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.

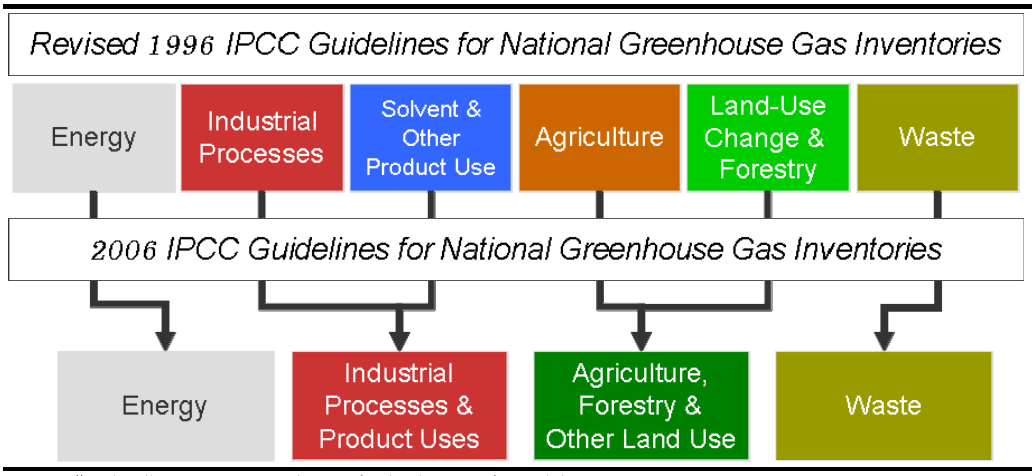
These inventories have now been updated to take into account the methodologies specified in the *2006 IPCC Guidelines* as far as possible. While these methodologies are based on the same principles as the *Revised 1996 IPCC Guidelines,* three key differences exist - the categorisation of sources and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

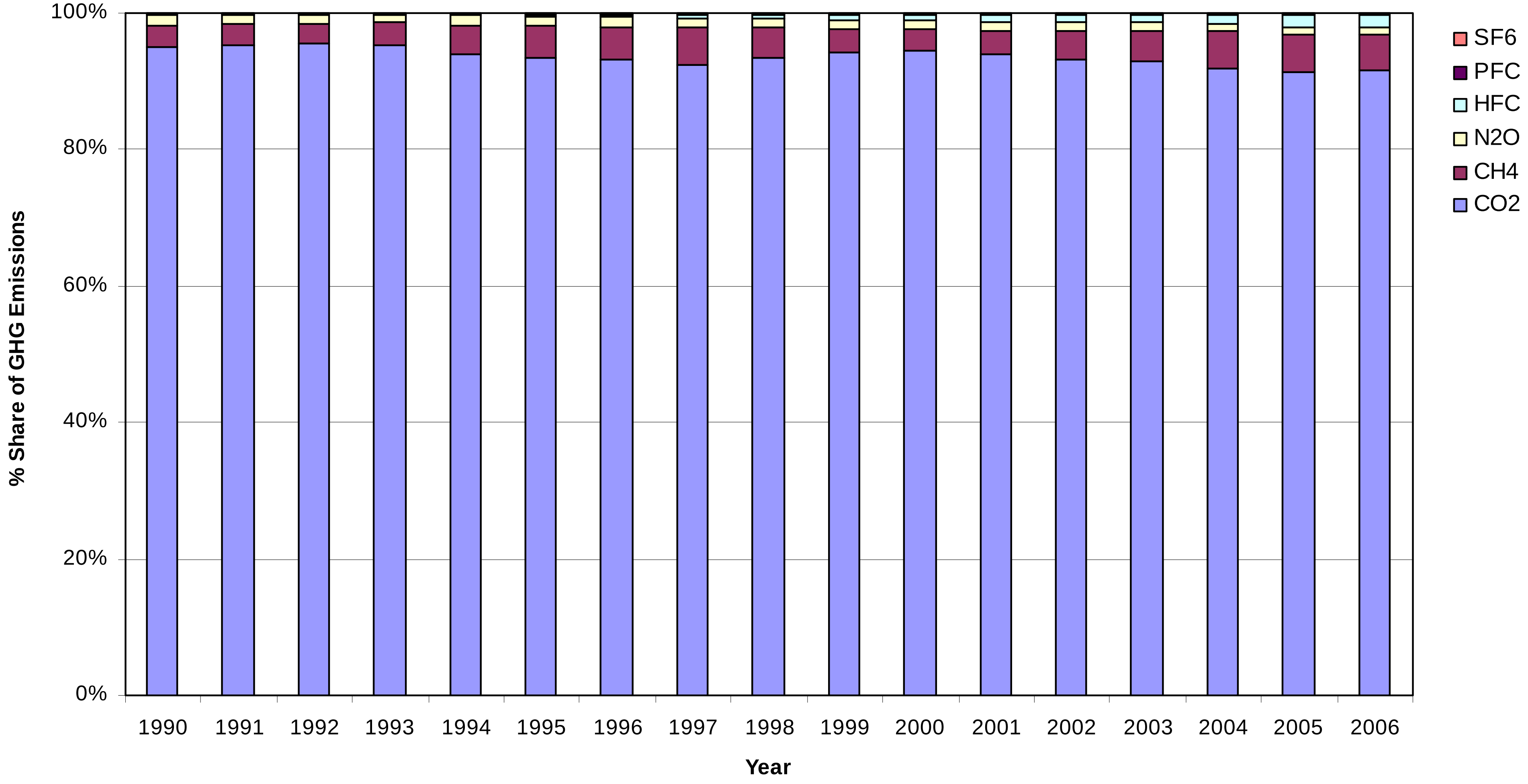
(b) International aviation and navigation as memo items are excluded from the inventory.

