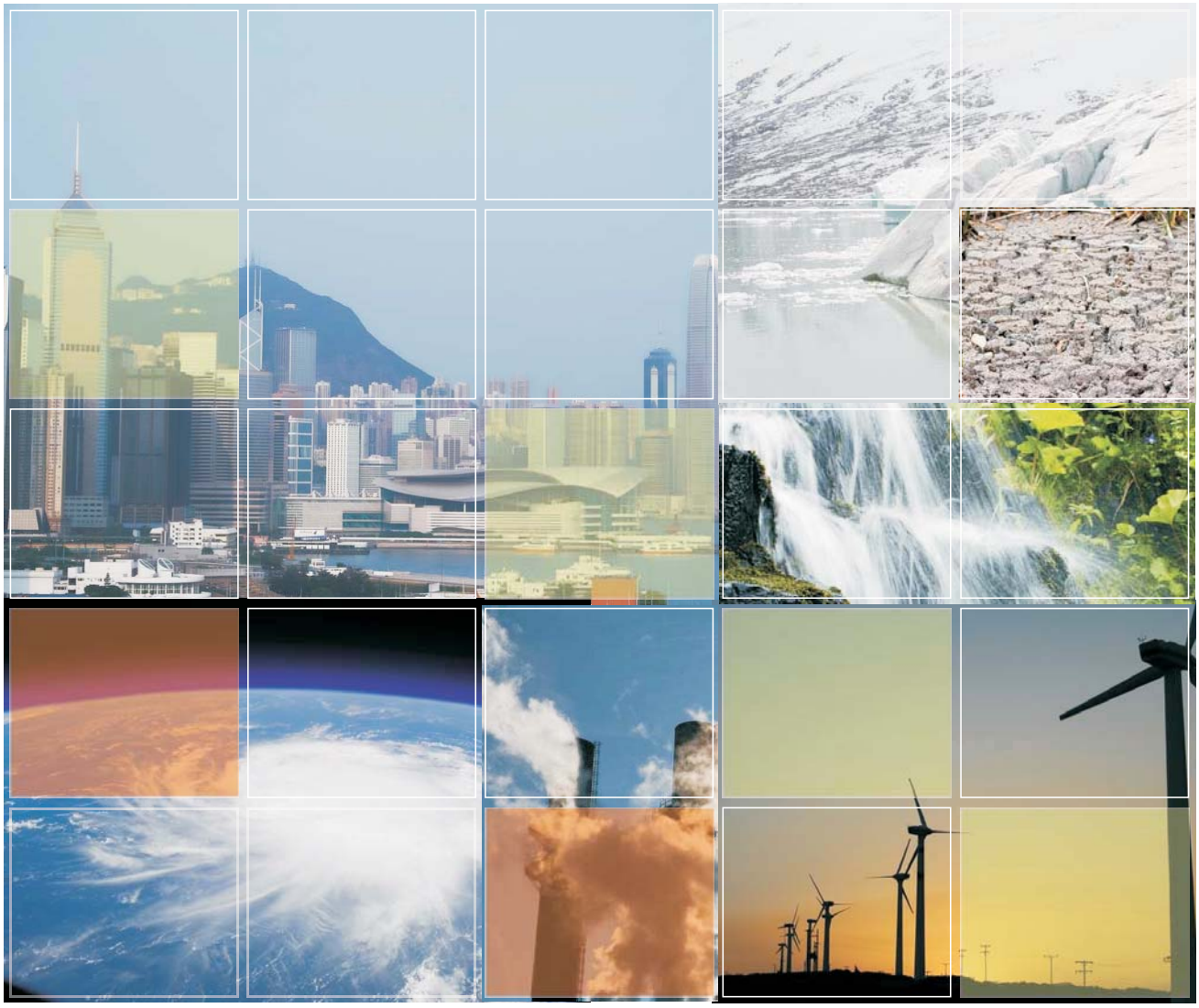
EXECUTIVE SUMMARY



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

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

December 2010

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EXEXUTIVE SUMMARY

Environmental Protection Department

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

December 2010

Reference 0082487

For and on behalf of
ERM-Hong Kong, Limited

Approved by: Dr Andrew Jackson

Signed:

Position: Managing Director

Date: 3 December 2010

CONTENTS

1 OVERVIEW: CLIMATE CHANGE AND THE HONG KONG SAR

BACKGROUND

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

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

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

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

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

OBJECTIVES

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

1.6 Individual objectives of the study are summarised as follows-

- review and update the **inventories** of GHG emissions and removals and project future trends;
- evaluate existing and recommend additional policies and measures to reduce GHG, emissions or increase sinks of GHG, and assess their cost-effectiveness, economic, social and environmental implications of such **mitigation** measures;
- characterise the **impacts** of climate change in Hong Kong, and evaluate existing and recommend additional strategies and measures to facilitate adequate **adaptation** to climate change;
- evaluate existing and recommend further strategies and measures to promote the development and application of environmentally sound technologies and scientific research pertinent to, and public **awareness** of, climate change.

