THE HONG KONG INSTITUTION OF ENGINEERS
香港工程師學會

Environmental Division
環境分部

ANNUAL SEMINAR

APRIL 2014

HONG KONG ENERGY CHALLENGES & SOLUTIONS

TECHNICAL REPORT

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Executive Summary

The Annual Seminar of the HKIE Environmental Division was held on 09 April 2014 at Hong Kong Convention and Exhibition Center with the leadership of the Organizing Committee Chairman Ir PC Lo and the Chairman of HKIE Environmental Division, Ir TY IP. With regard to increasing multidimensional energy demand in Hong Kong in a context of climate changes and lack of local natural energy resources, the Annual Seminar provided opportunity to experts, professionals and academics to share valuable experiences and views on the theme: "*Hong Kong Energy Challenges & Solutions*". Keynotes, presentations and discussions on this topic highlighted not only achieved progress in energy sustainability process, but also existing critical obstacles and difficulties which have to be overcome. Participants also noticed favorable aspects in the reformed fuel mix policy under consultation, susceptible to enhance current efforts in developing cleaner energy sources and provide long-term stabilization in energy sector. Development of strategies towards energy sustainability is on-going. However, regardless of existing challenges and having all stakeholders engaged and fully committed is crucial to successful reform and achievement of energy sustainability.

1. Introduction

Hong Kong Special Administration Region is a world-class financial, trading, shipping and business Centre of which the economy is driven by its higher value-added and knowledge-based services. To stay competitive and attain sustainable growth, Hong Kong needs not only to restructure and reposition itself in the light of the challenges posed by globalization, but also to secure its long-term energy demand. In a context of lack of indigenous energy resources, assuring a stable and affordable energy supply remains a cross-cutting and challenging issue to Hong Kong economic development. Increasing multidimensional energy demand enhances the pressure on Government and energy companies to develop strategies to keep supporting the functioning of the economy and the social development. At the same time, related pollution issues, and drastic weather with severe disasters from climate changes, are exacerbating the challenge, threatening commodity prices, supply chain resilience and productivity.

Such situation undoubtedly requires a multipronged approach for energy, involving not only supply reliability (assuring provision of sufficient energy to support economic and social activity and minimize supply disruptions, depending on tapping new energy sources as well) and affordability (maintaining the energy at the price that assures social development and the competiveness of the economy with more inclusive technological development and supporting policy reforms), but also security (assuring the provision of energy from safe sources) and environmental performance (entailing aggressive exploration of all options to curb burgeoning energy demand and promoting emissions abatement measures with a shift towards research and development of climate mitigation, adaptation and risk reduction). Hence, systematic proactive reform that combines and synchronizes government priorities, choices and all stakeholders' involvement, is an urgent imperative to mobilize resources towards a real sustainability.

In this view, the Annual Seminar, by providing a platform of discussion and sharing of valuable experiences and expertise, aimed to focus on energy future sustainability related challenges with plausible solutions and technological development. This technical report summarizes discussed salient aspects including current trend of energy demand and supply; emissions reduction and climate changes challenges; innovations in cleaner energy sources development and policy transformation needed to drive a stable and resilient economic environment. The report also provides with perspectives and challenges of promoting multidimensional energy sustainability in Hong Kong.

2. Overview of Hong Kong Energy Trend

In Hong Kong, with a lack of indigenous primary energy resources, a substantial share of imported energy is converted into secondary energy such as electricity and gas for final consumption[4;11]. To ensure the prosperity and stability of Hong Kong, the Central Government of China keeps supporting energy co-operation between the Mainland and Hong Kong through an intergovernmental memorandum of understanding signed by the Hong Kong Government and the National Energy Administration of the People's Republic of China in 2008. This inter-governmental agreement contemplated energy cooperation between the Mainland and Hong Kong on the long term and stable supply of nuclear electricity, so that Hong Kong can make greater use of clean energy. The natural gas sources considered for Hong Kong are the offshore gas fields being developed in the South China Sea; piped gas like the one from second West-to-East Gas Pipeline bringing gas from Central Asia; and liquefied natural gas from receiving terminal(s) in the Mainland.

Electricity is supplied by CLP Power Hong Kong Limited (CLP Power) and The Hongkong Electric Company Limited, an associate company of Power Assets Holdings Ltd. CLP Power supplies electricity from its Black Point (2500 MW), Castle Peak (4108 MW) and Penny's Bay (300 MW) power stations[7]. Natural gas and coal are the main fuels used for electricity generation at the Black Point and Castle Peak power stations. Lamma Power Station with a total installed capacity of 3,737 MW is the sole power generation facility of The Hongkong Electric Company Limited.[12] Natural gas used at Lamma Power Station is imported through a submarine pipeline from the LNG Terminal of Guangdong Dapeng LNG Company Limited in Guangdong Province.

Hong Kong's other sources of imported energy are Singapore and Indonesia. In 2011, Singapore accounted for 72.5% of imports of fuel oil and 58.8% of unleaded motor gasoline while Indonesia has been the main supplier of steam coal imported into Hong Kong. Natural gas and liquefied petroleum gas (LPG) are the main types of gaseous fuels in Hong Kong for domestic, commercial and industrial use. However, town gas which is manufactured locally using naphtha and natural gas as feedstock is also being distributed by the Hong Kong and China Gas Company Limited and has the major share in the domestic market [5].

From 2012 statistics, as a whole, coal maintained the highest share of the fuel for electricity generation (53%) in Hong Kong, followed by imported nuclear (23%), natural gas (22%), and Oil & others (2%) in

2012[4;11]. Electricity supply remains relatively affordable for masses (less than 2% of household expenditure). The cost per kWh for the majority average domestic consumption of 275kWh per month is currently HK$1 for The Hongkong Electric Company Limited and HK$1.08 for CLP Power (Fig.1) [4;11]. However, the average net tariff per unit for all customers in January 2014 was HK$1.108 for CLP Power and HK$1.349 for The Hongkong Electric Company Limited [7]. In terms of final electricity demand in Hong Kong, CLP Power experienced demand growth of 13.4% from 2003-2013 (1.3% p.a.) versus 3.5% for The Hongkong Electric Company Limited (0.3% p.a.) in the same period. The averaged total growth rate of electricity consumption for Hong Kong is 10.7% over 2003-2013 (1.0% p.a.) [11].

