REVISED EXECUTIVE SUMMARY

Environmental Protection Department

Greenhouse Gas Emission Control Study: *Revised Executive Summary*

December 2000

Environmental Resources Management
21/F, Lincoln House
979 King's Road
Taikoo Place
Island East, Hong Kong
Telephone: 2271 3000
Facsimile: 2723 5660

REVISED EXECUTIVE SUMMARY

Environmental Protection Department

Greenhouse Gas Emission Control Study: *Revised Executive Summary*

December 2000

Reference C1867

For and on behalf of Environmental Resources Management	
Approved by:	Freeman Cheung
Signed:	
Position:	Deputy Managing Director
Date:	22 December 2000

CONTENTS

EXECUTIVE SUMMARY

Background

1. The UN Framework Convention on Climate Change (UNFCCC) of 1992 provides a framework for controlling the emissions of greenhouse gases (GHGs). In addition, the Kyoto Protocol of 1997 has established a set of quantified GHG emissions limitations and reduction commitments which have the objective of mitigating emissions of the relevant countries by at least 5% below 1990 levels to the commitment period during 2008 to 2012. Countries, or "parties" that have signed up to a cap are listed in Annex I of the Convention and therefore referred to as "Annex I parties."

2. Hong Kong is not a party to the UNFCCC in its own right, but as a highly developed economy, it is the Government's policy as responsible global citizens to contribute to the global effort to control GHG emissions to reduce the risk of climate change. Although there are no GHG emission reduction targets in Hong Kong at the time of writing, Government has already developed programmes that would reduce GHG emissions, via initiatives related to energy conservation and efficiency, waste reduction and management, and transport related measures, such as the introduction of LPG taxis.

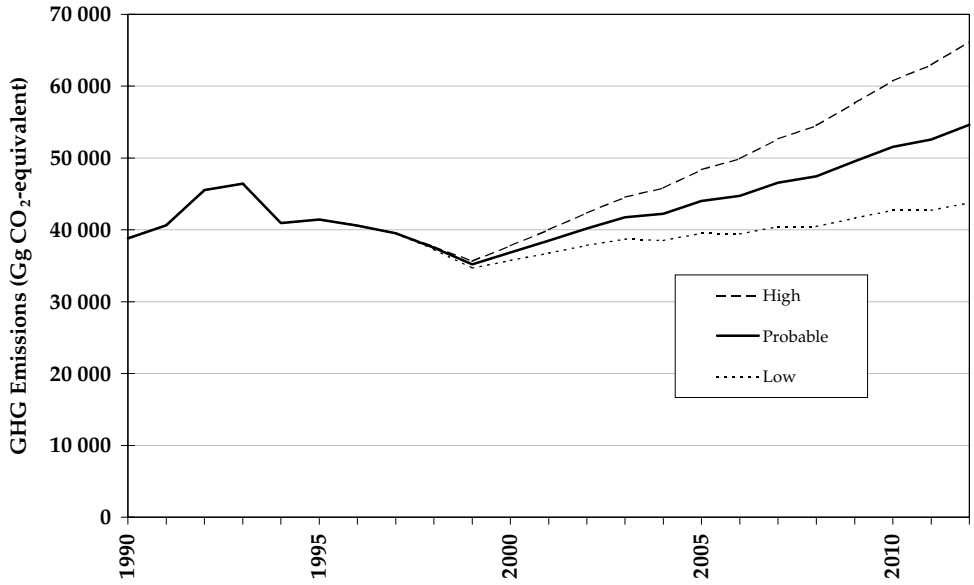
Trends

3. The general trend of GHG emissions in Hong Kong is shown in *Figure 1*. All emissions are expressed in carbon dioxide equivalent terms. From a peak in the early 1990s, GHG emissions declined throughout the mid- and late-1990s, largely as a result of the migration of manufacturing facilities across the border to mainland China and the displacement of a significant proportion of coal for electricity generation by both imported nuclear power and natural gas-fired combined-cycle plant.

4. On the assumption of a return to steady GDP growth from the early 2000s onwards – in line with Government's general expectations – GHG emissions have been projected to increase steadily, returning to and passing 1990 levels after 2001-02. On a low economic growth assumption, GHG emissions are not projected to reach 1990 levels until 2005-06 and under a high growth assumption they are projected to pass 1990 levels in 2001 and continue to grow.

