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Energy Policy for Hong Kong

(Supply-Side Fuel and Energy Mix Strategy)

Prepared by: Dashun Policy Research Centre

2013

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(Supply-Side Fuel and Energy Mix Strategy)

(January 2013)

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Dashun Policy Research Centre Limited

Since its establishment in 2011, Dashun Policy Research Centre Limited (DPRC) has carried out a number of research projects concerning the development of Hong Kong. One of the completed projects is to study the energy policy of Hong Kong, which was carried out by DPRC in conjunction with the School of Energy and Environment of City University.

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EXECUTIVE SUMMARY

The objectives of this study are to (a) present an overview of energy policy and energy-related issues in selected economies and (b) provide a framework of supply-side fuel and energy mix strategy for the electricity, town-gas and transport sectors to meet Hong Kong Government's proposed new Air Quality Objectives (AQOs) for adoption in 2014 and 50-60% carbon intensity reduction by 2020 as compared with 2005.

Overview of Energy Policy

To understand how Hong Kong fares in its energy and energy-related environmental objectives/policies relative to other world economies, a brief review of these objectives/policies in seven economies, in addition to Hong Kong, was first carried out for comparison. These include Singapore, Korea, Taiwan, Japan, Australia, United Kingdom and Mainland China.

In Asia, Singapore is at the forefront of striving to balance the policy objectives of economic competiveness, energy security and environmental sustainability. The Fukushima Diachi nuclear disaster in March 2011 has forced Japan to re-evaluate its nuclear programme and to re-examine its energy mix, which paves the way for a greater adoption of renewable energy for electricity generation in Japan. The Australian Government passed legislation to introduce carbon tax starting from 1 July 2012. The United Kingdom Government also has plans in place to make a substantial cut in carbon dioxide emissions. As part of its 12th Five-Year Plan (2011-2015), China has established the goals of cutting its carbon intensity 17% by 2015, compared with 2010 levels, and cutting energy intensity 16% during the period.

It is observed that most economies consider economic growth, environmental quality and energy security as fundamental goals of a sound and sustainable energy policy although the relative importance of the different goals can vary depending on their unique geographical, economic, social and political circumstances and their respective endowment on natural resources. Nevertheless, the growing complexity and strategic importance of energy policy demands a "supra-departmental" approach by the Hong Kong Government to come up with detailed objectives, strategies and action plans to tackle the challenges of energy security, safety, reliability, affordability, air quality and climate change to sustain economic growth and achieve social harmony, and Hong Kong's commitments as a responsible global citizen.

Supply Side Fuel & Energy Mix Strategy Framework

Electricity Sector

Hong Kong's electricity is supplied by two vertically-integrated power companies: the Hongkong Electric Company Limited (HEC) and CLP Power Hong Kong Limited (CLP). As in 2011, CLP has a total installed capacity of 8,888MW and the maximum demand was 6,702MW (32% reserve margin) while HEC has a total installed capacity of 3,766MW and the maximum demand was 2,498MW (50% reserve margin).

In 2011, the fuel mix for CLP consists of 49.5% coal, 20.5% gas and 30% nuclear while that for HEC is 67% coal and 33% gas. While emission caps on SO_2, NOx and RSP were firstly imposed in the renewed licences of power plants in 2005, further tightening of emission caps was implemented for 2010, and will continue to be imposed in 2015 and 2017 by the

Technical Memorandum under the Air Pollution Control Ordinance. However, no statutory control of CO_2 emission has been put in place.

To meet the proposed new AQOs in 2014, the electricity sector is required to raise the use of natural gas in the fuel mix for local electricity generation to 50%, which translates to about 40% of overall fuel mix. Based on the emissions performance in 2011, HEC should be able to comply with the statutory 2015 emission caps without the need to increase the amount of gas in its fuel mix, but CLP has to double the amount of natural gas in 2011 to about 40% and maintain 30% nuclear power in its fuel mix, i.e. reduce coal to 30%, assuming a 1% annual increase in electricity consumption.

The Hong Kong SAR Government's Climate Action Agenda Consultation Document proposed to increase nuclear power to 50% in the fuel mix to meet the target of 50-60% reduction in carbon intensity (representing 19 – 33% in carbon quantity) by 2020, relative to 2005. However, after the Fukushima nuclear incident, the Government stated in November 2011 that the safety aspect of nuclear power generation should firstly be ascertained before consideration is given to the future fuel mix. Given the minimum load of Hong Kong system demand is less than half of the daily peak throughout the year, the adoption of 50% nuclear power in fuel mix would require measures such as an increase in the capacity of existing pump storage units to deal with the system trough constraint.

The Consultation Document's proposed increase of natural gas in fuel mix from 23% to 40% means that both CLP and HEC will need to enter new gas supply contracts to secure sources of additional and/or new natural gas at substantially higher prices, which will inevitably lead to a significant increase in electricity tariff. As the proposed two wind farms (300MW) and one IWMF (3,000t/d) together can only provide about 2% of Hong Kong's electricity generation, the feasibility of achieving the proposed 3-4% renewable energy (RE) in fuel mix is open to question.

Furthermore, the proposed substantial reduction of coal in fuel mix from 54% to less than 10% will greatly diminish the need for the electricity sector's in-service 6,608 MW coal fired units, a portion of which had been retrofitted with advanced emission reduction system at a substantial cost. With 90% of natural gas and nuclear power coming from one single source, i.e. the Mainland, this proposal could raise concern in terms of supply security for electricity generation.

Against this background, this study looked at three alternative scenarios for CO_2 reduction, using assumptions of increase of electricity consumption, emission factors, electricity production cost and the percentage of nuclear power available. These are summarized as follows.

Scenario 1 *(Government proposal)*:	40% gas, 50% nuclear, 7% coal, 3% RE, electricity sector CO_2 reduction 57.3%, production cost 113 ¢/kWh
Scenario 2:	40% gas, 33% nuclear, 25% coal, 2% RE, electricity sector CO_2 reduction 28.4%, production cost 110 ¢/kWh
Scenario 3:	50% gas, 25% nuclear, 23% coal, 2% RE, electricity sector CO_2 reduction 23.7%, production cost 119 ¢/kWh
Scenario 4:	45% gas, 25% nuclear, 28% coal, 2% RE, electricity sector CO_2 reduction 19.6%, production cost 113 ¢/kWh

Each of the above four scenarios, which requires additional gas supply and imported nuclear energy aimng to meet the Government's proposed 2014 AQOs and 2020 carbon emission redution target, has its own pros and cons in terms of level of emission reduction, increase in electricity production costs, security of fuel supply and reliability of power supply. It is imperative that the Government should firm up with the Mainland authorities the provisions of integrated cross-boundary infrastructure for supply of additional gas and imported nuclear energy to Hong Kong beyond 2020. This has to be implemented as early as possilbe due to the need for comprehensive planning and considerable lead time for the design and construction of the required infrastructure and facilities.

As regard to which of the four scenarios, or any other scenario of fuel mix for electricity generation should be chosen, public engagement is essential as a community consensus is required to achieve a balance between green and clean electricity and the cost of electricity to be paid by consumers.

Of course, governments and utilities worldwide are also focusing on energy efficiency and the development of renewable energy and green energy alternatives. The Government should also revisit the cost-benefit of full interconnection of the two power grids for full power transfer so as to reduce the overall reserve margin, and electricity market reform and development of smart grid and smart metering system before the expiry of the current Scheme of Control Agreements.

Town Gas Sector

The Hong Kong and China Gas Company Limited (Towngas) is one of the suppliers of gas to domestic, commercial and industrial customers in Hong Kong. It is the sole provider of town gas in Hong Kong sharing the market with LPG companies. It supplies town gas to 75% of Hong Kong households and some commercial and industrial customers. Town gas is produced at two production plants with a total production rate of 12 million m^3 per day. Although naphtha with low sulphur content was used as feed stock for manufacturing town gas in the earlier days, natural gas accounted for about 57% of production fuel in 2010 while landfill gas accounted for about 2.3% and naphtha made up the balance. In the same year, the energy consumed for gas cooking and heating was only 9.3% of Hong Kong's total energy consumption, and the emissions of SO_2, NOx, RSP and CO_2 were less than 1% of Hong Kong's emissions. It is not surprising that no improvement measures are required in the town gas sector to achieve the proposed new AQOs in 2014 as well as the carbon emission reduction target in 2020.

It is noted that while total replacement of naphtha with natural gas is technically feasible, a detailed study of the economic (network and appliance modification/replacement works and costs, fuel price, etc) and social (disruption and disturbance) costs versus environmental benefits of feedstock conversion to 100% natural gas should be carried out.

Transport Sector

The transport sector, including road vehicles and local ferries, accounts for 18% of the GHG emissions in Hong Kong and is the main source of most roadside air pollutant emissions, such as SO_2, NOx and RSP, with the highest coming from goods vehicles that uses diesel. Thus, early retirement of aged diesel vehicles and early replacement of Euro III commercial diesel goods vehicles with models meeting latest Euro standards are efficient air quality improvement measures in Hong Kong. Moreover, wider use of hybrid and electric vehicles (EV) to replace conventional internal combustion engine type vehicles can reduce air pollutant emissions significantly, especially roadside emission.

This study also quantitatively evaluates other emission reduction measures for green transport, in terms of emission reduction potential, costs and benefits. Based on the findings, one can make a priority list of green transport recommendations for improvement of air quality. The overall emission reduction for the transport sector can be accomplished by comprehensive strategies including cleaner vehicles and transport demand management. With reference to local and overseas green transport practices and policies, specific green transport measures have been identified and more details are provided in this report.

Way Forward

The adoption of new AQOs in 2014 and the setting of 2015 and 2020 emission reduction targets should help Hong Kong improve its air quality. As air quality policies should be premised on protection of public health, it is opined that the Hong Kong Government should commit to adopting WHO's Air Quality Guidelines as early as practicable and come up with concrete and workable measures.

A framework for addressing climate risks is crucial to sustainable development. The Mainland Government has set a voluntary target to reduce China's carbon intensity by 40% to 50% in 2020, using 2005 as base year. It is opined that Hong Kong, being one of the most developed economies in China and a responsible international city, should consider setting a target, more aggressive than the currently proposed 50% to 60% carbon intensity reduction, in support of the national policy and worldwide effort in tackling climate change.

Hong Kong is an open society with diverse vested interests. Setting acceptable levels of air quality and carbon emission reduction targets would lead to changes in supply-side fuel and energy mix, and most likely an increase in electricity tariff, transport fare and costs of living, all of which would inevitably invite extensive and intensive debate. This is a complex issue and raises many questions. For the well-being of future generations, the Hong Kong Government should actively engage the public and stakeholders in the early stage of policy formulation process, and set out clear objectives and road map for Hong Kong to make the transition to be a truly clean, low carbon, preferred city.

1. INTRODUCTION

1.1 Background

Given that all life on earth depends in some way upon energy, it is beyond dispute that energy is a commodity of national importance. There are seven billion people on earth who use energy each day to make their lives richer, more productive, safer and healthier. Energy is vital for the effective operations of our society and a driving force for quality human development and economic prosperity. Even with advances in efficiency, rising populations and expanding economies will produce a net increase in global energy demand. By 2040, there will be nearly 9 billion people on the planet, up from about 7 billion today, and global demand for all forms of energy is projected to rise about 30% from 2010 to 2040[(1)].

Energy is part of our lives more than ever before, but the production, transmission and consumption of energy have an adverse impact on the environment. There are sufficient scientific evidence that the huge amount of CO_2 released from explosive consumption of fossil fuels to produce energy since the Industrial Revolution is responsible for climate change which not only damages our infrastructures, natural environment and eco-system, but threatens the survival of humans. The combustion process of fossil fuels also emits harmful pollutants, notably SO_2, NOx, RSP, VOC, CO, etc, seriously deteriorating local air quality. Never before have such challenges become so important worldwide, and they are in fact on the top agenda of every country and region. The critical question is how enough energy can be produced to sustain economic growth, but at the same time, effects on the environment in the production and consumption of energy can be minimized.

Hong Kong is a metropolitan city and service-oriented economy with a GDP (nominal) of US$243,302 million[(2)] and US$34,259[(3)] per capita (ranking 25th) in 2011. With the scarcity of flat land within a territory of 1,104 m^2 (75% country side) accommodating a high and ever increasing population (7,108,100 in June 2011)[(4)], secured energy resource is essential to create a quality habitable environment inside the high-rise commercial and residential buildings where most economic and social activities are conducted But, Hong Kong has no indigenous energy resources and has to import all primary fuels to meet its energy requirements.

Hong Kong prides itself as Asia's World City and an international financial centre, and has been ranked by the Heritage Foundation as the world's freest economy for 18 consecutive years [(5)]. This is attributed to having good governance built on core values such as the rule of law, freedom, equality and openness underpinned by continued economic development. It is of paramount importance that Hong Kong should have a comprehensive, coherent and effective energy policy put in place to support its continued economic growth.

The growing complexity and strategic importance of energy policy demands a "supra-departmental" approach to come up with detailed objectives, strategies and action plans to meet the needs of human activities, the aspirations of the community and Hong Kong's commitments as a responsible global citizen. The responsible bureaux should study a wide range of energy issues, including energy conservation and efficiency, promotion of competitive energy market, diversity of energy supplies (including renewable energies), investment in energy research and development, and stepping up international cooperation. The outcomes of a comprehensive energy policy are to enhance energy security, promote enduring economic growth and tackle environmental challenges, in particular air pollution and anthropogenic climate change.

1.2 Objectives of the Study

Against this background, the objectives of the Study are to:

- present an overview of energy policies and energy-related issues, such as carbon emissions and air pollution, and
- provide a framework of supply-side energy mix strategy as part of Hong Kong Energy Policy to meet the Hong Kong Government's (i) proposed new AQOs for implementation in 2014 and (ii) proposed 50-60% carbon intensity reduction in 2020 using 2005 as base year.

1.3 Structure of Report

Following the Section 1 - Introduction, this Report is presented as follows:

- *Section 2 - Overview of Energy Policy of Selected Economies*: The economies selected in this Section include Hong Kong, Singapore, Korea, Taiwan, Japan, Australia, the United Kingdom and Mainland China. Information on energy policy, climate change policy/initiatives, energy and/or carbon emission reduction targets, air quality standards, green transport plan, legislations, bills and consultation papers, etc. being adopted or proposed by the selected economies if available are presented.

- *Section 3 – Operations of Sectors Responsible for Major Local Sources of Emissions*: Given that power stations, vehicles and vessels are the major sources of local air pollution and carbon emissions in Hong Kong, this Section outlines the regulatory framework, infrastructure, operations, emissions control, inventory and performance, etc. of the power sector and transport sector. The scope of transport sector is confined to local land transport and vessels operating within Hong Kong waters. Aviation and shipping (ferries, tug boats, ocean-going vessels, etc.) are not covered in the transport sector because of the complexity in the involvement of international treaties/regulations on emissions control and also lack of data/information in the public domain. For completeness, production of town gas for cooking and heating as source of emissions is included.

- *Section 4 – Framework of Supply-side Energy Mix Strategy for Control of Emissions*: This Section recaps the initiatives and measures outlined by the Hong Kong Government for adoption in the proposed New Air Quality Objectives for implementation in 2014 and the proposed carbon intensity reduction of 50% to 60% in 2020 using 2005 as base year. Impacts of the aforesaid Government's proposals on the operations of electricity sector, gas cooking and heating sector, and transport sector together with suggested framework of strategy to achieve the Government's objectives and targets are presented. The suggested framework of strategy is intended to maintain a balance between the policy objectives of economic competitiveness, energy security, reliability and safety, and environmental sustainability.

2. OVERVIEW OF ENERGY POLICIES OF SELECTED ECONOMIES

Most countries consider economic growth, environmental quality and energy security as fundamental goals of a sound energy policy. However, countries differ from their perception of the relative importance of the different goals. In the case of energy security, it is defined different by different countries, depending on their unique geographical, economic, social and political circumstances and their respective endowment on natural resources.

This Section intends to give an insight into the energy and energy-related environmental policy of Hong Kong and a brief overview of the same put in place by three neighboring developed economies, namely Singapore, Korea and Taiwan, three western industrialized economies, namely Japan, Australia and the United Kingdom, and Mainland China.

2.1 Hong Kong SAR

2.1.1 Energy consumption

Hong Kong has no indigenous energy resources, and imports all primary fuels to meet its energy requirements. Hong Kong imported 10,324,200 tonnes of coal, 2,819,070 tonnes of natural gas, 389,000 kilolitres of LPG, 512,090 kilolitres of motor gasoline and 6,571,500 kilolitres in 2011[6].

Table 1 shows the statistics of energy end-use requirements in Hong Kong from 2005 to 2011. The final energy consumption in 2011 was 311,945 terajoule. The energy consumption per capita increased by 6.3 % to 43.885TJ whereas the energy intensity decreased by 18.7% to 165TJ/HK$1billion GDP over a period 6 years.

Year	**Energy[6][7] Consumption (Terajoule (TJ))**	**Population[4][7] (x1,000)**	**Energy Consumption MJ per Capita**	**GDP[3][8] (HK$million)**	**Energy Intensity (TJ per HK$1billionGDP)**
2005	281,179	6,813	41.27	1,382,590	203
2006	281,880	6,857	41.08	1,475,357	191
2007	286,910	6,926	41.42	1,615,574	178
2008	285,430	6,978	40.91	1,677,011	170
2009	283,540	7,004	40.48	1,622322	175
2010	297,488			1,743,858	171
2011	311,945	7,108	43.88	1,890,900	165

N.B. Figures of GDP from 2005 to 2009 are in "chained 2009 dollars" and "current price" for 2010 and 2011

Table 1 – Hong Kong Energy End-Use Requirements (2005-2010)[7]

Table 2 shows the energy consumption distribution in Year 2009. As expected, the commercial sector took a lion share of the total energy consumption due to the service-oriented nature of Hong Kong's economy.

Consumer Sector	Commercial	Transport	Residential	Industry	Total
Energy Consumption (TJ)	113,261	90,242	55,204	24,834	283,540
% of Total	40%	32%	19%	9%	100%

Table 2 – Energy Consumption Distribution (Consumer Sectors) in 2009 [8]

2.1.2 Regulating Authority and Advisory Body

2.1.2.1. Government Bureau and Departments

The following government bureaux and departments are responsible for the formulation and/or execution of policies and/or regulations relating to Hong Kong's environmental protection, energy supply/demand and sustainable development:

- *Environment Bureau (EnB)*: The Bureau, headed by the Secretary for the Environment, is responsible for all policy matters on environmental protection, energy supply, energy efficiency and conservation, electricity and gas supply industries, as well as sustainable development.
- *Energy and Sustainable Development Branch*: The Branch headed by the Deputy Secretary for the Environment is responsible to the Secretary for the Environment for all policy matters relating to energy and sustainable development.
- *Environmental Protection Department (EPD)*: The Department is mainly responsible for developing policies covering environmental protection, nature conservation, enforcing environmental legislation, monitoring environmental quality, and providing collection, transfer, treatment and disposal facilities for wastes.
- *Energy Efficiency Office*: The Office set up under the Electrical and Mechanical Services Department is to provide technical expertise and coordinate Government's efforts to promote energy efficiency and conservation. The Office issues codes of practice, such as Building Energy Codes, establishes guidelines, and is involved in working groups and related committees in the efficient use and conservation of electricity.

2.1.2.2. Government Advisory Body

The following bodies set up by the Government have advisory role on policy matters relating to Hong Kong's environmental protection, energy supply/demand and sustainable development:

- *Council for Sustainable Development*: The Council established by the Chief Executive is to advise the Government on the priority areas in promoting sustainable development and the preparation of a sustainable development strategy for Hong Kong that will integrate economic, social and environmental perspectives.
- *Advisory Council on the Environment*: The Council is to keep under review the

state of the environment in Hong Kong, and advises the Government, through the Secretary for the Environment, on appropriate measures which might be taken to combat pollution of all kinds, and to protect and sustain the environment.

- *Energy Advisory Committee*: The Committee is a non-statutory committee set up to advise the Government on energy policy, including policy matters concerning energy supply and demand, energy conservation and efficiency, and other related matters referred to it by the Government.
- *Environmental Campaign Committee*: The Committee is to promote public awareness of environmental issues and encourage the public to contribute actively towards a better environment.

2.1.3 Energy Policy Objectives, Air Quality and Action Agenda

It appears that Hong Kong does not have a well-structured, cohesive and comprehensive energy policy. What Hong Kong has in place is a set of energy policy objectives(9), i.e. (i) to ensure that the energy needs of the community are met safely, reliably, efficiently and at reasonable prices and (ii) to minimise the environmental impact of energy production and use and promote the efficient use and conservation of energy. More specifically, the aims (10) are

- To ensure safe, reliable and efficient energy supply at reasonable prices while minimising the environmental impact caused by the production and use of energy through the established monitoring arrangements for the operation of the two power companies and the town gas supply company;
- To enhance electrical and gas safety through the introduction and enforcement of safety standards; to promote competition and transparency in the local fuel market; and
- To raise public awareness of and achieve energy efficiency and conservation through education, promotion, and implementation of various programmes; and to promote the use of electric vehicles in Hong Kong.

Having said that, some of the major initiatives and measures adopted or being actively pursued by the Hong Kong Government to address the issues of energy security, climate change, environmental protection and ecology conservation in its pursuit of green economy and sustainable development are highlighted below.

2.1.3.1 Sydney Declaration

Hong Kong is among the 21 Asia Pacific Economic Cooperation economies to adopt the *2007 Sydney Declaration on Climate Change and Energy* (11), and has committed to working towards achieving an APEC-wide regional aspiration with the goal of a reduction in energy intensity of at least 25% by 2030, using 2005 as base year. This requires a wide range of initiatives on energy conservation and efficiency on all sectors covering electricity generation, built environment and transport including public engagement.

2.1.3.2 Energy Security

According to the *Memorandum of Understanding on Energy Cooperation*(12) signed on 28 August 2008, the Central People's Government (CPG) supports the China Guangdong Nuclear Power Holding Co Limited to renew its supply agreement with Hong Kong for a further term of 20 years. The quantity of electricity supply will be no less than the current level in principle. On the supply of natural gas, the CPG supports China National Offshore Oil Corporation's renewal of its supply agreement with Hong Kong for a further term of 20 years. Furthermore, it was agreed in principle that the feasibility of supplying natural gas to Hong Kong via the Second West-East Natural Gas Pipeline would be studied, and an LNG terminal will be jointly built in the Mainland for supply to Hong Kong. This is to ascertain that Hong Kong has adequate and secured supply of clean energy in its pursuit of green economy. It is believed that the supply of natural gas to fuel CLP Black Point Power Station via the 2^{nd} West-East Natural Gas Pipeline will commence in early 2013.

2.1.3.3 Climate Change Strategy

Hong Kong's greenhouse gas emission per capita in 2008 was about 6 tonnes, putting it slightly below the world average of 7 tonnes per person[(13)]. To demonstrate to the world that Hong Kong as a global citizen is committed to combat climate change, the Environment Bureau in September 2010 requested responses from the public to a Consultation Document on *Hong Kong's Climate Change Strategy and Action Agenda for the Coming Decade*[(14)]. The consultation document set out a series of possible supply-side options and demand-side measures aiming to reduce Hong Kong's carbon intensity by 50%-60% and carbon quantity by 19%-33% in 2020 compared with 2005 level. This is in line with the Mainland's commitment to a 40-45% carbon intensity reduction by 2020 compared to 2005 levels.

2.1.3.4 Air Quality Objectives

Given clean air is vital to health of the people and plays an important role in maintaining the competiveness of Hong Kong as an international business centre, the Environment Bureau issued the *Air Quality Objectives Review* in 2009 for public consultation. Subsequently, the Government proposed on 17 January 2012 to adopt as shown in Table 3 a new set of Air Quality Objectives (AQOs) [(15)] together with a package of air quality improvement measures.

The Government was of the view that the delivery of the proposed new AQOs, which are partially meeting the WHO's AQGs and the air quality improvement measures, would help combat air pollution, thereby improving quality of life, reducing medical cost and indirectly raising labour productivity. It appears that the proposed new AQOs are quite close to those being adopted by most European countries and the United States. Taking account of the lead time for completing the legislative process and necessary preparation work, it is expected the new AQOs will take effect in 2014.

Pollutants	Averaging Time	Existing AQOs (μg/m³)	Proposed AQOs (μg/m³)	WHO Recommendations			
				IT-1	IT-2	IT-3	AQGs
SO2	10-mins	---	500	---			500
	24 hours	350	125	125	50		20
PM_{10}	24 hours	180	100	150	100	75	50
	Annual	55	50	70	50	30	20
$PM_{2.5}$	24 hours	----	75	75	50	37.5	25
	Annual	----	35	35	25	15	10
NO_2	1 hour	300	200	----			200
	Annual	80	40	----			40
O_3	8 hours	240 (1hr)	160	160			100
CO	1 hour	300,000	30,000	----			30,000
	8 hours	10,000	10,000	----			10,000
Pb	Annual	1.5 (3 mons)	0.5	----			0.5

Table 3 - Hong Kong Existing & Proposed AQOs and WHO Air Quality Guidelines

2.1.3.5 Energy Efficiency

As buildings account for about 90 per cent of the total electricity consumption in Hong Kong, improving building energy efficiency can help promote energy efficiency as a whole and reduce the city's greenhouse gas emissions. The *Codes of Practice for Energy Efficiency of Building Services Installation for Building Energy Audit* under the Buildings Energy Efficiency Ordinance which was gazetted on 10 February 2012 (16) and put into full operation on 21 September 2012. The Government estimated that for new buildings the implementation of the Ordinance would result in energy savings of 2.8 billion kWh in the first decade of full operation of the Ordinance, equivalent to a reduction in CO_2 emissions of about 1.96 million tonnes.

The Mandatory Energy Efficiency Labeling Scheme (MEELS), an energy conservation initiative, through the Energy Efficiency (Labelling of Products) Ordinance is in operation. Under the MEELS, energy labels are required to be shown on the prescribed products for supply in Hong Kong to inform consumers of their energy efficiency performance. The MEELS currently covers 5 types of products, namely room air conditioners, refrigerating appliances, compact fluorescent lamps, washing machines and dehumidifiers (17).

2.1.3.6. Green Transport

Motor vehicles are the main source of Hong Kong's roadside air pollution and also contribute about 18% of local greenhouse gas emissions. Promoting green transport will not only improve air quality but also reduce carbon emissions, which will help mitigate global climate change. A Steering Committee headed by the Financial Secretary was set up in April 2009 to make recommendations on the strategy and specific measures to promote the use of electric vehicles (EVs) in Hong Kong as one of the key measures to promote green economy(18). With the maturity of EV technology and setting up of complementary infrastructure such as the charging network, it is expected that EVs will be introduced into the market in the coming few years. Furthermore, a $300 million Pilot Green Transport Fund (19) was launched on 30 March 2011, aiming to encourage the transport sector to test out green and innovative transport technologies for better air quality.

2.1.3.7. Regional Cooperation

On 1 September 2011, the governments of Guangdong Province, the HKSAR and the Macao SAR jointly launched a three-month public consultation on initial proposals for *Regional Cooperation Plan on Building a Quality Living Area*(20). The Plan was to facilitate the implementation of the "Outline of the Plan for the Reform and Development of the Pearl River Delta (2008-2020)". This was a pioneering initiative which would set the scene for the cooperation of the three sides in transforming the Greater Pearl River Delta region in a model city cluster of green and quality living.

Having considered the suggestions received during the 3-month public consultation period, the HKSAR Environment Bureau, the Guangdong Province Housing and Urban-Rural Development Department and the Macao Secretariat for Transport and Public Works jointly announced on 25 June 2012 the Regional Cooperation Plan on Building a Quality Living Area (the Plan)(21). Long-term cooperation directions are drawn up in the five major areas of environment and ecology, low-carbon development, culture and social living, spatial planning and green transportation systems. The Plan is the first regional plan jointly compiled by Hong Kong, Guangdong and Macao, aiming to transform the Greater Pearl River Delta region into a low-carbon, high-technology and low-pollution city cluster of quality living, with a view to enhancing its overall competitiveness and attractiveness. The Plan underscores the sustainable concept of striking a balance between economic and social development and the environment. Among the many recommendations are:

- Hong Kong and Guangdong to complete and publicise the air pollutant emission reduction plan for Hong Kong and the PRD region up to 2020 based on the Pearl River Delta Regional Air Quality Management Plan (2002-2010), and to explore opportunities in reducing emissions from vessels in Greater PRD waters.
- All three parties to promote low-carbon development and take forward regional co-operation in combating climate change.

2.3 The 2013 Policy Address

Section V – Environmental Protection and Conservation of the 2013 Policy Address (22) delivered by the Chief Executive on 16 January 2013 outlines the Government's policy on tackling key environmental issues such as air quality and waste management. Measures to improve Hong Kong's air quality include:

- Reconfirming the 2015 and 2020 emission reduction targets already set with the Guangdong Government (23) at the 12th meeting of the Hong Kong-Guangdong Joint Working Group on Sustainable Development and Environmental Protection held in November 2012.
- Broadly achieving the new Air Quality Objectives by 2020.
- Enacting legislation to further tighten the emission caps for power plants for the years beyond 2017.
- Setting aside HK$10 billion in subsidy to phase out the 80,000 plus heavy polluting pre-Euro and Euro 1 to III diesel commercial vehicles that could reduce the overall emissions of particulate and nitrogen oxides by 80% and 30% respectively.

- Promoting bus route rationalization to reduce the number of overlapping or under-utilized services, and retrofitting or replacing catalytic converters on franchised buses, taxis and mini buses to cut emissions.
- Considering bringing in new legislation to enforce the requirement for ocean-going vessels at berth to switch to low-sulphur diesel.
- Injecting HK$5billion into the Environment and Conservation Fund to provide long-term and sustained support for green actions initiated by the community.

2.2 Singapore

Singapore is a relative low-lying island state in the tropics with a total area of 704 km^2. About 23% of Singapore's land area consists of forest and nature reserves. As of 2011, the population of Singapore was 5.18 million. The 2011 Index of Economic Freedom ranks Singapore as the second freest economy in the world, behind Hong Kong. According to the Corruption Perceptions Index, Singapore is consistently ranked as one of the least corrupt countries in the world, along with New Zealand and the Scandinavian countries [(24).] Singapore is the world's 37th largest economy with GDP (nominal) of US$259,850 million[(2)] and GDP per capita (nominal) of US$49,271 [(3)] (ranking 12th) in 2011.

Despite having no significant energy resources of its own, Singapore has established itself as Asia's energy centre, the world's 3rd largest oil trading hubs, and one of the top 5 oil refinery centres in the world. In 2009, Singapore exported 84Mtoe of energy products, of which petroleum products accounted for 98.6%. According to the World Bank's publication [(25)], Singapore's energy consumption per capita in 2010 was 6,456 kg of oil equivalent.