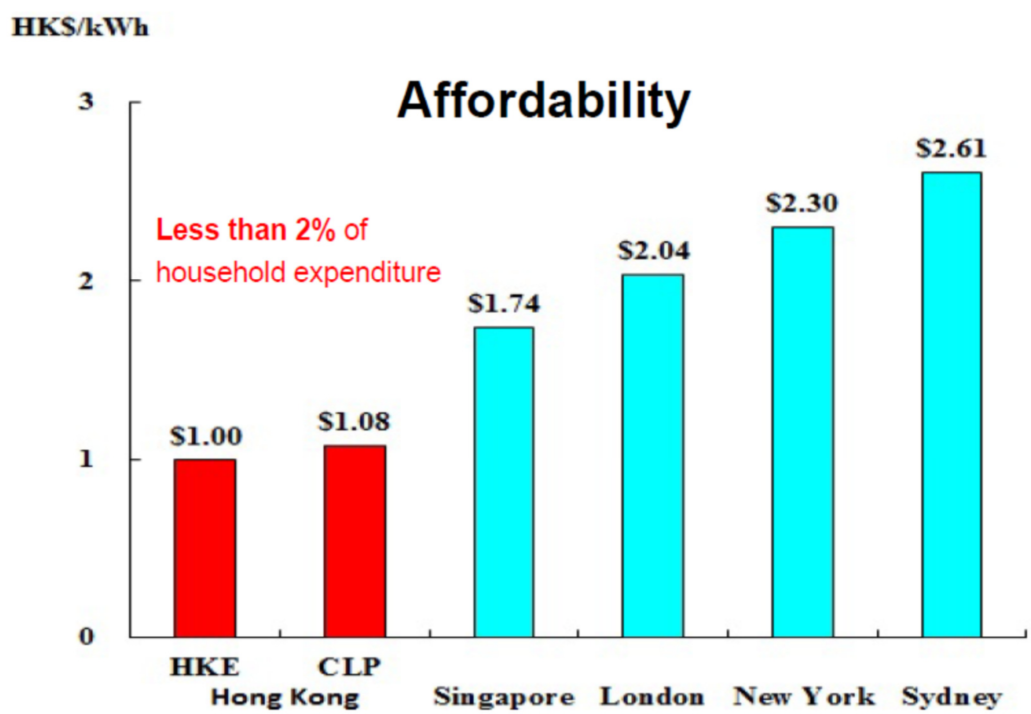

Figure 1: Electricity Price for Hong Kong in 2014 and Other Regions in 2013 (Based on Monthly Domestic Consumption)

The building sector (residential and commercial) accounted for the largest share of electricity consumption at 92%, followed by industry (6%) and transport (2%).

3. Emissions Reduction and Energy Development Challenges

3.1 Government Commitment

A major target pursued by Hong Kong Government is to reduce the energy intensity by 25% by 2030 (based on the 2005 level) as set out in the APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development issued in September 2007. As underlined by the participants[1;2;4;11;12] of the Annual Seminar, building is considered as the largest energy consumption sector with about 90% of the electricity used in Hong Kong and the power generation accounts for 66% of greenhouse gas emissions (as shown in Fig.2). Thus, efforts are being invested in cleaner power generation process and in the building sector for energy efficiency through number of instruments including Buildings Energy Efficiency Ordinance, establishment of BEAM Plus and the Energy Efficiency Labelling Scheme to raise environmental impact awareness, promote green building, energy efficiency and renewable energy[11]. Under the Energy Efficiency Labelling Scheme, energy labels are required to be shown on the products for supply in Hong Kong to inform consumers of their energy efficiency performance.

Emissions reduction strategies have been tightened up at the supply side for Hong Kong power industry. In addition to the Air Pollution Control Ordinance, the Emission Performance Linkage Mechanism was introduced under the Scheme of Control Agreement by the Government to drive the power companies to reduce emissions including SO_2, respirable suspended particulates (RSP) and NOx [11;12]. Both CLP Power and The Hongkong Electric Company Limited have adhered to the scheme to support Government initiatives. Various technologies such as electrostatic precipitators, flue gas desulphurization and low NOx burners were introduced in the power generation processes over the past few years to achieve the required emission improvement [12].

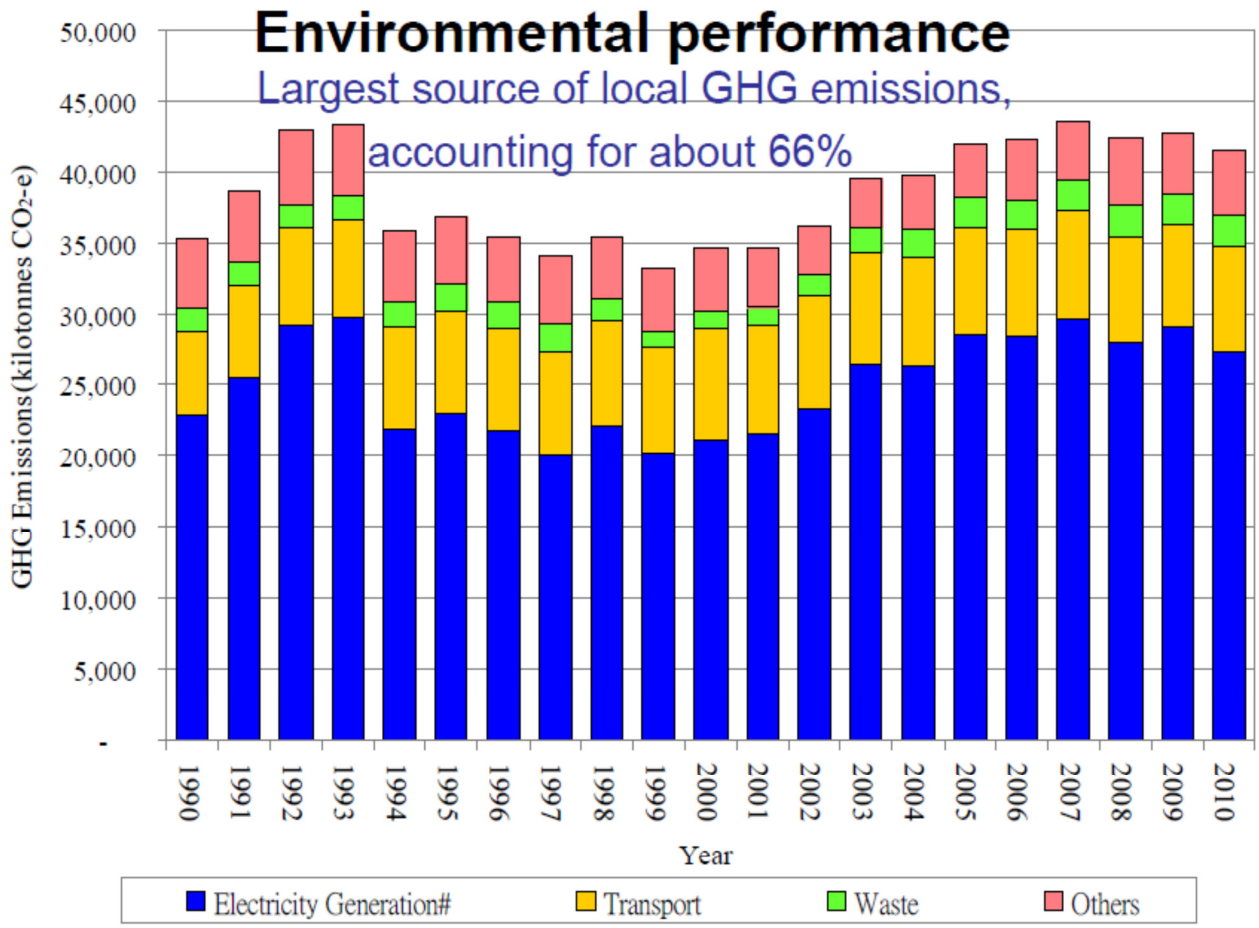

Figure 2: Hong Kong Greenhouse Gas Emissions by Sector

New financial incentive schemes for renewable energy development (including a higher permitted rate of return of 11%) have been also introduced in 2008[12]. Substantial measures have been implemented in transport field including: extension of public transport (with yearly increasing market shares of the franchised public transportation as shown in Fig.3); tightening vehicle emission standards; adopting an incentive-cum-regulatory approach to phase out pre-Euro IV diesel commercial vehicles; subsidising franchised bus companies to retrofit Euro II and Euro III buses with selective catalytic reduction devices; and promoting the use of electric vehicles [2;4].