2 GREENHOUSE GAS EMISSIONS

APPROACH

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

2.2 The inventory has been developed based on the relevant COP decisions and using internationally agreed and adopted methods. In order to further improve the accuracy of the inventory, the estimation methodologies in the latest version of the internationally recognised guidelines, ie the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (1), were used if the relevant information in Hong Kong SAR was unavailable.

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

HISTORIC TREND IN EMISSIONS IN HONG KONG, 1990 TO 2006

2.4 The trend in total GHG emissions in Hong Kong since 1990 is presented in *Exhibit 1*. The emissions of CO_2-e have risen from 35.3 million tonnes in 1990 to 42.3 million tonnes in 2006. The use of energy (2) is the principal source of GHG emissions, contributing an average of approximately 93% of annual emissions over the period.

2.5 A breakdown of emissions from major sectors is provided in *Exhibits 1* and *2*. It is evident that emissions from electricity generation (accounting for about 57 to 67% of the total) and transport (about 16 to 23% of the total) are the most influential. Indeed, emissions from electricity generation generally were on the increase over the period, with the exception of a marked drop

between 1993 and 1994 due to the introduction of low-carbon nuclear energy imports from Mainland China, in place of local generation by coal-fired power plants.

Exhibit 1 Breakdown of GHG Emissions by Major Sectors, 1990-2006

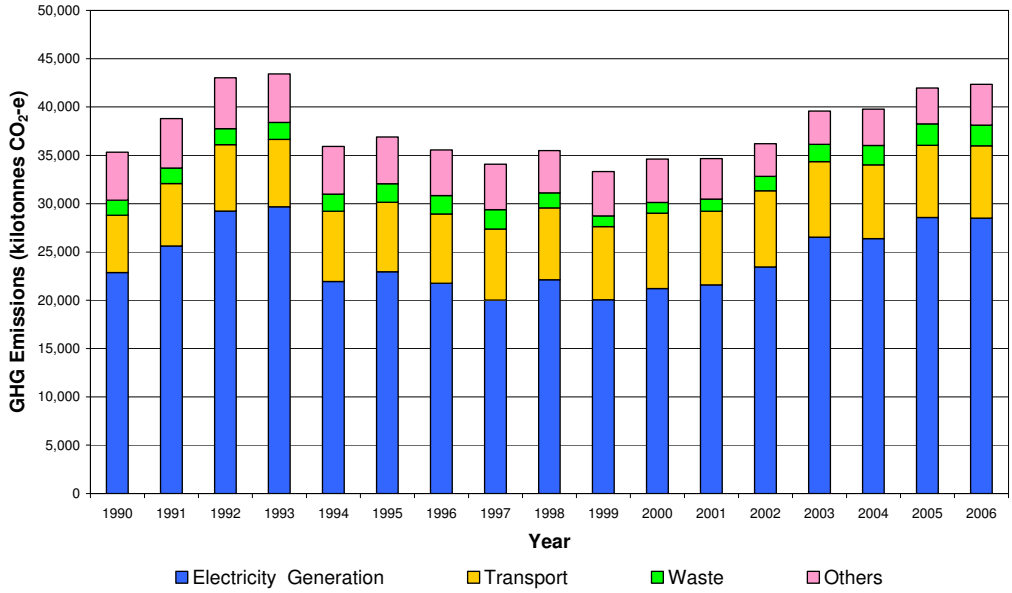


Exhibit 2 Detailed Breakdown of HK GHG Emissions by Concerned Sub-sector and its Percentage Share, from 1990 to 2006

