exacerbate many other stresses already affecting Hong Kong's natural systems. Maximising the resilience of local ecosystems to adapt by protecting them from other pressures is likely to protect valuable ecosystem services. Building on the policies and measures that are already in place for nature conservation could be the most cost-effective way to deal with climate change given the existing infrastructure, mandate and encapsulated knowledge to address the issues.	• Review all existing biodiversity strategies, policies, measures, programmes, plans, legislations and regulations to identify those that may be climate-sensitive.	Prevent, Prepare	• AFCD	Short Term
				• Where applicable, integrate climate change considerations into existing nature conservation programmes, policies and measure. For example, include priority species (*Option BIO-R1 - Establish priorities*) in existing protection ordinance(s).	Prevent, Prepare	• AFCD	Medium / Long Term
BIO-I2	Gather existing knowledge	Incomplete knowledge of Hong Kong's biodiversity	As the IPCC notes, climate change is likely to be observed first in natural systems. Hong Kong is disproportionally rich in biodiversity. However, there is an incomplete knowledge of the full extent of Hong Kong's biodiversity.	• Share, formalize and centralize data, information and knowledge of various institutions and groups across the SAR, and identify gaps and research needs.	Prepare	• AFCD • Academia • NGOs	Short Term

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			Natural resource and conservation planning, and other informed decisions, require an improved understanding of the potential climate impacts on local biodiversity. Various research groups have already carried, or are carrying, out impact studies on the local biodiversity.				

Table 6.2 Climate Change Adaptation Options for Built Environment and Infrastructure

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Research & Investigation							
BUE-R1	Identify at-risk infrastructure	Future climate and variability	Structures, assets, infrastructure that suffer from today's climate variability and extremes are likely to be more vulnerable to future climate impacts. Repairing or upgrading critical infrastructure that is already at risk (including roads, water systems and other infrastructure that are already worn or overcapacity) should be a priority. *Some Available Guidance and Tools:* • UKCIP tools (NB. These tools have been designed for UK organizations (eg the use of UKCP09 scenarios); they may be adjusted to the local situation, by using the Hong Kong climate change scenarios (*Option R1- Produce and Update Climate Change Scenarios*), for instance.): (i) UKCIP Adaptation Wizard: a good starting point for those who do not have a good understanding of climate change and their climate risks. (ii) UKCIP Risk, Uncertainty and Decision-	This option could be implemented in the following stages: *Stage 1: Identify critical infrastructure at risk.* • Identify critical infrastructure previously affected by weather events, e.g. damages, service interruption, performance loss etc. • Infrastructure may include transport (e.g. the airport, MTR), communications (e.g. telecommunications), drainage systems, sewer and wastewater treatment systems, slopes, coastal defence, energy (e.g. power plants, transmission infrastructure), water supply (e.g. reservoirs, water treatment works, water mains), human health (eg hospitals). • Identify causes and the pathway of damages, services interruptions, performance loss etc. *Stage 2: Assess current tolerances.* • Assess these infrastructure's current tolerances through sensitivity analysis to: - Identify and/or quantify critical thresholds and failure points of critical infrastructure - Examine the implications of a range of climate change scenarios (*Option R1- Produce and Update Climate Change*	Prepare	• Public sector • Private developers • Property managers • Public transport providers • Power companies	Short Term

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			Making Framework: those who have some knowledge of their climate risks but want to fully understand them and get a good understanding of the adaptation options. (iii) UKCIP guidance on Identifying adaptation options: used in parallel to the other UKCIP tools. • NYC Climate Change Task Force's forthcoming report on existing at-risk infrastructure: it may detail the methodology adopted for NYC, which could be tailored to the local situation for adoption by relevant stakeholders.	*Scenarios*) and reasonable worst case scenarios (*Option R1e*). *Stage 3: Compile information into a central risk register.* • Prioritise assets / infrastructure that have suffered from past weather events for upgrading, replacement or adaptation. Stage 4: Identify adaptation options. • Upon prioritisation of the components of each system: (i) Develop a range of potential adaptation options attempted or contemplated worldwide in consultation with a team of experts and stakeholders. (ii) Evaluate potential engineering solutions and technological applications in terms of their relative contribution towards achieving the desired outcome, the relative nature of associated risks, economic costs and benefits, technical feasibility, and their potential conflicts and synergies with other objectives (social, economic, legal, and related policies and regulations), as well as consideration of the implications of non-climatic factors, to determine their applicability to the possible impacted areas. (iii) Examine the cost-benefits-risks under a range of climate change scenarios (*Option R1- Produce and Update Climate Change Scenarios*) and extreme weather scenarios (*Option R1e - Reasonable Worst Case Scenarios*). • It may be necessary to engage a wide range of stakeholders from both the public and private sector that operate, maintain or regulate the critical infrastructure, as well as professional bodies such as engineers and architects. • Similar to NYC's approach, a Task force could be formed to coordinate this task and leverage resources from various areas.			
BUE-R2	Update flood risk maps	Flooding (from rivers, sea, surface water, and coastal	DSD's current flooding blackspots list and location maps are produced based on historic flooding records and complaints received. At present, they do not provide any information on potentially new and	• Based on *Option R1 (Produce and Update Climate Change Scenarios)*, produce and regularly update flood risk / warning maps that cover flood risk from different sources e.g. rivers, sea, surface water, coastal erosion etc. • Identify appropriate means of making such	Prepare	• DSD	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
		erosion etc)	changes in flood risks arising from climate change. Implications of making of such maps publicly available need to be considered.	information publicly available - implications of this option may include that some properties or areas at-risk could become potentially uninsurable or experience a significant drop in asset value, which would need to be further discussed and examined with the industry and stakeholders.			
Institutional Strengthening & Capacity Building							
BUE-I1	Develop climate risk screening tool	Future climate and variability	The World Bank has developed ADAPT (Assessment and Design for Adaptation to Climate Change: a Prototype Tool), a computer-based tool to screen proposed development projects for potential risks posed by climate change and variability. The tool is meant for use by development practitioners, including bank staff, bilateral agencies, the NGO community and client governments. This tool involves: (1) identification of project activities and location; (2) consultation of a climate database; and (3) a climate risk assessment based on expert assessment. It may be cheaper to cost in adaptation options at the design stage than to attempt to retrofit it in the future. Such a tool could be used for screening new plans for developments (in particular, coastal developments) currently in the design stage to avoid mal-adaptation.	• Similar to the World Bank's ADAPT tool, develop a screening process to mainstream climate due diligence into developments in a manner that is easy to use for non-technical staff. Such a tool could be integrated with existing planning procedures, e.g. sustainability assessments or EIAO. (i) In its simplest form, the tool needs not be quantitative but rather an iterative screening tool to flag up issues of concern where a project's future viability may be in doubt or where adaptive action needs to be considered. (ii) A transparent decision making process is needed. (iii) Formal guidance on decisions as to whether to "over-engineer" if relying on worst case scenario projections or "under-engineer and rely upon retrofitting" if relying on current international consensus science, depending on the appetite for risk. • Resilience to particular climatic hazard(s) (eg future sea levels) could be a required criterion for Government support or funding of local and private coastal projects.	Prevent, Prepare	Development of this screening tool is a new area and the parties responsible for it will be determined by the Government.	Short Term
BUE-I2	Periodically review construction-related codes / guidelines / design standards against climate	Future climate and variability, extreme weather conditions	As buildings and infrastructure typically have long asset lives, longer term conditions (ie those in mid and latter half of this century) should not be disregarded in strategic planning. Existing construction-related codes and design standards for buildings and infrastructure (in particular, drainage and sewerage systems, transport infrastructure, flood protection standards)	Using information from *Option BUE-R1* (*Identify at-risk infrastructure*), this option could be implemented in the following stages: *Stage 1: High level overview* • Evaluate the effectiveness of existing codes and design standards in past weather, in particular extreme events; identify any causes of failure. • Identify those technical areas and particular standards	Prepare	• ArcSD • BD • CEDD • DSD • HD • HyD • LandsD • PlanD • TD	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
	change scenarios		may have been designed based on historical trends, which may no longer represent future conditions. Hence, adjustments may be needed to ensure their effectiveness under future climate. Elements to be examined may include, but are not limited to, the elevation of buildings, building envelope performance, foundation design, long-duration flood impacts, effluent discharge standards, debris impact, design of transport infrastructure under high / extreme temperatures (e.g. distortion of soldered rails and track buckling for rails), design of future public projects, impacts on abandoned facilities and contaminated land. To deal with scientific uncertainties, the planning stage of any development at risk from future climate change could consider (1) resilient strategies (i.e. one that seeks to identify approaches that will work reasonably well across a range of future circumstances that have been identified); and, (2) adaptive strategies (i.e. those that can be adjusted as new information becomes available).	where a revision of the codes / standards / guidelines may be necessary. *Stage 2: Identify possible changes to design standards in particular areas* • Conduct sensitivity analysis on the capability of existing systems (e.g. hydraulic capacity of effluent discharge systems, stormwater drainage, wastewater flow rates and wastewater treatment facilities) for a range of climate change scenarios (*Option R1- Produce and Update Climate Change Scenarios*), identify critical threshold values and failure points of existing infrastructure triggering the need for management action. • Assess the cost-benefits-risks of these possible changes, including under reasonable worst case scenarios (*Option R1e - Reasonable Worst Case Scenarios*) that account for future climate. • A number of assignments could be carried out on different subject areas covered under different standards / guidelines (e.g. DSD Storm Drainage Manual, Port Works Manual). *Stage 3: Provide recommendations for updating of specific standards / codes / guidelines* • Obtain independent review and carry out industry consultation. • There would be scope for some packaging together of a number of standards / codes / guidelines that cover similar or overlapping subject areas.			
BUE-I3	Regularly update the Hong Kong Urban Climatic Map	Urban heat island (UHI) effect	The UHI effect is found in Hong Kong. In 2006, PlanD commissioned a feasibility study on *Urban Climatic Map and Standards for Wind Environment*, which included the production of an Urban Climatic Map. This Urban Climatic Map can serve as a baseline and maps Hong Kong's UHI effect under present day conditions. This map could be used to monitor the changes in Hong Kong's UHI effect in the coming decades.	• Review / update this Urban Climatic Map regularly, say every four to five years. • Using the information provided by the Urban Climatic Map and other environmental monitoring data, review the *Hong Kong Planning Standards and Guidelines* regularly and update as necessary. • Using the Urban Climatic Map to identify "hotspots", and hence priority action areas. New developments within these areas could be encouraged to contribute to offsetting the UHI effect.	Prepare	• PlanD • EPD • HKO	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
BUE-I4	Develop flood risk strategies	Flooding	Heavy rain events are not uncommon in Hong Kong especially in the summer months; sea level rise could pose additional flooding threat. Hong Kong has substantial developments in low lying areas, at or near the coastline. Future sea levels should not be omitted in any sustainable development and coastal flood risk should be considered alongside other spatial planning issues. The frequency, patterns and severity of flooding (from the sea and other sources) may change and become more damaging as climate changes. In order to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas of highest risk, flood risk should therefore be accounted for at all stages in the planning process. *Some Available Guidance:* • England's Planning Policy Statement 25: Development and Flood Risk (PPS25) (2006): sets out Government policy on development and flood risk. • Defra's Appraisal of flood and coastal erosion risk management: A Defra policy statement (June 2009): guidance for operating authorities and others in England on decision making on the sustainable management of flood and coastal erosion risk. • Defra's SD3: Risk Management Guidance (forthcoming): this project aims to develop broader risk management tools and, after wide consultation, publish a new set of policy statements covering all levels of appraisal.	• Develop strategies to address flood risk from sea, rivers and land (i.e. surface run-off), overwhelmed sewers and drainage systems associated with climate change, which could include the following elements: (i) Appraise risk - identify land at risk (e.g. coastal zones, low-lying areas) and the degree of risk of flooding from different sources in their areas; prepare flood risk appraisals / assessments; (ii) Manage risk – frame policies to avoid development in areas of flood risk and identify parties to manage any residual risk; and, (iii) Reduce risk - reduce the causes and impacts of flooding. (iv) Adopt a partnership approach – to ensure that plans are effective and decisions on planning applications can be delivered expeditiously.	Prepare	• PlanD • DSD	Short Term
BUE-I5	Develop a strategy to	Slope stability	The GEO's studies indicate that the effects of climate change will have significant	(i) Understand the impacts of climate change and identify relevant major geohazards	Prepare	GEO, CEDD, HKO	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
	manage challenges of climate change and major geohazards		implications on slope safety. However, the current understanding in the relevant technical issues (e.g. relevant climate change scenarios, scale and extent of relevant geohazards and their potential impacts, etc.) is limited. There is a need to develop a plan to improve understanding of the impacts of climate change on slope safety and develop strategies/measures to manage the risk arising from major geohazards identified.	(ii) Develop strategies and measures for managing the risk arising from the major geohazards (iii) Promote sustainable construction practices in geotechnical works.			
Education & Public Awareness							
BUE-E1	Promote green roofs	Urban heat island (UHI) effect	Green roofs and green walls can reduce summer overheating and reduce the need for artificial cooling and heating in the summer and winter, respectively. The technology of green roofs is relatively well established. ArchSD commissioned a study to examine the application of green roof in Hong Kong, which was completed in 2007. In addition to economic benefits, green roofs have environmental, and amenity and aesthetic benefits as outlined in the study. The recommendations of this study could be actively taken forward and need not be repeated here.	• Actively promote, and encourage the adoption of, green roofs to the private sector such as private developers and property managers: (i) Emphasise the longer term benefits (e.g. the environmental and economic benefits). (ii) Educate developers and property managers on maintenance issues to ensure that green roofs continue to be effective. (iii) Consider the associated safety risks during high winds, tropical cyclones, other extreme weather conditions etc. • Maximise green roofs opportunities in newer urban areas, and also in urban renewal projects. • Provide incentives for retro-fitting green roofs on existing roofs, and/or consider statutory mandate for green roofs on new buildings or renewal projects, including residential and commercial buildings, and both public and private developments. • Examine the application and effectiveness of green walls (e.g. the use of climbers on walls), covering issues such as structural issues and horticultural research on the viability of different species.	Prevent	• ArchSD • BD • EMSD • HD • PlanD	Ongoing
BUE-E2	Promote cool roofs	Urban heat island (UHI) effect	"Cool roofs" have a coating of light coloured water sealant to limit the absorption of solar energy and damage from daily temperature fluctuations. Similar to green roofs (*Option BUE-4*), cool roofs can also facilitate	• Promote cool roofs where green roofs are not suitable. • Adopt cool roofs for government buildings where green roofs are technically not feasible. • Collate data for assessing the effectiveness of cool roofs and analysing the costs and benefits, eg regular	Prevent	• ArchSD • BD • EMSD • HD • PlanD	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			mitigation whilst enhancing adaptive capacity at relatively little cost to stakeholders. It should be noted that: • If appropriate to the location, green roofs should be the preferred option because of the multiple benefits they provide, such as improving air quality, alleviating urban flooding. • Cool roofs require less capital investment and could be considered for lower rise, older premises which may not, for structural or financial reasons, be able to consider a green roof. • It has been found that the disadvantages of a cool roof in winter may offset the advantages in the summer in very cold climates (eg Minneapolis) and climates in which the summers are cloudy and cool (eg Seattle). However, the benefits in summer generally outweigh the winter penalty in sunbelt cities like LA and Phoenix. In the sub-tropical climate of Hong Kong, cool roofs would certainly be advantageous.	monitoring cool roofs to track the progress and their effectiveness. • Consider adopting London TFL (Transport for London)'s approach to minimise cooling needs in public transport by requiring all new vehicles entering service to have heat reflective white painted roof panels, and vehicles that are in service to be refurbished (which include painting roof panels white).		• TD	

Table 6.3 Climate Change Adaptation Options for Business and Industry

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Institutional Strengthening & Capacity Building							
BUS-I1	Develop Hong Kong business assessment tool on climate change impacts	Business risks and/or opportunities	The Business Areas Climate Impacts Assessment Tool (BACLIAT), developed by UKCIP, is used to assess the potential impacts of climate change (both risks and opportunities), either on business or on an entire business sector. BACLIAT encourages a comprehensive assessment, by inviting consideration of the opportunities as well as the threats from a changing climate, under the headings: Markets; Finance; Logistics; Premises; People; and, Process.	• Consider developing a Hong Kong business assessment tool on climate change impacts. Reference could be made to a similar tool, BACLIAT, developed in the UK for their business climate impacts assessment	Prepare	• EPD • HKO	Short Term
Disaster Management & Emergency Planning							
BUS-E1	Mandate business continuity planning for essential operations	Business / operation disruptions	It is essential to ensure continuity of critical functions in the event of a disruption, and effective recovery afterwards.	• If future scenarios are severe, then consider the possibility to mandate BCM for certain essential operations, such as frontline responders, emergency services, etc.	Prepare	• FSB	Medium / Long Term
Education & Public Awareness							
BUS-P1	Promote business climate impact assessment	Business risks and/or opportunities	To assist the private sector and other organizations recognize the potential threats and opportunities presented by climate change.	• Engage with stakeholders to raise awareness and initiate discussion about climate change adaptation risks to business and markets. • Actively promote the Hong Kong business assessment tool on climate change impacts to organisations that operate in Hong Kong and encourage the use of the Hong Kong business assessment tool on climate change impacts checklist (Ref *Option BUS-I1)*	Prepare	• EPD • HKO	Short Term
BUS-P2	Encourage business continuity planning	Business / operation disruptions	Organisations needs to recover and restore operations quickly in the event of a disaster or extended disruption. It is therefore important to identify in advance the risks and actions to be taken after an event to enable a rapid return to normal.	• Actively promote BCM to commercial and voluntary organizations in Hong Kong, and encourage businesses to improve their Business Continuity Management in respect of climate risks (*Option R1- Produce and Update Climate Change*	Prepare	• EABFU • FSB	Short Term

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			In order to be successful, Business Continuity Management (BCM) must be regarded as an integral part of an organisation's normal ongoing management processes.	*Scenarios*).			

Table 6.4 Climate Change Adaptation Options for Energy Supply

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Monitoring							
EGY-M1	Monitor for changes in energy demand and supply patterns	Changing energy demand and supply patterns	The production, and use, of energy are sensitive to changes in the climate, although the effects of climate change on energy supply and demand will also depend on patterns of economic growth, land use, population growth and distribution, technological change and social and cultural trends that shape individual and institutional actions.	• Monitor for any changes in energy demand/supply patterns (in particular for those associated with climatic events), including peak energy demand/supply, gradual and seasonality changes etc, and identify the causes for these changes.	Prepare	• EMSD • ENB • Power Companies	Ongoing
Institutional Strengthening & Capacity Building							
EGY-I1	Periodically review likely changes in energy demand and supply patterns	Changing energy demand and supply patterns	As mentioned in *EGY-M1* (*Monitor for changes in energy demand and supply patterns*), climate change will have an influence on the production, and use, of energy.	• Consider the latest available climate change scenarios (*Option R1- Produce and Update Climate Change Scenarios*) and the associated impacts during its regular review and forecasts of energy demand and supply.	Prepare	• EMSD • ENB • Power Companies	Ongoing
EGY-I2	Diversify fuel sources and fuel suppliers	Energy security	Hong Kong has no indigenous fuel sources and imports all its main sources of fuel, thus it may be impacted by climatic disruption further up the supply chain and beyond the host country's control. Any interruption to the supply of power due to a shortage of fuel supplies, or impacts along the transportation route or on the supplier, could have significant implications.	• Encourage a diverse mix of different energy fuels and fuel suppliers.	Prevent	• ENB	Medium / Long Term
EGY-I3	Assess impacts along the energy supply chain	Impacts along the energy supply chain	As mentioned in Option *EGY-2* (*Diversify fuel sources and fuel suppliers*), Hong Kong is vulnerable to impacts and climatic disruptions further up its energy supply chain. It is necessary to improve our understanding on the risks and challenges along the supply chain, which would facilitate the identification of effective actions to minimise the occurrence of an impact.	• Encourage (or, at a later stage, mandate) power companies to report on how they assess and act on the climate risks and opportunities along the energy supply chain, including those at fuel sources and the route of importation.	Prepare	• EMSD • ENB • Power Companies	Short Term
Disaster Management & Emergency Planning							

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
EGY-E1	Energy supply contingency planning	Energy supply interruptions	Hongkong Electric and CLP emphasize their ability to prevent energy supply interruptions and quick response towards any interruptions. As any energy supply interruptions could have significant implications for the whole city, contingency planning that accounts for potential future climatic disruptions may be required.	• Encourage power companies to incorporate climate change related risks and challenges (eg future extreme weather scenarios, sea-level rise), both in Hong Kong (such as power generation, transmission and distribution) and along the supply chain (such as primary fuel imports and supply), in their risk assessments. This may involve: (1) Enhancing existing and identify new preventive measures to reduce the probability of an impact associated with climate change. (2) Assess the effectiveness of existing respond / recover actions under future climate scenarios (*Option R1- Produce and Update Climate Change Scenarios*); update and revise as necessary.	Prepare	• EMSD • ENB • Power Companies • SB	Ongoing

Table 6.5 Climate Change Adaptation Options for Financial Services

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Research & Investigation							
FIN-R1	Examine the potential for expanding the role of insurers in climate risk management	Climate risk management	There are uncertainties in climate change and the associated impacts, hence risks. Insurance exists to manage risk, and hence the insurance sector has a key role in climate risk assessment and loss control. Residential property insurers in California are required (under California Insurance Code (CIC) Section 10081) to offer earthquake coverage subject to the minimum dwelling and personal property requirements for the peril of earthquake and the offer must be accepted . This spreads the losses that could otherwise be faced by the property owners and/or occupants. In Hong Kong, building owners and owners' corporations are advised to purchase Property All-Risk Insurance in addition to the mandatory Third Party Risk Insurance; however all-risk insurance is not mandatory [(1)].	• If in the future, climate scenarios are especially severe, then explore the possibility of mandating infrastructure and assets located in hazard-prone areas and vulnerable assets.	Prevent	Examining the insurance coverage on climate risks located in hazard-prone areas is a new area and the parties responsible for it will be determined by the Government.	Medium / Long Term
				• Examine the legal implications of the insurance industry in dealing with climate risks and opportunities. In addition to some of the key questions in *Option FIN-1 – Examine the impacts on the insurance industry*, other questions may include: - How should the insurance industry, as major shareholders, use its influence to	Prevent, Prepare	• FSB	Ongoing

(1) California Department of Insurance (http://www.insurance.ca.gov/0100-consumers/0060-information-guides/0040-residential/earthquake-insurance.cfm) [Date accessed: 18 February 2009].

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
				help adapt to climate change? - How can the insurance industry encourage and reward good practices by policyholders and developers? - Should the insurance industry invest in communicating the impacts of climate change and the role of insurance to the public? - Should the insurance industry be advising policyholders now of potential uninsurable zones in the future? - Should the insurance industry be working with mortgage lenders to identify potential high-risk areas? - Should the insurance industry pay for climate research and have closer contact with academics in relevant fields?			
FIN-R2	Examine legal roles of insurance industry and regulators	Business risks and/or opportunities	Insurers are acknowledged as a major source of advice on risk. As mentioned in the Business and Industry sector (*Table 9.3*), decisions made by insurers that do not consider climate change may be open to future legal challenge (*BUS-2 – Examine legal roles of professional advisers and regulators*).	• Examine the legal responsibilities of the insurance industry and regulators that consider and advise on the relative climate risks and opportunities. Some key questions to consider in consultation with the insurance industry may include: - Should the industry invest in communicating the impacts of climate change and the role of insurance to the public? - Should the insurance industry be advising policyholders now of potential uninsurable zones in the future? - Should the insurance industry be working with mortgage lenders to identify potential high-risk areas?	Prepare	Examining the legal responsibilities of the insurance industry is a new area and the parties responsible for it will be determined by the Government.	Short Term

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Institutional Strengthening & Capacity Building							
FIN-I1	Climate Risk Disclosure (Insurance Industry)	Business risks and/or opportunities	Regulators would be concerned about how the financial health of the insurance sector, the availability and affordability of insurance for consumers would be impacted. Standardised disclosure of climate risk would provide regulators the information they need to better understand the risks the industry faces. *Some Available Guidance:* • Ceres's *Global Framework for Climate Risk Disclosure: A statement of investor expectations for comprehensive corporate disclosure* (2006): a new statement on disclosure that investors expect from companies.	• Encourage companies to disclose to regulators/investors the financial risks from climate change, and actions being taken to respond to those risks.	Prepare	• FSB	Medium / Long Term
Education & Public Awareness							
FIN-P1	Examine the implications on the insurance industry	Impacts on the insurance industry	Climate change can affect every aspect of insurance, including both sides of the insurance industry's balance sheets. While the insurance industry can develop new risk transfer mechanisms and loss-prevention products and services, US insurers, for instance, have experienced growth in weather-related catastrophe losses from around US$1 billion (1970s) to US$17 billion per year (past decade).	• Engage with, and encourage, the local insurance industry to consider risks and opportunities associated with climate change through awareness raising.	Prepare	• FSB	Short Term
FIN-P2	Examine the implications on the banking industry	Impacts on the banking industry	The banking industry has substantial economic significance in Hong Kong and provides the hub between all other financial sectors. It provides a wide range of financial services (eg lending, structured finance, leasing, asset management, equity investments and savings), which could be directly or indirectly impacted by climate change. The market value of some properties of certain	• Engage with, and encourage, the local banking industry to consider risks and opportunities associated with climate change through awareness raising. • Implications and issues arising from climate change may need to be discussed in consultation with the banking industry. Some key questions may include:	Prepare	• FSB	Short Term

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			designs or in certain locations may decline significantly should they become uninsurable in future climate (eg increased flooding risk may lead to potential buyers unable to raise a mortgage). Climate change impacts may negatively affect the future revenue stream of businesses, and hence their ability to secure or repay a loan. Opportunities may arise as alternative risk transfer products (eg catastrophe bonds) become more popular. It is therefore important that banks and their shareholders are aware of the climate risks and opportunities and the associated implications on their core lending and saving books.	- To what extent are future scenarios related to climate change considered in credit assessment and lending portfolio planning by the banking industry? - To what extent are climate change impacts relative to different geographical areas considered by the banking industry when determining lending and equity portfolio policies? - To what extent do banks require borrowers to demonstrate that they have identified and incorporated climate change impacts on their business model, including value chains?			
BUS-P1	Promote business climate impact assessment	Business risks and/or opportunities	Similar to the Business and Industry sector (*Table 9.3*), financial organizations may be encouraged to use Hong Kong business assessment tool on climate change impacts to assess the potential impacts (both risks and opportunities) of climate change.				
BUS-P2	Encourage business continuity planning	Business / operation disruptions	As mentioned in the Business and Industry sector (*Table 9.3*), BCM could be used to help financial organizations to recover or restore partially or completely from interruptions.				

Table 6.6 Climate Change Adaptation Options for Food Resources

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Research & Investigation							
FOD-R1	Examine the effects on local live poultry production and live pig husbandry	Impacts on local live poultry production and live pig husbandry	Local agricultural production has a potential role in reducing Hong Kong's reliance on food imports and the associated vulnerabilities along the food supply chain. Local live poultry production and live pig husbandry satisfies almost 40% and 10% of local demands, respectively.	• Examine the direct (e.g. extreme weather events) and indirect (e.g. costs and availability of livestock feed grains) impacts on local live poultry production and live pig husbandry.	Prepare	• AFCD • Academia • Local agricultural sector	Short Term
FOD-R2	Examine the impacts on food supply chain and food hazards	Resilience of local food supply chain	Hong Kong's food supply is dependent on a sophisticated and complex chain and infrastructure, in particular energy in its various forms. The food system may be prone to interruptions in energy supplies used for agriculture, food processing and refrigeration, food transport and in food retailing. Also, food hazards, including those from biological, chemical and physical agents, will have impacts to the human health and food supply in Hong Kong.	• Identify and examine the risks and challenges along the food supply chain, including those arising from: (i) Just-in-time operations across the industry. (ii) Energy supply and reliability. (iii) Capability of switching ports / entry points in the event of disruptions. (iv) reduction of food supply and varieties due to food hazards.	Prepare	To be identified	Short Term
FOD-R3	Research effects on vulnerable groups	Distributional impacts	Similar to the Human Health sector (*Option HEA-R3 – Research effects on vulnerable groups*), climate change and its impacts (eg food price rises) are likely to disproportionately affect the low-income population and other vulnerable households, and their ability to eat well.	• Investigate the potential risks and challenges of food security facing the vulnerable population and households. • This could be a collaborative effort with community-level organisations and/or other NGOs.	Prepare	To be identified	Short Term
Monitoring							
FOD-M1	Monitor food prices	Household food security	Everyone should have the opportunity to access and afford a healthy diet. Some of the challenges in this area of Hong Kong's food security may include the effects of rising food prices on affordability, impacts of major shocks to food supply chains affecting the production, distribution and/or retailing of food. At present, only the daily fresh food supply and	• Monitor movements in prices of major food stuff (eg rice), and factors that could lead to fluctuations in prices.	Prepare	To be identified	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			wholesale prices of major fresh food are monitored by AFCD.				
FOD-M2	Monitor overseas agricultural impact studies	Impacts on Hong Kong's food trade partners	In 2008, major sources of food and beverages imports were China (19.0%; for poultry and pork, prepared or preserved meat), Brazil (11.4%; for poultry and pork, dried / salted /smoked fish), United States (12.8%; for poultry and pork, mollusks, nuts), Thailand (5.7%; for rice) and Australia (5.0%; for crustaceans, molluscs, milk and cream) [(1)]. Climate change impact studies are available for some of the key food trade partners (as follows). These studies and others provide an indication on the vulnerability of agricultural production at these regions, which may have implications on the food exported to Hong Kong. • China: e.g. the joint UK-China project on Impacts of Climate Change on Chinese Agriculture (ICCCA) • Brazil: yet to complete an impact study • US: e.g. US Climate Change Science Program [(2)], US Global Change Research Program [(3)] • Thailand: e.g. a study by Climate Institute, the Mekong Programme [(4)] (a Regional Cooperation Programme for the Sustainable Development of Water and Related Resources in the Mekong Basin owned by its member countries)	• Monitor climate change agricultural impact studies for Hong Kong's key food importers (such as their production capability in future climate) for new and updated data and information as they become available.	Prepare	To be identified	Ongoing

(1) Market Profile of Hong Kong's food and beverage industry by the New Zealand Trade and Enterprise (http://www.nzte.govt.nz/explore-export-markets/market-research-by-industry/Food-and-beverage/Documents/Market-Profile-Hong-Kong-Food-and-Beverage-April-2009.pdf)

(2) Synthesis and Assessment Product 4.3 (SAP 4.3): The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States (http://www.usda.gov/oce/global_change/sap_2007_FinalReport.htm)

(3) Global Climate Change Impacts in the United States (http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts)

(4) Climate Change in Thailand: Impacts and Adaptation Strategies (http://www.climate.org/topics/international-action/thailand.htm)

(5) Australia's Agriculture - Impacts of Climate Change (http://www.climatechange.gov.au/impacts/agriculture.html#research)

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			• Australia: e.g. Australia's Farming Future [(5)]				
Institutional Strengthening & Capacity Building							
FOD-I1	Allocate responsibility for security of food supply	Security of food supply	At present, a number of bodies are responsible for different issues related to food supply, security and safety; there is no one single agency responsible for food security in Hong Kong. Vulnerable groups (e.g. the poor) in Hong Kong could be most affected by climate change impacts.	• Allocate the responsibility for security of food supply to an agency, such as the Food Control Committee.	Prevent Prepare Respond Recover	To be identified	Short Term
FOD-I2	Develop food security indicators	Food supply, security and safety	Food security has many dimensions and may be assessed in relation to six themes: availability, access, affordability, nutrition, quality, safety and resilience. Due to the complex and cross-cutting nature of Hong Kong's food supply chain, themes / indicators could be developed (similar to the UK example) to provide insights into the range of issues underlying our food security and how they fit together. These also allow the short, medium and long term risks and challenges, and "what-if" scenarios to be examined. These themes and indicators should be kept under regular review, and should be revised or developed as necessary.	• Similar to the recent *UK Food Security Assessment* (2009) [(1)], develop indicators in the Hong Kong context for the following themes: (i) Hong Kong availability and access (ii) Hong Kong food chain resilience (iii) Household food security (iv) Safety and confidence • Monitor overseas findings (e.g. the UK Food Security Assessment (2009)) on food security in relation to: (i) Global availability (ii) Global resource sustainability	Prepare	To be identified	Ongoing
FOD-I3	Encourage / increase domestic agricultural production	Impacts on food imports	Hong Kong is not self-sufficient in food and relies heavily on imports. Climate change impacts on Hong Kong's key food trade partners may have knock-on implications on commodity prices and their ability to export food to Hong Kong. For instance, Hong Kong was shown to be sensitive to the rice crisis in April 2008, which occurred as a result of an influx in prices and export restrictions. There is a need for Hong Kong to reduce its exposure to	• Encourage / increase domestic agricultural production to reduce reliance on food imports: - There are, however, voluntary surrender schemes for poultry farmers and pig farming licences due to public health concerns. How to achieve the balance of these may deserve further investigation. - In addition to AFCD's current agricultural policies, alternative crops may be identified. • The local food production can't support the whole	Prevent	To be identified	Medium / Long Term

(1) Defra, UK food security assessment (http://www.defra.gov.uk/foodfarm/food/security/assessment.htm)