(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:

QC– The Compilation Team

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.

QC – The Review Team

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.

QA – The Independent Verification Team

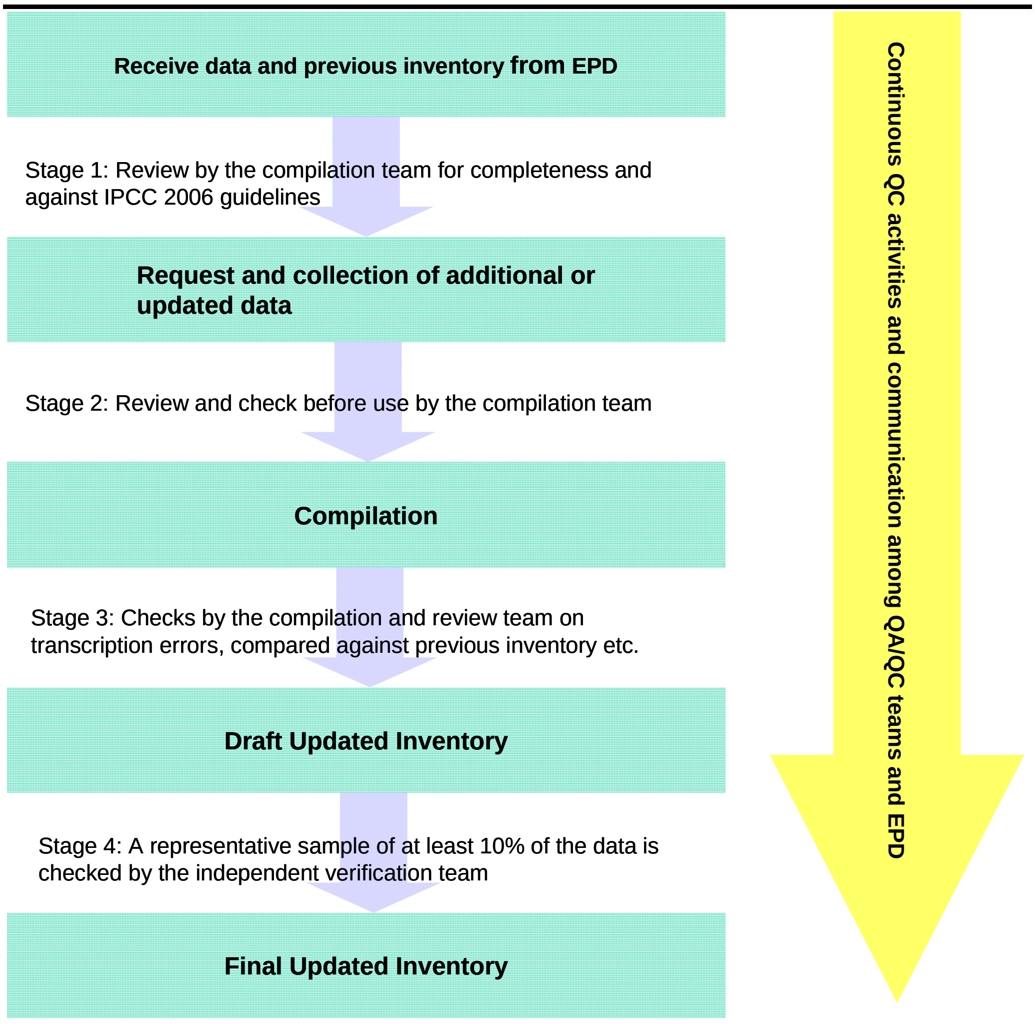
This team is independent of the compilation and review teams and has not been directly involved in the data compilation/ development process. The team is engaged at the final stage of the QA/QC process to verify calculations in the updated inventory, identifies any errors and/or miscalculations and then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