Year	HK GHG Emissions by Sectors (kilotonnes CO_2-e)[a]							Percentage Share of HK GHG by Sectors (%)						
	Electricity Generation[b]	Transport	Other End Use of Fuel [c]	Waste	Industrial Process and Product Use	Agriculture, Forestry, Other Land Use	Total	Electricity Generation[b]	Transport	Other End Use of Fuel [c]	Waste	Industrial Process and Product Use	Agriculture, Forestry, Other Land Use	Total
1990	22,900	5,940	4,620	1,550	215	141	35,300	64.7%	16.8%	13.1%	4.4%	0.6%	0.4%	100%
1991	25,600	6,470	4,360	1,600	638	123	38,800	66.0%	16.7%	11.2%	4.1%	1.6%	0.3%	100%
1992	29,200	6,870	4,500	1,660	651	100	43,000	68.0%	16.0%	10.5%	3.8%	1.5%	0.2%	100%
1993	29,700	6,970	4,200	1,750	724	87	43,400	68.4%	16.1%	9.7%	4.0%	1.7%	0.2%	100%
1994	21,900	7,270	4,030	1,770	830	77	35,900	61.1%	20.2%	11.2%	4.9%	2.3%	0.2%	100%
1995	23,000	7,180	3,810	1,940	935	85	36,900	62.2%	19.5%	10.3%	5.3%	2.5%	0.2%	100%
1996	21,800	7,170	3,680	1,900	952	86	35,500	61.2%	20.2%	10.3%	5.3%	2.7%	0.2%	100%
1997	20,000	7,340	3,590	2,000	1,060	75	34,100	58.7%	21.5%	10.5%	5.9%	3.1%	0.2%	100%
1998	22,100	7,430	3,330	1,550	977	70	35,500	62.4%	20.9%	9.4%	4.4%	2.8%	0.2%	100%
1999	20,100	7,570	3,470	1,120	1,020	85	33,300	60.2%	22.7%	10.4%	3.4%	3.1%	0.3%	100%
2000	21,200	7,800	3,450	1,110	977	78	34,600	61.2%	22.5%	10.0%	3.2%	2.8%	0.2%	100%
2001	21,600	7,640	3,220	1,250	862	85	34,700	62.3%	22.0%	9.3%	3.6%	2.5%	0.2%	100%
2002	23,400	7,890	2,800	1,490	503	82	36,200	64.8%	21.8%	7.7%	4.1%	1.4%	0.2%	100%
2003	26,500	7,810	2,830	1,800	538	74	39,600	67.0%	19.7%	7.1%	4.5%	1.4%	0.2%	100%
2004	26,400	7,640	3,060	1,990	636	67	39,800	66.3%	19.2%	7.7%	5.0%	1.6%	0.2%	100%
2005	28,600	7,480	2,770	2,220	867	74	42,000	68.1%	17.8%	6.6%	5.3%	2.1%	0.2%	100%
2006	28,500	7,480	2,730	2,140	1,380	74	42,300	67.4%	17.7%	6.5%	5.1%	3.3%	0.2%	100%

Notes:

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

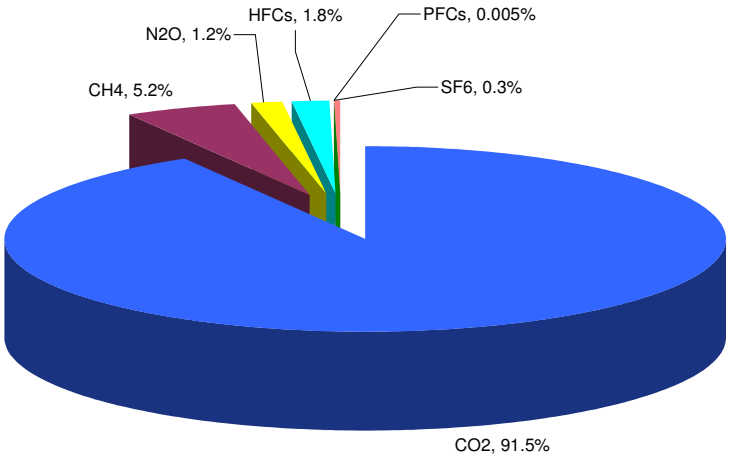
(b) Including towngas production – accounts for about 1% of GHG emissions as in the energy production sector

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

2.6 Following the above-mentioned two sectors, emissions from the waste sector are the next most significant, contributing an average of approximately 4.5% per annum.

2.7 Of the six main GHGs, carbon dioxide (CO_2) is the dominant emission, and is responsible for more than 90% of the total. *Exhibit 3* summarises the emissions by gas type for the year 2005.

Exhibit 3 ***HK Domestic GHG Emission Inventory by Gas Type in 2005***



Note: CO_2 – carbon dioxide; CH_4 – methane; N_2O – nitrous oxide; HFCs – hydrofluorocarbons; PFCs - perfluorocarbons; SF_6 – sulphur hexafluoride

PROJECTED EMISSIONS, 2005 TO 2030

2.8 If there were no additional measures to control the emission of GHGs, emissions from Hong Kong are projected to increase, albeit in a non-linear manner, by 7% over the period 2005 to 2030. *Exhibit 4* summarises some of the key indicators in the Base Case and the associated emissions estimates.

Exhibit 4 Major Indicators: Base Case

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

Notes:

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

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

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

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

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

3 MITIGATION OF EMISSIONS

INTRODUCTION

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

MITIGATION MEASURES

3.2 As over 90% of Hong Kong's GHG emissions arise from the energy supply sector, the use of energy in buildings and transport, and from landfills, the greatest potential for Hong Kong to further mitigate its GHG emissions lies within these sectors. Key criteria for selection of policies and measures are

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

3.3 Based on local and international policy reviews, and with consideration of the key selection criteria, the study identified and shortlisted the following measures that were considered potentially suitable for further consideration of their feasibility for implementation before 2030 (3).