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			the vulnerabilities associated with food imports.	population of Hong Kong and therefore Hong Kong may not be able to reduce overall reliance on food imports from various jurisdictions including Mainland China. However, the impact of any food supply disruptions (including price fluctuations) could be mitigated to some extent by encouraging/ increasing domestic agricultural production. Given the share of Hong Kong's food imported from Mainland China, coordination with and support from the CPG is likely to be required in the event of significant disruptions to the food supply.			
Disaster Management & Emergency Planning							
FOD-E1	Food supply contingency planning	Food supply shortage	Under the *HKSAR Emergency Response System*, SWD is responsible for providing essential relief items, including food, to the victims following an emergency or disaster. According to the *Daya Bay Contingency Plan*, the Food Control Committee is triggered by an emergency situation. This measure, however, is currently restricted to the safety of foodstuff in relation to a nuclear incident. The *East Asia Emergency Rice Reserve* (*EAERR*) programme, which serves as food aid, may provide some buffer and strengthen food security in encountering food shortage due to temporary natural disaster or man made calamity. These responsive actions are taken in response to an incident. Our openness to trade should, theoretically, make Hong Kong resilient in terms of disruptions from one or a few sources of supply. However, a contingency plan is currently lacking to deal with any disruptions along the food supply chain that could impact on the local food security.	• Develop an emergency response management plan to deal with unforeseen food shortages resulted from unexpected breakdowns in domestic or international sources of supply or other emergency situations that could affect Hong Kong's food supply and security: (i) Set up an emergency structure to handle the situation, which could include: assess the impact of disruption to the local food supply, provide strategic leadership over preparation of the proposed emergency response management plan, coordinate response, as well as to keep close contact with the industry. (ii) Identify the roles of relevant government units and personnel, and other stakeholders in the food chain business. (iii) Examine how food retailers could switch sources of supply rapidly in case of disruption. The associated communication, transport and energy networks could be incorporated. (iv) Identify critical thresholds for food supplies / reserves for essential food items (e.g. rice) for activating the plan.	Prepare	To be identified	Short Term

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
				(v) Assess the plan against future climate scenarios (*Option R1- Produce and Update Climate Change Scenarios*) and "what-if" scenarios (e.g. if rice exports from Thailand dropped to a significantly low level).			
Education & Public Awareness							
BUS-P2	Encourage business continuity planning	Business / operation disruptions	Although the food chain has generally proved to be remarkably robust, business continuity planning is becoming more important and to help individual business and organisation recover and restore from interruptions.	• Work with key food chain businesses to ensure sufficient continuity planning occurs in respect of climate risks, particularly in light of the risks arising from just-in-time operations across the industry. • Actively promote Business Continuity Management (BCM) (*Option BUS-E1*) to stakeholders in the Food Resources sector.	Prepare	To be identified	Short Term

Table 6.7 Climate Change Adaptation Options for Human Health

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Research & Investigation							
HEA-R1	Research effects on vulnerable groups	Distributional impacts	Climate change is having, and will have, strongly differential effects on people within Hong Kong and between regions, on this generation and future generations. The impacts of climate change are likely to disproportionately affect the poor, sick, poorly housed and other vulnerable groups such as the elderly whose own adaptive capacity may be limited. For example, Hong Kong's heavy reliance on mechanical cooling (and heating) may raise some equity issues on certain demographics and socio-economic groups as they may not have access to or cannot afford air-conditioning. These issues may be exacerbated by the aging population in the territory.	• Investigate the potential impacts and challenges facing the vulnerable groups, in collaboration with the medical community and organisations that provide primary health care, support and social welfare.	Prepare	• Academics • DH • FHB • HA • Health practitioners • HKO • SWD	Ongoing
Monitoring							
HEA-M1	Observe the effects of extreme temperatures	Health concerns associated with extreme temperatures	The excessive mortality and morbidity related to extreme weather conditions are not specifically monitored. Filling this gap may be needed.	• Set up monitoring programmes to observe the health implications of extreme temperatures on the local population and the associated distributional impacts in collaboration with Hong Kong Observatory, Department of Health, and Hospital Authority.	Prepare	• DH • FHB • HA • Health practitioners • HKO • SWD	Short Term
Institutional Strengthening & Capacity Building							
HEA-I1	Communicate information on extreme temperatures to health practitioners and the public	Extreme temperatures	Heat stroke has attracted much attention in Hong Kong especially in recent years. While the awareness of heat stress / heat stroke has generally increased, hot weather may also induce other illnesses such as cardio-respiratory diseases. In addition to heat stroke / heat stress, these illnesses could have resource implications on health and	• When an extended period of hot spell is expected, alert the emergency departments and other medical staff or health practitioners for potential increased levels of patients and/or hospital admissions (including those for hot weather related illnesses). • As a preventive measure, Enhanced Risk Communication for Prevention of Heatstroke has	Prepare	• DH • HA • FSD • Health practitioners	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
			medical services.	been established between HK Observatory and DH			
HEA-I2	Periodically review emergency relief services – temporary accommodation	Extreme temperatures	• More shelters may be needed to cater for the potential increase in demand associated with future climate variability or the changing demographics. • Elderly and people with disabilities may find temporary shelters that are located within walking distance from their homes more welcoming, and hence the service could be utilised.	• Based on *Option R1* (*Produce and Update Climate Change Scenarios*), periodically review the adequacy and effectiveness of temporary cold and night heat shelters, such as their geographic location and distribution, their provision and opening hours etc.	Respond	• HAD	Medium / Long Term
HEA-I3	Periodically review welfare policies	Distributional impacts	An effective, well-funded adaptation safety net may be needed for the segment of the population least capable of coping with climate change impacts (e.g. the elderly, poor and sick); a common but differentiated mitigation strategy may be needed to protect the most vulnerable.	• Reviews should consider whether additional measures are needed when considered against future climate scenarios (*Option R1- Produce and Update Climate Change Scenarios*).	Prevent	• SWD	Medium / Long Term
HEA-I4	Review existing surveillance systems for detecting non-endemic diseases	New / non-endemic diseases, in particular vector-borne diseases	Global aviation, in particular, has facilitated the spread of diseases worldwide. The existing measures by the Port Health Office, CHP and others, may not eliminate the risk of new or non-endemic diseases from being introduced into, and possibly become established in, Hong Kong (e.g. incubation period of some diseases imply that they may not be picked up at port control points). A well-known example is the West Nile Virus: this flavivirus (commonly found in Africa, West Asia, and the Middle East) was first found in the US in 1999 but is now permanently established in the Western Hemisphere. Vector-borne diseases may deserve particular attention under a changing climate.	• Review existing vector surveillance and control measures (such as those for Dengue fever).	Prepare	• DH • FEHD • HA • Health practitioners • Medical community	Ongoing
HEA-I5	List changing disease patterns and impacts on vulnerable population	• Vector-borne diseases • Non-endemic diseases	No local research was identified on the effects of climate change on the changing patterns of endemic and non-endemic diseases, as well as other illnesses such as chronic or cardio-respiratory diseases. For infectious diseases, the Scientific Committees of the	• List the changing disease patterns (including non-endemic diseases that could pose a threat to Hong Kong) and health distributional impacts associated with climate change, as research priorities under the *Health and Health Services Research Fund* (HHSRF) and	Prepare	•Academic/Medical community	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
	associated with climate change as research priorities and provide funding		Centre of Health Protection (CHP) currently focus on major communicable diseases and research on their patterns of change. The *Research Fund for the Control of Infectious Diseases* (*RFCID*) aims to encourage, facilitate and support research on the prevention, treatment and control of infectious diseases, in particular, emerging infectious diseases such as SARS. This or another fund could be extended to cover the implications of climate change on these and other diseases.	the *RFCID*, or as special consultancy studies by academics and professionals in environmental health. • More local research on impact of climate change on infectious diseases should be encouraged.			
Disaster Management & Emergency Planning							
HEA-E1	Periodically review warning, alert / monitoring systems	Accidents and emergency situations	Weather extremes (e.g. heavy rains, floods, and hurricanes) have severe impacts on human health. Hong Kong is familiar with extreme weather events such as tropical cyclones, and has some of the best disaster preparedness systems of any world city.	• Based on *Option R1* (*Produce and Update Climate Change Scenarios*), regularly evaluate the effectiveness of warning and monitoring systems based upon actual climate events.	Prepare	• DSD • HKO • GEO	Ongoing
HEA-E2	Periodically review emergency services / contingency plans	Accidents and emergency situations	Nevertheless, wealthy and well-prepared nations could still be highly vulnerable to more extreme weather events, as demonstrated in the European heatwave (2003), Hurricane Katrina (2005) and UK floods (2007) examples. It is therefore important that our familiarity with extreme weather and extant adaptive capacity do not induce complacency, particularly under future climate scenarios.	• Re-examine the goals and strategies of emergency preparedness, response and recovery (including the Hong Kong Contingency Plan for Natural Disasters) as the climate changes. • Examine the implications of extreme weather scenarios (*Option R1e – Reasonable Worst Case Scenarios*) on resources, such as emergency response staff, ambulances, helicopters, equipments, public weather shelters, as well as post-disaster actions.	Prepare	• FSD • HA • HAD • HKPF • SB	Ongoing
HEA-E3	Plan and prepare for reasonable worst case situations	Accidents and emergency situations		• Incorporate reasonable worst case scenarios (*Option R1e – Reasonable Worst Case Scenarios*) that account for future climate into the contingency plans and other emergency management planning process.	Prepare	• HKO • SB	Ongoing
Education & Public Awareness							
HEA-	Educate	New / non-	Local medical community and healthcare	• Provide additional education and/or training on	Prepare	• Academic/	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
P1	medical community on related diseases	endemic diseases, in particular vector-borne diseases	professionals may not be familiar with non-endemic diseases and may therefore lead to a delayed response in disease control.	non-endemic diseases to the general medical community and healthcare professionals to help them identify any potential cases or outbreaks of non-endemic diseases, which in turn, would enable an effective response.		Medical community	

Table 6.8 Climate Change Adaptation Options for Water Resources

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
Research & Investigation							
WAT-R1	Assess impacts along the water supply chain	Impacts along the water supply chain	The WSD has been implementing a Total Water Management (TWM) strategy since 2008. It aims to manage the demand and supply in an integrated, multi-sectoral and sustainable manner. It is also aimed to better prepare Hong Kong for uncertainties such as acute climate changes and low rainfall and to enhance Hong Kong's role as a good partner to other municipalities in the Pearl River Delta in promoting sustainable use of water in the light of rapid growth of water demand in the region. Since a majority of Hong Kong's raw water supply is imported from Dongjiang, information on water resources for the Dongjiang basin would be useful in assessing the vulnerability of the imported water resources from Guangdong. Some studies, such as Guo (1995) (122), Ying (2000) (123) and Jiang *et al*. (2007) (124), have examined the hydrological impacts of climate change and the associated implications on water resource systems for the Dongjiang Basin. However, substantial uncertainties are inherent in the rainfall projections and the sign of change can be unclear, which would have significant implications on water resources.	Building on the existing climate change impact studies on regional water resources, a continuation and expansion of the TWM to address the vulnerabilities and to assess the relative significance of the risks of the various elements along Hong Kong's water supplies chain. This may include: (1) The effects of the potential changes in rainfall amount and patterns on: • Dongjiang river flows • Dongjiang water quality (2) The effects of climate change (eg warmer temperatures, drier conditions, more frequent / intense extreme weather events etc) on: • Resilience of assets and infrastructure both within Hong Kong and the Mainland • Water demand / supply under the anticipated socio-economic changes in parts of the Guangdong province which rely on the supplies from Dongjiang (3) Stress-test the water supply agreement with Dongjiang and the associated implications for Hong Kong. "What-if" scenarios, including a reasonable worst case scenario, could be used to assess the effects on the water supply available to Hong Kong.	Prepare	• WSD • In collaboration with Dongjiang water authorities and supported by the HKO, Guangdong Meteorological Bureau (GMB) and academia	Ongoing
Institutional Strengthening & Capacity Building							
WAT-I1	Periodically review Total Water Management (TWM) Strategy	Changes in water supply and demand	Water demand and supply in Hong Kong are managed through the Total Water Management (TWM) Strategy. The measures and initiatives in the current TWM Strategy may be inadequate to deal with future climate.	• Review the current TWM Strategy regularly, say every 5 years, to: - Incorporate the latest available science based on *Option R1- Produce and Update Climate Change Scenarios.* - Examine the effectiveness of the measures on both the demand and supply side management.	Prevent, Prepare	• WSD	Ongoing

Code	Option	Vulnerability / Hazard Addressed	Rationale	Framework	Type of Instrument	Possible Responsible Parties	Timescale
				- Enhance existing adaptation options as necessary, e.g. mandate the "Water Efficiency Labelling Scheme" (WELS) based on feedback from relevant stakeholders. - Explore and adopt new adaptation options as necessary, e.g. provide rebates for installing rainwater collection tanks for schools, commercial and industrial customers etc; tax incentives for water technologies.			
Disaster Management & Emergency Planning							
WAT-E1	Contingency planning for droughts	Water supply shortage	Despite the water supply agreement with the Guangdong authorities, it is possible that contractual obligations cannot physically be met, for instance during periods of low rainfall or water stress in Dongjiang. Hong Kong needs to be prepared for such a situation.	• Review drought contingency plans as desirable from time to time–	Prepare	• DevB • HKO • WSD	Ongoing

6.3 *CROSS-SECTORAL CLIMATE CHANGE ADAPTATION OPTIONS: RESEARCH ACTIVITIES*

This section highlights some general climate change research activities that would help to improve our understanding in the potential impacts associated with climate change in the local context, and thus facilitate adaptation actions across the different sectors.

6.3.1 *Option R1 – Produce Climate Change Scenarios*

Projections of future climate presented in the IPCC Assessment Reports are of global (ie global averages) or continental scale in nature. However, climate change will not be uniform across the globe; rather it will occur at different rates and magnitudes at different locations. Local climate change scenarios (ie projections for Hong Kong) are therefore necessary. A single set of scenarios of future climate that contain the same assumptions about the future state of the economy would allow the results for different assessments and analysis (e.g. for the various sector components) to be comparable and compatible [(125)].

The Hong Kong Observatory has a comprehensive database for a range of meteorological, atmospheric and oceanographic variables, some since record began in 1885. The Observatory and various local research institutes have conducted research on a number of climate change related topics. It would seem sensible for the Observatory to lead and coordinate strategic research programmes on climate change to enhance our understanding on the local future climate and to fill data and information gaps.

The Observatory could hold primary responsibility for investigating the priority research areas (as presented below in *Section 6.3.2*) to produce the necessary scenarios, although local, regional or international collaboration may be necessary. While the Observatory is concerned with pure (and some applied) research into natural and anthropogenic climate change and the production of climate change scenarios, it may be in a good position to create a platform for centralising the existing efforts and knowledge in climate change research to produce the necessary scenarios for government planning.

It is also important to develop a mechanism to effectively communicate any scientific findings to decision makers and resource planners. For example, it is vital that users of climate change scenarios (e.g. decision makers and planners, both technical and non-technical staff) are aware of their limitations and sources of uncertainties.

All these could have resource implications on the existing institution. Although the Observatory may conduct some research in collaboration with local research institutes, the establishment of a "climate change team" may be necessary to develop and coordinate strategic research programmes on climate change for Hong Kong. Further, additional resource, including financial and staff with the relevant technical expertise, is likely to be required.

6.3.2 *Research Areas for Scenarios*

Based upon the IPCC AR4 projections, the Hong Kong Observatory has produced updated local temperature and rainfall scenarios for the 21st century; studies on extreme temperature and rainfall projections that use higher temporal resolution model data (daily) are forthcoming. Despite these, a more complete set of climate change scenarios for Hong Kong is desirable. Given the uncertainties in climate projections, a range of climate change scenarios would enable decision makers and resource planners to make informed judgements about the potential impacts of climate change. They could also explore the effects and implications of different planning decisions under a range of plausible futures in Hong Kong.

While some research needs are unique to certain sector, this section highlights some generic areas where high uncertainties and/or low confidence are inherent in their projections, and further research and investigation in these areas are considered beneficial in climate change adaptation based on our current knowledge and understanding, and they should not be considered exhaustive.

Option R1a – Sea Level Rise Scenarios

A significant proportion of Hong Kong's development concentrates in low lying coastal zones and on reclaimed land, in particular on either side of Victoria Harbour. This implies that many buildings and infrastructure are at risk of coastal flooding. Hong Kong is ranked in the 9th place in terms of assets exposed to coastal flooding in the 2070s, with exposed assets estimated at US$1,164 billion (over HK$9,000 billion) (126).

Buildings and infrastructure tend to have long asset life and investment decisions made at present day could have implications for many decades. However, the rate and magnitude of change in future sea levels remain one of the major sources of uncertainties at the international level. To facilitate sufficient and timely adaptive response, scientific developments across the globe in sea level change research should continue be monitored. Sea level rise during this century is projected to have substantial geographical variability. Therefore, where sufficient information is available, the implications of the global projections on the regional perspective (e.g. changes in ocean currents) could be examined. This may require considerable efforts and collaboration from the research community and significant technological advancement. As our understanding in climate change impacts on sea level changes improves, localized and location-specific effects such as storm surges could be investigated. These may need to be a collaborative effort with regional and/or international scientists.

In addition to eustatic changes (ie changes in global sea level independent of local factors), local mean sea level may also be influenced by vertical land movements associated with isostatic adjustment. Measurement of the vertical ground movement at tide gauge stations which started in 2004 will support long term sea level change studies in future. The effects of vertical ground movement on the sea level change could be examined for Hong Kong, and this would contribute to our understanding in sea level changes determined based on tide gauge data. Its effects on the wider region of Southern China could also be investigated as a collaborative effort to enhance our understanding in regional sea levels.

Option R1b – Seasonal Climate Change Scenarios

The local temperature and rainfall projections produced by HKO provide little information on the seasonal climate change. Compared to the human system, the seasonal behaviours of many species and ecological communities such as breeding, flowering, emergence and migration are linked to either climatic conditions or food availability, seed dispersers and pollinators, and are therefore very sensitive to seasonal changes in climate. Information on changes in seasonality may also be useful for energy resource planners in reviewing energy demand patterns.

Changes in seasonality, for temperature and rainfall in particular, would be useful in assessing the impacts and vulnerabilities on ecology and biodiversity. This information could also supplement the existing temperature and rainfall projections for Hong Kong.

Option R1c – Changes in Marine Environment Scenarios

Relatively little is known about climate change impacts on the marine environment, such as sea surface temperatures, ocean acidity, dissolved oxygen and ocean currents especially on the regional or local scale. This enhances the difficulties and challenges in impact and vulnerability assessments for Hong Kong's marine ecosystems and biodiversity. Further, changes in the marine environment may also have an influence on the goods and services it provides, e.g. impacts on local and regional aquaculture and fishing activities.

Specific overseas research programmes that aim to understand the effects of climate change on the marine environment and marine ecosystems are important sources of knowledge that could be transferred to Hong Kong. These should be monitored for updates and new developments as they become available. Where necessary, local monitoring and research could be carried out at certain sites such as those of ecological significance such as marine parks and reserves (e.g. Hoi Ha Wan, Sha Chau and Lung Kwu Chau Marine Park) to supplement the knowledge gained from international experience. These information would assist in the formulation of effective policies and measures in marine nature conservation and protection.

Option R1d – Extreme Weather Events

Weather extremes such as tropical cyclone have the potential to cause significant damage. The scientific community has yet to produce conclusive findings on the connections between tropical cyclones and climate change.

While more intense tropical cyclones may result in a warmer climate, changes in tracks or areas of impact remain unknown.

Continual monitoring on the scientific developments in climate change and tropical cyclones research is necessary. When sufficient information is available, international findings could be incorporated into local climate change projections.

Hong Kong's weather is also influenced by the Asian summer monsoon, which is in itself related to the El Niño Southern Oscillation (ENSO). As consistency is still lacking in model projected discernible changes in ENSO amplitude or frequency, international findings on this area should be monitored for updates and new development.

Option R1e – Reasonable Worst Case Scenarios

Despite the uncertainties in climate change projections, reasonable worst case scenarios for Hong Kong could allow planners and decision-makers to ask "what-if" questions, consider their impacts on climate-sensitive natural and human systems, plan for reasonable worst case situations and examine their implications on resources etc.

For instance, storms with intensities equivalent to Category 4 or 5 are historically uncommon in Hong Kong. Hence, tropical cyclones with these intensities may be included as a reasonable worst case scenario. Sea level rise may also be included as a variable.

Option R1f – Probabilistic Projections

Planners and decision-makers need as much information as possible on how climate will evolve in order to adapt effectively. As uncertainties (namely modelling uncertainty, and that due to natural variability and in future emissions) continue to remain in climate change projections, the move away from single projections and towards probabilistic ones has become increasingly desirable. The probabilities attached to different levels of future climate change represent the relative degree to which each climate outcome is supported by the evidence currently available, taking into account the latest understanding of climate science and observations, and using expert judgement.

Probabilistic projections for the UK Climate Projections (UKCP09) reflect major known uncertainties in relevant climate system processes. A comprehensive review of the methodology used to convert the ensembles of climate model simulations into probabilistic estimates of future climate is provided in UKCP09.

Hong Kong could consider developing probabilistic scenarios based on the UKCP09, as these would provide better science for climate change impacts and vulnerability assessment, and in turn, the development of effective adaptive response. This could be a collaborative effort for the region that may also involve inputs from overseas experts.

6.3.3 *Option R2 – Undertake Further Sectoral Research on Impacts and Vulnerabilities*

To increase the adaptive capacity of communities, infrastructure, and economic activities, important vulnerabilities and priorities need to be identified and established through detailed regional or even local assessments [127]. It should be stressed that the climate change impacts and vulnerability assessment in this Study serves as a preliminary assessment for Hong Kong that aims to provide an indication of the key vulnerabilities and where more immediate actions are warranted. More detailed semi-quantitative and quantitative risk-based assessments are therefore needed for some sectors or areas to identify the influence, the specific receptors at risk, the pathways linking climate hazard to receptors, help identify or refine and appraise climate adaptation and climate change risk management options.

While this study has made a start at identifying vulnerabilities in Hong Kong, considerable amounts of additional data and information are needed prior to the formulation of effective climate change adaptation measures and policies. More information on the potential climate change impacts would highlight specific areas for adaptation, which often involves a better understanding of the baseline conditions in Hong Kong. Although some research activities may be designed to have a distinct sectoral and local focus, some studies may require coordination between different sectors and actors, for example in information and knowledge sharing.

Specific areas of research required are highlighted in the sectoral tables in *Section 6.2* above.

6.3.4 *Option R3 – Establish Fund for Adaptation Research*

A sound research base is needed for decision-makers and planners in all areas and in both the public and private sector to understand the risks / opportunities arising from climate change, and potential adaptation options. A research budget would be needed to support research and monitoring activities that aim to improve our understanding of the climate system, impacts of climate change on society and adaptive responses. Funding schemes would also be needed to facilitate the implementation of climate change adaptation measures.

6.4 *CROSS-SECTORAL CLIMATE CHANGE ADAPTATION OPTIONS: EDUCATION AND PUBLIC AWARENESS*

This section presents options for education and raising the level of public awareness and understanding of climate change issues across all sectors.

6.4.1 *Option P1 – Raise Public Awareness*

Public awareness and understanding are paramount in the discussion about how to adapt to climate change. There is a relatively low level of understanding of vulnerabilities and adaption options amongst the general population of Hong Kong. Communication of climate change, in particular, the causes and potential impacts on ecosystems, promotion of water conservation, climate variability and concepts such as risk and uncertainty, along with the need for adaptation activities could be implemented. Appropriate policy responses and management goals are more likely to be widely supported when there is informed public discussion of the potential impacts of climate change.

6.5 *CO-ORDINATION AND REVIEW*

6.5.1 *Option A1 – Periodically Review Institutional Arrangements*

Since climate change is multi-disciplinary by nature; the formulation and implementation of adaptation measures would be more efficient and effective through cross-sectoral and international efforts from the private sector as well as those from the Government. To ensure that institutional arrangements and Government departments are coordinating climate change response and adaptation efforts, institutional arrangements need to be periodically reviewed and aligned as necessary to ensure co-ordination between different departments and that the Government is making decisions that is informed by the latest science.

6.6 *DECISION-MAKING IN THE FACE OF UNCERTAINTY*

Adaptation planning should incorporate a range of different approaches as each of them would have its own strengths and weaknesses and there is no single "preferred" methodology. When adaptation strategies are being developed, a procedure for periodic review and assessment of progress should be created; adaptation planners should be prepared to make "course corrections" when updated and new information on climate change and methodology becomes available.

Many decisions in business (such as investment decisions) and politics are regularly made in the face of uncertainty. In spite of the uncertainties associated with the projected future climate and the potential climate risks, "uncertainty" should not be used as an excuse for not taking appropriate action. While overinvestment in adaptation may be worse from a welfare perspective than underinvestment, overinvestment has been considered to be *far preferable* to inaction [128]. For this reason, uncertainty about the exact optimal amount of adaptation should not prevent investment in adaptation, although caution is needed.

A flexible or adaptive management that involve implementing the required adaptation measure(s) in a phased manner could be an effective solution when both the risks associated with inaction and the uncertainty and the risk associated with introducing mal-adaptive measures are high. This approach involves introducing incremental adaptation options in a timed or sequential manner, based on the evaluation of risks, costs, feasibility and contribution to desired outcomes. It addresses the obvious risks now, but also allows for incremental or directional change in future, as vulnerability, knowledge, experience and technology evolve.

Continual review of the performance of introduced measures is needed for identifying the need for, and nature of, next steps. A decision to "delay" introducing adaptation measure(s) may be necessary where the risk of mal-adaptation (i.e. under or over-adapting) is particularly high, when the climate risks are below defined thresholds or when the required adaptive capacity (e.g. regulatory or institutional circumstances) is insufficient to support taking the specified measure. Delaying is only effective when there is continual adaptive capacity building, and also time monitoring and evaluating evolving risks and adaptation options.

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Annex A

Potential Climate Change Consequences in Hong Kong by Sector

Please note the following potential consequences should not be considered exhaustive or definitive. The consequences projected are *possible* outcomes as a result of climate change and assume no adaptation measures other than those currently in place. The consequences identified are essentially putative; whilst they are based on the current scientific understanding of climate change, the academic evidence base for climate change impacts contains considerable uncertainties and is rapidly evolving.

CONTENTS

A1 POTENTIAL FUTURE CONSEQUENCES OF CLIMATE CHANGE IN HONG KONG IDENTIFIED THROUGH A REVIEW OF INTERNATIONAL AND LOCAL LITERATURE

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
Agriculture						
Poultry Production						
• Exceedence of thermal tolerance of poultry species. • Changes in poultry pest and disease regime, leading to increased mortality in flocks, rising veterinary costs and possible health impacts to consumers and farm workers. • Increased proliferation of bacteria and microorganisms leading to greater risk of conditions such as salmonella poisoning. Risk of public health incident and transmission to humans and reputational damage for the industry. Products will have a shorter shelf life. Higher refrigeration costs are likely for processing plants and abattoirs.	• Changes in poultry pest and disease regime, leading to increased mortality in flocks, rising veterinary costs and possible health impacts to consumers and farm workers. • Risk of flooding, power cuts, asset damage and business interruption.	• Risks to feedstock and water supplies from the mainland and overseas – reducing availability and increasing costs. Reduced availability of water locally. Increased costs likely for purchasing additional water.	• Rising costs of grain and other feed due to climate change impacts overseas. • Risk to assets, infrastructure, energy supplies, livestock and farm workers and business interruption.	• Significant potential for influx of climate change refugees from neighbouring flooded regions increasing demand and raising prices. Also risk of contamination to water supplies which could impact production. Risk of loss of coastal and low lying farms.	• Depletion of marine mollusc populations globally due to increasing acidity will increase costs of oyster shell and cockle grit – vital components of chicken feed.	
Pig Husbandry						
• Exceedence of thermal tolerance of pig breeds. • Changes in pig pest and disease regime, leading to increased mortality in herds, rising veterinary costs and possible health impacts to consumers and farm workers. • Increased proliferation of bacteria and microorganisms leading to greater risk of food poisoning agents.	• Changes in pig pest and disease regime, leading to increased mortality in herds, rising veterinary costs and possible health impacts to consumers and farm workers. • Risk of flooding,	• Risks to feedstock and water supplies from the mainland and overseas – reducing availability and increasing costs. Reduced availability of water locally. Increased costs likely for purchasing	• Rising costs of grain, silage and other feed due to climate change impacts overseas. • Risk to assets, infrastructure, energy supplies, livestock and farm workers and	• Significant potential for influx of climate change refugees from neighbouring flooded regions increasing demand and raising prices. Also risk of contamination to water supplies		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
• Risk of public health incident and transmission to humans and reputational damage for the industry. Products will have a shorter shelf life. Higher refrigeration costs are likely for processing plants and abattoirs.	power cuts, asset damage and business interruption.	additional water.	business interruption.	which could impact production. Risk of loss of coastal and low lying farms.		
Dairy Farming and Cattle Husbandry						
• Exceedence of thermal tolerance of dairy and beef cattle species. • Changes in bovine pest and disease regime, leading to increased mortality in herds, rising veterinary costs and possible health impacts to consumers and farm workers. • Increased proliferation of bacteria and microorganisms leading to greater risk of conditions such as salmonella poisoning in dairy products. Risk of public health incident and transmission to humans and reputational damage for the industry. Temperature changes are also likely to affect consumer demand for dairy products i.e. increased demand for ice cream. Products will have a shorter shelf life. Higher refrigeration costs are likely for dairies.	• Changes in bovine pest and disease regime, leading to increased mortality in herds, rising veterinary costs and possible health impacts to consumers and farm workers. • Risk of flooding, power cuts, asset damage and business interruption.	• Risks to feedstock and water supplies from the mainland and overseas – reducing availability and increasing costs. Reduced availability of water locally. Increased costs likely for purchasing additional water.	• Rising costs of grain, silage and other feed due to climate change impacts overseas. • Risk to assets, infrastructure, energy supplies, livestock and farm workers and business interruption.	• Significant potential for influx of climate change refugees from neighbouring flooded regions increasing demand and raising prices. Also risk of contamination to water supplies which could impact production. Risk of loss of coastal and low lying farms.		
Fruit, Flower and Vegetable Production						
• Temperature changes are also likely to affect consumer demand with increasing demand for salad vegetables. Products will have a shorter shelf life. Higher refrigeration	• Changes in plant pest and disease regime, leading to decreased yield and increased costs i.e.	• Reduced availability of water locally. Increased costs likely for purchasing additional water.	• Risk to assets, infrastructure, energy supplies, loss of crops, risks to farmer workers and	• Significant potential for influx of climate change refugees from neighbouring flooded regions		• Increase in atmospheric CO_2 concentrations - Providing sufficient water

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
costs are likely for processing plants and wholesalers. • Change in distribution of pollinator species, may lead to pollination problems for crops that require external pollinators, ie most fruits. • Exceedence of thermal tolerance of cultivar species, may lead to greater use of greenhouses with climate control increasing costs for growers. Also the risk that as cultivars with tolerance of higher temperatures are likely to be selected, extreme cold snap events could devastate yields and blossom formation of fruit trees. • Changes in plant pest and disease regime, leading to decreased yield and increased costs i.e. pesticides, and their potential impacts on workers and local water courses.	pesticides, and their potential impacts on workers and local water courses. • Risk of flooding, power cuts, asset damage, loss of crop and business interruption.	Reduction in soil moisture levels and production as a result.	business interruption.	increasing demand and raising prices. Also risk of contamination to water supplies which could impact production. Risk of loss of coastal and low lying farms.		supplies and soil moisture is available, this could lead to an increase in yield of some crops. • Decrease in global solar radiation levels - This may negatively impact the yield of some crops which require high levels of solar irradiance.
Aquaculture and Fisheries						
Marine Capture Fishery						
• Warmer sea surface temperatures may result – May have an influence in marine productivity; changes in marine species distribution / occurrence. Increased potential for hypoxia events.	• Increased potential for hypoxia events. • Possible decreases in salinity and the associated implications for the fisheries sector.		• Storm interference with fishing operations.		• Implications for fish reproduction and stock replenishment as fish eggs are more sensitive to pH change than juveniles and adults. • Depletion of fish stocks due to loss of food chain (i.e. calcareous	• Potential change in ocean currents - Change in commercial fisheries species distribution / occurrence.

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					invertebrates and plankton).	
Marine Culture Fishery						
• Warmer sea surface temperatures may result - Exceedence of thermal tolerance of fish in surface waters. • Increased potential for hypoxia events.	• Increased potential for hypoxia events. • Possible decreases in salinity and the associated implications for the fisheries sector.		• Cage damage, loss of stock, interference with access and operations.		• Implications for fish reproduction and stock replenishment as fish eggs are more sensitive to pH change than juveniles and adults.	
Inland Pond Fishery						
• Warmer pond water temperatures may result - Exceedence of thermal tolerance of fish; reduce dissolved oxygen levels.	• Flooding may result - Flooding, loss of stock, increased construction costs.	• Increased operation costs as additional water supplies are sought.		• Flooding, loss of pond sites and stock, relocation costs.		
Oyster Culture Fishery						
	• Exceedence of salinity tolerance of oysters	• Exceedence of salinity tolerance of oysters		• Decreased area of mudflat for clutches.		
Biodiversity and Nature Conservation						
Terrestrial and Aquatic Ecology						
• Change in species distributions/occurrence/ migration patterns. Loss of montane species. • Increase in stream water temperature will affect both life and breeding cycle of aquatic species. • Exceedence of thermal tolerance of terrestrial organisms (especially herpetofauna and insects) and heat stress. Impacts to organisms' seasonal behaviours/ adaptations. Greater risk of heat stroke and heat stress for	• Increased risk of stream wash outs – putting eggs and young of numerous aquatic species at risk. This will also disrupt food chains. Impacts to organisms' seasonal behaviours/ adaptations. • Increased storm	• Increased risk of wildfires and loss of forest ecosystem components. Health of conservation workers put at risk. Low stream flows will concentrate pollutants putting aquatic wildlife under stress.	• Risk to conservation assets, infrastructure, energy supplies, and conservation workers. Damage to woodlands. Higher stream flows and incidence of stream wash out, landslides etc.			