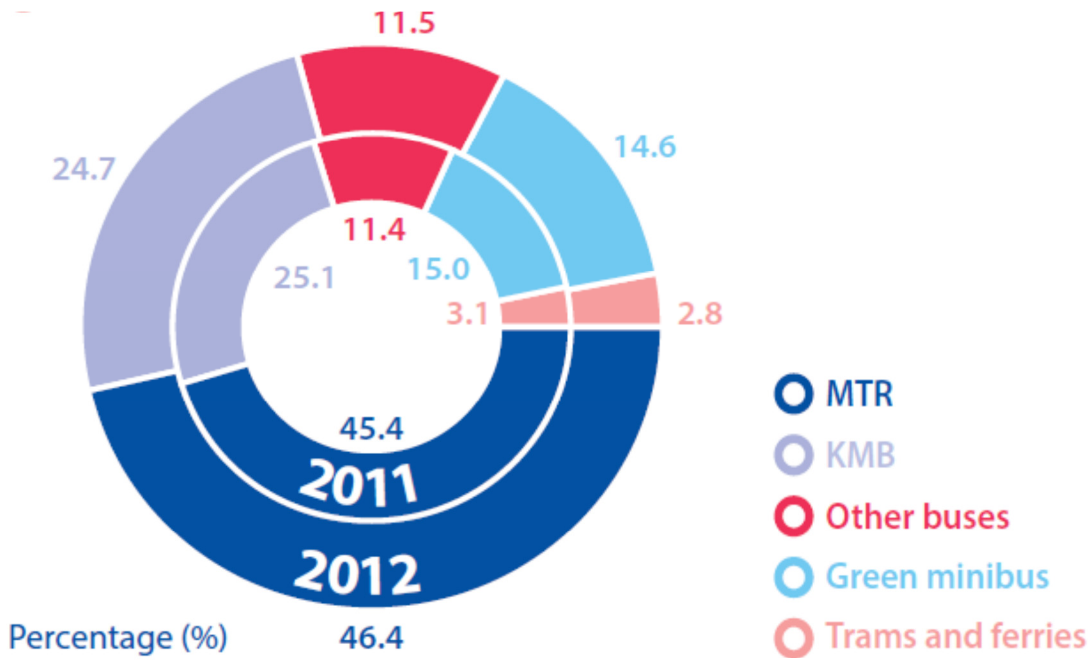

Figure 3: Market Share of Franchised Public Transportation in Hong Kong

3.2 Achievements and Challenges

(1) Noticeable Progress

As a result of above instruments, important achievements are noticeable on air quality improvement. In 2012, SO_2, NO_X and RSP emissions from public electricity generation were reduced by 72%, 43% and 63%, respectively as compared with the emissions in 1997. Compared with 2006, the ambient concentrations of SO_2 and RSP have been reduced by 41% and 13%, respectively, in 2013. The roadside SO_2 and RSP have also been reduced by 48% and 24% in the same period [4;11].

In the field in green energy development, the Government has taken the lead in using renewable energy by installing a 350 kW PV system on the roof of the Electrical and Mechanical Services Department headquarters. The Government also installed solar water heating system in government premises, such as swimming pools, to save energy used for water heating [11]. On the other hand, water-cooled air-conditioning systems using fresh water cooling towers which are more energy efficient than air-cooled systems, have been promoted by the Government. A voluntary Fresh Water Cooling Towers Scheme was launched to promote a wider use of fresh water in evaporative cooling towers for air conditioning systems in non-domestic buildings for energy efficiency. At the end of December 2013, 499 installations were completed under the Scheme. It is estimated that these installations could save up to about 314 million kWh of electricity and 219,000 tonnes of carbon dioxide emissions per annum. The main objective is to expand the use of district cooling or water-cooled air conditioning, so that by 2020 up to 20% of all commercial buildings will have up to 50% better refrigeration performance compared with buildings using regular air conditioners. Initial phases of the project have been completed and the Kai Tak Cruise Terminal Building in 2013.

With the financial incentive scheme to power companies for renewable energy development, CLP Power is continuing the feasibility study for an offshore wind farm. An offshore meteorological wind mast was installed to collect site environmental data. CLP Power completed Phase 2 of the 192kW renewable energy power system on Town Island in late 2012. The system now consists of 672 solar panels and two wind turbines supplying renewable energy to the Island [7]. The Hongkong Electric Company Limited's renewable energy assets also performed well, with Lamma winds generating more than 7000 MWh of electricity since being commissioned in 2006, offsetting more than 6000 tonnes of carbon dioxide emissions [12]. Another 1 MW thin-film photovoltaic (TFPV) solar power system was installed in two stages on building roofs at Lamma Power Station, generating more than 3000MWh of electricity since the first commissioning in 2010, offsetting more than 2500 tonnes of carbon dioxide emissions.

The Hongkong Electric Company Limited plans to install about 30 sets of 3MW class offshore wind turbines at a capital cost of about HKD 3 billion with a total generation capacity of around 100 MW, producing 175 GWh of electricity and offsetting 150 000 tonnes of carbon dioxide emissions annually after completion. In 2012, The Hongkong Electric Company Limited built a wind monitoring station at its proposed offshore wind farm site to collect meteorological and oceanographic data for detailed design purposes.

In the nuclear sector, CLP Power has contracted to purchase around 70% of the electricity generated by the two 984 MW pressurized water reactors at the Guangdong Daya Bay Nuclear Power Station in mainland China to help meet the long-term demand for electricity in its supply area. In 2009, the Government approved the extension of CLP Power's contract from 2014 for the supply of nuclear-generated electricity from Guangdong Daya Bay Nuclear Power Station. The extension of the contract ensures a continued supply of cleaner electricity to Hong Kong, China, which will help alleviate air pollution and greenhouse gas emissions locally [7;12].

In terms of nuclear safety, following the Fukushima accident in 2011, a comprehensive safety review was conducted by the National Nuclear Safety Administration (NNSA) at all nuclear power stations in China, including Guangdong Daya Bay Nuclear Power Station. Preliminary results confirmed that the design and operation of Guangdong Daya Bay Nuclear Power Station are in full compliance with existing national regulations and standards. Prior to the NNSA's review, the Station had also conducted its own internal review and had been formulating improvement initiatives to deal with natural disasters of extreme severity in order to further enhance its safe operation [7]. Moreover, to increase the public's confidence in nuclear safety, CLP Power announced an enhanced notification mechanism for 'non-emergency licensing operational events in 2011. These events carry no nuclear safety consequences and have no impact on the external environment or public safety. The enhanced mechanism for reporting such non-emergency licensing operational events within two working days was generally well received by the public. CLP Power will also contribute to an enhanced program of public education and awareness about nuclear energy through initiatives such as plant visits (Nuclear Exhibition Centre), roving exhibitions and an online education platform. The program aims to better inform the public and stakeholders on nuclear-related matters, and to bring a higher degree of confidence in the future role of nuclear energy in powering Hong Kong [7].

Important progress has been also achieved for energy efficiency in public transport sector, especially with MTR Corporation [2]. As the most important integral element of the Hong Kong's public transportation network, the Corporation endeavours to grow its financial strength and world-class standing, all the while, maintaining its corporate responsibilities and commitments of environmental stewardship. With ingenuity and innovative thinking, a balance can be struck between energy optimization, customer service and environmental protection. As reflected in Fig.4 below, with a double digit growth in patronage since 2008, MTR has been able to maintain constant energy efficiency in terms of energy consumption per car km.

