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Research Note

Towards a Clearer Picture of Air Pollution: The Norwegian Emissions Inventory as a Standard

Emissions inventories are an essential tool for evaluating, managing, and regulating air pollution and are the foundation of cost-effective emissions control. This research note introduces the "good practice" emissions inventory produced by Norway, as a standard for Hong Kong to aspire towards.

1. Why a detailed emissions inventory matters

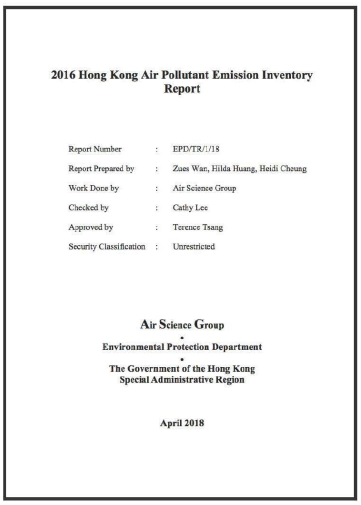
- Emissions inventories are an essential tool for evaluating, managing, and regulating air pollution and are the foundation of cost-effective emissions control (Mobley & Cadle, 2004).
- Major reductions in the largest emissions sources have made **accurate inventories of previously minor sources much more important** to the understanding and improvement of local air quality (Miller, Hidy *et al.*, 2006).
- Advanced emissions inventories can use top down (eg satellite measurements, air quality monitoring) and bottom-up (eg calculations based on factory production) approaches to deliver a detailed picture of a region's emissions. These may be used by local policymakers and also form the basis of reports to national or international bodies, eg United Nations Framework Convention on Climate Change (UNFCCC) for CO_2 emissions.
- A gross emissions inventory including only large emissions sources can **severely underestimate emissions**. For example, actual atmospheric emissions in northeast British Columbia found nitrogen oxides (NOx) and volatile organic compound (VOC) emissions more than double the emission inventory estimates. These previously **hidden emissions arose from over 10,000 small and unregulated point sources which were not included in the official emissions inventory** (Krzyzanowski, 2009).
- Poor or inadequate emissions inventory can have a **detrimental effect on environmental policy**: for example, substantial delays to US acid-rain action resulted from disputed inventories in the late 1970s and 1980s (Mobley & Cadle, 2004).

2. Hong Kong's emissions inventory

- Hong Kong's emissions inventory is produced annually by the Environmental Protection Department (EPD).

- The 36-page 2016 report published in April 2018 (EPD, 2018a) comprises estimates of emissions from seven source categories:

    - electricity generation;
    - road transport;
    - shipping;
    - civil aviation;
    - other combustion sources;
    - non-combustion sources; and
    - hill fires.


2016 Hong Kong Air Pollutant Emission Inventory Report

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Security Classification : Unrestricted

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- It covers six major air pollutants:

    - SO_2;
    - NOx;
    - particulate matter (PM10);
    - fine respirable particles (PM2.5);
    - volatile organic compounds (VOCs); and
    - carbon monoxide (CO).

- There is no breakdown of the individual sources of pollution, or any provision of the emissions factors, data or techniques used in the calculations.

- The inventory also includes a section on cooperation with the Guangdong government and some regional pollution statistics. However, the source of this data is opaque.

- The government separately publishes a brief inventory of greenhouse gas emissions (EPD, 2018b) limited to CO_2-equivalent tonnage.

3. Norway's emissions inventory

- The Norwegian Emissions Inventory is a joint undertaking between the Norwegian Environment Agency and Statistics Norway.

- Statistics Norway made its first emission inventory for some gases in 1983 for the calculation year 1973. The emission estimation methodologies and the QA/QC procedures have been developed continuously since then. The overarching model was developed by Statistics Norway (Daasvatn *et al.*, 1992, Daasvatn *et al.*, 1994). It was redesigned in 2003 in order to improve reporting to the UNFCCC and to improve quality assurance/quality control (QA/QC) procedures.

- Between 2005 and 2016, it was developed primarily as a methodology document (Statistics Norway, 2016) outlining techniques and emissions factors for 21 pollutants: this document was a database of pollutants with all the associated mathematical models and techniques for estimating tonnage. Actual quantities were then published separately using this document as a foundation.

Cube concept

The Norwegian emission model is organised around a general emission model called "Kuben" ("the Cube"), of which three axes are fuels, industries and sources

For a given pollutant, there is one emission factor for each combination of fuel, industry and source. For example, there's not simply one "emissions factor" for burning natural gas; the emissions model takes into account the different pollutant regimes of natural gas burned in a small industrial boiler; or in a pottery kiln; or natural gas flared at a petrochemical plant. As another example, the model distinguishes the difference between LPG burned in a small household boiler; and LPG burned as car fuel.

- Since 2017, the methodology and the data are combined into one report now known as the Informative Inventory Report (IIR) (Norwegian Environment Agency, 2018a). This report documents the methodologies used in the Norwegian emission inventory of acidifying pollutants, particulate matters, heavy metals and persistent organic pollutants submitted under the UN Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution.

