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HONG KONG'S ROLE IN LOW CARBON DEVELOPMENT: CHALLENGES AND WAY FORWARD

TECHNICAL REPORT

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Executive Summary

The Annual Forum of the HKIE-Environmental Division was held on 18 April 2016 at Hong Kong Exhibition and Convention Center with the leadership of the Chairman of the Organizing Committee, Ir Kelvin Tang; guidance and support from the Chairman of the HKIE-Environmental Division, Ir PC LO.

In accordance with the Paris Agreement (COP 21), global unprecedented economic, social and technological transformation is needed to keep global average temperature increase below 2°C. This requires from all Parties a dramatic reallocation of investment away from carbon-intensive economy to multi-dimensional low-carbon and climate-resilient strategies axed on the development of cost-effective green technologies and policies (solar photovoltaic arrays, wind farms, green buildings, carbon pricing, smart grids, green fuel, green transport, electric vehicles etc.). Thereby, China has primed industry greening and pledged dynamic low carbon economy with strategic plans over the coming years. As key city in the Pearl River Delta Region and fully integrated into sustainable alternatives for climate adaptation and mitigation within the Asia Pacific Economic Cooperation, Hong Kong has to play a key role within such national low carbon development momentum and fully seize existing large regional opportunities to boost local environmental market, increase green consumption and diversify its economy.

It is thus opportune for HKIE-Environmental Division to promote the discussion on Hong Kong's strategies for sustainable low carbon development with stakeholders. While some investments in carbon-efficient fossil-fuel infrastructures will still be needed over the coming years to support economic development, there is an imperative to significantly scale-up economy to green alternatives.

(1) Stakeholders' Commitment and Challenges

Incontestably, important efforts are being invested by local stakeholders to stimulate green development in Hong Kong. The stakeholders, under the leadership of the Government, have demonstrated ability in exploring and implementing strategic plans on potential greenhouse emission contributing sectors in Hong Kong such as energy, mobility and infrastructure. Incentives, showcases, capacity building, and information disclosure with smart technologies are under process on flourishing waves. Current achievements clearly show promising future on the adhesion of key stakeholders to sustainable low carbon options. Nevertheless, substantial efforts are still needed on advanced technological researches and updated comprehensive multi-sectoral policy agenda to overcome persistent challenges associated with the economy greening process and ensure a sufficiently attractive return from low-carbon options and investments.

Critical challenges currently embedded in the low carbon strategies in Hong Kong lie in legislation, sustainable cost-effectiveness, comfort, safety, performance and competitiveness of existing green technologies (in particular in the fields of mobility and energy where further innovations are needed to make current options economically attractive); regulation options for long-term low carbon investment and green consumption; accuracy and value of climate risk prediction and adaptation anticipation; regulation options and promotion of corporate sustainability outcomes; and effectiveness of public-private partnerships coordination for advanced researches on emerging green technologies.

(2) Way Forward

Given the importance of above cross-cutting and challenging aspects, the Forum recommended establishment and disclosure by sector of accurate data associated with climate risk assessment, prediction, monitoring, reporting and verification systems. This is particularly crucial for energy, mobility and infrastructure sectors. Improvement of legislation to include creating channels for stakeholders with low-carbon strategies, accountable governance systems, and direct engagement with local banks, is necessary as well. The Forum particularly recommended stakeholders' direct access to climate finance to facilitate low-carbon investment; adequate and specific technical assistance and capacity-building to stakeholders for project preparation (to enable them to identify, develop and implement "bankable" programmes and projects for low-carbon, climate-resilient infrastructures); enhancement of Government green procurement strategy to all departments and sectors; introduction of a mandatory carbon rating system associated with carbon tax and energy efficiency trading scheme for infrastructure and buildings.

On the other hand, stakeholders are recommended to mobilize further incentives and resources to promote expansion of renewable energy, waste-to-energy technologies; increase the use of landfill gas and work towards greater integration with the Mainland China in terms of energy and climate change policy; adopt a strategic plan for carbon pricing, and explore the possibility of an interjurisdictional emissions trading scheme within the Pearl River Delta Region; enhance private-public partnerships and incentives for the promotion of green fuel and innovative cost-effective researches on electric vehicle.

In short, Hong Kong has the potential to demonstrate that low carbon alternatives provide with strong opportunities for economic diversification and growth, and could take a lead in regional environmental industry to map out pathways for the Pearl River Delta Region and other Asian countries.