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
conservation workers.	damage to woodlands. Increased risk of landslides will impact terrestrial species. Health of conservation workers also put at greater risk as extreme conditions increase. Risk of damage to assets from extreme weather at conservation sites.	Impacts to organisms' seasonal behaviours/ adaptations. Shallower streams likely to experience higher water temperatures putting some organisms beyond their thermal tolerance.				
Marine Ecology • Warmer sea surface temperatures may result - Change in species distributions/occurrence/ migration patterns. Exceedence of thermal tolerance of marine organisms. Increased potential for hypoxia events. Bleaching /mortality of hermatypic corals due to increased seawater temperature.	• Increased flows of debris from terrestrial water courses increasing marine pollution. Increased potential for hyposaline events and impacts to corals. Potential flooding of conservation assets.		• Risk to conservation assets, infrastructure, energy supplies, and conservation workers. Damage to coral communities. Increased wave scouring will affect beach and intertidal ecosystems. Increased flows of debris from terrestrial water courses, increasing marine pollution. •	• Loss of intertidal habitats. Loss of low lying conservation assets. Increased risks of marine pollution as formerly terrestrial areas become submerged, releasing any pollution present at industrial sites into the marine environment.	• Reduction in growth/ strength of skeletons/shells of calcifying organisms (e.g. hard corals). Serious negative impacts on marine food chain and particularly those species that use reef areas as nurseries for their young.	

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Built Environment and Infrastructure						
Building Stock						
• Risk of subsidence and foundation damage. Also risk of damage to utilities cabling and pipes. • Loss of thermal comfort and increased use of artificial cooling. • Possible health risks should power supply be interrupted. • Power interruptions more likely due to demand /supply mismatch.	• Asset damage from flooding, landslides etc. • Increased risk of rain penetration of building fabric, lightning strike etc. • Health risks to building occupants. • Possible business interruption and reputational damage. • Increased insurance costs.	• Risk of subsidence and foundation damage. Also risk of damage to utilities cabling and pipes. • Possible business interruption and reputational damage. • Increased insurance and maintenance costs.	• Asset damage from flooding, storm surge, landslides, wind damage etc. • Increased risk of rain penetration of building fabric, loss of structural integrity, lightning strike etc. • Health risks to building occupants. • Possible business interruption and reputational damage. • Increased insurance and repair costs.	• Loss of low lying assets and damage to foundations from changes to hydraulic pressure. • Health risks to building occupants. • Possible business interruption and reputational damage. • Increased insurance and relocation costs.		
Transport Infrastructure						
• Risk of subsidence and foundation damage. Damage to tracks and road surface. Also risk of damage to utilities cabling and pipes leading to greater excavation of roads for repairs. • Loss of thermal comfort and increased use of artificial cooling needed on transport vehicles. • Possible health risks should power supply be interrupted. • Power interruptions more likely due to demand /supply mismatch.	• Asset damage from flooding, landslides lightning strike etc. • Health risks to travellers and staff. • Possible business interruption and reputational damage. • Increased insurance and repair costs. • Power and		• Asset damage from wind damage, storm surge, flooding, landslides, lightning strike etc. • Health risks to travellers and staff. • Possible business interruption and reputational damage. • Increased insurance	• Loss of low lying assets from inundation and storm surge and damage to foundations from changes to hydraulic pressure. • Health risks to travellers and staff. • Possible business interruption and		

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	communications system interruption likely. • Tunnel flooding and electrical damage possible.		and repair costs. • Power and communications system interruption likely. • Tunnel flooding and electrical damage possible.	reputational damage. • Increased insurance and relocation costs. • Tunnel flooding and electrical damage possible.		

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Communications Infrastructure						
• Risk of power interruption due to supply / demand mismatch.	• Asset damage from flooding, landslides lightning strikes to transmitters etc. • Health risks to staff. • Possible business interruption and reputational damage. • Increased insurance and repair costs. • Power interruption likely.		• Asset damage (transmitters, cabling) from wind damage, storm surge, flooding, landslides, lightning strike etc. • Health risks to staff. • Possible business interruption and reputational damage. • Increased insurance and repair costs. • Power interruption likely.	• Loss of low lying assets from inundation and storm surge and damage to foundations from changes to hydraulic pressure. • Health risks to staff. • Possible business interruption and reputational damage. • Increased insurance and relocation costs.		
Drainage Infrastructure (including stormwater drainage, sewerage systems and wastewater treatment facilities)						
• Increase odour problems emanating from sewers. • Greater rates of evaporation, risk of reduced dilution of pollutants. Possible damage to some concrete structures. • Risk of power interruption. • Possible formation of algae blooms in the receiving waters of wastewater treatment facilities.	• Asset damage from flooding, landslides to culverts and pumping plant etc. • Health risks to staff. • Possible business interruption and reputational damage. • Increased insurance and repair costs. • Power and communication	• Due to reductions in soil moisture levels, increased subsidence may affect underground pipes and cables, and also building foundations.	• Asset damage from flooding, backing up of both stormwater and sewerage systems, landslides to culverts and pumping plant etc. • Health risks to staff. • Possible business interruption and reputational damage. • Increased insurance	• The hydraulic capacity of sewage treatment plant discharge systems may be reduced. • Discharge problems at sewerage and stormwater outflows – risking backing up. Flooding of system beyond designed capacity. • Loss of low lying		

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	interruption likely. • Discharge problems at sewerage and stormwater outflows – risking backing up. Flooding of system beyond designed capacity. • Increase in hydraulic load of wastewater treatment facilities. • The effective dilution of wastewater flow due to stormwater infiltration may impact the effectiveness of the existing wastewater treatment processes.		and repair costs. • Power and communication interruption likely. • The hydraulic capacity of effluent discharge systems may be severely reduced if storm surges coincide with high tides. • Impacts on wastewater flow rates due to an increase in stormwater entering sewerage systems. This may increase the hydraulic load of waste water treatment facilities throughout Hong Kong. • The effective dilution of wastewater flow due to stormwater infiltration may impact the effectiveness of the existing wastewater treatment processes.	assets from inundation and storm surge and damage to foundations from changes to hydraulic pressure. • Health risks to staff. • Possible business interruption and reputational damage. • Increased insurance and relocation costs.		
Business and Industry						

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
Trade and Logistics						
• Increased costs from additional air conditioning usage. Increased risk of power cuts. • Health risks to staff from working outside in elevated temperatures. Raised temperatures in transportation units such as containers and HGVs – possible negative impacts on staff and transported goods. • Increase in very hot days may result - Damage to transport infrastructure i.e. rail bucking, tarmac melt, risks to delivery times.	• Risk of flooding, power cuts, asset damage and business interruption up and down the supply chain and across key logistics routes. Failure to deliver on time.	• Increased risk of water supply restrictions and increased costs for purchasing additional water. May lead to reduction in production output for manufacturing processes which are water intensive. May also impact operation of water-cooled AC systems.	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Business continuity issues due to power cuts and transportation problems i.e. cancelled flights, lost berths etc. Failure of supply chains and JIT. Power cuts. Increased siltation of harbour and navigation channels.	• Significant disruption likely to PRDEZ manufacturing leading to reduced export and re-export trade. Business continuity issues. Raised insurance costs. Risk of loss of low lying assets including wharfs and warehousing.		
Manufacturing						
• Increased costs from additional air conditioning usage. Increased risk of power cuts, production interruption and failure to fulfil orders on time. • Health risks to staff from working outside in elevated temperatures. Raised temperatures in transportation units such as containers and HGVs – possible negative impacts on staff and transported goods – failure to fulfil orders due to damage and spoiling of perishable goods in transit.	• Risk of flooding, power cuts, asset damage and business interruption up and down the supply chain and across key logistics routes. Failure to fulfil orders on time due to delays in receiving raw materials and part finished components.	• Increased risk of water supply restrictions and increased costs for purchasing additional water. May lead to reduction in production output for manufacturing processes which are water intensive. Leading to failure to fulfil orders on time and associated	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Crop damage could lead to increased raw materials costs for manufacturers. Business continuity issues due to power cuts and transportation problems i.e. failure	• Significant disruption likely to PRDEZ manufacturing leading to reduced export and re-export trade. Business continuity issues. Raised insurance costs. Risk of loss of low lying assets including warehousing.		

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		reputational damage. Increased raw material costs for food and beverage manufacturers. May also impact operation of water-cooled AC systems.	of mass transit meaning workers cannot get to work, failures in supply chains and JIT leading to inability to fulfil orders. Power cuts.			
Professional and Producer Services						
• Increased costs from additional air conditioning usage. Increased risk of power cuts. • Health risks to staff from working outside in elevated temperatures.	• Risk of flooding, power cuts, asset damage and business interruption up and down the supply chain and along public transportation routes.	• Increased risk of water supply restrictions and increased costs for purchasing additional water. May lead to reduction in production output for manufacturing processes which are water intensive. May also impact operation of water-cooled AC systems.	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Business continuity issues due to power cuts and transportation problems i.e. staff unable to get to work. Failure of supply chains and JIT. Power cuts. Reputational damage.	• Significant disruption likely to PRDEZ manufacturing leading to reduced producer services demand. Business continuity issues. Raised insurance costs. Risk of loss of low lying assets particularly waterside property alongside Victoria Harbour.		
Energy Supply						
Electricity Generation						
• Increased demand from air conditioning and refrigeration. May lead to supply interruptions, power spikes and load shedding. • Health risks to staff from working	• Demand from pumping out floodwaters is likely to increase. May lead to supply	• May lead to reduced generating capacity at the Guangzhou pumped storage	• Damage to assets and infrastructure including communications. Risk of loss of life	• Significant disruption likely to international trade risks primary fuel supply. Business		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
outside in elevated temperatures. Increase in very hot days / hot nights - Generators may encounter problems in acquiring sufficiently cold cooling water to operate their plant safely. May lead to supply interruptions, power spikes and load shedding. • Increase in very hot days - Damage to transport infrastructure i.e. rail bucking, tarmac melt, risks to delivery of primary fuels. May lead to supply interruptions, power spikes and load shedding • Decreased number of cold days - Reduction in demand for electric heating.	interruptions, power spikes and load shedding.	power station. Reduction in peak capacity. May lead to supply interruptions, power spikes and load shedding.	and limb. Staff unable to get to work. May lead to supply interruptions, power spikes and load shedding.	continuity issues. Raised insurance costs. Risk of loss of low lying assets including coal un-loaders and some power plant depending on elevation. May lead to supply interruptions, power spikes and load shedding.		
Electricity Transmission and Distribution						
• Increased transmission system losses as lines sag, requiring increased generation to meet demand. May lead to supply interruptions, power spikes and load shedding. • Health risks to staff from working outside in elevated temperatures.	• Risk of flooding, lightning strike, landslides, leading to damage to power lines and other assets. May lead to supply interruptions, power spikes and load shedding.		• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Staff unable to get to work. May lead to supply interruptions, power spikes and load shedding.	• Raised insurance costs. Risk of loss of low lying assets including pylons and substations. May lead to supply interruptions, power spikes and load shedding.		
Primary Fuel Imports and Supply						
• Health risks to staff from working outside in elevated temperatures. Increase in very hot days - Damage to	• Risk of flooding, lightning strike, landslides, leading		• Damage to assets and infrastructure including	• Significant disruption likely to international trade.		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
transport infrastructure i.e. rail bucking, tarmac melt, risks to delivery times. • Decreased number of cold days - Reduction in demand for energy for heating.	to disruption of transport routes and to deliveries of primary fuels risking fuel shortages and electricity blackouts, brownouts and load-shedding.		communications. Risk of loss of life and limb. Staff unable to get to work. Fuel supply vessels may be affected. A serious impact on Hong Kong could involve a reduction in port capacity which would delay vital deliveries. May lead to supply interruptions, power spikes and load shedding.	Business continuity issues. Raised insurance costs. Risk of loss of low lying assets including wharfs and warehousing. May lead to supply interruptions, power spikes and load shedding.		
Financial Services						
Banking						
• Increased demand from air conditioning and refrigeration. May lead to blackouts, brownouts and load shedding. Business interruption. Health risks to staff should power fail. Increase in very hot days - Damage to transport infrastructure i.e. rail bucking, tarmac melt, risks to supply chain, productivity and business interruption for investments. • Decreased number of cold days - Reduction in demand for cold weather products, negative impacts on investments in these sectors.	• Power cuts, asset damage, business interruption. Poor performance of investments affected by flooding and secondary impacts i.e. power cuts, supply chain failures.	• Power cuts, asset damage, business interruption. Poor performance of investments affected by reduced rainfall and secondary impacts i.e. power cuts, supply chain failures.	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Staff unable to get to work. Power cuts, business interruption, depreciation of asset values, poor performance of investments,	• Significant disruption likely to international trade. Business continuity issues. Raised insurance costs. Risk of loss of low lying assets. Power cuts, business interruption, depreciation of asset values, poor performance of		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
			reputational damage.	investments, reputational damage.		
Insurance						
• Increased demand from air conditioning and refrigeration. May lead to blackouts, brownouts and load shedding. Business interruption and costs of insured losses. Health risks to staff should power fail. Increase in very hot days - Damage to transport infrastructure i.e. rail bucking, tarmac melt, risks to supply chain, productivity and business interruption for investments. Costs of insured losses. • Decreased number of cold days - Reduction in demand for cold weather products, negative impacts on investments in these sectors. Cost of insured losses.	• Power cuts, asset damage, business interruption. Poor performance of investments affected by flooding and secondary impacts i.e. power cuts, supply chain failures. Cost of insured losses.	• Power cuts, business interruption. Poor performance of investments affected by reduced rainfall and secondary impacts i.e. power cuts, supply chain failures. Cost of insured losses.	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Staff unable to get to work. Power cuts, business interruption, depreciation of asset values, poor performance of investments, reputational damage. Cost of insured losses.	• Significant disruption likely to international trade. Business continuity issues. Raised insurance costs. Risk of loss of low lying assets. Power cuts, business interruption, depreciation of asset values, poor performance of investments, reputational damage. Cost of insured losses.		
Other Financial Services						
• Increased demand from air conditioning and refrigeration. May lead to blackouts, brownouts and load shedding. Business interruption. Health risks to staff should power fail. • Increase in very hot days - Damage to transport infrastructure i.e. rail bucking, tarmac melt, risks to supply chain, productivity and business interruption for investments.	• Power cuts, asset damage, business interruption. Poor performance of investments affected by flooding and secondary impacts i.e. power cuts, supply chain failures.	• Power cuts, business interruption. Poor performance of investments affected by reduced rainfall and secondary impacts i.e. power cuts, supply chain	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Staff unable to get to work. Power cuts, business interruption,	• Significant disruption likely to international trade. Business continuity issues. Raised insurance costs. Risk of loss of low lying assets. Power cuts, business		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
• Decreased number of cold days - Reduction in demand for cold weather products, negative impacts on investments in these sectors.		failures.	depreciation of asset values, poor performance of investments, reputational damage.	interruption, depreciation of asset values, poor performance of investments, reputational damage.		
Food Resources						
Food Imports						
• Exceedence of thermal tolerance of poultry and livestock species resulting in more expensive and lower availability of imports. • Reduced agricultural output due to increased incidence of pests and diseases as warmer temperatures mean pathogens can survive the winter. Increased cost and lower availability of imports. • Reduced agricultural output from areas affected by drought and those that are already marginal or where crops are at their thermal comfort thresholds. Rising costs, reduced import availability, alternative sources may have to be found. Increased risk of sterility in Thai rice crops leading to harvest failure.	• Damage to agricultural assets, risk to workers, loss of crops and livestock. Transportation disruption. Reduced agricultural output in affected regions, raising the cost and decreasing the availability for imports.	• Risks to feedstock and water supplies reducing availability and increasing costs. Increased desertification in some parts of northern China. Reduced agricultural outputs in affected regions, raising the cost and decreasing the availability for imports. Reduced rainfall would lead to a reduction in Thai rice harvest, leading to higher rice prices. Increased requirement for food aid.	• Business interruption, power cuts, transport delays, loss of assets and infrastructure, damage to crops and loss of livestock. Rising costs of grain and other feed due to climate change impacts resulting in more expensive poultry and grain fed meat imports (beef). Greater requirement for food aid globally raising commodity prices and reducing supply raising commodity prices and reducing supply.	• Loss of low lying land, particularly rice production areas in southern China and Thailand. Disruption to transportation. Increased costs and decreased availability of imports.	• Depletion of marine mollusc populations globally due to increasing acidity will increase costs of oyster shell and cockle grit – vital components of chicken feed. Increasing cost of poultry. Will also dramatically reduce availability of shellfish, and increase the costs for importing. Reduced fishing yields will also increase costs.	
Food wholesale and retail						

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• Increased proliferation of bacteria and microorganisms leading to greater risk of conditions such as salmonella poisoning. • Risk of public health incident and transmission to humans and reputational damage for the industry. Products will have a shorter shelf life. Higher refrigeration costs are likely for processing plants and abattoirs.	• Risk of flooding, power cuts, asset damage and business interruption.	• Raised operating costs for water intensive industries such as food processing. Possible supply interruption leading to business interruption and increased prices.	• Risk to assets, infrastructure, energy supplies, employees, transport and business interruption leading to failures of JIT delivery and increased risk of spoilage in transported goods. Potential loss of shipping vessels. Increased costs and decreased availability of imports.	• Significant potential for influx of climate change refugees from neighbouring flooded regions increasing demand and raising prices. Also risk of contamination to water supplies which could impact production. Risk of loss of low lying assets i.e. warehouses.		
Human Health						
Accidents / external health stresses						
	• Increased number of accidents, particularly RTAs, and risks of injury from flooding (injury and drownings) • Increased risk of injury from lightning strike, wildfire; damage to buildings causing injury		• Increased risk of injury from debris, gusting, drowning, RTAs			• Decrease in visibility - increased number of RTAs

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
Respiratory Diseases						
• Changes in the survival of some pathogens • Potentially greater incidence of some respiratory diseases caused by pathogens influenced by temperature change	• Changes in the survival of some pathogens and changes in the incidence of some respiratory diseases					
Vector Borne Diseases						
• Increased potential for some vectors and potentially a greater incidence of some vector borne diseases	• Increased potential for some vectors and potentially a greater incidence of some vector borne diseases					
Water Borne Diseases						
• Increased proliferation of bacteria and microorganisms leading to greater risk of food poisoning and diarrheal illnesses	• Flooding, increased proliferation of bacteria and microorganisms leading to greater risk of diarrheal diseases		• Increased incidence of flooding and waterborne diseases (particularly diarrheal diseases) as a result			
Chronic Health Conditions						
• Higher average temperatures may have a negative impact on air quality, which could result in increased mortality and morbidity associated with respiratory and cardiovascular conditions • Decrease in cold days – reduction in cold weather harvesting of vulnerable populations • Increase in very hot days and hot						

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
nights – increase in hot weather harvesting of vulnerable populations						
Health Infrastructure						
	• Increased number of RTAs lengthening ambulance response times and putting paramedic crews at greater risk of themselves being involved in RTAs • Risk of flooding of buildings and assets and disruption to services • Increased risk of damage to hospital buildings and communication masts and loss of electricity	• Increased operation costs as additional water supplies are sought, or in a worst case scenario situation - water supply interruptions which could potentially limit ward availability and surgery schedules although hospitals are priority users so disruption is highly unlikely	• Increased risk of damage to hospital buildings and communication masts and loss of electricity • Potential delays to deliveries of food and medical supplies due to interruptions of maritime and road freight	• Flooding, loss of healthcare facilities and relocation costs		• Decrease in visibility – increased number of RTAs, lengthening ambulance response times and putting paramedic crews at greater risk of themselves being involved in RTAs
External Infrastructure						
• Risks to food, energy and water supplies from the mainland and overseas – reducing availability and increasing costs	• Risks to food, energy and water supplies from the mainland and overseas – reducing availability and increasing costs		• Risks to food, energy and water supplies from the mainland and overseas – reducing availability and increasing costs • Delays and interruptions to shipping and land	• Potential population displacement from flooded areas which may stretch health infrastructure and sanitary conditions • Forced migration of environmental refugees could		• Risks to food and water supplies from the mainland and overseas – reducing availability and increasing costs. • Reduced availability of

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
			transportation of food and other products	enhance transmission of disease due to intermingling of populations with introduction of novel diseases into non-immune populations • Risk of flooding to water treatment facilities potentially causing industrial contamination of drinking water		food may lead to greater domestic raising of food ie poultry which could increase the risks from Avian Influenza. Conversely changes to wild bird migration routes due to temperature changes in northern Eurasia may affect the incidence of bird flu in Hong Kong by affecting the size and seasonal distribution of the host population of visiting migrant birds

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
Leisure and Tourism						
Hotels						
• Increased demand from air conditioning and refrigeration in hotels, tourist attractions and transport hubs. Increased demand combined with supply constraints may lead to power cuts and business interruption / reputational damage. Health risks to staff and visitors should power fail. Reduced thermal comfort for overseas visitors. • Increase in very hot days - Negative health impacts on elderly guests – compounded in the event of power cuts.	• Power cuts, asset damage, business interruption, risk to visitor health and safety during flood events. Secondary impacts i.e. power cuts, supply chain failures. Poor visitor perception of Hong Kong, adverse publicity.	• Power cuts, asset damage, business interruption. Risk to visitor health and safety during flood events. Secondary impacts i.e. power cuts, supply chain failures. Reduction in water quality. Poor visitor perception of Hong Kong, adverse publicity.	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Staff unable to get to work. Power cuts, business interruption, reputational damage – Hong Kong perceived to be a 'dangerous' destination.	• Significant disruption likely to international trade. Business continuity issues. Raised insurance costs. Risk of loss to low lying assets including significant number of hotels. Power cuts, business interruption, infrastructure damage, depreciation of asset values, reputational damage to Hong Kong viewed as being an "unprepared destination".		
Tourist attractions / tourism services						
• Increased demand from air conditioning and refrigeration in hotels, tourist attractions and transport hubs. Increased demand combined with supply constraints may lead to power cuts and business interruption / reputational damage. Health risks to	• Power cuts, asset damage, business interruption. Risk to visitor health and safety during flood events. Secondary impacts i.e. power	• Risk to visitor health and safety during flood events. Secondary impacts i.e. power cuts, supply chain failures.	• Damage to assets and infrastructure including communications. Reduction in quality / availability of some tourism	• Significant disruption likely to international trade. Business continuity issues. Raised insurance costs. Risk of loss to low		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
staff and visitors should power fail. Reduced thermal comfort for overseas visitors. Possible increases in outward tourism as Hong Kong residents seek cooler climes during the hottest times of the year. Reduction or even loss of some species upon which eco-tourism depends leading to a potential reduction in eco-tourists. • Increase in very hot days - Negative health impacts on elderly guests.	cuts, supply chain failures. Reduction in quality / availability of some tourism activities eg. outdoor tourism attractions or events. Poor visitor perception of Hong Kong, adverse publicity.	Reduction in quality / availability of some tourism activities i.e. golf courses, water rides in theme parks. Reduction in water quality. Poor visitor perception of Hong Kong, adverse publicity. Reduction or even loss of some species upon which eco-tourism depends leading to a potential reduction in eco-tourists.	activities eg. outdoor tourism attractions or events. Risk of loss of life and limb. Staff unable to get to work. Power cuts, business interruption – Hong Kong perceived to be a "dangerous" destination.	lying assets Loss of mangroves and other species at Mai Po and Deep Bay, reduction or even loss of some species upon which eco-tourism depends leading to a potential reduction in eco-tourists. Power cuts, business interruption, infrastructure damage, depreciation of asset values, reputational damage to Hong Kong viewed as being an "unprepared destination".		
Transportation						
• Increased demand from air conditioning and refrigeration. Risk of power cuts and business interruption / reputational damage. Health risks to staff and visitors should power fail. Reduced thermal comfort for overseas visitors. Possible increases in outward tourism as Hong Kong residents seek cooler climes	• Power cuts, asset damage, business interruption. Risk to visitor health and safety during flood events. Secondary impacts i.e. power cuts, supply chain failures.	• Risk to visitor health and safety during flood events. Secondary impacts i.e. power cuts, supply chain failures. Risks of interruption to transport services	• Damage to assets and infrastructure including communications. Risk of loss of life and limb. Staff unable to get to work. Power cuts, business	• Significant disruption likely to international trade. Business continuity issues. Raised insurance costs. Risk of loss to low lying assets i.e. the runway at Chek		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
during the hottest times of the year. Reduced lift for aircraft potentially causing delays and passengers left stranded at the airport. Loss of ecotourism revenue. • Increase in very hot days - Negative health impacts on elderly guests. Impacts of extreme temperatures on transport include damage to infrastructure i.e. buckling of rail tracks, melting tarmac, loss of thermal comfort in some forms of transport i.e. cable car. Disruption to sightseeing and visitor dissatisfaction as a result.	Interruption to transport services. Passengers stranded at the airport raising operating costs and visitor dissatisfaction, adverse publicity.	i.e. MTR, buses, aviation. Passengers stranded at the airport raising operating costs and visitor dissatisfaction. Loss of ecotourism revenue.	interruption, interruption to mass transit system and sight seeing, grounding of flights, stoppage of ferries and passengers left stranded at the airport / terminals, reputational damage – Hong Kong perceived to be a “dangerous” destination. Loss of ecotourism revenue.	Lap Kok. Power cuts, business interruption, infrastructure damage, depreciation of asset values, reputational damage to Hong Kong viewed as being an “unprepared destination”. Loss of fares from ecotourists.		
Water Resources						
Hong Kong Impounding and Service Reservoirs • Increased consumer demand for water. Greater rates of evaporation leading to reductions in raw water yield. Possible risk of power interruptions leading to interruptions in water pumping and treatment.	• Reduced water quality. Reduced yield due to increase in wet season overflow. Possible damage to dam structures from over topping. Possible damage to surrounding property and assets from overflow flooding.	• Reduced yield due to reduction in dry season. • Rainfall leading to risk of supply interruptions with subsequent socio-economic damage, rising costs, health impacts and reputational damage.	• Reduced water quality. Increased risk of reservoir overflow. Possibility of reduced yield as a result. Possible damage to dam structures. Possible damage to surrounding property and assets from overflow			

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
	Increased risk of power cuts, business interruption and inability of staff to get to work – possibly reducing operational performance. Risk to staff life and limb. Asset damage. Reputational damage.		flooding. Increased risk of power cuts, business interruption and inability of staff to get to work – possibly reducing operational performance. Risk to staff life and limb. Asset damage. Reputational damage.			
Water Supply Imports from Dongjiang						
• Increased consumer demand for water. Greater rates of evaporation leading to reductions in raw water yield. Reduction in water quality from erosion, salinity etc. Greater processing requirements. Possible risk of power interruptions leading to interruptions in water pumping and treatment.	• Reduced water quality. Reduced yield due to increase in wet season overflow. Possible damage to dam structures from over topping. Possible damage to surrounding property and assets from overflow flooding. Increased risk of power cuts, business interruption and		• Reduced water quality. Increased risk of reservoir overflow. Possibility of reduced yield as a result. Possible damage to dam structures. Possible damage to surrounding property and assets from overflow flooding. Increased risk of power cuts, business	• Increased salinity of the PRD, possible salinization of freshwater aquifers. Increased risk of flooding leading to industrial pollution of the water supply.		

Increase in Surface Temperatures	Increase in Heavy Rain, Thunderstorm Days etc.	Increase in Frequency / Severity of Drought and Years with Low Annual / Seasonal Rainfall	Increase in Frequency and / or Severity of Extreme Weather Events eg Tropical Cyclones	Sea Levels Rise	Increase in Ocean Acidity	Other Impacts
	inability of staff to get to work – possibly reducing operational performance. Risk to staff life and limb. Asset damage. Reputational damage. Increased risk of flooding leading to industrial pollution of the water supply.		interruption and inability of staff to get to work – possibly reducing operational performance. Risk to staff life and limb. Asset damage. Reputational damage. Increased risk of flooding leading to industrial pollution of the water supply.			

Annex B

Review of Extant Adaptive Capacity in Hong Kong by Sector

Table B1 General Existing Policies / Measures that may Contribute to Adaptive Responses (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Reference
Environmental Protection Department	Inter-departmental Working Group on Climate Change (IWGCC)	Comprised of 5 bureaux and 16 departments, the Inter-departmental Working Group on Climate Change was established in 2007. The Working Group is to co-ordinate, develop and promote actions in reducing GHG emissions and adapting to climate change.	Not Specified	Mandatory	Prepare	The bureaux and departments involved include: Environment Bureau Development Bureau Transport and Housing Bureau Food and Health Bureau Education Bureau Economic Analysis and Business Facilitation Unit, Financial Secretary's Office Environmental Protection Department Hong Kong Observatory Electrical and Mechanical Services Department Housing Department Planning Department Agriculture, Fisheries and Conservation Department Architectural Services Department Buildings Department Civil Engineering and Development Department Drainage Services Department Food and Environmental Hygiene Department Health Department Home Affairs Department Leisure and Cultural Services Department Transport Department Water Supplies Department	Actions in Hong Kong in Climate Change. n.d. Environmental Protection Department. <http://www.epd.gov.hk/epd/english/climate_change/hkactions.html> [Accessed 29 Jan 09]
Environmental Protection	Joint exercise on marine	The exercise was conducted to ensure the comparability	Not Specified	Mandatory	Prepare	-	Co-operation with the Mainland.

