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Re-examination on Energy Saving & Environmental Issues in Lighting Applications

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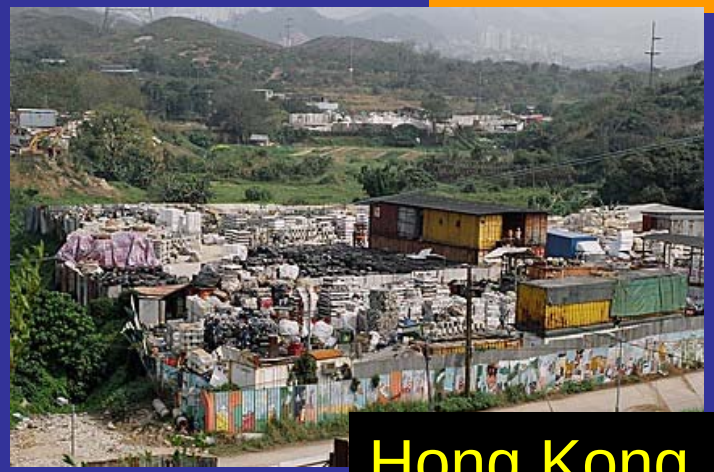
Background

About 70% of global e-waste is being dumped in China…….

August 2006

- Cable TV (HK) reported that 135 out of 160 children in Shantou (汕頭) village had high level of heavy metal in their blood.

China



Hong Kong

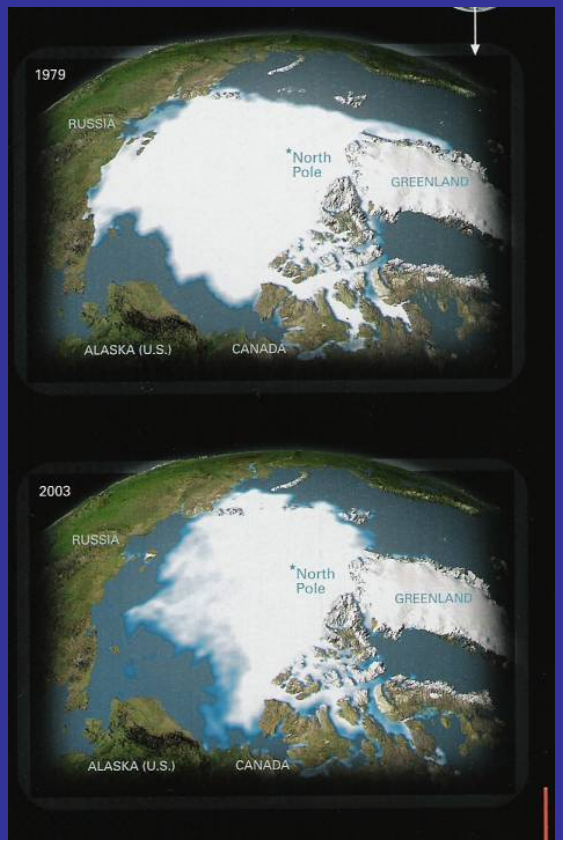
December 2006

- Canadian Authority intercepted 500 tons of e-waste being smuggled to Hong Kong & China for dumping.
- 3 Major types of e-waste have been identified:
  1. Computers
  2. Batteries
  3. Electronic ballasts & electronic compact fluorescent lamps

What is Green Technology ?

- Reduction of

  Greenhouse gas (Atmosphere) AND Waste (Land & Water)



These two factors must go hand in hand

Common misconceptions

- Climate-friendly technology $\neq$ Green
  - [Citigroup Research Report Jan. 2007]
    - Energy saving is a means to reduce CO2 emission.

- Nuclear Power Plants generate zero CO_2. But nuclear waste is harmful for > 10,000 years!
- Electronic compact fluorescent lamps e-CFL
  - Lifetime: 4000 hours to 15000 hours (5 months to 20 months)

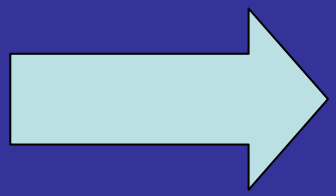
Example - Lighting technology

- "Energy saving" is not necessarily "green" unless we can reduce e-waste & toxic chemicals

e-CFLs

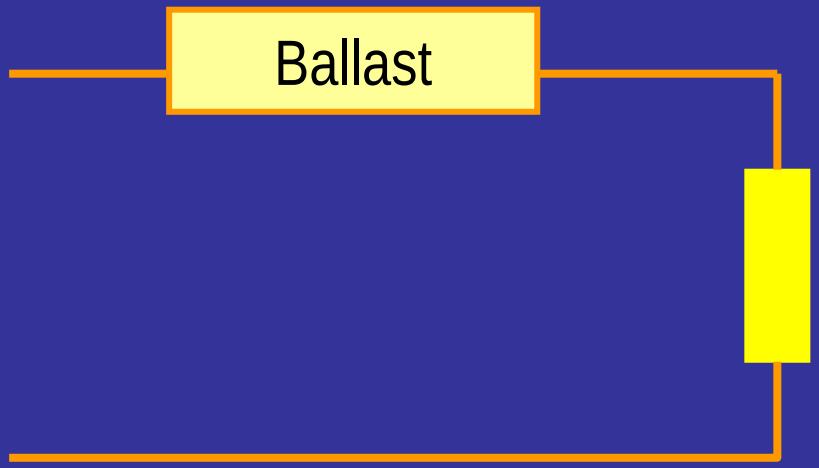
Energy saving

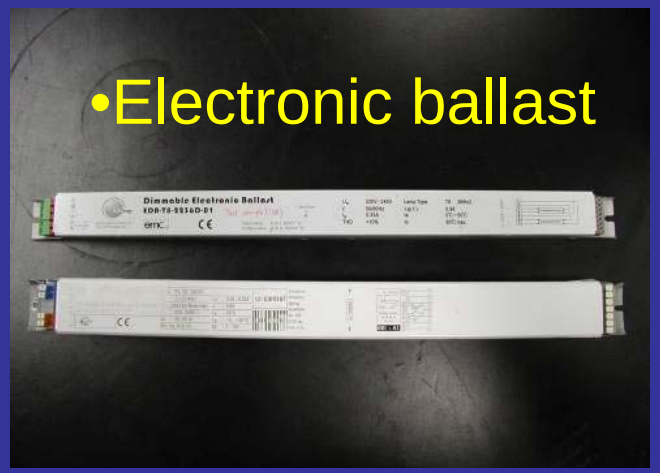
less than 2 years



Toxic chemicals (e.g. Mercury & PBBs) and e-waste as pollutants for thousands of years