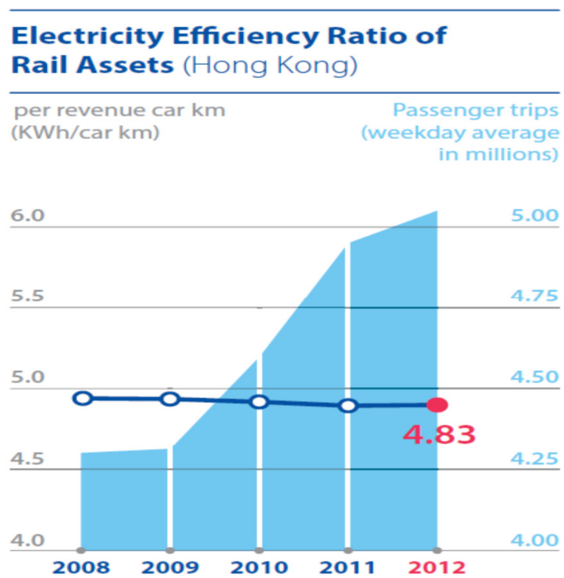

Figure 4: Electricity Efficiency Ratio of Rail Assets over time

From year 2008 to year 2012, there has been 14% reduction in energy utilization using the international benchmarking parameter of kWh per passenger km. Traction energy usage is the largest energy sector within the Corporation. Similar to other metro system in the world, the urban line system is designed with "Regenerative Braking System" which converts a portion of the immense amount of braking energy back to an electrical form, which is then fed back into the power supply system and can then be utilized by other trains within the vicinity. High energy optimization with less mechanical braking, reduction of wear and tear on mechanical parts, reduction of foul odours and reduction in heat generation within the tunnels, have been achieved. From benchmarking exercises with other metro systems, K trains performance in urban lines is already among the best in the class in terms of regeneration efficiency. Number of proactive climate change mitigation measures rea also being implemented by the Corporation through various instruments including Clinton Climate Initiatives at Olympic Station, LED lighting replacement program in trains and station (generating 40% energy saving compared to Fluorescent Lighting), environmental control system in stations with an approximate energy saving of 27,000 MWh or an equivalent to 18,900 tonnes of Green House Gas (GHG) reduction annually, environmentally-friendly station entrance. Obviously, keeping abreast of new social and technological developments, the MTR Corporation is fulfilling the commitment to deliver a safe, reliable and comfortable passenger service in a cost effective and environmental friendly manner [2].

(2) Challenges

In sight of noticeable in energy cleaning, energy efficiency, renewable energy initiatives, reduction of greenhouse gas and other air pollutant emissions, the stakeholders still have to deal with number of persistent challenges.

Even though the ambient PM2.5 concentration can comply with the proposed new Air Quality Objective, it is still far higher than the WHO limit. As shown in Fig. 5, roadside pollution is still quite high and remains a big public-health issue with frequent critical haze events occurring in autumn and winter. Tighter control of emissions from vehicle and other sources is needed. In the long-run, adoption of cleaner energy and changing industrial structure must be implemented [10].

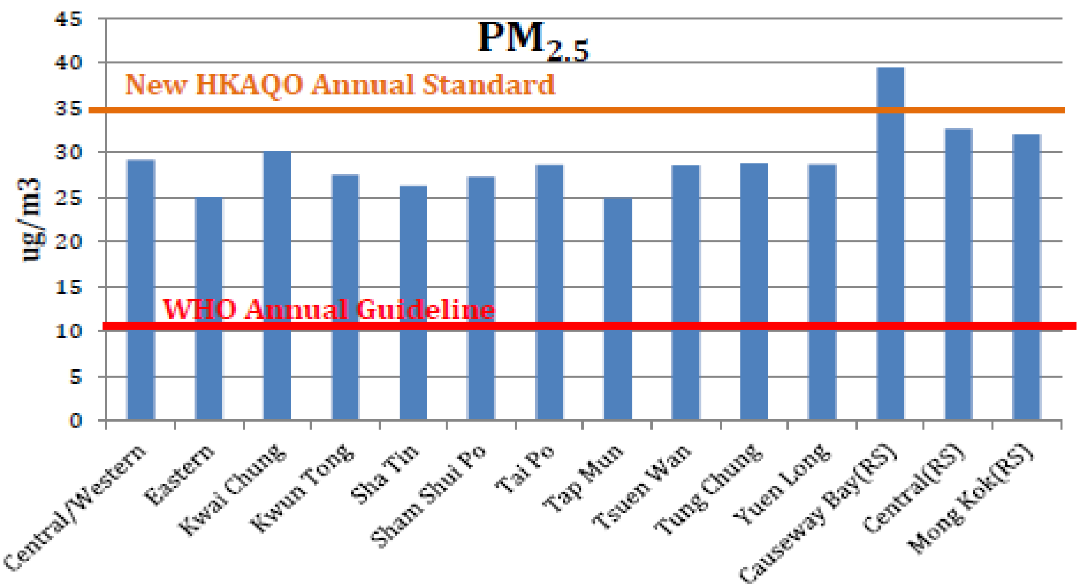

Figure 5: Annual Mean $PM_{2.5}$ concentrations in 2012 in Hong Kong from HKEPD's Air Quality Monitoring Network (RS stands for roadside)

Moreover, with increasing interrelations and interactions between Guangdong Province and Hong Kong, cooperation on the regional trans-boundary air pollution control shall be strengthened in order to achieve more significant reduction of heavy air pollutant emissions, especially particulate matter from power plants, since incremental trends of PM are still noticeable over China with a long range transport affecting Hong Kong (Fig.6) [10].