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Reference
Department	monitoring with the State Oceanic Administration's National Marine Environment Monitoring Centre, South China Sea Environment Monitoring Centre and Government Laboratory	of marine monitoring data between Hong Kong and the Mainland. The exercise was to prepare for Hong Kong's participation in the National Marine Environment Monitoring Network.					Environmental Protection Department. <http://www.epd.gov.hk/epd/misc/ehk03/eng/hk/hk_collaboration.html> [Accessed 8 June 09]
Hong Kong Observatory	Joined the Asia-Pacific satellite data re-transmission services	The Observatory can share satellite data with other meteorological services in the region. Satellite data is one of the important sources of data for numerical weather prediction models.	Not Specified	Mandatory	Prepare	-	Hong Kong Observatory 2007-2008. <http://www.weather.gov.hk/abouthko/hko2007-2008e.pdf> [Accessed 8 June 09]
Hong Kong Observatory	Educational Package on Climate Change	The package comprises of an animated cartoon DVD, a booklet, a power point presentation CD, climate change factsheets and a copy of the "*An Inconvenient Truth*", and was distributed to schools in Hong Kong in 2007. The aim is to increase awareness and understanding of climate change and its impacts.	Not Specified	Voluntary	Prepare	The contents of the package can be viewed online. HKO has also given presentations in primary and secondary schools to promote awareness and understanding of climate change in Hong Kong.	Educational Package on Climate Change. 2007. Hong Kong Observatory. <http://www.hko.gov.hk/climate_change/ed_package/start.htm> [Accessed 29 Jan 09]
Education Bureau	Provision of teacher	These programmes aim at	Not Specified	Voluntary	Prepare	-	Example of teacher training programme:

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Reference
	development programmes and support materials on climate change	introducing effective strategies, enriching teachers' knowledge and providing support in teaching climate change in schools					"Cross-KLA subject collaboration on the learning and teaching of climate change" ＜Activity ID: CDI020071765＞ Example of support materials: "Climate change — a cross-curricular learning and teaching resource pack"
Education Bureau	Organisation of student activities and school events on climate change	These activities and events aims at strengthening students' understanding of the climate change issue and providing opportunities for students to apply what they have learnt	Not Specified	Voluntary	Prepare	-	Example: Student Environmental Protection Ambassador Scheme 2009/09 (Theme: climate change) ＜http://www.childhealthhongkong.com/school_system/2009_10/files/EDB CM08128E.pdf＞
HKO (together with Guangdong Meteorological Bureau, the Macao Meteorological and Geophysical Bureau, and the Hongkong	*Climate is changing, act now!* Exhibition	The aim was to improve the public's understanding of climate, including the causes of climate change and its impacts and mitigation measures.	Not Specified	Voluntary	Prepare	-	Climate is Changing, Act Now! Exhibition. n.d. Hong Kong Observatory. <http://www.weather.gov.hk/climate_change/act_now_exhibition2008/exhibition_e.htm> [Accessed 29 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Reference
and Shanghai Banking Corporation Limited)							
Emergency Support Unit Security Bureau	Contingency Plan for Natural Disasters	Summary of Government alerting systems and organizational framework in responding to natural disasters and severe weather. The controlling authorities consist of three phases. Phase I deals with rescue of life, protection of property and containment of further deterioration Phase II deals with returning the community to an acceptable condition which satisfies the physical, psychological, and social needs of the community. Phase III is to restore the community to the state prior to the disaster.	Not Specified	Mandatory	Prepare, respond	Natural disasters and severe weather conditions which this report covers include: tropical cyclones, rainstorms, floods, landslips, thunderstorms, and tsunamis. Phase One is under the direction of emergencies services such as Fire Services Department and/or Hong Kong Police Force with the support from other departments and agencies. Phase Two is led by Home Affairs Department is the lead coordinating department with cooperation from Social Welfare Department and Housing Department. Phase Three includes Departments involved include Home Affairs Department, Highways Department, Housing Department, and other departments with a heavy emphasis on public works.	Contingency Plan for Natural Disasters <http://www.sb.gov.hk/eng/emergency/ndisaster/CPND%20(3-2009).pdf> [Accessed 16 Sep 09]
Emergency Support Unit Security Bureau	Emergency Response System	The policy of the emergency response system of Hong Kong which operates under a graduated three tier system through the three phases of emergency response. Tier One involves emergency services operating under their own	Not Specified	Mandatory	Prepare, respond	Tier One includes command and control centres that assess the situation, Police Headquarters Command and control Centre and Police Regional Higher Commands, and Fire Services Communication Centre. Tier Two generally include incidents which are likely to have threats to life, property, security, and which may grow to be more	The Government of Hong Kong Special Administrative Region Emergency Response System <http://www.sb.gov.hk/eng/emergency/ers/ers.htm> [Accessed 16 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Reference
		direction. If necessary, Tier One services will alert the Security Bureau Duty Officer thus activating Tier Two Responses involving the SBDO and Emergency Support Unit. Tier Three involves the Emergency Monitoring and Support Centre and it is activated when a major incident involving threats to life, property, and security.				complex. Tier operates through the three phases of emergency response which are rescue, recovery and restoration.	
International and Local NGOs	Combat Climate Change Coalition (CCCC)	Comprised of Greenpeace China, Oxfam Hong Kong and WWF Hong Kong, and twelve local NGOs, CCCC aims to urge the HK Government to cut greenhouse gases and develop a holistic policy for climate change.	Not Specified	Voluntary	Prevent	The CCCC goals reflect those of mitigation strategies rather than adaptation. Local NGOs include: Breakthrough Limited Catholic Messengers of Green Consciousness Hong Kong Confederation of Trade Unions Hong Kong Church Renewal Movement Hong Kong Social Workers' General Union Roundtable Network Senior Citizen Home Safety Association St. James' Settlement - Community Oriented Mutual Economy The Boys' & Girls' Clubs Association of Hong Kong The Chinese YMCA of Hong Kong The Hong Kong Asthma Society The Hong Kong Federation of Women's Centres	Greenpeace China, Oxfam Hong Kong, WWF Hong Kong and Twelve Other Community Organisations Ally against Climate Change < http://www.greenpeace.org/china/en/press/release/establish-cccc-20090525> [Accessed 16 Sep 09]

Table B2 Existing Policies / Measures that may Contribute to Adaptive Responses to Agriculture (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
General Policies / Measures								
The Agriculture, Fisheries and Conservation Department	Public Health (Animals and Birds) (Chemical Residues) Regulation	The regulation aims to control feeding of chemicals to food animals. It also established the "Maximum Residue Limits (MRL)" for 37 other chemicals in meat, offal or milk with limits in line with international standards.	Not Specified	Mandatory	Prepare	-	• Human health risks	CAP 139N Public Health (Animals and Birds) (Chemical Residues) Regulation <http://www.legislation.gov.hk/eng/home.htm>[Accessed 2 June 09]
The Agriculture, Fisheries and Conservation Department	Poultry (Slaughtering for Export) Regulations	It regulates the poultry slaughtering for exporting to other countries and districts including licences, premises and equipments, method of slaughter and how to prepare poultry products.	Not Specified	Mandatory	Prepare	-	• Increased proliferation of bacteria and microorganisms • Human health risks	CAP 139E Poultry (Slaughtering for Export) Regulations <http://www.legislation.gov.hk/eng/home.htm>[Accessed 3 June 09]
The Agriculture, Fisheries and Conservation Department	Public Health (Animals and Birds) (Licensing of Livestock Keeping) Regulation	The regulation states the application and revocation of licence of livestock keeping in Hong Kong.	Not Specified	Mandatory	Prepare	-	• Increased proliferation of bacteria and microorganisms • Human health risks	CAP 139L Public Health (Animals and Birds) (Licensing of Livestock Keeping) Regulation <http://www.legislation.gov.hk/eng/home.htm> [Accessed 3 June 09]
The Agriculture, Fisheries and Conservation Department	Public Health (Animals and Birds) Regulations	The general regulations which control the public health imported of animals and birds.	Not Specified	Mandatory	Prepare			CAP 139A Public Health (Animals and Birds) (Licensing of Livestock Keeping) Regulation <http://www.legislation.gov.hk/eng/home.htm>

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								[Accessed 16 Sep 09]
The Agriculture, Fisheries and Conservation Department	Agricultural Policy	The agricultural policy is described on the Agriculture, Fisheries, and Conservation Department's website as one which follows the general policy of the free market. The role of the government is to provide basic infrastructure and technical support but leaves the industry to adjust to market forces.	Not Specified	Mandatory	Prepare			AFCD Agriculture in HK <http://www.afcd.gov.hk/english/agriculture/agr_hk/agr_hk.html> [Accessed 16 Sep 09]
Pig Husbandry								
Health, Welfare and Food Bureau	Voluntary Surrender of Pig Farming Licences	The Voluntary Surrender of Pig Farming Licences was launched in April 2006. The scheme aims to reduce the number of pig farms in Hong Kong thereby reducing associated public health and environmental pollution problems. Under the scheme, pig farmers are granted ex gratia payments or loans for surrendering their livestock licences or terminating their farm business.	The granted ex gratia payments or loans to pig farmers will range between $450,000 and $25.45 million depending on the size of their farms.	Voluntary	Prevent	As to October 2008, 222 pig farmers had surrendered their licences under this scheme.	• Increased proliferation of bacteria and microorganisms • Human health risks	Voluntary Surrender of Pig Farming Licences <http://www.fhb.gov.hk/en/committees/board/2006/paper20060406_63.html> [Accessed 2 June 09] Hong Kong the fact: agriculture and fisheries <http://www.gov.hk/en/about/abouthk/factsheets/docs/agriculture.pdf>[Accessed 2 June 09]
Poultry Production								
Food & Health Bureau	Live chicken import cap	Hong Kong limits the number of live chickens import from Mainland. The bureau will monitor the live chicken supply and maintain close liaison with the trade. The number of imported live chickens will be suitably adjusted for major festive occasions to meet the	Not Specified	Mandatory	Prepare	-	• Increased proliferation of bacteria and microorganisms • Human health risks	Live chicken import cap to stay <http://news.gov.hk/en/category/healthandcommunity/070904/html/070904en05004.htm> [Accessed 3 June 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		stronger demand.						
Food & Health Bureau	Reduce live chicken number in Hong Kong	Agriculture, Fisheries and Conservation Department limited the live chicken population in Hong Kong of 2,000,000 in 2006.	Not Specified	Mandatory	Prepare	-	• Increased proliferation of bacteria and microorganisms • Human health risks	Progress of Comprehensive Plan of Action to Deal with the Global Problem of Avian Influenza <http://www.fhb.gov.hk/download/committees/board/doc/info_paper_6.pdf> [Accessed 9 June 09]
Agriculture, Fisheries and Conservation Department	Voluntary Surrender Scheme for Poultry Farmers	The Voluntary Surrender Scheme for Poultry Farmers was launched in 2005. The scheme aims to reduce the number of pig farms in Hong Kong thereby reducing associated public health and environmental pollution problems. Under the scheme, Farmers are granted ex gratia payments.	The Government has set aside $344.5 million for making ex-gratia.	Voluntary	Prevent	As to October 2008, 143 poultry farmers had surrendered their licences under this scheme.	• Increased proliferation of bacteria and microorganisms • Human health risks	Voluntary Surrender Scheme for Poultry Farmers <http://www.info.gov.hk/gia/general/200508/05/08050126.htm> [Accessed 2 June 09] Hong Kong the fact: agriculture and fisheries <http://www.gov.hk/en/about/abouthk/factsheets/docs/agriculture.pdf> [Accessed 2 June 09] Voluntary surrender scheme opens <http://www.news.gov.hk/en/category/healthandcommunity/050805/html/050805en05003.htm> [Accessed 2 June 09]
Fruit, Flower and Vegetable Production								
Agriculture, Fisheries and Conservation Department & the Vegetable Marketing Organization	Accredited Farm Scheme	The objective of Accredited Farm Scheme is to protect the environment and consumers against residues of agricultural pesticides, which was introduced in 1994. Strictly monitoring is carried out in accredited farms	Not Specified	Voluntary	Prepare	As to the end of 2007, there were 225 farms in Hong Kong and the mainland of China accredited, supplying more than 80 tonnes of accredited produce	• Changes in disease regime • Human health risks	Accredited Farm Scheme <http://www.afcd.gov.hk/english/agriculture/agr_accfarm/agr_accfarm_intro/agr_accfarm_intro.html> [Accessed 2 June 09] Hong Kong the fact:

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		on uses of pesticides and produce is further checked for pesticide residue before they are sold at accredited retail outlets.				daily.		agriculture and fisheries <http://www.gov.hk/en/about/abouthk/factsheets/docs/agriculture.pdf>[Accessed 2 June 09]

Table B3 Existing Policies / Measures that may Contribute to Adaptive Responses to Aquaculture and Fisheries (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Agriculture, Fisheries and Conservation Department	Committee on Sustainable Fisheries	The committee was set up in 2006 to study the long term goals and directions as well as feasible options and implementation strategy for the sustainable development of the fisheries industry, with regard to fisheries trends, ecological sustainability, economic viability and other relevant factors, such as financial implications and social impact. It also considers the fisheries management options to conserve fisheries resources in Hong Kong waters.	Not Specified	Voluntary	Prevent, Prepare	-	• Depletion of fish stocks	Agriculture, Fisheries and Conservation Department Annual Report 2007-2008 <http://www.afcd.gov.hk/english/publications/publications_dep/publications_dep.html> [Accessed 3 June 09]
Agriculture, Fisheries and Conservation Department	Fisheries Development Loan Fund	The loan aims to promote sustainable fisheries development. It helps fishermen switch to sustainable fisheries or related operations and develop sustainable aquaculture businesses.	$290 million	Voluntary	Prevent, Prepare	-	• Depletion of fish stocks	Fisheries Development Loan Fund <http://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_techsup/fish_cap_fdlf.html> [Accessed 3 June 09]
Agriculture, Fisheries and Conservation Department	The Fisheries Education Centre	The education centre promotes the public awareness of the need and importance for fisheries conservation.	Not Specified	Voluntary	Prepare	In 2007, there were 4000 people visiting the centre.	• Depletion of fish stocks	Aberdeen Fisheries Education Centre opens <http://afcd.gov.hk/textonly/english/publications/publications_press/pr382.html> [Accessed 3 June 09]
Agriculture, Fisheries and Conservation Department	Fisheries Protection Ordinance	The ordinance aims to protect fish and against destructive fishing practices, such as fishing with explosives, toxic substances, electricity, dredging and suction devices.	Not Specified	Mandatory	Prevent	-	• Depletion of fish stocks	CAP 171 Fisheries Protection Ordinance <http://www.legislation.gov.hk/eng/home.htm> [Accessed 3 June 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Agriculture, Fisheries and Conservation Department	Marine Fish Culture Ordinance	Under the ordnance, all marine fish culture activities in Hong Kong are required to operate under licence in designated fish culture zones.	Not Specified	Mandatory	Prevent, Prepare	-	• Depletion of fish stocks • Human health risks	CAP 353 Marine Fish Culture Ordinance <http://www.legislation.gov.hk/eng/home.htm> [Accessed 3 June 09]
Agriculture, Fisheries and Conservation Department	Fish Health Inspection Programme	The programme aims to promote the sustainable fish culture in Hong Kong and reduce the negative environmental impact. Early detection of fish disease outbreaks, training was provided to fish farmers on disease prevention measures and fish disease diagnosis and treatment services were given in case of an outbreak. The culture techniques were also provided to farmers.	Not Specified	Voluntary	Prevent, Prepare	-	• Human health risks • Depletion of fish stocks	Agriculture, Fisheries and Conservation Department Annual Report 2007-2008 <http://www.afcd.gov.hk/english/publications/publications_dep/publications_dep.html> [Accessed 3 June 09]
Agriculture, Fisheries and Conservation Department	Marine Fish (Marketing) Ordinance	The ordnance aims to ensure the orderly marketing of fresh marine fish. It regulates the wholesale marketing of marine fish and against the illegal marine fish selling.	Not Specified	Mandatory	Prevent	-	• Human health risks	CAP 291 Marine Fish (Marketing) Ordinance <http://www.legislation.gov.hk/eng/home.htm> [Accessed 3 June 09]
Agriculture, Fisheries and Conservation Department	Regular monitoring work in fish culture zones	The Department conducts regular monitoring on the water quality of fish culture zones and implements red tide monitoring and management measures. Rapid risk assessment will be reported after red tide incidents.	Not Specified	Voluntary	Prevent, Prepare, Respond	-	• Depletion of fish stocks • Human health risks	Agriculture, Fisheries and Conservation Department Annual Report 2007-2008 <http://www.afcd.gov.hk/english/publications/publications_dep/publications_dep.html> [Accessed 3 June 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Agriculture, Fisheries and Conservation Department	AFCD Accredited Fish Farm Scheme	Good aquaculture practices and hygiene standards must be met and a predefined management system must be followed by participating farms. This improves transparency and safety of local aquaculture products and allows products that have passed the quality assurance tests with satisfactory results to be marketed under the unique brand name of the scheme.	Not Specified	Voluntary	Prevent	-	• Human health risks	AFCD Accredited Fish Farm Scheme <http://hkaffs.org/en/index.html> [Accessed 21 December 09]

Table B4 Existing Policies / Measures that may Contribute to Adaptive Responses to Biodiversity and Nature Conservation (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Agriculture, Fisheries and Conservation Department (AFCD)	Protection of Endangered Species of Animals and Plants Ordinance	The Ordinance gives effect to CITES in Hong Kong. A licence is required to import, introduce, export, re-export or in possession of the listed species. The Ordinance applies to all parties who conduct activities involving endangered species except for those situations specified in the Ordinance. Amendments are made to the Ordinance regularly corresponding to CITES changes.	Not Specified	Mandatory	Prevent, Prepare	A reward scheme has been set up to provide financial incentive for the public to provide information on illegal import, export and possession of endangered species. The Endangered Species Resource Centre has been established to promote public awareness on endangered species protection. The department also have a range of activities and programs in place to raise public awareness and improve the understanding of endangered species protection.	• Changes in species distributions / occurrence • Loss of some species • Other stresses on species associated with human activities	Endangered Species Protection. 2006. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_end/con_end.html> [Accessed 30 Jan 09] Protection of Endangered Species of Animals and Plants Ordinance in *The Ordinance*. 2006. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_end/con_end_reg/con_end_reg_ord/con_end_reg_ord.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	Wild Animals Protection Ordinance	The Ordinance protects important habitats by designating the areas as restricted areas under Schedule 6 to restrict access to these areas. Currently, there are 3 restricted areas namely Yim Tso Ha Egretry, Mai Po Marshes and Sham Wan Beach. The purpose is to protect wild animals (and their eggs and nests) specified under Schedule 2 of the Ordinance. A permit issued by the Department is	Not Specified	Mandatory	Prevent	Hunting, disturbance to the nests and eggs of protected wild animals are prohibited except in accordance with a special permit. Possession of protected wild animals is also not allowed. Feeding is also not allowed.	• Changes in species distributions / occurrence • Loss of some species / ecosystems / habitats • Other stresses on species / ecosystems / habitats associated with human activities	Chapter 170 Wild Animals Protection Ordinance in Bilingual Laws Information System. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=170&Count=30&Collapse=170.3#170.3> [Accessed 30 Jan 09] Nature Outlook: Review of

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		required to gain access into these restricted areas.						Nature Conservation Policy. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/con_nncp_prce/con_nncp_prce.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department; Ocean Park Hong Kong	Conservation of sea turtles in Hong Kong	The sea turtles are protected through the Wild Animals Protection Ordinance and the Protection of Endangered Species of Animals and Plants Ordinance. In addition to these two Ordinances (which led to the restriction of the nesting site), AFCD has also implemented various measures to conserve the species such as satellite tracking and artificial incubation.	Not Specified	Mandatory	Prepare	Artificial incubation is considered as the last option to help save the sea turtle eggs. This is especially the case when the developing embryos are likely to die due to poor nesting conditions. In addition, incidental observation and records of stranded individuals are kept for study purposes. Two green turtles have also been fitted a satellite transmitter which traced their movement and their migration route. This has provided further understanding on the migration of Green Turtles nesting in the Sham Wan Restricted Area.	• Changes in sea turtle species distributions / occurrence • Loss of some species • Impacts to sea turtle behaviours / adaptations • Other stresses on sea turtle and their ecosystems / habitats associated with human activities	Conservation of sea turtles in Hong Kong. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_fau/con_fau_sea/con_fau_sea_con/con_fau_sea_con.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	The Conservation Programme for the Chinese White Dolphin in Hong Kong	The programme outlines a conservation plan which aims to better manage the habitats of the dolphins, to raise awareness, conduct further population and ecological studies and promote cross-boundary co-operation.	Not Specified	Mandatory	Prepare	Management improvement includes minimising the impacts of coastal development on dolphins and designating more marine protected area.	• Changes in Chinese White Dolphin species distributions / occurrence • Loss of some species • Impacts to Chinese	The Conservation Programme for the Chinese White Dolphin in Hong Kong. 2000. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/publications/publications_con/files/conpgm.pdf> [Accessed

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
							White Dolphin behaviours / adaptations • Stresses on Chinese White Dolphin and their ecosystems / habitats associated with human activities	30 Jan 09]
Lands Department	Practice Note: Application for Tree Felling or Transplanting for private projects	Land owners and their authorised persons are responsible to ensure that no trees are unnecessarily felled and that proposed tree felling or transplanting obtains written consent from the Director of Lands in certain leases.	Not Specified	Mandatory	Prevent	-	• Changes in species distributions / occurrence • Loss of some species • Other stresses on species / ecosystems / habitats associated with human activities	Practice Note: Application for Tree Felling or Transplanting for private projects. 2002. Lands Department. <http://www.landsd.gov.hk/en/images/doc/8-2002.pdf> [Accessed 03 Feb 09]
Agriculture, Fisheries and Conservation Department	Ecological Assessment	Helps to protect ecologically important areas from adverse development impact by requiring proponents of designated projects to avoid causing adverse environmental impacts as far as practicable. If total avoidance is not practicable, the project proponents are required to mitigate the adverse impact to an acceptable level. AFCD is responsible for reviewing ecological assessments in	Not Specified	Mandatory	Prevent	-	• Changes in species distributions / occurrence • Loss of some species / ecosystems / habitats • Other stresses on species / ecosystems / habitats associated with developments	Review of Ecological Assessment of Major Development Proposals. <http://www.afcd.gov.hk/english/conservation/con_nat/con_nat_intro/con_nat_intro_rev.html > [Accessed 11 Nov 09] Environmental Impact Assessment Ordinance - Technical Memorandum . <http://www.epd.gov.hk/eia/english/legis/index3.html > [Accessed 11 Nov 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		environmental impact assessment studies, planning studies and development applications.						
Agriculture, Fisheries and Conservation Department; Country and Marine Parks Authority	Country Parks Ordinance	The Ordinance provides for the designation, control and management of country parks and special areas in Hong Kong. The ecology and biodiversity of these areas are conserved and recreational and educational needs are met at the same time. Developments and activities are regulated to ensure the areas are preserved. In addition to Country Parks, smaller areas with high conservation value – such as special areas, are also protected. These special areas, in general, emphasize more on conservation and education than on recreation.	Not Specified	Mandatory	Prevent	-	• Changes in species distributions / occurrence in country parks and special areas • Loss of some species / ecosystems / habitats in country parks and special areas • Other stresses on species / ecosystems / habitats associated with human activities	Chapter 208 Country Park Ordinance in *Bilingual Laws Information System*. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=196&Count=30&Expand=208#208> [Accessed 30 Jan 09]Nature Outlook: Review of Nature Conservation Policy. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/con_nncp_prce/con_nncp_prce.html> [Accessed 30 Jan 09]
Planning Department	Town Planning Ordinance	Land use is regulated in order to meet the intended use of individual areas (planned by the government, such as residential, commercial or industrial areas). The Ordinance also prevents development or incompatible land uses on ecologically sensitive sites. Both government and private land can be designated as conservation zonings.	Not Specified	Mandatory	Prevent	Conservation zonings categories: *Special scientific interest (SSSI) - areas with rare fauna or flora species or representative habitats; stringent control imposed; all activities require approval from Town Planning Board. * Conservation area (CA), Coastal protection area (CPA) - protect the natural characteristics and landscape of	• Changes in species distributions / occurrence • Loss of some species / ecosystems / habitats • Other stresses on species / ecosystems / habitats associated with developments	Chapter 131 Town Planning Ordinance in *Bilingual Laws Information System*. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=109&Count=30&Collapse=131.2#131.2> [Accessed 30 Jan 09] Nature Outlook: Review of Nature Conservation Policy. n.d. Agriculture, Fisheries and

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						the sites (not necessarily for its ecological value); apart from agricultural and conservation related activities, approval from Town Planning Board is required for all other activities.		Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/con_nncp_prce/con_nncp_prce.html> [Accessed 30 Jan 09]
Town Planning Board	Green Belt Zoning	Allow the development of green corridors by conserving existing landscape features and prevent urban development from dominating by defining an outer limit. Application needs to be submitted to the Board for developments in a Green Belt Zone.	Not Specified	Mandatory	Prevent	-	• Changes in species distributions / occurrence • Loss of some species / ecosystems / habitats • Other stresses on species / ecosystems / habitats associated with developments	Town Planning Board guidelines for application for development within green belt zone under section 16 of the Town Planning Ordinance. 1991. Town Planning Board. <http://www.info.gov.hk/tpb/en/forms/Guidelines/pg10_e.pdf> [Accessed 03 Feb 09]
Town Planning Board	Wetland Buffer Area	To protect the ecological integrity of the fishponds and wetlands within the Wetland Conservation Area (WCA) and to prevent developments that would have a negative off-site impact on the ecological value of fishponds.	Not Specified	Mandatory	Prevent	-	• Changes in species distributions / occurrence in fish ponds and wetlands • Loss of some species / ecosystems / habitats in fish ponds and wetlands • Depletion of fish stocks in fish ponds • Other stresses on species / ecosystems / habitats associated with developments	Town Planning Board Guidelines for application for developments within deep bay area under section 16 of the Town Planning Ordinance. 1999. Town Planning Board. <http://www.info.gov.hk/tpb/en/forms/Guidelines/pg12b_e.pdf> [Accessed 03 Feb 09]
Town Planning Board	Wetland Conservation Area	To conserve the ecological value of the fish ponds which form an integral part of the wetland ecosystem in the Deep Bay Area.	Not specified	Mandatory	Prevent	New developments are not allowed unless it is required to support the conservation of the area or if it is an essential	• Changes in species distributions / occurrence in fish ponds	Town Planning Board Guidelines for application for developments within deep bay area under section 16 of the Town Planning

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						infrastructural project with overriding public support with an ecological impact assessment.	• Loss of some species / ecosystems / habitats in fish ponds • Depletion of fish stocks in fish ponds • Other stresses on species / ecosystems / habitats associated with developments	Ordinance. 1999. Town Planning Board. <http://www.info.gov.hk/tpb/en/forms/Guidelines/pg12b_e.pdf> [Accessed 21 Dec 09]
Agriculture, Fisheries and Conservation Department	Conservation Management of the Ramsar Site	The Mai Po and Inner Deep Bay area was listed as a Wetland of International Importance under the Ramsar Convention to conserve the wetland habitats and the wildlife especially migratory birds at the site. A Conservation Strategy and Management Plan for the Ramsar site is in place to lay down a general framework for the conservation and wise use of the area and to raise public awareness of the importance of Mai Po and Inner Deep Bay wetlands.	Not Specified	Mandatory	Prepare	Sites within the Mai Po and Inner Deep Bay area have also joined the East Asian - Australian Shorebird Reserve Network and the Anatidae Site Network in the East Asian Flyway.	• Changes in species distributions / occurrence, in particular migratory birds at the site • Loss of some species / ecosystems / habitats at the site • Other stresses on species / ecosystems / habitats at the site	Birds of Hong Kong in HK Species. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/hkbiodiversity/speciesgroup/speciesgroup_birds.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	Forests and Countryside Ordinance	Under the subsidiary legislation of the Ordinance - Forestry Regulations, *no person shall without lawful excuse sell, offer for sale, or have in his possession or under his custody or control any portion of* the listed plants. But these regulations do not apply to plants grown outside Hong Kong or on any land held from the Government under a lease, licence or permit or by virtue of an Ordinance.	Not Specified	Mandatory	Prevent	-	• Changes in species distributions / occurrence • Loss of some species • Other stresses on species associated with human activities	Chapter 96 Forests and Countryside Ordinance in *Bilingual Laws Information System*. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=76&Count=30&Expand=96.1#96.1> [Accessed 30 Jan 09] Forestry Regulations. 2006.

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_flo/con_flo_for/con_flo_for.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	Marine Parks Ordinance	An Ordinance to provide for the designation, control and management of marine parks and marine reserves, and for purposes connected therewith. (Enacted 1995)	Not Specified	Mandatory	Prevent, Prepare	For the purposes of this Ordinance, it shall be the duty of the Authority-(a) to make recommendations to the Chief Executive in Council for the designation of areas as marine parks or marine reserves (Amended 34 of 2000 s. 3);(b) to control and manage marine parks and marine reserves, and to take such measures in respect of marine parks and marine reserves as the Authority considers necessary, for the purposes of (i) protecting, restoring and, where the Authority considers necessary, enhancing the marine life in and marine environment of any marine park or marine reserve; (ii) managing the uses of resources in marine parks to meet the needs and aspirations of present and future generations of mankind; (iii) facilitating recreational activities in marine parks; and (iv) providing opportunities for educational and scientific	• Changes in species distributions / occurrence in designated areas • Loss of some species / ecosystems / habitats in designated areas • Other stresses on species / ecosystems / habitats associated with human activities	Hong Kong Ordinances. Marine Parks Ordinance. - Chapter 476. <http://www.hklii.org/hk/legis/en/ord/476/> [Accessed 20 Apr 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						studies in the marine life in and marine environment of marine parks and marine reserves; and(c) generally to administer this Ordinance (Enacted 1995).		
Planning Department	Hong Kong Planning Standards and Guidelines Chapter 10 (HKPSG)	The chapter is divided into several parts. Firstly, some general principles of conservation are reviewed. Secondly, there is a discussion of measures to conserve natural landscapes and habitats, followed by measures to conserve monuments, historical buildings, archaeological sites and other antiquities. A brief review of conservation enforcement is provided at the end.	Not Specified	Mandatory	Prevent	The definition of conservation follows four principles that should be adopted in land use planning: - retain significant landscapes and ecological attributes and heritage features as conservation zones; - restrict uses within conservation zones to those which sustain particular landscapes and ecological attributes and heritage features; - control adjoining use to minimise adverse impacts on conservation zones and optimise their conservation value; and - create, where possible, new conservation zones in compensation for areas of conservation value, which are lost to development.	• Changes in species distributions / occurrence • Loss of some species / ecosystems / habitats • Other stresses on species / ecosystems / habitats associated with developments and human activities	Hong Kong Planning Standards and Guidelines - Chapter 10 (HKPSG). Planning Department. <http://www.pland.gov.hk/tech_doc/hkpsg/english/ch10/ch10_text.htm> [Accessed 20 Apr 09]
Agriculture, Fisheries and Conservation Department	Hong Kong Herbarium	Collect, identify and preserve Hong Kong flora species. The Herbarium supports the studies on the taxonomy, ecology and conservation of flora species in Hong Kong. It provides assistance	Not Specified	Mandatory	Prepare	-	• Loss of some flora species	Hong Kong Herbarium. 2006. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_flo/con_flo_hkh/con_flo_hkh.html>

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		to government departments, researchers and students regards to Hong Kong flora species with its extensive collection and supporting library. The Hong Kong Herbarium also produces the *Check List of Hong Kong Plants* which is updated regularly.						[Accessed 30 Jan 09] Introduction in Hong Kong Herbarium. n.d. Agriculture, Fisheries and Conservation Department. <http://www.hkherbarium.net/Herbarium/frame.html> [Accessed 30 Jan 09]
Environment and Conservation Fund	Environment and Conservation Fund Ordinance	The Environment and Conservation Fund (ECF) was established in 1994 under the Ordinance. ECF supports educational activities, research, technology demonstration and other environmental and conservation related projects and activities.	Approximately $1 billion since establishment (as of Jan 2009)	Voluntary	Prepare	Interested parties may submit an application which will be assessed against a set of criteria.	• Changes in species distributions / occurrence • Loss of some species • Impacts to organism's seasonal behaviours / adaptations	Application for ECF. n.d. Environment and Conservation Fund. <http://www.ecf.gov.hk/en/application/index.html> [Accessed 30 Jan 09] Guide to Application. 2007. Environment and Conservation Fund. <http://www.afcd.gov.hk/english/conservation/con_nncp/con_nncp_new/files/MAGuidetApplication2007.doc> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	Field Investigation	Trial pilots have been set up and monitoring carried out to assess the growth performance of various species in different environments and the effectiveness of a range of tree establishment techniques. In addition, methods to improve seedling establishment including the use of weed mat and tree	Not Specified	Mandatory	Prepare	-	• Changes in species distributions / occurrence • Loss of some species • Impacts to organism's seasonal behaviours / adaptations	Enriching our countryside with native flora. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_flo/con_flo_enr/con_flo_enr.html> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		guard are now in experimental stage.						
Agriculture, Fisheries and Conservation Department	Afforestation	A selection of the seeds of native species has been collected to produce seedlings for afforestation.	Not Specified	Mandatory	Recover	-	• Changes in species distributions / occurrence • Loss of some native species	Enriching our countryside with native flora. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_flo/con_flo_enr/con_flo_enr.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	The Greenhouse of Field Investigation Unit	Based at Tai Tong Nursery, it is equipped with a climate control system as well as environmental growth chambers and seed depository. More than 100 species, especially the more fragile species and orchids have been conserved.	Not Specified	Mandatory	Prepare	-	• Loss of some species, especially the more fragile species and orchids	Conserving the rare and endangered flora. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_flo/con_flo_con/con_flo_con.html> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department	New Nature Conservation Policy (2004)	The policy aims to protect and conserve biodiversity for the present and future generation, while taking into account of the social and economic aspects. The objective is to identify, monitor and assess ecosystems, conservation areas, activities effecting biodiversity, and promote biodiversity conservation. Works such as research, surveys and raising awareness are conducted in partnership with NGOs, private sectors, communities, the academia and	Not Specified	Mandatory	Prevent, Prepare	Under the new policy, 12 priority sites have been identified based on an agreed scoring system for enhanced protection.	• Changes in species distributions / occurrence • Loss of some species / ecosystems / habitats • Other stresses on species / ecosystems / habitats	New Nature Conservation Policy. 2004. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/con_nncp.html> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		etc.						
Measures under the New Conservation Policy								
Agriculture, Fisheries and Conservation Department	Management Agreement Scheme (MA)	The government provides funding to NGOs, including green groups, educational institutions and community organisations to encourage landowners in entering agreements to enhance conservation measures at prioritised sites. NGOs will have management rights over the landowners after providing funds as an exchange in enhancing identified high value conservation sites. The landowners are to co-operate with NGOs in carrying out conservation measures. The Management Agreement scheme has been reviewed and proved effective, and has also raised awareness of biodiversity conservation.	Approved allocation of $4.62 million from the Environment and Conservation Fund (ECF) Committee for the implementation of three pilot MA projects. ECF has approved further funding for the projects to continue for another 2 years.	Voluntary	Prevent	-	-	Legislative Council Panel on Environmental Affairs: Pilot Scheme for Management Agreements under the New Nature Conservation Policy. 2005. Agriculture, Fisheries and Conservation Department and Environmental Protection Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/files/legco2.pdf> [Accessed 30 Jan 09] New Nature Conservation Policy. 2004. Environment, Transport and Works Bureau and Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/con_nncp_leaf/files/leaflet2.pdf> [Accessed 30 Jan 09]
Agriculture, Fisheries and Conservation Department, Environmental Protection Department	Public-Private Partnership (PPP)	Private developments at less sensitive identified conservation areas are allowed under the condition where the developer has to manage and conserve the (remaining) site (with high importance).	Not Specified	Voluntary	Prevent	The development is still required to comply with the relevant statutory requirements and take suitable measures to address the issues identified in the assessment by the Advisory Council on the Environment.	-	Legislative Council Panel on Environmental Affairs: Progress of implementation of the New Nature Conservation Policy. 2008. Environmental Protection Department and Agriculture, Fisheries and Conservation Department.