Lighting technology



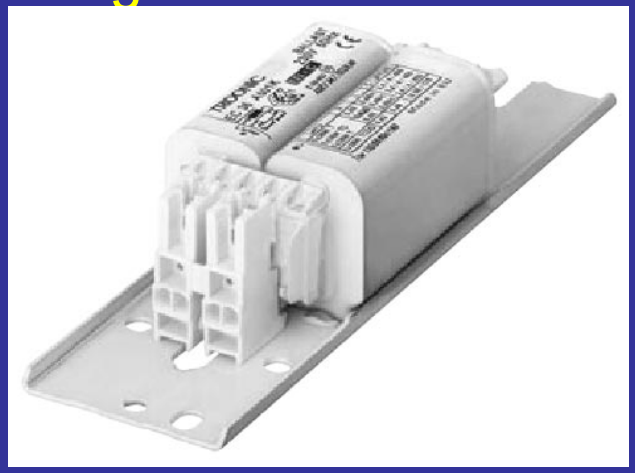


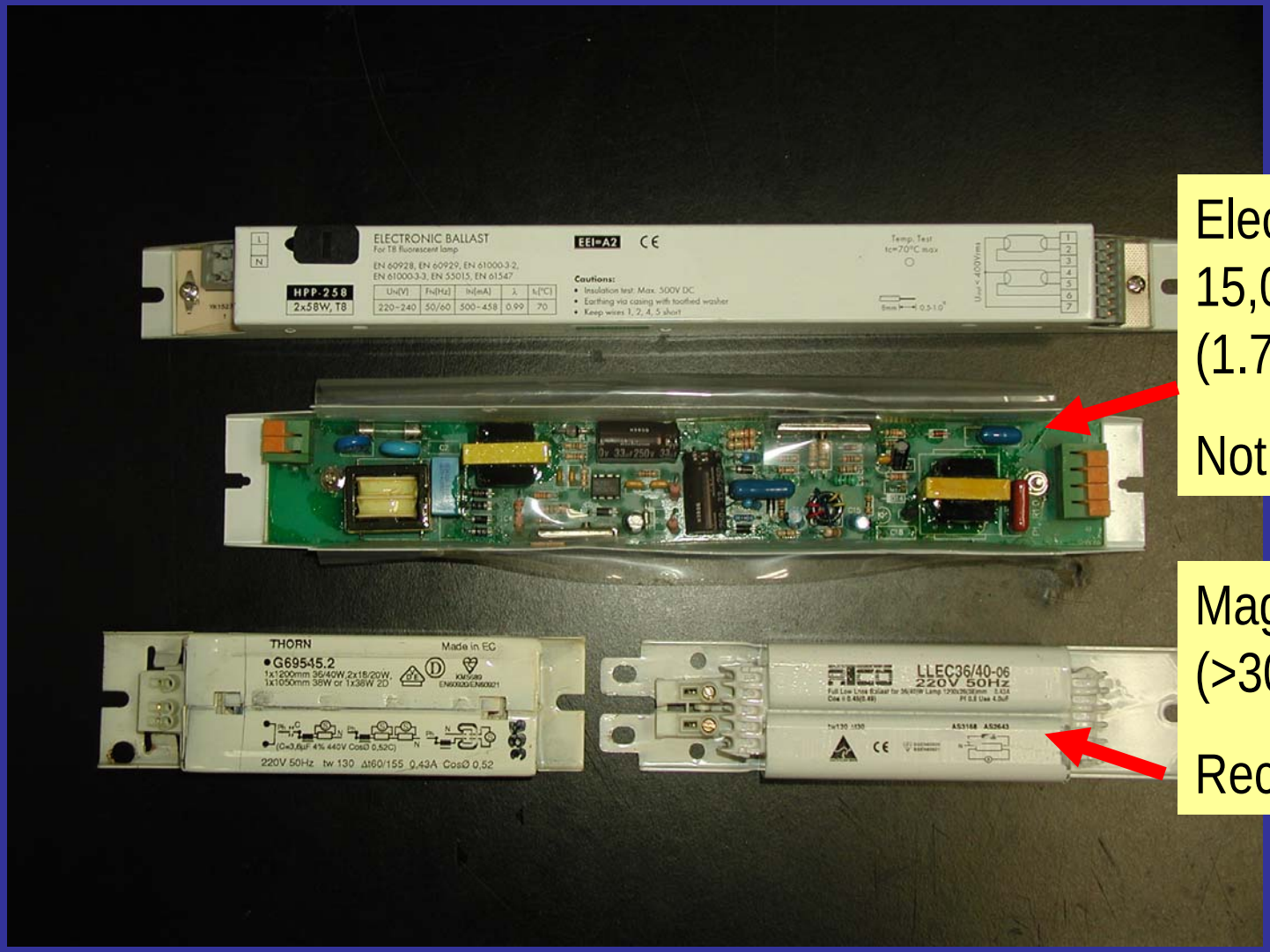
Discharge lamps

•High Intensity Discharge (HID) Lamps

•Fluorescent Lamps

- Magnetic ballast





Electronic ballast
15,000 hours
(1.7Year)

Not recycable

Magnetic ballast
(>30 Years)