1. Introduction

The drastic impacts of global climate change and resulting worldwide shortage of resources undoubtedly call for a radical change of life styles towards sustainable low carbon development. In this respect, global annual climate negotiations (Conference of Parties, COP) have been instituted under the United Nations Framework Convention on Climate Change (UNFCCC) to establish progressive global agreement on green built environment policies, climate resilience, energy sustainability, and innovative green technologies.
Accordingly, the Paris Agreement in December 2015 (COP 21) set up a “pledge and review” mechanism for substantial reduction of carbon emissions in order to hold global average temperature increase below 2˚C.

Regionally, climate action is driven in China by economic considerations, notably by the structural changes linked to the country's transition from a high-growth economic model to a more sustainable economic pathway (“the new normal”), mounting environmental concerns resulting from dramatic air, water and soil pollution and the growing awareness of the need to step up China's own climate change resilience and develop adaptation strategies. The 12^{th} Five-Year Plan (2011-2015) set out a climate policy framework with binding targets aiming at reducing energy intensity by 16%, CO_2 emissions by 17%, increasing the forest coverage rate to 21.66% and the share of non-fossil fuels in primary energy mix to 11.4%. At the COP 21, China pledged to modernize its coal power plants by 2020 and cut emissions by 60%. The coming 13^{th} Five years Plan (2016-2020) is likely to further boost climate action covered by pilot projects such as seven sub-national carbon emissions trading and low-carbon city schemes. In such perspective, Hong Kong, as leading city in the Greater Pearl River Delta Region, and member of Asia-Pacific Economic Cooperation (APEC), should play a preponderant role in regional low-carbon development strategies through joint actions and commitment from all stakeholders.

By bringing together various stakeholders including professionals, experts, academics, research institutions, businesses and policy makers, the Forum therefore aimed at exploring potential axes to significantly boost local environmental market, increase green consumption and reduce greenhouse gas emissions in line with the regional momentum of sustainable low carbon development. This technical report summarizes discussed salient aspects including climate resilience and challenges in Hong Kong, low carbon infrastructure strategies, strategies for urban mobility decarbonizing, regional carbon pricing and market setting, and recommendations for overcoming multi-dimensional challenges and enhancing stakeholder’s capacity building towards a real low carbon future. The Forum has been conceived and implemented as green event in accordance with standard green event guidelines, a benchmark of the HKIE-Environmental Division.

2 The Concept of Low Carbon Development

2.1 Definition and Objectives

Low carbon development has its roots in the UNFCCC adopted in Rio in 1992 and has been recognized as indispensable to sustainable development and included in the negotiating texts under the UNFCCC since the run up to COP15 in Copenhagen in 2009 and the Cancun Agreements in 2011(UNFCCC, 2011). The concept of low carbon development takes a "development-first" approach which rethinks development planning and proposes structural solutions (such as alternative infrastructure and spatial planning) with lower emission trajectories. It focuses on addressing and integrating climate change with development objectives. In practice, the concept combines new and existing elements to address policy objectives along with the need to slow climate change and prepare for its impacts (provisions to reduce vulnerability to climate change impacts).

Basically, low carbon development can serve as potential instrument for governments to present a long term vision on climate and strategic development pathway. It can also be used to establish a policy framework across various sectors and identify needs and priorities in close collaboration with all stakeholders. Low carbon development can also function as a reporting platform to international climate change community. Signaling national emissions and predicted climate change impacts may provide insights into global trends of existing resilience capacity and prospect of future policies.

At city scale, there is no universally applicable standard definition of low-carbon city. First, cities differ in their initial carbon endowments. Cities engaged in energy-intensive heavy industry, or those in colder areas requiring a lot of heating, will start with higher absolute carbon intensities than cities focusing on service and non-energy-intensive industries or those in moderate climates with less need for heating or cooling. Second, the essential of cities is to provide economic opportunities and quality of life for its citizens, and not simply focus on carbon reductions. Actions that compromise on this fundamental fact risk undermining a city’s long-term sustainability. Therefore, definition of a low-carbon city should focus on how cities change their carbon emission trajectories independent of their initial carbon endowments, but in ways that do not compromise economic development and liability. The goal of such type of development is not just to contain sprawl, but to manage urban expansion in a way that encourages dense, transit-oriented and liveable urban forms [13].