5. GHG emissions are projected to reach 52 million tonnes in 2010 under the Probable Business as Usual Scenario which is about 35% above the 1990 level. However, the per capita GHG emissions is projected to drop from 6.7 tonnes in 1990 to 6.4 tonnes in 2010.

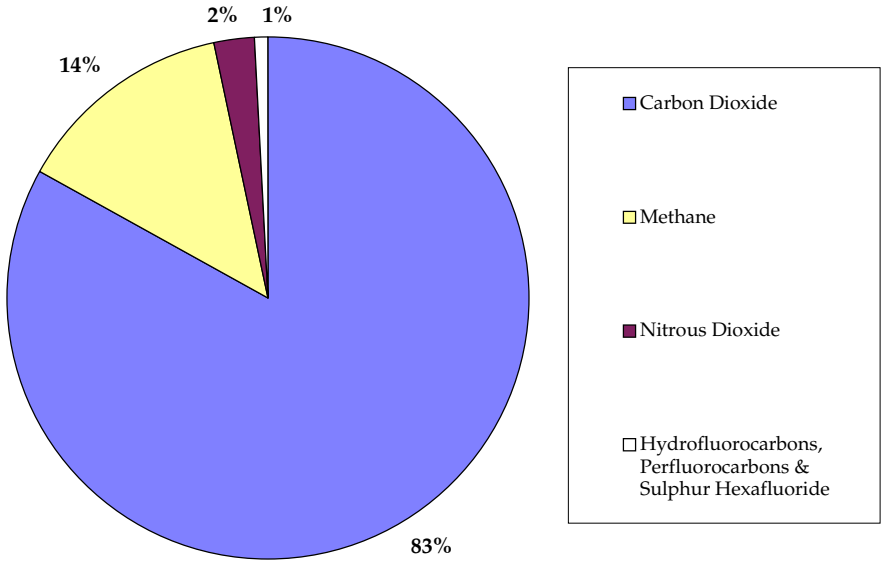
Figure 1 ***Historical and Projected Emissions (High, Probable and Low Cases of the Business-As-Usual Scenario), All GHGs, CO_2-e, 1990-2012***



Breakdown

6. In addition to the overall historical levels and general trends in GHG emissions, it is important to have a picture of the proportion of emissions by the various GHG species and by source categories or "sectors." *Figure 2* shows that CO_2 is clearly the dominant GHG in Hong Kong, accounting for over 80% of all GHG emissions in CO_2-equivalent terms. CH_4, predominantly from the waste sector, is the next most significant and N_2O and the remaining three gases form only a very small fraction of total emissions – even after taking into account their high GWP values to convert to CO_2-e terms.

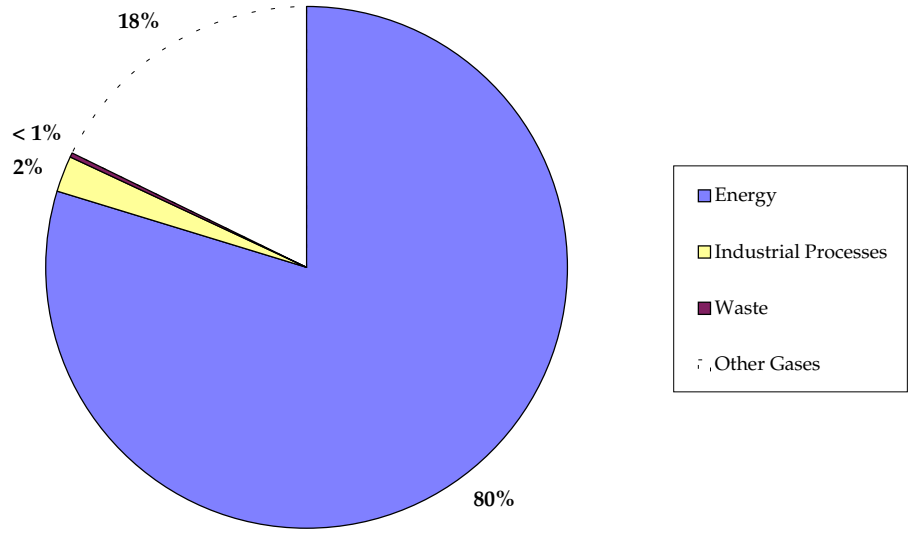
Figure 2 ***All Emissions by GHG Species as a Proportion of Total GHG Emissions, 1997***



Source: HKSAR Greenhouse Gas Emissions Inventory, prepared by ERM.