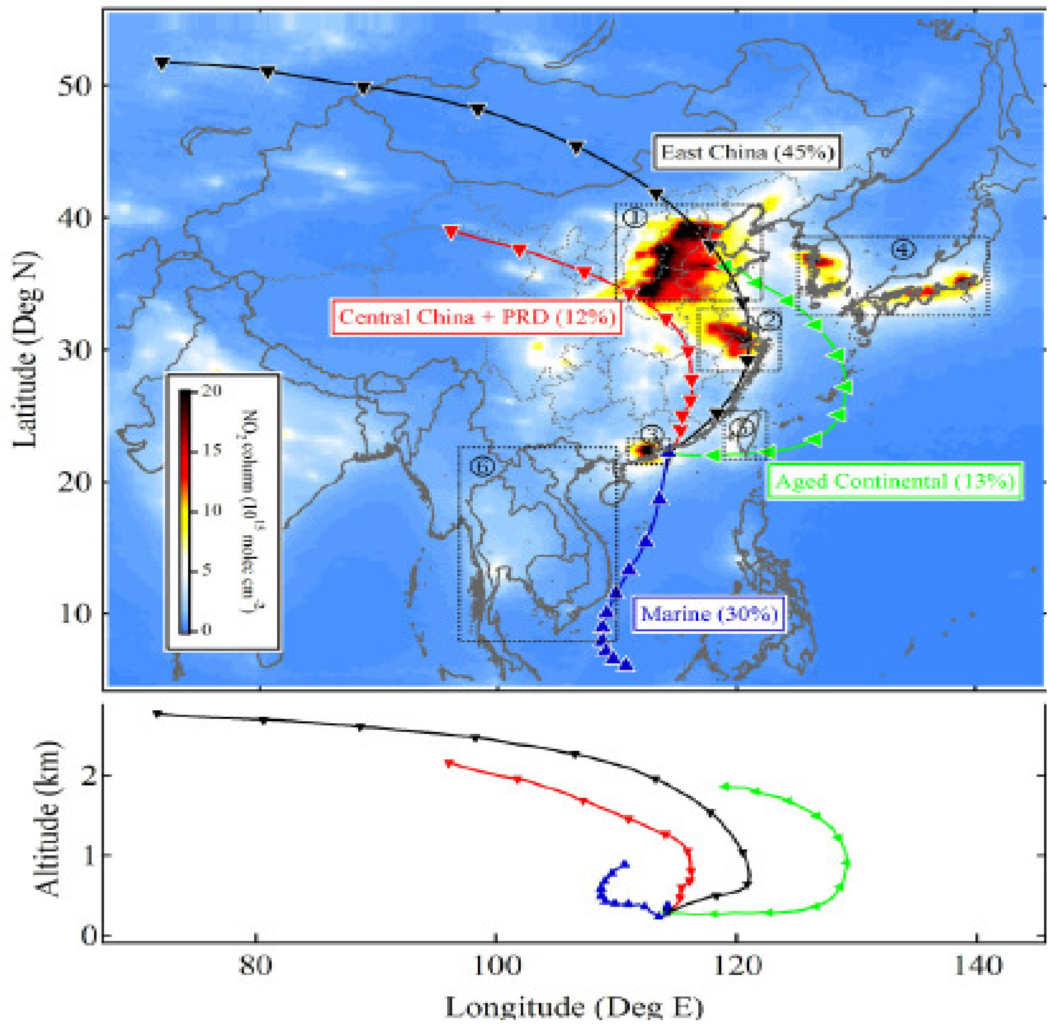

Figure 6: Schematic Long Range Transport of PM2.5 Generated from China

Another challenging aspect of climate changes is how to increase the resilience of energy infrastructure against extreme weather conditions and events, which can disrupt energy supply and damage production plants or distribution assets. For example, severe weather events in Taiwan and India have resulted in damage to CLP's fuel storage and power generation facilities in those locations [7]. Recent extreme weather events in South China and the PRD region highlight the importance of the need for greater

adaptability and resilience of energy infrastructure. Protective measures at both local and regional scales should therefore be developed for effective adaptation to potential severe climate change effects [7].
In building sector, in sight of invested efforts in promoting BEAM Plus in Hong Kong, only few buildings are qualified and really complied with required environmental performance in terms of energy efficiency and greenhouse gas emission reduction. There is a lack market demand for energy efficiency designs and low carbon building products. This poses the crucial issues of changing public internal behaviours, financing energy efficiency upgrade and adhering and managing Government expectations.

On the renewable energy side, although significant progress is noticeable with The Hongkong Electric Company Limited and CLP Power (which is considered as one of the largest investors in wind energy in Asia; largest foreign investor of wind power in India and China), the intermittent nature of solar and wind power sources are currently unable to provide reliable supply in Hong Kong. Furthermore, the quality of Hong Kong's on-shore renewable energy resources is quite limited with strong scarcity of available land. These aspects constitute critical challenges for large-scale local development of on-shore renewable energy. Thus, development of other forms of large scale green power sources, for example offshore wind farm, is necessary. This is economically and technically feasible [12].

On the other hand, most of the mitigation measures against climate changes for larger reductions of greenhouse gas emissions are still not commercially viable today as described in Fig.7 in the global context of carbon emission abatement. Based on Fig.7, clean energy has its cost; thereby, providing flexibility and optionality in managing emission targets at the minimal energy cost without compromising supply reliability and safety, is critically challenging. A key message addressed to the Conference of Parties (COP 19) by the power industry is the need for stable, predictable long-term policy frameworks and objectives [7]. Governments therefore need to develop long-term policy frameworks that cover time periods in the order of decades to provide the certainty necessary to attract the investment needed to deploy mature technologies that are available today and for the research and development needed for new technologies.

Any measures taken now should not only address our short-term fears and concerns, but they must be sustainable and have the ability to create long-term benefits to Hong Kong. Current innovative attempts in the development of cleaner energy sources (discussed in the next section) and integration of these sources to create a more diversified fuel mix portfolio, should be a part of the long term energy vision [7].

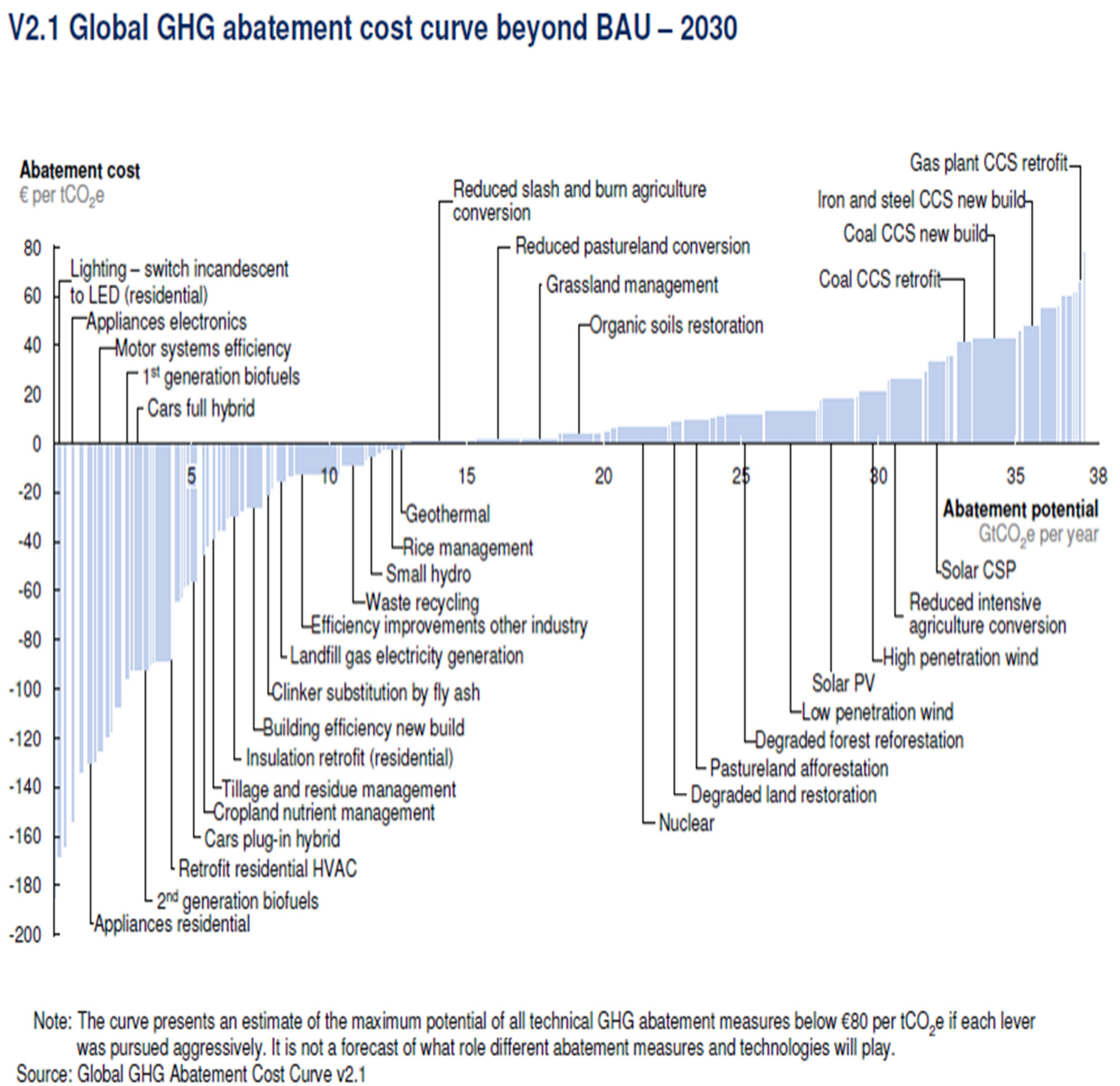

Figure7: McKinsey& Company's Global Greenhouse Gas Abatement Cost Curve v2.1, 2010

4 Innovative Attempts in Cleaner Energy Sources Development

As evoked above, innovations in cleaner energy development are strongly necessary to support future energy demand and environmental performance. As such, noticeable technological progress is visible in number of fields as described below.