2.2.1 Energy Policy

According to the *National Energy Policy Report* [(26)] published by the Ministry of Trade and Industry in 2007, Singapore recognizes that energy plays an indispensible role in its economy and will remain critical to its continued economic growth and development. The Report covers Singapore's national energy policy framework which strives to maintain a balance between the policy objectives of economic competiveness, energy security and environmental sustainability. The framework's focus is on the following six key strategies:

- Strategy 1: Promote competitive markets
- Strategy 2: Diversity energy supplies
- Strategy 3: Improve energy efficiency
- Strategy 4: Build energy industry and invest in energy R&D
- Strategy 5: Set up international cooperation
- Strategy 6: Develop of whole-of-government approach

Apart from the policy framework, the National Energy Policy Report also outlined the strategies adopted specifically for (i) power sector, (ii) transport sector and (iii) energy and environment, (iv) energy industry, (v) energy R&D and (vi) engaging international energy partners.

To improve Singapore's human capacity, a clean energy scholarship programme to fund some 130 Masters and PhD students over the next five years for study and research in local and top foreign universities was announced by the Prime Minister at the opening of Global Entrepolis held on 10 February 2008[(27)].

2.2.2 Climate Change Policy

Singapore takes the issue of climate change seriously. In early 2009, it announced the *Sustainable Singapore Blueprint* [28] which mapped out sustainable measures that Singapore would undertake until 2030. Prior to the Copenhagen Climate Change negotiations in 2009, Singapore committed to a 16% reduction in greenhouse gas emissions below business-as-usual levels in 2020, on the condition that there would be a legally binding global agreement in which all countries would implement their commitments in good faith.

The National Climate Change Secretariat was set up in July 2010 as a dedicated agency under the Prime Minister's Office to coordinate Singapore's domestic and international policies, plans and actions on climate change so as to secure a sustainable living environment for the nation's future generations. This was to be achieved by adopting a whole-of-government approach and working with the people and private sectors to (i) devise and implement cost-effective mitigation and adaptation solutions, (ii) to reap the opportunities arising from addressing climate change challenges, and (iii) to contribute towards global efforts to address climate change.

In June 2012, the National Climate Change Secretariat issued the *National Climate Change Strategy 2012*[29] document which outlines Singapore's plan to address climate change through a whole-of-nation approach. It presents the current thinking about climate change and its implications for Singapore. It also highlights the initiatives and strategies Singapore is pursuing to prepare for the challenges that climate change posed. The three key principles adopted in the document which guides Singapore's responses to the challenges of climate change are: (i) long-term and integrated planning, (ii) pragmatic and economically sound measures, and (iii) development of innovative solutions for Singapore and global markets. And the four approaches to address climate change are: (i) to reduce carbon emissions in all sectors, (ii) be ready to adapt to climate change effects, (iii) to harness green growth opportunities, and (iv) to forge partnerships.

2.2.3 Air Quality

The main sources of air pollution in Singapore are from the burning of fossils fuels for energy generation in industries, power stations and in the transportation sector. Other sources include open burning of waste materials and trans-boundary smoke and haze. The ambient air in Singapore is monitored through a telemetric network of air monitoring stations strategically located in different parts of Singapore. The National Environmental Agency (NEA)[30] of Singapore uses the United States Environmental Protection Agency (USEPA) standards to assess Singapore's ambient air quality (Table 4) to protect public health.

Pollutant		Averaging Time	Level	Form
CO		8-hour	9 ppm	Not to be exceeded more than once per year
		1-hour	35 ppm	
Pb		Rolling 3 months average	0.15 µg/m^3	Not to be exceeded
NO_2		1-hour	100 ppb	98th percentile, averaged over 3 years
		Annual	53 ppb	Annual Mean
O_3		8-hour	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution	$PM_{2.5}$	Annual	15 µg/m^3	annual mean, averaged over 3 years
		24-hour	35 µg/m^3	98th percentile, averaged over 3 years
	PM_{10}	24-hour	150 µg/m^3	Not to be exceeded more than once per year on average over 3 years
SO_2		1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		3-hour	0.5 ppm	Not to be exceeded more than once per year

Table 4 - Ambient Air Quality Standard for Key Pollutants in Singapore (October 2011)[30]

NEA also adopts a Pollutant Standards Index (PSI) developed by the USEPA to provide accurate, timely and easily understandable information about daily levels of air pollution. The monitoring stations measure air pollutants such as $SO_{2,}$ NOx, CO, ozone sulphur dioxide, and particulate matter called $PM_{10.}$ These pollutants are used in the determination of the index. The PSI value (Table 5) gives an indication of the air quality and their levels are categorized to indicate the associated general health effects.

24-Hour PSI	Air Quality Category	General Health Effects
Up to 50	Good	None for the general population
51 to 100	Moderate	Few or none for the general population.
101 to 200	Unhealthy	Mild aggravation of symptoms among susceptible persons i.e. those with underlying conditions such as chronic heart or lung ailments; transient symptoms of irritation e.g. eye irritation, sneezing or coughing in some of the healthy population.
201 to 300	Very unhealthy	Moderate aggravation of symptoms and decreased tolerance in persons with heart or lung disease; more widespread symptoms of transient irritation in the healthy population.
Above 30 0	Hazardous	Early onset of certain diseases in addition to significant aggravation of symptoms in susceptible persons; and decreased exercise tolerance in healthy persons; PSI levels above 400 may be life-threatening to ill and elderly persons. Healthy people may experience adverse symptoms that affect normal activity.

Table 5 - PSI Standard in Singapore[31]

In order to improve air quality in Singapore, the government has implemented the following measures to control air pollution:

- Minimising pollution at source by stipulating stringent air emission limits and fuel quality on industries and motor vehicles e.g. EURO IV emission standards for diesel vehicles;
- Stringent legislation and enforcement to control air pollution;
- Proper land use planning and judicious siting of pollutive industries away from population centres; and
- Promoting cleaner energy and energy efficiency e.g. green vehicles, use of compressed natural gas (CNG).

2.2.4 Green Transport

In 2008, the Land Transport Authority published the *Land Transport Mater Plan* [(32)] which points out that transport solutions can play a critical role in promoting environmental sustainability and a high quality living environment, and pledges to:

- Encourage energy efficiency and reduce carbon emissions by promoting the use of public transport and more energy efficient vehicles;
- Improve vehicle emission standards;
- Look into incentivizing bus and taxi operators to adopt cleaner technologies and fuels such as compressed natural gas; and
- Adopt environmentally sustainable practices in the planning.

2.3. South Korea

South Korea[(33)] lies in the north temperate zone with a predominantly mountainous terrain. It covers a total area of 99,392m^2 and has a population of almost 50 million. A developed country with a market economy, South Korea is a member of G20 and OECD, the world's 15th largest economy with GDP (nominal) of US$1,116,247 million[(2)] and GDP per capita (nominal) of US$22,424 [(3)] (ranking 34th) in 2011.

As of 2009, South Korea's consumption of primary energy was 243.3 million ton of oil equivalent, ranking it the 9th largest energy consumer in the world. Only 3.6% of total primary energy consumption is supplied by domestic energy production and the remaining 96.4% is imported from overseas countries. Oil accounts for 42.10% of the total energy consumption. Coal comes next with 28.2%, followed by LNG with 13.9%, nuclear 13.1%, and 2.7% energy from renewable sources [(34)]. According to the World Bank's publication [(25)], Korea's energy consumption per capita in 2011 was 5,175 kg of oil equivalent.

2.3.1 5-Year Plan for Green Growth

South Korea's energy policy objectives focus on energy security, economic growth and the environment. In July 2009, South Korea announced a *5-Year (2009 to 2013) Plan for Green Growth* [(35)] to serve as a medium-term plan for implementing the National Strategy. The 5-Year Plan for Green Growth represents a major attempt to fundamentally transform the country's growth strategy from "quantitative growth" to "low-carbon, qualitative growth". The green growth strategy contains policy goals and targets to tackle climate change, enhance energy security, create new engines of growth through investment in environmental sectors, and develop ecological infrastructure.
The 5-Year Plan for Green Growth outlines 3 strategies, 10 policy directions and 50 core

projects. It represents a guide for national policy directions for the green growth vision, specifying further action plans on investments, target goals for each year, including the role of various sectors and stakeholders, such as ministries, along with other government agencies in pursuing the green growth strategy. Under the plan, US$83.6 billion (2% of GDP) is to be spent in the areas of green technologies, resource and material efficiency, renewable energies, sustainable transport, green building and ecosystem restoration. The driving factors of green growth are new ideas, transformational innovations and state-of-art technology, aiming to sustain economic growth and at the same time ensure climate and environmental sustainability.

2.3.2 Climate Change Initiatives

South Korea's 2020 mid-term greenhouse gas mitigation target has three scenarios. Scenario 1 is for 21% reduction from business as usual (BAU) which represents 8% increase from 2005 level. Scenario 2 is for 27% reduction from BAU which means a return to 2005 level. Scenario 3 is for 30% reduction from BAU which represents 4% reduction from 2005 level. On 16 November 2009, the Presidential Committee on Green Growth adopted the most ambitious Scenario 3 by implementing aggressive measure with mitigation high cost.

Climate change initiatives laid out in the 5-Year Green Growth Plan include the adoption of a legal and regulatory framework, carbon emissions trading, the creation of a national GHG inventory report system, in addition to raising public awareness. Other measures include the adoption of new auto emission standards, a waste-to-energy programme, stricter heat insulation standards for buildings, and development of carbon capture and storage technologies.

2.3.3 Air Quality

The Ministry of Environment uses the Comprehensive Air-quality Index (CAI) to describe the ambient air quality based on health risk of air pollution. The index aims to help the public easily understand air quality level and protect the health of people from air pollution. The CAI has values of 0 through 500, which are divided into six categories as shown in the Table 6. Under the categorization, associated health effects are also defined to protect public health.

The South Korean Government implemented several policies to help reach strengthened air quality standards (Table 7), which were strengthened from 80 $\mu g/m^3$on annual basis and 150$\mu g/m^3$ on daily basis in 1993 to 50$\mu g/m^3$ and 100$\mu g/m^3$ in 2007, respectively. The 'Total Load Management System for Factories' addresses factory emissions, and it requires that major pollutants, such as PM_{10} and NOx, be reduced to half their current levels by 2014. New policies addressing vehicle emissions provide financial support for low-pollution diesel vehicles, emission-reducing equipment, low-pollution engines, low NOx burners, and the "early retirement" of vehicles generating higher pollution.

Additionally, public parks are being used as a management effort to address air quality. The Government is expanding green space with a goal of 10 million pyeong (3.3m^2 per person) by 2020, constructing Seoul Forest to create five separate parks and transforming the Nanjido landfill site into a park.

Category	Description	Health Effects
A	Good	A level that will not impact patients suffering from diseases related to air pollution
B	Moderate	A level which may have a meager impact on patients in case of chronic exposure
C	Unhealthy for sensitive groups	A level that may have harmful impacts on patients and members of sensitive groups
D	Unhealthy	A level that may have harmful impacts on patients and members of sensitive groups (children, aged or weak people), and also cause the general public unpleasant feelings
E	Very unhealthy	A level which may have a serious impact on patients and members of sensitive groups in case of acute exposure
F	Hazardous	A level which may need to take emergency measures for patients and members of sensitive groups and have harmful impacts on the general public

Table 6 - Categories of Comprehensive Air Quality Index in South Korea[36]

Pollutant	Averaging Time	Level
CO	8-hour	9ppm
	1-hour	25ppm
NO_2	Yearly	0.03ppm
	24-hour	0.03ppm
	1-hour	0.10ppm
O_3	8-hour	0.06ppm
	1-hour	0.1ppm
PM_{10}	Yearly	50µg/m^3
	24-hour	100µg/m^3
SO_2	Yearly	0.02ppm
	24-hour	0.05ppm
	1-hour	0.15ppm

Table 7 - Ambient Air Quality Standards in South Korea[37]

2.3.4 Green Transport

The 5-Year Green Growth Plan sets regulatory standards on fuel efficiency and GHG emissions from the transport sector that requires a redesign of cars to either drive 17km/litre or cut GHG emissions below 140g/km between 2012 and 2015. New fuel efficiency and emission rules to be applied to 30% of automobiles sold in 2012, rising to 100% by 2015.

To address emissions in the public transportation sector, compressed natural gas buses are being introduced throughout cities over time, with the number increasing from 74 in 2001 to 2,746 in 2002 and 23,000 in 2010. The Bus Rapid Transit System was also established to create bus lanes in the center of roads for more efficient traffic flows, and congestion fees are collected at specific tunnels. South Korea also adopts a renewable fuel standard, making it mandatory by 2013 for transport fuel suppliers to provide 3% bio-diesel, bio-ethanol and bio-gas in their transportation fuel for automobiles by 2012, and 7% in 2020.

An investment of US19.7 billion in green cities and further development of railway and other means of mass transport are expected to increase the role of public transportation to 55% of total transport use by 2013. Bicycle use is being promoted with the construction of 3,114km of additional bicycle lanes between 2009 and 2018. It is anticipated that this would increase the use of bicycle from 1.5% in 2009 to 5% in 2013.

2.3.5 Nuclear Energy Policy

According to World Nuclear Association[38], the South Korean Government in November 2011 reaffirmed its commitment to nuclear energy, and targeted completion of six new reactors by 2016. Nuclear energy remains a strategic priority for South Korea's energy resources. The Ministry for Knowledge Economy announced plans for 59% of domestic electricity to be from nuclear by 2030, and for South Korea to be the third largest rector exporter by 2030, supplying 20% of the market, under a plan known as Nu-Tech 2030.

2.4 Taiwan

Taiwan has an area of 35,985 km^2 and its climate is marine tropical. As in April 2012, the population of Taiwan was 23,245,018. Taiwan, one of the "Four Asian Dragons" alongside Hong Kong, South Korea and Singapore, is the world's 26th largest economy with GDP (nominal) of US$466,424 million[2] and GDP per capita (nominal) of US$21,900[3] (ranking 40th) in 2011. Taiwan relies on imports for more than 98 percent of its primary energy. The distribution of energy supply is given in Table 8.

Oil	Coal	Natural Gas	Nuclear	Hydro	Renewable	Total
49.09%	32.09%	10.16%	8.28%	0.28%	0.15%	100%

Table 8 – Distribution of Energy Supply in 2009 [39]

As of 2010, Taiwan's consumption of primary energy was 120.3 million kilolitres of oil equivalent, and the energy consumption per capita was 5,222 kilolitres. The distribution of consumption among the consumer sectors is shown in Table 9.

	Industry	**Transport**	**Services**	**Residential**	**Farming**	**Others**	**Total**
Consumption (kilolitres)	73,170	15,560	13,180	12,890	980	4,600	120,380
% of Total	60.78%	12.92%	10.95%	10.71%	0.82%	3.82%	100%

Table 9 – Distribution of Energy Consumption in 2009 [39]

2.4.1 Energy Policy [40]

Given its energy supply vulnerable to external disruption, Taiwan's top priority is to develop clean, sustainable, and independent energy and achieve the balance among energy security, environmental protection, and industrial competitiveness, and reduce CO_2 emissions through various strategies.

The Taiwanese Government has been active in promoting energy efficiency to set a target of energy efficiency of 33% by 2025. This target is higher than Japan's commitment to APEC with the target of 25%-26% efficiency. In July 2009, the Executive Yuan approved a proposal consisting of 16 measures to transform Taiwan into a “low carbon” country by 2020. The Ministry of Economic Affairs’ proposal set a long-term goal of cutting total annual greenhouse gas emissions to 2000 levels by the year 2025. Mandatory programs have been established for the purpose of energy conservation, including energy audit and energy efficiency standards for certain electrical and electronic products.

2.4.2 Emissions Control

According to Taiwan Economic News[(41)], the Minister of Environmental Protection Administration (EPA) in July 2012 stated that the Government will begin collecting air pollution fee in 2015. The charge is part of the Government’s plan to cut down Taiwan’s greenhouse gas emission by resorting to the effective Air Pollution Control Act. It is noted that the Greenhouse Gas Reduction Bill should be the legal basis of the greenhouse gas cut implementation, but the Bill has yet to clear the legislative floor. The EPA submitted a draft bill in 2006 to the Legislative Yuan in line with the Government’s pledge to cut down the island’s greenhouse gas emission in 2020 to the level it produced in 2005.

The EPA is implementing the reduction in three stages. In the first stage, beginning 1 July 2012, all Taiwan’s manufacturers are required to report to the EPA their emission volumes of carbon dioxide, methane clathrate, nitrous oxide, chlorofluorocarbon, sulphur hexafluoride and perfluorocarbon gases. In the second stage, set to begin in 2015, the EPA will begin to collect air pollution fee based on the emission standards which EPA will establish in the two years starting in 2012. In this stage, manufacturers can pay the fee or buy carbon right. In the third stage, which is still indefinite in terms of implementation date, the EPA will move to control total emission volume, a practice that may push the island’s manufacturers to buy carbon rights overseas.

2.4.3 Air Quality

Air pollution is one of the most serious problems in Taiwan, due to heavy traffic and a high concentration of industrial plants. The EPA reports ambient air quality through Pollutant Standards Index (PSI), which is an index based on measurements of the concentrations of five air pollutants: PM_{10}, SO_2, CO, NO_2 and ozone. Air quality standards have been developed for each of these. For each pollutant, a value of 100 is assigned to the maximum permitted concentration of that pollutant. After determining a value for each of the five pollutants, the highest of the five numbers is reported as the PSI for the day. The PSI categories and their general health effects have been clearly defined by EPA (Table 10).

PSI	Descriptor	General health effects
0 ～ 50	Good	None
51 ～ 100	Moderate	Few or none for the general population.
101 ～ 199	Unhealthy	Mild aggravation of symptoms among susceptible people, with irritation symptoms in the healthy population.
200 ～ 299	Very Unhealthy	Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease; widespread symptoms in the healthy population.
>=300	Hazardous	Early onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons. At PSI levels above 400, premature death of ill and elderly persons may result. Healthy people experience adverse symptoms that affect normal activity.

Table 10 - General Health Impacts with Different Categories of PSI Values in Taiwan[42]

The ambient air quality standards have been established for each of the criteria air pollutants by different average periods. Table 11 shows the current standard in Taiwan.

Pollutant		Averaging Time	Level
Carbon Monoxide (CO)		Hour average	35 ppm
		8hr average	9 ppm
Nitrogen Dioxide (NO_2)		Hour average	0.25 ppm
		Year average	0.05 ppm
Ozone (O_3)		Hour average	0.12 ppm
		8hr average	0.06 ppm
Particle Pollution	$PM_{2.5}$	24hr average	35 μg/m^3
		Year average	15 μg/m^3
	PM_{10}	24hr average	125 μg/m^3
		Year average	65 μg/m^3
Sulfur Dioxide (SO_2)		24hr average	0.25 ppm
		Day average	0.1 ppm
		Year average	0.03 ppm
TSP		24hr average	250 μg/m^3
		Year average	130 μg/m^3

Table 11 - Ambient Air Quality Standards for Key Pollutants in Taiwan[43]

To reach the same air quality standards as advanced countries and to improve overall air quality, the EPA has set the objectives of reducing the percentage of days with PSI>100 below 2% by 2011 and below 1.5% by 2016 as medium- and long-range targets. Based on current situations and forecasts of air quality concentrations, EPA of Taiwan also reinforced control measures or tightened standards for fugitive particulates and ozone precursors in addition to existing control measures and programs. The EPA also takes gradual steps to adopt a total quantity control system, enforce stricter standards, advocate the use of clean fuel oil, and promote green products as well as public transportation.

2.4.4 Nuclear Energy Policy

According to the World Nuclear News[44], Taiwan's new Nuclear Energy policy, unveiled at a news conference in November 2011, stated that the Chinshan, Kuosheng and Maanshan nuclear power plants will not operate beyond their planned 40-year lives and that Taiwan's fourth nuclear power plant at Lungmen will not begin operations until all safety requirements have been met. Furthermore, the island's oldest two units will face early closure provided both Lungmen units are in commercial operation before 2016.

The new policy has been prepared in keeping with the principles of no power rationing, maintenance of stable electricity prices and continued reduction of carbon dioxide emissions to meet international goals. It is also noted that the new policy is in line with Article 23 of the Basic Environment Act, which directs the government to make plans that will eventually see Taiwan become nuclear-free.

2.4.5 Administrative Framework

Recognizing energy plays a vital role in national economic development, the Taiwan Government established the Energy Commission under the Ministry of Economic Affairs in November 1979, and reorganized it as the Bureau of Energy in July 2004. The Bureau of Energy is in charge of formulation and implementation of energy policies such as the Energy Management Act, Electricity Act, Petroleum Administration Act, Regulations Governing Administration of Gas Utilities, Renewable Energy Development Act, and other energy-related regulations. In addition, the Bureau of Energy guides the operations of energy enterprises. It also carries out such tasks as the evaluation of energy supply and demand, the establishment of an energy database system, the promotion of energy conservation and renewable energy programs, the implementation of research and development of energy technology, and the promotion of international energy cooperation [(45)].

The Center for Energy Research at the National Central University has initiated a plan to educate energy professionals. It coordinates professors from related disciplines and builds a diversified teaching platform to recruit young students and researchers. Educating young scientists in the field of green technology and encouraging them to create innovative products is to provide Taiwan with an edge in the international market [(40)].

2.5 Japan

Japan [(46)] is an archipelago of 6,852 islands with a total area of 377,835km^2, housing the world's tenth-largest population with over 126.4 million people as of 2011. A major economic power and a member of G7 and OECD, Japan is the world's third-largest economy with GDP (nominal) of US$5,870,357 million[(2)] and GDP per capita (nominal) of US$45,870[(3)] (ranking17th) in 2011. According to the World Bank's publication [(25)], Japan's energy consumption per capita in 2011 was 3,584kg of oil equivalent.

Japan is dependent on imports of virtually all fossil fuels. Given its heavy dependence on imported energy, Japan has been striving to diversify its sources. As of 2008, 46.4% of energy in Japan is produced from petroleum, 21.4% from coal, 16.7% from natural gas, 9.7% from nuclear power, and 2.9% from hydro power. As nuclear power offers an indigenous option, it becomes a cornerstone of Japan's energy policy. In 2009, nuclear power produced 25.1% of Japan's electricity.

2.5.1 Strategic Energy Plan 2010

The 2nd revision of the *Strategy Energy Plan*(47) (formulated in 2003) was issued by the Ministry of Economy, Trade and Industry (METI) in June 2010 prior to the Fukushima Daiichi nuclear disaster that took place on 11 March 2011. The Strategic Energy Plan articulates the fundamental direction of energy policy in Japan based on the Basic Act of Energy Policy, and is required to be reviewed at least every 3 years, i.e. by 2013.

On top of the basic objectives of energy policy, viz. energy security, environmental protection and efficient supply, the 2nd revision of the Strategic Energy Plan included two new objectives: energy-based economic growth and reform of the energy industrial structure. In consistence with the new growth strategy, the revised Plan set out quantitative policy targets and specific policy measures. This will fundamentally change Japan's energy supply and demand system by 2030.

2.5.2 Emission Targets and Measures

According to the revised Strategic Energy Plan 2010, Japan has set the following ambitious targets towards 2030:

- Doubling the energy self-sufficient ratio (18% in 2010) and the self-developed fossil fuel supply ratio (38% in 2010)
- Raising the zero-emission power source ration to about 70% (34% in 2010)
- Halving CO_2 emissions from the residential sector
- Maintaining/enhancing energy efficiency in industrial sector at the highest world level
- Maintaining/obtaining top class shares of global markets for energy-related products and system

The above targets would translate to the following:

- Domestic energy-related CO_2 emission will be reduced by 30% or more in 2030 compared to the 1990 level
- A 30% emission reduction means about half of the reduction will be achieved from the level in 2010 to 2050 (80% compared to 1990) will have been realized in 2030

Measures to achieve the targets outlined in the Strategic Energy Plan cover but not limited to the following:

- Supply Side
  - Securing resources and enhancing supply stability (high level diplomacy, public-private partnership, etc)
  - Expanding the introduction of renewable energy (feed-in-tariff, R&D/finance support, tax reduction, etc)
  - Promoting nuclear power generation (prior to Fukushima Daiichi nuclear disaster)
  - Advanced utilization of fossil fuels (clean coal technology, IGCC plant, CCS technology, etc)
  - Enhancing electricity and gas supply system (advanced smart grid/smart meters, doubling wholesale market, etc)

- Demand Side

- Industrial Sector: Enhancing energy conservation and efficiency (technology innovation, fuel conversion, etc)
- Residential Sector: Compulsory energy-saving standards for houses, high efficiency lights, net-zero-energy houses by 2030, etc.
- Commercial Sector: Support of development of innovative energy efficient goods and products, new energy consumption standards for all buildings, net-zero-energy public buildings by 2020, etc.
- Transport Sector: 2020 new fuel efficiency standard, support of development of advanced battery chargers for electric vehicles, development of fuel cells/hydrogen supply infrastructure for fuel cell vehicles, raising nest-generation vehicles' share of new vehicle sales up to 70% by 2030, etc.

2.5.3 Air Quality

The current Air Pollution Control Law in Japan amended in 1996, was originally enacted in 1968, in order to protect the public health and preserve the living environment with respect to air pollution. In the past few years, Japan has increased its focus on developing and implementing pollution control technologies and innovations that are energy efficient. For a country that is steeped in tradition, the Government's new environmentally sound policies are markedly different than its previous approach to economic development, which was implemented without regard to the effect on the environment. The current air quality standard for the key pollutants is shown in Table 12.

<table>
<tr><th colspan="2">Pollutant</th><th>Averaging Time</th><th>Level</th></tr>
<tr><td colspan="2" rowspan="2">Carbon Monoxide (CO)</td><td>Hour average</td><td>20 ppm</td></tr>
<tr><td>Daily average</td><td>10 ppm</td></tr>
<tr><td colspan="2" rowspan="2">Nitrogen Dioxide (NO_2)</td><td>Hour average</td><td>0.25 ppm</td></tr>
<tr><td>Daily average</td><td>0.04-0.06 ppm</td></tr>
<tr><td rowspan="4">Particle Pollution</td><td rowspan="2">$PM_{2.5}$</td><td>Annual average</td><td>15 µg/m^3</td></tr>
<tr><td>24 hours</td><td>35µg/m^3</td></tr>
<tr><td rowspan="2">PM_{10}</td><td>Day average
24hr average</td><td>125 µg/m^3</td></tr>
<tr><td>Year average</td><td>65 µg/m^3</td></tr>
<tr><td colspan="2" rowspan="2">Sulfur Dioxide (SO_2)</td><td>Hourly average</td><td>0.1 ppm</td></tr>
<tr><td>Day average</td><td>0.04ppm</td></tr>
<tr><td colspan="2" rowspan="2">TSP</td><td>24hr</td><td>100 µg/m^3</td></tr>
<tr><td>Hourly value</td><td>200 µg/m^3</td></tr>
</table>

Table 12 - Air Quality Standards of Key Pollutants in Japan [(48)]

In December 2000, the Tokyo Metropolitan Government passed the Municipal Environment Protection Ordinance of Tokyo to promote innovative environmental measures ahead of efforts by the national government. For years, Tokyo has been positively addressing environmental concerns such as industrial pollution, vehicle-related pollution and global warming. The measures taken by Tokyo, one of the world's largest cities, to secure the health and safety of its citizens could become a useful model for other Asian countries.

- Automobile Exhaust Gas Regulations: As industrial pollutants such as soot and smoke from factories were dramatically reduced, increases in vehicle traffic and the number of diesel cars on the road prevented the improvements in air pollution from automobile exhaust fumes.

- Diesel Vehicle Regulation: The Tokyo government introduced the regulation in 1999, concerning the health effects of the PM contained in gas emissions from diesel vehicles. A landmark court decision in the Amagasaki pollution lawsuit in January 2000 found that the PM from diesel vehicles was correlated with health problems, especially cancers and respiratory disorders.
- Clean fuel: local governments in Japan have designated compressed natural gas (CNG) vehicles, liquefied petroleum gas (LPG) vehicles, electric vehicles and hybrid vehicles as low-emission vehicles and promoted the use of these cars.

Another negative impact on Japan's air quality is the poor air quality in the Asian nations surrounding Japan. Japan is concerned about environmental issues not only throughout Asia but also throughout the entire world. As such, Japan is an active member of the international community committed to resolve these common issues. For example, the city of Tokyo joined “Asian Network of Major Cities 21” established in 2001 to reduce air pollution in a regional and global scale.

2.5.4 Post-Fukushima Energy Policy Review

As in 2009, 29% of Japan’s electricity was produced by nuclear power, 61% by fossil fuel (coal, oil and LNG), 8% by hydro power and 1% by renewable energy (0.3% solar and 0.4% wind) [(49)]. However, following the Fukushima Daiichi nuclear disaster in March 2011, all of the country’s 54 nuclear power plants were taken offline on 5 May 2012 due to public opposition. This has shaken the core of Japanese energy policy.

The loss of energy from the nuclear reactors was made up by aggressive energy efficiency and conservation efforts, but also by sharply increased imports of LNG, crude oil, and fuel oil. LNG imports in 2011 increased by nearly 25% and oil use went up by nearly 85% [(47)]. As a result, it was reported that an additional US$35 billion was spent on fossil fuel imports in 2011 to avoid blackouts during the summer peak. Due to the important need to cope with demand of electricity in 2012 summer, Japan’s Prime Minister on 16 June 2012 gave the green light for the resumption of two nuclear reactors at Oi in western Japan operated by the Kansai Electric Power Company despite public opposition [(50)]. One of the nuclear reactors at Oi in western Japan was re-started on 1 July 2012. As of December 2012, Ōi Units 3 and 4 are Japan's only operating nuclear power plants.

On 22 August, 2011, Japan’s Parliament approved legislation for the feed-in tariffs to help diversify its energy mix by promoting investment in renewable energy sources following the Fukushima disaster. On April 25 2012, a government panel recommended preferential rates, a new price incentive program for wind power, solar power and thermal power generators, marking another step in scaling back at nuclear power and reducing carbon emission. Japan aims to add 2,500MW of solar, geothermal, wind, biomass, and hydropower capacity after the feed-in tariff scheme comes into force in July 2012. This would increase its renewable energy capacity for electricity generation to 13% in 2013[(51)].

The Strategic Energy Plan issued in 2010 by METI to reduce the energy related carbon emission by 30% in 2030 compared to the 1990 level requires significant expansion of nuclear power for electricity generation to 50% by 2030. However, the Fukushima nuclear disaster has forced Japan to revalue its nuclear program and to reexamine its energy mix. The

Japanese Government opened up public consultations on energy policy by presenting three scenarios on Japan's energy-mix out to 2030: 0% nuclear with 35% renewables; 15% nuclear with 30% renewables; and 20-25% nuclear with 30-25% renewables. The new Energy Plan was due by the end of August 2012 but there has been strong public opposition to options other than the 0% scenario. The Government wants to take the middle 15% nuclear option but with enough public support to avoid major political damage. This would likely mean a delay in the publication of the Energy Plan to allow politicians to "sell" the 15% nuclear policy [(52)].

It is believed that the new Energy Policy will also likely increase the share of LNG to 30-35% share while reducing the share of nuclear to 15%. This will trigger the building of additional gas-fired generation capacity and conversion of older capacity to more efficient models. New and efficient coal-fired power plants, such as integrated gasification combined cycle, are also likely be permitted and built [(53)].