Recycable

Lifetime Limitations & Electronics Waste

Integrated

Disposed as a single unit

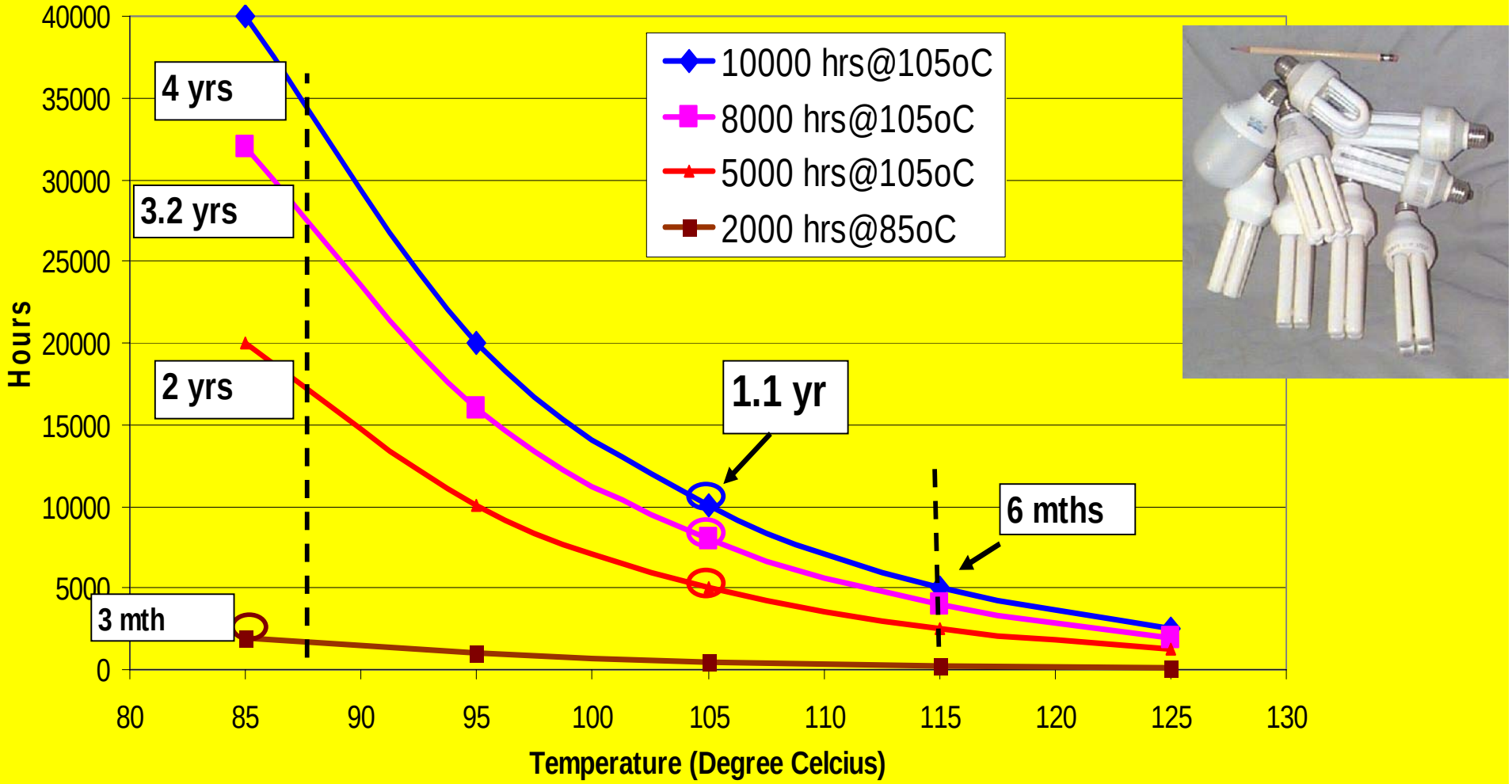
Electronic

Detachable

Recyclable

Magnetic

Projected lifetime of Electrolytic Capacitors



No. of Years based on 24-hr daily operation

e-CFLs as an Example

- (Hong Kong)
  - 2 Million families x 5 e-CFLs each year
- 10 million x 5mg of Hg = 50 tonnes of Hg.
- Hg toxicity level – micro-gram (μg)

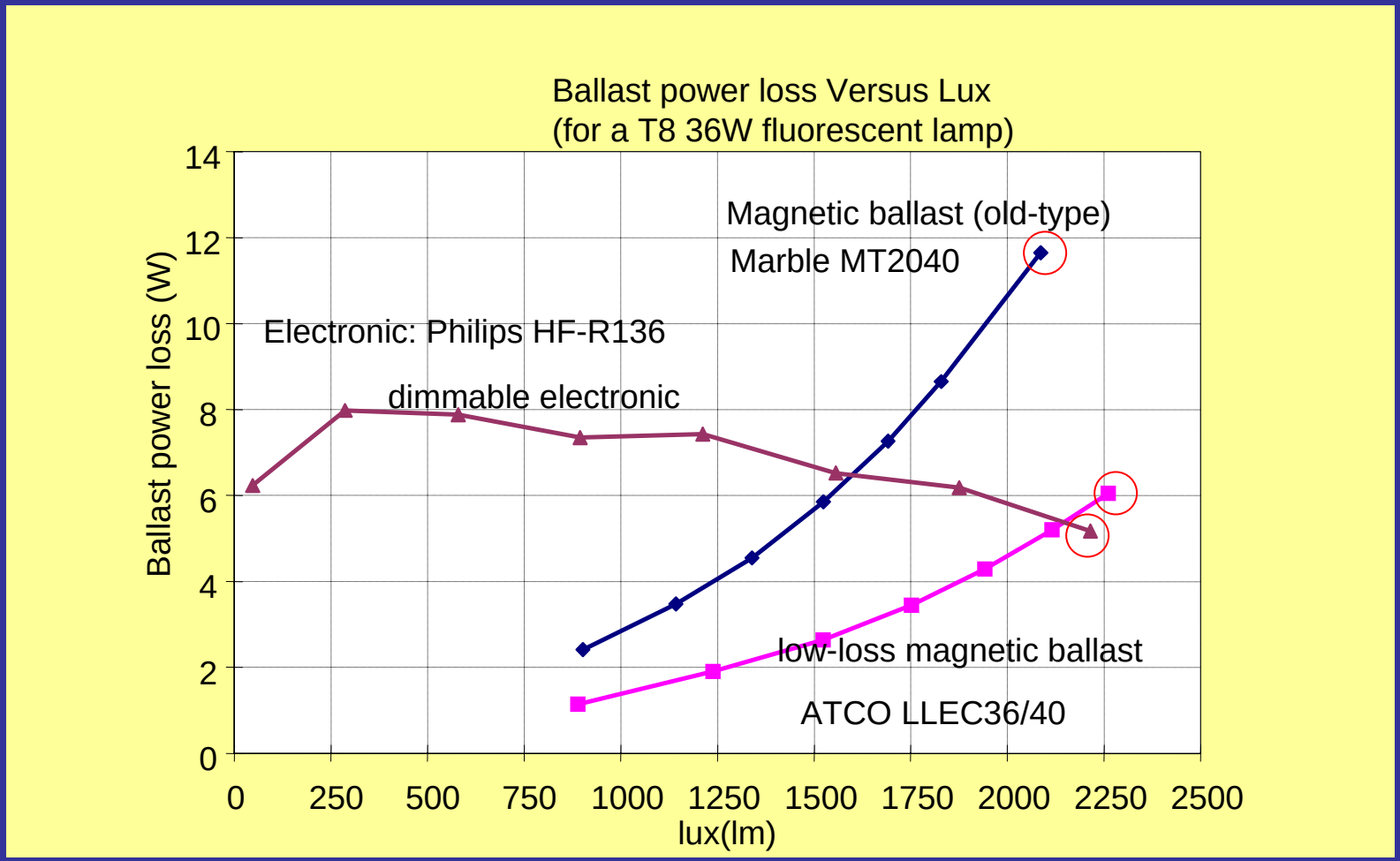
- Danger starts at disposal at home, garbage trucks …