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

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*

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

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*

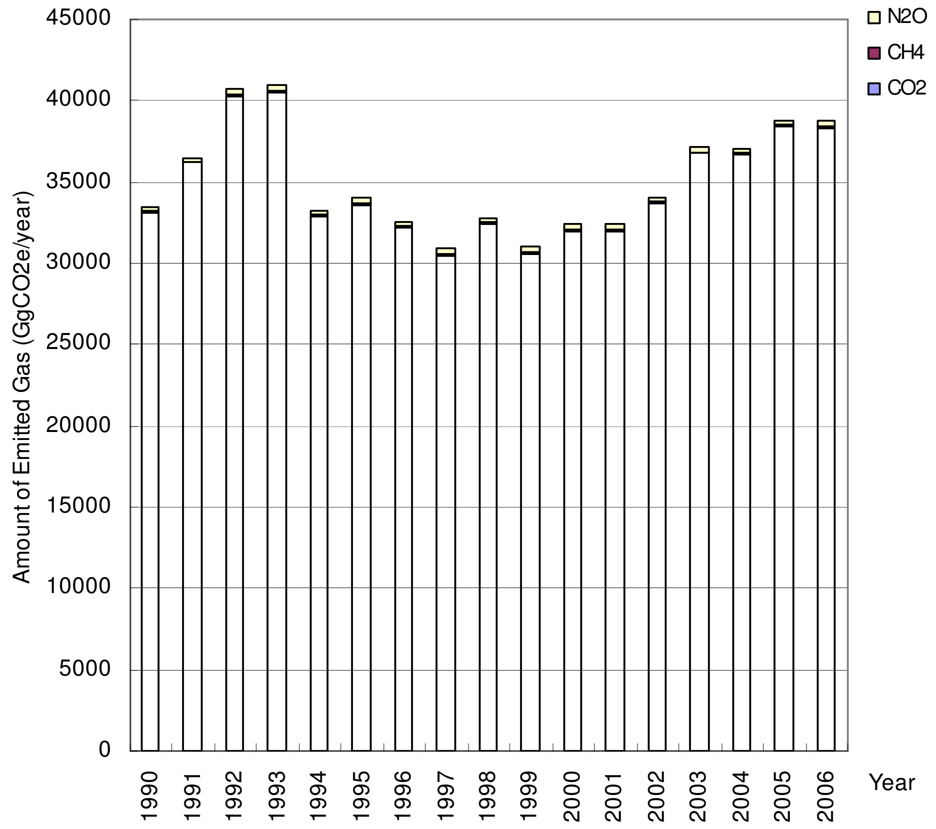
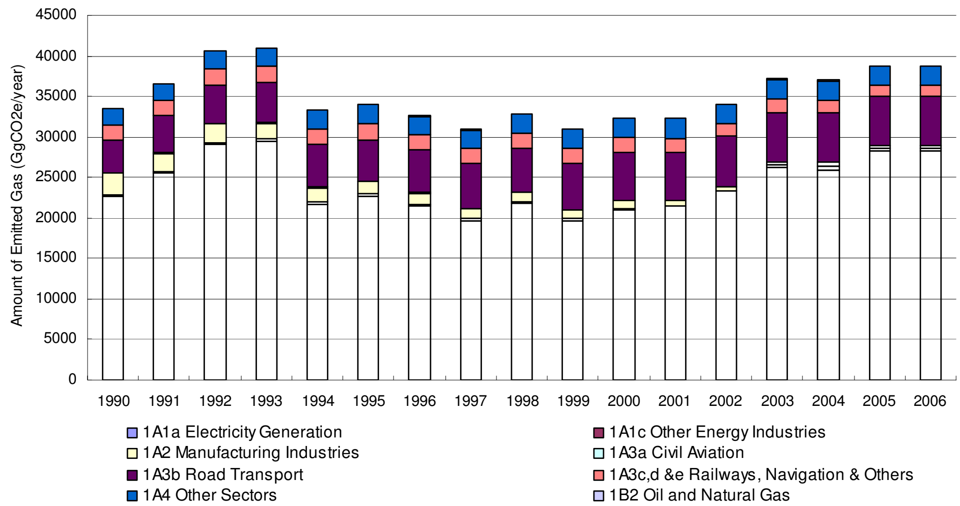