The Government is also taking a serious look at restructuring the power industry, which is still partially regulated. It is considering removing in the next 2 to 3 years the existing regional power supply boundaries, which effectively gives the 10 power utilities regional monopolies. One option is "legal" unbundling, in which power utilities would be required to form holding companies and, under that, establish subsidiaries for generation and transmission. It is believed that unbundling would generate market competition so that newcomers can enter the market and compete. Consumers will also be able to choose their power suppliers and hence the tariff is expected to be lower.

2.6 Australia

Australia's land mass of 7,617,930 km^2 is on the Indo-Australian Plate, and is surrounded by the Indian and Pacific oceans [(54)]. As in June 2012, the population of Australia was about 24.94 million. A highly developed country, Australia is a member of the G20 and OECD, the world's 13th largest economy with GDP (nominal) of US$1,515,468 million[(2)] and GDP per capita (nominal) of US$66,371[(3)] (ranking 5th) in 2011. With the 2nd highest human development index globally Australia ranks highly in many international comparisons of national performance, such as quality of life, health, education, economic freedom, and the protection of civil liberties and political rights.

In 2010, Australia was the 9th largest energy producer in the world and one of only three OECD net energy exporting countries. Energy exports accounted for 68% of Australia's total energy production [(55).] As of 2009-10, 37.5% of energy in Australia is produced from coal, 34.6%% from oil, 23.1% from natural gas, and 4.8% from renewable sources. Australia's total final energy consumption was 3,703 petajoules (PJ), and the consumption by sector is given in Table 13[(56)]. According to the World Bank's publication [(25)], Australia's energy consumption per capita in 2010 was 5,296 kg of oil equivalent.

Mining	Manufacturing & Construction	Transport	Commercial	Residential	Others	Total
340PJ	1,036PJ	1,416PJ	309PJ	440PJ	162PJ	3,703PJ
9.2%	28.0%	38.2%	8.3%	11.9%	4.4%	100%

Table 13 – Energy Consumption by Sector in Australia (2009-10)

2.6.1 Report on Energy Reform (2007)[57]

The Report on *Energy Reform – Way Forward for Australia* submitted on 12 January 2007 by the Energy Reform Implementation Group to the Prime Minister had concluded that further reforms would deliver more economic benefits. More market contestability, improved transmission planning and regulation, and facilitating efficient financial markets, are priority reform areas. It was reckoned that these reforms, taken as a whole, could increase Australia's real Gross Domestic Product (GDP) by about $400 million per year, with retail energy price reductions of about 2%.

2.6.2 Policy and Strategy

Following policy papers, strategic frameworks and consultation papers were published in the past few years:

- 2009 July – *National Strategy on Energy Efficiency* (58): Developed a national strategy to accelerate energy efficiency efforts, streamline roles and responsibilities across levels of governments, and help households and businesses prepared for the introduction of the Carbon Pollution Reduction Scheme

- 2011 May - *Garnaut Climate Change Review – Update 2011 Australia in the Global Response to Climate Change* (59) : Examined the impacts of climate change on the Australian economy, and recommended medium to long-term policies and policy frameworks to improve the prospects for sustainable prosperity

- 2011 July - *The Clean Energy and Other Skills Package* (60) : The Package is to invest up to $32 million over 4 years to enable trades people and professionals in key industries to develop the skills needed to deliver clean energy services, products and advice to Australian communities and businesses.

- 2011 December – *National Energy Security Assessment (NESA)* (61): The NESA is not a policy document, but is an important input into the development of government policy through the Energy White Paper process. Its analysis considers the main factors challenging the adequate, reliable and competitive delivery of energy in each of the liquid fuel, natural gas and electricity sectors. This assessment considers the key influences on energy security in Australia in the short, medium and long terms covering the period 2011 to 2035.

- 2011 December – *Strategic Framework for Alternative Transport Fuels* (62) : To identify key issues and provides a framework to address issues affecting future investment in, and production and use of alternative transport fuels as required to maintain Australia's transport fuel security while moving towards a low carbon economy in 2030.

- 2011 December – *Draft Energy White Paper- Strengthening the Foundations for Australia's Energy* (63) : The 325 pages draft Energy White Paper seeks to provide a policy framework to address challenges in energy sector and help maintain Australia's competitiveness. It sets out a series of proposed priorities designed to provide a framework to give investors, consumers and planners a clear sense of direction and confidence in Australia's energy future. Four priority action areas proposed to enhance Australia's energy potential are:

- Strengthening the resilience of Australia's energy policy framework
- Reinvigorating the energy market reform agenda
- Developing Australia's critical energy resources, particularly Australia's gas resources
- Accelerating clean energy outcomes

2.6.3 Air Quality

Through the National Environment Protection Council, the Australian Governments agreed to the National Environment and Protection Measure for Ambient Air Quality in 1998 aiming to improve the public health through improved air quality. The Measure sets air quality standards that are legally binding on each level of government. Jurisdictions put strategies in place to reduce emissions and to achieve the standards set out below. The standards relate to six criteria air pollutants: CO, NO_2, SO_2, photochemical oxidants, lead and particles. Table 14 lists the air quality standards for different average time period.

Pollutant		Averaging Time	Level	Maximum allowable exceedences
Carbon Monoxide (CO)		8 hours	9.0ppm	1 day
Lead		1 year	0.50 µg/m3	none
Nitrogen Dioxide (NO_2)		1 hour	0.12 ppm	1 day
		1 year	0.03 ppm	none
Ozone (O_3)		1 hour	0.10 ppm	1 day
		4 hours	0.08 ppm	1 day
Particle Pollution	$PM_{2.5}$	1 day	25 $\mu g/m^3$	advisory reporting
		1 year	8 $\mu g/m^3$	standard
	PM_{10}	1 day	50 $\mu g/m^3$	5 days
Sulfur Dioxide (SO_2)		1 hour	0.02 ppm	1 day
		1 day	0.08 ppm	1 day
		1 year	0.02 ppm	none

Table 14 Air Quality Standards for Key Pollutants in Australia [64]

To indicate the air pollution level, a number of state governments in Australia have devised an air quality index (AQI) to characterise the quality of the air. An index value less than 100 means the pollutant has not exceeded the standard. A value equal to or greater than 100 means the pollutant has exceeded the relevant air quality standard. The AQI reflects the residual risks to public health at a given index level. An index value for any given pollutant is its concentration expressed as a percentage of the relevant standard. Table 15 shows the category of AQI and their associated health effects.

Air Quality Descriptor	Air Quality Index	Associated Health Effects
Very Poor	150+	Air quality is unhealthy and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects.
Poor	100–149	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range.
Fair	67–99	Air quality is acceptable. However, there may be a health concern for very sensitive people.
Good	34–66	Air quality is considered good, and air pollution poses little or no risk.
Very Good	0–33	Air quality is considered very good and air pollution poses little or no risk.

Table 15 - Air Quality Index and Associated Health Effects in Australia (65)

Air pollution is an important public health issue and imposes high health and monetary costs on the community and governments. The Australian Institute of Health and Welfare estimated that urban air pollution was responsible for more than 3000 premature deaths in 2003, mainly of the elderly. This was almost twice the number of deaths caused by traffic accidents in the same year. Heart disease was the most common cause of death from long-term exposure to air pollution. Air pollution also exacerbates asthma and contributes to other respiratory illnesses in children and the elderly. Asthma was the leading cause of disease in children in 2003. National initiatives to reduce the impact of road transport on environment quality, urban amenity and human health. The strategies for air pollution control in Australia include:

- monitoring in-service petrol vehicle emissions
- improving the emissions performance of the Australian vehicle fleet, by improving fuel quality and reducing in-service diesel vehicle emissions through the National Environment Protection (Diesel Vehicle Emissions) Measure
- managing and promoting the Product Stewardship for Oil Program, which provides incentives to increase used oil recycling in the Australian community and ensures the environmentally sustainable management of used engine oil.

2.6.4 Carbon Emissions Reduction Targets

According to the Department of Climate Change and Energy Efficiency's website (66), Australia will:

- Reduce its GHG emissions by 25% compared with 2000 levels by 2020 if the world agrees to an ambitious global deal capable of stabilising levels of GHGs in the atmosphere at 450 ppm CO_2 or lower;

- Unconditionally reduce its emissions by 5% compared with 2000 levels by 2020 and up to 15% by 2020 if there is a global agreement that falls short of securing atmospheric stabilisation at 450 ppm CO_2 under which major developing economies commit to substantially restraining their emissions and advanced economies take on commitments comparable to Australia's; and

- Reduce GHG emissions by 80 per cent compared with 2000 levels by 2050.

2.6.5 Carbon Pricing Scheme [67]

To move towards a low-carbon economy, Australia passed legislation to introduce a carbon pricing scheme in February 2011. The carbon pricing mechanism is composed of an initial three years' carbon tax, starting from 1st July 2012 and switching to a market-based emission trading scheme thereafter. For the fixed price period of the initial three years, the scheme will affect 500 of Australia's biggest polluting companies, which generate more than 25,000 tons of carbon dioxide each year. Activities such as burning of fossil fuel for electricity generation and transportation, heavy industries, e.g. steel making or concrete, mining industries, e.g. coal and liquefied natural gas, and waste management will be liable under the scheme.

The price started at A$23 per ton as of 1 July 2012. In each of the next two years, it will rise by 2.5% cent in real terms, assuming inflation of 2.5 per cent a year. This will give industries time to adapt to the new system and start planning ways to reduce their pollution. In the flexible price period, starting from July 2015, the carbon price will be set by the market. The revenue from the carbon tax will be recycled by the Government in three main areas: assisting households; supporting jobs and enhance competitiveness; and investing in clean energy and climate change programmes.

2.7 The United Kingdom

The United Kingdom (UK) lies between the North Atlantic Ocean and the North Sea with a total area of approximately 243,610 km^2. It has a temperate climate with plentiful rainfall all year round [68]. As in June 2010, the population of the UK was about 62.26 million. A leading European and global trading partner and financial centre, the UK is a member of the G7 and OECD, the world's 7th largest economy with GDP (nominal) of US$2,429,184 million[2] and GDP per capita (nominal) of US$38,811 [3] (ranking 22nd) in 2011. According to the World Bank's publication [25], the UK's energy consumption per capita in 2011 was 3,017 kg of oil equivalent.

As of 2010, the final energy consumption[69] was 159.1 million tonnes of oil equivalent (MToe) and the distributions among user and sectors are shown in Table 16 and Table 17 below:

Transport	**Domestic**	**Industry**	**Other Users (Services, Agriculture, etc)**	**Non-Energy Use**	**Total**
55.7 MToe	48.5 MToe	27.9 MToe	18.3 MToe	8.7 MToe	159.1 MToe
35.0%	30.5%	17.5%	11.5%	5.5%	100%

Table 16 – Energy Consumption by User in the United Kingdom

Petroleum	**Natural Gas**	**Electricity**	**Others***	**Total**
72.4 MToe	52.5 MToe	27.8 MToe	6.4 MToe	159.1 MToe
45.5%	33%	17.5%	4%	100%

* *Includes coal, manufactured fuels, renewables & waste, and heat sold.*

Table 17 – Energy Consumption by Type of Fuel/Energy in the United Kingdom

2.7.1 Policy and Strategy

According to Wikipedia [70], the current energy policy of the UK is set out in the *White Paper on Energy* of May 2007, *Low Carbon Transition Plan* of July 2009, *Climate Change Act* 2008 and *Carbon Plan* of December 2011, building on previous work including the 2003 *Energy White Paper* and the *Energy Review Report* in 2006. It is led by the Department of Energy and Climate Change and the current focuses of policy are on: reforming the Electricity Market, rolling out smart meters and improving the energy efficiency of the UK building stock through the *Green Deal*.
The 343-page *White Paper on Energy May 2007- Meeting the Energy Challenge* [71] set out the Government's international and domestic energy strategy to address the long term energy challenges faced by the UK, and to deliver the following four key policy goals:

- To put the UK on a path to cut carbon dioxide emissions by some 60% by about 2050, with real progress by 2020;
- To maintain reliable energy supplies;
- To promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve productivity; and
- To ensure that every home is adequately and affordably heated.

According to the *White Paper on Energy*, the Climate Change Act 2008 established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below base year levels by 2050, to be achieved through action at home and abroad. To drive progress and set the UK on a pathway towards this target, the Act introduced a system of carbon budgets which provided legally binding limits on the amount of emissions that might be produced in successive five-year periods, beginning in 2008. The first three carbon budgets were set in law in May 2009 and required emissions to be reduced by at least 34% below base year levels in 2020. The fourth carbon budget, covering the period 2023–27, was set in law in June 2011 and required emissions to be reduced by 50% below 1990 levels.

Published on July 15, 2009, *the UK Low Carbon Transition Plan- National Strategy for Climate and Energy* [72] detailed the actions to be taken to cut carbon emissions by 34% by 2020, based on 1990 levels. As a result, by 2020 it is envisaged that:

- Over 1.2 million people will be employed in green jobs.
- The efficiency of 7 million homes will have been upgraded, with over 1.5 million of them generating renewable energy.
- 40% of electricity will be generated from low carbon sources (renewable, nuclear power and clean coal).
- Gas imports will be 50% lower than would otherwise have been the case.
- The average new car will emit 40% less carbon compared to 2009 levels.

In June 2011, the Coalition Government enshrined in law a new commitment to halve greenhouse gas emissions, on 1990 levels, by the mid-2020s. Presented to the Parliament in December 2011, the 220-page *Carbon Plan: Delivering our Low Carbon Future* [73] sets out how the UK will achieve decarbonisation while maintain energy security in a way that minimizes costs to consumers bills and helps to attract new investment in low carbon infrastructure, industries and jobs. The *Carbon Plan* covers the following sectors:

- Low carbon buildings
- Low carbon transport
- Low carbon industry
- Low carbon electricity
- Low greenhouse gas agriculture and forestry

Published in November 2012, the document *The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK* [74] sets out the direction for energy efficiency policy for the coming decades. It spells out the UK's ambition, the barriers that the nation needs to address and the additional steps the nation takes to stimulate the energy efficiency market. It also shows how the UK can act to connect finance with demand, encourage innovation and make energy information more accessible to the consumer.

2.7.2 Draft Energy Bill

In May 2012, the Secretary of State for Energy and Climate Change presented the 307-page *Draft Energy Bill* [75] to the Parliament for pre-legislative scrutiny by the Energy and Climate Change Committee. The key elements of the Draft Energy Bill are:

- Implement the Electricity Market Reforms;
- Clarify the role of the regulator, Ofgem;
- Establish an Office for Nuclear Regulation;
- Make changes to the offshore transmission regulatory framework; and
- Make provisions for the potential sale of Government pipeline and storage system

The Bill proposes to radically reform the electricity industry aiming to bring secure, clean, low carbon and cost effective electricity to help combat climate change and minimize price rises. The aim of the reforms is to create a balanced mix of renewables, new nuclear power and carbon capture and storage and ensure fair competition. With an extra £110 billion invested in the low-carbon energy, it is claimed that the reforms will be better for the UK's economy, leaving it less vulnerable to rising global energy prices and supporting as many as 250,000 jobs in the energy sector. The reforms would enable the UK to achieve its climate change and renewable targets, including 34% reduction in its CO_2 emissions by 2020 (relative to 1990); at least an 80% reduction by 2050; and ensuring that by 2020 15% of the energy consumed in the UK comes from renewable sources. Subject to the approval by Parliament, the Energy Bill is expected to achieve Royal Assent in 2013, so that the Electricity Market Reform should be fully up and running in 2014 as planned.

2.7.3 Air Quality

The development of air pollution control in the UK has been strongly influenced by the smogs experienced in cities during the 1950s. The UK National Air Quality Strategy was published in 1997 and 2000 with commitments to achieve new air quality objectives throughout the UK by 2005. The Environment Act of 1995 included a requirement for the development of a strategy to address areas of poor and declining air quality. The air quality objectives for the key air pollutants in UK are shown in the following Table 18:

The fundamental aim of the government environmental agency is to render polluting emissions harmless. It is necessary, therefore, to firstly define a level of harmlessness, and then to establish a policy towards the achievement of the levels by means of objectives as costs and benefits balance. An approach of 'exposure reduction' for $PM_{2.5}$ has been implemented in UK to seek a more efficient way of achieving further reductions in the health effects of air pollution. The exposure reduction approach is based on the principle that for pollutants with a low or zero threshold for adverse effects, it will generally be more beneficial to public health, and potentially more cost-effective to reduce pollutant levels across the whole population of an urban area or region rather than in a small area or "hotspot". The framework of delivering this approach contains two inseparable parts:

- air quality objectives/limit values (often called "backstop objective" or "concentration cap") to ensure some basic level or quality of air which all citizens should experience, embodying the "environmental justice" concept;
- an objective based on reducing average exposures across the most heavily populated areas of the country (often called "percentage reduction" or "exposure reduction" objective), in order to generate further cost effective public health improvements over and above the basic level of protection generated by the objective above.

Pollutant		Averaging Time	Level	Remarks
Carbon Monoxide (CO)		eight hour daily mean	10 mg/m^3	
Lead		Annual	0.5 µg/m3	
Nitrogen Dioxide (NO_2)		One hour	200 µg/m3	not to be exceeded more than 18 times a calendar year
		Annual	40 µg/m3	
Particle Pollution	$PM_{2.5}$	Annual	25 µg/m3	20% on 11th June 2008, decreasing on the next 1st January and every 12 months thereafter by equal annual percentages to reach 0% by 1st January 2015
	PM_{10}	One day	50 µg/m3	not to be exceeded more than 35 times a calendar year
		Annual	40 µg/m3	
Sulfur Dioxide (SO_2)		One hour	350 µg/m3	not to be exceeded more than 24 times a calendar year
		One day	125 µg/m3	not to be exceeded more than 3 times a calendar year

Table 18 -Air Quality Standards for Key Pollutants in the United Kingdom [76]

This will act to make policy measures more cost-effective and is more likely to maximise public health improvements across the general population. For example, traffic management can make a significant contribution to help reduce emissions of pollutants from road vehicles, such as schemes to restrict or exclude less clean vehicles from certain roads or areas, including low emission zones, or reduce road congestion.

2.8 Mainland China

Covering approximately 9.6 million km^2, China is the world's second largest country by land. The national census of 2010 recorded the population of approximately 1,338,612,968. Since the introduction of China's economic reform and open-up policy in 1978, China has become the world's fastest-growing major economy(77). In 2011, China's total GDP (nominal) was US$7,203,784 million(2) with GDP per capita (nominal) of US$5,417 (3) (ranking 90th). As of 2012, it is the world's second-largest economy, after the United States, by both nominal total GDP and purchasing power parity, and is also the world's largest exporter and second-largest importer of goods. According to the World Bank's publication (25), China's energy consumption per capita in 2010 was 1,807 kg of oil equivalent.

China is the largest energy consumer in the world: second-largest consumer of oil (8,924 barrels per day in 2011) behind the United States, and the largest producer and consumer of coal (3,826 million short tons) in the world which accounts for almost half of the world's coal consumption. Although the use of natural gas is rapidly increasing in China, consumption was 4,624 billion cubic feet in 2011. China is the world's largest carbon emitter and the total carbon dioxide emission from consumption of fossil fuels was 8,320 million tonnes in 2010(78).

As a result of soaring energy demand from a staggering pace of economic expansion and the related growth of energy-intensive industry, China overtook the United States to become the world's largest contributor to CO_2 emissions in 2007. In late 2009, China announced a commitment to reduce its carbon intensity by 40% to 45% below 2005 levels by 2020. Achieving the 2020 goal will require strengthening and expansion of energy efficiency policies in industry, buildings, appliances, and motor vehicles, as well as further expansion of natural gas, renewable and nuclear power capacity for electricity generation(79).

2.8.1 12th Five-Year Plan (2011-2015): Energy and Environment

On 14 March 2011, the China's National People's Congress approved a new national development programme for the next five years from 2011 to 2015. Among the seven priority industries established in the *12th Five-Year Plan (2011-2015)*, three of them are related to energy and environment: viz. new energy (nuclear, wind and solar power), energy conservation and environmental protection, and clean energy vehicles(80). The plan calls for non-fossil fuels to reach 11.4% of primary energy consumption by 2015. Similarly it targets a 16% reduction in energy consumption per unit of GDP and a 17% reduction in carbon dioxide emissions per unit of GDP over the same period. The plan also aims to reduce major pollutants: chemical oxygen demand and SO_2 by 8%, ammonia nitrogen and nitrogen oxide by 10% (81).

Priorities of some of energy infrastructure included in the 12th Five-Year Plan (2011-2015) are (82):

- *Nuclear power* – Accelerate the development of nuclear power in coastal provinces, promote nuclear power construction in central provinces steadily, and construct nuclear power projects with a total installed capacity of 40 million kW.

- *Renewable Energy Sources* – Construct large-sized hydropower stations in key watersheds, such as those of the Jinsha, Yalong and Dadu Rivers, and commence the construction of hydropower projects with a total installed capacity of 120 million kW. Construct 6 onshore and 2 coastal and offshore large wind power bases, with an additional installed capacity of over 70 million kW. Construct solar energy power stations with a total installed capacity of over 5 million kW with focus on Tibet, Inner Mongolia, Gansu, Ningxia, Qinghai, Xinjiang and Yunnan

- *Oil and Gas Pipe Networks* – Construct the China-Kazakhstan crude oil pipeline (Phase 2), the China-Myanmar oil and gas pipeline (domestic section), the Central Asia natural gas pipeline (Phase 2), and the West-to-east Gas Transmission Lines 3 and 4. The total length of oil and gas transmission pipelines attains about 150,000 kilometers. Accelerate the construction of gas storage facilities.
- *Power Grids* – Accelerate the construction of outward power supply projects from large coal power, hydropower and wind power bases, and create some cross-regional power transmission channels using advanced technologies. Complete 330 kV or above power transmission lines of 200,000 kilometers. Carry out trials of intelligent power grid construction, improve substations to intelligent ones, extend the application of intelligent watt-hour meters, and construct electric vehicle charging facilities.

2.8.2 Air Quality

China's Ministry of Environmental Protection (MEP) is responsible for monitoring the ambient air quality in China. As from 28 August 2008, MEP monitors daily pollution level in 86 major cities. The API level is based on the level of 5 atmospheric pollutants, namely sulfur dioxide (SO_2), nitrogen dioxide (NO_2), suspended particulates smaller than 10 μm in aerodynamic diameter (PM10), carbon monoxide (CO), and ozone (O_3) measured at the monitoring stations throughout each city. An individual score is assigned to the level of each pollutant and the final Air pollutant Index (API) is the highest of those 5 scores (Table 19). The pollutants can be measured quite differently. The concentrations of SO_2, NO_2 and PM10 are measured as average values per day. CO and O_3 are more harmful and are measured as average values per hour. The final API value is calculated per day. The API has a range of values from 0 to 300+, which are divided into seven categories as shown in Table 19. Under the categorization, associated health effects and health implications (daily targets) are defined to protect public health.

Due to the domination of coal in the energy structure, the urban atmospheric environment in China has been seriously polluted by high concentrations of SO_2 and Total Suspended Particulates (TSP) with the growing acid precipitation levels and significant contributions to greenhouse gases (GHGs). With the rapid development of economy, urbanization and transportation in the past two decades, vehicle exhaust pollution also increased substantially. In February 2012, China released a new ambient air quality standard*, GB 2095-2012,* which sets limits for the first time on $PM_{2.5}$. The new standards will not take effect until 2016, although many cities and regions in China have been implementing the standards earlier than the national timeline.

API	Air Pollution Level	Health Implication
0 - 50	Excellent	No health implications
51 -100	Good	No health implications
101-150	Slightly Polluted	Slight irritations may occur, individuals with breathing or heart problems should reduce outdoor exercise.
151-200	Lightly Polluted	Slight irritations may occur, individuals with breathing or heart problems should reduce outdoor exercise.
201-250	Moderately Polluted	Healthy people will be noticeably affected. People with breathing or heart problems will experience reduced endurance in activities. These individuals and elders should remain indoors and restrict activities.
251-300	Heavily Polluted	Healthy people will be noticeably affected. People with breathing or heart problems will experience reduced endurance in activities. These individuals and elders should remain indoors and restrict activities.
300+	Severely Polluted	Healthy people will experience reduced endurance in activities. There may be strong irritations and symptoms and may trigger other illnesses. Elders and the sick individuals should remain indoors and avoid exercise. Healthy individuals should avoid outdoor activities.

Table 19 - Health Impacts with Different Categories of API Values in China

China's current air quality standards include two classes of limiting values. Class I standards apply to special regions such as national parks. Class II standards apply to all other areas, including urban and industrial areas. Table 20 presents the current ambient air quality standards in China, as specified in GB 3095-2012.

Pollutant	Average Time	*Class 1*	*Class 2*	Unit
SO_2	annual	0.02	0.06	mg/m^3
	24 hours	0.05	0.15	
	hourly	0.15	0.50	
NO_2	annual	0.04	0.04	
	24 hours	0.08	0.08	
	hourly	0.200	0.200	
CO	24 hours	4	4	
	Hourly average	10	10	
O_3	Max 8 hour average	100	160	$\mu g/m^3$
	Hourly average	160	200	
PM10	annual	40	70	
	24 hours	50	150	
PM2.5	annual	15	35	
	24 hours	35	75	
TSP	annual	80	200	
	24 hours	120	300	

Table 20 - Ambient Air Quality Standards in China [83]

In order to improve air quality, China mainly adopts the following policies for air pollution control from the year 2000:

- Adjusting the industrial structure and layout, and taking effective measures to prevent and control the industrial pollution;
- Launching in-depth comprehensive control of air pollution in urban environments;
- Increasing energy efficiency, disseminating the cleaner coal technologies and improving the energy structure;
- Making vigorous efforts to launch forestation programmes
- Promoting the advance of environmental science and technology, and developing the environmental industry;
- Applying economic incentives in the area of environmental protection; and
- Perfecting environmental legislation and intensifying environmental management.

2.8.3 2012 Energy Policy White Paper

In October 2012, the Information Office of the State Council of PRC published the 2012 edition of *White Paper on Energy Policy*. The White Paper points out that (i) energy is the material basis for the progress of human civilization and an indispensable basic condition for the development of modern society, (ii) energy remains a major strategic issue for China as the country moves towards its goals of modernization and common prosperity for its people, and (iii) it is an important strategic task of the Chinese government to maintain long-term, stable and sustainable use of energy resources. The Paper with the following contents summarizes the current status of energy development in China and puts forward the development policies and objectives for the energy industry [(84)].

- Current energy development
- Policies and goals of energy development
- All-round Promotion of Energy Conservation
- Vigorously Developing New and Renewable Energy
- Promoting Clean Development of Fossil Energy
- Improving Universal Energy Service
- Accelerating Progress of Energy Technology
- Deepening Institutional Reform in the Energy Sector
- Strengthening International Cooperation in Energy

2.9 Summary

2.9.1 Highlights of Energy Policy

2.9.1.1 Hong Kong

Hong Kong has no indigenous energy sources, and hence imports all primary fuels to meet its energy requirement. The objectives of Hong Kong's Energy policy are to ensure that the energy needs of the community are met safely, reliably, efficiently and at reasonable prices, and to minimise the environmental impact of energy production and use and promote the efficient use and conservation of energy. Despite the absence of a comprehensive Energy Policy document, the Administration had in the past three years sought public responses to several important consultation documents, notably (i) 2009 Air Quality Objectives Review, (ii) 2010 Hong Kong's Climate Change Strategy and Action Agenda, (iii) 2011 Combating Climate Change: Energy Saving and Carbon Emission Reduction in Buildings, and (iv) 2011

Regional Cooperation Plan on Building a Quality Living Area. A new set of AQOs were proposed in January 2012 and preparation for legislation process is underway. It is hoped that a structured, coherent and comprehensive Energy Policy will be produced during the 5-year term of the new Administration that took office on 1 July 2012.

2.9.1.2 Singapore

Despite having no significant energy resources of its own, Singapore has established itself as Asia's energy centre, the world's 3rd largest oil trading hubs, and one of the top 5 oil refinery centres in the world. The Singaporean Government pointed out that energy plays an independent role in Singapore's economy, and will remain crucial to its continued economic growth and development. The ultimate aim of its energy policy is to support Singapore's continued economic growth. As a small country with limited natural and energy resources, Singapore is mindful of the impact that energy supply disruption could have on its economy and society. Singapore considers it is imperative to manage the security of its energy resources and the key strategy is to diversify energy resources. The Singapore Government published several important documents: notably (i) 2007 Energy for Growth – National Energy Policy Report, (ii) 2009 Sustainable Singapore Blueprint, and (iii) 2012 National Climate Change Strategy.

2.9.1.3 South Korea

In South Korea, only 3.6% of total primary energy consumption is supplied by domestic energy production and the remaining 96.4% is imported from overseas. South Korea's energy policy objectives focus on energy security, economic growth and the environment. The South Korean Government is of the view that new energy policies are necessary to relieve higher oil prices' adverse impact on Korean economy and to overcome the vulnerability due to the country's high dependence on energy import. On 6 July 2009, the Government approved the 5-Year (2009 to 2013) Plan for Green Growth to serve as a medium term plan for implementing the national strategy. By 2013, a total of 107 trillion Won of the government budget will be allocated in the 5-Year Plan for Green Growth.

2.9.1.4 Taiwan

Taiwan relies on imports for more than 98 percent of its primary fuel to meet its energy requirement. In July 2009, the Executive Yuan approved a proposal consisting of 16 measures to transform Taiwan into a "low carbon" country by 2020. The Ministry of Economic Affairs' proposal set a long-term goal of cutting total annual greenhouse gas emissions to 2000 levels by the year 2025. Mandatory programs have been established for the purpose of energy conservation, including energy audit and energy efficiency standards for certain electrical and electronic products. The Taiwan Government will begin collecting air pollution fee in 2015. In the wake of Japan's nuclear crises in March 2011, the Taiwan Government unveiled its new nuclear energy policy in November 2011 calling for a dramatic reduction in reliance on nuclear powers.

2.9.15 Japan

Japan is dependent on imports of virtually all fossil fuels to meet its energy requirement. Japan's energy policy has been in the past focusing on efficiency, diversity, and development of indigenous energy sources. Because virtually all fossil fuels must be imported, nuclear power had offered an indigenous option that became a cornerstone of Japan's energy policy. Nuclear power is also affordable, especially compared to purchasing oil and gas on world markets. However, the Great East Japan Earthquake and tsunami of March 11, 2011, followed by the reactor damage at Fukushima Daiichi, have shaken the core of Japanese energy policy.

As of May 5, 2012, all of the country's 54 nuclear power plants had been taken offline due to ongoing public opposition following the Fukushima Daiichi nuclear disaster, and this has shaken the core of Japanese energy policy. However, due to the need to cope with demand of electricity in summer, Japan's Prime Minister on 16 June 2012 gave the green light for the resumption of two nuclear reactors at Oi in western Japan operated by the Kansai Electric Power Company despite public opposition. One of the nuclear reactors at Oi was re-started on 1 July 2012. The Strategic Energy Plan approved in 2010 clearly requires further review. Furthermore, the decision of the three scenarios for Japan's energy-mix in 2030 due in August 2012 is likely to be delayed to allow politicians to "sell" the "15% nuclear" policy.