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								<http://www.afcd.gov.hk/english/conservation/con_nncp/files/ea0428cb113313e.pdf> [Accessed 30 Jan 09]
Enhancement of Existing Conservation Measures resulting from the review of the Nature Conservation Policy	Ecological Monitoring	To maintain and develop a Hong Kong ecological database by conducting ecological surveys. In order to update and assess the status of rare species and its conservation status, experts are consulted regularly. Information about the conservation value of different sites is available to government departments in connection with land use and development planning.	Not Specified	Mandatory	Prepare	-	-	Legislative Council Panel on Environmental Affairs: Progress of implementation of the New Nature Conservation Policy. 2008. Environmental Protection Department and Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/files/ea0428cb113313e.pdf> [Accessed 30 Jan 09]
	Planning Control	Land use is controlled and restricted through the land use zoning system to ensure sites with high conservation status are protected. The Schedule of Uses in respect of the Outline Zoning Plans of priority sites for enhanced conservation has also been amended.	Not Specified	Mandatory	Prevent	Priority Sites: * Ramsar Site * Sha Lo Tung * Tai Ho * Fung Yuen * Luk Keng Marsh * Mui Tsz Lam and Mau Ping * Wu Kau Tang * Long Valley and Ho Sheung Heung * Deep Bay Wetland outside Ramsar Site * Cheung Sheung * Yung Shue O * Sham Chung	-	Legislative Council Panel on Environmental Affairs: Progress of implementation of the New Nature Conservation Policy. 2008. Environmental Protection Department and Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/files/ea0428cb113313e.pdf> [Accessed 30 Jan 09]
	Raising	Attract members of the general	Not Specified	Mandatory	Prepare	-	-	Legislative Council Panel on

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	awareness	public to country parks by improving facilities and diversifying visitors' experience by presenting nature conservation in various themes.						Environmental Affairs: Progress of implementation of the New Nature Conservation Policy. 2008. Environmental Protection Department and Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/conservation/con_nncp/files/ea0428cb113313e.pdf> [Accessed 30 Jan 09]

Table B5 Existing Policies / Measures that may Contribute to Adaptive Responses to Built Environment and Infrastructure (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
General Infrastructure								
Environmental Protection Department	Review of the Territorial Development Strategy - Hong Kong 2030: planning vision and strategy	The Hong Kong 2030 strategy is the framework for future developments in Hong Kong. It sets out a range of actions to improve the city's infrastructure while achieving government policy targets and addressing social, economic and environmental needs. The review began in 2000, comprises of a strategic environmental assessment study which addresses long-term environmental sustainability issues. The recommendations in the strategy are categorised into three levels: directions, themes, and measures. Directions are broad statements that guide major proposals in achieving objectives; themes address more specific issues; and measures are the potential actions.	Not Specified	Mandatory	Prepare	-	-	Hong Kong 2030 Planning Vision and Strategy. 2007. Planning Department. <http://www.pland.gov.hk/p_study/comp_s/hk2030/eng/finalreport/> [Accessed 11 Feb 09]
Planning Department	Hong Kong Planning Standards and Guidelines	The guidelines provide basic planning criteria and design standards in balancing the needs of social and economic developments and its impact on the environment. Other guidelines include development sensitives, environmental considerations, utility services, potentially hazardous installations and etc. It also provides specific guidelines for the Hong Kong Island, Kowloon, New Towns and Rural Areas	Not Specified	Mandatory	Prevent	The guidelines identified urban design issues that need to be considered in general and specific areas. In relation to waterfront development, the guidelines made a range of suggestions such as the Building Free Zone, air ventilation, development height profile and etc.. The waterfront development guidelines are mainly *to make Victoria Harbour attractive, vibrant*, accessible and symbolic of Hong Kong. This includes guidelines on	-	Hong Kong Planning Standard and Guidelines. n.d. Planning Department. <http://www.pland.gov.hk/tech_doc/hkpsg/english/index.htm> [Accessed 02 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						the height of the buildings, open space for recreational and/or retail activities, landscaping and etc.		
Drainage Services Department	Stage III of the Shenzhen River Regulation Project	The Hong Kong government and Shenzhen government made efforts to conduct the Shenzhen River Regulation Project. The third stage of works involved improving four kilometres of river channel, reconstructing Lo Wu Railway Bridge, Lo Wu Old Pedestrian Bridge, Man Kam To Vehicular Bridges and two Dongjiang Water Mains. The completion of Shenzhen River Regulation Project ensures transportation between the two places without interruption by flooding, enables infrastructure projects to proceed steadily and creates the favourable conditions for economic development in Hong Kong and Shenzhen.	Not Specified	Mandatory	Prevent	-	-	HK and Shenzhen's joint effort completes regulation of Shenzhen River. <http://www.info.gov.hk/gia/general/200704/24/P200704240276.htm> [Accessed 8 June 09]
The Hong Kong Institute of Architects (HKIA) The Hong Kong Institution of Engineers (HKIE) The Hong Kong Institute of Landscape Architects (HKILA) The Hong	Hong Kong Professional Green Building Council	The HKPGBC conducts collaborative research on local and global developments on green building, promotes seminars and training on the subject, and advises government on a green building labelling scheme.	Not Specified	Voluntary	Prepare, prevent	-	-	Hong Kong Professional Green Building Council <http://www.hkpgbc.org/index.html> [Accessed 16 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Kong Institute of Surveyors (HKIS) The Hong Kong Institute of Planners (HKIP)								
Building Stock								
Buildings Department	Code of Practice on Wind Effects in Hong Kong 2004	The Code of Practice provides equations on calculating total wind force on a building, total along-wind force on enclosed building, wind tunnel testing and etc. These are to be incorporated into the design of buildings, but do not apply to buildings of unusual shapes or where wind conditions are influenced by complicated topography.	Not Specified	Mandatory	Prevent	-	• Asset damage from wind	Code of Practice on Wind Effects in Hong Kong. 2004. Buildings Department. <http://www.bd.gov.hk /english/documents/cod e/windcode2004.pdf> [Accessed 03 Feb 09]
Housing Department	Micro-Climate Studies Enhance Environmenta l Performance of Housing Block	Use of micro-climate studies in housing projects in order for designers to plan for enhanced environmental performance. Micro-climate studies examine the climate characteristics of the housing estate site, such as wind speed, natural ventilation, solar heat gain, daylight and noise.	Not Specified	Voluntary	Prevent, Prepare	-	-	Micro-climate studies enhance environmental performance of housing blocks. 8 April 2007. Press Release. Housing Department. <http://www.housingaut hority.gov.hk/en/aboutu s/news/pressreleases/0,, 2-0-16185--0,00.html> [Accessed 29 Jan 09]
Electrical and Mechanical Services Department	Prescriptive Building Energy Codes	The four codes on building services installations were developed by the Electrical & Mechanical Services Department (EMSD), progressively from 1998 to 2000, and implemented on a voluntary basis under	Not Specified	Voluntary	Prepare	-	-	Energy Efficiency Registration Scheme for Buildings. < http://www.emsd.gov.h k/emsd/eng/pee/eersb_

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		EMSD's Hong Kong Energy Efficiency registration Scheme for Buildings (HKEERSB). These four codes respectively stipulate the minimum efficiency standards of corresponding components and systems. The four codes of practice include: • Energy Efficiency of Lighting Installations • Energy Efficiency of Air Conditioning Installations • Energy Efficiency of Electrical Installations • Energy Efficiency of Lift and Escalator Installations						pub_cp.shtml > [Accessed 09 Nov 09]
Electrical and Mechanical Services Department	Performance-based Building Energy Code	This performance approach considers the various components of building energy consumption, addresses to their interrelation, allows trade-off among them, and provides room for innovative design.	Not Specified	Voluntary	Prepare	The PB-BEC is targeted to provide an alternative path of compliance to the prescriptive codes, but not to replace them.	-	Performance-based Building Energy Code, 2007. < http://www.emsd.gov.hk/emsd/e_download/pee/pb-bec_2007.pdf> [Accessed 09 Nov 09]
Buildings Department	Code of Practice for Overall Thermal Transfer Value in Buildings 1995	This Code of Practice provides technical guidance for developers, engineers and other persons responsible for the design and construction of buildings. It includes general principles of control of overall thermal transfer, appropriate standards for thermal conductivity, surface film resistance, absorptivity for wall and roof surfaces and air space resistance for walls and roofs.	Not Specified	Mandatory	Prevent	This Code applies to all hotels and commercial buildings as defined in the Building (Energy Efficient) Regulation.	• Loss of thermal comfort • Increased use of mechanical cooling	Code of Practice for Overall Thermal Transfer Value in Buildings 1995. Building Authority. <http://www.bd.gov.hk/english/documents/code/e_ottv.htm> [Accessed 03 Feb 09] Building (Energy Efficiency) Regulation, 1995. < http://www.arch.hku.hk

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								/research/BEER/bee-reg.htm> [Accessed 09 Nov 09]
Electrical and Mechanical Services Department	HK Energy Efficiency Registration Scheme for Buildings	Launched in October 1998 by the Electrical & Mechanical Services Department, the Scheme serves to promote the application of the Building Energy Codes (BECs) A registration certificate will be issued to a building that successfully meets the individual BEC standards. In addition, a registered building can also use the Scheme's "Energy Efficient Building Logo" on related documents to publicize the achievement on energy efficiency.	Not Specified	Voluntary	Prepare			HK Energy Efficiency Registration Scheme for Buildings. < http://www.emsd.gov.hk/emsd/eng/pee/eersb.shtml> [Accessed 09 Nov 09] Hong Kong Energy Efficiency Registration Scheme for Buildings, 2007. < http://www.emsd.gov.hk/emsd/e_download/pee/hkeersb.pdf> [Accessed 09 Nov 09]
Planning Department / School of Architecture, Chinese University of Hong Kong	Feasibility study on climatic map and standards for Wind Environment	The urban climatic map could help identify streets of better ventilation, spots of better comfort, the problematic zones, and buildings which have negative effect on wind penetration. Such necessary information will provide a sound basis for town planners and designers to make planning decisions.	Not Specified	Mandatory	Prepare	Climatic mapping provides planners a holistic point of view of the city. How development of one district will affect nearby districts will easily be revealed in the map.	• Urban Heat Island effect	Urban Climatic Map and Standards for Wind Environment - Feasibility Study Inception Report: October 2006. <http://www.pland.gov.hk/p_study/prog_s/ucmapweb/ucmap_project/content/reports/inception_report.pdf> [Accessed 28 Aug 09]
Electrical and	District	The Government plans to implement a	Not	Mandatory	Prepare	The DCS is the first project of its	• Increased use	Territory-Wide

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Mechanical Services Department	cooling systems at Kai Tak Development	district cooling system at the Kai Tak Development to supply chilled water to buildings in the new development area for centralised air-conditioning. DCS is a centralised cooling system which provides chilled water to the air-conditioning system of user buildings for cooling purpose. The central chiller plant supplies chilled water and conveys it to the user buildings via underground chilled water pipe network.	Specified			kind to be implemented by the Government in Hong Kong.	of mechanical cooling	Implementation Study for Water-cooled Air Conditioning System in Hong Kong <http://www.emsd.gov.hk/emsd/e_download/pee/wacs_tws_es_eng.pdf> [Accessed 28 Aug 09]
Architectural Services Department	Green roof applications in Hong Kong	The Architectural Services Department has worked on the initiative since 2001, and finished many projects on new Government buildings, including schools, offices, hospitals, community facilities and quarters The Department completed the Study on Green Roof Application in Hong Kong in 2007 which reviewed the latest concepts and design technology of green roof and recommended technical guidelines suitable for application in Hong Kong, covering various aspects including choice of plants, waterproofing layer, thermal insulating layer, drainage layer, planting soil, irrigation as well as maintenance and repair.	Not Specified	Voluntary	Prevent, Prepare	The study also included 6 short term recommendations and 3 medium to long recommendations on green roof directions for Hong Kong.	• Loss of thermal comfort • Increased use of mechanical cooling	Study on Green roof applications in Hong Kong <http://www.archsd.gov.hk/english/knowledge_sharing/1353-Green-Roofs-ES-2007-02-16.pdf > [Accessed 4 Sep 09] 'Green roofs' set for new housing estates <http://news.gov.hk/en/category/environment/061115/html/061115en04004.htm> [Accessed 4 Sep 09]
Leisure and Cultural Services Department	Green School Subsidy Scheme	The Green School Subsidy Scheme provided 665 schools and kindergartens with cash to add more greenery to their campuses and to organise greening education activities for their students with technical advice given by visiting instructors.	Tree planting projects will not exceed $20,000 for each school	Voluntary	Prepare	The objective of the scheme is to encourage campus greening, promote a green culture among students and cultivate their interest in growing plants.	-	Greening School Subsidy Scheme 2009/2010 <http://www.lcsd.gov.hk/green/subsidy/en/index.php> [Accessed 4 Sep 09]

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Housing Department	To explore the feasibility of implementing the Green Roof environmental improvement programme in PRH estates	Explore the feasibility of implementing the "Green Roof" environmental improvement programme was implemented at Wo Lok Estate and Fu Shan Market building.	Not Specified	Voluntary	Prepare	-	• Loss of thermal comfort • Increased use of mechanical cooling	Year-end Review of the Housing Authority's 2008/09 Corporate Plan <http://www.housingauthority.gov.hk/hdw/content/document/en/aboutus/ha/paperlibrary/ha/ha2009.pdf> [Accessed 3 Sep 09]
Transport Infrastructure								
Airport Meteorological Office (AMO) under Hong Kong Observatory	Aviation Weather Services	The AMO is responsible for provision of warnings on hazardous weather which may affect the safety of aircraft operations within a designated airspace over the northern part of the South China Sea. It is also responsible for making weather observations, and issue weather forecasts.	Not Specified	Mandatory	Prepare	-	•Infrastructure / asset damage and impacts associated with bad weather • Possible business / operation interruption	Aviation Weather Services <http://www.hko.gov.hk/aviat/amt_e/airportmetser_e.htm> [Accessed 4 June 09]
Hong Kong Observatory	Design of coastal projects	As there are more storm surges and long term sea level rise, their effects have been taken into consideration in the design of coastal projects.	-	Voluntary	Prepare	-	• Impacts associated with relative sea level rise, e.g. coastal flooding, asset damage, health and safety risks	HKO announces findings on long-term sea level change in HK <http://www.weather.gov.hk/wxinfo/news/2004/pre0614e.htm> [Accessed 4 June 09]
Transport Department	Intelligent Transport Systems	The department has been developing the Intelligent Transport Systems (ITS) which can help alleviate climate change impacts. For	Not Specified	Mandatory	Respond	-	• Impacts associated with climate change	The Development of Intelligent Transport Systems (ITS) in Hong

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		example, the Journey Time Indication System being in operation since 2003 provides motorists with traffic information to make suitable route choices to cross the harbour so as to avoid traffic congestion, thus bringing about benefits of reduction in fuel consumption and polluted emissions.						Kong <http://www.td.gov.hk/about_us/technology/the_development_of_intelligent_transport_systems/index_t.htm> [Accessed 4 June 09]
Civil Engineering and Development Department	Highway Slope Manual	The manual provides a standard of good practice on slope engineering for project planning, design, construction and maintenance on highway slopes. The manual recommended a geotechnical review to be conducted when planning for new highway and road improvement projects, and a geotechnical assessment if necessary. It also suggested site investigations should take place not only in the planning stage, but also throughout the project. Ground investigations such as identification of weak zones through soil tests, observations of possible adverse topographical features, surface water distribution and seepage points needs to be incorporated into the geotechnical hazard models. Groundwater is to be investigated as well for its potential impacts on the design and stability assessment of geotechnical works for a highway project. The manual provides a general guidance on how the above assessments should be carried out. Other issues that need to be taken into consideration are also suggested: drainage, landscaping, safety precautions, maintenance and emergency preparedness.	Not Specified	Voluntary	Prevent	-	• Infrastructure and asset damage from landslides	Highways Slope Manual in Publications. N.d. Civil Engineering and Development Department. <http://www.cedd.gov.hk/eng/publications/manuals/manu_em2.htm> [Accessed 03 Feb 09]

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Highways Department	Structures Design Manual for Highways and Railways	The Structures Design Manual for Highways and Railways sets out standards and provides guidance on the design of highway and railway structures in Hong Kong. The manual suggested a range of measures to be carried out for constructing highways such as: use of materials, testing materials against heat stress, testing of welds, wind loading design and etc.	Not Specified	Mandatory	Prevent	BS5400 is adopted - British Standard 5400 provides recommendations on design and construction of steel, concrete and composite bridges use in highway and railway.	• Risk of subsidence and foundation damage • Damage to transport infrastructure e.g. rail bucking, tarmac melt	Structures Design Manual for Highways and Railways. 3rd e.d. 2006. Highways Department. <http://www.hyd.gov.hk/eng/public/publications/sdm/filelist.htm> [Accessed 03 Feb 09]
Slope Stability								
Civil Engineering and Development Department (Landslip Preventive Measures Branch of the Geotechnical Engineering Office)	Landslip Preventive Measures (LPM) Programme	The aim of the on-going LPM Programme is to reduce the risk of landslide from substandard Government slopes. Private slopes are also investigated and private owners will be required to upgrade substandard slopes (according to the Building Ordinance). The department has identified 2500 substandard government slopes where upgrading works are scheduled to complete by 2010, and 3000 private slopes are being studied.	$12.2 billion since 1976 (as of 1 March 2009) $600 million p.a. for the 10 year extended programme (2000-10)	Mandatory	Prevent, Prepare	-	• Infrastructure and asset damage from landslides	LPM Project in On-going projects. n.d. Civil Engineering and Development Department. <http://www.cedd.gov.hk/eng/projects/landslip/land_lpm.htm> [Accessed 04 Feb 09] The Landslip Preventive Measures (LPM) Programme in *Information Note 04/2008*. 2008. Civil Engineering and Development Department. <http://www.cedd.gov.hk/eng/publications/information_notes/doc/in_2008_04e.pdf〉 [Accessed 04 Feb 09]

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Geotechnical Engineering Office, Civil Engineering and Development Department	How to Protect Your Family and Yourself when the Landslip Warning is in Force Leaflet	A leaflet to inform the public how to protect themselves and their family when landslip warning is in force.	Not Specified	Voluntary	Prevent, Prepare	-	Slope safety	How to Protect Your Family and Yourself when the Landslip Warning is in Force <http://hkss.cedd.gov.hk/hkss/eng/download/leaflet/leaflet-how-to-protect-your-family-eng.pdf> [Accessed 17 June 09]
Hong Kong Slope Safety, Civil Engineering and Development Department	How to Keep Your Slope Safe website	The website provides the information on the slope maintenance, who is responsible for the slope safety, standard of good practice on slope maintenance etc.	Not Specified	Mandatory	Prevent, Prepare	-	Slope safety	How to Keep Your Slope Safe<http://hkss.cedd.gov.hk/hkss/eng/download/how2keep/index.htm> [Accessed 17 June 09]
Geotechnical Engineering Office, Civil Engineering and Development Department	Layman's Guide to Slope Maintenance	The guidance recommends a standard of good practice for the maintenance of man-made slopes and retaining walls. It provides information on how to conduct maintenance inspections and maintenance works necessary to avoid the instability of slopes.	Not Specified	Voluntary	Prevent, Prepare	-	Slope safety	Layman's Guide to Slope Maintenance <http://hkss.cedd.gov.hk/hkss/eng/download/layman/Layman_guide_e_2006.pdf> [Accessed 17 June 09]
Geotechnical Engineering Office, Civil Engineering and Development Department	GEO Emergency Service to Government Departments	When the Landslip Warning is in force, the GEO Emergency Control Centre operates to provide geotechnical advice about landslides for government departments. When landslides happen, despatch geotechnical engineers will go to incident spot to advise on emergency measures (e.g. road closures) and urgent repair works.	Not Specified	Mandatory	Respond	-	Slope safety	GEO Emergency Service <http://hkss.cedd.gov.hk/hkss/eng/safemeasure/emergency/emergency.htm> [Accessed 17 June 09]

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The Geotechnical Engineering Office (GEO) and Hong Kong Observatory	Landslip Warning System	Landslip Warning is issued according to the rainfall data monitored by GEO and HKO. If the 24-hour rainfall is expected to be heavy enough to cause numerous landslides, the Landslip Warning will be issued.	Not Specified	Mandatory	Prepare	-	Slope safety	Detailed Information on Landslip Warning System <http://hkss.cedd.gov.hk/hkss/eng/safemeasure/warning/landslip.htm> [Accessed 17 June 09]
Drainage Infrastructure (including stormwater drainage, sewerage systems and wastewater treatment facilities)								
Drainage Services Department	Preventive Maintenance	Approximately 79% of total drains and watercourses are inspected every year especially before and during wet seasons. Closed circuit televisions are installed to monitor drains where man-entry inspections are not possible. Tidal channels are desilted and dredged regularly to ensure maximum flood carrying capacities.	Approximately $100 million (p.a.)	Mandatory	Prevent	Status: ongoing Annual inspection on the flood control installations is conducted to ensure that they would be fully operational in times of rainstorm. DSD also works with other departments to keep streets clean to prevent litter from blocking roadside gullies and catchpits. Stormwater drainage asset inventory and maintenance systems are also being developed as part of the regional drainage master plans (mostly developed). The system will provide an accurate up-to-date record of the inventory and the hydraulic and structural performance of the drainage system. This will allow early identification of faults and deficiencies in the system, and to draw up action plans and	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity	Preventive Maintenance in Flood Prevention. n.d. Drainage Services Department. <http://www.dsd.gov.hk/flood_prevention/preventive_maintenance/index.htm> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						maintenance schedules.		
Drainage Services Department	Land Drainage Ordinance	The Ordinance was enacted in 1994, where the Government has the authority to access private land to carry out maintenance works and to remove obstructions to watercourses.	Not Specified	Mandatory	Prevent	Status: ongoing	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Chapter 446 Land Drainage Ordinance in *Bilingual Laws Information System*. n.d. Department of Justice. <http://www.legislation.gov.hk/eng/home.htm> [Accessed 02 Feb 09]Land Drainage Ordinance in Flood Prevention. n.d. Drainage Services Department. <http://www.dsd.gov.hk/flood_prevention/land_use_management_legislation/ldo/index.htm> [Accessed 02 Feb 09]
Drainage Services Department	Rural Drainage Rehabilitation Scheme – drainage rehabilitation works at Sha Po Tsuen Stream	Widening and straightening of the Sha Po Tsuen Stream to raise flood protection level of the area and reduce the risk of flooding during heavy rainstorms.	$60.9 Million	N.A.	Prevent	Status: completed	• Flooding of system beyond designed capacity • Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_824.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Tsuen Wan and Kwai Chung	Construction of about 1,200m drainage pipes and structural rehabilitation of about 450m existing drains and culverts.	Approximately $81 million	N.A.	Prevent	Status: completed	• Flooding of system beyond designed capacity • Asset	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
							damage from flooding	/our_projects/flood_recently_completed/index_UID_839.htm> [Accessed 30 Jan 09]
Drainage Services Department	Yuen Long, Kam Tin, Ngau Tam Mei and Tin Shui Wai drainage improvements	Alleviate flooding problems at Cheung Kong, Tai Kong Po, Tsat Sing Kong and Ha Che of Kam Tin and San Wai Tsuen of Ngau Tam Mei by constructing five secondary drainage channels in the area.	Approximately $140 million for stage one, not specified for stage two	N.A.	Prevent	Status: completed	• Flooding of system beyond designed capacity • Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_825.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement Works at Yung Shue Long New Village in Lamma Island, Tseng Lan Shue in Sai Kung and Shui Lau Hang in Ta Kwu Ling	Construction of drainage improvement works: a) at Yung Shue Long New Village, Lamma Island - i) about 130 metres of a 2-metre wide rectangular concrete channel; ii) deepening of about 44 metres of an existing concrete channel by 0.5 metre; and, iii) a maintenance access and ancillary drainage works. b) at Tseng Lan Shue, Sai Kung - i) about 140 metres of a 4-metre wide box culvert; and ii) a maintenance access and ancillary drainage works. c) at Shui Lau Hang, Ta Kwu Ling - i) about 440 metres of a 3.5-metre wide	Approximately $46 million	N.A.	Prevent	Status: completed	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_959.htm> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		rectangular concrete channel; and ii) a maintenance access and ancillary drainage works.						
Drainage Services Department	Drainage improvement for Ma Wat River at Kau Lung Hang	To alleviate flooding problems in Kau Lung Hang and increase flood protection standards to meet long-term development needs by constructing approximately 1.8 km long drainage channels near Kau Lung Hang and north of Hong Lok Yuen, Tai Po.	Approximately $230 million	N.A.	Prevent	Status: completed	• Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_971.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Northern Hong Kong Island - Intercepting drains at Queen's Road Central	To alleviate flooding hazards in low-lying area in Sheung Wan by: 1) constructing 530 metres of stormwater drains ranging from 900 millimetres (mm) to 1500 mm along Lok Ku Road and Queen's Road Central; and 2) constructing 130m of single cell drainage box culverts of internal size 2250mm wide and about 1250mm high along Gilman's Bazaar	Approximately $46 million	N.A.	Prevent	Status: completed	• Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_1051.htm> [Accessed 30 Jan 09]
Drainage Services Department	Yuen Long bypass floodway	This aims to alleviate flooding problems in the low-lying area to the south of Yuen Long Town and reduce flooding hazards of Yuen Long Town through: 1) the construction of a drainage channel of about 3.8km long from Sham Chung Tsuen to Kam Tin River near Sha Po Tsuen; 2) the construction of an inflaTable Bam and a low flow pumping station at the downstream	$476.2 million	N.A.	Prevent	Status: completed	• Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_265.htm> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		end of the proposed drainage channel; 3) the construction of 18 box culverts; 4) the construction of roads and ramps with associated drainage and water works along the proposed drainage channel; 5) environmental mitigation measures including creation of an artificial wetland and landscaping works; and 6) environmental monitoring and audit programme.						
Drainage Services Department	San Tin Eastern Main Drainage Channel	Aims to alleviate flooding problems in the low-lying areas at the east of San Tin and Ki Lun Tsuen of Yuen Long through: 1. the construction of a trapezoidal drainage channel of about 2.2km long from Castle Peak Road along the western side of San Sham Road to Shenzhen River; 2. the construction of an inflaTable Bam and a low flow pumping station; 3. the construction of a vehicular bridge; 4. the construction of roads and ramps with associated drainage and water works; 5. environmental mitigation measures including compensatory planting, wetland creation and landscape works; and 6. an environmental monitoring and audit programme	$354.2 million	N.A.	Prevent	Status: completed	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_777.htm> [Accessed 30 Jan 09]
Drainage Services Department	Village Flood Protection for Tai Kiu and Shui Pin Tsuen, Yuen	Aims to alleviate flood risks in 2 low-lying villages in Yuen Long - Tai Kiu and Shui Pin Tsuen. Tai Kiu Pumping Station:1. A floodwater storage pond 2. A floodwater pumping station and associated electrical and	Approximately $63 million	N.A.	Prevent	Status: completed	• Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Long, New Territories	mechanical works; and 3. Associated internal access and drainage works Shui Pin Tsuen Pumping Station:1. An underground floodwater storage tank 2. A floodwater pumping station and associated electrical and mechanical works; and 3. Associated internal access and drainage works.						/our_projects/flood_recently_completed/index_UID_958.htm> [Accessed 30 Jan 09]
Drainage Services Department	Main drainage channels for Yuen Long and Kam Tin	Aims to alleviate flooding problems in the low-lying areas of Kam Tin along the Kam Tin River between Wang Toi Shan and Kam Tin San Tsuen through the construction of: 1. a drainage channel of about 3.1km long along the section of Kam Tin River between Kam Tin San Tsuen and Wang Toi Shan; 2. an inflaTable Bam, an air blower house, an irrigation water tank and a pumping chamber; 3. a gauging station to replace the existing Kam Tin River Gauging Station; 4. roads with associated drainage works; 5. four vehicular bridges and five footbridges; 6. environmental mitigation measures including landscaping works; and 7. an environmental monitoring and audit programme for the works.	$419.3 million for stage 2 (Kam Tin San Tsuen to Wang Toi Shan section)	N.A.	Prevent	Status: completed	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UID_778.htm> [Accessed 30 Jan 09]
Drainage Services Department	Main drainage channel for Ngau Tam Mei	The project aims at alleviating the flooding problems in the lower catchment area of Ngau Tam Mei of Yuen Long, including Chuk Yuen Tsuen, Yau Mei San Tsuen, Man Yuen Tsuen and Tai San Wai area. The scope of the project comprises the	$442.5 million for phase 1 (Yau Mei San Tsuen to Tai Sang Wai	N.A.	Prevent	Status: completed (Phase 1)	• Asset damage from flooding	Flood Prevention Projects Recently Completed. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_recently_completed/index_UI

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		construction of : - 1. a drainage channel of about 2.3km long from Castle Peak Road near Yau Mei San Tsuen to Tai Sang Wai; 2. an inflaTable Bam and a low flow pumping station; 3. an irrigation pumping station; 4. roads and ramps with associated drainage and water works; 5. four vehicular bridges; and 6. environmental mitigation measures including landscaping works.	section)					D_245.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement in Tuen Mun and Sham Tseng	Construction of: 1,100 m of drainage channel at So Kwun Wat, and 750 m of drainage pipeline, drainage channel and box culvert at Nai Wai.	$76.5 million for Package B	N.A.	Prevent	Status: ongoing	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	On-going flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_on_going/index_UID_1205.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement in Southern Lantau	Aims to alleviate flooding problems at Pak Ngan Heung, Luk Tei Tong, Tai Tei Tong and Ling Tsui Tau in Mui Wo, and some local areas at Cheung Sha Sheung Tsuen, Lo Uk Tsuen and Pui O Ham Tin San Tsuen in Southern Lantau through the construction of drainage channels, box culverts, drains and	$97.7 million	N.A.	Prevent	Status: ongoing	• Asset damage from flooding	On-going flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_on_going/index_UID_1122.ht

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		ancillary drainage works.						m> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement Works in Sha Tin	Construction of about 2.8 km of upgrading works and new drains in the Sha Tin urban area.	$72.4 million	N.A.	Prevent	Status: ongoing	• Flooding of system beyond designed capacity• Asset damage from flooding	On-going flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_on_going/index_UID_846.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement in Kwu Tung South and Fu Tei Au, Sheung Shui	Construction of about 1.8km of drainage channels in Kwu Tung South and Fu Tei Au, Sheung Shui, New Territories.	$58.3 million	N.A.	Prevent	Status: ongoing	• Asset damage from flooding	On-going flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_on_going/index_UID_1115.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement works in Ping Kong, Kau Lung Hang, Yuen Leng, Nam Wa Po and Tai Hang areas	Construction of about 5.1 km long drainage channels/box culverts in Ping Kong, Kau Lung Hang, Yuen Leng, Nam Wa Po and Tai Hang areas.	Approximately $260 million	N.A.	Prevent	Status: ongoing	• Asset damage from flooding	On-going flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_on_going/index_UID_1165.htm> [Accessed 30 Jan 09]
Drainage Services Department	Reconstruction and Improvement of Kai Tak Nullah (Choi	The project includes the reconstruction and decking of a section of approximately 400m along the Nullah from its upstream near Po Kong Village Road to Tai Shing Street/Tung Tai Lane and the reconstruction and	Approximately $1600 million	N.A.	Prevent	Status: to be commenced in early 2010	• Discharge problems at drainage outflows – risking backing	Up-coming flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Hung Road Section) in Wong Tai Sin	rehabilitation of approximately 200m along Nullah from Tai Shing Street/Tung Tai Lane to Tung Kwong Road.					up • Flooding of system beyond designed capacity • Asset damage from flooding	/our_projects/flood_up_coming/index_UID_1052.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement in Southern Hong Kong Island	Upgrade of 4.6km long stormwater drains within urban catchments in Pokfulam, Tin Wan, Aberdeen, Ap Lei Chau and Stanley, and construction of small-scale drainage improvement works within rural catchments in Pokfulam Village and Shek O.	Approximately $50 million	N.A.	Prevent	Status: to be commenced in early 2011	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Up-coming flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_up_coming/index_UID_1164.htm> [Accessed 30 Jan 09]
Drainage Services Department	Drainage Improvement Works in Pok Fu Lam, Wah Fu, Tin Wan, Aberdeen, Wong Chuk Hang and Shek O of Southern Hong Kong Island	Upgrade of 1.3km long stormwater drains within urban catchments in Pokfulam, Wah Fu, Tin Wan, Aberdeen, Wong Chuk Hang, and construction of drainage improvement works within rural catchments in Pokfulam Village and Shek O.	Approximately $50 million	N.A.	Prevent	Status: up-coming	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from	Up-coming flood prevention projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/flood_up_coming/index_UID_1294.htm> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
							flooding	
Drainage Services Department	Rural Drainage Rehabilitation Scheme	Construction of: 3.9km drainage channel along a section of Sheung Yue River from Tsiu Keng Lo Wai to Fanling Highway; 500m drainage channel along a section of Ying Pun Ho from Chan Uk Po to the confluence with Sheung Yu River; 500m drainage channel along Kwu Tung Stream from Fanling Highway to the confluence with Sheung Yue River; total of 4.2km maintenance access roads along the proposed drainage channels; and demolition and reprovision of 6 footbridges and 2 agricultural weirs.	$359 million	N.A.	Prevent	Commencement: 30 April 1999Completion Date: End 2001	• Asset damage from flooding	Sewerage Treatment. n.d. Drainage Services Department. <http://www.dsd.gov.hk/sewerage/sewage_treatment/index_t.htm> [Accessed 30 Jan 09]
Drainage Services Department	West Kowloon Drainage Improvement	Improvement of 11km of stormwater drains.	$1,214 million	N.A.	Prevent	Location of significant improvements and benefits of Stage 2 phase 2 and stage 3 phase 1 works: Yau Ma Tei, Mong Kok, Tai Kok Tsui, Sham Shui Po Start: Mar 2001 Complete: Mid 2007	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	West Kowloon Drainage Improvement - Lai Chi Kok Transfer Scheme	Construction of the 3.7km Lai Chi Kok stormwater transfer tunnel, 6 drop shafts together with associated stilling basin and outfall structures.	$1.8 billion	Mandatory	Prevent	Location of significant improvements and benefits: Lai Chi Kok, Cheung Sha Wan and Shum Shui Po Start: Early 2008 Complete: End 2012	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Northern Hong Kong Island - Hong Kong West Drainage Tunnel	Construction of 18km stormwater drainage tunnel.	$3,045 million	N.A.	Prevent	Location of significant improvements and benefits: Causeway Bay, Wan Chai, Central, Sheung Wan, Kennedy Town Start: End of 2007 Complete: Early 2012	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Northern Hong Kong Island - western lower catchment works	Construction of 4.4km stormwater drains.	$251 million	N.A.	Prevent	Location of significant improvements and benefits: Chai Wan, Shau Kei Wan, North Point, Causeway Bay, Wan Chai, Central, Sheung Wan, Kennedy Town Start: Early 2008 Complete: End 2012	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement works in Tai Po	Construction of 9.8km of stormwater drains and a stormwater pumping station and drainage channels.	$123 million	N.A.	Prevent	Location of significant improvements and benefits: Tai Po Town Areas, Lam Tsuen Valley, Wun Yiu, Yuen Tun Ha, She San Tsuen, Tung Tsz, Shuen Wan, Wai Ha, Ting Kok Road Start: Early 2008 Complete: Early 2011	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								30 Jan 09]
Drainage Services Department	Drainage improvement works in upper Lam Tsuen River, She Shan River, upper Tai Po River, Ping Long and Kwun Hang	Construction of 4.4km drainage channels and box-culvert.	$426 million	N.A.	Prevent	Location of significant improvements and benefits: Upper Lam Tsuen River, She Shan River, upper Tai Po River, Ping Long and Kwun HangStart: End 2007Complete: Mid 2011	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Tsuen Wan, Kwai Chung and Tsing Yi - Tsuen Wan drainage tunnel	Construction of 5.35km stormwater drainage tunnel.	$1,260 million	N.A.	Prevent	Location of significant improvements and benefits: Tsuen Wan and Kwai Chung Start: End 2007 Complete: End 2011	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Sai Kung	Construction of 2km drainage channels.	$158 million	N.A.	Prevent	Location of significant improvements and benefits: Sha Ha, Pak Kong, Ho Chung, Sai Kung Town Start: End 2007 Complete: End 2009	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Drainage Services Department	Drainage improvement in East Kowloon	Construction of 11km stormwater drains.	$188 million (Package B phase 2)	N.A.	Prevent	Location of significant improvements and benefits: Hung Hom, Ma Tau Wai, Kowloon City, Kwun Tong, San Po Kong Package B Phase 2 Start: Apr 2007 Complete: Early 2011	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in Northern Hong Kong Island - Sheung Wan stormwater pumping station	Construction of stormwater pumping station.	$178 million	N.A.	Prevent	Location of significant improvements and benefits: Sheung Wan Start: Jun 2006 Complete: End 2009	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2006-07*. 2007. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0607/EN/appendices/DSD_AR06_App(A).pdf> [Accessed 30 Jan 09]
Drainage Services Department	Drainage improvement in East Kowloon	The project aims to alleviate flooding problems in East Kowloon including Tsim Sha Tsui, To Kwa Wan, Wong Tai Sin and Yau Tong areas. The project includes the construction of approximately 5km long stormwater drains and box culverts started in May 2005 for completion in Oct 2008.	$250 million for Package A	N.A.	Prevent	Location of significant improvements and benefits: Tsim Sha Tsui, To Kwa Wan, Wong Tai Sin, Yau Tong Package A Start: May 2005 Complete: January 2009 (Status: in Progress as of 10 Feb 09)	• Asset damage from flooding	On-going Flood Prevention Projects. n.d. Drainage Services Department. <http://www.dsd.gov.hk/our_projects/our_project_status_ongoing/index_UID_960.htm> [Accessed 09 Feb 09]
Drainage Services Department	River training works for the Upper River	Training of drainage channel.	$756 million	N.A.	Prevent	Start: Aug 1999 Complete: Mar 2003	• Asset damage from flooding	Appendix A - Major Flood Control Projects in *DSD Annual Report 2005-*