Figure 2.2 *GHG Emissions of the Energy Sector 1990-2006, by sub-sector*



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***

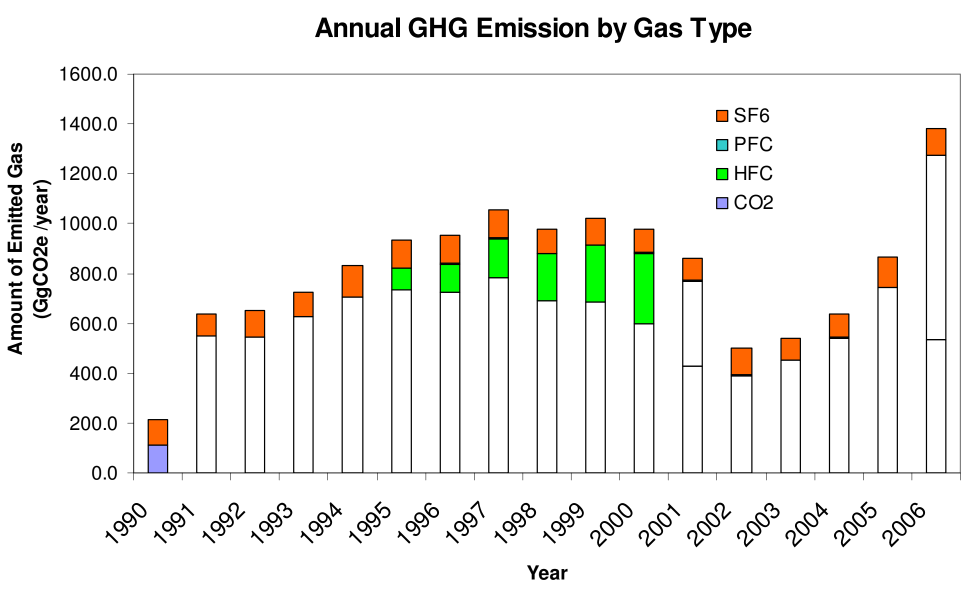

Figure 2.4 GHG Emissions of the IPPU Sector 1990-2006, by sub-sector

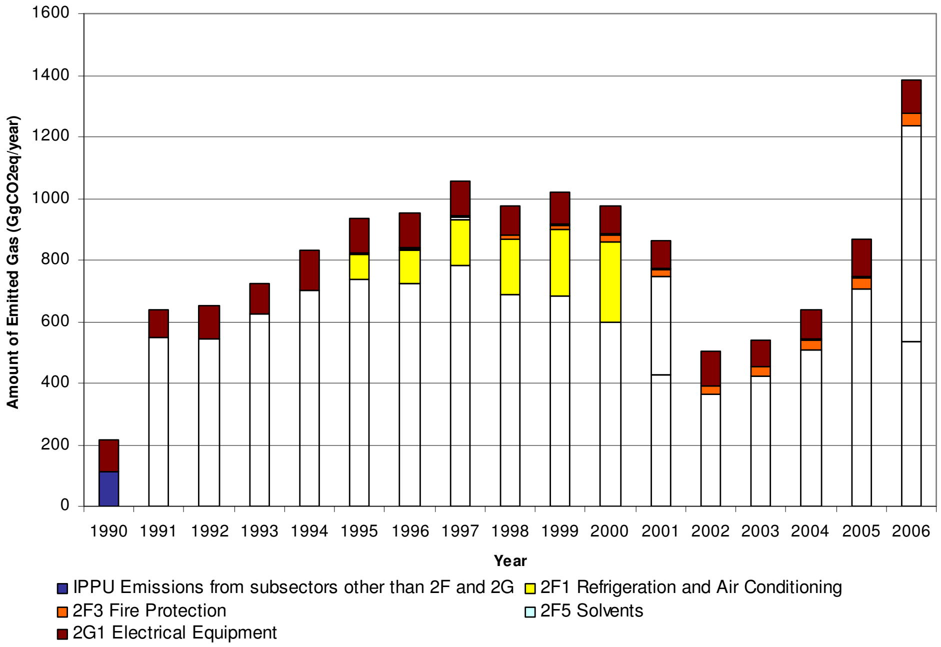