2.9.1.6 Australia

In 2010, Australia was the 9th largest energy producer in the world and one of only three OECD net energy exporting countries. The Australian Government stated that energy is fundamental to Australia's modern economy and society, and access to secure, reliable and competitively priced energy has been a cornerstone of Australia's economic and social development. In this context, it is critical that energy policy continues to strike an appropriate balance in delivering energy security, facilitating economic development and meeting clean energy growth. Maintaining Australia's energy security continues to be a paramount goal for the Government.

The Australian Government published a number of important documents, notably (i) 2009 National Strategy on Energy Efficiency, (ii) 2011 Garnaut Climate Review, (iii) 2011 Clean Energy and Other Skills Package, (iii) 2011 National Energy Security Assessment, (iv) 2011 Strategic Frameworks for Alternative Transport Fuels, and (v) 2011 Draft Energy White Paper: Strengthening the Foundations for Australia's Energy Future. On 11th July 2011 Prime Minister, Julia Gillard, announced that the implementation of the new carbon tax from 1 July 2012. It is believed that the Carbon Tax plan attempts to cut pollution and provide an incentive to invest in renewable energy.

2.9.1.7 The United Kingdom

The UK imported about 30% of primary fuels to meet its energy requirement. The UK Government pointed out that energy is essential in almost every aspect of people's lives and is fundamental to the success of the UK's economy. The Government has set out a plan to support the transition to a secure, safe, affordable and low-carbon energy system, and mobilize commitment to ambitious action on climate change, internationally. The Government is determined to address the twin challenges of tackling climate change and maintaining the UK's energy security in a way that minimizes costs and maximizes benefits to the UK's economy.

The UK Government published a number of important documents, notably (i) 2007 White Paper on Energy, (ii) 2009 UK Low Carbon Transition Plan – National Strategy for Climate and Energy, (iii) 2011 Carbon Plan: Delivering our Low Caron Future, (iv) 2012 Draft

Energy Bill, and (v) 2012 Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK.

2.9.1.8 Mainland China

China overtook the United States to become the world's largest contributor to CO2 emissions in 2007. In late 2009, China announced a commitment to reduce its carbon intensity by 40% to 45% below 2005 levels by 2020. The *12th Five-Year Plan (2011-2015)* approved in March 2011 calls for non-fossil fuels to reach 11.4% of primary energy consumption by 2015. Similarly it targets a 16% reduction in energy consumption per unit of GDP and a 17% reduction in carbon dioxide emissions per unit of GDP over the same period. The plan also aims to reduce major pollutants by 8% to 10%. As part of its strategy to meet carbon-intensity and energy-intensity targets, China is aiming for more efficient nuclear-power development, and also plans to boost hydropower construction in the southwest and increase the length of its high-speed railway to 45,000 kilometers.

In October 2012, China published the 2012 edition of *White Paper on Energy Policy*. The White Paper points out that (i) energy is the material basis for the progress of human civilization and an indispensable basic condition for the development of modern society, (ii) energy remains a major strategic issue for China, and (iii) it is an important strategic task of the Chinese government to maintain long-term, stable and sustainable use of energy resources.

2.9.2 GDP, Energy Consumption and Carbon Emission

Table 21 summarizes the GDP per capita, energy consumption per capita and carbon emission per capita of Hong Kong and the other six economies selected in the Study. As expected, Hong Kong's per capital energy consumption and carbon footprint is the lowest due to the service nature of its economy. Being a global leading mineral and energy export nation with heavy industry base, it is not surprising to see that Australia's per capital energy consumption and carbon footprint is the highest.

	Hong Kong	Singapore	Korea	Taiwan	Japan	Australia	United Kingdom	China
World Organization Affiliation	APEC WTO	APEC WTO	APEC OECD WTO	Nil	G7 OECD WTO	APEC OECD WTO	G7 OECD WTO	WTO
2011 GDP (Nominal) per Capita(US$)	34,259	49,271	22,424	21,900	45,870	66,371	38,811	5,417
2011 GDP per Capita World Ranking	25	12	34	40	17	5	22	90
2011 Energy Consumption per Capita (Kg of oil eqv.)	1,951*	6,456*	5,175	5,222	3,584	5,296	3,017	1,807*
2010 CO_2 per Capita (Tonne)	6.51	8.93	10.57	-	8.58	17.87	7.54	5.14

*Figures are for 2010

Table 21 – Per Capita GDP, Energy Consumption and Carbon Emissions (3)(25)(85)

2.9.3 Policy, Strategy and Targets

Table 22 summarizes the energy policy/plan, climate change policy/plan, carbon emission reduction targets, air quality policy/standards, etc. being implemented or to be formulated by Hong Kong and other six economies selected in this Study.

	Energy Policy/ Plan/ Bill	Climate Change Policy/Plan	CO_2 Emission Reduction Targets	Air Quality Policy/ Standards	Others
Hong Kong	Energy Policy Objectives 2012 Chief Executive Policy Address: Energy & Environment	2010 Climate Change Strategy & Action Agenda	50 -60% carbon intensity in 2020 (2005 as base)	New AQOs for 2014	
Singapore	2007 Energy For Growth-National Energy Policy Report	2009 Sustainable Singapore Blue Print; 2012 National Climate Change Strategy	Reduce emissions by 7% to 11% below 2020 BAU levels	Air Quality Standards 2011	2006 Green Plan 2012; 2008 Land Transport Master Plan;
Korea	5-year Plan for Green Growth (2009-2013)(covering Energy)	Included in Five-year Plan for Green Growth	4% carbon reduction by 2020 (2005 as base year)	Air Quality Standards	
Taiwan	Energy Management Act	2009 Proposal on Low Carbon Country	Bring carbon level to 2000 by 2050	Air Quality Standards	
Japan	2010 Strategic Energy Plan	Included in Strategic Energy Plan	30% carbon reduction by 2030 (1990 as base)	Air Quality Standards	
Australia	2007 Energy Reform Report; 2011 National Energy Security Assessment; 2011 Draft Energy White Paper	2011 Garnaut Climate Change Review; Carbon Pricing Scheme started on 1st July 2012	25% carbon reduction by 2020 (2000 as base)	Air Quality Standards	2011 Strategic Framework Alternative Transport Fuels
The United Kingdom	2007 White Paper on Energy; 2012 Draft Energy Bill 2012 Energy Efficiency Strategy	2011Carbon Plan: Delivering our Low Carbon Future	1990 levels by mid 2020s; 50% carbon reduction by 2050 (1990 as base)	Air Quality Standard Regulations 2007	
China	12th Five-Year Plan (2011-2015); 2012 Energy Policy White Paper	Broadly covered in 12th Five-Year Plan (2011-2015);	40%-50% carbon intensity reduction below 2005 levels by 2020 :17% reduction in carbon intensity within Five-Year Plan	2012 Ambient Air Quality Standard *GB 2095-2012*	

Table 22 – Energy and Environmental Policies, Strategies and Targets

3. OPERATIONS OF SECTORS RESPONSIBLE FOR MAJOR LOCAL SOURCES OF EMISSIONS

Being a service-oriented economy, power stations, and vehicles and vessels are the key sources of carbon emission and local air pollution in Hong Kong. For completeness, town gas production as a source of emissions is also covered. This section gives an overview of the regulatory framework, infrastructures, operations and inventory of all these three sectors: power sector, town gas sector and transport sector. Regulatory control on air pollution and carbon emissions from these sectors are also presented.

3.1 Electricity Sector

Table 23 shows Hong Kong's electricity consumption by sectors from 2005 and 2009. As expected the commercial sector took a lion share of 64.8% in the total energy consumption due to the service-oriented nature of Hong Kong. It is noted that the electricity consumption increased by 3.6% over a period of 4 years from 2005 to 2009, i.e. less than 1% per year. Furthermore, the electricity consumption in 2009 is 149,366TJ, i.e. about 52.6% of Hong Kong's total energy consumption of 283,540TJ.

Year	Commercial (TJ)	Residential (TJ)	Industrial (TJ	Transport (TJ)	Total (TJ)
2005	88,561	35,811	14,636	5,163	144,171
2006	93,317	35,428	14,015	2,444	145,204
2007	95,051	36,422	13,104	2,495	147,072
2008	95,543	37,100	12,182	2,520	147,345
2009	96,728	38,972	11,143	2,523	149,366
2009 % of Total	64.8%	26.1%	7.4%	1.7%	100%

Table 23 – Electricity Consumption by Sectors (2005 – 2009)[(8)]

Given that the electricity sector takes up more than half of the Hong Kong's energy consumption, it is not surprising that the electricity sector was responsible for 67% of CO_2 emission in 2008[(14)] and also a significant source of local air pollutant emissions in 2010 [(15)].

3.1.1 Regulatory Framework

The electricity sector has always been privately owned and operated in Hong Kong. Today, electricity is supplied by two vertically-integrated (generation-transmission-distribution-retailing) power companies: the Hongkong Electric Company Limited (HEC) which was incorporated in 1890 and CLP Power Hong Kong Limited (CLP) which was incorporated in 1901. Both power companies do not have a franchise but are currently regulated by the Energy and Sustainable Development Branch of the Environment Bureau through Scheme of Control (SOC) Agreement.

The HKSAR Government entered into two 10-year term SOC Agreements dated 7 January 2008, one with the HEC [(86)] and another with CLP[(87)]. The SOC Agreements are not due to expire until 2018, but there is a 5-year interim review scheduled in 2013. According to the Environment Bureau [(88)], the SOC Agreements stipulate that the power companies undertake to provide sufficient facilities to meet present and future electricity demand of their respective supply areas. In return, they are entitled to receive a permitted rate of return on their fixed assets (9.99% for average net fixed assets and 11% of average renewable net fixed assets). The SOC Agreements also provide the framework for the Hong Kong Government to regulate the power companies and monitor their corporate affairs to protect the interests of consumers. The power companies are required to seek the approval of the Executive Council for certain aspects of their development plans, including projected basic tariff levels, and the Government's consent to their annual tariff adjustments. Technical, environmental and financial performances of the power companies are subject to annual auditing review conducted jointly by the Government and the power companies. There are other incentive/penalty adjustments in respect of emissions performance, supply reliability, operational efficiency, customer services, energy efficiency and renewable.

The SOC Agreements do not offer the power companies any franchises, nor do they define a supply area for either power company, or exclude newcomers to the market. On a de facto basis, CLP supplies electricity to Kowloon and the New Territories, including Lantau and Cheung Chau, whereas HEC supplies electricity to Hong Kong Island and Lamma Island. Both power companies achieve a supply reliability of more than 99.99%, which is among the highest global industry standards.

3.1.2 Electricity Generation Facilities

As in 2011, Hong Kong has a total installed electricity generating capacity of 12,624MW, including 70% of the capacity of units 1 and 2 of the Guangdong Daya Bay Nuclear Power Station and 50% of Phase 1 of the Guangzhou Pumped Storage Power Station. The maximum demand recorded in 2011 was 9,200MW.

3.1.2.1. CLP Electricity Generation Facilities [89]

Electricity supplied by CLP to Kowloon and the New Territories, including Lantau, Cheung Chau and several other outlying islands is generated from Black Point Power Station, Castle Peak Power Station, Penny's Bay Power Station, Daya Bay Nuclear Power Station and Guangzhou Pump Storage Power Station. At the end of 2011, CLP's electricity generating capacity was 8,888MW and the maximum demand recorded in 2011 was 6,702MW, giving a reserve margin of 32.7%. Fuel Mix for electricity generation is in terms of install capacity is shown in Fig. 1 and Table 24.

3.1.2.2. HEC Electricity Generation Facilities [90]

Electricity supplied by HEC to Hong Kong Island and Lamma Island is generated at Lamma Power Station. At the end of 2011, HEC's installed capacity was 3,736MW and the maximum demand recorded was 2,498MW, giving a reserve margin of 49.6%. Fuel mix for electricity generation is in terms of installed capacity is shown in Fig. 2 and Table 25.

Fig.1 - Castle Peak/Black Point/Penny's Bay/Daya Bay/Pump Storage (89)

	Coal Fired Unit	Gas Fired Unit	Oil Fired Unit	Nuclear Power	Pump Storage
Castle Peak P/S	4,108MW (4x350+4x677)	0		0	0
Black P/S	0	2,500MW (8x312.5)		0	0
Penny's Bay P/S			300MW (3x100)		
Daya Bay P/S	0	0	0	1,378MW (70% of 1,968)	
Pump Storage P/S	0	0	0	0	600MW (50% of 1,200)
% of Installed Capacity	46.2%	28.1%	3.4%	15.5%	6.8%

Table 24 – CLP's Fuel Mix in Terms of Installed Capacity(89)

Fig. 2 – Lamma Coal-Fired/ Gas-Fired/Wind Power/Solar PV (90)

	Coal Fired Units	Gas Fired Units	Oil Fired Units	Wind Turbine	Solar PV
Lamma P/S	2,500MW (3x250+5x350)	680MW (1x335+1x345)	555MW (4x125+1x55)	0	0.55MW
Lamma Wind	0	0	0	0.8MW	0
% of Installed Capacity	67.0%	18.2%	14.8%	0.02%	0.01%

Table 25 – HEC's Fuel Mix in Terms of Installed Capacity(90)

3.1.3 Coal, Natural Gas and Nuclear Energy for Electricity Generation

3.1.3.1 Coal for Electricity Generation

CLP has eight coal-fired generating units (Station A: 4x350MW and Station B: 4x677MW) at Castle Peak Power Station with a total installed capacity of 4,108MW. Station A was commissioned from 1982 to 1985, whereas Station B from 1986 to 1990. All eight coal-fired units have electrostatic precipitator (EP) built-in as standard design which is capable of removing more than 99% of particulates. Retrofit of selective catalyst reactor (SCR), Over-fire Burners and flue gas desulphurization (FGD) to each of the four 677MW coal-fired units in stage was completed in 2011. Today, all four 677MW coal-fired units with a total capacity of 2,708MW at Castle B Station have their NOx and SO_2 emissions reduced by not less than70% and 90% respectively.

HEC also has eight coal-fired generating units (Stage 1: 3x250MW, Stage 2: 3x350MW and Stage 3: 2x350MW) at Lamma Power Station with a total installed capacity of 2,500MW. Stage 1 was commissioned from 1982 to 1984, Stage 2 from 1985 to 1992 and Stage 3 from 1995 to 1997. All eight coal-fired units have EP built-in as standard design which is capable of removing more than 99% of particulates. The latest three 350MW are also fitted with FGD as standard design. Retrofit of FGD to the remaining two older 350MW and one 250MW coal fired-units was completed in 2010, and this bring the capacity of coal-fired fitted with FGDs to 2,000MW with the capability of removing more than 90% SO_2. HEC's coal fired units have not equipped with SCR, but all the five 350MW coal-fired units have Low NOx Burner System in place to reduce NOx formation by more than 50%.

Citing coal-fired generating units as major sources of emission of air pollutants, Hong Kong Government decided that all new generating units should be powered by natural gas with effect from 1997 (91).

3.1.3.2 Natural Gas for Electricity Generation

CLP's Black Point Power Station has installed gas-fired capacity of 2,500MW, comprising eight 312.5MW combined cycle gas turbine (CCGT) generating units which were commissioned in stages from 1996 to 2006. All these CCGT units are of the first generation of single-shaft "F" Class design with a rated thermal efficiency of about 54%. As shown in Fig. 3, the gas-fired units are solely fueled by natural gas from Yacheng 13-1 gas field offshore of Hainan Island through a 778 km high pressure submarine gas pipeline since 1966. The Yacheng 13-1 gas field is approaching the end of its useful life with rapid decline in supply.

CLP is involved in the Second West-East Natural Gas Pipeline construction project which is an outcome of the Memorandum of Understanding signed by HKSAR and Central People's Government in August 2008 that secures gas and nuclear power supplies for Hong Kong for the next 20 years. CLP has also signed a framework of agreement with Petro China and Shenzhen Gas to jointly develop a LNG terminal in Shenzhen of China as part of the Gas Pipeline project. These are key gas supply sources delivering gas supply to Black Point Power Station required to replace the existing dwindling gas reserve in Yacheng 13-1 gas field (92).

Fig. 3 – Natural Gas Supply to Black Point Power Station (image courtesy of CLP)

According to CLP Annual Report 2011, the construction of a new gas receiving station and plant modifications at Black Point Power Station in preparation of those new sources of gas supply was approved by the Government in early 2011 and all works will be completed by early 2013. This would enable the gas-fired units at Black Point Power Station to migrate from existing Yacheng gas supply to various new gas supplies from the Mainland. As an interim measure, CLP entered a Gas Sales Agreement with CNOOC in December 2011 to facilitate a small gas field, located in South China Sea adjacent to the depleting Yacheng field, to supplement the existing gas supply for 5 years [(93)].

The National Development and Reform Commission approved PetroChina and CLP's investment in the branch line of 2nd West-to-East Pipeline (WEPII) in December 2011 to provide long term supply of natural gas to Black Point Power Station. In December 2012, the Executive Council of the Hong Kong Government approved the Gas Supply Agreement to supply natural gas to Hong Kong from the WEPII over the next 20 years. Construction of the 20km sub-sea gas pipeline from Dachan Island to Black Point Power Station is completed and new supply is expected to arrive by early 2013 to replace the depleting Yacheng 13-1 gas reserves [(94)].

HEC has two CCGT generating units (1x335MW and 1x345MW) with a total gas-fired capacity of 680MW at Lamma Power Station. The 335MW CCGT unit commissioned in 2006 is of the more matured single-shaft "F" Class design with a rated thermal efficiency of 56.5%. The 345MW CCGT unit consists of two "D" Class 125MW gas turbines retrofitted with one 95MW steam turbine and the upgrading work to include gas-fired capability was completed in 2010 to meet the 2010 emission caps. All two CCGT units are powered by liquefied natural gas (LNG) sourced from two countries, namely Australia and Qatar.

LNG for powering the 335MW CCGT units at Lamma Power Station is supplied from Guangdong LNG Terminal at Cheung Tou Jiao via a 92km long submarine gas pipeline (Fig. 4) under a 25-year Gas Supply Contract signed in 2004. It is believed that due to volatility of price of natural gas, a shorter term (5 years) Gas Supply Contract to bring in additional quantity of LNG from the same LNG terminal to power the 345MW CCGT unit was signed in late 2009.

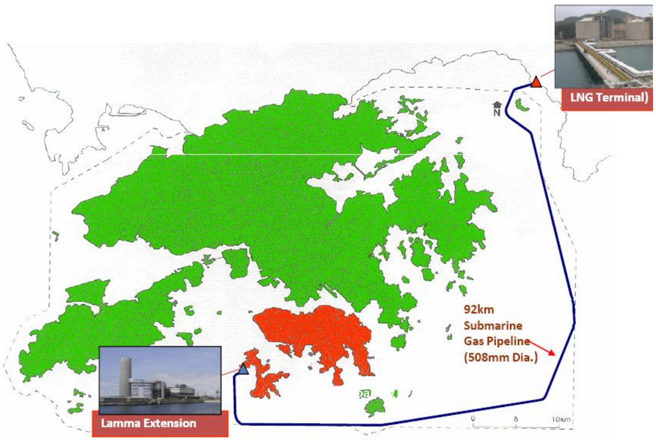

Fig. 4 – LNG Supply to Lamma Power Station (image courtesy of HEC)

3.1.3.3 Nuclear Energy for Electricity Generation

CLP has 25% equity in the 1,968MW (2x984MW) Guangdong Daya Bay Nuclear Power Station (Fig. 5) which was commissioned in 1994 and is the first commercial nuclear power station the Mainland China. Daya Bay Nuclear Power Station produces around 14 billion kWh of electricity annually of which 70% (i.e. about 10 billion kWh) is imported by CLP to its supply area through the 400kV Guangdong-CLP interconnection. In September 2009, the supply contract between Daya Bay and CLP was extended to 2034 [95].

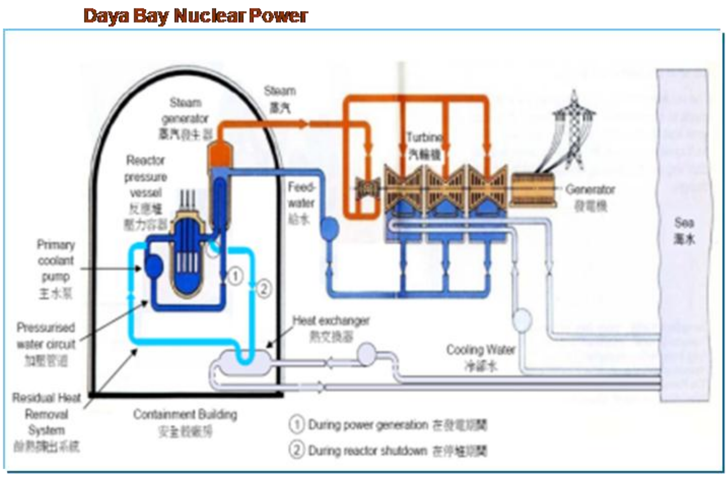

Fig. 5 – Schematic of Daya Bay Nuclear Power Plant (image courtesy of CLP)

As nuclear power plant takes a long time to start and stop, it is safer, more reliable and more economical for it to operate at constant production level to supply base load demand. Consumer demand varies significantly throughout each day and across different seasons, and the daily range of system load demand can differ up to two times in Hong Kong during different times of the year. The 600MW Guangdong Pump Storage Plant has important load-balancing role by storing excesses output from nuclear power plant in the form of potential energy of water (pumped from a lower elevation reservoir to a higher elevation), and then releasing the stored water through turbines to produce electric power during periods of high electricity demand.

As HEC's transmission network is not interconnected with Guangdong's power grid, no nuclear power is imported from the Mainland by HEC to its supply area at this stage.

3.1.4 Renewable Energy for Electricity Generation

3.1.4.1 Wind Power for Electricity Generation

HEC has a land based grid-connected 800kW wind turbine located on Lamma Island which has been in operation since 2006. It is a demonstration plant and can produce about one million kWh of electricity annually. As Hong Kong is located close to the Earth's equator where wind resource is rather weak, the load factor of the Lamma Wind project is about 15%.

It is generally believed that Hong Kong's scarcity of land with its unique topography makes it more feasible to build sizable wind turbines offshore. HEC and CLP have each proposed to build an off-shore wind farm with an installed capacity of 100MW south-west of Lamma Island (Fig. 6) and 200MW south-east of Ninepin group (Fig. 7) respectively. Hong Kong is blessed with surrounding deep-water sea but it poses huge engineering challenges to offshore wind farm development. This raises the capital cost of Hong Kong's proposed 300MW offshore wind farms to about HK$10 billion, which works out HK$33,300/kW. As mentioned above, wind resource around Hong Kong is considered to be low and it is estimated that the 300MW offshore wind farms can generate 560million kWh/year electricity i.e. about 1.2% of electricity generated for Hong Kong's local consumption in 2011. This translates to a capacity factor of 22% which is significantly less that can be achieved in Northern Europe with a capacity factor well over 35%.

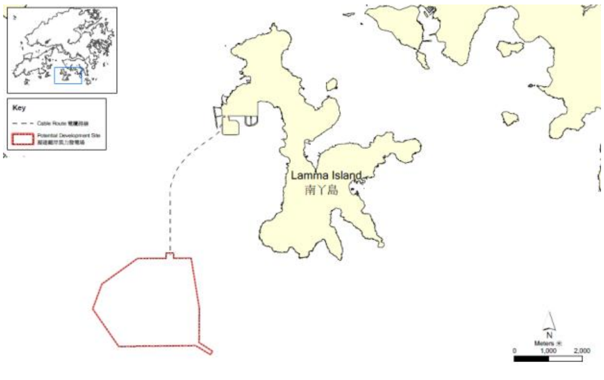

Fig. 6 – HEC's Proposed 100MW wind farm
(image courtesy of HEC)

Fig. 7 – CLP's Proposed 200MW wind farm
(image courtesy of CLP)

The layout of wind turbines have to be in staggered array with wide separation (4 to 6 times of blade diameter) to eliminate or minimize wake effect for effective capture of wind resource. Large footprint for wind farm is necessary and a 200MW wind farm producing about 375 million kWh would take up the area of entire Lamma Island.

Environmental Permits for construction of both wind farm projects were granted to CLP in August 2009 and HEC in May 2010. Construction of wind monitoring equipment is in progress with a view to have the wind farms commissioned in 2015 the earliest.

It is worth-mentioning that wind power is an intermittent, unreliable and unpredictable source for generation of electricity and cannot deal with peak-saving or base-load operations. It is not a firm capacity and requires fossil-fuelled or nuclear power plant as back-up.

3.1.4.2 Solar PV for Electricity Generation

HEC's 550kW solar PV system using thin-film technology was commissioned on 1st July 2010. Even though Hong Kong has relatively abundant sunlight, the 550kW TFPV (thin film photovoltaic) system made up of 5,500 panels can produce about 700,000 kWh/year of electricity which is better than the design expectation of 620,000 kWh/year. However, this translates to a rather low capacity factor of 14.7%. Furthermore, the capital cost of the project is HK$23million, i.e. HK$42,000/kW, which appears to be 28% higher than offshore wind farms. HEC is planning to increase the total installed capacity of solar PV system at Lamma Power Station to 1MW by 2013.

Assuming that Lamma Island with an area of 13.55km^2 can be fully utilized to install PV panels, it can accommodate about 1,600 sets of HEC's TFPV system which can generate about 988 million kWh of electricity per year, i.e. only 2% of electricity generated for Hong Kong's local consumption in 2011. Again, it should be noted that solar power is an intermittent, unreliable and unpredictable source for generation of electricity and cannot deal with peak-saving or base-load operations. It is not a firm capacity and requires fossil-fuelled or nuclear power plant as back-up.

3.1.5 Electricity Generation and Consumption

Table 26 shows Hong Kong's electricity generated for local consumption, electricity sales and gross domestic products (GPD) over a period of 5 years from 2006 to 2010. It is worth-noting the following:

- Electricity generated (including imported nuclear power) for local consumption in Hong Kong increased modestly but steadily by about 4 % from 44.98 billion kWh to 46.73 billion kWh over a period of 5 years, whereas the GDP increased by 18.2% and population by about 3.1%over the same period. This reflected that electricity consumption would not follow the trend of GDP even during the financial turmoil that took place in 2008/2009.

- The electricity consumption in Hong Kong is about 89.5% of the amount of electricity generated. This translates that about 10% of electricity generated is used up for power station's electricity consumed by ancillary equipment and pollution control facilities and for covering loss in the transmission/distribution systems.

Year	Electricity Generated for Local Consumption (billion kWh)	Electricity Sales (Consumption) (billion kWh)			GDP (Current Price) (HK$M)	Population
		Domestic	Non-Domestic	Total		
2006	44.98	9.84	30.49	40.33	1,475,357	6,857,100
2007	45.87	10.11	30.74	40.85	1,615,574	
2008	45.73	10.31	30.63	40.94	1,677,011	
2009	46.59	10.83	30.68	41.50	1,622322	
2010	46.73	10.93	30.93	41.86	1,743858	7,067,800
Change from 2006 to 2010	**+3.9%**	+11.1%	+1.4%	**+3.9%**	**+18.2%**	**+3.1%**

Table 26 – Hong Kong Electricity Generation & Sales and GDP (Year 2006 to 2010)(96)(97)

Due to disparity in the coverage of supply areas, Table 27 shows that CLP and HEC have provided about 74% and 26% of electricity consumption of Hong Kong in 2010 and 2011.

3.1.6 Current Fuel Mix, Emission Inventory and Performance

As a result of the stringent control measures implemented by the Hong Kong Government on over the past years, emissions from power plants have been substantially reduced over the years as shown in Fig. 8 even though demand for domestic electricity has increased (99).

	2010		2011	
	Billion kWh	% of Total	Billion kWh	% of Toal
CLP	30.93	73.9	31.17	74.1
HEC	10.93	26.1	10.89	25.9
Total	41.86	100	42.06	100

Table 27 – CLP and HEC electricity sales in 2010 and 2011(93)(98)

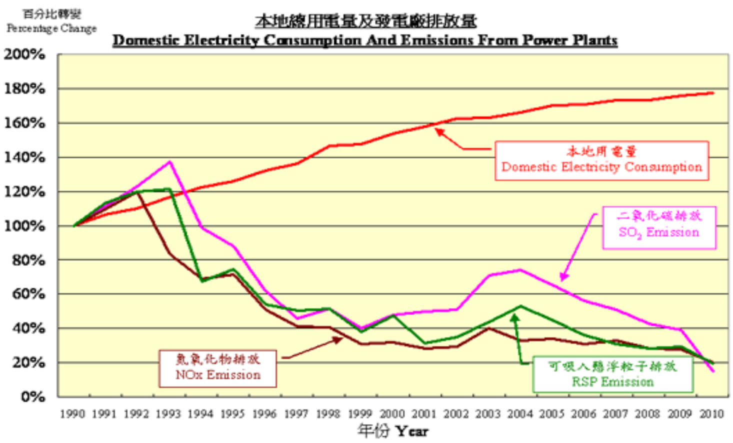

Fig. 8 – Electricity consumption and emissions from power plant from 1990 to 2010(99)

Table 28 shows the fuel mix adopted by CLP and HEC for power generation in 2005, 2010 and 2011. The marked difference of HEC was attributed to the introduction of LNG as fuel for power generation since 2006.

	2005 (Estimated)				2011 *(2010)*			
Fuel	Coal	Gas	Nuclear	Oil	Coal	Gas	Nuclear	Oil
CLP	39.8%	30%	30%	0.2%	49.1% *(39.7%)*	20.5% *(30.1%)*	30.1% *(30.0%)*	0.3% *(0.2%)*
HEC	99.8%	0%	0%	0.2%	66.8% *(66.8%)*	33% *(33%)*	0% *(0%)*	0.2% *(0.2%)*

Table 28 – Fuel mix of CLP and HEC for Power Generation (100 to 103)

As shown in Table 29, significant improvements ranging from 33.4% to 81.8% were achieved in emission of air pollutants, viz. sulphur dioxide (SO_2), nitrogen oxides (NOx) and respirable suspended particulates (RSP) in 2010 and 2011 compared to those in 2005. This was attributed mainly to the effects of pollution emissions reduction systems retrofitted to three coal-fired units completed by HEC in 2010 and four coal-fired units by CLP in 2011 respectively. The increase use of natural gas for power generation by HEC in 2010 also helped reduce its emissions of pollutants and carbon dioxide (CO_2).

	2005				2011 *(2010)*			
Emissions	SO_2 (kT)	NOx (kT)	RSP (kT)	CO_2 (MT)	SO_2 (kT)	NOx (kT)	RSP (kT)	CO_2 (MT)
CLP	46.1	27.9	1.9	17.63	9.8 *(12.3)*	17.3 *(21.2)*	0.8 *(0.8)*	20.06 *(17.91)*
HEC	31.0	18.5	1.5	9.9	4.20 *(5.49)*	8.84 *(9.71)*	0.21 *(0.24)*	8.60 *(8.62)*
Total	77.1	46.4	3.4	27.53	14.0 *(17.79)*	26.14 *(30.91)*	1.01 *(1.04)*	28.66 *(26.53)*
Changes	Base				-81.8% *(-76.9%)*	-43.7% *(-33.4%)*	-70.3% *(-69.4%)*	+4.1% *(-3.6%)*

Table 29 – Emissions Inventory of CLP's and HEC's Power Plants(100 to 103)

However, the overall CO_2 emission was increased by 4.1% in 2011 compared to that in 2005. The increase in CO_2 was mainly attributed to CLP's increased use of coal fired generating due to dwindling gas supply from Yacheng gas field.