- High Density Polyethylene insulation layer used in landfill has limited lifetime (50-80 years?)
  - Time bomb for environmental disaster!

CFLs have exception in RoHS and still contain mercury.

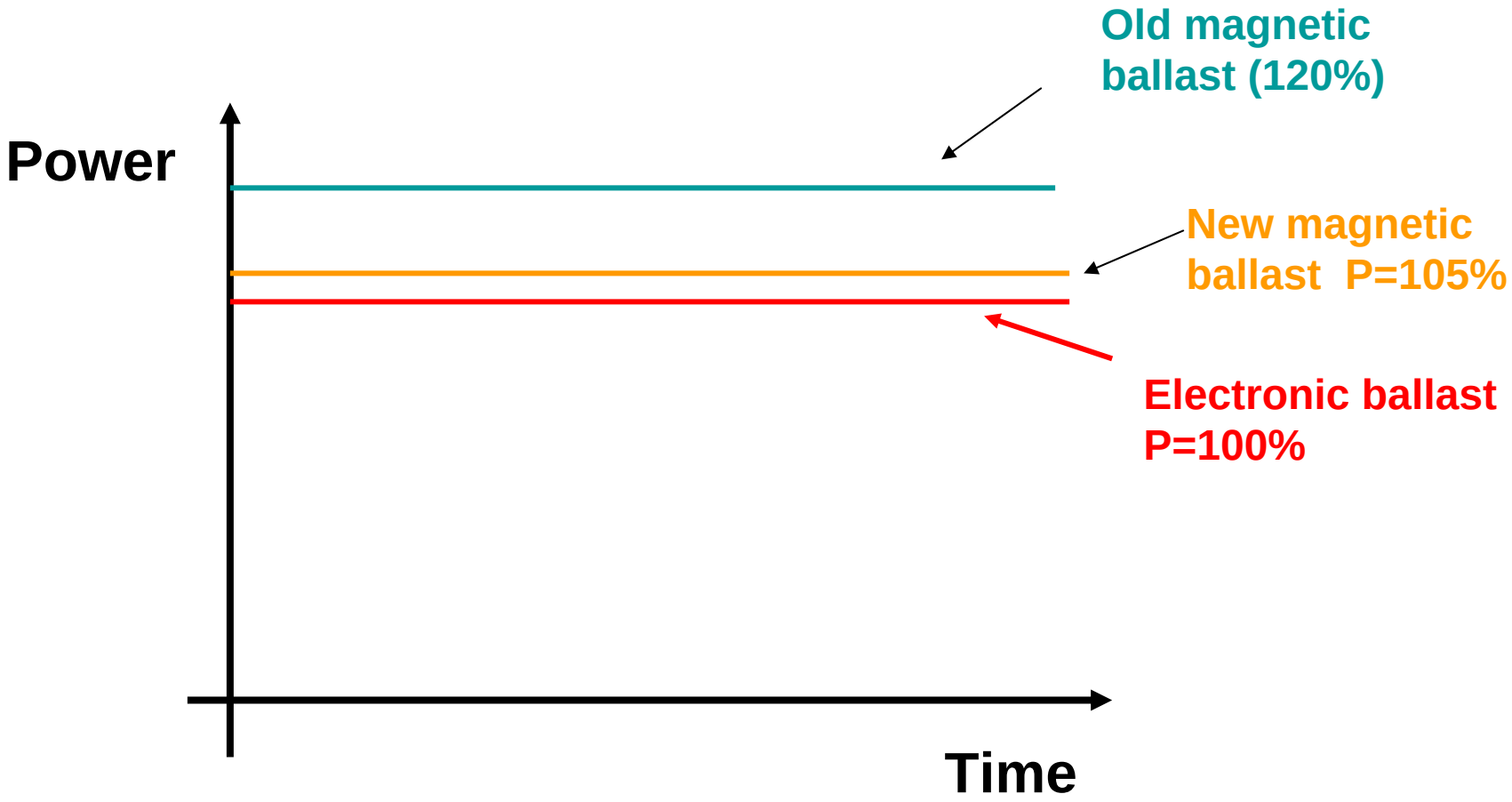
Having less mercury will not make them good for the environment.

The Myth of Electronic Ballasts being more energy-efficient than Electromagnetic Ballasts