When successful, low-carbon development can unlock agglomeration effects and networking advantages, spurring innovation and productivity. It can also significantly reduce the cost of providing services and infrastructure such as public transport, energy, waste and water. And it can significantly increase the viability of public transport and other urban investments by promoting more intensive use and reducing total infrastructure requirements. Making cities more compact, connected and efficient has the potential to generate sustained urban productivity improvements and a wide range of economic, social and environmental benefits. These benefits strengthen the concept of low-carbon development for much greater climate ambition, which is crucial to ensure that emission reductions are not quickly overwhelmed by the impacts of continued economic and population growth.

2.2 Global Actions

The international cooperation on low carbon development is governed by the UNFCCC and its Kyoto Protocol, Cancun and Paris Agreements with a number of new instruments including the Clean Development Mechanism, Technology Needs Assessments, National Communications, Nationally Appropriate Mitigation Actions (NAMAS), Measurement, Reporting and Verification (MRV), Technology Mechanism, Green Climate Fund, Global Environmental Facility, Climate Technology Centre, Technology Executive Committee and International Climate Initiative. The COP 21 global agreement pledged to establish a Capacity-building Initiative for transparency in order to build institutional and technical capacity, both pre- and post-2020. This initiative will support Parties to launch a work plan for the period 2016–2020 in assessing how to increase synergies through cooperation and avoid duplication among existing bodies established under the Convention that implement capacity-building activities.

The main axes of actions include collaborating with institutions under and outside the Convention; identifying capacity gaps and needs and recommending ways to address them; promoting the development and dissemination of tools and methodologies for the implementation of capacity-building; fostering global, regional, national and subnational cooperation; identifying and collecting good practices, challenges, experiences, and lessons learned from work on capacity-building by bodies established under the Convention; exploring how developing country Parties can take ownership of building and maintaining capacity over time and space; identifying opportunities to strengthen capacity at the national, regional, and subnational level; fostering dialogue, coordination, collaboration and coherence among relevant processes and initiatives under the Convention, including through exchanging information on capacity-building activities and strategies of bodies established under the Convention; and providing guidance to the secretariat on the maintenance and further development of the web-based capacity-building portal.

The Global Environment Facility has been also assigned to make arrangements to support the establishment and operation of the Capacity-building Initiative for Transparency as a priority reporting-related need, including through voluntary contributions to support developing countries in the sixth replenishment of the Global Environment Facility and future replenishment cycles, to complement existing support under the Global Environment Facility to strengthen the Technology Mechanism and requests the Technology Executive Committee and the Climate Technology Centre and Network, in supporting the implementation of the Agreement, to undertake further work relating to technological research, development, enhancement of endogenous capacities and demonstration.

In the area of mitigation, International Climate Initiative supports partner countries in developing and implementing innovative instruments for reducing their greenhouse gas emissions. These include measures for transitioning to a sustainable, low-emission economic and energy supply structure and developing low-carbon development strategies, nationally appropriate mitigation actions and systems for measurement, reporting and verification of greenhouse gas emissions and reduction measures. The international Climate Initiative has been advising more than 25 partner countries on the preparation of their Intended Nationally Determined Contributions since early 2014. Numerous international projects also pursue the aim of mobilizing additional public and private capital for climate change mitigation. The conceptual focus is on policy advice, capacity building and appropriate training measures, and also technological lighthouse projects and cooperation schemes.

The private sector has a key role to play in achieving the 'two-degree target' agreed at the COP 21, and mobilizing its resources will be essential in achieving far-reaching climate protection goals. The International Climate Initiative therefore supports projects that eliminate major barriers to greater engagement by the private sector, for example by reducing the financial risks associated with investing in climate technologies in developing countries and emerging economies. International cooperation also provide capital for public-private partnerships, impart the necessary expertise (enabling finance institutions to support energy, efficiency projects in target countries) and create suitable conditions for private investment in target countries by providing advisory support to governments [13].

Besides the UNFCCC, a growing number of international organizations and consultancies have also been involved in low-carbon development programmes, including the UNDP, UNEP, the World Bank (including through its Energy Sector Management Assistance Programme (ESMAP)), Climate Works, the Climate Development Knowledge Network, WWF, and a variety of bilateral donors. The United Nations Development Programme has developed a guidebook of ‘Preparing Low-Emission Climate-Resilient Development Strategies’ to assist national and sub-national governments in developing countries to prepare low-emission, climate resilient development strategies that aim to simultaneously address the threats, risks, vulnerabilities and uncertainties associated with global climate change and the pressing development needs countries face as they pursue sustainable development.