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Indus							*06*. 2006. Drainage Services Department. <http://www.dsd.gov.hk/annual_reports/0506/eng/appendix-A_eng.pdf> [Accessed 02 Feb 09]
Drainage Services Department	Village Flood Protection Scheme for San Tin Villages	The scheme aims to prevent floodwater with a return period of 1 in 200 years from entering the village areas from downstream channels, and at the same time capable of collecting and storing runoff from San Tin villages for subsequent discharge to the existing streams without affecting the life and property of the villagers.	Almost $130 million	Mandatory	Prevent, Prepare	Status: completedThe major elements of the scheme are:* 1.9km long flood protection embankment * 2.2ha floodwater storage pond * 2 storey high pumping station * 680m twin-cell concrete box culverts connecting the pumping station* maintenance access connecting the floodwater storage pond and pumping station	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Village Flood Protection Scheme for San Tin Villages. 1999. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/access_information/code_access_information/list/VFPS%20for%20San%20Tin%20Villages.pdf> [Accessed 30 Jan 09]
Drainage Services Department	Flood Protection Standards	A set of flood protection standards is for the planning and design of the public stormwater drainage systems. The standards are developed based on factors including land use development scenarios, economic growth, socio-economic needs, consequences of flooding, and benefit-cost analysis of flood mitigation measures.	Not Specified	Mandatory	Prepare	Status: on-going All stormwater facilities in new developments have to be designed to withstand a severe flood event, which will occur at the Average Recurrence Interval (approximately once within the period) stated below: - Urban drainage trunk systems (200 years) - Urban drainage branch systems (50 years)	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Flood Protection Standards. Drainage Services Department. <http://www.dsd.gov.hk/flood_prevention/flood_protection_standards/index.htm> [Accessed 15 April 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						- Main rural catchment drainage channels (50 years) - Village drainage (10 years) - Intensively used agricultural land (2-5 years) The definition of flood events is based on the combination of rainfall intensity and tide levels. It will not be always possible or practical to upgrade the existing drainage systems, especially those within the old urban areas, to the current standards. In these special circumstances, a pragmatic approach is necessary in order to determine the best possible flood protection levels that can be achieved having regard to the constraints imposed by the existing highly intensive development.		
Drainage Services Department	Flood Warning System	Real-time water levels monitoring at major rivers and channels to provide information for analysing the flood situation and alerting rescue departments. Local flood warning systems are installed at flood prone villages to alert villagers when the flood water reaches a predetermined level. The warnings are announced through flood sirens or through automatic telephone calls to the village representatives.	Not Specified	Mandatory	Prepare, Respond	Status: on-going	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset	Chapter 4 Ready for the Rainy Days in *DSD Annual Report 00/01*. 2001. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/TC/publications_publicity/publicity_materials/annual_reports/0001rpt/05e.html> [Accessed 30 Jan 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
							damage from flooding	
Drainage Services Department	Emergency Planning	To manage flood hazards, DSD has set up a 24-hour hotline which enables their direct labour force / contractors to deal with the flooding complaints as soon as possible. DSD tries to ensure that complaints received in the morning are investigated on the same day or the next morning for those received after 1 pm. Complaints received are recorded by a computerised Drainage Complaints Information System so that data could be retrieved and analysed later.	Not Specified	Mandatory	Prepare, Respond	Status: on-going	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Emergency Planning. Drainage Services Department. <http://www.dsd.gov.hk/flood_prevention/preventive_maintenance/emergency_planning/index.htm> [Accessed 15 April 09]
Drainage Services Department	Emergency and Storm Damage Organisation	To handle emergency and flooding problems outside office hours.	Not Specified	Mandatory	Prepare, Respond	Status: on-going	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Emergency Planning. Drainage Services Department. <http://www.dsd.gov.hk/flood_prevention/preventive_maintenance/emergency_planning/index.htm> [Accessed 15 April 09]
Drainage Services Department	An Emergency Control Centre	The centre is overseen by senior professionals and is activated when the situation warrants in order to coordinate emergency clearance of blocked drains and watercourses throughout	Not Specified	Mandatory	Prepare, Respond	Status: on-going	• Discharge problems at drainage outflows –	Emergency Planning. Drainage Services Department.<http://www.dsd.gov.hk/flood_prev

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		the territory, to handle the large number of complaints and reports of flooding, and to disseminate information within the Government and to the public. Crucial hydraulic structures, such as the facilities within the flood pumping station and the inflaTable Bams at major channels constructed for stormwater quality improvement, are closely monitored by telemetry and video surveillance for visual monitoring of important electrical, mechanical and civil components.					risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	ention/preventive_maintenance/emergency_planning/index.htm> [Accessed 15 April 09]
Drainage Services Department	Drainage Master Plan Studies	The Drainage Services Department has commissioned 8 Stormwater Drainage Master Plan (DMP) Studies to provide recommendations on flood prevention, meeting long term development needs, together with the cost involved.	Not Specified	Mandatory	Prepare	Status: studies completed; measures in progress Some of the recommendations made in these studies have been or will be implemented. The models used in these studies included MIKE 11 and HydroWorks.	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Drainage master plan studies in Flood Prevention. n.d. Drainage Services Department. <http://www.dsd.gov.hk/flood_prevention/our_achievement/other_areas/index.htm> [Accessed 30 Jan 09] Flood Prevention Drainage Master Plan < http://www.dsd.gov.hk/flood_prevention/long_term_improvement_measures/dmp/index.htm> [Accessed 16 Sep 09]
Drainage Master Plan Studies:								
Drainage Services Department	Yuen Long, Kam Tin, Ngau Tam Mei and Tin	The main objective of the YLDMP is to recommend first aid, short and long term improvement measures for the secondary and local stormwater drainage systems	Cost of recommended measures:	Voluntary	YLDMP - Prepare Recommen	Status: studies completed; measures in progress The study has identified a list of		Yuen Long, Kam Tin, Ngau Tam Mei and Tin Shui Wai Drainage Master Plan Study:

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Shui Wai Drainage Master Plan Study (YLDMP)	within the study area. The Asset Inventory and Management System and Real Time Flow Monitoring System was developed and implemented in the study. The recommendations (such as minimum floor levels and drainage criteria) were accompanied by an implementation programme with cost estimates.	$535 million for stage 1 (Sep 2001 to Jun 2006) Stage 2: $130 million (Oct 2007 to Sep 2010)		dations - Prevent	flood prone villages, and the necessary measures required for those areas without flood protection measures. In addition, it identified areas where further work is required, such as the construction of secondary channels, drainage networks, and setting minimum floor levels for new buildings in the floodplain (prevention from a 200 year return period flood event).		Executive Summary. 1999. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/YL%20KT%20Study%20Report%20Eng.pdf> [Accessed 02 Feb 09]
	Stormwater Drainage Master Plan Study in Northern Hong Kong Island	The objectives of the study is to: * examine and assess the conditions and inadequacies of the stormwater drainage systems and associated facilities within the Study Area; * recommendations to improve drainage system to meet current standards and future needs together with construction cost estimates * develop a prioritised programme/staging of works based on costs and benefits for implementation of the recommended works; and * develop a stormwater drainage assest inventory and management system	Total cost of recommended measures: $2,141.24M	Voluntary	Study - Prepare Recommendations - Prevent	Status: study completed The study has conducted assessments through hydraulic modelling, utility intrusion investigation, and flood and rainfall survey. A range of recommendations were made in the study on potential options for improvement, taking into account of the geological aspects, transport network and etc. Three drainage improvement works items were recommended: * Hong Kong West Drainage Tunnel * Lower Catchment Improvement * Sheung Wan Stormwater Pumping Station		Stormwater Drainage Master Plan Study in Northern Hong Kong: Executive Summary. 2003. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/NHK%20Study%20Report%20Eng.pdf> [Accessed 02 Feb 09]
	Stormwater	The objectives of the study is to:* examine	Total	Voluntary	Study -	Status: study completedThe study		Stormwater Drainage

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Drainage Master Plan Study in Tsuen Wan, Kwai Chung and Tsing Yi Drainage	and assess the conditions and inadequacies of the stormwater drainage systems and associated facilities within the Study Area;* recommendations to improve drainage system to meet current standards and future needs together with construction cost estimates* develop a prioritised programme/staging of works based on costs and benefits for implementation of the recommended works; and * develop a stormwater drainage assest inventory and management system	Estimated Capital Costs for proposed improveme nt works: $1,184 million		PrepareRec ommendati ons - Prevent	assessed the drainage system in the area, including the 13 major catchments, through the use of computer models. Two major recommendations were made at the end of the study, each of which was assessed against a set of criteria such as the configuration of the systems, topography and geology; land requirements; interfaces with utilities and underground structures; highway and traffic considerations; environmental considerations; maintenance and reliability; capital and operating costs. The study has also identified the remaining risks that may occur under certain circumstances and recommended regular inspections.		Master Plan Study in Tsuen Wan, Kwai Chung and Tsing Yi: Executive Summary. 2002. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/TW%20Study%20Report%20Eng.pdf> [Accessed 02 Feb09]
	Stormwater Drainage Master Plan Study in Tuen Mun and Sham Tseng (TMDMP)	Similar to the above Drainage Master Plan Studies commissioned by the government, the objective of the TMDMP is to assess the drainage system in the proposed area, and to provide recommendations on improvements, together with the estimated costs and timeline.	Total Estimated Cost for implementi ng the proposed programme : $75 million (at Dec 1998 prices), $0.55 million for structural	Voluntary	Study - Prepare Recommen dations - Prevent	Status: study completed Recommendations were made addressing issues identified in the assessments: * First aid measures for flood prone areas * Drain-laying in streets * Demolition of vehicular bridge * Bank raising * Box culvert and pipe * Trapezoidal channel with grasscrete banks		Stormwater Drainage Master Plan Study in Tuen Mun and Sham Tseng: Executive Summary. 2002. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/TMST%20Study%20Report%20Eng.pdf> [Accessed 02 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
			repairs					
	Drainage Master Plan Study in the Northern New Territories	Similar to the above Drainage Master Plan Studies commissioned by the government, the objective is to assess the drainage system in the proposed area, and to provide recommendations on improvements, together with the estimated costs and timeline.	Total Estimated Cost for implementing the recommendations: $1,386 million	Voluntary	Study - Prepare Recommendations - Prevent	Status: study completed Proposed improvement works: * Upgrading and rehabilitation of pipes and culverts to provide improvement to the existing drainage systems in identified areas * Construction of drainage channels * Improvement on secondary and local channels		Drainage Master Plan Study in the Northern New Territories: Executive Summary. 2003. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/NNT%20Study%20Report%20Eng.pdf> [Accessed 02 Feb 09]
	Stormwater Drainage Master Plan Study in Sha Tin and Tai Po	Similar to the above Drainage Master Plan Studies commissioned by the government, the objective is to assess the drainage system in the proposed area, and to provide recommendations on improvements, together with the estimated costs and timeline.	Total Estimated Cost for implementing the recommended programme: $386 million Structural Repairs: $8.3 million	Voluntary	Prepare	Status: study completed Recommendations were: * Drain-laying in streets * Modifications to river bank walls * Construction of flood water pumping station * Installation of flap valves at outfalls * Construction of floodwall * Drainage diversion		Stormwater Drainage Master Plan Study in Sha Tin and Tai Po: Executive Summary. 2003. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/STTP%20Study%20Report%20Eng.pdf> [Accessed 02 Feb 09]
	Stormwater Drainage Master Plan Study in Sai	Similar to the above Drainage Master Plan Studies commissioned by the government, the objective is to assess the drainage system in the proposed area, and to provide	Total Estimated Cost for implementi	Voluntary	Prepare	Status: study completed Recommendations include: * Widen and deepen the rivers to a trapezoidal channel with		Stormwater Drainage Master Plan Study in Sai Kung, East Kowloon and Southern Lantau:

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Kung, East Kowloon and Southern Lantau	recommendations on improvements, together with the estimated costs and timeline.	ng the recommendations: $802.5 millionStructural Repairs: $4.4 million			grasscrete and masonry bank and natural bed * Construction (or enlarge) of box vulvert * Construction of concrete kerbs along riverbanks * Construction of high parapet wall * Construction of pipes Development and implementation of Asset Inventory and Management System (AMS) and Real Time Flow Monitoring System (RTFM)		Executive Summary. 2003. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/SK%20EKLN%20Study%20Report%20Eng.pdf> [Accessed 02 Feb 09]
	Stormwater Drainage Master Plan Study in Southern Hong Kong Island	Similar to the above Drainage Master Plan Studies commissioned by the government, the objective is to assess the drainage system in the proposed area, and to provide recommendations on improvements, together with the estimated costs and timeline.	Total Estimated Cost for implementing the recommendations: $4.2 million Structural Repairs: $4.4 million	Voluntary	Prepare	Status: study completed Proposed Plan: * First Aid Measures * Overall improvement programme (enlarge pipes, construction of box vulvert and etc) * Roadside drainage improvement		Stormwater Drainage Master Plan Study in Southern Hong Kong Island: Executive Summary. 2005. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/flood_prevention/our_achievement/other_areas/SHKI%20Study.pdf> [Accessed 02 Feb 09] (Available in Chinese only)
Civil Engineering and Development	Design, Construction and Handing Over of	General requirements for the design and approval of Drainage and Sewerage projects are given in the Project Administration Handbook for Civil Engineering Works, 2008	Not Specified	Mandatory	Prepare	Extreme Sea Levels are given by the Hong Kong observatory, return periods depend on the design life. Water Quality Control	• Discharge problems at drainage outflows –	Design, Construction and Handing Over of Drainage and Sewerage Works. Civil Engineering

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Department	Drainage and Sewerage Works	Edition. More detailed information is given in the Stormwater Drainage and the Sewerage Manual, respectively.				is governed by the Water Pollution Control Ordinance (WPCO, 1980) and by the Dumping at Sea Order 1975 (additionally, Air Pollution Ordinance, Noise Control Ordinance and relevant Technical Memoranda). Calculations and methods for the estimations of peak flows (and in the case of wastewater also composition and characteristics) are given in the respective manuals. Concerning the discharge method, both manuals describe requirements for the design of gravitational flows and the artificially enhanced discharge systems (pump or channel systems).	risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	and Development Department. Technical Circular No. 08/2004. <http://www.cedd.gov.hk/eng/publications/technical_circulars/doc/tc_08_04.pdf> [Accessed 16 April 09] Project Administration Handbook for Civil Engineering Works, 2008 Edition. Civil Engineering and Development Department. <http://www.cedd.gov.hk/eng/publications/standards_handbooks/stan_pah.htm> [Accessed 16 April 09] Storm Water Drainage Manual. 2000 Edition. Civil Engineering and Development Department. <http://www.dsd.gov.hk/FileManager/EN/publications_publicity/other_publications/technical_manuals/Stormwater%20Manual.pdf> [Accessed 16 April 09] Sewerage Manual Part 1. 1995 Edition. Civil

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								Engineering and Development Department. <http://www.dsd.gov.hk/FileManager/EN/publications_publicity/other_publications/technical_manuals/Sewer%20Manual%20Part%201.pdf> [Accessed 16 April 09]
Drainage Service Department and Environmental Protection Department	Sewerage Master Plan	In 1989, a sewage disposal strategy was adopted by the Government. Since then, 16 Sewerage Master Plan Studies have been undertaken by Environmental Protection Department to cover all of Hong Kong. In order to account for the growth of the population in Hong Kong, the 16 Sewerage Master Plans are being reviewed to accommodate the changes in planned population.	Not Specified	Mandatory	Prepare	-	• Discharge problems at drainage outflows – risking backing up • Flooding of system beyond designed capacity • Asset damage from flooding	Sewerage Master Plan. Drainage Service Department 2009. <http://www.dsd.gov.hk/sewerage/sewerage_improvement_content/sewerage_master_plan_project/index.htm> [Accessed 16 April 09]
Hong Kong Observatory in co-operation with the Lands Department and Hong Kong Polytechnic University	Vertical ground movement measurements	Measurements of the vertical ground movement at tide gauge stations, using satellite-based Global Positioning System techniques started in 2004. This data will support long term sea level change studies in future.	Not Specified	Mandatory	Prepare	Information on predicted and real time tide are provided on the Hong Kong Observatory website.	• Impacts associated with relative sea level rise, e.g. coastal flooding, health and safety risks	Press Release HKO announces findings on long-term sea level change in HK (14 June 2004). Hong Kong Observatory. <http://www.weather.gov.hk/wxinfo/news/2004/pre0614e.htm> [Accessed 15 Apr 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Hong Kong Observatory	Tidal information	A number of automatic tide gauges have been installed at sites along the coast of Hong Kong since 1950s. The North Point/Quarry Bay (NPQB) tide gauge station provides the longest tidal records in Hong Kong.	Not Specified	Mandatory	Prepare	Tide gauge station at North Point measured the sea level of Victoria Harbour from 1954 to 1985, and then was relocated to Quarry Bay in 1986. Both stations were built on reclaimed land (other stations were not built on reclaimed land) and the Port Works Division of the Civil Engineering Department carried out the monitoring of settlement of the station. Station at Tai Po Kau has been recording sea levels in Tolo Harbour since 1963. Station at Tsim Bei Tsui since 1974. Station at Waglan Islands since 1976. Station at Shek Pik since 1997.	• Impacts associated with relative sea level rise, e.g. coastal flooding, health and safety risks	HKO Reprint 556 Long Term Sea Level Change in Hong Kong. Hong Kong Observatory.
Works Branch	Technical Circular No. 6/90 - Greenhouse Effect - Allowance in Design	The possible implications of the Greenhouse Effect should be considered at an early stage in all designs - make an allowance for the Greenhouse Effect, assuming a 10 mm increase in mean sea-level per year.	Not Specified	Voluntary	Prevent, Prepare	Allowance for the Greenhouse Effect in designs should not generally be made, except for the following circumstances:(i) Where doing so would entail no extra capital or maintenance costs;(ii) Where doing so would entail minimal extra capital (2% maximum increase) and/or maintenance costs;(iii) For projects of design life of at least 50 years that are particularly sensitive to sea-level changes, and where to increase levels or make other alterations at a later stage would	• Impacts associated with relative sea level rise, e.g. coastal flooding, asset damage, health and safety risks	

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						be very difficult or expensive.		
Civil Engineering and Development Department	Land Reclamation Guidelines	General requirements for the design and approval of construction projects are given in the Project Administration Handbook for Civil Engineering Works, 2008 Edition. Specifics on the Design of constructions in the harbour area of Hong Kong are given in the Port Works Design Manual (Part 1 and 3). While Part 1 covers general design considerations for Marine Works, Part 3 specifies on the design of land reclamations.	Not Specified	Mandatory	Prevent, Prepare	The Project Administration Handbook provides an overview over governmental departments and organisations that have to approve (part of) the planning of a construction. Minimum heights for Port Constructions are determined by the Extreme Water Level Tables from the Hong Kong Observatory, where the return period has to be selected in accordance with the design life of the planned construction (see PWDM Part 1). The settlement of the land reclamation is estimated in the design process, and has to be verified with measurements after the construction process has been completed (see PWDM Part 3).	• Impacts associated with relative sea level rise, e.g. coastal flooding, asset damage, health and safety risks	Port Works Design Manual. 2002 Edition. Civil Engineering and Development Department. <http://www.cedd.gov.hk/eng/publications/manuals/index.htm> [Accessed 16 April 09] Project Administration Handbook for Civil Engineering Works. 2008 Edition. Civil Engineering and Development Department. <http://www.cedd.gov.hk/eng/publications/standards_handbooks/stan_pah.htm> [Accessed 16 April 09]
Town Planning Board	Protection of the Victoria Harbour Ordinance	The Protection of the Harbour Ordinance (PHO) provides that "the harbour is to be protected and preserved as a special public asset and a natural heritage of Hong Kong people, and for that purpose there shall be a presumption against reclamation in the harbour."	Not Specified	Mandatory	Prevent	The Protection of the Harbour Bill passed the Legislative Council, and became a PHO, on 27 June 1997. The PHO then only protected the Central Harbour, and through a subsequent amendment, was extended to the whole of the Victoria Harbour in 1999.	• Impacts associated with relative sea level rise, in particular those occurring on reclaimed land on either side of Victoria Harbour	Protection of the Harbour Ordinance and the Court of Final Appeal Judgment. Harbour Front Enhancement Committee. 2004. <http://www.harbourfront.org.hk/eng/content_page/protection.html?s=2> [Accessed 16 April 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Environmental Protection Department	Environmental Impact Assessment Ordinance	For assessing the impact on the Environment of certain projects and proposals, for protecting the environment and for incidental matters. Designated projects must apply for an environmental permit which must outline prevention and mitigation measures. If total avoidance is not practicable, the project proponents are required to mitigate the adverse impact to an acceptable level.	Not Specified	Mandatory	Prevent	-		Chapter 499 Environmental Impact Assessment Ordinance in Bilingual Laws Information System. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=486&Count=30&Expand=499#499> [Accessed 17 Sep 09]

Table B6 Existing Policies / Measures that may Contribute to Adaptive Responses to Business and Industry (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Qualifications Framework (QF) Secretariat under the Education Bureau and the Logistics Industry Training Advisory Committee (ITAC)	Specification of Competency Standards (SCS) for logistics Industry	The standards consists of competency standards of different levels including these major functional areas Operation Management, Planning and Design of Logistics Solutions, Sales, Marketing and Customer Services, Cargo Transport and Handling, Cargo Safety and Security, Import/Export Documentation, Insurance and Legal Matters, E-Logistics, Occupational Safety and Health and Quality Management. According to this standard, training providers can design training programmes that would help learners achieve the specified competency standards. Environmental management, environmental assessment of working procedure, environmental protection and contingency procedures for environmental accidents are covered in different levels in the Quality Management chapter. It requires practitioners to consider how to reduce the environmental accidents and minimise its impacts.	-	Voluntary	Prepare	-	• Environmental accidents associated with climate change, e.g. heavy rainfall, tropical cyclones, thunderstorm, hot weather etc.	Specification of Competency Standards (SCS) <http://www.hkqf.gov.hk/guie/SCS_list.asp> [Accessed 8 June 09]

Table B7 Existing Policies / Measures that may Contribute to Adaptive Responses to Energy Supply (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Hong Kong SAR Government	Scheme of Control Agreements (SCA)	New Scheme of Control Agreements was reached with the two power company in Hong Kong in 2008. The terms listed under the new agreements will encourage emission reduction, energy efficiency; enhance service quality and operational performance, and the use of renewable energy. Consumers are also protected where it ensures reliable and secure electricity supply is available at a reasonable price.	Not Specified	Mandatory	Prevent	-	• Increased use of mechanical cooling • Risk of power interruption due to supply/demand mismatch, power spikes and load shedding • Reduction in peak capacity • Increased transmission system losses as lines sag	New Scheme of Control Agreements reached with the two power companies. Press Releases. 7 January 2008. Information Services Department. <http://www.info.gov.hk/gia/general/200801/07/P200801070187.htm> [Accessed 04 Feb 09] Scheme of Control Agreement. n.d. Hong Kong Electric Holdings Limited. <http://www.heh.com/hehWeb/AboutUs/SchemeOfControlAgreement/Index_en.htm> [Accessed 04 Feb 09]
Electrical and Mechanical Services Department	Electricity Ordinance	The Electricity Ordinance under the direction of the EMSD is designed to that there is a continued supply of electricity and that activities carried out in the vicinity of electricity supplies do not hinder safety. Part III specifically lists the powers and obligations of electricity suppliers. Section 11 of the Electricity Ordinance deals with the event of an electricity interruption. In the event of an interruption, the electricity supplier shall (1) give the Electrical and Mechanical Services Director a report of the cause of the interruption and what remedial action has been or will be done to prevent a recurrence of the interruption if requested by the Director and (2) the Director may	Not Specified	Mandatory	Prevent, respond	-	-	CAP 406 Electricity Ordinance < http://www.legislation.gov.hk/blis_pdf.nsf/6799165D2FEE3FA94825755E0033E532/64775510C11F557B482575EF0003EE3E/$FILE/CAP_406_e_b5.pdf > [Accessed 17 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		by notice require an electricity supplier who receives electricity directly from a source outside of Hong Kong to inform the Director and any other person specified by the Director of a loss or impending loss of all or a portion of the electricity supply from that source or of an impending failure to receive an expected supply of electricity from that source and the Director may specify in the notice the type of information required and the method and frequency of reporting it. Section 17: Emergency disconnection allows energy suppliers to disconnect energy at the risk of electrical accident. Section 18: Disconnection to ensure supply stability allows energy suppliers to disconnect supply of electricity if it will ensure the safe and stable operation of energy.						
Electrical and Mechanical Services Department	Electricity Supply Lines (Protection) Regulation	The main objective of the ESLPR is to regulate construction site activities including the use of heavy machinery to prevent damaging the underground power cables and overhead lines. The ESLPR was promulgated in 2000 with a view to preventing power interruptions and electrical accidents arising from damages by third parties.	Not Specified	Mandatory	Prevent	-	-	CAP 406H Electricity Supply Lines (Protection) Regulation <http://www.legislation.gov.hk/blis_pdf.nsf/6799165D2FEE3FA94825755E0033E532/DB5D88FE24875A10482575EF000458D3/$FILE/CAP_406H_e_b5.pdf> [Accessed 17 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Emergency Support Unit Security Bureau	HKSAR Emergency Response System	Chapter 9 of the Emergency Response System specifies the roles and responsibilities of departments and agencies. In the event of electricity and town gas supplies being interrupted during severe weather conditions, the Director of Electrical and Mechanical Services working in close liaison with the utilities companies will be responsible for ensuring that, as quickly as practicable, carry out repair works to resume supply. Upon request, the Department will also provide special equipment to assist with search and rescue operations.	Not Specified	Mandatory	Respond	-	-	Ch.9 HKSAR Emergency Response System <http://www.sb.gov.hk/eng/emergency/ers/pdf/ERSc9.pdf> [Accessed 10 Sep 09]
Hong Kong SAR Government	Demand Side Management Agreement	The two power companies have agreed to promote energy efficiency and conservation through various programmes in co-ordination with the Government. The programmes aimed to influence consumers' electricity consumption patterns: * Energy Efficiency Programme (labelling, energy codes, guidelines) * Peak Clipping Programme (Pricing) * Load Shifting Programme * General education/ informational Programmes	Not Specified	Voluntary	Prevent, Prepare	-	• Increased use of mechanical cooling • Risk of power interruption due to supply/demand mismatch, power spikes and load shedding • Reduction in peak capacity	Government and power companies sign agreements on demand side management. Press Release 31 May 2000. Information Services Department. <http://www.info.gov.hk/gia/general/200005/31/0531171.htm> [Accessed 04 Feb 09] Introduction to DSM. n.d. Hong Kong Electric Holdings Limited. <http://www.heh.com/hehWeb/CommunityAndEducation/EnergyEfficiencyAndConservation/DemandSideManagement/Index_en.htm> [Accessed 04 Feb 09]

Table B8 Existing Policies / Measures that may Contribute to Adaptive Responses to Financial Services (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Hong Kong Monetary Authority	Banking Ordinance Cap 155	Under Section 101 of the Banking Ordinance, a minimum capital adequacy ratio of 8% must be maintained. The ratio is intended to be a measurement of a bank's capital position in respect of its exposures to credit risk, market risk and operational risk (that is the risk of direct or indirect losses resulting from inadequacies or failings in the processes or systems, or of personnel, of an institution; or from external events).	Not Specified	Mandatory	Prevent	-	• Business interruption • Poor performance of investments	Capital Adequacy Ratio in *Guide to Hong Kong Monetary and Banking Terms* .n.d. Hong Kong Monetary Authority. <http://www.info.gov.hk/hkma/gdbook/eng/c/capital_adequacy_ratio_index.htm> [Accessed 07 Feb 09]
Hong Kong Monetary Authority	Supervisory Policy Manual	A guideline for authorised institutions in meeting the minimum standards of the Banking Ordinance and the latest supervisory policies and practices. It also provides recommendations on how may these standards be met.	Not Specified	Voluntary (Guidelines to meeting the Banking Ordinance)	Prepare (Respond, Recover)	The manual also include guidelines on the establishment of business continuity plan. It advised authorised institutions to adopt two-tier plans where one deals with near-term problems and the other to deal with a longer-term scenario. In addition, guidelines on operational risk management and strategic risk	• Business interruption • Poor performance of investments • Business continuity issues	Business Continuity Planning. Guidelines and Circulars. 31 Jan 2002. Hong Kong Monetary Authority. <http://www.info.gov.hk/hkma/eng/guide/circu_date/20020131a_index.htm> [Accessed 07 Feb 09] Supervisory Policy Manual. 2008. Hong Kong Monetary Authority. <http://www.info.gov.hk/hkma/eng/bank/spma/index.htm> [Accessed 07 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						management are also included in the manual.		
Home Affairs Department - Building Management	Property-All-Risks Insurance (Property insurance)	Building owners and owners' corporations are advised to purchase property insurance in addition to the mandatory Third Party Risk Insurance. When there is any loss or damage to the common properties of the building due to fire or other risks (e.g. flooding) covered by the terms of the policy, the insured can seek the insurance company for indemnity.	Not Specified	Voluntary	Respond	Guidelines to owners' corporations on private building insurance.	• Damage to assets and infrastructure • Cost of insured losses	Types of Building Insurance in Financial Management, Procurement and Insurance. n.d. Home Affairs Department - Building Management. <http://www.buildingmgt.gov.hk/en/financial_management_procurement_and_insurance/5_3_2.htm> [Accessed 07 Feb 09]