3.1.7 Emission Caps and Emission Reduction Targets

Fig. 9 shows the 2010 emission inventory of Hong Kong released by the Environmental Protection Department in October 2012 [104]. Electricity generation is still considered one of the major sources of emissions in Hong Kong, despite significant emissions reductions made by power plants in the past years.

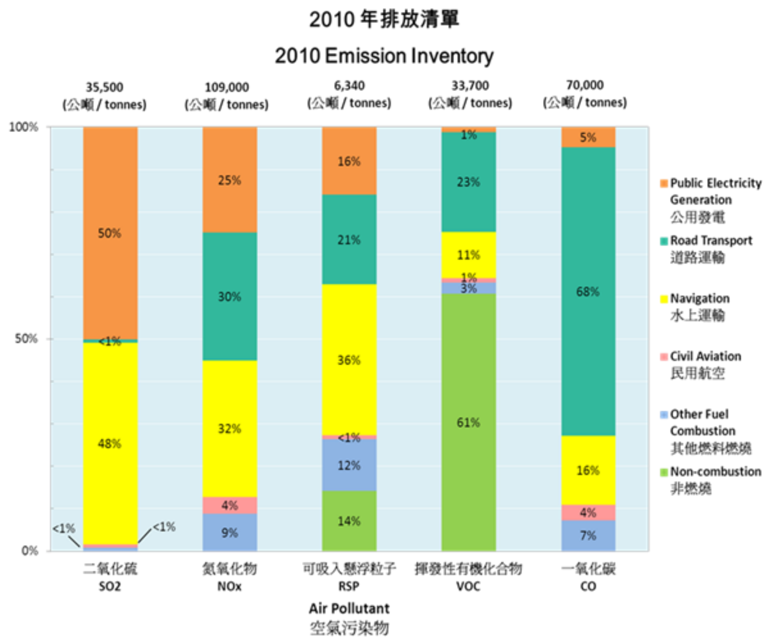

Fig. 9 – Hong Kong 2010 Emission Inventory(104)

3.1.7.1 Emission Caps for 2015 and 2017

Under the Air Pollution Control Ordinance, power plants are subject to licensing control, under which they are required to use the Best Practicable Means to prevent the emissions from causing air pollution. Emission caps on SO_2, NOx and RSP are imposed in the renewed licences of power plants since 2005. As shown in Table 30, the Authority has further tightened via the second Technical Memorandum emission allowances by 34% to 50% for the two power companies in relation to the emission years from 1 January 2015 (105 to 107). It is noted that there was and is still no statutory control of CO_2 emissions from power plants in Hong Kong.

The HKSAR Government presented a paper titled "Review of the Second Technical Memorandum for Allocation of Emission Allowances for Power Plants" (105 to 107) for discussion at the LegCo Environmental Panel Meeting on 4 July 2012. The paper sought Members' views on the proposal to reduce the emission allowances for power plants for the emission years starting from 1st January 2017 by way of issuing the third Technical Memorandum under section 26G of the Air Pollution Control Ordinance (Cap. 311). As shown in Table 31, the HKSAR government has further tightened via the 3rd Technical Memorandum emission allowances by 34% to 50% for the two power companies in relation to the emission years from 1 January 2017. It is noted that there was and is still no statutory control of CO_2 emissions from power stations.

It is interesting to note that HEC's actual emissions in 2011 would be able to comply with the 2017 Emission Caps on SO_2 and RSP even taking account of the projected increase in electricity consumption of up to 10%. But there is uncertainty in meeting the NOx emission cap due to the deterioration of gas turbine performance in both output capacity and capability of Low NOx burner system caused by aging effects.

It is worth noting that at the LegCo Economic Development Panel meeting on tariff reviews held on 11 December 2012, CLP pointed out the need to double the volume of gas in the fuel mix from 20.5% in 2011 to 45% in order to meet the 2015 emission caps [(108)]. This means that more than 45% of gas in fuel mix is required to meet the further tightening 2017 emission caps based on the assumption that the amount of imported nuclear power and the performance of coal plant in emission control remain unchanged. Certainly, any increase in imported nuclear from Daya Bay Nuclear Power Station would help emissions reduction.

3.1.7.2 Emission Reduction Targets for Hong Kong in 2015 and 2020

According to the Hong Kong Government's press release on 23 November 2012 [(109)], the governments of Hong Kong and Guangdong have laid down the 2015 and 2020 emissions reduction targets as shown in Table 32. It is believed that the electricity sector's share of 2015 emissions reduction should have been covered by the 2nd Technical Memorandum (Section 3.1.7.1). The impact of 2020 emissions reduction targets on the operations of electricity sector can be evaluated once the amount of allocation of each pollutant to the electricity sector is known. According to the 2010 emission inventory, it is expected the electricity sector and navigation sector would still take a large share of SO_2 reduction whereas the land transport sector and the navigation sector would be at the forefront in reducing NOx and RSP.

	Emission Caps for Power Plants (Tonnes per Year)			% of Gas in Fuel Mix
	SO_2	NOx	RSP	
HEC				
2010 Caps *(2010 Actual)* *(2011 Actual)*	9,370 *(5,490)* *(4,200)*	15,890 *(9,710)* *(8,840)*	470 *(240)* *(210)*	 33% 33%
2015 Caps	6,780	10,020	300	
2015 Caps/2010 Caps	-27.6%	-36.9%	-36.2%	
CLP				
2010 Caps *(2010 Actual)* *(2011 Actual)*	15,750 *(12,300)* *(9,800)*	26,710 *(21,200)* *(17,300)*	790 *(808)* *(800)*	 30.1% 20.5%
2015 Caps	5,702	17,532	531	
2015 Caps/2010 Caps	-63.8%	-34.4%	-32.8%	
Total (HEC + CLP)				
2010 Caps *(2010 Actual)* *(2011 Actual)*	25,120 *(17,790)* *(14,000)*	42,600 *(30,910)* *(25,840)*	1,260 *(1,040)* *(1,010)*	
2015 Caps	12,482	27,552	831	
2015 Caps/2010 Caps	-50.3%	-35.3%	-34.1%	

Table 30 – 2015 Emission allowances for existing power plants [(105 to 107)]

	Emission Caps for Power Plants (Tonnes per Year)			% of Gas in Fuel Mix
	SO_2	NOx	RSP	
HEC				
2010 Caps ***(2010 Actual)*** ***(2011 Actual)***	9,370 *(5,490)* *(4,200)*	15,890 *(9,710)* *(8,840)*	470 *(240)* *(210)*	33% 33%
2015 Caps	6,780	10,020	300	
2017 Caps	5,200	9,450	250	
2017 Caps/2015 Caps	**-23.3%**	**-5.7%**	**-16.7%%**	
CLP				
2010 Caps ***(2010 Actual)*** ***(2011 Actual)***	15,750 *(12,300)* *(9,800)*	26,710 *(21,200)* *(17,300)*	790 *(808)* *(800)*	30.1% 20.5%
2015 Caps	5,702	17,532	531	
2017 Caps	5,199	16,500	500	
2017 Caps/20105Caps	**-8.8%%**	**-5.9%**	**-5.8%**	
Total (HEC + CLP)				
2010 Caps ***(2010 Actual)*** ***(2011 Actual)***	25,120 *(17,790)* *(14,000)*	42,600 *(30,910)* *(25,840)*	1,260 *(1,040)* *(1,010)*	
2015 Caps	12,482	27,552	831	
2017 Caps	10,399	25,950	750	
2015 Caps/2010 Caps	-50.3%	-35.3%	-34.1%	
2017 Caps/2015Caps	**-16.7%**	**-5.8%**	**-9.7%**	

Table 31 – 2017 Emission Allowances for Existing Power Plants[105 to 107]

Emissions	SO_2	**NOx**	**RSP**	**VOC**
2010 (Tonnes)	35,500	109,000	6,340	33,700
2015 Targets	-25%	-10%	-10%	-5%
2020 Targets	-35% to -75%	-20% to 30%	-15% to 40%	-15%

Table 32 – Hong Kong 2015 and 2020 Emissions Reduction Targets [109]

3.2. Town Gas Sector

The Hong Kong and China Gas Company Limited, commonly known as Towngas, is one of the suppliers of gas to domestic, commercial and industrial customers in Hong Kong. It is the sole provider of town gas in Hong Kong sharing the market with LPG companies. Founded in 1862, it is one of the oldest listed and leading public energy utility in Hong Kong. It supplies town gas to 75% of Hong Kong households, and also to commercial and industrial customers with a supply reliability rate of over 99.9%. In June 2012, Towngas celebrated its 150 years services in Hong Kong [110].

3.2.1 Regulatory Framework [111]

There is a wide spectrum of both gas and electricity appliances for cooking and water-heating available in the market, creating a competitive energy market environment of which Towngas operates in.

Although Town gas is currently not subject to any price or profit regulation by the Hong Kong Government, it has entered voluntarily into an Information and Consultation Agreement (ICA) with the Hong Kong Government since 1997. The current 3-year ICA is valid till April 2015. The objective of the ICA is to increase transparency in Towngas' tariff setting mechanism, and to provide justification thereof, in the event of tariff adjustments. As stipulated in the ICA, Towngas needs to consult the Government three months in advance and upon request, brief the Legislative Council Panel on Economic Development and the Energy Advisory Committee on tariff adjustments. Furthermore, Towngas is required to disclose certain corporate information to the public on an annual basis (111).

The Gas Standards Office of the Electrical and Mechanical Services Department is the enforcing body of the Gas Safety Ordinance to control, in the interest of public safety, the importation, manufacture, storage, transport, supply and use of gas, including town gas, and other related matters.

3.2.2 Town Gas Production

In Hong Kong, town gas is produced at two production plants (Fig. 10) with a total production rate of 12 million m^3 per day. Major supplies of 97% come from the Tai Po Plant, with the Ma Tau Kok Plant making up the rest. Since, 1973, Naphtha with low sulphur content has been used as feed stock for manufacturing town gas (112).

In 1999, Towngas built Hong Kong's first landfill gas (LFG) utilisation plant at the Shuen Wan Landfill. LFG is treated on site and then transmitted through 1.3km of underground pipelines to the Tai Po production plant for use in the gas production process. Liquefied Natural gas (LNG) supplied through a 34-kilometre twin submarine pipeline from Guangdong LNG Terminal in Shenzhen to Tai Po plant for production of town gas, was introduced as dual feed stock in 2006. In 2007, Towngas began collecting LFG from the Northeast New Territories Landfill. LFG is treated on site to remove carbon dioxide, hydrogen sulphide and non-methane hydrocarbons and then transferred through a 19-km long pipeline to Tai Po Production Plant, where it is used as a heating fuel for gas production (113).

Fig. 10 Taipo (left) and Ma Tau Kok (right) Gas Production Plant (Courtesy Towngas).

As in 2010, natural gas accounted for about 57% of production fuel while LFG accounted for about 2.3% and naphtha makes up the balance (113). As Shown in Table 33, the sale of volume of town gas in Hong Kong remains steady from 2005 to 2010.

	2010	2009	2008	2007	2006#	2005
SO_2 Factor kg/million MJ	0.03	0.03	0.048	0.04	0.03	0.04
SO_2 * (tonnes)	0.827	0.818	1.320	1.080	0.810	1.090
Change	-24.1%					Base
NOx Factor (kg/million MJ)	4.59	4.39	4.55	4.68	6.82	8.16
NOx *(tonnes)	126.6	119.7	125.5	126.6	184.4	222.5
Change	-43.1%					Base
CO_2 (tonnes)	355,958	357,043	370,647	360,388	420,601	448,654
Change	-20.7%					Base

LNG Commenced in mid 2006

Table 33 – Operating Data of Towngas (2005 – 2010) (113)(114)

3.2.3 Emission Performance and Challenges

Towngas's decision to introduce NG in 2006 as the key initiative for cleaner production of town gas was commendable. As shown in Table 34, the reduction of SO_2 by 24.1%, NOx by 43.1% and CO_2 by 20.7% emissions in 2010, using 2005 as base year are clearly attributed to the adoption of 57% of NG as feedstock. It is reckoned that completed replacement of naphtha by NG would almost eliminate SO_2 emission, and reduce NOx to less than 50 tonnes and SO_2 to less than 300,000 tonnes.

It is noted that the sale of town gas in 2010 was 27,578 million MJ which is about 18% of that of electricity consumption of 41.86 billion kWh (150,700 million MJ). Given naphtha is cleaner than coal, the amount of SO_2, NOx and CO_2 emissions from the consumption of town gas for cooking/heating is significantly less than the electricity sector (see Table 29).

	2010	2009	2008	2007	2006	2005
Installed Capacity (million m^3/day	12	12	12	12	12	12
Feedstock	Naphtha, LNG & LFG	Naphtha, LNG & LFG	Naphtha, LNG & LFG	Naphtha, LNG & LFG	Naphtha, LNG & LFG	Naphtha, & LFG
Towngas Sale (million MJ)	27,578	27,274	27,583	27,041	27,043	27,261

Table 34 – Town gas Production Emission Data (113)(114)

3. 3. Transport Sector

The transport sector in Hong Kong includes road transport, sea transport and air transport. According to the Study Brier, the scope of study covers land transport and local ferries only. Hong Kong has a highly developed and sophisticated local transport network, encompassing both public and private transport. The public transport systems include railways, trams, buses, minibuses, taxis and ferries. Everyday, about 11.6 million passenger journeys are made through the public transport system, accounting for 90% of all daily passenger trips, which makes it the highest rate in the world[115]. The high carrying capacity of the public transport makes Hong Kong a global role-model of efficient transport system. However, transport and particularly road transport has long been recognized as a major contributor to the local environmental issues such as declining air quality [116, 117].

3.3.1 Regulatory Framework

Hong Kong's road transport activities are primarily regulated by the Road Traffic Ordinance (Cap 374)[118]. The Ordinance not only regulates road traffic, vehicle and users of roads and related matters, but also includes provisions to limit pollution from vehicles. It limits the pollution from motor vehicles by enforcing the emission standards through requiring the vehicles to take an emission tests at authorized emission testing centers.

Unlike the government-sponsored transit systems of many other cities, Hong Kong's public transport is operated by private companies. In order to regulate the operations of these privately-operated public transport systems, there are different ordinances specifically for different transport services. For example, the Mass Transit Railway Ordinance (Cap. 556) provides the granting of a franchise to the MTR Corporation Limited to operate the Mass Transit Railway and to construct and operate any extension to the Mass Transit Railway[119]. It regulates the operations of the railway and certain bus services under the franchise, including all aspects of safety concerning those railways. Similarly, in the public bus sector, the bus operators are regulated by the Public Bus Services Ordinance (Cap. 230) ("PBSO") which provides for the granting of franchises to operate public bus services on specified routes, and the regulation of the operation and maintenance of such services[120].

3.3.2 Local Transport

With about 293 licensed motor vehicles on every kilometer of the road[115], Hong Kong hosts the highest traffic density in the world[121]. Table 35 shows a breakdown of motor vehicles licensed by type. Among all the motor vehicles types, private cars account for a largest proportion in terms of fleet size, which is nearly 70%. By comparing the vehicle number between 2005 and 2011 (Table 36), it is interesting to find that the number of total motor vehicles has increased by 89,641 from 2005 to 2011, among which 84,090 vehicles are private cars, accounting for more than 93% of the increased fleet.

Apart from motor vehicles, there are also railways, trams and ferries in operation in Hong Kong. Railways (including Mass Transit Railway, Airport Express and Light Rail) are the backbone of Hong Kong's public transport system which account for about 37% of all trips made on public transport each day. Trams include a total of 161 double-deck electric trams (for trips between Shau Kei Wan and Kennedy Town and around Happy Valley) and a cable-hauled funicular railway (running between Central and the Peak)[115]. Another type of transport mode that plays a role in meeting people's mobility needs is local ferries. A total of 12 operators provide 20 regular licensed and two franchised passenger ferry services to outlying islands and cross the Victoria Harbour. In 2010, about 136,000 passengers took local ferry services daily [122].

Type	2005 (‘000)	2011 (‘000)
Private cars	351	435
Motor cycles (including motor tricycles)	34	39
Taxis	18	18
Buses, public and private	13	13
Light buses, public and private	6	7
Goods vehicles	111	111
Special purpose vehicles	1	1
Government vehicles (excluding military vehicles)	6	6
Total	540	630

Table 35 – Motor Vehicles Licensed by Type

3.3.3 Fuel-Mix for Transport

Today’s vehicles run on a variety of fuels. In addition to petrol/gasoline that is still used in the vast majority of vehicles, there are a number of alternative fuels available that offer the potential to reduce the consumption of hydrocarbon fuel and hence minimize the amount of harmful emissions, though each comes with its own merits and drawbacks. In Hong Kong, most vehicles are currently powered by petrol, diesel, liquefied petroleum gas (LPG).

	Total licensed motor vehicle	Motor vehicles per 1000 population	Total licensed private cars	Private cars per 1000 population
2005	540,640	77.6	350,753	50.4
2011	630,281	88.7	434,843	61.2
Change	+89641 (+16.6%)	+11.1 (+14.3%)	+84090 (+24.0%)	+10.8 (+21.4%)

Table 36 – Comparison of Number of Motor Vehicles in 2005 and 2011 [123-126]

3.3.3.1 Petrol/Gasoline

Petrol/gasoline is the most common fuel used in cars today. The popularity of petrol could be attributed to the fact that it is the most readily available fuel and allows vehicles for quick starting, fast acceleration, easy combustion and quiet operation[127]. However, petrol produces toxic exhaust chemicals such as carbon monoxide, hydrocarbons and nitrogen oxides that contribute to pollution, smog and global warming. Moreover, petrol is made from crude oil which is non-renewable and will probably be exhausted one day. Heavy reliance on petroleum products therefore poses a potential threat to energy security.

Unleaded petrol is the most environmentally friendly form of petrol and is widely used in Hong Kong. More than 70% of motor vehicles in Hong Kong currently run on unleaded petrol fuel and most of them are private cars and motor cycles.

3.3.3.2 Diesel

Diesel fuel is widely used in transport vehicles such as trucks, buses, boats and trains. Diesel vehicles tend to last longer than petrol vehicles, and have a 30 % better fuel efficiency than the average petrol vehicle(127). Compared with petrol vehicles, diesel vehicles release less carbon dioxide, but create more organic compounds and nitrous oxide that contribute to ozone smog. Diesel is also made from the non-renewable energy source of crude oil. Ultra low sulphur diesel (ULSD) is a cleaner form of diesel that reduces emissions of black smoke, particulates, hydrocarbons, carbon monoxide and carbon dioxide compared to standard diesel.

About 24% of motor vehicles in Hong Kong, particularly goods vehicles and buses, are powered by diesel. Since April 2002, ULSD (with a sulphur content of 0.005%, Euro IV requirement) has been the statutory minimum requirement for motor vehicle diesel(128). However, it is worth noting that the majority of local vessels, including ferries, are using diesel fuel with sulphur content of 0.5%(128).

3.3.3.3 Liquefied Petroleum Gas

Liquefied Petroleum Gas (LPG) is a hydrocarbon fuel which is made up of mainly propane and butane. It is usually regarded as a clean fuel alternative to gasoline and diesel. LPG is free of lead and most additives, and also contains very little sulphur. Compared with petrol and diesel, LPG produces fewer toxins when burned and does not contribute to smog in the same way that diesel and gasoline do (114).

At present, there are 62 LPG filling stations (Fig. 11) in operation in Hong Kong. About 99.9% taxis in Hong Kong have switched from diesel to LPG since the end of 2003. About 60% of the registered public light buses (Fig. 11) are also fueled by LPG.

Fig. 11 LPG Filling Station (Left) and LPG Bus (Right) (129)

3.3.3.4. Natural Gas

Natural gas is a clear, odorless and non-corrosive gas that can be stored in tanks as compressed natural gas (CNG) or liquefied natural gas (LNG) to run a combustion engine(129). Since natural gas requires no vaporisation, it has lower idling speeds, better performance and a more complete combustion, all of which help reduce emissions(129). It is estimated that vehicles fitted with a CNG fuel system can produce 80 percent less ozone-forming emissions than gasoline burning cars (129). However, some studies estimate that CNG will actually produce more greenhouse gas emissions when upstream methane losses along pipelines are considered(129).

At present, supply of natural gas to Hong Kong is confined to two power companies as fuel for electricity generation, as well as to Towngas as feed stock for manufacturing town gas for cooking and heating. It is not too clear that whether the MOU[12] signed by the Hong Kong and Central governments in August 2008 to assure adequate natural gas to Hong Kong for the next 20 years also cover the transport sector. Significant up-front investment on transmission and storage infrastructure is required before introduction of natural gas vehicles[129] (Fig. 12).

3.3.3.5 Bio-diesel

Bio-diesel is a renewable fuel manufactured from vegetable oils, animal fats, waste cooking oil, sugar beet etc. It can be used to power motor vehicles in pure form or in blends with motor vehicle diesel. Bio-diesel burns much cleaner than gasoline or diesel and produces far less carbon dioxide emissions when used. It has similar performance with Euro V diesel in respect of the potential to improve roadside air quality[132].

At present, there are three biodiesel production plants in Hong Kong. In order to promote the use of biodiesel, the Government has set out specifications for pure biodiesel and biodiesel blended with motor vehicle diesel in the Air Pollution Control (Motor Vehicle Fuel) Regulation (Chapter 311L) in 2010 so as to ensure fuel quality, boost users' confidence and help control its impact on the environment. The government has also introduced duty-free incentive for motor vehicle bio-diesel[132].

Fig. 12 – Natural Gas Vehicle[129]

3.3.3.6. Ethanol and Methanol

Ethanol is a bio-fuel alternative fuel made from the fermentation and distillation of starch, generally from crops. Ethanol has become popular as a fuel source because in most cases it is one of the only fuels that can fuel a gasoline engine without modifications of the engine[132]. Ethanol is most commonly blended with petrol to increase octane and reduce emissions. Similarly, methanol (also known as wood alcohol) has been used as an alternative fuel, which can be blended with petrol, or used as raw materials to produce hydrogen for fuel-cell[132]. Currently, there is no ethanol fuel producers or importers in Hong Kong[132].

3.3.3.7. Electric Vehicle

Electric Vehicles (EVs) have been heralded as one promising solution to sustainable transport. The major characteristic of EVs is that the torque is supplied to the wheels by an electric motor that is powered either solely by a battery or in combination with an internal combustion engine. EVs can be categorized into six main types: hybrid electric vehicles (HEVs), battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), photovoltaic electric vehicles (PVEVs), fuel cell vehicles (FCVs) and supercapacitor-driven vehicles (typically buses)(133).

HEVs usually have a gasoline or diesel engine and an electric battery-powered motor. HEVs are often not plugged into an electricity source but recharge their batteries while braking, cruising, and idling(129). Hybrid vehicles are more fuel efficient and produce less harmful emissions than petrol/diesel cars as the internal combustion engine only operates for a fraction of the time. It is reported that fuel saving can be up to 40 - 50% for HEVs currently available in the market when compared with a petrol vehicle of similar specifications(128). Since hybrid electric vehicles do not require external charging of the battery, there is no need to build up expensive charging infrastructure which is required for pure electric vehicles.

Plug-in Hybrid Electric Vehicles refer to vehicles that can use, independently or not, fuel and electricity, both of them rechargeable from external sources(133). PHEVs can be seen as an intermediate technology between BEVs and HEVs.

BEVs are vehicles propelled solely by electric motors. The source of power stems from the chemical energy stored in battery packs which can be recharged on the electricity grid(133). The future of BEVs strongly depends on the battery developments including its performance and cost. The biggest environmental benefit of BEVs is the zero tailpipe emissions.

FCV is a type of hydrogen vehicle which uses a fuel cell to produce electricity, powering its on-board electric motor. Hydrogen engines are significantly more efficient than conventional engines and their only emissions are heat and water vapor. FCVs are envisaged as vehicles of the future as their potential benefits are substantial. However, it faces several technological challenges. Experts estimate that it will take 10-20 years of research and development before FCVs can begin to make an impact(133).

Fig. 13 – EV Battery Charge (Left) and Electric Light Bus (Right) (134)

By October 2011, there were about 220 registered BEVs (33 government-owned and 190 private and business-owned) and more than 330 EVs standard chargers in operation in Hong Kong(134). In order to promote the use of EVs, the charging facilities available for use by the public are basically offering free services. The government has waived the First Registration Tax for EVs till end March 2014. The number of charging stations throughout the territory has also increased to 1,000 by 2012 as announced by the government(134).

3.3.4 Energy Consumption

Year	Transport Sector (TJ)	All Sectors (TJ)
2005	97,361 (35%)	281,179
2006[#1]	94,784 (34%)	281,880
2007	97,521 (33%)	286,910
2008	91,991 (32%)	285,430
2009	90,242 (32%)	283,540
2008	91,991 (32%)	285,430
2009	90,242 (32%)	283,540

[#1]Not including electricity consumption at railway/bus stations from 2006 onwards

Table 37 – Transport Energy End-use (2005-2009)[(7)(8)]

As shown in Table 37, the amount of energy consumed in the transport sector has been in the order of 32 to 35% of Hong Kong's total energy consumption since 2005. However, there is a gradual reduction of energy consumption in the transport sector in 2008 and 2009 which is in line with the overall situation. This could be attributed to the global economic slowdown as well as the active energy savings drive by the HKSAR Government.

Table 38 shows a further breakdown of energy end-use by fuel type from 2005 to 2009. It appears that transport sector consumes a large portion of oil, which suggests the need to reduce reliance on non-renewable energy not only to cut down emissions but enhance energy security. It is necessary to switch major vehicle fuel from petrol and diesel to alternative clean fuels.

Year	**Electricity(TJ)**		**Town Gas & LPG (TJ)**		**Coal & Oil (TJ)[#2]**		**Total Transport (TJ)**
	Transport[#1]	All sectors	Transport	All sectors	Transport[#3]	All sectors	
2005	5,163	144,171	12,719	43,656	79,479	93,352	97,361
2006	2,444	145,204	13,831	43,150	78,510	93,526	94,785
2007	2,495	147,072	14,034	43,363	77,992	96,475	94,521
2008	2,520	147,345	14,883	44,264	74,588	93,821	91,991
2009 (% of sector)	2,523 (7%)	149,366 (100%)	15,389 (34.8%)	44,206 (100%)	72,331 (80.4%)	89,968 (100%)	90,242

[#1]Starting from 2006, the end-use figure does not include electricity consumption at railway/bus stations
[#2]Excluding coal and oil consumed for electricity production, remaining coal is for cement/steel works
[#3] Majority of energy in this fuel category consumed by the transport sector is oil (petrol and diesel)

Table 38 – Breakdown of Energy End-Use by Fuel Type[(7)(8)]

Table 39 shows the energy end-use in transport sector by segment. Overall, passenger segment uses more energy than freight segment. However, in terms of specific vehicle type, it appears that goods vehicle is the biggest energy consumer, followed by bus and car.

Year	Freight Segment (TJ)		Passenger Segment (TJ)						Total (TJ)
	Goods vehicle	Others[#1]	Bus	Taxi	Car	Motor cycle	Rail[#2]	Others	
2005	32,830	6,793	20,243	11,323	16,682	454	5,163	3,873	97,361
2006	32,551	6,601	20,127	12,351	16,267	426	2,444	4,017	94,784
2007	31,771	6,411	19,666	12,623	17,118	463	2,495	3,973	97,521
2008	30,438	5,285	18,815	13,555	17,059	480	2,520	3,839	91,991
2009	28,729	4,374	18,862	14,001	17,421	468	2,523	3,864	90,242

[#1] *End-uses under this heading includes rails and marine energy uses, etc.*

[#2] *End-uses under this heading includes marine and internal air transportation energy uses, etc.*

Table 39 Energy End-Use by Segment (2005-2009)(7)(8)

3.3.5 Fleet Mix and Emission Inventory

3.3.5.1. Fleet Mix by Fuel Type

Tables 40 and 41 show the fleet mix of transport vehicles in Hong Kong by fuel type in 2005 and 2011 respectively. It can be seen that about 72% of vehicles are powered by petrol and about 24% by diesel. Despite active promotion by the government as mentioned in Section 3.3.3.7, the number of electric vehicles grows rather slowly from 56 to 276 over a period of 7 years.

	Petrol	**Diesel**	**Electric**	**LP Gas**	**Others**	**Total**
Motor Cycles	34,018	1	5	0	1	34,025 (6.37%)
Private Car	348,797	1,946	5	0	5	350,753 (65.65%)
Taxis	0	9	0	18,001	0	18,010 (3.37%)
Bus	0	13,269	2	0	0	13,271 (2.48%)
Light bus	5	3,683	1	2,515	0	6,204 (1.16%)
Goods vehicles	2,304	108,681	4	0	0	110,989 (20.77%)
Special purpose vehicles	80	762	39	97	16	994(0.19%)
Total[#]	385,204 (72.10%)	128,351 (24.02%)	56 (0.01%)	20,613 (3.86%)	22 (0.00%)	534,246

[#] Excluding government vehicles

Table 40 – Fleet Mix by Fuel Type in 2005

	Petrol	Diesel	Electric	LP Gas	Others	Total
Motor Cycles	38,591	1	15	0	10	38,617 (6.19%)
Private Car	432,628	2,021	172	0	22	434,843(69.69%)
Taxis	5	2	0	18,125	0	18,132 (2.91%)
Bus	0	13,277	0	0	0	13,277 (2.13%)
Light bus	2	3,170	4	3,369	0	6,545 (1.05%)
Goods vehicles	1,174	109,984	6	0	0	111,164 (17.82%)
Special purpose vehicles	89	1,056	79	178	4	1,406 (0.23%)
Total#	472,489 (75.72%)	129,511 (20.76%)	276 (0.04%)	21,672 (3.47%)	36 (0.01%)	623,984

Excluding government vehicles

Table 41 – Fleet mix by fuel type at end of 2011

A breakdown of private cars and franchised bus based on European emission standard is given in Tables 42 and 43. As of 2011, about 45% of private cars achieve the emission standard of Euro IV or above. But still, about 25% are equipped with Euro II or older engines. The oldest diesel engines (Euro II and below) are 34 times dirtier than the newer, cleaner engines (Euro VI and above). The situation in franchised bus is even worse. As of 2009, more than 75% of buses on Hong Kong's roads are equipped with Euro II or older engines, only less than 1% of buses meet the current cleanest engine standards.