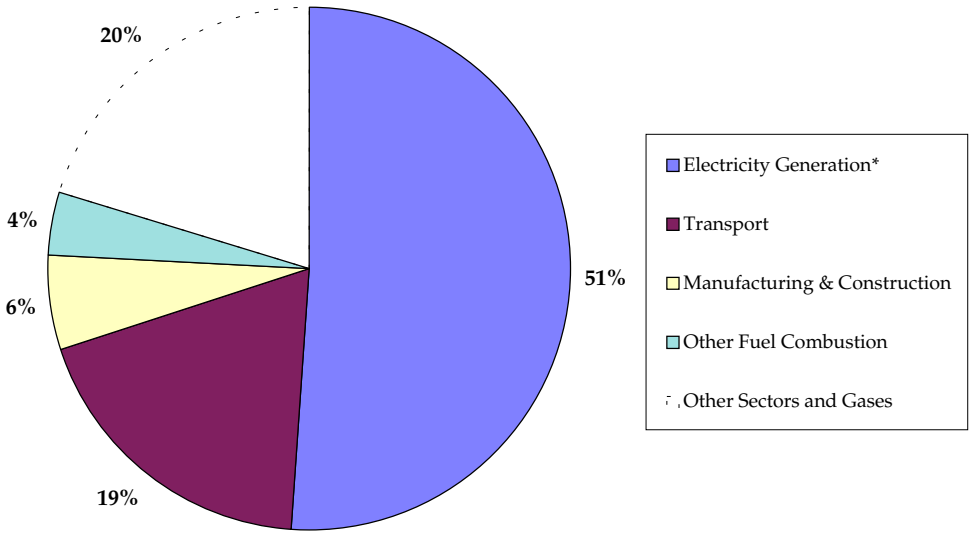
7. *Figure 3* further breaks down the CO_2 emissions by IPCC sectors,(1) showing that the energy sector is the main contributor to emissions of this gas.

Figure 3 ***CO_2 Emissions by Sector as a Proportion of Total GHG Emissions, 1997***



Source: HKSAR Greenhouse Gas Emissions Inventory, prepared by ERM.
Note: GHG emissions produced in the cracking process to convert naphtha to town gas are classified under "Industrial Process" in the IPCC classification scheme.

Figure 4 ***Energy Sector CO_2 Emissions as a Proportion of Total GHG Emissions, 1997***



Source: HKSAR Greenhouse Gas Emissions Inventory, prepared by ERM.
* Note: The 51% shown in the graph is technically "Energy Industries," of which about 99% is electricity generation

(1) Inter-Governmental Panel on Climate Change (IPCC) has developed guidelines to report GHG emission based on six sectors. These guidelines are used internationally to prepare GHG inventories.

8. *Figure 4* further breaks energy sector CO_2 emissions into the various sub-sectors. It is clear that the generation of electricity (ultimately the result of demand for energy services in the residential, commercial and industrial sectors, with a very small contribution from rail transport) is the major source of CO_2 emissions in Hong Kong, accounting for just over half of *all* of Hong Kong's GHG emissions in CO_2-equivalent terms in 1997. Transport is the second-most significant source of CO_2 emissions, accounting for nearly 20% of all GHG emissions in 1997.

Modelling

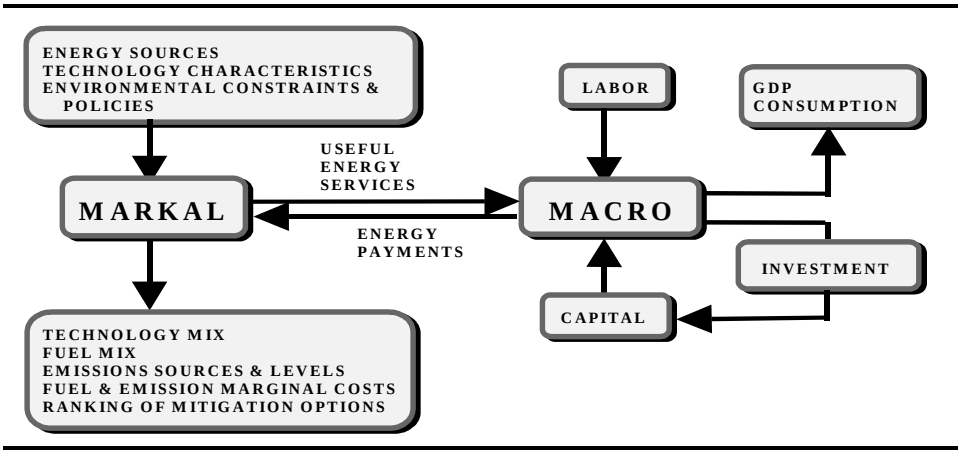
9. The quantitative analysis of potential GHG emission control measures was performed using the MARKAL-MACRO energy-economy software optimisation model.(1) MARKAL-MACRO is the only detailed energy-environment model linked to a macroeconomic growth model generally available world-wide. It is an internationally recognised model, used by 77 institutions in 37 countries throughout Asia, Europe, the Americas and Africa.(2) Hong Kong can now join the group of economies world-wide with up-to-date, working MARKAL-MACRO models of their energy-economic systems. MARKAL-MACRO is used in mainland China, and a MARKAL-MACRO model implementation has been developed for Guangdong Province by the Guangdong Energy Techno-Economic (ETE) Research Centre. There may be valuable opportunities for cooperative analysis and closely coordinated development of policy initiatives between Hong Kong and Guangdong on energy-environment-economic issues, including air pollution as well as GHG emissions.