(a) Building and Appliance Sectors

- Expanding the scope and tightening the requirements of the Building Energy Codes (BEC) to achieve energy efficiency improvements of major installations (e.g lighting and lifts) in commercial buildings, expanding the use of district cooling systems (DCS)/water-cooled air conditioning systems (WACS) to reduce energy needs for cooling, and tightening the Overall Thermal Transfer Value (OTTV) (4) standards and promoting extensive use of green roofing, etc to reduce energy demands;

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

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

(b) Transport Sector

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

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

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

- Implementation of a Hong Kong "Importers' Average Fleet Efficiency" standard [5].

(c) Waste Sector

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

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

- Full utilization of gas captured from wastewater treatment;

- Full utilization of sludge treatment with energy recovery.

(d) Electricity Generation

- Using more natural gas to generate electricity locally;

- Increasing the share of renewable energy (RE);

- Increasing the import of nuclear generated electricity from Mainland China.

BASE CASE AND MITIGATION SCENARIOS

3.4 The analysis of mitigation measures undertaken in the study utilises predominantly quantitative analyses of a set of scenarios to support the development of policy options. An integrated energy-economic-environmental modelling framework, the Hong Kong MARKAL-MACRO model, was used for this purpose. The Hong Kong MARKAL-MACRO model captures the interactions between the various stages of the energy system, enables a wide range of energy resources and technologies to be analysed, and enables the aggregate economic consequences to be assessed. More than 60 countries (including China) use country-specific MARKAL-MACRO models for GHG mitigation analysis.

3.5 A Base Case was established in the model so as to enable the comparative analysis of alternate policy options or scenarios so that their relative merits and disadvantages can be identified. The Base Case represents a "business as usual" condition in which no additional measures beyond existing and committed policies in place by 2005 were added.

3.6 Three alternate scenarios were developed so that their impacts could be assessed against the Base Case:

- **Scenario 1 (the 'AQO Scenario')** includes relevant mitigation measures proposed in the AQO Study(6), including the increased use of natural gas and renewable energy sources for electricity generation, wider use of road vehicles using clean fuels, and enhanced energy efficiency in the building and appliance sector.

- **Scenario 2 (the 'Accelerated Scenario')** builds upon Scenario 1 and includes additional efforts on measures to increase energy efficiency and reduce energy demand, particularly in the building and transport sectors. Local sources of renewable energy such as waste-to-energy facilities are utilised by 2020. This scenario also assumes the continuation of a certain level of integration of the power system between Hong Kong and its neighbouring areas. Electricity imported from Mainland China in 2020 is the same as that in 2005. In 2030, the scenario assumes that 50% of the electricity used has no associated carbon emissions (7), and is either locally produced or imported from the Mainland.

- **Scenario 3 (the 'Aggressive Scenario')** builds upon Scenario 2 and accelerates the integration of the power system in Hong Kong with its neighbouring areas. It assumes that Hong

Kong would make full use of natural gas supply guaranteed by the Mainland under the relevant Memorandum of Understanding (MOU) on Energy Co-operation, for electricity generation in 2020. It also assumes that nuclear electricity imported from the Mainland in 2020 would be able to meet 50% of the local demand for electricity.

EMISSIONS ABATEMENT AND DOMESTIC CARBON INTENSITY

3.7 The reductions in GHG emissions over the planning period are summarised in *Exhibit 5* and illustrated in *Exhibit 6* for each of the alternate Scenarios and the Base Case.

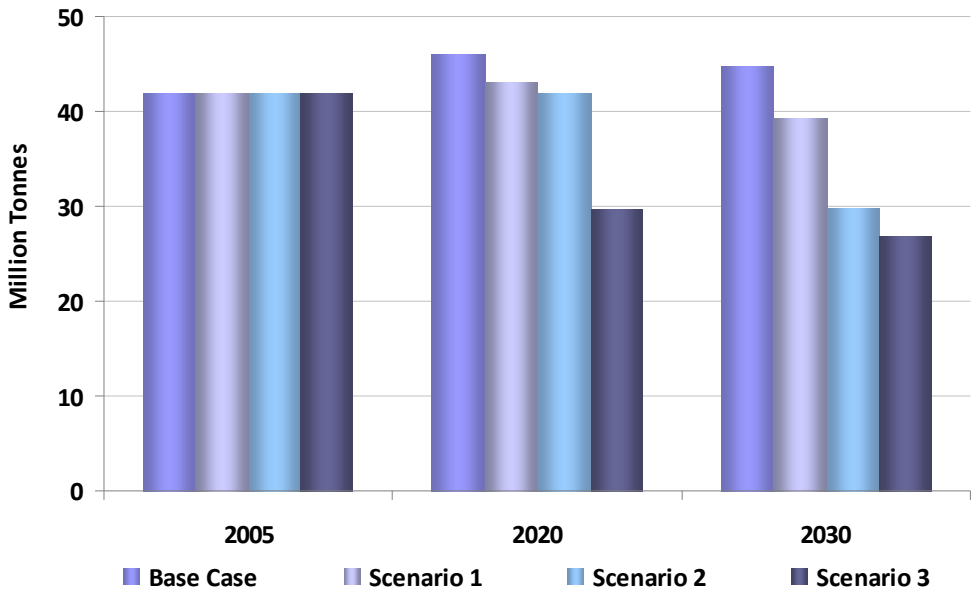
Exhibit 5 GHG Emissions in Hong Kong by Scenario (Million Tonnes CO_2-$_e$)