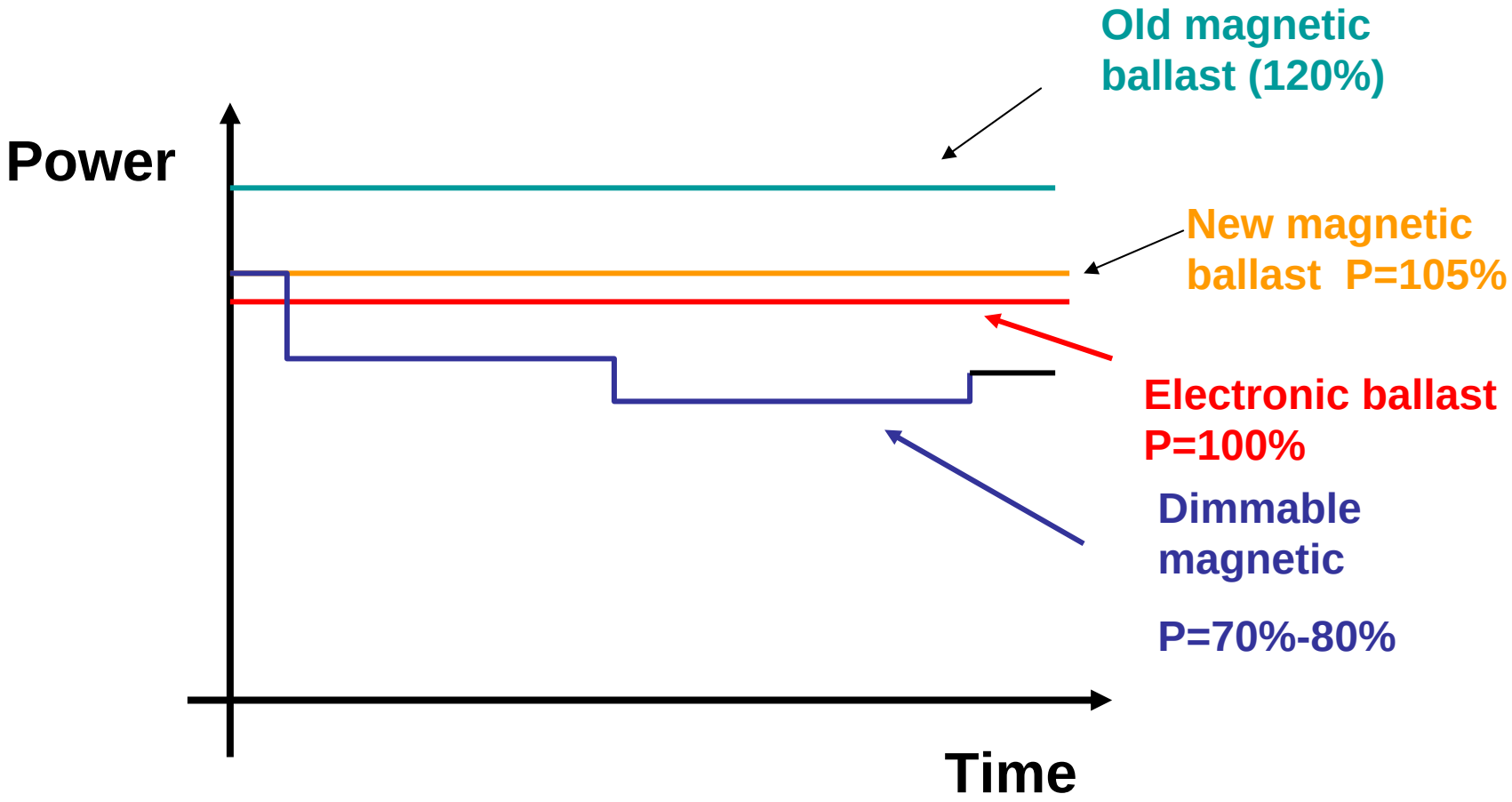


IEEE IAS Conference (Oct. 2005)

New-generation of magnetic products are as energy-efficient as electronic products



[Note: The time factor is often neglected. The majority of electronic ballasts are non-dimmable and so users lose their choice of saving energy during off-peak hours.]



Save energy *without*

- **generating lots of electronics waste**
- **high maintenance/replacement/disposal costs**

Comparison

	Electronic Ballast (for tubular lamps)	Magnetic Ballast (for tubular lamps)	Electronic Ballast (compact lamps)	Magnetic Ballast (compact lamps)
Lifetime	15,000 hrs (1.7 years)	>30 years	6000-15000 hrs (8-20 months)	>150,000 hrs (17 years)
Recycle	No	Yes	No	Yes
Cost	High	Low	High	Low
Environmental	Disaster (e-waste)	Friendly	Disaster (e-waste)	Friendly

Lifetime data quoted from manufacturers

Magnetic ballasts for T5 lamps will be available in late 2007

Conclusions

- For large public lighting systems, encourage the use of low-loss magnetic ballasts in order to reduce the number of electronic waste (electronic ballasts).
- Encourage the use of “detachable” CFLs so that the magnetic ballasts and lamps can be recycled.
- Use of central dimming technology for low-loss magnetic ballast systems so that lighting energy can be used wisely *when* and *where* it is necessary and to the *appropriate* level.
- International regulatory organizations should put more emphasis on the use of low-loss magnetic ballast for lighting applications.
- Integrated e-CFLs must be disposed & processed as hazardous materials. Governments must set up e-waste collection and handling facilities.
- A *sustainable (Green)* technology must satisfy both *Energy* and *Waste* requirements. It should be *recyclable*.

Re-examination on Energy Saving & Environmental Issues in Lighting Applications

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Abstract:

The increasing use of electronic ballasts has prompted new concerns on the consequential rise in electronics waste due to the relatively short life time of electronic ballast products. It is high time for researchers in lighting to re-examine the advantages and disadvantages of existing technology in terms of energy saving and environmental protection. This paper addresses the electronic wastes problem of electronic ballasts and highlights the needs for a re-examination of existing lighting technologies.

1: Background

There is a common misconception that energy saving is always equivalent to environmental protection. On one hand, energy saving is one factor for environmental protection. On the other hand, if the energy saving products have short lifetime, the impacts of the toxic/non-biodegradable electronic waste would easily outweigh the energy-saving advantage. Recent promotion of electronic ballasts has ignored an important fact that electronic ballasts, limited by the lifetime of the electrolytic capacitors, have become a major source of electronic waste. Compared with electromagnetic ballasts, electronic ballasts have much shorter lifetime and are not recyclable. This prompts new concerns about their environmental impacts due to the accumulation of huge amount of toxic and/or non-biodegradable electronic waste components and materials. In this paper, we present an updated lifetime projections of electronic ballasts for both tubular and compact fluorescent lamps and highlight the increasing environmental issue arising from the wide-spread use of electronic ballasts. A critical comparison between electronic ballasts and low-loss magnetic ballasts is re-examined. Finally, we suggest the use of a centrally dimmable low-loss magnetic ballast system for large public lighting networks.