Such guidebook does not offer a short definition of low-emission development but instead provides a series of detailed steps to the formation of low emission development plans including identification of key stakeholders and establishment of participatory planning and coordination frameworks; generation of climate change profiles and vulnerability scenarios; identification and prioritization of mitigation and adaptation options; assessment of financing requirements; and development of low-emission climate-resilient roadmaps for project development, policy instruments, and financial flows.

Many cities grouped in the Carbon Neutral Cities Alliance (CNCA) are also leading on climate change and low carbon development programmes, and delivering significant economic and social benefits in the process with the support of international networks such as C40, ICLEI and United Cities and Local Governments (UCLG), and multilateral development banks. Remarkable consensus exist among international urban development practitioners and prominent organisations and networks on the need for collaboration in five mutually reinforcing areas including facilitating knowledge-sharing among cities on policy reform and innovation to inform and inspire action; utilising common platforms and standards to enable cities to make their commitments public, credibly record their energy use and greenhouse gas emissions, develop low-carbon strategies, and measure their results; and building the capacity of local governments.

This allows political leaders and municipal staff to effectively plan, design and execute low-carbon development plans and strategies; financing low-carbon urban infrastructure by improving cities’ access to domestic and international financial markets; and supporting national governments to empower cities for investment and innovation. Greenhouse gas reduction schedules and targets of the Carbon Neutral Cities Alliance are summarized on Fig.1 [13].