10. A major strength of MARKAL-MACRO compared with most other models is that it marries a 'bottom-up' or 'engineering' energy system optimisation model (MARKAL) with a 'top-down' or 'economic' model (MACRO). It is a complete techno-economic model: a Computable General Equilibrium model with an integrated Reference Energy System. This provides the dual advantage of technical detail and the feedback effects that occur in the real economy, as indicated in the conceptual overview of the MARKAL-MACRO model structure in *Figure 5*. The integrated nature of MARKAL-MACRO's methodology — across energy, the environment and the economy — allows the model to assess the impacts and the economic costs and benefits of the measures and policy instruments under consideration for the control of GHG emissions from the Hong Kong Special Administrative Region (HKSAR) in a consistent and even-handed manner, thus providing insight into their relative merits.

(1) MARKet ALlocation / MACROeconomic. MARKAL was developed in a cooperative multinational project over a period of almost two decades by Energy Technology Systems Analysis Programme of the International Energy Agency, known as IEA-ETSAP. MARKAL-MACRO resulted from the collaboration of the Swedish and US participants in ETSAP with Professor Alan Manne of Stanford University.

(2) A list of these countries is available at http://www.ecn.nl/unit_bs/etsap/users/main.html, on the ETSAP web site, along with links to other information about MARKAL, MARKAL-MACRO, the ANSWER Windows user interface used in the Hong Kong project, and on-going model development. The list of countries continues to grow, particularly in the Asian region. For example, an Australian-led project is currently underway to implement MARKAL-MACRO in six ASEAN countries.

Figure 5 *Overview of MARKAL-MACRO Model Structure*



11. The time frame for analysis specified in the terms of reference for this study was up to the year 2012, which corresponds to end of the first five year commitment period under the Kyoto Protocol, from 2008-2012. Future use of MARKAL-MACRO for on-going policy development could be performed with alternative time frames, if required.

Measures and Policy Instruments

12. The measures analysis phase of the study identified the following groups of measures:

- ***end use efficiency***, targeted at air conditioning and lighting, the major end uses in the commercial and residential sectors, as well as residential refrigeration;
- ***wider use of natural gas***, modelling increased supply of natural gas imported as LNG, modelled as displacing coal in electricity generation(1), replacing existing town gas network to natural gas and displacing diesel in large vehicle transportation (in the form of CNG);
- ***transport measures***, including diesel-to-LPG and petrol-to-biofuel blend fuel switching, hybrid petrol-electric vehicles, fuel cell vehicles, electric vehicles and electric trolley buses;
- ***alternate and renewable energy sources***, including fuel cells for distributed electricity generation, decentralised (building-integrated) solar photovoltaic and wind power;
- ***waste measures***, including waste-to-energy technologies such as capture of landfill gas, anaerobic digestion and direct combustion; and
- ***miscellaneous small impact measures***, including plantations for sequestration and monitor and control of high GWP gases (refrigerants) and electrical insulation gases.

(1) Two variations were modelled: retrofitting gas burners to the boilers of existing coal-steam plant and retiring all coal plant by 2012 and replacing it with new CCGT plant. These are very much 'what-if' scenarios: further detailed engineering studies would be required to confirm their full technical and financial implications for the Hong Kong electricity sector.

13. The following groups of policy instruments were also identified:

- ***general support instruments***, such as public information and education; and
- ***cross-sectoral economic instruments***, including emission taxes and emission caps.