Table B9 Existing Policies / Measures that may Contribute to Adaptive Responses to Food Resources (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Agriculture, Fisheries and Conservation Department	Introduction of Controlled-Environment Greenhouse (CE Greenhouse)	Development of greenhouse technology with suitable climate in order to produce (intensively) high value crops such as white bitter cucumbers, rock melons, edible fungi and lilies. The technology has been promoted to farmers through seminars and demonstrations.	Not Specified	Voluntary (however farmers must apply for a letter of approval from the Lands Department to set up the technology)	Prepare	-	• Reduced agricultural output • Increased cost and lower availability of imported food	Agriculture. n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/misc/download/annualreport2006/big5/agriculture.html> [Accessed 29 Jan 09] Introduction of Controlled-Environment Greenhouse (CE Greenhouse). n.d. Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/agriculture/agr_ceg/agr_ceg_ceg/agr_ceg_ceg.html> [Accessed 04 Feb 09]
St. James' Settlement	People's Food Bank	Established in 2003, the People's Food Bank provides the poor with temporary food assistance. It is funded by some subsidies by the Hong Kong government, but most food, money, tools, and equipment are donated by benefactors.	Not specified	Voluntary	Prepare, respond	NGOs - food bank	-	People's Food Bank < http://foodbank.sjs.org.hk/en/home.action> [Accessed 16 Sep 09]
Trade and Industry Department	Rice Control Scheme	Rice is scheduled as a reserved commodity which is to ensure that there is a reserve of rice sufficient for consumption in emergencies or short term	Not specified	Mandatory	Prepare	TID - ordinance for certain quantity of rice in HK	• Reduced agricultural output	Rice Control Scheme <http://www.tid.gov.hk/english/import_export/nontextiles/nt_rice/files/rice_guidelines.pdf> [Accessed 16 Sep

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		shortage supply. All rice stockholders registered with the Trade and Industry Department must comply with the scheme and only rice stockholders may import rice into Hong Kong for local consumption. The current level deemed sufficient for consumption by the local population for a reasonable period of time is fifteen days. A rice stockholder must either maintain 17% of its registered import quantity or 17% of the immediate preceding import period.						09]

Table B10 Existing Policies / Measures that may Contribute to Adaptive Responses to Human Health (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
General Policies / Measures								
Hong Kong Observatory	Cold and Very Hot Weather Warnings	Warnings are issued by the Hong Kong Observatory when Hong Kong is threatened by cold or very hot weather. The warning aims to alert members of the public of the risk of heatstroke or low body temperature. It also notifies government departments such as the Social Welfare Department and Home Affairs Department to provide assistance to those in need (i.e. temporary shelters, distribution of blankets). The Hong Kong Observatory and Department of Health will also give advice on measures to prevent health issues such as hyperthermia and sunburn.	Not Specified	Mandatory	Prepare, Respond	-	• Human health risks, e.g. increase in weather harvesting of vulnerable populations, such as aged	Cold and Very Hot Weather Warnings. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/warning/coldhot.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	Rainstorm Warning System	Rainstorm warnings are issued when heavy rain is expected and is likely to cause major disruptions such as flooding and landslips. The warnings are classified into three levels: Amber, Red and Black. Similar to other Hong Kong Observatory warning services, information is broadcasted to alert the public and allow emergency services to be prepared. The Hong Kong Observatory also provides guidance on safety measures to	Not Specified	Mandatory	Prepare, Respond	-	• Infrastructure and asset damage from heavy rain events, e.g. from floods, landslips, accidents etc • Human health risks	Rainstorm Warning System. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/warning/rainstor.htm> [Accessed 06 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		the public under each level of rainstorm warning.						
Hong Kong Observatory	Fire Danger Warning System	The Fire Danger Warning is to alert the public when fires may start and spread easily due to certain weather conditions (i.e. humidity, wind speed). The warnings are classified into Yellow (high risk) and Red (extreme risk).	Not Specified	Mandatory	Prepare, Respond	-	• Increase risk of wildfires • Human health risks	Fire Danger Warnings in *HKO Warnings and Signals Database*. n.d. Hong Kong Observatory. <http://www.hko.gov.hk/wxinfo/climat/warndb/warndb6_e.shtml> [Accessed 06 Feb 09] Fire Danger Warning. n.d. Hong Kong Observatory. <http://www.hko.gov.hk/publica/gen_pub/fdw_e.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	Thunder-storm Warning	Thunderstorm warning issued by the Hong Kong Observatory is to alert the public of the likelihood of thunderstorms and the affected areas. HKO also provides guidance on preventive measures (e.g. stay indoors, do not swim or engage in water sports).	Not Specified	Mandatory	Prepare, Respond	-	• Infrastructure and asset damage from wind, lightning strike • Human health risks	Thunderstorm Warning. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/warning/thunder.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	Landslip Warning	When the Geotechnical Engineering Office expects the occurrence of numerous landslips, a landslip warning will be issued by the Hong Kong Observatory and broadcasted. The	Not Specified	Mandatory	Prepare, Respond	-	• Infrastructure and asset damage from landslips	Landslip Warning. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/warni

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		warning is to alert members of the public, engineers, contractors and others who are likely to suffer losses form landslips to take precautionary measures.					• Health risks to building occupants	ng/landslip.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	Special Announcement on Flooding in the Northern New Territories	A Special Announcement on Flooding in the northern New Territories will be issued by the Hong Kong Observatory whenever heavy rain affects the area and flooding is expected to occur or is occurring in the low-lying plains of the northern New Territories.	Not Specified	Mandatory	Prepare, Respond	-	• Asset damage from flooding	Special Announcement on Flooding in the Northern New Territories. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/warning/flood.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	The Tropical Cyclone Warning Service	The Hong Kong Observatory will issue tropical cyclone warnings whenever a tropical cyclone centres within 800 km of Hong Kong to alert the public (and government departments) of the threats and danger a tropical cyclone poses to Hong Kong. Different levels of warning are issued according to actual or expected wind strength affecting Hong Kong. The warnings broadcasted will contain information on cyclone location, intensity and expected movement, associated weather and hazardous impact, and advice on precautionary measures.	Not Specified	Mandatory	Prepare, Respond	Separate warnings are issued for shipping, aviation and other specialised users.	• Asset damage from wind, flooding, storm surge, landslides, lightning strike etc• Human health risks	The Tropical Cyclone Warning Service. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/tsheet/tcwarn.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	Strong Monsoon Signal	The Strong Monsoon Signal is issued when winds associated with the summer or winter monsoon are blowing in excess of or are expected to exceed 40 kilometres per hour near sea level anywhere in Hong Kong.	Not Specified	Mandatory	Prepare, Respond	-	• Asset damage from wind • Human health risks	The Strong Monsoon Signal. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/warning/smse.htm>

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		The signal aims to inform the public and engineers of strong gusty wind in order to take preventive measures such as the removal of loose outdoor objects (that are likely to be blown away) and securing scaffoldings, hoardings and temporary structures.						[Accessed 06 Feb 09]
Hong Kong Observatory	Marine Weather Forecasts and Warnings	Marine weather forecasts for shipping are issued twice a day by the Central Forecasting Office of the Hong Kong Observatory. They contain warnings of winds of gale force or above, a synopsis of significant meteorological features and 24-hour forecasts of weather and sea state for ten marine areas in the South China Sea and the western North Pacific. These forecasts are broadcast via NAVTEX, an international broadcast system for disseminating navigational information by the coastal radio station for ships in the region.	Not Specified	Mandatory	Prepare, Respond	When a tropical cyclone is located within the area bounded by latitudes 10N and 30N and longitudes 105E and 125E, the Hong Kong Observatory issues additional warnings for shipping at 3-hourly intervals giving detailed information on the location, intensity and forecast movement of the tropical cyclone, and also wind and wave conditions associated with it.	• Human health risks	Marine Meteorological Services. 2003. Hong Kong Observatory. <http://www.hko.gov.hk/wservice/tsheet/marine.htm> [Accessed 06 Feb 09]
Hong Kong Observatory	Ultraviolet Index Information Service	An Ultraviolet (UV) Index of 11 or higher will trigger advisory messages from the Hong Kong Observatory about avoiding prolonged exposure to the sun and preventing eye and skin damage. The advisory messages will be included in the Observatory's hourly weather report.	Not Specified	Mandatory	Prepare, Respond	The Observatory has been measuring and disseminating UV levels since 1999 and the UV Index forecast commenced in May 2006.	• Human health risks	The Observatory enhances the Ultraviolet Index Information Service. Press Release 17 July 2008. Hong Kong Observatory. <http://www.weather.gov.hk/wxinfo/news/2008/pre0717Ae.

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								htm> [Accessed 05 Feb 09]
Department of Health	Elderly Health Service	The Elderly Health Services (EHS) was set up in July 1998 to promote the health of the elderly population through provision of community-based, client-oriented and quality primary health care services, with a whole person, multi-disciplinary team approach and maximum participation of everyone including the elderly themselves. The main services of EHS include elderly health centres and visiting health teams. Elderly health centres provide a comprehensive primary health care programme encompassing health assessment, counselling, curative treatment and health education. Visiting health teams provide health promotion programmes for the elderly to increase their health awareness and self-care ability. A total of 18 elderly health centres and 18 visiting health teams, one in each district, were established.	Not Specified	Voluntary	Prevent, Prepare	Other activities which EHS are involved in include education and awareness raising. Resource kits for both the elderly and elderly care providers are provided on the website along with educational information (pamphlets, books, and videos) and healthy living promotion. A newsletter is provided in traditional Chinese for the elderly to inform them of health services, tips, and information.	• Increase in weather harvesting of vulnerable populations	Department of Health Annual Report 05/06. <http://www.dh.gov.hk/tc_chi/pub_rec/pub_rec_ar/pdf/tabB08.pdf>; <http://www.dh.gov.hk/english/pub_rec/pub_rec_ar/pdf/0203/chapterfour08.pdf> [Accessed 30 Mar 09]
Department of Health	Promoting Health in Hong Kong: A Strategic Framework for Prevention	The overall goal of the strategy is to improve the health and quality of life of people in Hong Kong, which will in turn help lower their chance of having non-communicable diseases. To optimise health gains, this strategic framework	Not Specified	Mandatory	Prevent, Prepare	-	• Increase in harvesting of vulnerable population with non-communicable	Promoting health in Hong Kong: A strategic framework for prevention and control of non-communicable

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	and Control of Non-communicable Diseases	will focus on the major risk factors that are potentially preventable or modifiable and have significant impact on the health of the Hong Kong population.					diseases	diseases. n.d. Department of Health. <http://www.dh.gov.hk/english/pub_rec/pub_rec_ar/pdf/ncd/ENG%20whole%20DOC%2016-10-08.pdf> [Accessed 05 Feb 09]
Department of Health	HealthyHK	The HealthyHK website serves as a platform to disseminate statistical information related to the health of our population.	Not Specified	Not Applicable	Prepare	-	• Increase incidence of communicable and non-communicable diseases	HealthyHK. n.d. Department of Health. <http://www.healthyhk.gov.hk/phisweb/en/> [Accessed 29 Jan 09]
The Agriculture, Fisheries and Conservation Department	Public Health (Animals and Birds) Regulations	It regulates the import of animals and birds and removal of animals and birds in Hong Kong. It states that no person shall bring into Hong Kong any bird unless it is accompanied by a valid health certificate.	Not Specified	Mandatory	Prepare	-	• Increased proliferation of bacteria and micro-organisms • Human health risks	CAP 139A Public Health (Animals and Birds) Regulations <http://www.legislation.gov.hk/eng/home.htm>
Senior Citizen Home Safety Association	The PE Link Service	The Senior Citizen Home Safety Association provides services to the local elderly and aims to promote their quality of lives while protecting their proper care. The PE Link Service provides elderly and those in need 24-hour emergency support through a easy-to-use communication	Sponsored by Social Welfare Department: One-off: HK$2,500, Rent: HK$100/	Voluntary	Prevent, respond	NGOs - e.g. Senior Citizen Home Safety Association (Personal Emergency Assistance)	• Human health risks	SCHSA PE Link Service <http://www.schsa.org.hk/eng/service/pel.html> [Accessed 16 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		system.	month Sponsored by Housing Department: One-off HK$2,500 Sponsored by Housing Society: Rent: 1 set HK$100/ month Self Pay: One-off: HK$2,500 with HK$70 monthly service fee Rent: HK$100/ month + HK$300 deposit					

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Civic Exchange	Hedley Environmental Index	The Hedley Environmental Index estimates the costs to the community of to air pollution. These come in two forms: negative health impacts and dollar values.	Not Specified	Voluntary	Prepare			Hedley Environmental Index <http://hedleyindex.sph.hku.hk/home1.php> [Accessed 17 Sep 09]
Environmental Protection Department	Environmental Impact Assessment Ordinance	In granting or rejecting an environmental permit, the impact to the health and well being of people is considered.	Not Specified	Mandatory	Prevent			Chapter 499 Environmental Impact Assessment Ordinance in Bilingual Laws Information System. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=486&Count=30&Expand=499#499> [Accessed 17 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Accidents & Emergencies / External Health Stresses								
Home Affairs Department	Department Emergency Co-ordination Centre (DECC)	When weather warnings are announced by the Hong Kong Observatory, the DECC will be activated together with a 24 hour emergency hotline to provide updates on weather information and assistance to the public. The centre works in collaboration with other government departments and voluntary agencies to provide emergency relief such as temporary accommodation, hot meals, clothing and etc. Financial assistance will also be provided to those injured or family members of those who passed away in a disaster. In addition, social workers and psychologists will be organised for those in need.	Not Specified	Mandatory	Respond	In addition, other departments such as the Fire Services Department have emergency plans to manage disasters such as major fires, landslips and flooding. The Fire Services Department communication centre is linked to all fire stations, major hospitals, ambulance depots and other emergency services. This will allow other agencies such as the Government Flying Service and the Auxiliary Medical Service to rescue and provide assistance those in need. The emergency plans are reviewed and updated regularly.	• Increased number of accidents	Emergency Relief Services. n.d. Home Affairs Department. <http://www.had.gov.hk/en/public_services/emergency_services/emergency.htm> [Accessed 05 Feb 09] Emergency Services in Hong Kong: the facts. 2008. Information Services Department. <http://www.gov.hk/en/about/abouthk/factsheets/docs/emergency_services.pdf> [Accessed 05 Feb 09]
Security Bureau	Emergency Monitoring and Support Centre (EMSC)	The EMSC is activated when major emergencies or natural disasters happen or are likely to happen. It monitors the response of the emergency and support services, and provides support to these services. It briefs the Chief Executive and senior officials on developments and disseminates central government policy decisions and advice. Relevant government personnel will be mobilized	Not Specified	Mandatory	Respond	-	• Increased number of accidents	Emergency Services in Hong Kong: the facts. 2008. Information Services Department. <http://www.gov.hk/en/about/abouthk/factsheets/docs/emergency_services.pdf> [Accessed 05 Feb 09]HKSAR Government emergency structure in Daya Bay Contingency Plan of the

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		rapidly to assess the situation, to give decision-makers advice based on that assessment and to recommend countermeasures.						Hong Kong Special Administrative Region. n.d. Security Bureau. <http://www.sb.gov.hk/eng/emergency/dbcp/section4_3.htm> [Accessed 05 Feb 09]
Civil Aid Service	Civil Aid Service Central Command Centre	The centre was established in 1999 as the hub of incident control to support emergency services and government departments to enhance operational efficiencies. The Commander of the Centre is responsible and has the authority to arrange and assign resources and provide updates to all relevant parties.	Not Specified	Mandatory	Respond	-	• Increased number of accidents	CAS Central Command Centre. n.d. Civil Aid Service. <http://www.cas.gov.hk/eng/org/org_ccc.html> [Accessed 05 Feb Jan]
Security Bureau	Emergency Response System: the policy, principles and operation of the Government's emergency response system	The documents outlines the actions that will be taken under an emergency situation, including the Three Tier System, the rescue, recovery and restoration phase and communication with the public. It also sets out the roles and responsibility of departments and agencies.	Not Specified	Mandatory	Respond, Recover	The Three Tier System is designed to utilise resources effectively under an emergency situation, involving different levels of departments and agencies according to the circumstances. Emergency services such as the Hong Kong Police Force and the Fire Services Department are responsible for attending emergency situations at the Tier One Response level. Tier Two Response will be activated when incidents may threaten the safety of	• Increased number of accidents	The Government of the Hong Kong Special Administrative Region Emergency Response System: the policy, principles and operation of the Government's emergency response system. 2000. Emergency Support Unit, Security Bureau. <http://www.sb.gov.hk/eng/emergency/ers/ers.pdf> [Accessed 05 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						human life, property and security and the Security Bureau Duty Officer needs to be informed. At this level, the Emergency Support Unit will be monitored by the Government Secretariat. Tier Three Response is activated in situations where there are widespread threats to life, property and security, and require extensive Government emergency resources. The Emergency Monitoring and Support Centre will also be activated and other security committees will be involved if necessary.		
Security Bureau	Contingency Plan for Natural Disasters (including those arising from severe weather conditions)	The plan set out a variety of actions to be taken under specific events, such as tropical cyclones, rainstorm, flooding, thunderstorm and tsunami. It also listed out the roles and responsibilities of controlling authorities (categorised into phase e.g. rescue) and non-government organisations such as the media for broadcasting information.	Not Specified	Mandatory	Respond	The contingency plan is updated annually by the Security Bureau and the adequacy and effectiveness of the plan is fully tested on regular basis. All bureaux, departments and agencies are required to notify the Security Bureau of any changes (i.e. resource availability) that may affect the contingency	• Increased number of accidents	Security Bureau Circular No. 3/2007. Contingency Plan for Natural Disasters (including those arising from severe weather conditions). 2007. Emergency Support Unit. <http://www.sb.gov.hk/eng/emergency/ndisaster/cpnd-e092007.pdf>

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						plan, in order for the Security Bureau to issue amendments.		[Accessed 05 Feb 09]
Social Welfare Department / Housing Department / Marine Department / Agriculture, Fisheries and Conservation Department / Home Affairs Department (depending on the types of grant)	Emergency Relief Fund	The fund is to provide financial assistance to persons who are in need of relief as a result of a natural disaster such as tempest, typhoon, rainstorm, landslide and flooding. In addition, victims of fire, house collapse, boat capsize, shipwreck, explosion, eviction from a dangerous building or building affected by a Court Order as a result of natural disaster are also eligible for assistance. The Social Welfare Department is specifically responsible for burial, death, disability, injury, and interim maintenance grants.	Not Specified	Voluntary	Recover	-	• Increased number of accidents	Emergency Relief Fund Information Leaflet. n.d. <Agriculture, Fisheries and Conservation Department. <http://www.afcd.gov.hk/english/publications/publications_agr/files/erem.doc> [Accessed 04 Feb 09] Emergency Relief Fund Annual Report < http://www.swd.gov.hk/doc/social-sec/ERFAR08e.pdf> [Accessed 16 Sep 09]
Social Welfare Department	"Hong Kong is My Home" Social Club for Ethnic Minorities	To strengthen the supportive network of ethnic minorities, to promote mutual help amongst them	Not specified	Voluntary	Prepare	Social Welfare Dept - minority / disadvantaged groups; emergency relief		Social Welfare Department < http://www.swd.gov.hk/en/index/site_district/page_kcytm/sub_528/> [Accessed 16 Sep 09]

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Security Bureau	Emergency Response Operations Outside the Hong Kong SAR	The document outlines the action to be taken by government departments, agencies and relevant organisations when emergency situation arises outside of Hong Kong SAR. When Hong Kong Residents are involved in overseas emergency situation, emergency response personnel may be sent to the location to provide assistance. Otherwise, the Hong Kong government may contribute to international aid only.	Not Specified	Mandatory	Respond, Recover	-	• Increased number of accidents	Security Bureau Circular No. 4/2007. Emergency Response Operations Outside Hong Kong SAR. 2007. Emergency Support Unit, Security Bureau. <http://www.sb.gov.hk/eng/emergency/eroohk/eroohk_1107.pdf> [Accessed 05 Feb 09]
General Communicable Diseases								
Department of Health	Prevention and Control of Disease Ordinance (PCDO)	The Ordinance came into operation in July 2008, replacing the Quarantine and Prevention of Disease Ordinance. The PCDO aims to prevent and control infectious diseases and to enable compliance with the requirement of the World Health Organisation's International Health Regulations.	Not Specified	Mandatory	Prevent, Prepare, Respond	-	• Increased incidence of communicable diseases	Chapter 599 Prevention and Control Disease Ordinance in *Bilingual Laws Information System*. 2008. Department of Justice. <http://www.legislation.gov.hk/eng/home.htm> [Accessed 05 Feb 09] Prevention and Control of Disease Ordinance (Cap. 599) effective since 14 July 2008. 2008. Surveillance and Epidemiology Branch, Centre for

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								Health Protection. (36) in DH SEB CD/1-115/3. <http://www.dh.gov.hk/english/useful/useful_ld/files/ltod20080711.pdf> [Accessed 05 Feb 09]
Family Health Service (Department of Health), Centre for Health Protection	Childhood Immunisation Programme	The aim of the programme is to prevent infants and children from childhood infectious diseases (tuberculosis, poliomyelitis, hepatitis B, diphtheria, whooping cough (pertussis), tetanus, measles, mumps, rubella and pneumococcus infections). Parents can bring their children to any Maternal and Child Health Centre for immunisation, free of charge (eligible persons only) or to private doctors. School Immunisation Teams of the Department of Health will visit primary schools to provide immunisation service to school children.	Not Specified	Voluntary	Prevent	On the advice of the Scientific Committee on Vaccine PrevenTable Biseases under the Centre for Health Protection, pneumococcal conjugate vaccine has been included in the Childhood Immunisation Programme since September 2009. The department has also published a list of vaccines that have not been included in the Childhood Immunisation Programme.	• Increased incidence of communicable diseases	Hong Kong Childhood Immunisation Programme. Centre for Health Protection. <http://www.fhs.gov.hk/english/health_info/files/i_10.pdf> [Accessed 11 Feb 09]

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Centre for Health Protection	Centre for Health Protection Strategic Plan on Prevention and Control of Communicable Diseases 2007-2009	The strategic plan identified three key areas for the three year period: Real-time surveillance, rapid intervention and responsive risk communication. * Strengthen infectious disease surveillance system and network to improve the sensitivity and timeliness of outbreak detection* Prepare and plan for public health emergencies to implement control measures to minimise outbreaks effectively* Raise stakeholders'' awareness of and preparedness for public health threats* Provide training to healthcare professionals continuously to meet new demands and needs in various public health areas.	Not Specified	Mandatory	Prevent, Prepare	-	• Increased incidence of communicable diseases	Centre for Health Protection Strategic Plan on Prevention and Control of Communicable Diseases 2007-2009. 2006. Centre for Health Protection. <http://www.chp.gov.hk/files/pdf/grp-CHP%20Strategic%20Plan%202007-09-Final.pdf> [Accessed 05 Feb 09]
Centre for Health Protection	Central Notification Office (CENO)	Central Notification Office (CENO) has been set up under the Centre for Health Protection to centralize communicable diseases notifications and monitoring in Hong Kong.	Not Specified	Mandatory and voluntary	Prevent, Prepare, Respond	-	• Increased incidence of communicable diseases	Central Notification Office On-line. n.d. Centre for Health Protection. <www.chp.gov.hk/ceno> [Accessed 05 Feb 09]
Centre for Health Protection	24-hour Outbreak Response	To investigate outbreaks of infectious diseases in the community and instigate control measures.	Not Specified	Mandatory	Respond	-	• Increased incidence of communicable diseases	Centre for Health Protection Strategic Plan on Prevention and Control of Communicable Diseases 2007-2009. 2006. Centre for Health Protection. p. 74 <http://www.chp.gov.hk/files/pdf/grp-

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								CHP%20Strategic%20 Plan%202007-09-Final.pdf> [Accessed 05 Feb 09]
Hospital Authority	Infectious Disease Control Training Centre	Training Centre works in collaboration with the Centre for Health Protection to provide relevant training programs for different groups. It aims to develop a healthcare team with sound knowledge and skills in infection control and infectious disease management, to improve crisis management capability through leadership development programs.	Not Specified	Mandatory	Prepare	The Training Centre has the following main objectives: 1) Proficient Infection Control Team; 2) Effective infectious disease management service through team approach; 3) Effective leadership for Crisis Management; 4) Robust surveillance system to monitor the trend of infectious diseases in the community and to detect signs of outbreak; and 5) Proactive occupational safety and health team.	• Increased incidence of communicable diseases	Infectious Disease Control Training Centre. n.d. Hospital Authority. <http://www3.ha.org.hk/idctc/default.asp> [Accessed 05 Feb 09] Infectious Disease/ Infection Control 5-year Training Plan. n.d. Hospital Authority. <http://www3.ha.org.hk/idctc/Objectives.doc> [Accessed 05 Feb 09]
Centre for Health Protection (Department of Health)	Emergency Response Mechanism	The Centre for Health Protection has established three key centres as part of its emergency response mechanism: Risk Communication Centre, Outbreak Intelligence Centre and the Emergency Hotline Centre. The objective of the Risk Communication Centre is to provide a suitable venue for release of updated outbreak information to the media and public. The Outbreak Intelligence Centre performs ongoing,	Not Specified	Mandatory	Respond	-	• Increased incidence of communicable diseases	Centre for Health Protection Strategic Plan on Prevention and Control of Communicable Diseases 2007-2009. 2006. Centre for Health Protection. p. 12 <http://www.chp.gov.hk/files/pdf/grp-CHP%20Strategic%20

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		systematic collection, analysis, and interpretation of outbreak related data from different sources to enable real-time planning, implementation and evaluation of outbreak control strategies and ensure a closely coordinated and effective response against disease outbreak. The Emergency Hotline Centre is open for public enquiries under emergency situations.						Plan%202007-09-Final.pdf> [Accessed 05 Feb 09] New CHP's facilities ready for action. Press Releases. 23 March 2006. Information Services Department. <http://www.info.gov.hk/gia/general/200603/23/P200603230087.htm> [Accessed 11 Feb 09]
Centre for Health Protection	Emergency Response Centre	The Emergency Response Centre will act as the nerve centre of Department of Health in dealing with major outbreaks of infectious diseases. The Centre is to keep the community better informed about public health risks during major infectious disease outbreaks and work closely with other Government departments in combating the disease. During major outbreaks of infectious diseases, the ERC will collate up-to-date information about the disease from relevant departments and organisations, compile progress reports for information of the senior Government officials; inform the public the latest development via press conferences and briefings held at the Risk Communication Centre.	Not Specified	Mandatory	Prepare, Respond	-	• Increased incidence of communicable diseases	New CHP's facilities ready for action. Featured Topics 23 March 2006. Centre for Health Protection. <http://www.chp.gov.hk/content.asp?lang=en&info_id=6076> [Accessed 05 Feb 09]

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Department of Health, Food and Environmental Hygiene Department, Hong Kong Observatory	-	DH and FEHD are monitoring the international and local findings on the relationship between climate change and infectious diseases. DH is also working with other departments to prevent and control the spread of infectious diseases in relation to climatic factors through diseases surveillance.	Not Specified	Voluntary	Prepare	-	• Increased incidence of communicable diseases	LCQ17: Studies on relationship between local climatic factors and infectious diseases. Replies to LegCo questions. 11 May 2005. Food and Health Bureau. <http://www.fhb.gov.hk/en/legco/replies/2005/lq050511_q17.htm> [Accessed 09 Feb 09]
Centre for Health Protection	Risk Communication Advisory Group	The Group is to advise the Centre for Health Protection on risk communication strategies and development of action plans. The group also review the Centre for Health Protection existing risk communication measures.	Not Specified	Mandatory	Prepare	-	• Increased incidence of communicable diseases	Risk Communication Advisory Group. n.d. Centre for Health Protection. <http://sc.info.gov.hk/gb/www.chp.gov.hk/text/rcag1.asp?lang=en&id=136> [Accessed 05 Feb 09]
Centre for Health Protection	Clinical Infection and Public Health Forums & Infection Control Forums	The forums, supported by the Infectious Disease Control Training Centre, take place on a monthly basis to allow health professionals to share experiences and knowledge on infectious diseases and infection control issues of public health impact.	Not Specified	Voluntary	Prepare	-	• Increased incidence of communicable diseases	Centre for Health Protection Strategic Plan on Prevention and Control of Communicable Diseases 2007-2009. 2006. Centre for Health Protection. p. 80 <http://www.chp.gov.hk/files/pdf/grp-CHP%20Strategic%20

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								Plan%202007-09-Final.pdf> [Accessed 05 Feb 09]
Respiratory Diseases								
Education Bureau, Environmental Protection Department, Department of Health	Air Pollution Index (API)	A circular is sent out recommending school authorities to reduce physical exertion and outdoor activities of vulnerable or all students (i.e. students with heart or respiratory illnesses) when API of a certain level has been detected or forecasted.Hong Kong Observatory (HKO) will notify the Central Health Education Unit and the Information and Public Relations Unit of the Department of Health to alert the public of the air pollution index.	Not Specified	Voluntary	Prepare, Prevent	The Environmental Protection Department will provide daily air pollution concentrations and warnings to schools once API exceeds 100.	• Negative impact on air quality; increased mortality and morbidity associated with respiratory and cardiovascular conditions	EDB Circular No.3/1998. 10 June 1998. Education Department Hong Kong. <http://www.edb.gov.hk/UtilityManager/circular/upload/SMC/MC98003E.PDF> [Accessed 29 Jan 08]
Environmental Protection Department	Review of Air Quality Objectives	The Environmental Protection Department has, in June 2007, commissioned an 18-month comprehensive study to review Hong Kong's Air Quality Objectives (AQO) on the basis of the standards by the World Health Organisation, the European Union and the United States, and to develop a long-term air quality management strategy.	Not Specified	N/A	Prevent, Prepare, Respond	The scope of the study is to review and characterize the current state of air quality in Hong Kong, to examine the reasoning by WHO and US EPA devising their respective air quality guidelines, to estimate the development of air quality in different scenarios, to asses the conditions for the implementation of different standards, to derive practicable options to revise Hong Kong's	• Negative impact on air quality; increased mortality and morbidity associated with respiratory and cardiovascular conditions	Environmental Protection Department website. <http://www.epd.gov.hk/epd/english/environmentinhk/air/air_quality_objectives/air_quality_objectives.html> [Accessed 30 Mar 09]

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						AQO, and to review air quality monitoring.		
Food and Health Bureau	Emergency Preparedness for Influenza Pandemic In Hong Kong	The aim is to: * Reduce risk of human infections * Early detection of influenza pandemic * Enhance emergency preparedness and response for influenza pandemic Some of the measures include: on-going surveillance and monitoring, communicate with stakeholders on preventive measures, regulate importation of live poultry, trainings on infection control, conduct research to guide response measures, three-level response system, and etc.	Not Specified	Mandatory	Prevent, Prepare, Respond	-	• Increased incidence of respiratory diseases	Emergency Preparedness for Influenza Pandemic in Hong Kong. 2007. Food and Health Bureau. <http://www.chp.gov.hk/files/pdf/checklist-e_flu_eng_200708.pdf> [Accessed 05 Feb]
Food and Health Bureau	Framework of Government's Preparedness Plan for Influenza Pandemic	Establishment of the Hong Kong Government Three-level Response Systems. The three levels (Alert Response, Serious Response and Emergency Response) are based on different risk-graded epidemiological scenarios relevant to Hong Kong, and each of them prescribes a given set of public health actions required. The measures are designed to match with the World Health Organization's guideline	Not Specified	Mandatory	Prevent, Prepare, Respond	-	• Increased incidence of respiratory diseases	Framework of Government's Preparedness Plan for Influenza Pandemic. 2007. Food and Health Bureau. <http://www.chp.gov.hk/files/pdf/Flu_Plan_Framework_eng_14Mar_20050408.pdf> [Accessed 05 Feb 09]

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		for pandemic influenza planning.						
Vector Borne Diseases								
Food and Environmental Hygiene Department	Vector surveillance measures	These include the use of Oviposition Trap (Ovitrap), Area Ovitrap Index (AOI), and Monthly Ovitrap Index (MOI), to detect and monitor the presence of adult Aedine mosquitoes.	Not Specified	Mandatory	Prepare	Advice on anti-mosquito measures (i.e. mosquito control and prevention) and prevention of dengue fever are also provided to the public, construction sites, schools, housing estates, ports, ferry, hospitals/clinics, and Picnickers and Hikers.	• Greater incidence of some vector borne diseases	Pest Control. Department of Health, Food and Environmental Hygiene Department. <http://www.fehd.gov.hk/safefood/Pcas.html> [Accessed 01 Jun 09]
Food and Environmental Hygiene Department	Pest Control	Pest control work, such as the control of rodents, mosquitoes and other arthropod pests with medical importance is carried out by the Pest Control Teams of Food and Environmental Hygiene Department. The methodology in pest control is continuously reviewed to ensure effectiveness and efficacy in abating the disease vectors. Pest control aims to prevent and control the breeding of disease vectors, and to control the breeding of arthropod pests which cause nuisance to people.	Not Specified	Mandatory	Prepare	-	• Greater incidence of some vector borne diseases	Pest Control. Department of Health, Food and Environmental Hygiene Department.<http://www.fehd.gov.hk/safefood/Pcas.html> [Accessed 01 Jun 09]