2. Lifetimes of electronic ballasts for tubular and compact fluorescent lamps

Despite the15%-20% energy saving of electronic ballasts when compared with the traditional magnetic ballasts, the short lifetime of electronic ballast, which is limited by the electrolytic capacitor, is a major weakness of such technology. The lifetime of electrolytic capacitors is highly dependent on the operating temperature. In general, it is reduced by half if the operating temperature is increased by 10^{o}C and is doubled if the operating temperature drops by 10^{o}C. Fig.1 show the projected lifetimes of 4 types of electrolytic capacitors commonly available in manufacturing industry. For tubular fluorescent lamps (FL), the electronic ballasts are housed in rectangular metal cases that are usually placed above the lamps in the lighting fixture. Typical operating temperature of the electrolytic capacitors under such condition is around 85^{o}C-90^{o}C. For electronic compact fluorescent lamps (CFL), the electronic ballasts are housed inside the small plastic housing. In many installations, the electronic ballasts are placed directly above the lamps so that the heat is trapped inside the plastic housing. Typical operating temperature is well above 100^{o}C. Assuming that typical operating temperatures of the electrolytic capacitors used for tubular lamps and compact lamps are 87^{o}C and 105^{o}C, respectively and that the lamps are operated 24 hours daily, the lifetime projections of the electronic ballasts are shown in Fig.1. It can be seen that, with existing technology, the lifetimes of electronic ballasts for tubular FL is about 4 to 5 years and that for electronic CFL is only 1.1 years. These figures are consistent with market data as the typical lifetime of electronic CFL is only 10,000 hours. These figures are also consistent with users' experience.

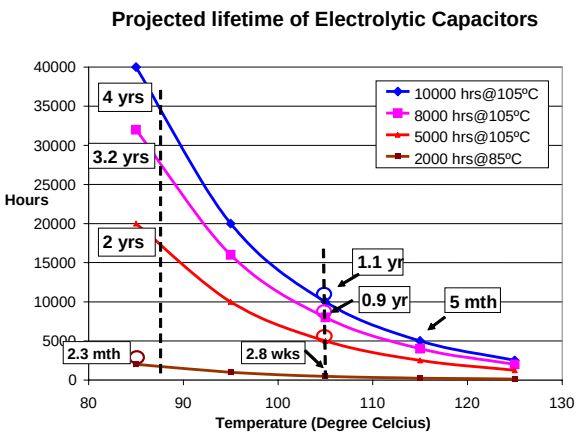


Fig.1 Projected lifetime of electrolytic capacitors[3]

3 Re-examination on electronic and magnetic ballast technology

With recent advances of material science, low-loss magnetic ballasts have power loss close to that of electronic ballasts. New generation of low-loss magnetic ballasts [1] also have very long lifetime (typically above 50 years at 105^{o}C). There are also confirmations [2,3] that under slightly reduced voltage condition, a dimmable magnetic ballast system can be more energy-efficient than electronic ballast systems. They have been installed in Heshan City, China for controlling over 8,000 street lamps since 2004 with a remarkable record of annual energy saving of over 27% and lamp failure reduction of over 30% [4]. For indoor applications, they have been installed in several public hosing estates in Hong Kong for controlling public lighting systems in corridors, stairs and hallways with typical average energy saving of 25%.

Table 1 shows a typical comparison on the lifetime of ballast products based on existing market data. The short lifetimes of electronic ballast products can easily be seen from Table 1. Take CFL as an example, magnetic CFL with detachable FL can last 15 times longer than the electronic ballasts. This situation is similar for the ballast lifetime comparison for tubular FLs.

Table 1

Products	Lifetime	recyclable
Electronic ballasts for tubular FL	15000 hrs	No
Magnetic ballast	>50 years	Yes
Electronic ballast for CFL	10000 hrs	No
Magnetic ballast for CFL [5]	150000 hrs	Yes

The authors suggest that the lighting industry and regulatory bodies should reconsider their policies about the promotion of electronic ballasts and magnetic ballasts. Electronic ballasts do have some advantages such as flickering-free features. But for most of the large lighting systems used for public areas such as street lamps, multi-storey car parks, corridors, stairs and hallways, flickering-free is not necessary. We propose the followings as effective means to energy saving and environmental protection:

1. The use of low-loss magnetic ballasts for large public lighting systems in order to reduce the number of electronic waste due to the use of electronic ballasts.
2. Encourage the use of detachable lighting device structure so that the magnetic ballasts and FLs can be recycled.
3. Use of dimming technology for low-loss magnetic ballast systems so that lighting energy can be used wisely when and where it is necessary and to the appropriate level. [Note: this time factor is often neglected. The majority of electronic ballasts are non-dimmable and so users' choice of saving energy during off-peak hours is removed.]
4. Promote the right technology for the right applications so as to minimize the amount of electronic waste.
5. International regulatory organizations should put more emphasis on the use of low-loss magnetic ballast and non-radioactive starters for lighting applications.

4 Conclusion

Considering the long lifetime (>30 years) of electromagnetic ballasts and recyclability of their magnetic chokes, it is envisaged that such combined technology can provide an improved environmentally-friendly and energy-saving solution for large-scale electric lighting systems, particularly for lighting systems in large public areas. Due to the elimination of many electronic ballasts, this proposed technology has the potential of drastically reducing huge amount of electronic waste. With the positive results obtained in several large-scale projects based on this concept, it is hoped that international regulatory organizations should re-consider their current policies and prompt lighting technology that is both environmentally-friendly and energy saving.

References:

[1] Tridonic ATCO webpage.
[2] Leonardo Energy webpage
[3] Chung H., Ho N.M., Yan W. Hui S.Y.R., and Tam P.W., "Energy Efficiency Comparison of Dimmable Electromagnetic and Electronic Ballast Systems" ***IEEE Transactions on Industrial Electronics*** (in presss)
[4] Yan W. and Hui S.Y.R., "Dimming Characteristics of Large-scale High-Intensity-Discharge (HID) Lamp Lighting Networks using a Central Energy-Saving System", IEEE ISA Conference, Tampa, FL, USA, Oct, 2006.
[5] Lumatech webpage

混淆「節能」與「環保」概念，容易引至環保災難

從近日幾段有關「節能環保」的報導，反影出社會大眾容易混淆「節能」與「環保」兩種概念。筆者過往十多年從事電力轉換及照明系統之節能科技研究，希望藉這篇文章，讓關心環境保護的讀者，特別是環保團體的朋友、政府和大機構的負責人，明白「節能」與「環保」兩種概念之分別，以避免因爲概念混淆而無意之中作出破壞環境的決定。