Measures Analysis Results

14. The analysis of the short-listed measures indicated that:

- the measure with the most significant potential for GHG emission reduction is the wider use of natural gas, with larger short-term reductions from the retrofit variation and larger long-term reductions from the CCGT variation;(1)
- efficiency measures on the demand-side could also reduce GHG emissions, although the potential for reduction is smaller than for the generation-side measures;
- measures that seek to reduce methane emissions arising from the waste sector would have reasonably significant GHG emission reduction potential;(2)
- the potential for wind power and solar photovoltaic energy is relatively small in the period to 2012, but worth investigating further;(3)
- the potential for distributed generation using fuel cells is also considerable, but the technology is currently in its early stages and not expected to be cost-competitive within the study time frame; and
- the potential for sequestration within the SAR is very small, but could be considered a side-benefit of schemes to improve tree cover in some areas of the SAR.

(1) This is in addition to the substantial portion of the potential for wider use of natural gas that is already accounted for in the projection, where it is assumed that all new plant will be natural gas CCGT plant, that a certain amount of such new plant will come on stream in the projection period and that operation of that plant will have priority over coal in the dispatch schedules. The measure analysed in this Study represents the potential impacts from the early retirement of all coal plant by 2012 and its replacement with natural gas CCGT plant.

(2) Measures in this sector were modelled assuming that they would be small additions to or side-benefits from initiatives already under consideration for the management of waste, including strategies for waste bulk reduction.

(3) The small amount of data available indicates that the wind characteristics at some coastal sites in Hong Kong may be adequate for wind power, however the overall resource and the potential sites to install turbines within the SAR are very limited. The potential would be greatly increased by considering sites outside the SAR, including offshore areas beyond the maritime boundary to the south and east. Solar photovoltaic energy has greater potential installation sites in Hong Kong than wind, particularly considering on-grid building-integrated installations.

Strategies

15. The measures short-listed were grouped to form five strategies, each building on the previous one:

- Strategy A - all the no- and low-cost measures
- Strategy B - all Strategy A measures and wider use of natural gas
- Strategy C - all Strategy B measures and solar photovoltaic
- Strategy D - all short-listed measures
- Strategy E - all measures with emission caps

16. The results of the MARKAL-MACRO model runs show that by 2012:

- Strategy A would lead to a CO_2 reduction of over 1 500 Gg relative to the Base Case;
- Strategy B would extend the impact to over 9 000 Gg relative to the Base Case under the retrofit variation and nearly 16 000 Gg under the early coal plant retirement/new CCGT variation, with cumulative impacts to 2012 for Strategy B of 43 000 and 53 000 Gg for these two variations respectively;
- Strategy C, requiring a small percentage of energy to be generated by distributed solar photovoltaic panels, would have a relatively small impact on overall GHG emissions, of up to about 750 Gg under the retrofit variation (5% of electricity generated by PV), and
- the inclusion of the remaining miscellaneous measures in Strategy D would have up to 4 000 Gg additional impact by 2012 (retrofit variation with PV);
- Strategy E was modelled as various emission caps first applied in 2009, the lowest being 24 Gg of CO_2-e per year, which would deliver further reductions in addition to Strategy D of between 1 000 Gg and 15 000 Gg per year.

17. The measures to reduce GHG emissions would bring co-benefits:

- reducing about 5 500 t of SO_2, 20 000 t of NO_x and 2 500 t of RSP in 2012 under Strategy A;
- reducing about 85 000 to 95 000 t of SO_2, 62 000 to 75 000 t of NO_x and 5 700 t of RSP in 2012 under Strategy B, C and D;
- relative to Base Case emissions of 116 000 t of SO_2, 187 000 t of NO_x and 15 000 t of RSP.(1)

18. Interestingly, while there is a general trend of SO_2 and NO_x co-benefits from the GHG emission reduction measures, emissions of these local pollutants do not increase and decrease strictly in line with the GHG emissions, but change independently as a result of changes in the mix of available plant capacity and optimum plant dispatch under the various cases. This suggests that care

(1) Note: the Base Case emission are provided for comparison only and do not represent a complete inventory of emissions of these substances.

would be required to implement successfully a coordinated and consistent approach to controlling GHG emissions and reducing local air pollution.