Table 2.5 GHG Emissions of the IPPU Sector from 1990-2006

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*

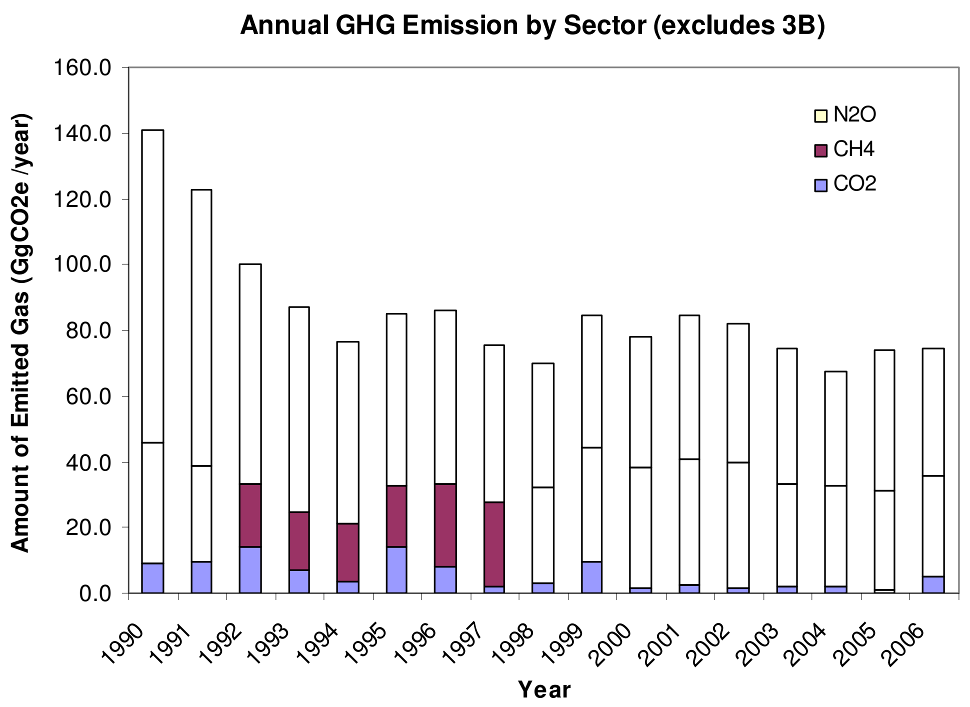


Figure 2.6 *GHG Emissions of the AFOLU Sector 1990-2006, by sub-sector*

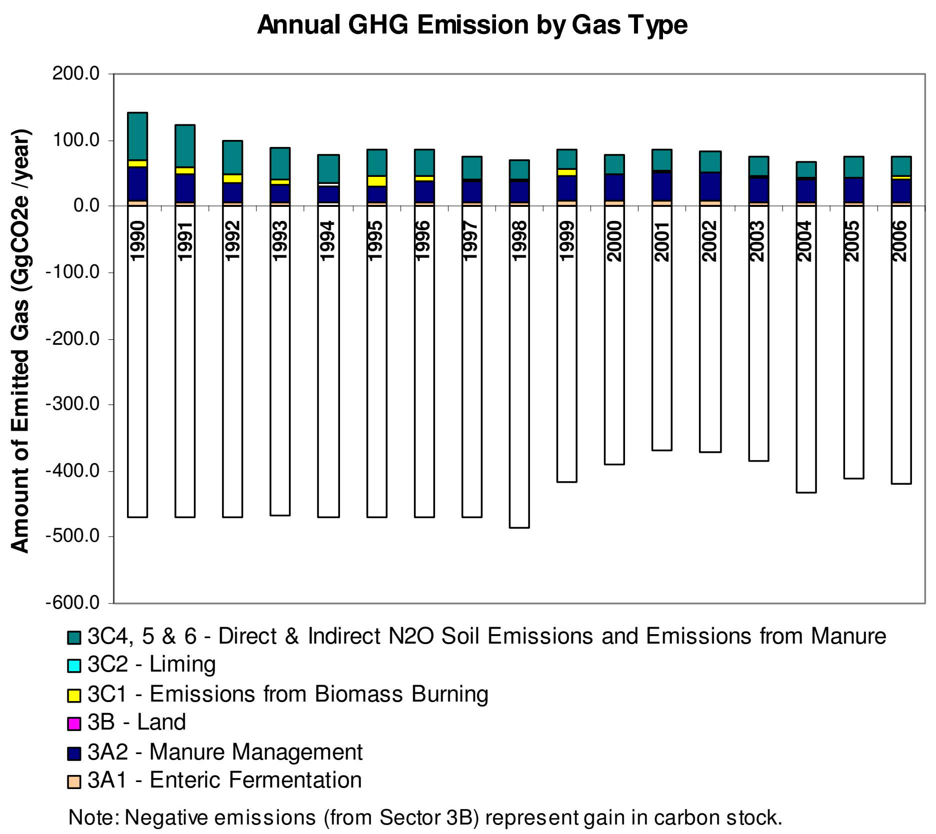