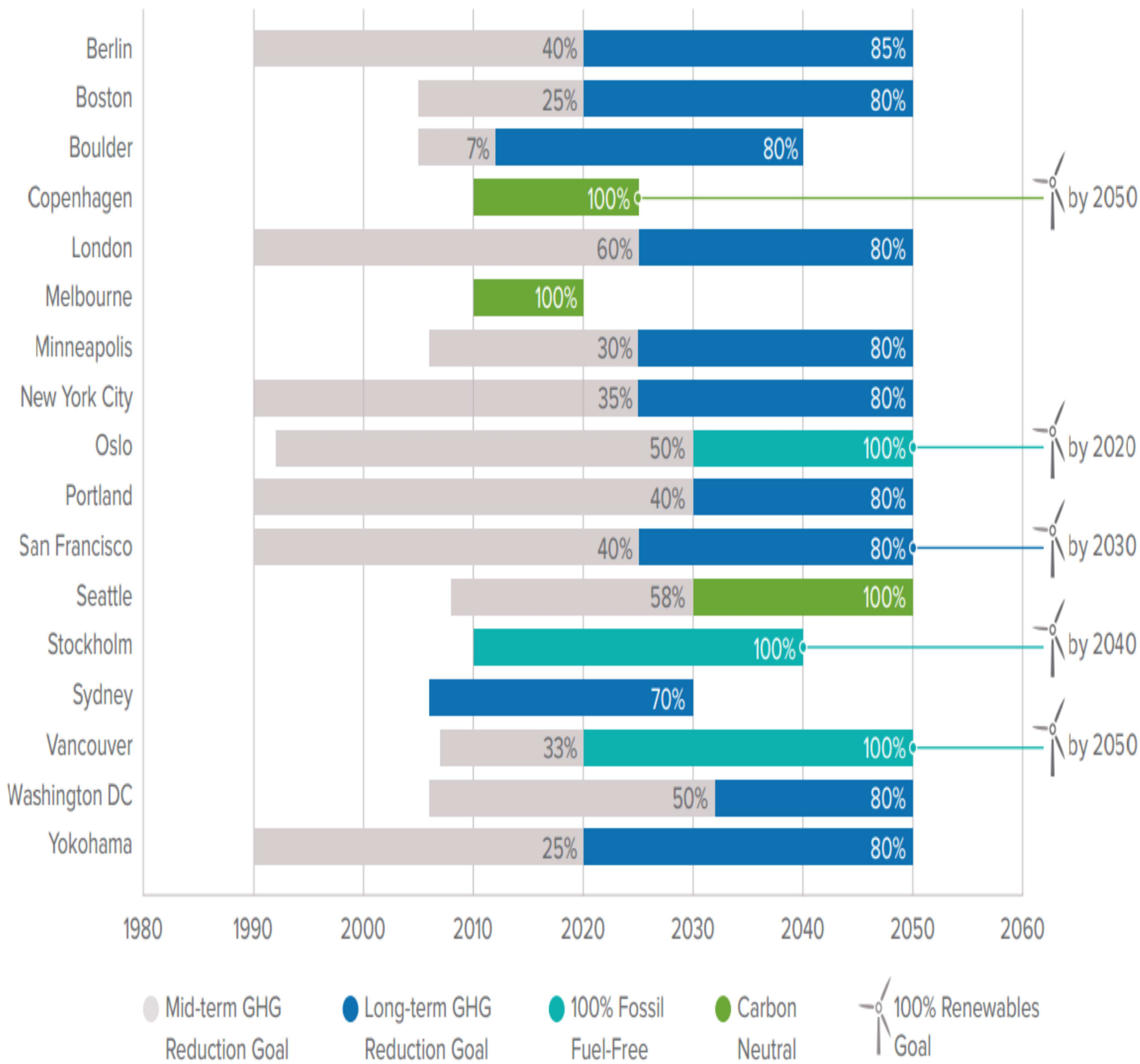

Figure 1: Long-Term and Interim Greenhouse Target of Carbon Neutral Cities Alliance

2.3 National Commitment

As co-chair of the IPCC working group 1, China has organized and financed research projects of climate change and low carbon development, established National Climate Center, National Climate Change Strategy and International Cooperation Center and provided strong support to public consensus and policy making on climate change policy and action plan. With the 12th Five Years Plan, carbon intensity of per unit GDP decreased by 20% from 2010 to 2015, the energy consumption per unit of GDP has been reduced by19.1% with an annual improvement rate of 4.15% much higher than the world average, energy efficiency technology has been introduced, developed and popularized in many sectors such as power generation, iron making, aluminum making, cement production, etc., building standard scheme has been applied to cut the energy consumption in building by one half to three fourth, and the public transport first, and track traffic priority policy have been successfully implemented [14]. With regards to specific low carbon strategies and comprehensive action plan for integrated decentralized low carbon development, six provinces (Guangdong, Liaoning, Hubei, Shaanxi, Yunnan, Hainan), and thirty six cities, including Beijing, Shanghai, Tianjin, Chongqing, and Shenzhen, etc., have been selected as demonstration provinces and cities for low carbon development with potential achievement of energy and carbon intensity decrease over the last five years.

In addition, China committed during the COP 21 Summit to lower carbon dioxide emissions per unit of GDP by 60%-65% in 2030 (from 2005 level), increase the forest stock volume by around 4.5 billion cubic meters by 2030 (from 2005 level), promote green power dispatch, prioritize the distribution and dispatching of renewable power and fossil fuel power generation with higher efficiency and lower emission levels, start in 2017 the national emission trading system covering key industry sectors such as iron and steel, power generation, chemicals, building materials, paper-making, and nonferrous metals; reach the share of green buildings up to 50% in newly built buildings in cities and towns by 2020; improve the share of public transport in motorized travel up to 30% in big- and medium-sized cities by 2020, finalize next-stage fuel efficiency standards for heavy-duty vehicles in 2016 and implement them in 2019, and accelerate action on HFCs including effectively controlling HFC-23 emissions by 2020 [9;13;14].

In terms of main actions over the coming five years (13th Five Years Plan, 2016-2020), China aims at promoting the low carbon development in industry, energy, transport and buildings, supporting cities and provinces to peak the carbon emission earlier, establishing the national carbon emission trading system (ETS) covering 6 sectors (iron and steel, power generation, chemicals, building materials, paper-making, and nonferrous metals), enhancing the demonstration of low carbon development in selected provinces and cities, developing demonstration districts of near zero carbon emission, carbon emission reporting, emission quota system for key entities, carbon emission standards of products and processes; and popularizing low carbon products and technology. The key targets of the 13th Five Years Plan are summarized on Fig.2 [14].

Hong Kong, as part of the Pearl River Delta (PRD) and an economically affluent area, aspires to become the greenest city in China. The Framework Agreement on Hong Kong / Guangdong Co-operation set up in 2010 provides a firm basis for building Green PRD Quality Living Area with cleaner air, less pollution and a lower carbon environment. The concept of Green PRD is not just a bilateral agreement, but integrated into the national low carbon strategic plan. Increasingly, Hong Kong and Mainland China recognise the importance of regional collaboration on low carbon development and closely interact to overcome challenges. By going green, Hong Kong would maintain its competitiveness and standing of international city in the Region [14].