19. Changes to GDP provide an indication of the economic implications of the measures modelled in Markal-Macro. According to the model results,

- Strategy A would have a small positive impacts on GDP throughout the study period (a 0.02 percentage point increase in the annual average GDP growth rate to 2012). This strategy would have a negligible negative impact on the long run marginal costs of electricity (0.06 cents per kWh by 2012);
- Strategies B, C and D would tend to slow down GDP growth, with the CCGT variation of Strategy B impacting on the GDP most significantly, with annual average GDP growth to 2012 reduced from 2.8% in the Base Case to 2.6% in Strategy B. These strategies would have significant impact on the long run marginal costs of electricity (1.34 to 1.91 cents per kWh by 2012);
- Strategy E, with a GHG emissions cap would reduce annual average GDP growth to 2012 by 0.12 to 0.45 percentage points for caps between 36 Gg per annum and 24 Gg per annum respectively. This strategy would have very major impacts on the long run marginal costs of electricity (2.82 cents per kWh for a 36 Gg cap and 14.54 cents per kWh for a 24 Gg cap in 2012).

20. Long-run marginal costs indicate the cost of generating an additional unit of electricity or of saving a unit of electricity in the long-run, including the costs both of plant capacity and of fuel and operation. Although not the same as tariffs, the two are related: increasing long-run marginal costs will tend to drive up tariffs, decreasing long-run marginal costs will tend to drive down tariffs. In Hong Kong under the present Scheme of Control Agreements, tariffs are currently set based on costs plus return on investment calculation and so tend to reflect average rather than marginal costs. The relationship between long-run marginal costs and tariffs would be somewhat complex, requiring the results of the economic analysis to be used as inputs in a detailed financial analysis which is beyond the scope of this study.

Targets

21. Four distinct mechanisms by which Hong Kong might establish a mitigation objective have been identified:

- establish an emission reduction target;
- introduce specific policies and measures;
- specify levels of performance for the emission intensity or the energy intensity of the economy or specific sectors; and/or
- introduce a system of economic instruments.

22. These objectives are not mutually exclusive and very often they would complement each other. Emission targets can be expressed in several alternative forms:

- absolute;
- intensity; and
- benchmarked.

23. Most other developed economies have adopted absolute targets, as required in the Kyoto Protocol, which sets targets against the 1990 levels for the five year period 2008-2012. Hong Kong is not a signatory Party to the Protocol but may choose to follow this international practice of developed economies as part of its policy to contribute to the global effort to control GHG emissions to reduce the risk of climate change.

Approach and Institutional Framework

24. To implement the GHG emission control measures identified, a phased approach is suggested, with an initial phase (2000-2009) to adopt no- and low-cost measures in Strategy A. Should a decision be made to achieve a more significant reduction in GHG emissions, the measures in Strategy B, C or D could then be implemented (2003-2012). This would enable Hong Kong to reduce GHG emissions to around 30% below the business as usual scenario. The remaining measures in Strategy D are considered suitable for implementation in the longer term (beyond 2012). (1)

25. It is also suggested that a body within Government be set up to take up the following functions:

- monitoring and annual updating of the GHG emissions inventory; and
- review the effectiveness of policy instruments.

26. It is also suggested the existing inter-departmental Coordinating Committee on Global Climate Change (CCGCC) be enhanced to update the policy on climate change.