4.1 Energy from Sewage Treatment

Sewage, which is normally regarded as waste, is generated in large volume in the course from daily activities in Hong Kong. With advanced energy recovery technologies, sewage can be converted into energy effectively and efficiently through the application of suitable sewage treatment processes as being experienced by the Drainage Service Department [8]. Sludge is produced during a secondary sewage treatment process. Prior to delivery to landfill sites, stabilization process is applied to the sludge produced from secondary treatment of sewage to remove the harmful substances. Anaerobic digestion is a traditional process used for the stabilization of bio-solids and widely employed in the secondary sewage treatment works worldwide. Organic materials of the sludge are broken down into less harmful inorganic products and various kinds of gases (biogas) are produced as a result of biodegradation of the organic materials [8].

Previously, only little proportion of extracted biogas was used as fuel for hot water boilers and electricity generation and a large portion was burned and flared to the atmosphere. After 2006, combined Heat and Power (CHP), was applied. Such technology increases the overall efficiency of an energy recovery system through simultaneous generation of heat and power from a single energy source. It encompasses a range of equipment, but always includes an electricity generator and a heat recovery system. Taking into account the recovery of thermal energy, the overall efficiency of CHP plant can reach 90%. Biogas collected from digesters is first stored in a gas holder. It is then compressed and purified by desulphurization and moisture removal before to be fed at a constant pressure into the CHP plant. Energy stored in the biogas is then converted into thermal energy and mechanical energy which drives a synchronous generator for producing electricity to meet part of the power demand for the sewage treatment process. With a total capacity of 3,645 kW, all CHP plants in DSD are now operating in on-grid configuration (connected and operated in parallel with the power supply grid). The CHP plant in Shatin STW, with a capacity of 1.4MW (Fig 8), is the largest HV grid connected generating unit operating in Hong Kong [8].

Figure 8: CHP installed in Shatin Sewage Treatment Works

Recent development of the CHP system is also noticeable. Between 2006 and early 2013, two more CHP generators were installed, which were at Shek Wu Hui STW and Tai Po STW. The total installed power generating capacity from the utilization of biogas then reached 1,590 kW and the generators had converted 9.32 million m^3 of biogas to some 20.2 million kWh of electricity, which is equivalent to the annual electricity consumption of over 2,240 4-member households. In monetary term, it represents a saving of about HK$17.5 million in electricity cost. The reduction of greenhouse gas emission, after installing these CHP generators, is equivalent to 14,140 tonnes of CO_2. Over end 2013 and early 2014, two further CHPs were commissioned in Shatin STW and Tai Po STW, with a capacity of 1,400 kW and 630 kW respectively [8].

CHP as one of the fast-growing installations in DSD, is considered to be one of the practical ways for turning waste to resource by recovering the chemical energy in biogas from sewage sludge. DSD will therefore continue to explore the feasibility of additional CHPs in various sewage treatments works to cater for the increasing demand in sewage treatment capacity and to keep abreast of the latest development in CHP development with a view to further enhancing energy saving. As such, further studies will be carried out for installing additional new CHPs in sewage treatment works to achieve optimum biogas utilization [8].

4.2 Commercial Use of Landfill Gas

Currently Hong Kong produces about 13,000 tonnes of solid waste per day disposed of in the three strategic landfill, namely Southeast New Territories (SENT) Landfill, Northeast New Territories (NENT) Landfill and West New Territories (WENT) Landfill. An experiment consisting of exploitation of the commercial use of landfill gas was conducted by the Hong Kong and China Gas Company Limited at the Shuen Wan closed landfill successfully since 1999. The process consists of extracting the gas during the anaerobic digestion of the putrescible waste in the landfill [5]. The typical composition of raw landfill gas (LFG) is summarized in Table 1.

Table 1: Composition of LFG

LFG Composition	Volume % (dry basis)
Methane, CH_4	50 - 60 %
Carbon Dioxide, CO_2	30 - 40 %
Nitrogen, N_2	Up to 10%
Oxygen, O_2	1 – 2 %
Hydrogen Sulphide, H_2S	~250 ppmv
Organic Sulphur	~50 ppmv

Landfill gas collected from solid waste landfill sites is now utilized on site for generation of electricity for on-site consumption and as heating fuel in the leachate treatment plant. The extraction of LFG is controlled by an automatic system to deliver LFG to different consuming units at set quantities and pressures. LFG is supplied fuel to the generators that produce electricity for on-site lighting and power, to heat raw leachate in the Ammonia Stripping Plant (ASP) to remove and oxidize ammonia as part of the leachate treatment process. Any surplus is transferred to a flare to convert CH_4 to CO_2 and reduce the greenhouse effects and minimize the potential hazards arising from gas build-up within the landfill sites as well. The most important project of landfill gas exploitation is set at NENT landfill site (Fig.9) which was operational since 2007 after agreement between HKCG and the operator of NENT landfill, Far East Landfill Technologies Ltd (FELT) finalized in 2003. The agreement aimed to jointly develop a project to use treated LFG as a heating fuel in the town gas production plant at Tai Po. Due to cost-effectiveness issue, a treatment unit (TU) has been installed at NENT to remove carbon dioxide, hydrogen sulphide and non-methane hydrocarbons from the raw landfill gas. The product gas, Synthetic Natural Gas (SNG), contains over 80% methane and is delivered to the Town gas Tai Po production plant as heating fuel through a 19 km, 400mm diameter dedicated polyethylene (PE) underground pipeline [5].

Figure 9: NENT Landfill Gas Treatment Unit

One of interesting processes in the Tai Po gas production plant is the steam reforming where methane is converted to hydrogen to control the heating value of the product town gas (Figure 10). The Tai Po steam reformers burn naphtha as fuel and SNG produced from NENT LFG can be used as another source of thermal energy. According to the full design capacity of the Treatment Unit, up to 40% of the naphtha burned can be replaced by SNG from NENT. SNG now accounts for ~2% of the Tai Po gas production plant's total energy input. When the NENT TU is working at its full design capacity, utilization of NENT SNG as a heating fuel in the Tai Po Gas Production Plant can save 43,000 tonnes of naphtha per year which equates to the avoidance of 135,000 tonnes of CO_2 emission. The total energy supplied from

NENT so far is about 2,510 TJ. This helps saving about 52,710 tonnes of naphtha and avoiding 165,660 tonnes of CO_2 emissions [5].

Figure 10: Tai Po Plant Steam Reformer

SENT and WENT landfills are other strategic landfills which are currently flaring off a large amount of surplus LFG every day. HKCG is actively negotiating with the landfill operators and EPD to find beneficial ways for all parties to utilize the LFG. However, the speaker underlined that although recovered landfill gas is commonly used worldwide for power generation or upgraded to natural gas standard to fuel vehicles or to inject into the gas grid for household, commercial and industrial (C&I) use; it is not the case in Hong Kong. A lot of hurdles need to be overcome in order to sell electricity generated from LFG to the electricity grid. Therefore, power generated from landfill gas can only be used internally. The existing town gas distributed in Hong Kong is not natural gas. Also, the natural gas cannot be burnt safely in the town gas appliances. Thus, even upgraded landfill gas to natural gas standard cannot be injected into the town gas grid for household, commercial and industrial use. Another common application in the world is to upgrade landfill gas to natural gas and use it to fuel natural gas vehicles (NGVs). However NGVs are currently not available in Hong Kong and the introduction of NGV is questionable as there is no infrastructure as well as no policy or legislation on it yet [5].