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Water Borne Diseases								
Water Supplies Department	Water Quality	The water supplied by the Department complies with the Guidelines for Drinking-water Quality (2004) recommended by the World Health Organisation. Water quality is monitored through regular water sampling at various points in the supply and distribution system (i.e. water treatment works, service reservoirs, trunk mains, connection points and domestic taps), and the results are checked against the WHO guidelines. Tap water is safe for human consumption without boiling on the condition that buildings' plumbing system is managed properly.	Not Specified	Mandatory	Prevent	The following assumptions were made in the WHO Guidelines for Drinking-water Quality: * per capita daily consumption of 1 litre of unboiled water (developing guidelines for microbial hazard) * daily per capital consumption of 2 litres by a person weighing 60kg (for potentially hazardous chemicals)	• Reduced water quality • Greater incidence of some water borne diseases	Guidelines for Drinking-water Quality. 3rd e.d. Vol. 1. 2004. World Health Organization. <http://www.who.int/water_sanitation_health/dwq/GDWQ2004web.pdf> [Accessed 11 Feb 09] Water Quality. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/others/faq_wq.htm> [Accessed 11 Feb 09]
Water Supplies Department	Water Safety Plan (WSP)	The plan commenced in early 2007 to ensure the quality of water is maintained in Hong Kong. In order to do so, the department has planned to prevent, reduce and remove contamination during storage, distribution and handling of drinking water. The WSP provides details on hazard identification, risk assessment, monitoring and operational requirements, pollution control measures, as well as verification of treated water quality to confirm the overall safety of the supply system. The	Not Specified	Mandatory	Prevent	Based on WHO recommendations, the Department of Health and WSD have agreed on the adoption of a set of guideline values for chemical and bacteriological parameters as the health-based targets for the drinking water supply in HK. Additional resources including equipment and manpower are envisaged	• Reduced water quality • Greater incidence of some water borne diseases	ACQWS Paper No. 17 Water Safety Plan For Water Supplies Department. 2006. Water Supplies Department. <http://www.wsd.gov.hk/acqws/doc/p17.pdf> [Accessed 06 Feb 09] Water Safety Plan for the Water Supplies Department. n.d. Water Supplies

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		monitoring of water quality includes physical, chemical, bacteriological, biological and radiological examination of water samples collected at strategic points of the supply and distribution system. The water quality data of Hong Kong and the Dongjiang water supply are published and updated every six months. Another duty of the WSP is to set up contingency plans.				to cater for the fulfilment of the compliance monitoring of health-based targets, tightened operational monitoring and pollution control, reduction of identified risks, management of document control system, review and auditing work, etc. related to the implementation of the WSP. As a start-up, a new Gas Chromatograph Mass Spectrometer has been acquired and a new Trace Analysis Laboratory at Ma On Shan Water Treatment Works has been set up in order to accomplish the target. Follow-up actions will be initiated to seek other resources such as instruments to enhance monitoring and manpower including Waterworks Chemist, Engineering Laboratory Technician and operational staff to address requirements for risk reduction, source protection, operational control, compliance monitoring, document		Department. <http://www.wsd.gov.hk/en/text/water/water_safety.htm> [Accessed 06 Feb 09]

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						control, WSP review and audit, etc.		
Water Supplies Department	Quality Water Recognition Scheme for Buildings (Fresh Water Plumbing Quality Maintenance Recognition Scheme prior to 2008)	The aim of the scheme is to encourage building owners to maintain buildings' plumbing systems to ensure good water quality is provided at the taps. One of three grades of certificate is awarded to successful applicants to recognize the proper maintenance of the building's plumbing systems, issued by the Water Supplies Department. The criteria is to have the plumbing system inspected every three months, defects promptly rectified, clean water tanks every three months and sample water quality regularly which needs to meet the acceptable limits of the water quality indicators.	Not Specified	Voluntary	Prevent	-	• Reduced water quality • Greater incidence of some water borne diseases	Quality Water Recognition Scheme for Buildings. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/edu/fwpqmrse/fwpqmrse.htm> [Accessed 11 Feb 09]
Environmental Protection Department	Marine Water Quality Monitoring	EPD monitors the water quality of some 1,700 sq km of the territory's marine waters. The marine monitoring programme covers about 90 water and 60 sediment sampling stations in the open sea, semi-enclosed bays and typhoon shelters. The monitoring programme serves the following purposes: - indicate the state of health of marine waters; - assess compliance with the statutory Water Quality Objectives (WQOs); - reveal long-term changes in water quality; - provide a basis for the planning of				-	• Reduced seawater quality	Marine Water Quality Monitoring in Hong Kong. Environmental Protection Department. <http://www.epd.gov.hk/epd/english/environmentinhk/water/marine_quality/mwq_monitoring.html> [Accessed 01 Jun 09]

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		pollution control strategies.						
Environmental Protection Department	Water Quality Objectives	Hong Kong is divided into 10 Water Control Zones (WCZs) and each WCZ has a set of Water Quality Objectives (WQOs). The rates of annual compliance with the key WQOs (i.e. dissolved oxygen, ammonia, total inorganic nitrogen and E.coli) are assessed based on all the data collected during the year.				-	• Reduced seawater quality	Marine Water Quality Monitoring in Hong Kong. Environmental Protection Department. <http://www.epd.gov.hk/epd/english/environmentinhk/water/marine_quality/mwq_monitoring.html> [Accessed 01 Jun 09]
Food Borne Diseases								
Centre for Food Safety	Food Surveillance Programme	The Food Surveillance Programme is designed to control and prevent food hazards. The food surveillance programme will be strengthened by making it more risk-based and with a wider coverage. A Food Research Laboratory has been set up within the Public Health Laboratory Centre, which was completed in late 2001. The laboratory research conducted will provide scientific data for risk assessment and formulation of food surveillance strategies. The Centre also promotes public awareness and promulgates surveillance results for public information.	Not Specified	Mandatory	Prevent	-	• Greater incidence of some food borne diseases	Food Surveillance Programme. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/programme/programme_fs/programme_fs.html> [Accessed 04 Feb 09]

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Centre for Food Safety	Hazard Analysis and Critical Control Point (HACCP) System	The HACCP system identifies, assess and control hazards in food production processes. The system is a cost effective way to prevent potential food hazards by early identification during the production process rather than testing end products. Various food safety guidelines are available to food business and the general public to better understand food safety and prevention of food diseases.	Not Specified	Voluntary	Prevent	-	• Greater incidence of some food borne diseases	Hazard Analysis Critical Control Point (HAPCCP) System. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/programme/programme_haccp/programme_haccp.html> [Accessed 04 Feb 09]
Centre for Food Safety	Frozen Confections Regulations (this Regulation is under the Public Health and Municipal Services Ordinance)	This regulation provides a standard in which frozen confections for sale or to be stored, and restrict the sale of frozen confections.	Not Specified	Mandatory	Prevent	-	• Greater incidence of some food borne diseases	Food legislation/ guidelines in Food Laws in Hong Kong. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/food_leg/food_leg.html> [Accessed 04 Feb 09]
Centre for Food Safety	Microbiological Guidelines for Ready-to-eat Food	The guideline aims to assist inspection officers in interpreting the microbiological analyses of ready-to-eat food. Analysis results can be checked against the criteria listed in the guidelines for safety and hygiene quality. The guideline also recommends appropriate follow-up action for food safety monitoring and control measures.	Not Specified	Voluntary	Prevent	-	• Greater incidence of some food borne diseases	Microbiological Guidelines for Ready-to-eat Food. 2007 (revised). Centre for Food Safety. <http://www.cfs.gov.hk/english/whatsnew/whatsnew_act/files/MBGL_RTE%20food_e.pdf> [Accessed 04 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Centre for Food Safety	Risk Assessment in Food Safety	Risk assessment studies are conducted by the Centre, in particular, food related hazards that will affect public health are investigated. Findings are published, and made available to the public together with recommendations addressing the (potential) hazards identified.	Not Specified	Mandatory	Prevent	-	• Greater incidence of some food borne diseases	Risk Assessment in Food Safety. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/programme/programme_rafs/programme_rafs.html> [Accessed 04 Feb 09]
Centre for Food Safety	Restriction on the import of food into Hong Kong	Under the Public Health and Municipal Services Ordinance, it specified that food importers are to comply with local food standards and are encouraged to obtain health certificates from the country of origin certifying that the products are fit for human consumption. An official certificate issued by the Food Authority of the originating country or written permission from the Hong Kong Food and Environmental Hygiene Department is required for any person to bring any fresh, frozen or chilled meat and poultry into Hong Kong.	Not Specified	Mandatory	Prevent	There are specific legal requirements or administrative arrangements for the import of the following selected food items due to their perishable or high-risk nature: (a) game, meat and poultry; (b) milk and milk beverages; (c) frozen confections; and (d) marine products.	• Greater incidence of some food borne diseases	Chapter 132 Public Health and Municipal Services Ordinance in *Bilingual Laws Information System*. n.d. Department of Justice. <http://www.legislation.gov.hk/eng/home.htm> [Accessed 04 Feb 09]
Centre for Food Safety	Slaughterhouses and Disease Surveillance	The unit is responsible for disease surveillance by sampling food animals regularly, tested by the Veterinary Laboratory of the Agriculture, Fisheries and Conservation Department. Any suspected diseases discovered are to be reported. The unit is also responsible for collecting and verifying Animal Health	Not Specified	Mandatory	Prevent, Prepare	Slaughterhouses are monitored and inspected by the Department as well to ensure hygiene and environmental standards are met and only meat safe for human consumption is released for sale in market.	• Greater incidence of some food borne diseases	Slaughterhouses and Disease Surveillance. N.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/import/import_sds.html> [Accessed 04 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		Certificates of imported food animals from the Mainland and admission forms of pigs from local farms.				Slaughterhouses in Hong Kong regulated by the sub-legislation Cap 132BU Slaughterhouses Regulation under the Public Health and Municipal Services Ordinance.		
Food and Environmental Hygiene Department	Monitoring Pesticides Residues in Food	Sampling and testing of different foods for levels of pesticide residues, to ensure levels are within tolerance levels that are safe for human consumption.	Not Specified	Mandatory	Prevent	-	-	Monitoring Pesticides Residues in Food in *Import Control and Food Safety Guidelines*. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/import/import_icfsg_11.html> [Accessed 04 Feb 09]
Food and Health Bureau, Food and Environmental Hygiene Department (FEHD), Centre for Food Safety	Food Business Regulation (under the Public Health and Municipal Services Ordinance (Cap. 132))	This regulation controls food hygiene, hygiene of food premises and food businesses by licensing. Regular inspections are conducted by the Food and Environmental Hygiene Department to ensure that licensed food premises comply with the licensing requirements and conditions as well as hygiene standards prescribed under the law.	Not Specified	Mandatory	Prevent	-	• Greater incidence of some food borne diseases	Food legislation/ guidelines in Food Laws in Hong Kong. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/food_leg/food_leg.html> [Accessed 04 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Centre for Food Safety	Food Safety Focus	"Food Safety Focus" aims to raise awareness on both local and overseas food safety issues. The programme provides up-to-date information on food hazards and public health risks, and preventive measures that can be taken by the members of the public. Publications are released monthly on chosen food safety related topics.	Not Specified	Voluntary	Prevent	-	• Greater incidence of some food borne diseases	Food Safety Focus. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/english/multimedia/multimedia_pub/multimedia_pub_fsf.html> [Accessed 04 Feb 09]
Centre for Food Safety	Food Alerts/ Seasonal Food Safety Tips	The Centre for Food Safety promotes the prevention and control of food diseases relating to climate change such as cholera. The Centre also conducts risk assessment studies on food safety. *Food alerts* keeps the public updated on new findings, risks, and other food safety issues.	Not Specified	Not Applicable	Prepare, Prevent	-	• Greater incidence of some food borne diseases	Food Alerts/ Seasonal Food Safety Tips. n.d. Centre for Food Safety. <http://www.cfs.gov.hk/eindex.html> [Accessed 29 Jan 09]
Food and Environmental Hygiene Department	Food Hygiene Code	The objective of this code is to provide a set of model requirements to help food business achieve a higher degree of compliance with the food regulations as enshrined in the Public Health and Municipal Services Ordinance, and its subsidiary legislation, and attain a higher standard of food hygiene and food safety through adoption of good practices. It also provides FEHD officers and food businesses detail advice and guidance on the application of relevant regulations and ways for compliance.	Not Specified	Not Applicable	Prevent	Guidelines are given on: * General design and construction of food premises (ventilation, water supply, waste storage etc) * Cleaning, sanitizing and maintenance of food premises, equipment and utensils * Safe Food Handling (food sources, storage, packaging, transportation) * Personal health, hygiene and training of food	• Greater incidence of some food borne diseases	Food Hygiene Code. 2003. Food and Environmental Hygiene Department. <http://www.fehd.gov.hk/publications/code/code_all_English.doc> [Accessed 04 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
						handlers		
Food and Health Bureau and Food and Environmental Health Department	Proposed Food Safety Bill	The Bill aims to strengthen food safety regulations such as mandatory registration of all food importers and distributors and require food traders to record sources of food supply. It also proposed to redefine "food" in regulations to include live fish, live amphibian and edible ice. The Food safety Bill is planned to be introduced into the Legislative Council in the 2009-2010 session.	$21 million (involving 12 posts) to enhance food safety work before enactment of the Bill.	Will become Mandatory	Prevent	-	• Greater incidence of some food borne diseases	Examination of Estimates of Expenditure 2008-09: Controlling officer's reply to initial written question. FHB(FE)004. 2008. Food and Environmental Hygiene Department. <http://www.fehd.gov.hk/legco/2008-09/eng/FHB(FE)004.pdf> [Accessed 04 Feb 09] The Proposed Food Safety Bill (for consultation). 2008. Food and Health Bureau. <http://www.fhb.gov.hk/download/press_and_publications/consultation/080121_food/e_food_safety_bill.pdf> [Accessed 04 Feb 090]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Occupational Health and Safety								
Labour Department	Code of Practice in times of Typhoons and Rainstorms	Taking into account the interests of employers, employees and the wider community, the Labour Department seeks to provide advice and practical guidelines on work arrangements in times of typhoons and rainstorms.	Not Specified	Voluntary	Prepare, Respond	Employers are asked to release non-essential employees from work when Typhoons Warning Signal 8 or above are approaching the city, and not to require them to come to work when Typhoon Warning Signal 8 or the Black Rainstorm signal are hoisted.	• Human safety and health risks	Code of Practice in times of Typhoons and Rainstorms. 2009. Labour Department. <http://www.labour.gov.hk/eng/public/wcp/Rainstorm.pdf> [Accessed 16 April 09]
Occupational Safety and Health Branch (Labour Department)	Prevention of Heat Stroke at Work in Hot Environment	A leaflet aimed to promote heatstroke prevention at work place, especially where outdoor manual work is required. It presented key information on heatstroke, such as the risk factors, symptoms of heatstroke and preventive measures. It also advised employers to make arrangements for employees to rest in cool or shady place during very hot periods regularly and minimise physical demand.	Not Specified	Voluntary	Prevent	-	• Increase in weather harvesting of vulnerable populations	Prevention of Heat Stroke at Work in a Hot Environment. 2007. Labour Department. <http://www.labour.gov.hk/eng/public/oh/heat.pdf> [Accessed 11 Feb 09]
Occupational Safety and Health Branch (Labour Department)	Risk Assessment for the Prevention of Heat Stroke at Work	A booklet aimed to prevent heat stress by workers engaged in manual work. Educates the reader through assessment and preventive measures. The accompanying checklist helps employers assess their workplace for heat stress dangers.	Not specified	Voluntary	Prevent	In 2009, the Labour Dept enhanced publicity efforts to ensure adequate protection of workers from heat stroke at work. Heat stroke prevention at work was extensively promoted through public health talks and various publicity channels.	• Increase in weather harvesting of vulnerable populations	Risk Assessment for the Prevention of Heat Stroke at Work <http://www.labour.gov.hk/eng/public/oh/HeatStress.pdf> [Accessed 16 Sep 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Labour Department	Occupational Safety and Health Ordinance (Cap. 509)	The Ordinance and its subsidiary legislation specify the responsibility of employers to ensure the safety and health of all employees. In particular to health issues, employers must ensure that sufficient potable water is provided at the workplace for the consumption by employees; employers are legally responsible for assessing the risk of heat stroke for their employees working in a hot environment and take appropriate preventive measures (especially when very hot weather warning has been issued by the Hong Kong Observatory); and employers are to ensure the workplace is adequately ventilated by fresh air.	Not Specified	Mandatory	Prevent	In 2009, the Labour Department enhanced enforcement efforts to ensure adequate protection of workers from heat stroke at work. -	• Increase in weather harvesting of vulnerable populations	Chapter 509 Occupational Safety and Health Ordinance in *Bilingual Laws Information System*. n.d. Department of Justice. <http://www.legislation.gov.hk/blis_ind.nsf/CurAllEngDoc?OpenView&Start=509&Count=30&Expand=509#509> [Accessed 11 Feb 09] Summer occupational safety and health - prevention of heat stroke at work in *Labour in Focus*. 2005. <http://www.labour.gov.hk/eng/major/LabourInFocus/05.htm> [Accessed 11 Feb 09]
Labour Department	Factories and Industrial Undertakings Regulations (Cap. 59A Reg 38)	Regulation 38 stipulates that in every notifiable workplace an adequate supply of drinking water either from a public main or from a source approved by a health officer shall be made available and conveniently accessible to all persons employed.	Not Specified	Mandatory	Prevent	-	• Increase in weather harvesting of vulnerable populations	Chapter 59A Factories and Industrial Undertakings Regulations <http://www.legislation.gov.hk/blis_pdf.nsf/6799165D2FEE3FA

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
								94825755E0033E532/88636DC3EA9BF29A482575EE0034D5C2/$FILE/CAP_59A_e_b5.pdf> [Accessed 21 Dec 09]
Labour Department	Construction Sites (Safety) Regulations (Cap 59I Reg 66)	Construction sites shall provide at site a supply of wholesome drinking water.	Not Specified	Mandatory	Prevent	-	• Increase in weather harvesting of vulnerable populations	Chapter 59I Construction Sites (Safety) Regulations <http://www.legislation.gov.hk/blis_pdf.nsf/6799165D2FEE3FA94825755E0033E532/CB7ACD5F5F2AF7D1482575EE00356ACA?OpenDocument&bt=0> [Accessed 21 Dec 09]
Occupational Safety and Health Branch (Labour Department)	Occupational Disease Casebook - Occupational Infection	Occupational biological hazards are outlined through case studies to promote preventive measures on occupational infection (e.g. Tuberculosis, Legionnaires' Disease)	Not Specified	Voluntary	Prevent	-	• Increase in weather harvesting of vulnerable populations	Occupational Disease Casebook: Occupational Infection. 2006. Labour Department. <http://www.labour.gov.hk/eng/public/oh/ohb95.pdf> [Accessed 11 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Occupational Safety and Health Branch (Labour Department)	Guidance Notes on Health Hazards in Construction Work	The guidelines have listed out a range of potential health hazards in relation to construction works and provided recommendations on preventive measures. Some of the health hazards identified were: silica dust, lead dust, asbestos dust, excessive noise, gases, vapours and fumes, entry into confined spaces, ionizing radiation, vibration, heat and manual handling. It is recommended that possible health hazards should be identified prior to commencement of construction work.	Not Specified	Voluntary	Prevent	-	• Increase in weather harvesting of vulnerable populations	Guidance Notes on Health Hazards in Construction Work. 2004. Labour Department. <http://www.labour.gov.hk/eng/public/oh/OHB82.pdf> [Accessed 11 Feb 09]
Education Bureau	Tropical Cyclones and Heavy Persistent Rain Arrangements for Kindergartens and Day Schools	Arrangements for schools and kindergartens under inclement weather conditions.	Not Specified	Mandatory	Prepare, Respond	Day-schools are closing when Typhoon Warning Signal 8 is expected and resume when Signal 8 or above is replaced by Signal 3 (for kindergartens and schools for physically handicapped children Signal 3 and Signal 1, respectively). Rainstorm warnings concern stages Red and Black, suspending school lessons when the rainfall event takes place before lessons start, and continuing lessons when the event takes place once lessons have started.	• Human health risks	Tropical Cyclones and Heavy Persistent Rain Arrangements for Kindergartens and Day Schools. Education Bureau. Circular No. 3/2007. <http://www.edb.gov.hk/UtilityManager/circular/upload/EMBC/EMBC07003E.pdf> [Accessed 16 April 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Education Bureau	Tropical Cyclones and Heavy Persistent Rain Arrangements for Evening Schools	Arrangements for evening schools under inclement weather conditions.	Not Specified	Mandatory	Prepare, Respond	Schools close when Typhoon Signal 8 or above are hoisted, but resume lessons when Signal 8 is replaced before 5:00 pm and no full-day school closure has been announced. Concerning the closure due to either Red or Black rainstorms, see above.	• Human health risks	Tropical Cyclones and Heavy Persistent Rain Arrangement for Evening Schools. Education and Manpower Bureau. Circular No. 4/2007. <http://www.edb.gov.hk/UtilityManager/circular/upload/EMBC/EMBC07004E.pdf> [Accessed 21 December 09]

Table B11 Existing Policies / Measures that may Contribute to Adaptive Responses to Leisure and Tourism (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary/ Mandatory	Type of Instrument	Remarks	Potential Impacts Addressed	Reference
Agriculture, Fisheries and Conservation Department	Shut down a Marine Park	In May 2007, Coral Beach of the Hoi Ha Wan Marine Park was closed for the purpose of allowing damaged coral to recover.	-	Mandatory	Respond	-	-	Agriculture, Fisheries and Conservation Department Annual Report 2007-2008 <http://www.afcd.gov.hk/english/publications/publications_dep/publications_dep.html> [Accessed 4 June 09]
Hong Kong Observatory	A network of automatic weather stations to monitor weather conditions	The Observatory set up the automatic weather stations in some tourist spots, e.g. Stanley, Sheung Shui and Pak Tam Chung. Real-time weather photos of several tourist spots are provided, e.g. Tsim Sha Tsui, Cheung Chau, Lau Fau Shan, Wetland Park, Tai Lam Chung, Peng Chau, Hong Kong South, Victoria Harbour and Waglan Island. This information enables the public and tourists to assess the latest weather conditions and help to plan their travels accordingly. Wind data of Sha Chau, Ngong Ping, Tai Mei Tuk, Tap Mun and Tate's Cairn is also provided for windsurfers and paragliders.	-	Mandatory	Prevent, Prepare	-	• Impacts associated with bad weather • Human health and safety risks	Hong Kong Observatory 2004-2005 <http://www.weather.gov.hk/abouthko/hko2004-2005e.pdf> [Accessed 4 June 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary/ Mandatory	Type of Instrument	Remarks	Potential Impacts Addressed	Reference
Leisure & Cultural Services Department	Arrangement during typhoons and rainstorms (applicable to LCSD camps only)	It states the arrangement of Day camp, Residential and Evening Camps and the campers who have checked in when typhoon signal No. 3 or above remains hoisted or Black Rainstorm Warning Signal is still in force. Similar arrangements are also in place for their other services, such as Dr. Sun Yat-sen Museum, Museum of Coastal Defence, Antiques and Monuments Office, Museum of History, Art Promotion Office, Water Sports Centres etc.	-	Mandatory	Respond	-	• Impacts associated with bad weather • Human health and safety risks	Arrangement during typhoons and rainstorms (applicable to LCSD camps only) <http://www.lcsd.gov.hk/camp/en/arrang.php> [Accessed 5 June 09]
Environmental Protection Department	Beach Water Quality Monitoring	The department has monitored the beach water quality since 1986. It conducts the monitoring every week and reports the Beach Rating in the form of press release.	-	Mandatory	Prepare	-	• Human health and safety risks	Beach Water Quality Report 1986 - 2000 <http://www.epd.gov.hk/epd/english/environmentinhk/water/beach_quality/bwq_report8600_ch1.html> [Accessed 5 June 09]
Leisure & Cultural Services Department	Flag Signals	The department implements the flag signals for safety reasons. There are five kinds of flag signals, Windsock, Red Flag, Shark Warning Flag, Yellow Flag and N Flag. Red flag will be hoisted due to bad water quality, bad	-	Mandatory	Prevent, Prepare	-	• Human health and safety risks	Safety Guideline <http://www.lcsd.gov.hk/watersport/en/guid_flag.php> [Accessed 5 June 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary/ Mandatory	Type of Instrument	Remarks	Potential Impacts Addressed	Reference
		weather e.g. heavy rainfall, tropical cyclones, thunderstorm, etc. In that case, people should stop all water activities.						

Table B12 Existing Policies / Measures that may Contribute to Adaptive Responses to Water Resources (as of February 2008 from the Inter-departmental Working Group on Climate Change of Hong Kong Government)

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
External Supply from Dongjiang								
Water Supplies Department	Agreement for the supply of Dongjiang water to Hong Kong for 2009-2011	The agreement will guarantee a stable and flexible supply of Dongjiang water up to 2011 based on the actual needs of Hong Kong. This will provide for Hong Kong's water demand even under extreme drought conditions with a return period of one in 100 years. Daily water supply is flexible to tie in with seasonal fluctuations in the local yield. The flexibility will allow better control of storage level in reservoirs and avoid wastage and save pumping costs.	2009: $2,959 million 2010: $3,146 million 2011: $3,344 million	Mandatory	Prevent	-	• Increased demand for water • Greater rates of evaporation • Risk of supply interruption	Agreement ensures stable supply of Dongjiang Water to Hong Kong. Press Releases 11 December 2008. <http://www.info.gov.hk/gia/general/200812/11/P200812110098.htm> [Accessed 06 Feb 09]
Hong Kong Impounding and Service Reservoirs								
Water Supplies Department	Total Water Management Programme	The aim of this programme is to promote water conservation and explore new water resources to secure Hong Kong's future water supply. It also aims to better prepare Hong Kong for uncertainties such as climate change. To address water demand, the key measures are: promote water conservation; leakage control; promote the use of water saving devices; water reclamation (use of seawater for toilet flushing); and tiered tariff structure to encourage	Not Specified	Mandatory	Prevent, Prepare	Regards to water supply: activities that may threaten the quantity and quality of water are assessed and monitored regularly and new water resources are to be explored (such as expansion of water gathering	• Increased demand for water • Greater rates of evaporation • Risk of supply interruption • Reduced yield due to rainfall variability	ACQWS Paper No.20 Total Water Management Strategy in Hong Kong. 2008. Advisory Council on the Environment. <http://www.wsd.gov.hk/acqws/doc/p20.pdf> [Accessed 29 Jan 09] Total Water Management in Hong Kong. n.d. Water Supplies Department.

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		water conservation. The Hong Kong Government has adopted a voluntary water efficiency labelling scheme for different plumbing fixtures and water-consuming appliances. The first group applies to showers for bathing. The aim of this is to promote water conservation, to promote public awareness, and to provide consumers an ability to select water saving products.				grounds, desalination plant)		<http://www.wsd.gov.hk/en/html/pdf/TWMe.pdf> [Accessed 02 Feb 09] The Hong Kong Voluntary Water Efficiency Labelling Scheme on Showers for Bathing < http://www.gov.hk/en/business/supportenterprises/bf/pdf/consultation/08025_cp_en.pdf> [Accessed 16 Sep 09]
Water Supplies Department	"Little Drop's Marvellous Journey" Roving Exhibition Panels	Students are the targeted audience of this water conservation promotion resource. The exhibition panel may be loaned to schools for a maximum of two weeks. The panels illustrate the water cycle and water treatment and distribution process in Hong Kong.	Not Specified	Voluntary	Prepare	-		Little Drop's Marvellous Journey Roving Exhibition Panels. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/edu/exhib/little_drops.htm> [Accessed 06 Feb 09]
	Easy Roll-up Banners	These banners are another approach in promoting water conservation (and water quality). They are not only available to schools but also to management companies. The banners are divided into four themes: * Save Water for the Future, Every	Not Specified	Voluntary	Prepare	-		Easy Roll-up Banners. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/edu/w_conserve/easybanner.htm> [Accessed 06 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		Drop Counts * Save Water Save Dollars * Quality Water Recognition Scheme for Buildings * Prevent Water Leaks						
	Leakage detection and monitoring systems	As part of the on-going Replacement and rehabilitation programme, the leakage detection and monitoring systems have been upgraded to enhance its operational performance. Flows meters and data loggers are installed in selective supply zones and distribution networks are monitored. The daily pressure and flow data are collected and stored in centralised computers for department staff to analyse and identify leakage and arrange remedial work.	Not Specified	Voluntary	Prevent	-		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]
	Comprehensive Pressure Management Scheme	The aim is to reduce leakage in the distribution networks while maintaining a stable supply pressure.	Not Specified	Mandatory	Prevent	-		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]
	Water Pricing	The four-tier water pricing system aims to promote water conservation. The minimum supply of water required for health and hygiene is supplied to consumers at no cost. Water consumption thereafter will be charged on volume base. The cost at second tier will take into account of the Government's contribution	Not Specified	Mandatory	Prevent, Prepare	-		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
		through rates, where the third tier of water supply will be charged at a non-subsidised production cost. The fourth tier will be charged 40 percent higher than the third tier.						
	Water Conservation Campaign	The campaign comprises of talks, seminars and exhibitions in housing estates and schools and across print and electronic media. At the same time, three water treatment plants have held public open days with guided tours which highlighted the technical aspects of water treatment. There were also exhibitions on water science, metering system and the mains replacement and rehabilitation programme.	Not Specified	Voluntary	Prepare	-		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]
	Water Efficiency Labelling Scheme	Similar concept to the Energy Efficiency Labelling Scheme, it promotes the use of water saving devices by indicating to consumers the levels of water consumption and efficiency rating of plumbing fixtures and appliances used in toilet, kitchen, bathroom and laundry.	Not Specified	Voluntary	Prepare	-		ACQWS Paper No. 20 Total Water Management Strategy in Hong Kong. 2008. Advisory Council on the Environment. <http://www.wsd.gov.hk/acqws/doc/p20.pdf> [Accessed 06 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Replacement and Rehabilitation Programme	The Programme aims to replace or rehabilitate approximately 3,000km of aged water mains in 15 years to improve the condition of the water supply network in order to maintain a reasonable level of services to consumers.	Approximately $15.7 billion	Mandatory	Prevent	-		ACQWS Paper No.20 Total Water Management Strategy in Hong Kong. 2008. Advisory Council on the Environment. <http://www.wsd.gov.hk/acqws/doc/p20.pdf> [Accessed 06 Feb 09] Replacement and Rehabilitation Programme of Water Mains. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/edu/rehab/index.htm> [Accessed 06 Feb 09]
	Reprovisioning of the Shum Wan Shan Fresh Water Pumping Station	Aims to enhance the reliability of water supplies to Tsueng Kwan O.	Not Specified	Mandatory	Prevent	-		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]
	Salt Water Supply System	Install mains along Castle Peak Road between Lok On Pai and Fu Tei. Construction of a pumping station at Lok On Pai, a service reservoir at Tai Kwai Tsuen and the laying of 8.4km of salt water mains (Stage 2).	$347 million (for Lok On Pai works)	Mandatory	Prevent	Construction will begin in early 2009.		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
	Reprovisioning Works at Sha Tin Water Treatment Works	To increase the capacity of the Tai Po Water Treatment Works by 550,000 cubic metres per day	Approximately $2.7 billion	Mandatory	Prevent	Construction is scheduled to begin in early 2010 and to be completed by the end of 2013.		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]
	Improvements to Mid-level and high-level water supplies	Construction of service reservoir, pumping station and mains to improve water supplies in the mid- and high-level areas on Hong Kong Island.	$235 million	Mandatory	Prevent	-		Annual Report 2007-2008. n.d. Water Supplies Department. <http://www.wsd.gov.hk/en/html/pdf/rpt0708/menu.htm> [Accessed 06 Feb 09]

Department / Organisation	Policy / Measure	Description	Cost of Policy / Measure	Voluntary / Mandatory	Type of Instrument	Remarks	Potential Consequences Addressed	Reference
Drainage Services Department, Water Services Department	Ngong Ping Sewage Treatment Works	The Ngong Ping Sewage Treatment Works is the first to produce reclaimed water in Hong Kong. The reclaimed water is used for toilet flushing in the area, rearing aquarium fishes and controlled irrigation within the facility. The treatment plant uses the Sequencing Batch Reactor technology (SBR) to remove nutrients and solids. Dual media filter is used to remove fine suspended solids that the SBR was not able to filter. Bacteria and virus will be sterilized using ultra-violet light tubes. A deodorisation unit has also been installed to remove odour from gases generated from the treatment plant before being discharged into the atmosphere.	Not Specified	Mandatory	Prevent	-		Ngong Ping Sewage Treatment Works. 2007. Drainage Services Department. <http://www.dsd.gov.hk/FileManager/EN/publications_publicity/publicity_materials/leaflets_booklets_factsheets/NPSTW.pdf> [Accessed 11 Feb 09] Use of Reclaimed Water. n.d. Hong Kong SAR. <http://www.gov.hk/en/residents/environment/water/usereclaimedwater.htm> [Accessed 09 Feb 09]
	Inter-reservoir Transfer Scheme (IRTS)	Construction of 2.8km long water tunnel for transferring overflow from Kowloon Byewash reservoir to Lower Shing Mun Reservoir. The works for the IRTS are scheduled to commence in early 2010 for completion in 2012.	Approximately $26 million	Mandatory	Prepare	UpcomingStart: Early 2010Complete: 2012	• Reduced yield due to rainfall variability	West Kowloon in Flood Prevention. n.d. Drainage Services Department.<http://www.dsd.gov.hk/flood_prevention/our_achievement/west_kowloon/index.htm> [Accessed 10 Feb 09]