Vehicle Class	**Emission Standards**				
	Pre-Euro	Euro I	Euro II	Euro III	Euro IV or above
	No of Licensed Vehicles				
Petrol	13,402	45,257	50,463	126,312	197,194
Diesel	986	639	65	3	328
Total#	14,388	45,896	50,528	126,315	197,522
	3.3%	10.6%	11.6%	29.1%	**45.4%**

#Hybrid vehicles are classified as petrol vehicles. Thus, Transport Department does not have separate statistics for hybrid vehicles

Table 42 Breakdown of Private Cars Fleet by Emission Standard (2011)

	Emission Standards				
	Pre-Euro	Euro I	Euro II	Euro III	Euro IV or above
	No of Licensed Vehicles				
Bus	456	1338	2688	1233	53
% of total fleet	7.9%	23.2%	46.6%	21.4%	0.9%
Total	5768				

Table 43 Breakdown of Franchised Bus Fleet by Emission Standard (2009) [135]

3.3.5.2 Emission Inventory

According to the Consultation Document on *Hong Kong's Climate Change Strategy and Action Agenda for the Coming Decade* [14], the transport sector is the second largest emission source of GHG emissions, contributing to about 18% of the total carbon emission profile in 2008. Road transport dominates the carbon emissions in this sector. Furthermore, according to the EPD's 2007 air mission inventory (Table 44), road transport is a major contributor to Hong Kong's air pollution. It accounts for 82%, 30%, 22% and 20% of Hong Kong's carbon monoxide (CO), RSP, NOx and volatile organic compounds (VOC) emissions, respectively[136].

It is worth noting that the air quality impact of marine navigation is also a concern. The ocean-going vessels use sulphur-heavy fuel of 4.5% sulphur and local ferries use fossil diesel with sulphur content of 0.5%. The 2007 air emission inventory shows that SO_2, NO_X and RSP (PM_{10}) emitted from all types of ships account for 5%, 16% and 7% respectively of the total emissions in Hong Kong.

Pollution Sources	**SO_2**	**NOx**	**RSP**	**VOC**	**CO**
Public Electricity Generation	60,400	44,800	1,600	435	3,540
Road Transport	475	20,900	1,680	7,770	59,200
Marine Navigation	3,670	15,100	416	265	2,170
Civil Aviation	308	5,350	23	296	2,160
Other Fuel Combustion[1]	3,300	11,000	1,180	1,160	4,970
Non-combustion[2]	NA	NA	734	29,800	NA
Total	68,100	97,200	5,640	39,700	72,000

Table 44 – 2007 Hong Kong Air Pollutants Emission Inventory

Since road transport has an impact on Hong Kong's GHG emissions and other pollutant emissions, detailed breakdown of emission inventory of motor vehicles in 2005 and 2011 is also provided in Table 45. These data are calculated using the EMFAC-HK model developed by EPD[137]. Based on the emission inventory shown in Table 43, it is worth noting the following:

- Goods vehicle fleet (98.9% running on diesel), producing most RSP (73.9%), NO_X (47.9%), SO_X (39.6%) and CO_2 (39.9%) among all the motor vehicle types, is the dominant roadside polluter.
- Private car fleet (99.5% running on petrol) is the second largest emission source of CO (30%), SO_2 (23.8%) and CO_2 (23.5%). The emissions of several pollutants from private car are significantly reduced in 2011 compared to that of 2005, except CO2 emissions which increases by 22%.
- Taxi fleet (100% running on LPG) produces most CO (31.9%); motor cycle fleet

(99.9% running on petrol) produces most VOC (37.2%); and bus fleet produces the second most NO_X (25.8%) and RSP (14.3%).

	CO	VOC	NO_X	RSP	SO_X	CO_2
Private Car (Tonnes/year)						
2005	33,819	3,429	2,984	63	23	860,984
2011	13,543	1,291	776	72	5	1,050,872
Taxi (Tonnes/year)						
2005	11,350	318	5,126	1	18	656,697
2011	14,364	553	6,871	0	3	667,176
Goods vehicles (Tonnes/year)						
2005	7,917	2,914	19,984	1,555	48	1,867,548
2011	6,012	1,897	16,238	1,031	8	1,784,956
Light Bus (Tonnes/year)						
2005	3,449	416	950	106	6	222,665
2011	4,108	640	1,090	80	1	221,511
Bus (Tonnes/year)						
2005	2,534	431	9,776	432	18	716,473
2011	1,655	287	8,745	200	3	710,327
Motor cycles (Tonnes/year)						
2005	7,877	2,797	205	16	0	30,299
2011	5,404	2,763	172	12	0	33,281
Total (Tonnes/year)						
2005	66,947	10,304	39,025	2,172	112	4,354,665
2011	45,086	7,432	33,892	1,395	20	4,468,122

Table 45 - Emission Inventory of Motor Vehicles in 2005 and 2011

4. FRAMWORK OF STRATEGY FOR CONTROL OF EMISSIONS

4.1 Government's Proposals

4.1.1 Overview of Proposed New Air Quality Objectives in 2014

In 2007, the Government commissioned a consultancy study to review Hong Kong's existing Air Quality Objectives (AQOs) which were established in 1987 and to develop a long-term air quality management strategy. Taking into account the World Health Organization (WHO)'s new guidelines and practices in other advanced countries, the review proposed a set of new AQOs benchmarked against the WHO's Interim Targets and Air Quality Guidelines, accompanied by a host of proposed air quality improvement measures that are required to help Hong Kong achieve the new objectives. The proposed new AQOs (Table 46) announced by the Secretary for the Environment on 7 January 2012(15) are said to be comparable to those being adopted by the European Union and the United States. Taking account of the lead time for completing the legislative process and other necessary preparatory work, including formulation of modelling guidelines and compilation of emissions inventories, it is expected that the proposed new AQOs would take effect in 2014.

Pollutants	Avg. Time	Existing AQOs		Proposed AQOs				
		(µg/m^3)	No of Exceed-ances Allowed	WHO IT-1[3] (µg/m^3)	WHO IT-2[3] (µg/m^3)	WHO IT-3[3] (µg/m^3)	WHO AQG (µg/m^3)	No of Exceed-ances Allowed
Sulphur Dioxide	10-min	--	--	-	-	-	**500**	3
	24-hr	350	1	**125**	50	-	20	3
Respirable Suspended Particulates (PM10)	24-hr	180	1	150	**100**	75	50	9
	Annual	55	NA	70	**50**	30	20	NA
Fine Suspended Particulates (PM2.5)	24-hr	--	--	**75**	50	37.5	25	9
	Annual	--	--	**35**	25	15	10	NA
Nitrogen Dioxide	1-hr	300	3	-	-	-	**200**	18
	Annual	80	NA	-	-	-	**40**	NA
Ozone	8-hr	240 [1]	3	**160**	-	-	100	9
Carbon Monoxide	1-hr	30,000	3	-	-	-	**30,000**	0
	8-hr	10,000	1	-	-	-	**10,000**	0
Lead	Annual	1.5 [2]	NA	-	-	-	**0.5**	NA

(shaded) Proposed new AQOs

Table 46 – Proposed New AQOs for Hong Kong in 2014

To attain the new AQOs, Hong Kong Government has drawn up the following 19 air quality improvement measures[138], and has been pressing ahead with implementation of measures over which the community has wider consensus.

Emission Capping and Control

i) Increasing the ratio of natural gas in local electricity generation to 50%
ii) Early retirement of aged/heavy polluting vehicles
iii) Earlier replacement of Euro III commercial diesel vehicles with latest Euro standards
iv) Wider use of hybrid and electric vehicles
v) 0.1% sulphur diesel for local vessels
vi) Government vessels to reduce NOx emissions
vii) Electrification of aviation ground support equipment
viii) Emission control for off-load vehicles/equipment
ix) Strengthening VOC control

Traffic Related Measures

x) Low emission zones
xi) Car-free zone and pedestrianisation scheme
xii) Bus route rationalization

Infrastructure Development and Planting

xiii) Expand rail network
xiv) Develop cycle tracks in new development areas

Energy Efficiency Measures

xv) Mandatory implementation of Building Energy Codes
xvi) Energy efficiency standards for domestic electrical appliances
xvii) LED for traffic signal/street lighting
xviii) Tree planting/roof-top greening
xix) District cooling system for Kai Tak Development

According to the Panel on Environmental Affairs Paper dated 16 April 2012[138], modeling results show that with implementation of the above proposed air quality improvement measures coupled with the continuous efforts of Guangdong in reducing air pollution, Hong Kong's ambient air quality would broadly comply with the proposed new AQOs.

4.1.2 Overview of Proposed Carbon Emissions Reduction Targets

In September 2010, Hong Kong Government launched a public consultation document titled *"Hong Kong's Climate Change Strategy and Action Agenda for the Next Decade"* [14]. The consultation document identified electricity generation and transport sector as the major local Greenhouse gas (GHG) emission sources (Table 47).

Year 2008	Electricity	Transport	Others	Total
Energy (TJ)	147,340	89,470	48,530	285,340
Energy (%)	52%	31%	17%	
CO_2 (KT)	28,000	7,350	6,650	42,000
CO_2 (%)	67%	18%	15%	100%

Table 47 - Local Sources of CO_2 Emissions in 2008[14]

The consultation document proposed that Hong Kong should adopt a voluntary carbon intensity reduction target of 50% to 60% by 2020 as compared with 2005 level, representing a 19% to 33% absolute reduction in the total GHG emissions in Hong Kong. Per capita emission is also expected to be reduced to 3.6 to 4.5 tonnes for Hong Kong (Table 48).

	2005	2008	2020
Carbon Footprint	6.2T/Capita	6.0T/Capital	3.6 to 4.5T/Capita
Total Carbon (kT)	42,000	42,000	28,140 to 34,020
Carbon Intensity (kg/HK$GDP)	0.029	0.025	0.0116 to 0.0145

Table 48 - Proposed GHG Emissions in 2020[14]

To attain the proposed carbon emission targets, the Government has drawn up the following mitigation measures[14], and has been pressing ahead with implementation of measures over which the community has wider consensus.

i) Maximizing energy efficiency
ii) Greening road transport
iii) Promoting use if clean fuels for motor vehicles
iv) Turning waste to energy
v) Revamping fuel mix for electricity generation

According to the Secretary for the Environment's reply to question raised at the Legislative Council on 2 November 2011 [139], over 1,200 responses were received during the more than three months consultation period completed in December 2011. It is noted that respondents were in general in support of implementing measures to combat climate change, and grasping the opportunity to develop a low carbon economy.

4.2. Electricity Sector

The small geographic area, dynamic urban environment and vibrant social and business activities conducted mostly in high-rise buildings and tall structures pose unique challenges to the electricity sector in meeting the following Government's policy objectives.

(i) to ensure that the electricity needs of the community are met safely, reliably, efficiently and at reasonable prices; and

(ii) to minimise the environmental impact of electricity production and use and promote the efficient use and conservation of electricity

The impact of the Government's proposals for control of emissions from the electricity sector is addressed with due consideration of the aforesaid objectives.

4.2.1 Impact of Proposed New AQOs

It is noted among the control measures proposed for achieving the new AQOs in 2014, raising the use of natural gas in the fuel mix of local electricity generation to 50% and prioritizing the use of coal-fired generation units equipped with advanced emission control equipment are key measures for the power sector. Given the imported nuclear power constitutes about 22.3% (74.1% x 30.1% in Tables 25 and 26) of overall fuel mix in 2011, 50% natural gas in the fuel mix for local generation represents 38.85% (50% x (1- 22.3%)), say, 40% in 2014.

However, as far as the power companies are concerned, the statutory requirement is to meet the limits of SO_2, NOx and RSP emissions stated in the Specified Process Licenses for their power plants. In the absence of information of the 2014 power plants licensing emission limits in the public domain, it is logically to believe that the emission allowances stipulated in the Technical Memorandum for 2015 as shown in Table 30 (Section 3.1.7.2) should be more stringent.

4.2.1.1 Impact on HEC's Operations

It is worth noting that HEC's actual SO_2, NOx and RSP emissions recorded in 2011 as shown in Table 30 (Section 3.1.7.2) are lower than the statutory 2015 emission caps ranging from 12% to 30%. Assuming the electricity demand in 2015 is to increase by 5%, it means that HEC can still meet the 2015 emission caps without the need to increase its current 33% natural gas in fuel mix and hence no new gas-fired unit installation is deemed necessary. Actually, the use of 50% gas in fuel mix for local generation, (i.e. 40% gas in fuel mix for electricity generation at Lamma Power Station) to achieve the proposed new AQOs in 2014 is not practical for HEC as the lead time required to install a new gas-fired unit is four years from receiving Government's approval to proceed. Technically, HEC's fuel mix of 33% gas and 67% coal adopted in 2011 can continue till 2015.

It is believed that no addition of new gas-fired unit is needed and the current two gas supply contracts, viz. 2006 for 25-year term and 2010 for 5 year-term can provide required LNG at least to 2014. Hence capital expenditure on generation facilities and adjustment of 2012 estimated gas price of US$12.64/mmBtu (HK$93.4/GJ) (average of two gas supply contracts) stated in the paper tabled by HEC at the LegCo Economic Development Panel meeting on tariff reviews held on 11 December 2012 [(140)] would not be significant. Given the tariff increase for 2013 is 2.9% compared to 2012[(140)], it is believed that pressure on tariff adjustments due to implementation of new AQOs in 2014 is likely moderate.

4.2.1.2 Impact on CLP's Operations

As shown in Table 30 (Section 3.1.7.2), the reduction of CLP's SO_2 and NOx emissions in 2011 compared with those in 2010 was attributed to the completion of FGD and SCR retrofit projects for the four 677MW coal-fired units at Castle Peak Power Station despite the fact that the amount of coal in the fuel mix increased from 39.8% to 49.1% and gas decreased from 30.1% to 20.5% (Table 28). It is believed that the significant reduction of amount of natural gas in fuel mix for electricity generation is due to the dwindling gas reserve in Yacheng 13-1 gas field.

CLP stated in the paper [108] tabled at the LegCo Economic Development Panel meeting on tariff reviews held on 11 December 2012 the need to double the gas volume from the 2011 level i.e. from 20.5% to 45%, to meet the 2015 emission caps. This would be more than that required by the Government on power sector for achieving the proposed new AQOs. Assuming that the amount of electricity generated (including imported nuclear power) for CLP's local customers' consumption is about 36 billion kWh in 2015 (5% increase from 2010) and based on capacity factor of 85%, it is reckoned that CCGT gas-fired units at Black Point Power Station with an installed capacity of 2,500MW should be able to generate up to 50% of required electricity. Furthermore, two 677MW coal-fired units which have dual-fuel (coal and gas) capability can serve as back-up in the event of unexpected unavailability of CCGT gas-fired units.

The dwindling gas reserve in Yacheng 13-1 gas field and the need for doubling the volume of natural gas in 2015 compared to that in 2011 to meet the emission caps require new sources of gas supply. On 8 May 2012, CLP warned that soaring price of natural gas from new supply sources could push electricity bills 40 % higher in the next few years [141].

It is worth noting that CLP pointed out in its submission [108] to LegCo Economic Panel that the estimated fuel cost in 2013 would increase by HK$2,117 million due to the use of more expensive gas (US$14/mmBtu) from the South China Sea under short-term gas to make up the shortage of gas (US$6/mmBtu) from the depleting Yacheng 13-1 gas field. With the special rebate of 2.1cents, HK$700 million (part of the increased fuel cost) put into the Fuel Clause Recovery Account and return of HK$555million from the Tariff Stabilisation Fund, the tariff increase for 2013 can be brought down to 5.9% compared to 2012. With the supply of more expensive natural gas (around US$18/mmBtu to US$20/mmBtu) from the Second West-to-East Pipeline in 2013 onwards, the tariff rise is expected to be higher from 2014 onwards.

4.2.1.3 Inventory of Air Pollutants at Sources

	2005			2015		
Emissions	SO_2 (T)	NOx (T)	RSP (T)	SO_2 (T)	NOx (T)	RSP (T)
CLP	46,100	27,900	1,900	5,702	17,532	531
HEC	31,000	18,500	1,500	6,780	10,020	300
Total	77,100	46,400	3,400	12,482	27,552	831
Change	Base			-83.4%	-40.6%	-75.6%

Table 49 Emissions at Source from Power Sector in 2005 and 2015[100 to 104]

Against the background outlined in Sections 4.2.1.1 and 4.2.1.2, the statutory emission caps imposed on power plants in 2015 as shown in Table 49 can be taken as the emissions at source from the electricity sector for evaluation of impact on the proposed New AQOs for 2014.

4.2.2 Impact of Proposed Carbon Emission Reduction

Given 67% of CO_2 emissions in Hong Kong is from electricity generation in 2008, the main plank of the Consultation Document on *Hong Kong's Climate Change Strategy and Action Agenda for the Coming Decade*(14) is to revamp **fuel mix** for electricity generation in 2020 as follows:

- Suppressing the percentage of coal-fired power in the fuel mix and keep coal-fired power plants at a very low utilization rate or as reserve, such that coal would account for no more than 10% of the fuel mix in 2020, compared with 54% in 2009;
- Taking into account the supply of natural gas secured under the MOU on Energy Cooperation signed by the HKSAR and the National Energy Administration of CPG in 2008, the share of natural gas in the fuel mix is to be increased to around 40% in 2020 from 23% in 2009; and
- Giving the benefit of zero-emissions, imported nuclear in the fuel mix is to be increased from 23% in 2009 to 50% in 2020, and the balance of fuel-mix of about 3-4% by renewable energy.

The proposed drastic changes in fuel-mix for power generation as shown in Fig. 14 will have significant impact not only on existing power infrastructure, carbon emission performance and electricity production cost but fuel supply security.

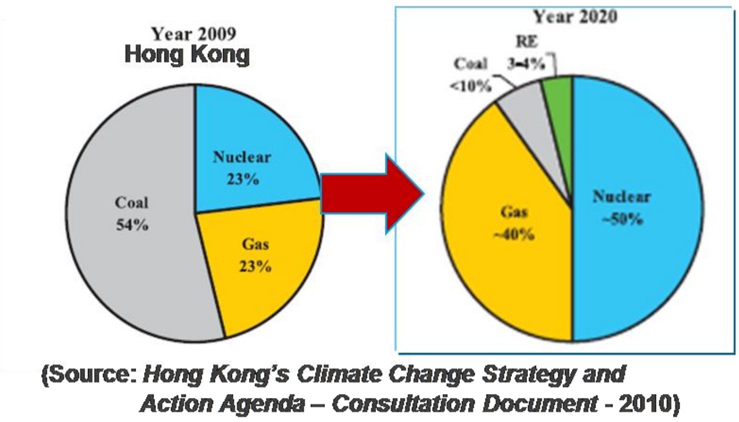

Fig. 14 – Proposed Revamp of Fuel Mix for Electricity Generation in 2020 (14)

4.2.2.1. Impact on Coal-Fired Generating Units

Hong Kong's current total installed coal-fired generating capacity is 6,608 MW which is made up of 4,108MW and 2,500MW from CLP and HEC respectively. In the fuel mix for electricity generation in 2011, CLP had 49.1% coal whereas HEC had 66.8% coal. Based on CLP's electricity sale of 31.168TWhr and HEC of 10.897 TWhr, this translates to an overall of 53.7% coal in overall fuel mix in 2011.

The Consultation Document's proposed reduction of coal in fuel mix to 6% - 7% in 2020 would require substantially smaller coal-fired capacity of not more than 1,500MW. It is understood that CLP and HEC will have their old coal-fired units of 1,400MW and 750MW respectively, i.e. total 2,150MW commissioned in 1980s, to retire after 35 years of service in the run-up of 2020. This would still leave 4,458MW capacity of operable coal-fired units, giving a surplus capacity of about 2,900MW.

It should be noted that retrofitting of CLP's four 677MW coal fired units (2,708MW) and HEC's three coal-fired units (950MW) with FGD for SO_2 removal and SCR/LMB for NOx emission reduction was completed in 2010/2011 at a total cost of about HK$10 billion. The adoption of 6% to 7% coal in fuel mix in 2020 would mean that abut 2,000MW out of the 3,618MW capacity of coal-fired units retrofitted with advanced FGD and SCR/LNB emission reduction systems would likely be idle after about 10 years service. Given HEC has a higher ratio of coal in the fuel mix, the impact on its coal-fired generating units is more significant. In any case, such early write-off of functioning generating units is probably undesirable.

4.2.2.2 Impact on Gas-Fired Generating Units

Because of the low carbon content of natural gas (CH_4) and high efficiency of gas turbine, gas-fired generating unit produces less than half the CO_2 emissions per kilowatt-hour of electricity compared with coal-fired units. Natural gas is therefore in high demand by developed economies, such as Japan and South Korea, with no or limited gas reserves.

Hong Kong's current total installed gas-fired generating capacity is 3,180 MW which is made up of 2,500MW and 680MW from CLP and HEC respectively. In the fuel mix for electricity generation in 2010/2011, CLP had 30.1%/20.5% gas whereas HEC had 33%/33% gas. Based on CLP's electricity sale of 30.93/31.168 billion kWh and HEC of 10.93/10.897 billion kWh, this translates to 30.9%/23.7% gas in overall fuel mix in 2010 and 2011 respectively. The significant reduction in using gas for electricity generation by CLP in 2011 is attributed to the dwindling gas reserve in the current supply source of Yacheng 13-1 gas field. It is noted the Consultation Document's proposed 40% natural gas in fuel mix is in line with the adoption of 50% natural gas for local electricity generation listed in the control measures for the proposed new AQOs in 2014.

It is believed that CLP's existing eight 312.5MW gas-fired generating capacity can cope with the Consultation Document's proposed increase of gas in fuel mix to 40% of gas in 2020, taking account of the projected increase in electricity generation. However, it is prudent and expedient to have at least one new gas-fired unit of 400MW in place by 2020 partly to be part of the package to replace the retired 4x350MW coal-fired units in order to maintain a reasonable reserve margin to ascertain high supply reliability. Should the gas in fuel mix increase to, say, 50% for scenario sensitivity study, it is for the same reasons to have at least two new gas-fired unit of 400MW in place by 2020. The capital expenditure of one new 400MW gas-fired unit and associated ancillary is about HK$3.5 to 4 billion, and the lead time is about 4 years from project inception to completion. The issue of new sources of gas supplies to meet 40% or 50% gas in fuel mix and the impact on the tariff has been addressed in Section 4.2.1.2.

The capacity of HEC's existing two gas fired generating units (335MW and 345MW) would not be able to meet the Government's proposed increase of gas in fuel mix to 40% of gas in 2020. Again, at least two new gas-fired unit of 400MW is required for 40% of gas in fuel mix, partly to replace some of the retired coal fired unit. It is prudent and expedient to have at least two new 400MW gas-fired units should the 50% of gas in fuel mix be adopted. The capital expenditure for one new gas fired-unit and associated ancillary would be HK$3.5 to 4 billion, and the lead time is about 4 years from project inception to completion.

To cater for 40% gas or 50% gas in fuel mix in 2020, HEC will need to increase the amount of gas supply from the existing source at Guangdong LNG Terminal or from another LNG Terminal located in the Great PRD region. Should the additional quantity of gas be sourced from the existing source, it is believed that the size of the existing sub-sea gas pipeline from the LNG Terminal to Lamma Power Station is adequate. What HEC needs is to have additional gas receiving stations at Lamma Power Station to cater for the increased amount of gas in fuel mix. Given that the price of LNG in the new gas supply contract to be entered with the LNG Terminal Operator for additional gas would be around US$18/mmBtu to US$20/mmBtu, much higher than the current supply at US$12.64/mmBtu [(140)], significant tariff rise is hence unavoidable.

4.2.2.3 Impact on Imported Nuclear Power

Nuclear power is controversial and there is always concern over its safety since the nuclear accidents such as the Chernobyl disaster in 1986 and The Three Mile Island accident in 1979. The Tohoku earthquake and tsunami in March 2011 seriously crippled the Fukushima Daiichi Nuclear Power Plant and has further reinforced such global fear. The release of huge hazardous radioactive materials into the atmosphere and the discharge of highly radioactive waste water to the sea have caused severe damages to the environment, ecosystems and food chains.

In the aftermath of the catastrophe of Fukushima Daiichi nuclear disaster, actions taken by various countries in 2011/2012 were as follows:

- Germany permanently shut down eight of its reactors and pledged to close all by 2020
- Italian voted overwhelmingly to keep their country non-nuclear
- Switzerland and Spain banned the construction of new reactors
- Taiwan President called for dramatic reduction in Taiwan's reliance on nuclear power
- Mexico sidelined construction of 10 reactors in favour of developing gas-fired plants
- Belgium considered to phase out its nuclear plants as early as 2015
- President Hollande promised to cut nuclear share of France's energy portfolio from 75% of electricity produced to 50%
- NRC of the USA voted 4-1 on 9 Feb 2012 to allow Atlanta-based Southern Co to build 2 nuclear power reactors (Unit 3 & 4) at its existing Vogtle Nuclear Power Plant in Georgia. The units will cost about US $14 billion and will enter service in 2016 and 2017.
- Japan's Prime Minster did call for a dramatic reduction in reliance on nuclear power, and all 54 nuclear power plants were off line on 5 May 2012. However, despite public opposition, Japan's Prime Minister on 16 Jun 2012 gave the green light for the resumption of 2 nuclear reactors at Oi in western Japan operated by Kansai Electric Power Company (No.3 Reactor started on 1 July) citing high electricity demand in Summer.
- Mainland China suspended approvals for nuclear power stations, and conducted rigorous safety checks at all nuclear projects, including those under construction. The State Council in June 2012 approved the nuclear facility safety Inspection

Report and the new nuclear Safety Plan proposed by National Nuclear Safety Administration. Reactors that are operating or under construction are spared major redesign, but future projects will face re-engineering, perhaps leading the Chinese to adopt safer 3rd Generation (GEN III) reactor designs.

The Daya Bay Nuclear Power Station has two 984MW generating units producing approx 14 billion kWh per year of electricity of which 70% is imported by CLP to Hong Kong through the 400kV Guangdong-CLP interconnection. This represents 30.1% of CLP's electricity generation or about 22% of Hong Kong as a whole in 2011. According to the Secretary for the Environment's reply to question raised at the Legislative Council on 2 November 2011[(139)], the Government admitted that in the wake of the Fukushima nuclear disaster there had been suggestions that Hong Kong should ban the use of nuclear power and relinquish all nuclear power currently in use. The Government also stated that the safety aspect of nuclear power generation should firstly be ascertained before further consideration is given to the future fuel mix for Hong Kong.

Nuclear power plant is known for having a high availability factor of up to 90%, and hence technically Daya Bay Nuclear Power Plant is capable of supplying 85% of its output capacity, i.e. about 17 billion kWh per year, to CLP. This would translate to about 33% of CLP's electricity production or 25% of Hong Kong as whole in 2020, assuming 1% per annum increase in electricity consumption. The existing 400kV Guangdong-CLP interconnection will have to be upgraded to cater for the increase in loading capacity and the capital investment is believed to be moderate. It is reckoned that the current capacity of CLP's 600MW Guangdong Pump Storage Plant should be able to deal with the system load trough constraint and perform balancing requirement as mentioned in Section 3.1.3.3.

Regarding the Consultation Document's proposed increase of nuclear power to 50% in fuel mix in 2020, new source of imported nuclear power from nearby Guangdong Province's nuclear power stations, such as Ling Ao and Yang Jiang, is required for CLP on top of that from Daya Bay Nuclear Power Station. Furthermore, the existing 400kV Guangdong-CLP interconnection would not be able to cope with such significant increase in loading and hence a new addition of a 400-kV transmission line is required. Given CLP's system daily load demand can differ up to two times during different times of the year [(142)], it is reckoned that additional pump storage plant capacity is required to deal with system load trough constraint and provide the necessary load balancing function. The amount of capital expenditure for building the necessary infrastructure would depend on the exact location of the source of nuclear power and the mode of transmission network.

Because HEC has no imported nuclear power and its grid is not interconnected with Guangdong's grid, it will be a daunting task for HEC to meet the proposed 50% nuclear power in fuel mix by 2020. For reasons of system reliability and the operation of its business, HEC may pursue to have dedicated 275kV submarine cables to bring nuclear power from Guangdong Province to its grid on Hong Kong Island (Fig. 15). Again, HEC's system daily load demand can differ up to two times during difference times of the year [(143)] pump storage plant is necessary to provide the necessary load-balancing function and deal with system trough constraint. The capital expenditure for building the necessary infrastructure would be enormous and the extent would depend on the exact location of the source of nuclear power and the mode of transmission network. Furthermore, the technical, environmental, permitting and social issues arising from acquiring way-leaves and construction of both land and sea sections of transmission lines are challenging. It is reckoned that a period of around 6 to 7 years is required to have imported nuclear power in place from project inception to completion.

Fig. 15 – Imported Nuclear Power from Guangdong Province

4.2.2.4 Wind Energy for Electricity Generation

Wind power is currently the most popular source of renewable energy for electricity generation particularly for those countries located close to the north or south poles where wind resources are abundant. Due to Hong Kong's land scarcity and unique topography it is considered technically not feasible to build a large number of sizable wind turbines on land. But the territory is surrounded by deep water which poses huge challenges to offshore wind farm development. This raises the capital cost of Hong Kong's proposed 300MW offshore wind farm as described in Section 3.1.4.1 to a huge sum of about HK$10 billion. Such amount is adequate to build three 400MW combined-cycle gas-fired generating units with a total installed capacity of 1,200MW.

Hong Kong is located close to the equator where wind resource is much less than places like North Sea and Iceland. The 300MW offshore wind farms (200MW planned by CLP and 100MW planned by HEC) are expected to generate about 560 million kWh of electricity per year which translates to a capacity factor of 22%, meaning 66MW of effective electricity output capacity. This is unfavorable when compared with the 1,000MW firmed output capacity from three 400MW gas-fired unit based on availability factor of 83%. Anyway, the output from the wind farms is about 1.1% of the projected electricity generation in 2020.

Given the wind power is an intermittent, unreliable and unpredictable source for generation of electricity and cannot deal with peak-saving or base-load operations, it is not a firmed capacity and requires fossil-fuelled or nuclear power plant as back-up. Further large development of offshore wind farm in a highly congested and very busy Hong Kong waters is not encouraged.

4.2.2.5 IWMF for Electricity Generation

The older generation incinerators, notably, Hong Kong's Kwai Chung plant commissioned in 1978, emitted hazardous compounds such as benzene and dioxin which are highly toxic and can cause cancer after high and long-term exposure. However, the present-day advanced waste to energy incineration facility is a proven technology and is equipped with state-of-art fuel gas treatment system which can meet stringent European emission standards. Many European countries have been using them for more than a decade, and in the Asia region, countries such as Japan, Singapore and Taiwan all have incinerators not only to tackle their waste problems but generate large amount of electricity as well.

In Hong Kong about 13,800 tonnes of waste are disposed of at landfills every day, of which the main trunk is 9,100 tonnes of MSW. The Government's proposed 3,000 tonnes/day Integrated Waste Management Facility (IWMF) as shown in Fig. 16 can help not only relieve pressure on Hong Kong's strategic landfills, but can generate about 480 million kWh of electricity per year (less than 1% of projected generation in 2020) without burning fossil fuel. The reduction of using fossil fuel for electricity generation, coupled with less MSW being landfilled, would reduce the total emission of greenhouse gas in Hong Kong by about 440 000 tonnes carbon dioxide each year(144).

Fig. 16 – Proposed 3,000T/Day IWMF at Shek Kwu Chau

However, the Environment Bureau had to abandon its HK$15 billion funding request for what it said was is an urgently needed waste incinerator and landfill expansion after failing to gain the support of lawmakers from across the political spectrum at the Environment Panel Meeting on 20 April 2012(145). Furthermore, The Court of First Instance on 7 June 2012 accepted a judicial review application filed by a resident of Shek Kwu Chau, opposing the Government's plan to build a waste incinerator on the island (146), and the verdict is still pending.