「節能」不一定等同「環保」
第一種最容易混淆的概念是將「節能」等同「環保」，最常見的例子是近年政府機電署鼓勵

(1) 以電子鎮流器(俗稱電子牛)取代電感鎮流器(俗稱線牛)和
(2) 大量採用電子式螢光燈(俗稱慳電膽)。

鎮流器是一種控制放射燈電流的設備，放射燈包括常用的「光管」和「街燈」，慳電膽其實是一種「摺起來的光管」。鎮流器可分爲電感式和電子式兩種，電感的結構相當簡單，只包含一個鐵芯和一組銅線，並沒有電子元件，產品的壽命一般超過三十年，鐵芯和銅線可以循環再用。電子牛是一種由多種電子元件組成的線路，一般藏在電子式慳電膽的膠蓋內，或在長光管的燈盤上面。

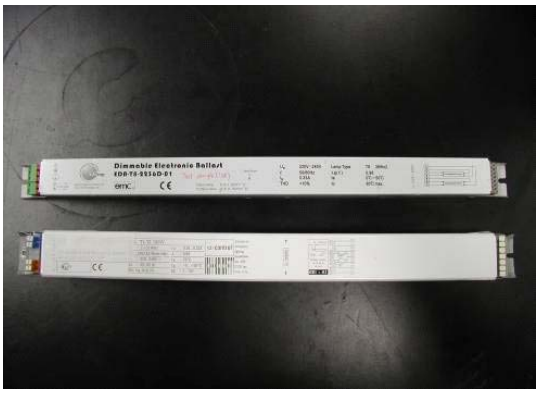
電子式慳電膽和電子牛的壽命從數個月到數年不等，產品的壽命受制於一種叫「電解電容」的元件，一般的電解電容在攝氏 85 度可運作二千小時，高質素的電解電容在攝氏 105 度可運作約八千小時。相對於線牛的三十年壽命，電子鎮流器的平均壽命大約是五年，慳電膽的壽命一般更短，由數星期到兩年左右。因爲電子牛和慳電膽含有不可分解及有毒的電子廢料，所以數個月至數年的「節能」會變成數百甚至數千年的「環境污染」。機電署早前公布會在紅磡隧道更換四千七百個電子牛，這項工程只可說是「節能」，萬萬不可說成「環保」，因爲在數年後，必會有四千七百塊不可分解及有毒的電子廢料需要處理。

大眾不要輕看電子牛和慳電膽可帶來的污染問題，我們每人日常只用一部手提電話，試想每人在家中及辦工室的照明系統，平均每人可能用超過十個不同種類的電燈。所以如果我們不能看清楚問題的嚴重性，很快便因爲選擇錯誤產品而產生大量不可分解及有毒的電子廢料。數年前很多機構(包括政府、半政府機構及多間大學等)都更換了大量的電子牛和慳電膽，相信在不久的將來，會有數以千萬計的電子廢料送往堆填區。電子廢物的問題已日漸浮現，若社會及政府不正視這問題，問題只會加速惡化。我們不應因爲誤會「節能」便是「環保」而不知不覺地破壞環境。

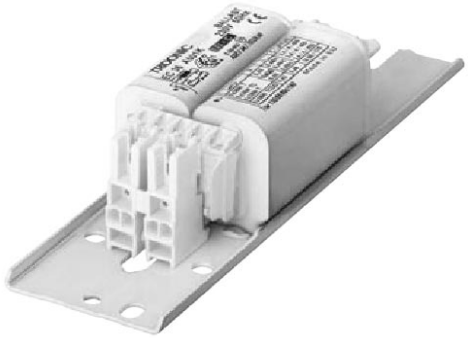
可採用節能環保兼備的新技術
現代社會不可能脫離高科技電子產品，環保也不應是「反科技」，我們須要作出平衡及理智的取捨，DDT 曾經是有效的殺蟲藥，當人類了解到它對環境的破壞後，便以其他更環保的技術取代。在照明系統上，其實市場上已經有一些「低損耗」的線牛和「電感式節能燈」。線牛的可靠性極高，在使用的數十年期間，不單可以減

少大量電子廢料、維修管理費、棄掉電子廢料和更換數次「電子牛」的費用，更重要是鐵芯和銅線在使用後仍然可以循環再用，完全避免產生電子廢料。再加上剛發明可與線牛兼容的中央調光技術，一個中央節能器便可將超過一百個傳統「不可調光」的線牛，變成「可調光」的「節能環保兼備」的系统，而其節能功效與電子牛相約。政府有關部門應該重新檢討現行的節能和環保政策，不要混淆「節能」與「環保」慨念，多宣傳正確的環保觀念和有關的技術，鼓勵應用節能及環保兼備的方法和技術。

許樹源　香港城市大學 電子工程系講座教授



以電子鎮流器(俗稱電子牛)



電感鎮流器(俗稱線牛)

電子式慳電膽

電感式慳電膽

電子廢料污染－中港的共同危機

去年 8 月，香港有線電視的一個時事節目，曾專題報導有關汕頭大學在國內一個處理電子廢料的村落所進行的研究，發現於 160 多個接受檢查的兒童當中，超過 130 個的血液裏含有過量的重金屬。同年 9 月，環保組織「綠色和平」引述聯合國的統計數字，指出全球每年生產二到五千萬噸電子產品，呼籲發達國家停止向發展中國家輸出有毒的電子垃圾。10 月份，一個有關香港沙頭角電子廢料回收工場的報導更披露香港的新界北已成為外國電子垃圾的回收站。其後在 11 月，全球最大的貨櫃船愛瑪馬士基號（Emma Maersk）從鹽田港處女航行抵達英國，卸下四萬噸半的禮品後竟換來一箱箱的「洋垃圾」。12 月份加拿大政府公開表示當地的二十七家公司已視中國大陸和香港為垃圾回收站；早在 2005 年 11 月，企圖將五百噸有毒的電子垃圾偷運到中國內地及香港棄置。加國政府相信這問題只是冰山一角，這次事件亦再次證明香港已成為洋垃圾的中轉站。加拿大環保署的報告指出，這些電子垃圾全部對人體及環境有害，它們包括

(1) 含鉛的電腦顯示屏、
(2) 鉛酸電池及
(3) 帶多氯聯苯(PCBs)的熒光燈鎮流器等。

2007 年 1 月，有報導指出全球百份之七十的電子廢料正運往中國…….