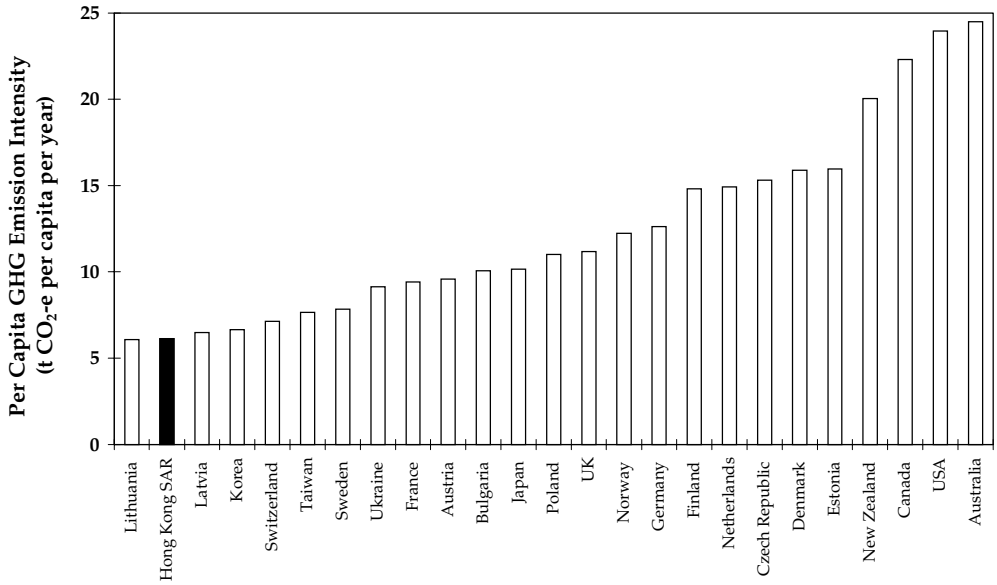
Policy Considerations

27. As a small, high income and developed region within a large, low income but rapidly developing country, Hong Kong is in a unique position with respect to global climate change. On the one hand, Hong Kong's GHG emissions are small relative to other countries on a per capita basis. *Figure 6* compares the GHG emissions of Hong Kong with other developed economies. Among all the developed economies selected, Hong Kong's per capita emission rate is amongst the lowest. Hong Kong does not have any major energy-consuming heavy industry. Furthermore, Hong Kong's emissions reduced significantly during the 1990s due to the relocation (principally to mainland China) of

(1) It should be noted that there is a high degree of uncertainty in the projections of the energy and environmental future of Hong Kong, which increases with the time horizon of the projections.

much of the manufacturing sector, the importation of nuclear power and the use of natural gas in generating some of its electricity. Hong Kong also has amongst the lowest emission intensity on an economic basis(1) (*Figure 7*), due to the reasons mentioned above and the dominance of low energy, high value-adding economic sectors such as financial services and import-export.

Figure 6 ***Per Capita Emissions of Major GHGs in Selected Economies in 1997*** (2)



Source: www.unfccc.org (1997 emissions of most countries except Australia, Hong Kong, Netherlands, Korea and Taiwan); ERM (2000) Greenhouse Gas Emission Control Study: Final Report (Emissions of Hong Kong, Australia, Netherlands, Korea and Taiwan); World Bank (1999) World Development Report 1998/99; World Bank (1998) World Development Indicators 1998; www.fao.org, all population figures, except Hong Kong; HKC&SD (1999) Hong Kong Annual Digest of Statistics, (Hong Kong population)

Conclusion

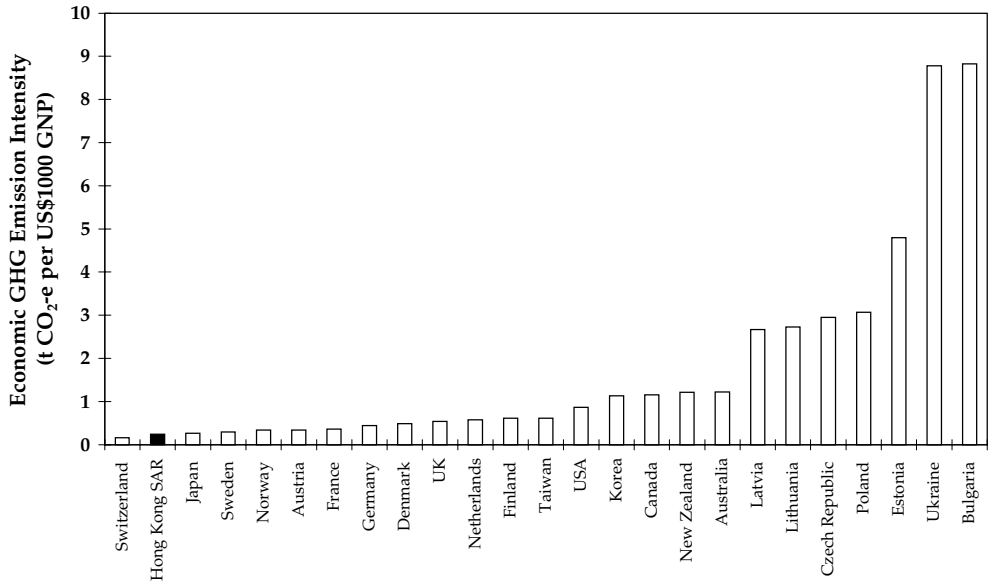
28. The most significant GHG emitted in Hong Kong is carbon dioxide and the most significant source of carbon dioxide emissions is electricity generation. Transport is the second largest source of CO_2 emissions. It is accurate to say that energy-related activities dominate GHG emissions in Hong Kong. The only other really significant GHG is methane from the waste sector.