4.2.2.6 Food Waste for Electricity Generation

Hong Kong generates over 1.3 million tons of food waste every year and the majority of it is disposed of in landfills. In the long-run, this practice is not sustainable as the three existing landfills in Hong Kong will soon reach capacity. Furthermore, food waste should not be regarded as waste materials as the organics embedded in them can be transformed into useful products such as bioenergy.

By using food waste as feedstocks for bioenergy production will not create negative social impacts that many other newly created feedstocks (e.g. corn) might cause. By using biological processes, food waste can either be converted into methane for heat and power purposes or to liquid fuels for transportation purposes. By converting food waste to bioenergy can solve two problems simultaneously. First, the food waste will be diverted away from landfills so this saves precious landfill spaces. Second, the produced energy can displace fossil fuels to reduce Hong Kong's carbon footprint. The feasibility to produce methane from food waste has already been demonstrated recently in laboratory-scale in Hong Kong.

According to the laboratory data and if all food waste in Hong Kong is treated, then the methane output is enough to generate 1 to 2% of Hong Kong's annual electricity consumption. Ideally, no food waste should be generated in the first place but if this is unavoidable, then converting it into methane should provide a source of renewable energy for Hong Kong and in parallel lowering the burden on the landfills.

4.2.2.7 Marine Energy for Electricity Generation

Marine energy generally refers to tidal and wave power, a form of renewable energy which can generate electricity with zero emission. Tidal power is predictable and that is its important advantage over intermittent wind and solar energy. Tides can be calculated with high accuracy years ahead because the moon and sun's position and gravitational pull on this earth is known. The time-lag of tides along a coastline can be advantageous in spreading peak energy capture. Importantly, water's higher density (approximately 800 times greater than air), means tidal turbines operate at lower flow speed and their size/weight is relatively small – both factors have important environmental and cost considerations. The use of existing supporting structures such as bridge piers or offshore wind turbine masts could also reduce installation costs while positioning tidal turbines in locations of high velocity flows.

For Hong Kong it is suggested that devices can be protected from storms and severe weather conditions by positioning them on the sea-bed or submerging them to mid-current level. But for a real assessment of Hong Kong's tidal current potential, mapping the tidal resource including sea-site surveys to identify locations of appropriate potential is necessary. Whilst it is noted that Hong Kong's tidal currents are not as vigorous as at Zhejiang and Fujian or Korea's Daibang nevertheless the advanced design of diffuser augmented devices can enhance marine energy capture, while its power predictability could offer network support.

Waves are the product of solar and wind energy. There are a few Hong Kong sites with reasonable wave energy but the best opportunities relate to induced waves resulting from constant shipping traffic. Hong Kong's narrow harbour and smooth walls deflect and increase wave action forming a constant source of energy that could be deployed in an oscillating water column (OWC) type device integrated within the harbour walls.

The environmental impact of Marine Energy Converters on marine life is modest. The devices are either on the sea-bed or mid-current, generally widely spaced and operating slowly, their impact is small but designs now specifically focus on marine life conservation.

4.2.2.8 Projected Carbon Emission Reduction

According to the trend of increase in electricity generated for local consumption from 44.98 billion kWh in 2006 to 46.73 billion kWh in 2010 as shown in Table 26 (Section 3.1.5) prevails, i.e. 1% per year, it is projected the amount of electricity generated in 2020 for local consumption will be 51.7 billion kWh. This has taken account of Government's drive for energy efficiency and conservation, such as Building Energy Efficiency Ordinance, Energy Efficiency Labeling Scheme, etc, and the completion of most of the on-going ten mega projects.

Based on average thermal efficiencies of in-service coal fired-unit and gas-fired units are about 40% and 50% respectively and taken consideration of part-load operations and significant energy consumed by emission reduction systems , it is reckoned that the corresponding carbon emission factors at source are 0.88kg/kWh and 0.43kg/kWh. As the operation process of electricity generation using nuclear power and renewable energy is emission free, their carbon emission factors are taken as zero.

The projected electricity generated in 2020 and typical carbon emission factors for coal-fired, gas-fired, nuclear energy and RE power plants as shown in Tables 50 and 51 are adopted to work out the impact of changing fuel mix for electricity generation on carbon emissions.

2006 Generation	2010 Generation	2020 (Estimated)
44.98 Billion kWh	46.73 Billion kWh	51.7 Billion kWh

Table 50 – Projected Electricity Generation in 2020

Coal	Gas	Nuclear	RE (wind)
0.88 Kg/kWh	0.43 Kg/kWh	0	0

Table 51 – Typical Carbon Emission Factors

In this study, we propose three alternate scenarios of fuel mix in 2020 for CLP, HEC and Hong Kong as a whole, which together with the Government's proposal (Scenario 1) are summarized in Table 52.

- *Scenario 1* (Government Proposal): 40% by natural gas, 50% by nuclear 7% by coal and 3% by renewable energy (RE)(14).

- *Scenario 2*: 40% by gas, 33% by nuclear, 2% by RE and the remaining 25% by coal.

  Due to the complexity of nuclear reactor system and the lack of needed flexibility to respond to rapid load change, nuclear power plant is designed mainly for based load operation. Given the daily range of load demand can differ up to two times during different times of the year in Hong Kong as shown in the system demand profiles of CLP and HEC (142)(143) and the need to operate gas-fired units to consume the quantity of natural gas committed in the take-or-pay gas supply contract, 33% nuclear power in fuel mix is considered a possible approach without putting unnecessary constraints on economic dispatch of other generating units. Furthermore, CLP's 33% nuclear in fuel mix can technically be provided by Daya Bay Power Plant based on the assumption that 85% of its capacity can be supplied to CLP instead the current level of 70%. HEC's 33% nuclear in fuel mix requires complete new source of supply.

  2% RE is based on (i) the output from the 200MW and 100MW wind farms proposed by CLP and HEC respectively planned for operation by 2020, and (ii) output from one 3,000 tonnes/day IWMF hopefully can be in operation by 2020 albeit issues of funding and judiciary review.

- *Scenario 3*: 50% by gas, 25% by nuclear, 2% by RE and the remaining 23% by coal.

  25% nuclear for Hong Kong is based on the assumption that CLP can increase the amount of imported nuclear from Daya Bay Power Plant to 33% of its fuel mix, i.e. same as Scenario 2. No imported nuclear power is therefore required by HEC. This can avoid the need for new source of imported nuclear power from the Mainland to alleviate the concerns raised by some quarters of Hong Kong community, and not to take away the nuclear power much needed by the Mainland to improve its local air quality and reduce carbon emissions.

- *Scenario 4*: 45% by gas, 25% by nuclear 2% by RE and the remaining 28% by coal. This is a hybrid of Scenarios 1 and 3 in terms of amount of gas in fuel mix.

Based on the projected electricity generation, typical emission factors of coal, gas, nuclear and RE, and the scenarios of fuel mix given in Tables 50 to 52, the projected carbon emissions from the electricity sector in 2020 for four scenarios are worked out as presented in Table 53 below. Scenarios 1, 2, 3 and 4 could achieve carbon reduction of 57.3%, 28.4%, 23.7%% and 19.6% respectively in 2020.

The extent of carbon emission reduction in electricity sector presented in Table 53 would be scaled down should there be significant increase in projected electricity consumption and increase in emission factors of coal-fired and gas-fired units due to deterioration in plant efficiency. Given that the room for significant reduction of carbon emission in the transport sector and others is limited, the electricity sector is expected to take a large share of reduction. Against this background, study of following variations is carried out and results are shown in Table 54. It can be seen that Scenario 1, Scenarios 2 and possibly Scenario 3 are within the proposed range of 19% to 33% carbon emission reduction target for Hong Kong.

- 5% increase in either projected electricity generation or fossil fuel power plant emission factors, i.e. 5% reduction in emissions
- Carbon emission reduction from electricity sector contributes two-third of Hong Kong's total carbon emission reduction
- Carbon emission reduction from non-electricity sectors contributes 3% to 5% of Hong Kong's total carbon emission reduction

	Gas	Nuclear	Coal	RE
Scenario 1 (Consultation Document)				
CLP	40%	50%	7%	3%
HEC	40%	50%	7%	3%
Hong Kong	40%	50%	7%	3%
Scenario 2				
CLP	40%	33%	25%	2%
HEC	40%	33%	25%	2%
Hong Kong	40%	33%	25%	2%
Scenario 3				
CLP	50%	33%	15%	2%
HEC	50%	0%	48%	2%
Hong Kong	50%	25%	23%	2%
Scenario 4				
CLP	45%	33%	20%	2%
HEC	45%	0%	55%	2%
Hong Kong	45%	25%	28%	2%

Table 52 - Scenarios of Fuel Mix for Electricity Generation in 2020

Electricity Sector	Generation for Local Consumption (billion kWh)	Fuel Mix				Carbon Emission Factor (kg/kWh)	Carbon Emission (Tonne)	Change
		Gas	Nuclear (Zero CO2)	Coal	RE (Zero CO2)			
2005	44.98						28,300	Base
2009	46.59	23%	23%	54%	0%	0.5741	26,750	-5.48%
2010	46.73	31%	22%	47%	0%	0.5469	25,560	-9.68%
Scenario 1	51.4	40%	50%	7%	3%	0.2336	12,080	-57.3%
Scenario 2		40%	33%	25%	2%	0.3920	20,270	-28.4%
Scenario 3		50%	25%	23%	2%	0.4174	21,580	-23.7%
Scenario 4		45%	25%	28%	2%	0.4399	22,740	-19.6%

Table 53 – Estimated Electricity Sector Carbon Emissions Reduction

	Carbon Emission Reduction					
	Electricity Sector Only			Other Sectors	Hong Kong All Sectors	Consultation Document Target
	Base	5% Decrease	Contribution to Hong Kong	Contribution to Hong Kong		
Scenario 1	57.3%	54.4%	36.5 % – 38.4%	3% to 5%	40% - 43%	19% - 33%
Scenario 2	28.4%	27.0%	18.1% - 19.0%		21% - 24%	
Scenario 3	23.7%	22.5%	15.1% - 15.9%		18% -21%	
Scenario 4	19.6%	18.6%	12.5% - 13.1%		16% -18%	

Table 54 – Estimated Hong Kong Carbon Emissions Reduction

4.2.2.9 Projected Electricity Production Costs in 2020

In general, production cost covers fuel cost, operation and maintenance cost, financial cost and asset depreciation. It is not feasible to estimate or project accurately the electricity production cost in 2020 particularly due to the uncertainty in fuel cost. As coal is procured on relative short term contract or from the spot market, the price could vary from year to year or even from month to month. Price of natural gas under 20 to 25 years long-term supply contract can also vary as the pricing mechanism consists of commodity element generally in line with the market price of oil and transport element. Furthermore, the price of new nuclear electricity imported from Guangdong is affected by the location of the nuclear plant, the distance and mode of transmission network, safety, security and reliability requirement, etc. It is necessary to emphasise that the projection of electricity production cost is made based on a number of assumptions and is used as basis for scenario comparison study purpose.

According to the Consultation Document [14] the average electricity production costs per kWh in 2009 were: HK40 - 60¢ for coal-fired plant, HK70-90¢ for gas-fired plant and HK50¢ for imported nuclear power. It is reckoned that HEC has the higher production cost of HK60¢ for coal-fired plant and HK90 ¢ for gas-fired plant. This is attributed not only to the disadvantage of HEC's much smaller scale of operation but also because most of its coal-fired plants were then fitted with flue gas desulphurization plant and using more expensive gas.

Based on the ratio of HEC's portion of coal (80%) and gas (20%) in fuel mix and production cost of HK60¢ and HK90¢ respectively, the electricity production cost is HK¢66/kWh. This is quite close to the figure of HK¢63.88/kW in 2009 as shown in Table 55. As such, it is worked out that Hong Kong's average electricity production cost in 2009 were HK45¢ for coal-fired plant, HK75¢ for gas-fired plant and HK50¢ for nuclear power based on CLP's 76% and HEC's 24% share of Hong Kong's electricity consumption.

HEC's non-fuel cost (including operating, interest, asset depreciation and amortization) is increased by 8% in 2 years from HK¢26/.30kWh in 2009 to HK¢28.67/kWh in 2011. Taking due consideration of CLP's supply covers about 76% of Hong Kong's total electricity consumption at a lower electricity production cost, the anticipated increase in capital investment for new gas and nuclear related infrastructure, etc, the non-fuel cost for the electricity sector as a whole in 2020 is taken as HK¢35/kWh.

HEC	2011	2010	2009
Coal/Gas (%)	67/33	70/30	80/20
Electricity Sales (10^6kWh)	10,897	10,933	10,921
Production Cost (HK$Million)			
Fuel Cost	5,538	4,570	4,104
Operating Cost	1,040	1,097	1,158
Interest	248	112	91
Depreciation & Amortisation	1,836	1,793	1,623
Total	8,662	7,572	6,976
Production Cost/Unit of Electricity Sale (HK¢/kWh)			
Fuel (% of Total)	50.82 (63.9%)	41.80 (60.4%)	37.58 (58.8%)
Non-Fuel (% of Total)	28.67 (36.1%)	27.46 (39.6%)	26.30 (41.2%)
Total	79.49	69.26	63.88

Table 55 – Break down of HEC's Electricity Production Cost (2009 to 2011)[98]

Coal for electricity generation is generally procured on short-term contract or from spot market due to progressive reduction in coal consumption, wider sources of supply, availability of spot market and sizable coal storage in power stations. It is noted that the 2012 average coal prices given in papers presented by CLP and HEC at the LegCo Economic Development Panel meeting on tariff reviews held on 11 December 2012 are HK$29.4/GJ and HK$33.24/GJ respectively[108][140]. Based on the typical calorific value of sub-bituminous coal is 5,500kcal/kg, the average price of coal to Hong Kong in 2012 was about US$90/tonne. This is in line with the South China coal swap price of US$91.10 and US$92.95 for 1st and 2nd quarter of 2013 respectively based on delivery to South China with calorific value of 5,500kcal/kg [147]. Having considered the price of coal to Hong Kong did touch $140/tonne in 2008/2009, coal price of US$115 for 2020 is therefore taken for cost evaluation which translates to fuel cost of about HK35¢/kWh. The production cost of coal-fired unit is estimated to be HK¢70/kWh (HK¢35/kWh+ HK¢35/kWh) in 2020.

It is noted that the 2012 average natural gas prices given in papers presented by CLP and HEC at the LegCo Economic Development Panel meeting on tariff reviews held on 11 December 2012 were US$7.74/mmBtu (HK$57.2/GJ) and US$12.64/mmBtu (HK$93.4/GJ) respectively[108][140] based on the pricing mechanism of their existing gas supply contracts. CLP's paper also revealed the prices of its gas supply sources are: US$6 from Yacheng 13-1 gas field and US$14 from short-turn South China Sea, and opined that the current market price of US$18 to 21/mmBtu would be the reference price for the long-term 2nd West to East Pipeline source. This is in line with the spot Asian LNG prices breached the US$18/mmBtu level in May 2012 as Japanese buyers paid up for cargoes to hedge summer demand [148].

It is believed that the price of natural gas for new gas supply contract would use the aforesaid gas price for reference. Given that the amount of gas for about 16% of HEC's generation is supplied from the 25-year Gas Supply Contract signed in 2004 at a lower price, the resultant price of gases from existing and new gas contracts for Hong Kong as whole is taken to be US$18/mmBtu for production cost estimation. This translates to fuel cost of HK$1.30/kWh, and hence the production cost of gas-fired unit is estimated to be HK¢165/kWh (HK¢130/kWh+ HK¢35/kWh) in 2020.

In the absence of information on nuclear power supply agreement between CLP and Daya Bay Power Plant, it is assumed that the production cost HK¢50/kWh in 2009 [14] would be adjusted by 3% a year, say, to HK¢70/kWh in 2020 for both Scenarios 3 and 4. For Scenarios 1 and 2, the production cost of imported power from new sources would have to increase by about 10% to HK¢75/kWh due to capital investment in new transmission infrastructure and enhanced safety measures.

Based on capital cost of HK10 billion for the 300MW offshore wind farms proposed by CLP and HEC, the capital pay back using straight line depreciation over a service life of 20 years translates to an asset depreciation cost of HK$0.9/kWh. For simplicity, it is assumed that wind farm is the sole source all RE. It is reckoned that the production cost is slightly higher than gas-fired power plant and is assumed to be HK¢170/kWh.

The electricity production cost per kWh for various fuels and energy in 2020 as outlined above is summarized in Table 56, and the estimated production cost of the four scenarios under study is shown in Table 57. It can be seen that electricity production cost in 2020 would range from 110¢/kWh to 119¢/kW, i.e. increased by 108% to 125% compared to 2009.

	Gas (HK¢/kWh)	Nuclear (HK¢/kWh)	Coal (HK¢/kWh)	RE (Wind) (HK¢/kWh)
2009 (Average)	70 – 90 (75)	50	40 - 60 (45)	N/A
Scenario 1	165	75	70	170
Scenario 2	165	75	70	170
Scenario 3	165	70	70	170
Scenario 4	165	70	70	170

Table 56 – Electricity Production Cost/kWh for Various Fuels/Energy in 2020

	Power Plant				Prod. Cost (HK¢/kWh)	Increase from 2009
	Gas	Nuclear	Coal	RE		
2009 - Consultation Document						
Fuel Mix	23%	23%	54%	0%	**53**	**Base**
Production Cost (HK¢/kWh)	70-90 (75)	50	40-60 (45)	0		
2020 - Scenario 1 (Consultation Document)						
Fuel Mix	40%	50%	7%	3%	**113**	**113%**
Production Cost (HK¢/kWh)	165	75	65	170		
2020 - Scenario 2						
Fuel Mix	40%	33%	25%	2%	**110**	**108%**
Production Cost (HK¢/kWh)	165	75	65	170		
2020 - Scenario 3						
Fuel Mix	50%	25%	23%	2%	**119**	**125%**
Production Cost (HK¢/kWh)	165	70	65	170		
2020 - Scenario 4						
Fuel Mix	45%	25%	28%	2%	**113**	**113%**
Production Cost (HK¢/kWh)	165	70	65	170		

Table 57 – Projected Electricity Production Costs

4.2.3 Suggested Framework of Strategy

4.2.3.1 Addressing Proposed New AQOs in 2014

Based on the findings presented in the preceding sections relating to the proposed new AQOs to be in operation in 2014, the following strategy is suggested for consideration:

i) The 2015 emission allowances as stipulated in the Technical Memorandum under the APCO (Section 3.1.7.1) imposed on power stations can be adopted as the emissions inventory at sources as shown in Table 58 together with outcomes of the other control measures to achieve the proposed new AQOs.

	SO_2 (Tonne)	NOx (Tonne)	RSP (Tonne)
CLP	5,702	17,532	531
HEC	6,780	10,020	300
Total	12,482	27,552	831

Table 58 – 2014 Power Plant Emissions Inventory at Sources

ii) HEC can maintain the same fuel mix for electricity generation as adopted in 2011, i.e. not less than 33% natural gas and not more than 67% coal with low sulphur content, to meet the 2015 emission caps imposed on Lamma Power Station (Sections 3.1.7.1 and 4.2.1.1)

iii) CLP has to change its current fuel mix as required to meet the 2015 emission caps imposed on its power stations, i.e. to maintain 30% imported nuclear, increase natural gas to up to 45%(108) and reduce coal to around 25%. The exact amount of gas in fuel mix would depend much on the impact of price of gas from WTPII (Section 3.1.3.2) on tariff, the performance of the generating units and the sulphur content in coal.

iv) No addition of gas-fired generating units is required by CLP as its existing capacity of gas-fired units should be adequate to cope with up to 50% gas in fuel mix (Section 4.2.1.2).

Given no significant changes in HEC's generation facilities and supply of natural gas, it is reckoned that there should not be significant impact of the proposed new AQOs in 2014 on HEC's electricity tariff. Given HEC's tariff increase for 2013 is 2.9% compared to 2012(140), it is believed that pressure on tariff adjustments due to implementation of new AQOs in 2014 is likely to be moderate, probably in line with local consumer price index.

Due to the dwindling gas reserve in Yacheng 13-1 gas field and the need for doubling the volume of natural gas up to 45% in fuel mix in 2015 to meet the emission caps, CLP's new gas supply from WEPII at price around three times higher than the current supply from Yacheng It is not surprising that CLP in May 2012 warned that soaring price of natural gas from new supply sources could push electricity bills 40% higher in the next few years (Section 4.2.1.2)

4.2.3.2 Addressing Proposed Carbon Emissions Reduction Targets

Based on the findings presented in the Sections 4.2.2.8 on carbon emissions reduction and Section 4.2.2.9 on electricity production cost for the four scenarios, outcome of further review of these scenarios are given below:

Scenario 1 – This scenario as proposed in the Consultation Document (14) can achieve the highest carbon emission reduction of 54% to 57% in electricity sector (36% to 38% of Hong Kong total) but requires 50% nuclear power in fuel mix. Not only new sources of imported nuclear power are required by both CLP (30% nuclear in current fuel mix) and HEC (no nuclear in current fuel mix) but such significant increase of nuclear power in fuel mix may impose constraints on the effective economic/environmental dispatch of other generating units. It is believed that this can be resolved by increasing the capacity of exiting pump storage units and securing enhanced natural gas supply flexibility to deal with system trough constraints (Section 4.2.2.3). It is worth noting that 50% nuclear and 40% gas would mean that the security and quality of electricity supply, a vital commodity for the effective operations of Hong Kong, is directly and indirectly dependent on the capability and reliability of Mainland's energy providers.

Scenario 2 – This scenario can achieve modest carbon emission reduction of 27% to 28% in electricity sector (or 18% to 19% of Hong Kong total) with lowest increase in electricity production cost. Technically CLP can achieve 33% of nuclear power in fuel mix in 2020 provided Daya Bay Power Plant agrees to increase its supply to Hong Kong to 85% from the current level of 70% of plant's output. It is reckoned that the capacity of the in-service 600MW Guangdong Pump Storage Plant is adequate to provide the required load-balancing function. Given CLP and HEC power grids are unlikely fully interconnected to facilitate adequate power flow in the run up of 2020, it is realistic to assume that HEC would prefer to have a dedicated transmission lines to bring imported nuclear to its supply area. New pump storage system is likely required for HEC to manage the system load balancing caused by imported nuclear power for base load operation. It should be noted that a lead time of 6 to 8 years is required by HEC to have the required infrastructure in place from project commencement.

Scenario 3 – This scenario can achieve modest carbon emission reduction of 22% to 23% in electricity sector (or 15% of Hong Kong total) due to the adoption of 50% gas (expensive fuel) and minimal increase in imported nuclear power in fuel mix. This spares HEC's need to build necessary infrastructure to bring in nuclear power to its supply area, which would not only save huge capital investment but avoid the impact of land and marine construction work on the environment and marine ecology.

Scenario 4 - The carbon emission reduction of 18% to 19% in electricity sector (or 12% to 13% of Hong Kong total) achieved by Scenario 4 is the lowest among all four scenarios. This together with the assumed 3% to 5% carbon emission reduction contributed by other factors cannot meet the reduction targets of 19% to 33% for Hong Kong as proposed in the Consultation Document.

It is worth noting that Scenarios 2, 3 and 4 are to make the best use of the sizable coal storage capacity in place at Castle Peak Power Station and Lamma Power Station. The availability of 23% to 28% coal in fuel mix (instead of 7% coal in Scenario 1) will provide some security of fuel supply for electricity generation needed to power Hong Kong's essential or at least emergency supporting services. This is synonymous to having sizable reservoirs in place in Hong Kong in the event of interruption of water supply from the Mainland.

4.3 Town Gas Sector

As in 2010, the energy consumed for gas cooking and heating was 27,578 TJ, i.e. only 9.3% of Hong Kong's total energy consumption of 297,488TJ. Table 59 shows the amount of emissions from the consumption of town gas for cooking and heating compared with Hong Kong's 2010 total emissions [(14)(149)].

2010	SO_2	NOx	RSP	CO_2
Hong Kong Emissions (tonnes)	35,500	109,000	6,340	42,000,000
Towngas (tonnes) (% of Hong Kong)	0.77 (negliglbe)	126 (negligble)	Negligible	356,000 (<1%)

Table 59 – 2010 Emission Targets and Emissions from Consumption of Towngas

Given the minimal emission of SO_2, NOx RSP pollutants and CO_2 emissions produced from the consumption of town gas for cooking and heating were less than 1% of Hong Kong's total emissions in 2010, it is not surprising that the air quality improvement measures to achieve the proposed new AQOs in 2014 did not make any reference to the emissions from the town gas sector.

Nevertheless, it is felt necessary to point out that natural gas can be used directly and safely for cooking and heating overseas and in the Mainland. It is generally considered less energy efficient and not environmentally desirable to mix natural gas with naphtha, a flammable liquid mixture of hydrocarbons, to manufacture town gas for cooking and heating. Given that the MOU(12) signed by the Hong Kong and Central governments in August 2008 can assure adequate natural gas to Hong Kong for the next 20 years, total replacement of naphtha with natural gas is technically feasible.

It is reckoned that complete replacement of naphtha by LNG would almost eliminate SO_2 emission, and reduce NOx likely to less than 50 tonnes and CO_2 to less than 300,000 tonnes. This would also save energy which would otherwise be consumed by the reforming process to manufacture town gas. However, considerations should be given to supply reliability in case of disruption of natural gas supply from Guangdong LNG terminal. Furthermore, the conversion work needs sectorization of the existing 3,500 km of gas network to allow zone by zone change and this requires massive road opening works for the installation of gas separation valves. Modification or replacement of gas appliances at customer premises is required for fuel conversion to natural gas from town gas. Detailed analyses of the initial fuel conversion capital cost, social impact due to conversion work disruption, environmental benefits and opportunity for market reform should be carried out to formulate the way forward.

4.4 Transport Sector

4.4.1 Overview of Government's Proposed Action Agenda

4.4.1.1 Proposed Air Quality Improvement Measures

Of the 19 measures proposed by the Government to achieve the new AQOs in 2014, 11 are related to the transport sector. Tables 60 and 61 below summarize the emission reduction potential, and the costs and benefits of each measure based on a report by Arup regarding a feasibility study of a review of AQO and development of a long term air quality strategy for Hong Kong.

4.4.1.2 Proposed Carbon Emission Reduction Measures

In the base year of 2005, the transport sector produced a total amount of 7,480,800 tonnes CO_2 emissions. If the proposed target of reducing carbon intensity by 50-60 % by 2020 as compared with 2005 applies to the transport sector, then a 19% to 33% absolute reduction which is about 1,421,200 to 2,468,400 tonnes could be achieved. In the consultation document on *Hong Kong's Climate Change Strategy and Action Agenda*, a number of action plans for the transport sector were proposed in order to help achieve this carbon emission reduction target [14]. Details of the proposed action agenda are summarised in Table 62.

4.4.2 Suggested Green Transport Strategy

4.4.2.1 General Principle

One of the major objectives in this study is to recommend strategies that could help achieve the proposed new AQO and carbon reduction targets. However, it is important to note that transport is different from other energy-use sectors because of its predominant reliance on fossil-fuel based resources and by the infeasibility of capturing emissions purely from transport vehicles[159]. Emission reduction strategies that are solely focused on fuels might increase negative rebound effects. A number of researchers have pointed out that extending the use of lower-cost, fuel-efficient vehicles will reduce per-distance vehicle operating cost and so will stimulate additional vehicle travel (a rebound effect) which counteracts savings in energy consumption and pollutant emissions and increases problems, such as congestion, roadway costs and accidents[160-162]. Therefore, for improvements in fuel efficiency to be translated into reduced overall emissions, policy measures are needed to impact upon both fuel/vehicle choice and vehicle use.

The general principle for emission reduction strategies in the transport sector of Hong Kong is that, transport problems (such as local air pollution, GHG emissions, energy security, traffic management etc.) should be taken into consideration as a whole when developing mitigation solutions. Other than a solely fuel-based strategy, more comprehensive strategies that include both cleaner vehicles (which uses alternative fuels) and transport demand management (which reduces total vehicle travel) should be implemented to help achieve overall emission reduction and sustainable transport in Hong Kong.

Air Quality Improvement Measures	Emission reduction potential (Tonnes)			
	SO_2	NOx	PM_{10}	VOC
Emission Capping and Control				
1. Early retirement of aged / heavily polluting vehicles	0	3102	300	184
2. Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards	0	743	75	24
3. Wider use of hybrid and electric vehicles (20% private cars and 10% franchised buses)	15	216	7	173
4. 0.1% sulphur diesel for local vessels subject to confirmation of technical feasibility[#1]	545	0	14.5	0
5. Government vessels adopt feasible measures to reduce nitrogen oxides emissions[#2]	N/A	N/A	N/A	N/A
6. Emission control for off-road vehicles / equipment	4	950	239	326
Traffic-related Measures				
7. Low emission zones[#3]	N/A	N/A	N/A	N/A
8. Car-free zone / pedestrianisation scheme[#4]	N/A	N/A	N/A	N/A
9. Bus route rationalization	4	156	7	9
Infrastructure Development and Planning				
10. Expand rail network	17	501	46	207
11. Develop cycle tracks in new development areas	0.1	2.3	0.1	0.1
TOTAL	585.1	5670.3	688.6	923.1

[#1] The Arup report suggests 0.005% sulphur diesel (ULSD) for local vessels but the government proposes the adoption of 0.1% sulphur diesel. Data of emission reduction potential of the government proposed measure in this report is re-estimated based on the data of the Arup report.
[#2] No data available
[#3, #4] A territory-wide net emission reduction is not expected because of possible diversion of traffic.

Table 60 – Emission reduction potential of proposed air quality improvement measures

Air Quality Improvement Measures **Emission Capping and Control**	Costs (HK$M)	Benefits (HK$M)	B/C Ratio
Early retirement of aged / heavily polluting vehicles	3,882	24,344	6.3
Earlier replacement of Euro III commercial diesel vehicles with models meeting latest Euro standards	2,668	6,134	2.3
Wider use of hybrid and electric vehicles (20% private cars and 10% franchised buses)	4,326	2,417	0.56
0.1% sulphur diesel for local vessels subject to confirmation of technical feasibility[#1]	N/A	N/A	N/A
Government vessels adopt feasible measures to reduce nitrogen oxides emissions[#2]	N/A	N/A	N/A
Emission control for off-road vehicles / equipment	845	2,123	2.5
Traffic-related Measures			
Low emission zones (Central, Mongkok, Causeway Bay)	3,696	2,586	0.7
Car-free zone / pedestrianisation scheme (Central, Mongkok, Causeway Bay)	42	400	10
Bus route rationalization	14	548	39
Infrastructure Development and Planning			
Expand rail network[#3]	N/A	3850	N/A
Develop cycle tracks in new development areas	836	8	0.1

[#1, #2] No data available

[#3] The railway strategy includes the Express Rail Line, the Sha Tin to Central Line (the Tai Wai to Hong Hum section), the West Island Line, the South Island Line (East), the Kowloon Southern Line, and the Kwun Tong Line Extension. Only air quality improvement benefits are estimated. For reference, capital cost of these lines would be about HK$56 billion.