Table 2.7 Detailed GHG Emissions from AFOLU Sector from the year 1990-2006

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

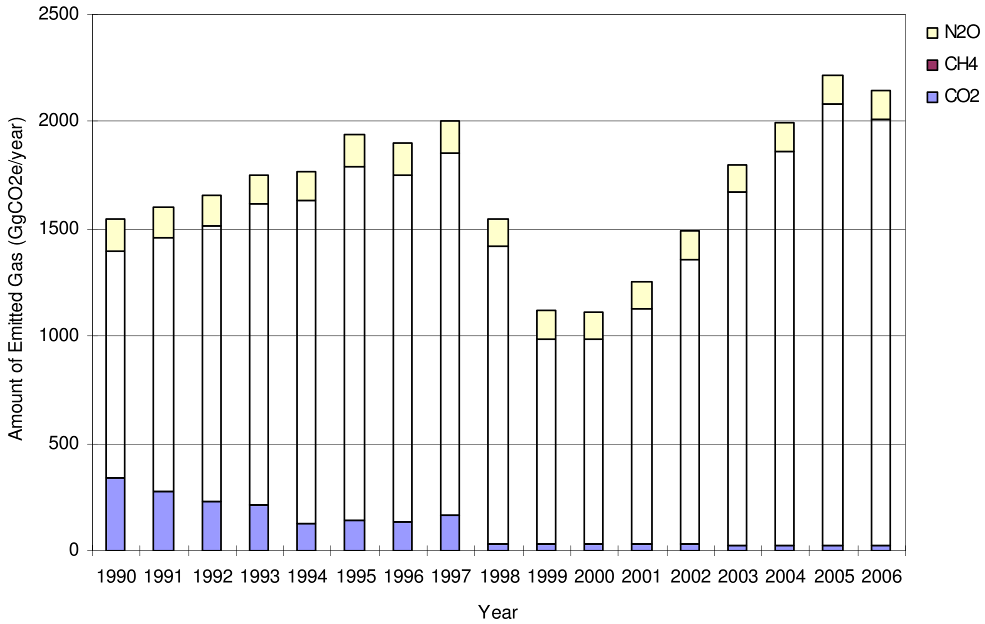
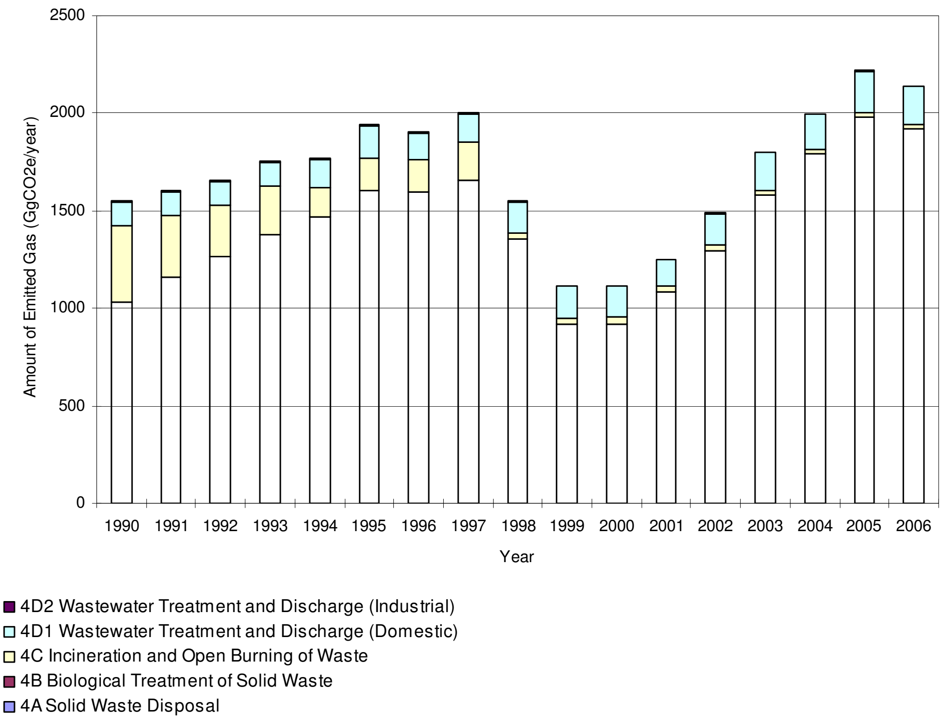


Figure 2.8 GHG Emissions of the Waste Sector 1990-2006, by sub-sector



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.

<u>*IPPU*</u>

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.

<u>*AFOLU*</u>

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.

<u>*Waste - 4A Solid Waste Disposal*</u>

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.