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

3.8 In the Base Case, total carbon emissions are projected to increase in absolute terms over time. Whilst predicted to deliver some GHG emissions reductions, Scenario 1 is not particularly effective and will only provide a 6% reduction over the planning period. It was concluded that although a strategy designed to address air quality issues has some co-benefits in reducing GHG emissions, further measures are needed.

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

Exhibit 6 *GHG Emissions in Hong Kong by Scenario (Million Tonnes CO_2-e)*



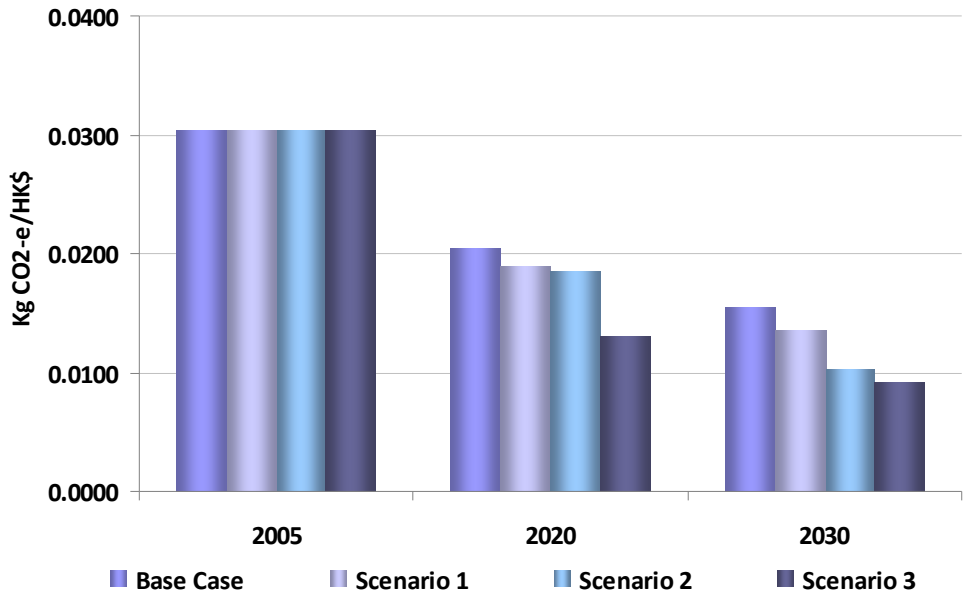
3.10 GDP is projected to grow at an annual average growth rate of 3.01% in the Base Case, and it is not predicted to be materially affected under the alternative scenarios. This is attributable to a variety of factors including energy efficiency measures, which will generate long-term savings in energy costs(8).

3.11 Carbon intensity, in terms of GHG emissions per GDP value, will be further decreased from the Base Case in 2005 by 37% (Scenario 1) to 57% (Scenario 3) by 2020, and will be reduced by 56% (Scenario 1) to 70% (Scenario 3) by 2030. The trends over the planning period are illustrated in *Exhibits 7* and *8*.

Exhibit 7 *Carbon Intensity (GHG Emissions per unit GDP in kg CO_2-e / HK$)*

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

Exhibit 8 Carbon Intensity (GHG Emissions per unit GDP in kg CO_2-e / HK$)



3.12 By 2020, carbon emissions per capita are predicted to fall from 6.2 tonnes to 5.6, 5.4, and 3.8 tonnes CO_2-e for Scenarios 1, 2 and 3, respectively. The corresponding projected figures for 2030 are 4.7, 3.6, and 3.2 tonnes CO_2-e per capita, respectively.

3.13 Mainland China announced a voluntary energy related carbon intensity target in November 2009, with the aim of achieving a 40% to 45% reduction against 2005 levels by 2020. Taking into account the uncertainties of the MARKAL-MACRO model and the projection in economic output, Scenario 3 can be expected to deliver a carbon intensity reduction of 54% to 60% by 2020[9].

3.14 To deliver a substantive reduction in carbon intensity, implementing Scenario 3 is preferred. As compared with other Scenarios, Scenario 3 could also deliver substantive reduction in GHG emissions in absolute terms between 2005 and 2020 and would deliver more GHG reduction than Scenario 2 by 2030. *Exhibit 9* summarises those key measures to support the achievement of carbon intensity reduction under Scenario 3 and possible progress of these measures by 2020 and 2030.