- Norway also publishes its National Inventory Report (NIR) (Norwegian Environment Agency, 2018b) focusing on greenhouse gases and for submission to the United Nation's Intergovernmental Panel on Climate Change (IPCC) under the Kyoto Protocol.

- The 2016 report published in 2018 is 284 pages long and fully conforms to the UNFCCC guidelines on good practice for emissions inventories[1] (IPCC, 2005). It digs down into processes as varied as "production of soap", "rock crushing plant", "use of fireworks" in a very detailed and comprehensive manner. Under transport, for example, it includes 47 different vehicle types; and for road transport modelling uses actual odometer mileages collected by the Department of Transport during annual or bi-annual road-worthiness tests.

- Aside from pollutant weight, Norway also maps by location, where possible, using a concept called "gridded emissions", mapping emissions to a 0.1°x0.1° grid. Emissions from large point sources or where the geographical location is known can be accurately placed on a map. Emissions

1 These guidelines are aimed at greenhouse gas emissions inventories but are adopted by Norway's entire emissions inventory activities.

from marine traffic, for example, are allocated using a vessel's Automatic Identification System (AIS) tracking; if the location of a pollution source is not known, or it's a mobile source, a weighted population model for the source is used.

- QA/QC of the overall report maintained by the separation of Norway Statistics and the Norwegian Ministry of Environment; inventory-level QC procedures are performed every year according to IPCC guidelines. Source-specific QA/QC is conducted as appropriate for each source.

4. Comparison between Hong Kong and Norwegian reports

- The most immediate inventory difference between Hong Kong and Norway is the scope of the reports: Norway's examines 24 pollutants across a 284-page report, while Hong Kong's examines 6 across 36 pages. The pollutants examined by Norway (Norwegian Environment Agency, 2018a) and Hong Kong (EPD, 2018a) are compared in Table 1.

Pollutant class	Pollutant	Hong Kong	Norway
Heavy metals	Lead	N	Y
	Cadmium	N	Y
	Mercury	N	Y
	Arsenic	N	Y
	Chromium	N	Y
	Copper	N	Y
Persistent organic pollutants	Polycyclic aromatic hydrocarbons (PAHs)	N	Y
	Dioxins/PCBs/HCBs	N	Y
Acidifying gases	SO_2	Y	Y
	NOx	Y	Y
	NH_3	N	Y
Particulates	PM2.5	Y	Y
	PM10	Y	Y
	Black carbon	N	Y
Other pollutants	CO	Y	Y
	VOCs	Y	Y
Greenhouse gases	CO_2	Y/N[2]	Y
	CH_4	N	Y
	N_2O	N	Y
	PFCs	N	Y
	HFCs	N	Y
	SF_6	N	Y

Table 1: Comparison of pollutants measured by Hong Kong and Norway

2 The EPD separately publishes a CO2-equivalent inventory (EPD, 2018b), however individual greenhouse gases are not separated, and there are no details as to what greenhouse gases are included. https://www.climateready.gov.hk/page.php?id=23

- Aside from scope, the emissions inventories differ in adoption of best practice. Table 2 below compares Hong Kong and Norway's adoption of IPCC (2005) "good practice" emissions inventory standards.

UN IPCC "Good practice" metric	Hong Kong	Norway
Transparent	N	Y
Documented	N	Y
Consistent over time	Y	Y
Complete	N	Y
Comparable	N	Y
Assessed for uncertainties	N	Y
Subject to quality control and assurance	Unknown	Y
Efficient in the use of resources available to inventory agencies	Unknown	Y
In which uncertainties are gradually reduced as better information becomes available	Unknown	Y

Table 2: Comparison of emissions inventory "good practice" adopted by Hong Kong and Norway

5. Discussion

An examination of Hong Kong's and Norway's emissions inventories reveal Norway's efforts to be far superior in terms of scope, quality control and transparency.

In terms of methodology, due to the opaque nature of Hong Kong's inventory we do not know if, behind the scenes, the EPD is using a document as comprehensive as Norway's.

However, we feel there is not such a rigorous design behind the Hong Kong inventory, and here's why: in 2017, we contacted EPD and requested cigarette pollution be included in future emissions inventory. The EPD obliged, and added cigarettes in its 2018 publication (EPD, 2016a). While we welcomed this addition, it does point to a rather haphazard nature of the inventory.

In a conversation with EPD on the subject, we were informed the EPD would be happy to include further pollution sources, provided there existed official government data on which to base calculations. EPD would not, however, on its own initiative, seek or request new data itself.

In this respect, to bring Hong Kong's emissions inventory to a "Norway" level, in terms of scope, we must first identify the gaps in the data, then, if base data does not exist, persuade government sources to acquire/develop the data (the hard part); then request it for inclusion in the inventory.

A more holistic approach would be preferred, and it is suggested we lobby the government first for a more transparent "working guide" or the methodology document behind the production of the emissions inventory; and, using the IPCC "good practice" guidelines as a benchmark, nudge the development in this direction in terms of QA/QC, while ensuring coverage expands to cover as many smaller sources as possible.

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