Nevertheless, it is fairly common in developed countries that commercialization of electricity generated from landfill gas or biogas or commercialization of natural gas upgraded from landfill gas or biogas can receive a certain incentive of green premium to compensate the investment cost for utilizing the waste energy. This green premium can be equal to or even higher than the electricity or gas price itself. Unfortunately there is currently no policy or legislation for subsidizing investment in biogas and landfill gas utilization in Hong Kong. It makes it unattractive for private companies to find a beneficial commercial model to utilize the landfill gas [5]. Appropriate policy is therefore highly needed in this field.

Besides landfills, HKSAR Government proposes to build organic waste treatment facilities to treat source separated food wastes. The tender for phase I has been issued and the tender for phase II is planned to be issued next year. A certain amount of biogas will be generated in the food waste digestion process which is also a good source of energy. HKCG is interested in the biogas from the Organic Waste Treatment Facilities Phase II, OWTF II because of its proximity in relation to their existing NENT SNG pipeline [5].

4.3 Direct Alcohol Fuel Cell Technology

Fuel cells are among the most considered future alternative energy conversion systems. A fuel cell is an electrochemical device that continuously and directly converts chemical energy to electricity. Conventional fuel-cell types require hydrogen as the fuel, which has to be free of impurities when operated at temperatures below 100°C. However the storage and distribution of hydrogen is still one of the open questions in the context of a customer-oriented broad commercial market [13].

The last two decades research effort has been devoted to direct alcohol fuel cells (DAFC) dedicated to overcome the hydrogen specific restrictions. In this direction, direct alcohol fuel cells have been extensively studied and considered as possible power production systems for portable electronic devices and vehicles in the near future. The speaker [13] assured that the hydrocarbon compounds (methanol or ethanol) used in DAFC are from renewable sources. This therefore minimizes the environmental impacts related to the development of such technology. The DAFC is also low temperature and heat transmission fuel cell which makes it ideal for various applications. The main concern of this technology is its current non-affordability, as recognized by the speaker. Because of the high cost of platinum-based catalysts, further research shall be oriented towards to the development of low or non-platinum electro-catalysts (anodes and cathodes) and nanostructured electro-catalysts based on non-noble metals [13].

5. Energy Policy Reforms and Sustainability Challenges

In 2010, the HKSAR Government issued a public consultation document, "Hong Kong's Climate Change Strategy and Action Agenda", which proposed that Hong Kong should adopt a voluntary carbon intensity reduction target of 50% to 60% by 2020 (base year 2005). Hong Kong's proposed carbon intensity target was in line with China's voluntary 2020 target, which was announced in 2009, of 40% to 45% carbon intensity reduction from the same base year. In order to achieve such target, Hong Kong Government has also proposed in the Consultation Paper to substantially revamp the fuel mix for electricity generation by 2020 and meet the target of imported nuclear energy (50%), natural gas (40%), coal (10%) and renewable energy (3%-4%) of Hong Kong's fuel mix for electricity generation. However, in light of Fukushima event in 2011, the previous target became difficult to achieve. Hence, new fuel mix ratio (under public consultation from 9 March to 9 June 2014) is proposed to balance the competitive energy objectives on safety, reliability, affordability and environmental performance [12].

5.1 Review of Future Fuel Mix for Electricity Generation

Besides Fukushima event, several reasons support the review of existing fuel mix. First, the existing fuel mix of coal (53%), imported nuclear (23%), natural gas (22%) and oil & RE (2%) in 2012, might not assure the objectives of 2020 evoked above. Moreover, the local coal-fired generating units will gradually retire starting from 2017. There would be a change in the future fuel mix in meeting both projected demand for electricity and environmental targets (air quality improvement and enhanced actions against climate changes). The public consultation on future fuel mix for electricity generation highlights two options as detailed in Tables 2 & 3 below [11]. The main challenge in this reform are to achieve a delicate balance among the four energy policy objectives namely safety, reliability, affordability and environmental performance.

Table 2: Options for Fuel Mix Policy Reform

Fuel Mix	Import		Natural Gas	Coal & RE
	Nuclear (Daya Bay)	Grid Purchase		
Existing (2012)	23%	-	22%	55%
Option 1: Purchase From the Mainland Power grid	20%	30%	40%	10%
Option 2: Using More Natural Gas for Local Power Generation	20%	-	60%	20%

Table 3: Comparative Analysis of Options of the Policy Reform for Fuel Mix

Safety	Both options pose no specific safety risks to Hong Kong
Reliability	**Option 1**: -Untested but not uncommon in other places -Technically feasible -Estimated future demand less than 2% of CSG's generation in 2012 -Strong support provided by CSG's entire power grid with multiple sources of supply -Local back-up generation to cater for emergencies **Option 2**: -Proven track record of reliability
Affordability	**Both options:** -No substantial difference in average unit cost -Roughly double the unit generation cost over the five years from 2008 to 2012; actual costs need to be further ascertained -Tariff implications cannot be ascertained at this stage **Option 2**: -Heavy reliance on natural gas price volatility
Environmental Performance	-Both options can achieve 2020 environmental targets **Option 1**: -Can reach higher environmental improvement targets when cross-boundary infrastructure is in place in around 2023 **Option 2**: -limited room for any further significant improvement
Implication for the post 2018 Electricity Market	**Option 1**: -May enhance interconnection between the two local power grids; more room to introduce competition at the generation level. **Option 2**: -Participation of new suppliers affected by the availability of land for any new generation facilities; allowing existing power companies to invest may add to the potential stranded costs
Diversification	**Option 1**: -Taps into cleaner fuels otherwise not available to Hong Kong. **Option 2**: -Increases the risk of heavy reliance on a particular fuel type
Flexibility in Scaling Up Future Supply	**Option 1**: -More flexible in meeting future demand **Option 2**: -Less flexibility to catch up with rising demand

From the perspective of policy objective, these two options actually might achieve the aim of reduction in emissions. However, the systematic retirement of all existing fired-coal generating units involves significant economic implications. The development of available renewable energy resources from broader perspectives should be an integral and indispensable part of the fuel mix policy reform in order to address the public's strong aspiration for renewable energy and demonstrate the Government commitment to supporting the national target for carbon reduction. Both options make the energy generated by coal to low levels. The main concerns are reliability, affordability and security. Under Option 2, the safety, reliability and environmental concern can be achieved, but affordability is subject to changes in prices of natural gas, a big unknown given the large swings in prices of natural gas [9].

Critiques on Option 1 are mainly related to the reliance on the China Southern Power Grid (CSG) in supplying energy to Hong Kong. A number of the Annual Seminar participants warned that the energy reliability will strongly depend on an outside power company, in which Hong Kong can have no control over. Heavy reliance on imported electricity, especially grid electricity which Hong Kong has no control, will create high supply reliability risks for Hong Kong by tapping into relatively less reliable electricity supply through a transmission link subject to impacts of adverse weather and disasters along the long transmission corridor. In particular, electricity consumers on Hong Kong Island will likely be forced to rely on a new single transmission path for meeting a significant portion of their electricity need since there is no existing interconnection between The Hongkong Electric Company Limited and Guangdong power systems [12].