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

necessary and will require support and participation from all sectors of the economy, as well as a favourable economic environment.

Exhibit 9 Key Measures to Support Achievement of Carbon Intensity Reduction under Scenario 3 and the Possible Progress of these Measures by 2020 and 2030

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

Notes:

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

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

BACKGROUND

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

IMPACTS ON HONG KONG

4.2 A climate change vulnerability assessment for Hong Kong has been carried out using scenarios that are based upon the science in the IPCC AR4 and publications produced by the Hong Kong Observatory (HKO).

4.3 HKO began making systematic observations of climatic variables more than 120 years ago. There are observable changes in many weather patterns over this period, particularly in the last 60 years when many of the key climate impacts that have been observed overseas have also been recorded in Hong Kong over the same period. Further climate change will exert many, albeit very different, impacts, on various sectors and sub-sectors of the Hong Kong economy. *Exhibits 10* and *11* summarise some of the major observed climatic changes in Hong Kong and the key impacts of projected future climate change scenarios, respectively.

Exhibit 10 Observed Climate Changes in Hong Kong (HKO)

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

Exhibit 11 Projected Changes in Climatic Factors by 2100 (HKO)

Variable	Current Conditions	Impact	Lower Bound	Upper Bound	Level of Confidence
Decadal mean annual temperature (°C)	23.1	27.9	24.5	32.3	High
Hot nights in June – August	12.2	41.2	22.0	68.7	Medium to Low
Very hot days (maximum temperature ≥ 33 °C) in June – August	8.2	15.3	9.6	23.5	Medium to Low
Cold days (minimum temperature ≤ 12 °C) in December - February	16.3	<1	<1	<1	Medium to Low
Annual rainfall (mm)	2383	2572	1763	3235	Low
Heavy rain days	6.1	6.5 (*)	2.5 (*)	8.3 (*)	Low
Years with annual rainfall < 1282 mm	2 (#)	3.6 (+)	Not defined	Not defined	Low

Notes:

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

*: 2070-2099

#: 1885-2008

+: 2010-2099

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

KEY VULNERABILITIES IN HONG KONG

4.4 Based on the future climate scenario outlined above, the key sectoral vulnerabilities were identified through a vulnerability assessment which involved the following four main stages:

1. Exposure and Sensitivity Analysis: This stage identified the exposure (i.e. the background climate conditions and their changes) that could impact on systems/receptors in each of the sectors as well as the sensitivity of the systems/receptors to such exposures.

2. Identification of Potential Consequences: This stage identified the potential consequences of the exposure and sensitivities identified under stage 1.

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

4. Selecting 'Key' Vulnerabilities: Based upon the preceding stages ERM identified key vulnerable sectors in Hong Kong.

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

4.6 Eight key sectors were identified as having a "high" vulnerability to climate change impacts, namely:

- Biodiversity and Nature Conservation;
- Built Environment and Infrastructure;
- Business and Industry;
- Energy Supply;
- Financial Services;
- Food Resources;

- Human Health; and
- Water Resources.

Different levels of impacts brought about by climate change may impact the abovementioned sectors. *Exhibit 12* shows some projected impacts to the 'key' vulnerable sectors.

Exhibit 12 Examples of Projected Impacts for 'Key' Vulnerable Sectors

'Key' Vulnerable Sectors	Projected Impacts
Biodiversity and Nature Conservation	• Climate change can increase loss of biodiversity and increase colonisation of invasive species • Damage to woodlands, coral communities due to increase in frequency and/or severity of extreme weather • Change in species distribution patterns due to increase in surface temperatures
Built Environment and Infrastructure	• Very high uncertainties in the magnitude and rate of sea level rise • Developments located on low-lying areas / reclaimed land are highly sensitive to climate change • Heavy rain, thunderstorm and extreme weather leading to the damage of building foundations, increased risk of rain penetration of building fabric, and damage to utilities cabling and pipes • Potential asset damage because of flooding, landslides, wind damage, storm surge, and lightning strike, etc.
Business and Industry	• Sector is very broad and a wide range of impacts could be felt across the sector • Heavy reliance on international trade, financial markets, imports of key products and services exposing Hong Kong to climate change impacts beyond its boundaries and increasing its vulnerability • Vulnerable to climate change impacts on other areas such as food and water resources, transportation and infrastructure, etc. • Higher insurance costs