以上種種正顯示電子廢料的污染問題已為中港的共同危機，作為教育工作者，我們十分關注電子廢料的處理問題。根據報導指出國內部份的電子廢料處理乃利用兒童和婦女將電子廢料加熱取回部份金屬，這種低技術的回收方法，不單讓婦孺在處理廢料的過程中容易重金屬中毒，餘下不能回收的大部份有毒物質，更會嚴重污染土地及地下水，做成長遠的、嚴重的環境污染。我們希望就這逼切的問題作出以下的一些建議以供中央政府及香港政府參考：

(1) 嚴格禁止進境傾倒、堆放及處置電子廢物；禁止進口不可循環再用或不可以「無害」方式循環再用的廢料；就國內處理電子廢物的能力限制進口可循環再用廢料的數量。
(2) 立法容許只有符合國際標準及保護設備的機構參與電子廢物回收，嚴禁使用低技術的電子廢料處理方法。
(3) 重金屬嚴重影響兒童及嬰兒的成長，遺禍深遠；中港政府應立法嚴禁利用兒童及懷孕婦女參與廢料處理工作。
(4) 電子廢料的進口只是問題的一部份，中港本身所產生的電子廢物也構成了一個嚴重的污染問題。中港政府應全面檢討現行的環保政策，以釐清「節能」與「環保」的概念。例如近年中港政府所推動的電子鎮流器及電子節能燈(慳電膽)，實「節能」有餘，「環保」不足，因該等產品壽命短促，可在數年或短至數月間耗損，變為大量有毒及不可分解的電子垃圾。其中的熒光燈鎮流器便為加拿大檢獲的數百噸準備運到中港的三大電子廢料之一。
(5) 電子廢料並非全部可循環再用，亦不容易成為賺錢的門徑。中港政府應考慮主動設立電子廢料回收機制及循環再用設施，統籌電子廢物的回收及循環再用。

(筆劃序)

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Misconception on 'energy saving' could do more harm to our environment

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GLOBAL warming has prompted many governments to consider taking serious actions to reduce greenhouse gas emission. It is, however, important to take the right measures that would not harm the environment in other ways. The alarming news reported recently about soil and water pollution in China as a result of improper handling of electronic wastes has signalled a potential disaster arising from a common misconception that 'energy saving is always environmentally friendly'.

The concepts of 'energy saving' and 'environmental friendliness' can be easily mixed up. In fact, an 'energy-saving' technology is not necessarily an 'environmentally friendly' one. For genuine environmental protection, we must (1) reduce greenhouse gas emission that is harmful to the atmosphere and (2) reduce waste/pollution in soil and water. These two requirements must go hand in hand.

Energy saving is a means to reduce greenhouse gas emission. But if a lot of waste is created in the process, it is not environmentally friendly. Without considering the waste factor, the best solution to reducing greenhouse gas emission is to use nuclear power because it has zero gas emission. But the nuclear waste is harmful for tens of thousands of years (longer than the history of human civilisation) and so many countries have decided not to use nuclear power for electricity generation. Those countries which use nuclear power must have a policy of handling nuclear waste before building nuclear power plants.

If any government officials think that they can use electronic compact fluorescent lamps (e-CFLs) to reduce greenhouse gas emission without considering the waste factor, they are making a huge mistake. Fluorescent lamps, be it in compact or tubular form, need a device called ballast to limit the lamp current. There are two types of ballasts, namely electronic ballasts and magnetic ballasts.

Limited by the lifetime of a component called electrolytic capacitor, e-CFLs have typical average lifetime ranging from seven months (6,000 hours) to about 14 months (10,000 hours). Each unit consists of two parts, namely an electronic ballast housed inside the plastic cover and a folded fluorescent lamp. The electronic ballast consists of toxic components and chemicals such as PBB and PCB, while the fluorescent lamp contains typically 3mg to 8mg of highly toxic mercury.

Another problem of e-CFLs is that the electronic ballast fails faster than the lamps.This causes unnecessary wastage of lamps and mercury. Using e-CFLs to reduce carbon dioxide emission for a short time could lead to rapid accumulation of toxic chemicals, heavy metals and non-biodegradable e-waste that can harm the environment for thousands of years.

Take Hong Kong as an example: If two million families throw away five e-CFLs each year, 10 million pieces of e-waste and 30-80 tonnes of mercury will be dumped in the landfill area annually. Toxicologists consider a mercury dosage in the order of microgram as a harmful quantity. One milligram is 1,000 micrograms.

As the ballast and lamp are integrated as a single unit in an e-CFL, consumers cannot safely (and must not) separate the two parts. So they will simply throw used e-CFLs into the garbage bins. This poses another danger to the workers who collect the wastes. As the lamps are crushed in the garbage trucks, the mercury vapour can escape.If inhaled, the mercury can damage internal organs and nervous systems of human beings.

Ordinary landfill liners are not designed to handle e-waste and heavy metals such as mercury. Hence, e-CFLs must be handled as hazardous waste and the Government must set up such recycling mechanism and facilities before considering phasing out incandescent lamps with e-CFLs.

Consumers must be reminded of their hazardous nature. For example, when an e-CFL cracks, the mercury can vaporise easily. Since mercury has a higher density than air, its vapour will concentrate in low-lying areas. Crawling children can easily inhale the mercury vapour.

However, there is a better alternative that is both energy-saving and environmentally-friendly. The new generation of low-loss magnetic ballasts are as efficient as electronic ballasts. Each magnetic ballast consists of a metal core and a set of copper winding (that is, no e-waste). Magnetic ballasts are highly reliable (>30 years of lifetime), almost maintenance-free, low-cost and recyclable. They can be designed to use with detachable compact lamps. Both parts can be recycled. The Government should encourage the use of magnetic ballasts for both compact and tubular fluorescent lamps, particularly for large public lighting systems used in car parks, warehouses, hallways, stairs and corridors of buildings.

It is imperative for all governments to develop a long-term strategy in educating the public about the importance of a sustainable society. Energy saving and environmental protection are pressing issues that deserve our immediate attention, but a proper concept of 'avoiding wastage' is far more important for making our society more sustainable. Any climate-friendly initiative without considering environmental impact could put the environment at risk.

In December last year, the Canadian Authority intercepted over 500 tonnes of electronic waste being smuggled to Hong Kong and China for dumping. This amount of electronic waste was just the tip of an iceberg. The Canadian Authority singled out electronic ballasts for fluorescent lamps as one of the three major types of electronic waste discovered. We must not let any misconception on energy saving become an unintentional reason for causing more harm to the environment.

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