Another uncertainty related to the feasibility of the infrastructures import is the public opposition, especially for nuclear power plants. There are numerous cases of social unrest against new infrastructures in Guangdong Province, e.g. thermal power plants in Shenzhen and Shantou, and a nuclear fuel processing plant in Jiangmen. With regard to the price competitiveness of imported electricity, Guangdong's grid electricity cost is among the highest in the Mainland. The new Mainland nuclear power plants have to adopt more stringent national safety and environmental standards/regulations, advanced and high-cost third generation technologies, and are subject to higher project time and cost overrun risks. There are also additional non-production costs like high transmission loss, expensive transmission infrastructures, extra redundancy for reliability purposes and necessary load management service to facilitate power absorption at Hong Kong side [12]. On the other hand, imported grid electricity is Guangdong's marginal generation and essentially coal generated. Such import will lead to higher regional emissions. As such, grid electricity import acts against the objectives of reducing carbon and other emissions [12].

Furthermore, regulation will be highly complicated for grid electricity import as there will be cross-border operations with a larger number of players, less clear reliability responsibilities, potential needs for third party grid access and interconnection. In addition, the potential sunk costs associated with a dedicated transmission link are likely greater than building local combined cycle gas turbines, and creates more serious obstacles for any future market changes. However, the speaker [12] and other participants in the Annual Seminar noticed that the expansion of local gas generation capacity in the policy reform (Option 2) is technically feasible in Hong Kong with high public acceptance. By allowing Hong Kong power companies to have full control of the electricity supply chain and higher operational flexibility, local generation is a key point for maintaining Hong Kong reliability performance. Local gas generation is expected to be price competitive over imported electricity. When compared with large scale electricity import, there are avoided direct and indirect costs like load management, extra transmission infrastructures and losses. Local gas generation will have more straightforward regulation for all-local operations, clear reliability responsibilities, avoided complications and less serious obstacles for future market changes.

In short, both Options are challenging, and are unable to provide strong guarantee in meeting sustainability objective. The public consultation is therefore expected to provide valuable insights into the main contingencies in both Options and guide the policy makers towards a choice that really assures long-term energy stability for Hong Kong.

5.2 Energy Market Re-structuration

(1) Learning from Alberta Energy De-regulation Experience

Within current energy policy reform in Hong Kong, and based on successful experience of Alberta (Canada), energy market re-structuration through a de-regulation might be helpful to achieve long-term cost stability and affordability [3]. De-regulation can be seen as a means of breaking up the monopolies in the domains of generation, transmission, distribution and retail. Concurrently, de-regulation enables free market powers to create competition amongst corporations in the generation and retail domains. Alberta's experience has demonstrated the importance and criticality of clear written rules, compliance monitoring and enforcement in a competitive market. In particular, the formation of independent regulatory bodies to provide oversight and enforcement of market rules as well as to facilitate stakeholder and industry dialogue is fundamental. If there's one thing to be learned from Alberta's experience, staying the course regardless of challenges encountered and having all stakeholders engaged and fully committed has proven to be one of the most important influences in successful market re-structuring [3].

However, the uniqueness characteristics and subtle differences of each jurisdiction mean that a systematic "copy and paste" approach is not feasible. There are many factors that are critical to the success of market re-structuring. In Alberta's case, sufficient and reliable generation and transmission (supply & demand) is fundamental, as well as the creation of well-organized regulatory bodies to administer the markets. In this process, Alberta decided to use a phase-in approach over many years. This approach allowed all stakeholders and customers to absorb the changes and stabilize. Alberta's success is largely attributed to the recognition that re-structuring could not happen overnight. Thus, should Hong Kong choose to open its energy markets, it is highly recommended to apply a phase-in approach [3]. Other important factors that should be considered include:

a) Ensure sufficient and reliable generation and transmission interconnections throughout the systems;

b) Creation of independent regulatory bodies such as utilities board or Commission to setup appropriate rules or regulation and provide oversight during and post re-structuration, especial on the compliance monitoring and enforcement;

c) Creation of an independent system operator to administer the markets;

d) The government must provide supports and take a leadership role to ensure reasonable balance between the interests of all stakeholders;

e) Collaboration amongst all stakeholders is a key. It will take time but it will be successful if all stakeholders are involved in the process.

2) Learning from Power Market Liberalization in Great Britain

Great Britain energy market liberalization demonstrated the importance of ownership unbundling and workable competition in generation and supply. The motivations of energy market liberalization were to improve public finance, drive efficiency with competition, reduce power of unionized labor, depoliticize energy, drive global trend towards open market and create market environment that provides long-term benefits to society [6]. The benefits were to be realized by relying on competitive wholesale markets for energy and to encourage innovation in energy supply technologies. Retail competition was supposed to allow consumers to choose the retail energy supplier offering the price / service quality combinations that best meet their needs and to allow competing generators and intermediaries to offer these services to consumers. Competing retail suppliers were also expected to provide an enhanced array of retail service products, risk management, demand management, and new opportunities for service quality differentiation to better match individual consumer preferences [6].

However, such experiment highlighted a number of important lessons for energy market liberalization. Should Hong Kong choose to liberalize its energy market, following aspects are to be considered [6]. First, the power market liberalization is less important than energy policy in determining overall outcomes for energy consumers. Second, liberalization is on-going process, no country or market has yet achieved optimal results. The system does not necessarily guarantee long-term market stability and lower cost to consumers. Third, falling to meet consumer expectations remains a key driver of market design. The liberalization is not the same as de-regulation and provides no guarantee of reduced political involvement in the power sector. Fourth, in Great Britain, vertical integration has allowed utilities to shift reported profit between generation and retail. This has reduced earnings volatility and helped to fend off regulatory scrutiny. Ultimately, consumers pay for low carbon sources of energy and other environmental initiatives. Sustainability and security of supply do not always fit neatly with a liberalization market [6].

6. Conclusions and Perspectives

In a context of shortfall of indigenous energy resources, assuring a long-term stable, safe, affordable and environmentally friendly energy supply is critical to Hong Kong economic development. The holistic approach must be to embed sustainability throughout the entire energy process from primary sources to final energy supply and consumption. The Government commitment and stakeholders' engagement enabled ensuring reliable and affordable energy supply in Hong Kong. Efforts are being invested in cleaner power generation process and in the building sector through number of instruments including the Scheme of Control Agreement (between Government and energy companies), Buildings Energy Efficiency Ordinance, BEAM Plus and the Energy Efficiency Labelling Scheme to deal with greenhouse gas emissions and climate change impacts. Improvement of air pollutant emissions reduction has been achieved through the Air Pollution Control Ordinance. In terms of enhanced reduction of greenhouse gas emissions, favorable conditions also exist in the proposed new fuel mix policy; the shift away from coal to gas for electricity generation will make a significant difference and improvement compared to the current situation.

However, another challenging aspect of climate change is how to increase the resilience of energy infrastructure against extreme weather conditions and events, which can disrupt energy supply and damage production plants or distribution assets. Recent extreme weather events in South China and the PRD region highlight the importance of the need for greater adaptability and resilience of energy infrastructures. In such context, supporting actions from the Government are highly expected to reduce the vulnerability to climate risks. Greater protective measures for effective adaptation to potential severe climate change effects should be developed to boost stakeholder's capacity in reducing climate change risks in energy sector. Support to the development and diversification of cleaner energy source technologies is also necessary to attract investment and drive innovation and excellence in energy sector.

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