'Key' Vulnerable Sectors	Projected Impacts
Energy Supply	• Interruptions in power supply are likely to result in economic and social costs. Also, electricity generation, supply and primary energy supply are vulnerable to climatic disruptions • High uncertainties in impacts along the supply chain and effects of warmer climate • Increased demand from air conditioning and refrigeration due to increase in surface temperatures leading to supply interruptions and power spikes • Risk of flooding, lightning strike, landslides, causing damage to power lines and other assets
Financial Services	• Direct risk relating to vulnerability of telecommunications and computer systems to storms, power failure and spikes • Indirect exposure in terms of changes to the risk profile of individual business and their investments • Some segments of financial services likely to be more exposed, e.g. insurance • Sector may be vulnerable to impacts on other areas i.e. infrastructure
Food Resources	• Extreme weather reducing agricultural outputs at sources of food imported to Hong Kong and pushing up commodity prices • Rise in temperature and increased incidence of pests and diseases affecting poultry and livestock species and resulting in more expensive and lower availability of imports

'Key' Vulnerable Sectors	Projected Impacts
Human Health	• Climate change expected to disproportionately affect vulnerable groups • Chronic health conditions such as cardio-vascular and respiratory diseases may be aggravated by climatic variables • Thermal stress, exacerbation of asthma and heat stroke may be caused directly by climatic variables • More accidents and emergency situations may result from increased frequency and/or intensity of extreme weather, such as storms, floods, droughts and tropical cyclones, etc. • Changes in some infectious disease transmission patterns are a likely consequence of climate change.
Water Resources	• Uncertainties in future rainfall levels could affect water availability • Water availability may be constrained by physical or contractual reasons • Changing distribution pattern of rainfall and rising regional demand for freshwater may impact on the sustainability of water supply • Increased consumer demand for water due to increase in surface temperatures • Possible salinization of freshwater aquifers due to sea level rise

4.7 Vulnerability of the above sectors is due to a number of factors including:

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

- High sensitivity to climatic factors, i.e. they are dependant upon long to mid-term climate stability or are designed to operate/function within a narrow window of climatic variation.

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

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

- Reliance upon extended infrastructure with multiple potential failure points, i.e. they have extensive supporting infrastructure in which there may be many potential areas that could fail due to the impact of climate change.

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

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

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

EXTANT ADAPTIVE CAPACITY IN HONG KONG

4.9 Hong Kong has already developed a significant capacity to deal with some of the consequences of climate change, including the following:-

- The Security Bureau is responsible for the Government's overall Emergency Response Plan that deals with various kinds of natural disasters or emergency conditions.

- Various Government departments or services providers have developed monitoring or emergency response mechanism to handle landslides, flooding or the dangerous buildings (including advertising signs) due to the impacts of bad weather, banking services, telecommunication services, public transport services, energy supply, major food supply (such as rice and wheat flour) etc.

- Various works departments have developed guidelines in 1990, in which relevant Government civil works projects should consider that the rate of mean sea level rise may increase at 10 mm per year so as to address the potential impacts from climate change.

- The Government provides emergency support services to the general public and offers assistance to those that are suffered from the emergency incidents and bad weather.

- In response to the climate change and extreme weather events, the Government has developed different warning systems, such as Tropical Cyclone Warning System, Rainstorm Warning System and Very Hot Weather Warning System, etc.

- Through the monitoring programme, the relevant Government departments closely monitor the conditions of ecology or species, pests such as *Aedes albopictus*, water resources, etc.

It is likely that some such policies may need to be enhanced, or that the climatic thresholds which trigger other policies may need to be made more conservative. Furthermore, the resources allocated to the implementation of policies and measures to protect and respond to climatic events may need to be increased to better respond to climate change.

ADAPTATION OPTIONS

4.10 A review of existing adaptation policies and measures adopted in Hong Kong as well as other world cities, including London, Singapore, Tokyo and New York City was performed to identify the following options for adapting to climate change:

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

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

- The application of cross-departmental bodies to ensure that institutional arrangements and Government departments are coordinating their climate change response and adaptation efforts. Such institutional arrangements need to be periodically reviewed and aligned as necessary to ensure that the Government is making decisions that are informed by the latest climate change science.

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

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

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

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

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

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

Exhibit 13 highlights sectoral-level adaptation options that the SAR Government and relevant stakeholders in Hong Kong could take.

Exhibit 13 ***Examples of Climate Change Adaptation Options for Key Vulnerable Sectors in Hong Kong***

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

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

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

4.12 In addition to the sectoral level adaptation options, some cross-sectoral adaptation measures are also proposed, including the

conduct of climate change research activities to fill any key data gaps in climate change science and mass communication of climate change topics to enhance public understanding of vulnerabilities and associated adaptation measures.

4.13 It should be noted that the options are based upon current understanding of climate change and will need to be periodically reviewed and updated as the science evolves. In particular, the IPCC is preparing its AR5 due for publication in 2015. More detailed analysis on the possible impacts of climate change on different sectors would then be available and hence new or updated adaptation strategies should be developed based on the updated findings.

4.14 Implementation of these proposed adaptation options are likely to lead to additional compliance costs on both the Government and the other concerned stakeholders. Hence, it was recommended that the implications, feasibility and costs and benefits of these measures should be evaluated before taking further actions.