Table 61– Costs and Benefits of proposed air quality improvement measures

Carbon Emission Reduction Measures	Whether similar to air quality improvement measures
Greening Road Transport	
1. Continue to invest in the mass transportation systems and improve public transport; step up access to public transportation; set up pedestrian areas and covered walkways	YES
2. Wider use motor vehicles running on alternative fuel such that 30% of private cars, 15% of buses and goods vehicles are hybrid and EVs or other vehicles with similar performance by 2020	YES
3. Implement importers' average fleet efficiency standards such that new vehicles will be 20% more energy efficient than the 2005 market average	NO
4. Introduce a greater variety of EVs, and collaborate closely with other organisations to expand the charging network for EVs	YES[#1]
5. Encourage people to walk or take public transport, and consider an environment-friendly vehicle if a private car is needed	NO
Promoting Use of Clean Fuels for Motor Vehicles	
6. Require petrol and diesel to be blended with 10% of ethanol and biodiesel respectively; look into the possibilities of better utilising waste cooking oils in producing biodiesel locally	NO
7. Increase access to adequate supply of biofuels by 2020	NO

[#1]Measure 4 is actually one of the means to achieve measure 2 which is to promote wider use of alternative fuels.

Table 62 – Proposed carbon emission reduction measures [(14)]

4.4.2.2 Green Transport Strategy

Based on reviews on local and international practices and policies, a package of potential strategies and measures that could be implemented in the transport sector to help reduce local emissions and achieve the new AQO and carbon reduction targets are proposed in this section. Broadly speaking, these measures fall into two major categories including transport demand management and cleaner vehicles. Details are presented as follows.

4.4.2.2.1 Transport Demand Management

Transport Demand Management is also called mobility management. It focuses on strategies that reduce total vehicle-kilometer-travelled[(161)].

(1) Favor modal shift to public transport, walking, cycling and combined mobility (car-sharing, carpooling, taxi, etc.)

Despite Hong Kong having the highest rate of ridership in public transport in the world, private vehicle fleet remains a non-negligible contributor to roadside air pollution. Switching people's transport mode from private vehicles to public transport, walking and cycling will not only help relieve traffic congestion and accidents, but also generate substantial emission reduction benefits.

a) Extend Rail Network

The government has committed to developing rail system as an important backbone of Hong Kong's transportation in the Policy Address Year 2007-2008. The ongoing railway expanding strategy include the Express Rail Line, the Sha Tin to Central Line (the Tai Wai to Hung Hom section), the West Island Line, the South Island Line (East), the Kowloon Southern Line, and the Kwun Tong Line Extension. These rail projects are scheduled in place by 2016. Another rail project - the North Island Line – will not be completed before 2021. An estimation of the emission reduction potential has been shown in Table 57.

b) Extend Bus Priority

Extending bus priority that improves the performance and amenity of public bus services will likely encourage more people to take public transport. Bus Rapid Transit (BRT) is a good example that aims to extend bus priority. The general idea of BRT is to create "a mass transit system using exclusive right-of-way lanes that mimic the rapidity and performance of metro systems but utilises bus technology rather than rail vehicle technology" (160). Many cities in the world have BRT systems in operation. Extending bus priority could also include dedicated full-day bus lanes, mandatory give-way at bus bays and bus priority at junctions, all of which have been currently implemented and proved effective in Singapore (150).

c) Promote Car-sharing

Car-sharing has been widely adopted as a low-carbon mobility solution in the world now. An increasing body of empirical evidence indicates that car-sharing can provide numerous transportation, land use, environmental, and social benefits (151-154). One example is the Zipcar in the US, Canada and the UK. The principle of car-sharing is that individuals gain the benefits of private cars without the costs and responsibilities of ownership. Car-sharing can be one-way or two-way vehicle sharing. In the one-way vehicle sharing systems, such as the mobility-on-demand (MoD) system currently in operation in Berlin, a user can simply walk to the nearest rack (pick-up point), pick up a vehicle by swiping a smart card, drive the car to the destination, and drop it off at another rack (drop-off point). Users do not have to return the vehicles to the original pick-up point(153). Efficient car-sharing system should be equipped with intelligent information communication technology allowing real-time and fine-grained mobility demand sensing and network management (152). Cleaner vehicles should also be applied to minimise its environmental impact.

d) Encourage cycling/walking

A well-planned cycling track that connects to the public transport hub will increase passengers' preference for using public transport, thereby helping reduce emissions. Major cities like Sydney and London have developed comprehensive cycle network.

In Shenzhen China, the local government is committed to promote public transport and cycling by building dedicated cycling tracks and developing bicycle-sharing systems to solve the "first-mile, last mile" problem. In Hong Kong, many new towns in the New Territories or new development areas where traffic density is relatively low have the potential to use bicycle for short-distance travel. Besides, setting up pedestrian areas and covered walkways where conditions are allowed will also facilitate easy access to public transport. An estimate of emission reduction potential by developing cycling tracks in new development areas has been shown in Table 57.

(2) Coordinated transport

Freight transport has placed a burden on Hong Kong's environmental quality as well as other transport and social aspects. The strategy of reducing the amount of inefficient deliveries through coordinated transport could help improve the overall environmental performance of goods vehicle fleet in Hong Kong. Coordinated transport in many cases is related to logistic management. The objective of coordinated transport is to develop integrated distribution systems in the designated areas so as to reduce the amount of goods deliveries through co-operation of various stakeholders and thus reduce energy use and pollutant emissions. A study on the case of Stockholm shows that the number of stops for unloading in the area has been reduced by 45 percent after its introduction of coordinated transport [155].

(3) Road pricing: distance-based truck toll system (DTTS)

To further help reduce pollution from freight transport, it might be feasible for Hong Kong to introduce road pricing especially a DTTS which has gained increasing attention in the European countries and the US. In Germany, the German federal government has introduced a distance-based truck toll for all heavy commercial vehicles and vehicle combinations with a permissible total weight of 12 tons or more (average charge €0.12 per kilometer) in 2005[155,156]. The toll system is capable of calculating and collecting road use charges based on the distance travelled through a combination of mobile telecommunications technology (GSM) and the satellite-based Global Positioning System (GPS). Under such kind of system, inefficient freight transport is discouraged so that energy consumption and vehicle emissions are expected to be reduced.

However, it should be noted that there is mounting evidence suggesting that to manage transport demand and transport emissions, any shift to road pricing needs to be in addition to, rather than replacing, fuel and vehicle excise duties[162] (which will be discussed later). Quantified data about air quality improvements brought by introduction of distance-based truck toll system needs further study.

4.4.2.2.2 Cleaner Vehicles

Cleaner vehicles are more efficient and alternative fuel vehicles which reduce per-distance emission rates. Cleaner vehicle strategy should not aim to increase total car number. In order to encourage wider use of cleaner vehicles, a number of strategies and measures can be implemented.

(1) Wider use of EVs (incl. hybrid vehicles) or vehicles with similar/better performance (20% private cars and 10% franchised buses)

EVs produce zero tailpipe emission[159]. Despite the indirect emissions from battery charging (which largely depends on the fuel mix of local electricity generation), EVs still offer a very clean alternative to traditional petrol/diesel vehicles. As mentioned in Section 2, many major cities/countries in the world are actively promoting EVs. The Hong Kong government is also implementing some policy measures as well as working with other organisations to encourage wider use of EVs. However, progress so far remains relatively low.

EVs are very suitable for predictable short trips (less than 160km per day) and many stops. This would include hotel and residential shuttle buses, school light buses, franchised public (light) buses, postal vehicles, corporate and government vans, blood donation vans and mobile libraries. It should be reminded that the public will take up EVs with confidence only if the necessary hard and soft infrastructures (i.e. charging facilities, as well as favourable EV polices) are in place to support them. Other than building charging infrastructure that requires high up-front capital costs and longer time to realize, battery leasing/swapping schemes, where fully-charged EV batteries are available for leasing or swapping in any traditional gas stations, would be a more cost-effective and convenient way to address the charging issues of EVs. Battery leasing would also greatly reduce the cost of EV ownership and boost market demand. In addition, wider use of EVs in car-sharing systems that have been suggested earlier may provide additional environmental benefits.

(2) Early retirement/replacement of aged/heavily polluted vehicles (pre Euro, Euro I, and II commercial diesel vehicles and franchised buses)

Of the vehicle fleet in Hong Kong, commercial diesel vehicles (include all goods vehicles, all light buses, as well as private and public non-franchised buses) are the dominant roadside air quality polluter and carbon emissions contributor. It is projected that by year 2015, there would still be 26283 commercial diesel vehicles and 2850 franchised buses with Euro II or older diesel engines[128]. As mentioned earlier, Euro II and blow diesel engines are 34 times dirtier than Euro VI and above diesel engines. Early replacement of these aged and heavily polluting vehicles with the latest Euro models will reduce significantly the vehicle emissions.

The government has completed a subsidy scheme in March 2010 to encourage the early replacement of pre-Euro and Euro I diesel commercial vehicles, and launched another subsidy scheme in July 2010 for Euro II diesel commercial vehicles. However, as at end December 2011, there were still 70 % of commercial vehicles with pre-Euro IV emission standard (i.e. of service life of 5 years or more) and there is a need to explore measures to expedite their replacement[157]. In this regard, other policy instruments such as emission-based vehicle tax (which will be discussed later) would be helpful. The emission reduction potential of early retirement of aged vehicles estimated by Arup is shown in Table 57.

(3) Introduction of emission-based vehicle tax

a) Carbon emission-based vehicle purchase tax

From June 2012 onwards, newly registered vehicles in Hong Kong must meet the

Euro V emission standard. However, no carbon-emission standard is set for these vehicles. The vehicle purchase tax (i.e. First Registration Fee or FRF) in Hong Kong is generally based on the purchasing price of a vehicle. It is suggested in this study that the government should introduce a carbon-based vehicle registration tax as what has been implemented in some countries such as Ireland and the UK.

Previous to July 2008, Vehicle Registration Tax (VRT) in Ireland was based on the engine size of the vehicle, with bigger engine sizes paying a higher rate of VRT. From July 2008, VRT for cars is based on CO2 emissions. Table 63 details the VRT rates currently applicable to cars in Ireland. The change to the VRT regime has impacted the car market and has the potential to significantly change the CO_2 emissions from the car fleet[158].

Band	CO_2 emissions levels	VRT rates
Band A	under 120 grams per kilometre	14% of OMSP (minimum €280)
Band B	121 – 140 grams per kilometre	16% of OMSP (minimum €320)
Band C	141 – 155 grams per kilometre	20% of OMSP (minimum €400)
Band D	156 – 170 grams per kilometre	24% of OMSP (minimum €480)
Band E	171 – 190 grams per kilometre	28% of OMSP (minimum €560)
Band F	191 – 225 grams per kilometre	32% of OMSP (minimum €640)
Band G	over 225 grams per kilometre	36% of OMSP (minimum €720)

Table 63 – VRT rates for cars in Ireland from 1 July 200

b) Emission-based vehicle circulation tax

In addition to FRT placed on the initial purchase of a vehicle, circulation tax placed on the ownership of vehicles also has an influence on the choice of a new vehicle. At present, the circulation tax (i.e. annual license fee) in Hong Kong is varied by the engine size of a vehicle. To promote cleaner vehicles, both Euro emission standards and CO_2 emission standards, instead of engine size, should be considered as major criteria for setting the circulation tax rates. Since emission-based circulation tax will increases the ownership cost of heavily polluting vehicles during its whole useful life, it is therefore helpful to speed up phasing out the aged vehicles in Hong Kong. CO_2 emission-based circulation tax can be found in the UK from its Vehicle Excise Duty and Company Car Taxation.

(4) Introduction of fleet-wide average CO_2 emission standards for vehicle importers

Fleet-wide average emission standards are policy strategies that target the vehicle supply side other than demand side. They provide manufacturers or importers with the flexibility of simultaneously meeting the demand of a wide spectrum of customers as well as the overall environmental performance required for the fleets produced or sold[14]. Similar measures have been implemented in the U.S. where new cars in the market are required to meet increasingly stringent fleet-wide average CO_2 emission standards. The EU is also setting new car sales fleet emissions targets (an average of 95g/km of CO_2 by 2020) which all manufacturers will need to achieve.

(5) Set increasingly stringent fuel standard for local vessels

Local vessels are currently running on diesel fuel with sulphur content of 0.5%. Tightening the fuel standard for local vessels will help reduce the emissions of pollutants particularly SO_2 from vessels. The government has completed a trial of local ferries using ULSD (i.e., diesel with a maximum sulphur content of 0.005%) in August 2010. The trial confirmed the technical feasibility of ULSD as fuel for local ferries. However, the extra handling cost of providing ULSD to the small number of local ferries becomes a major obstacle. Thus, the government proposed that the sulphur content of marine light diesel sold in Hong Kong changes from the current maximum limit of 0.5% to 0.1% (other than 0.005%). It is suggested here that the government should set increasingly stringent fuel standard for local vessels as long as technical and economic feasibility is confirmed. Besides, switching ocean-going vessels to low sulphur diesel at berth in Hong Kong should also be included in the action plan.

4.4.2.3 Implementation Plan

As stressed earlier, green transport solutions should take transport problems as a whole for consideration. It is not feasible to propose mitigation measures for addressing AQO and GHG reduction targets in a separate way since most measures can help achieve the two objectives simultaneously. Based on their complexity and required implementation time, green transport measures suggested can be further grouped into two major categories: short-term measures (by 2014-15) and medium-term measures (by 2020), as shown in Table 64.

Given the varying degree of contribution to emission reduction, some mitigation measures could be given high priority while the others could be given low one. Table 65 below summarises a rough estimate of the potential emissions reduction of each proposed measure based on certain scenarios and assumptions. It should be noted that the scenarios are developed for the purpose of analyzing the effectiveness of alternative measures and hence to inform a decision on the likely ranges of emissions reduction that may be viable in Hong Kong. There remains a degree of uncertainty concerning both the measures that will ultimately be adopted and the degree to which they are effective. 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 [(163)].

	By 2014 /15	By 2020	Addresses AQO	Addresses GHG	Different from govt
Transport Demand Management					
1. Favor modal shift to public transport, walking, cycling and combined mobility					
a) Extend Rail Network		√	√	√	
b) Extend Bus Priority	√		√	√	√
c) Promote Car-sharing	√	√	√	√	√
d) Encourage cycling/walking	√	√	√	√	
2. Coordinated transport (develop integrated distribution systems in the designated areas)	√	√	√	√	√
3. Road pricing: distance-based truck toll system		√	√	√	√
Cleaner Vehicles					
4. Wider use of EVs (incl. hybrid) or vehicles with similar/better performance (20% private cars and 10% franchised buses)	√		√	√	
5. Early retirement/replacement of heavily polluted vehicles (pre Euro, Euro I, and II commercial diesel vehicles and franchised buses)	√		√	√	
6. Introduction of emission-based vehicle tax					
a) Carbon emission-based vehicle purchase tax	√			√	√
b) Emission-based vehicle circulation tax	√		√	√	√
7. Introduction of fleet-wide average CO_2 emission standards for vehicle importers		√		√	√
8. Setting increasingly stringent fuel standard for local /ocean-going vessels	√		√		√

Table 64 – Summary of green transport measures

Green Transport Measures	Emission reduction potential (Tonnes)				
	SO_2	NOx	RSP/PM_{10}	VOC	CO_2
Transport Demand Management					
1. Favor modal shift to public transport, walking, cycling and combined mobility					
a) Extend Rail Network (14)	17	501	46	207	N/A
b) Extend Bus Priority #1	0.5	78	7.2	129	105,087
c) Promote Car-sharing (10% Private Cars replaced by electric Car-sharing vehicles) #2	0	97	6.7	97	160,943
d) Encourage cycling/walking (14)	0.1	2.3	0.1	0.1	N/A
2. Coordinated transport (develop integrated distribution systems in the designated areas) #3	1.6	3,248	206	379	356,991
3. Road pricing: distance-based truck toll system #4	0.8	1,624	103	190	178,496
Cleaner Vehicles					
4. Wider use of EVs (incl. hybrid) or vehicles with similar/better performance (20% private cars and 10% franchised buses) (14)	15	216	7	173	281,207
5. Early retirement/replacement of heavily polluted vehicles (pre Euro, Euro I, and II commercial diesel vehicles and franchised buses) (14)	0	3102	300	184	N/A
6. Introduction of emission-based vehicle tax					
a) Carbon emission-based vehicle purchase tax #5	0	0	0	0	N/A
b) Emission-based vehicle circulation tax #6	N/A	N/A	N/A	N/A	N/A
7. Introduction of fleet-wide average CO_2 emission standards for vehicle importers #7	0	0	0	0	N/A
8. Setting increasingly stringent fuel standard for local /ocean-going vessels #8	545	0	14.5	0	N/A
Total	580	8,868	691	1,359	1,082,724

#1 based on the assumption that 10% annual VKT by private car is shifted to bus and other public transport
#2 based on the assumption that one car-sharing vehicle (EV) can replace 6 private cars and an average 20% annual VKT is reduced among car-sharing vehicle members
#3 based on the assumption that 20% of road freight transport is reduced after the introduction of coordinated transport system
#4 based on the assumption that 10% of road freight transport is reduced after the introduction of road pricing
#5 # 7 the measures will only affect the emissions of future vehicle fleet
#6 emission reductions will be determined by the emission level set by the circulation tax
#8 the emission estimate is based on 0.1% sulphur diesel for local vessels and does not include ocean-going vessels

Table 65 – Emission reduction potential of suggested transport measures

5. CONCLUSION AND SUGGESTIONS

Based on the information, discussions and findings presented in the preceding sections, the following can be concluded with suggestions for consideration.

5.1 Energy Policy Review

Given energy is vital for the effective operations of our society and a driving force for quality human development and economic prosperity, it is of paramount importance to have in place a sound and sustainable energy policy which can maintain a balance among the fundamental goals of economic growth, energy security, affordability and environmental quality which are competing with times. However, countries differ from their perception of the relative importance of the different goals and have their own sets of energy priorities and strategies, depending on their unique geographical, economic, social and political circumstances and their respective endowment on natural resources.

The Fukushima nuclear disaster, increasing volatility of oil prices coupled with a rising demand for natural gas in Asia have prompted our neighboring countries, notably, Singapore, Korea, Taiwan and Japan to reinvent their comprehensive energy policy and to explore new energy resources needed to drive economies and development. This includes a rising emphasis on promotion of energy efficiency, diversification of energy supplies, investment in clean/alternative energy R&D and renewed interest in regional integration of fuel, energy and electricity supply.

Being a metropolitan city and service-oriented economy with no natural resources, Hong Kong is dependent on imports of all its fossil fuels and nuclear electricity to drive its economies and development. The World Energy Council [(164)] concluded that to make affordable, secure and environmentally-sensitive energy systems a reality, policymakers urgently need to develop interconnected, lasting and coherent energy policies. The growing complexity and strategic importance of energy policy demands a “supra-departmental” approach by the Hong Kong Government to come up with detailed objectives, strategies and action plans to tackle the challenges. This echoes the motion passed by the LegCo in January 2012 [(165)] urging the Government to establish an energy management authority to explore Hong Kong’s long term energy demand, formulate and execute an energy policy.

5.2 Supply-Side Fuel & Energy Mix Strategy Framework

5.2.1 Electricity Sector

Hong Kong has 7.1 million people living and working in a highly dense urban environment as 75% of the territory's total area of 1,104 km^2 is countryside. The small geographic area, dynamic urban environment and vibrant social and business activities conducted mostly in high-rise buildings and tall structures pose unique challenges to the two power companies, CLP and HEC, in providing safe, quality, reliable and affordable electricity. In 2011, the electricity consumption in Hong Kong was 42.065 billion kWh, about 74% of which was supplied by CLP and the remaining 26% by HEC.

As in 2011, Hong Kong had total generating capacity of 12,624MW, comprising

6,608MWcoal fired units, 3,180MW CCGT units, 855MW oil-fired GT units, 1,378MW nuclear power plant, 600MW pump storage system and 2MW renewable energy. The maximum system demand was 9,200MW and this gives a comfortable reserve margin of 37.2%. Given the capacity of the circuits interconnecting CLP power grid and HEC power grid is only 720MVA mainly for emergency back-up purpose, it is considered prudent to have reserve margin of not less than 25% as part and parcel of needed infrastructure to achieve supply reliability of 99.99%.

It is observed that the fuel mix adopted by both power companies for their electricity generation has been changing from time to time since 2005 primarily to cope with the increasingly tightening emission caps on SO2, NOx and RSP imposed on licences of their power plants via the Technical Memorandum under the Air Pollution Control (Specified Process) Regulation. In 2011, Hong Kong's fuel mix for electricity generation was 54% coal, 24% gas and 22% nuclear. The decrease in the amount of natural gas in 2011 compared to 31% in 2010 was attributed to the dwindling reserve in CLP's gas supply source of Yacheng 13-1gas field.

Regarding the need to increase the amount of gas in fuel mix to 50% of local generation as one of the key measures to achieve the proposed new AQOs in 2014, the mandatory requirement for power companies is to comply with their 2014 licensing emission limits which should not be more stringent than the emission allowances as stipulated in the 2nd Technical Memorandum for 2015. To achieve that, it is suggested that HEC should maintain its current fuel mix of 67% coal and 33% gas, whereas CLP has to increase gas from 20.5% in 2011 to about 40% and maintain 30% nuclear in its fuel mix in 2014. The approval by the Hong Kong Government in December 2012 for CLP's new 20-year gas supply contract is critical for ensuring a long-term and stable supply of natural gas from the WEPII to Hong Kong, helping to raise Hong Kong's air quality.

It is noted that 2015 and 2020 emission reduction targets covering SO_2, NOx, RSP and VOC have been set by the governments of Hong Kong and Guangdong Province in November 2012. It is believed that the electricity sector's share of 2015 emissions reduction should have been covered by the 2nd Technical Memorandum (Section 3.1.7.1). The impact of 2020 emissions reduction targets on the operations of electricity sector can be evaluated once the amount of allocation of each pollutant to power plants is known.

The Consultation Document's proposed fuel mix of 50% nuclear, 40% gas, 3-4% RE and the remaining 6-7% coal has significant impact on the existing electricity generation infrastructure, fuel/energy supply, emission performance and electricity production cost. As the minimum load of Hong Kong system demand is less than half of the daily peak throughout the year, there is concern over the impact of the proposed adoption of 50% nuclear power, usually for base load operation, on the effective and efficient operation of the electricity supply system as whole. It is believed that this can be resolved by measures such as increasing the capacity of existing pump storage units and enhancing the natural gas supply flexibility to deal with system trough constraint and to achieve optimum system load balancing requirement.

Table 66 summarizes the results of the impact of Consultation Document's proposed fuel mix (Scenario 1) and three alternatives (Scenarios 2, 3 and 4) on the emissions reduction and electricity production costs.

Fuel-Mix Scenario	2020 Carbon Emission Reduction				Production Cost per kWh	Remarks
	Base	5% Decrease	Contribution to Hong Kong	Consultation Document		
Scenario 1	57.3%	54.4%	36.5 % to 38.4%	19% to 33%	HK$1.13	New nuclear power sources for CLP & HEC; new gas source for HEC
Scenario 2	28.4%	27.0%	18.1% to 19.0%		HK$1.10	New nuclear power and gas sources for HEC; Some coal -fired unit retained
Scenario 3	23.7%	22.5%	15.1% to 15.9%		HK$1.19	New gas source for HEC; Some coal-fired units retained
Scenario 4	19.6%	18.6%	12.5% to 13.1%		HK$1.13	New gas source for HEC; Some coal-fired units retained

Table 66 – Impact of Fuel Mix on Carbon Emissions and Electricity Production Costs

Based on 67% of carbon emission in Hong Kong is produced from the electricity sector, Scenario 1 (Consultation Document proposal) alone can comfortably achieve the proposed reduction target of 19% to 33%. The cost of electricity production would go up to HK$1.13/kWh, representing an increase of 113% compared to that of 2009. Again all these results would depend much on the accuracy of number of assumptions adopted in the study.

Assuming the non-electricity sectors can contribute say, 3% to 5% of carbon emission reduction for Hong Kong, it appears that Scenario 2 together with that from the non-electricity can reach the lower end of the proposed range of emission targets. Its cost of electricity production is marginally lower than that of Scenario 1. One of the merits of Scenario 2 is that there is no need for CLP to seek new source of imported nuclear power by assuming that 85% of Daya Bay Nuclear Power Station's electricity output can be supplied to CLP, instead of the current level of 70%.

The much lower carbon emission reductions achieved by Scenarios 3 and 4 are attributed to relying only on Daya Bay Power Plant to supply nuclear electricity to Hong Kong. The higher electricity production cost is a result of increase in the use of more expensive gas. Their distinct merit is to spare the need to build expensive infrastructure to bring nuclear electricity to HEC's supply area.

It is worth noting that the 23% to 28% coal in fuel mix adopted in Scenarios 2, 3 and 4 would allow most of the coal-fired units retrofitted with advanced emission reduction systems in 2010/2011 remain in services after 2020. With a sizeable storage of coal at the power stations in Hong Kong, it will also provide certain security of fuel supply for electricity generation needed to power Hong Kong's essential or at least emergency supporting services.

The Consultation Document's proposed adoption of 3% to 4% local renewable energy in fuel mix by 2020 appears to be far too optimistic as the total output of two proposed offshore wind farms with a total installed capacity of 300MW, if materialized, can only contribute to slightly over 1% of Hong Kong's required electricity generation. It should be noted that wind power is an intermittent, unpredictable energy source and requires back up from either fossil fuel or nuclear power plant. The Government's proposed 3,000tonne/day IWMF, which can meet nearly 1% of Hong Kong's electricity demand, may not be completed before 2020 due to the on-going judiciary review hearing.

Each of the above four scenarios, which requires additional gas supply and imported nuclear electricity aimng to meet the Government's proposed carbon emission redution target, has its own pros and cons in terms of level of emission reduction, increase in electricity production costs, security of fuel supply and reliability of power supply. It is imperative that the Hong Kong Government should firm up with the Mainland authorities the provisions of integrated cross-boundary infrastructure for supply of additional gas and imported nuclear electriicty to Hong Kong beyond 2020. This has to be implemented as early as possilbe due to the need for comprehensive planning and considerable lead time for design and construction of required infrastructure and facilities. As regard to which of the four scenarios, or any other scenario of fuel mix for electricity generation should be chosen, public engagement is essential as a community consensus is required to achieve a balance between green and clean electricity and the cost of electricity to be paid by consumers.

The Fukushima disaster has hardened the public attitudes towards nuclear power, radically altering the global energy landscape. There is increasing pressure of public opinion for governments and utilities worldwide to focus more on energy efficiency and the development of renewable energy and green energy alternatives. Hong Kong's unique topographical setting and scarcity of land impose immense constraints on sizable development of wind and solar energy for electricity generation. However, there are other alternative sources of energy, such as food waste energy and marine energy as outlined in Sections 4.2.2.6 and 4.2.2.7 that can be further developed locally as supplement to using fossil fuel for electricity generation in Hong Kong.

Regarding improvement of supply side energy efficiency, the Hong Kong Government should in the wider interest of the society revisit the cost-benefit of full interconnection of the power grids operated by CLP and HEC for full power transfer to reduce Hong Kong's overall power generation reserve margin of 37.2% recorded in 2011, and to facilitate electricity market reform and development of smart grid and smart metering system before the expiry of the current Scheme of Control Agreements.

5.2.2 Towngas Gas Sector

Towngas is one of the suppliers of gas to domestic, commercial and industrial customers and sharing the market with LPG companies in Hong Kong. It is sole supplier of town gas in Hong Kong started in 1973 to use naphtha with low sulphur as feed stock for production of town gas. Utilization of land fill gas commencing in 1999 and the introduction of liquefied natural gas in 2006 to supplement naphtha are part of the utility company's drive to reduce emissions of air pollutants and greenhouse gases from production of town gas. As in 2010, natural gas accounted for about 57% of production fuel while LFG accounted for about 2.3% and naphtha makes up the balance.

It is noted that the emissions of SO_2, NOx, RSP and CO_2 produced from the consumption of town gas for cooking and heating were less than 1% of Hong Kong's emissions in 2010. It is not surprising that no specific improvement measures are required from the town gas sector to achieve the proposed new AQOs in 2014 as well as the carbon emission reduction targets in 2020.

Actually, natural gas is being used directly and safely for cooking and heating overseas and in the Mainland. Given that the MOU signed by the Hong Kong and Central governments in August 2008 can assure adequate natural gas to Hong Kong for the next 20 years, total replacement of naphtha with natural gas to reduce further emissions from town gas production and more cost effective use of the lands of Tai Po and Ma Tau Kok plants is technically feasible. However, detailed study of economic (network and appliance modification works, fuel price, etc) and social (disruption and disturbance) costs versus benefits of environmental quality and land resource of the conversion work to 100% natural gas is required.

5.2.3 Transport Sector

Environmental performance enhancement of our transport sector in terms of air pollutant emission reduction (i.e. SO_2, NOx, RSP and CO_2) can be accomplished by implementation of comprehensive strategies for both (1) cleaner vehicles, e.g. EV, and (2) effective transport demand management that promotes public transport and car-sharing. More urgent air quality improvement measures are to retire and replace diesel vehicles with ones that meet the latest Euro standards. Promotion of EV anticipates to achieve considerable reduction in CO_2 emission and roadside air pollutant reduction. Potential transport demand management measures include extension of rail network, extension of bus priority, car-sharing, promotion of cycling/walking, coordinated transport for logistics and road pricing.

If all the green transport measures are fully implemented, the potential emission reductions for SO_2, NOx, PM_{10}, VOC and CO_2 are 580, 8,868, 691, 1,359 and 1,082,724 tonnes, respectively. The GHG emission reduction is equivalent to 2% of the total GHG emission in Hong Kong.

5.3 Way Forward

The adoption of new AQOs in 2014 and setting of 2015 and 2020 emission reduction targets should be able to help Hong Kong improve its air quality, which plays an important role in maintaining the competiveness of Hong Kong as an international business centre. As air quality polices should be premised on protection of public health, it is opined that the Hong Kong Government should commit to adopting WHO's Air Quality Guidelines as early as practicable and come up with concrete and workable measures. At the same time, the Government should also strengthen cooperation with the mainland authorities over the monitoring, prevention and mitigation of air pollution problems with a view to building a quality living area in the Greater Pearl River Delta.

Climate change poses an unprecedented, global challenge for every country. A framework for addressing climate risks will be crucial to sustainable development. The Mainland Government has set a voluntary target to reduce China's carbon intensity by 40% to 50% in 2020, using 2005 as base year. It is opined that Hong Kong, being one of the most developed economy in China and a responsible international city, should consider setting a target, more aggressive than the currently proposed 50% to 60% carbon intensity reduction, in support of the national policy and world-wide effort in tackling the climate change.

Hong Kong is an open society with diverse vested interests. Setting acceptable levels of air quality and carbon emission reduction targets would lead to changes in supply-side fuel and energy mix, and most likely an increase in electricity tariff, transport fare and costs of living, all of which would inevitably invite extensive and intensive debate. This is a complex issue and raises many questions. For the well-being of future generations, the Hong Kong Government should actively engage the public and stakeholders in the early stage of policy formulation process, and set out clear objectives and road map for Hong Kong to make the transition to be a truly clean, low carbon, preferred city.

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