29. Measures and policy instruments to control GHG emissions in Hong Kong would clearly need to focus on energy- and waste-related activities. These two sectors can converge because the waste stream has an appreciable energy content and there are several promising waste-to-energy options among the GHG emission control measures, which are consistent with the need to reduce waste bulk in Hong Kong.

(1) This compares GHG emissions with economic activities (measured in GNP).

(2) For Australia and the Netherlands, only 1996 emission data is available. For Taiwan, only 1995 carbon dioxide emission data is available. For Korea, only 1990 emission data is available.

Figure 7 ***Emission of Major GHGs Per US$1000 GNP in 1997***



Sources: emissions data as for *Figure 6*; Oxford University Press (1997 Per capita GNP figure, except Australia, Netherlands, Korea and Taiwan), The World Bank, (GNP per capita in 1996 for Australia and Netherlands), ADB (1996) Key Indicators of Developing Asian and Pacific Countries, (for per capita GNP data of Taiwan in 1995 and Korea in 1990).

30. Some no- and low-cost measures are available to Hong Kong, which would reduce GHG emissions below the business as usual scenario in the period to 2012. More dramatic reductions would require substantial measures in energy- related activities. The most significant is the wider use of natural gas. To gain maximum impact from this measure by 2012 would cause some adverse impact on economic growth (GDP).

31. In the context of increased local environmental awareness and the 'moral' obligation of contributing towards alleviating global environmental problems, the Government of the HKSAR may adopt a formal policy of making voluntary efforts to control GHG emissions. Furthermore, the people and Government of Hong Kong have in recent years become increasingly aware of the importance of the impact of human activities on the environment and the potential for adverse consequences from environmental impacts. The decline of air quality in Hong Kong is the most notable example of this. While this project is focused on GHG emissions, which are of global rather than local significance, combined or integrated strategies could be adopted to improve both local air quality and to reduce GHG emissions. This is not to say that all GHG emission control strategies would necessarily improve local air quality or vice versa, but the potential for synergy does exist.

32. Hong Kong now has a comprehensive set of techno-economic policy tools: EEUDB, MARKAL-MACRO, PATH as well as the policy decision-making support tool CASET. With well-coordinated inter-bureau and inter-departmental cooperation, these tools can be used in a powerful and consistent way at all levels of policy formulation and implementation:

- EEUDB feeding the latest energy use data up to MARKAL-MACRO;

- MARKAL-MACRO used to analyse both GHG emissions and other air pollution issues in a consistent, integrated way to find synergies and form comprehensive policy responses;
- MARKAL-MACRO and PATH used in conjunction to explore simultaneously GHG emission control and air pollution reduction opportunities and their wider economic implications, along with the consequent effect on air quality;
- CASET used as a high-level decision-support tool for ensuring projects and initiatives fit with the overall policy framework.

33. More detailed data development is underway (eg, the forthcoming study on renewable energy in Hong Kong), which can be used to refine and develop the Hong Kong Markal-Macro model.

Next Steps

34. Decide on Hong Kong's detailed policy response to be adopted in terms of GHG emission control strategy, policy instruments and measures.

35. Establish at the Bureau level a high-level plan for the coordination of energy-economy-environment analysis and formulation of detailed policy responses, including the approach to coordinated and interactive use of the available policy tools (EEUDB, MARKAL-MACRO, PATH, CASET)

36. Establish a clear plan to:

- update the Hong Kong GHG inventory annually; and
- keep the MARKAL-MACRO model 'live' and up-to-date (either in-house or by out-sourcing).

37. Establish a formal set of inter-departmental procedures or protocols for updating MARKAL-MACRO data (eg: porting the annual Hong Kong Energy Statistics and EEUDB data updates into MARKAL-MACRO).

38. Refine the MARKAL-MACRO data and analysis as the results of more detailed sector-specific and technology-specific studies become available (eg, renewable energy study, indicators and benchmarking study, energy efficiency/DSM programmes, Pearl River Delta Air Shed study) and as new policy initiatives require supporting analysis.

39. Search for leverage opportunities and synergies between GHG emission control and reductions of local and trans-boundary criteria air pollutants. Consider linking Markal-Macro with Hong Kong's air dispersion model, PATH.

40. Establish a forum or channel of communication with MARKAL-MACRO modellers at ETE and EPB in Guangdong. Consider combining the Hong Kong and Guangdong MARKAL-MACRO models into a joint regional or sub-regional model for coordinated planning and policy formulation.