5 SUPPORTING ACTIVITIES

5.1 A review of Hong Kong's current research activities and other programmes and plans in relation to climate change was undertaken and the following initiatives are recommended for consideration.

5.2 **Research –** Local effects of climate change are not well characterised, with significant data gaps in research on local oceanic changes, biodiversity and affects on human health. More Government and private funding should be directed towards climate change research to fill key data gaps.

5.3 **Systematic Observations -** The HKO currently conducts a number of weather and related observations; however, there is a need for enhanced long-term monitoring of biodiversity and the terrestrial and marine environment by other Government departments such as Environmental Protection Department (EPD) and Agriculture, Fisheries and Conservation Department (AFCD).

5.4 **Technology Transfer and Capacity Building -** To reduce GHG emissions, Hong Kong could focus on technology transfer for climate change related applications and capacity building. The Government could encourage more Clean Development Mechanism projects in Hong Kong, and co-ordinate promoting the transfer of climate change-related technologies, such as electric vehicles and building energy efficiency technologies. Government support may include facilitating information sharing, providing subsidies or establishing a body to oversee the certification of emissions reducing practices.

5.5 **Public Awareness –** There is a need to introduce more education and training programmes so as to enhance public awareness, encourage supporting behaviours and practices and to develop consensus for legislation and investment. Programmes such as industry seminar training would encourage development of climate-friendly business strategies. In addition, inclusion of climate change topics in schools curriculum would increase awareness levels amongst the younger generations on the consequences of climate change. Increased collaboration with NGOs could also increase local public awareness.

5.6 **International/Regional Cooperation -** Hong Kong should extend its current collaboration in international and regional organisations in combating climate change. Hong Kong could play a role on topics such as energy efficiency and energy

research, as well as investments in green technologies and carbon markets. Continued collaboration with local partners in the Pearl River Delta of Mainland China, leading world cities and regional partners (APEC economies) could also include specific actions to address climate related issues. Moreover, sharing of knowledge on oceanic changes and associated research into flood risk strategies should also be encouraged. For example, Hong Kong has joined the 'Connecting Delta Cities' initiative which is led by Rotterdam and includes other cities such as Shanghai, London, and New York, to share knowledge on delta management and technology.

5.7 **Business activities –**As the extent of climate change impacts on businesses operating in or managed from Hong Kong is not well characterised, relatively few businesses have made it a focus of business planning or risk management. More funded research from the Government and/or private sectors on potential impacts on businesses should be encouraged to address this information gap.

6 CONCLUSIONS

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

6.2 Hong Kong is moving along a path to a low carbon economy. To further mitigate Hong Kong's GHG emissions, the Study recommended a series of measures and scenarios for further analysis and under the most aggressive scenario, these measures could reduce Hong Kong's carbon intensity by 54 to 60% by 2020 and, by 2030, will reduce total carbon emissions by approximately 36%

6.3 The cornerstones of this strategy will require:

(a) implementing mitigation measures:

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

(b) revamping the fuel-mix for electricity generation

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

6.4 The cross-sectoral nature of this strategy and the speed with which it needs to be implemented requires support from all sectors of the community.

6.5 As climate change is a global phenomenon the actions recommended to be taken in Hong Kong, whilst substantially reducing GHG emissions, will not be sufficient to prevent climate change from occurring. In the coming decades Hong Kong can expect to experience a changing climate.

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

6.7 Our assessment of vulnerabilities in Hong Kong has identified eight key sectors as having "high" vulnerability to climate change impacts, namely:

- Biodiversity and Nature Conservation;
- Built Environment and Infrastructure;
- Business and Industry;
- Energy Supply;
- Financial Services;
- Food Resources;
- Human Health; and
- Water Resources.

6.8 To adapt to future climate change impacts, sectoral and cross-sectoral adaptation measures have been recommended for further consideration. Adaptation options should be periodically reviewed to ensure that they remain adequate and take into

consideration developments in appropriate technologies and practices.

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

(2) The use of energy hereby refers the entire Energy Sector (Sector 1) in 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

(3) Only quantifiable mitigation measures are listed.

(4) An OTTV is a measure of the energy consumption of a building envelope.

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

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

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

(8) The current conclusion that GDP and its growth will not be materially affected in the alternative scenarios against the Base Case is made based on the currently available information. The economic modelling is at a macro scale, and the detailed economic impact of individual measure should be subject to further assessment at a later stage. In particular, some of the measures would require substantial investments, the costs of which and the resultant impacts on specific areas of the economy have not been assessed in detail. The consultants suggest that more detailed independent assessment should be conducted in pursuing any of the proposed measures.

(9) The national carbon intensity target refers to the energy related CO_2 per GDP value, while the domestic carbon intensity for Hong Kong refers to total GHG emissions per GDP value. Hong Kong will control GHG emissions from all sources, including non-energy related carbon emissions such as methane from landfills, and thus the carbon intensity target includes all types of GHG emissions.