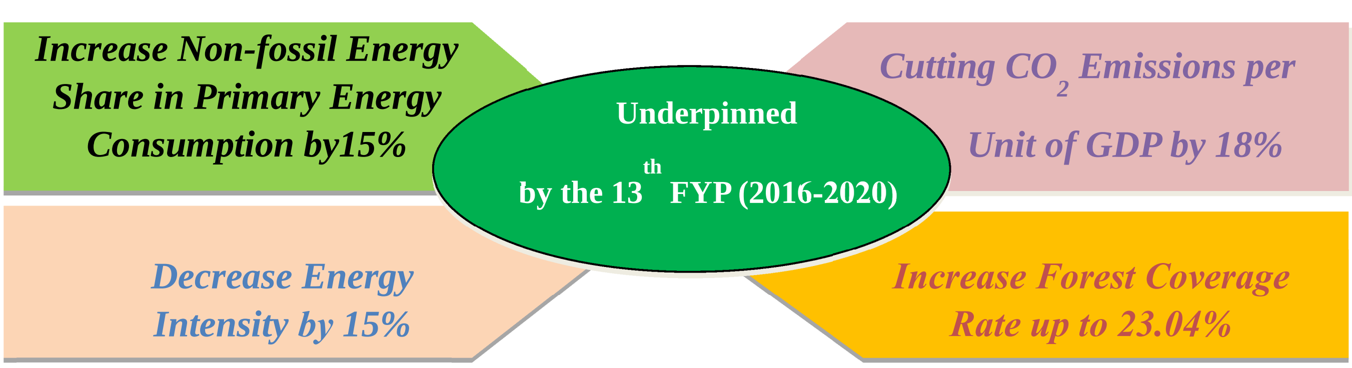

Figure 2: Legally Binding Targets in China's 13th Five Years Plan (2016-2020)

3 Climate Resilience and Challenges in Hong Kong

3.1 Climate Change Impacts on Pearl River Delta Region and Hong Kong

As mentioned above, Hong Kong is part of the Pearl River Delta (PRD) Region and either way closely associated with climate change impacts over the region. The PRD Region is the third largest river system in China, and it is one of the world's economical dynamic regions. The region is vulnerable to the rising sea level and frequently affected by temperature rising, storm events and associated coastal flooding. As reported by Hong Kong Observatory since 120 years, climate change results in rising in temperature in Hong Kong with an increase of the number of very hot days. In addition, there is likely to be greater variability in rainfall patterns with a higher frequency of extreme conditions and increase of number of heavy raining days; extremely wet and dry years are expected to become more frequent for the rest of the 21st century.

There are great stress to montane and freshwater ecosystems due to increase in surface temperatures and extreme weather; loss of inter-tidal habitats such as coral reefs or mangroves due to sea-level rise; harsher growing environments; increased erosion and landscape degradation and change in species distribution and migration patterns; aggravate chronic health condition; higher risk of thermal stress, exacerbation of asthma and heat stroke; more accidents and emergency situations; changes in transmission patterns of infectious diseases. Change in rainfall pattern and rise of demand under higher temperature may affect local water resources. It is also expected that the mean sea level rise in the South China Sea, including Hong Kong waters, would increase to tally with the global average in the late 21st century [6].

Hong Kong and the PRD are affected by about six tropical cyclones per year, and its low-lying areas are susceptible to associated storm-surge floods with high water levels. Direct economic loss due to storm surge event reached more than 10 billion RMB. Statistical assessment of potential flood risk in Hong Kong and the PRD region also showed that flood vulnerability in PRD is partly related to its level of socio-economic development. The PRD Region, which is less developed than Hong Kong, is more vulnerable to human costs (death and displacement). However, the economic losses in Hong Kong could be considerably higher at a city scale. In the PRD Region, predicted flooding without adaptation will result in about 3000 deaths, 15 million people displacements, and $40 billion in economic losses by 2100 as summarized on Table.1 [6].

Table 1: Summary of Annual Average of Future Damages in Hong Kong and PRD by 2100

Items	PRD	Hong Kong
Deaths (people)	300-3000+	200-1000+
Displacements (people)	1-15+ million	0.5-3 million
Economic Damage (USD)	1-40 billion	1-4 billion

Moreover, a comparative analysis of the number of deaths between China and the U.S. as a function of flood magnitude shows that the slope of China and the U.S. are remarkably different, at 0.61 and 0.27 respectively (Fig.3). The difference in the log-linear regression slope indicates that on average, at the same flood magnitude level, the U.S. experiences far fewer deaths than China. This characteristic could be considered as a vulnerability difference, and the slope value here is regarded as vulnerability factors. Using the same method and considering the high population density of Hong Kong with relative lower GDP per capita than U.S., the vulnerability factor for Hong Kong is estimated to 1.5 times higher than U.S [6].

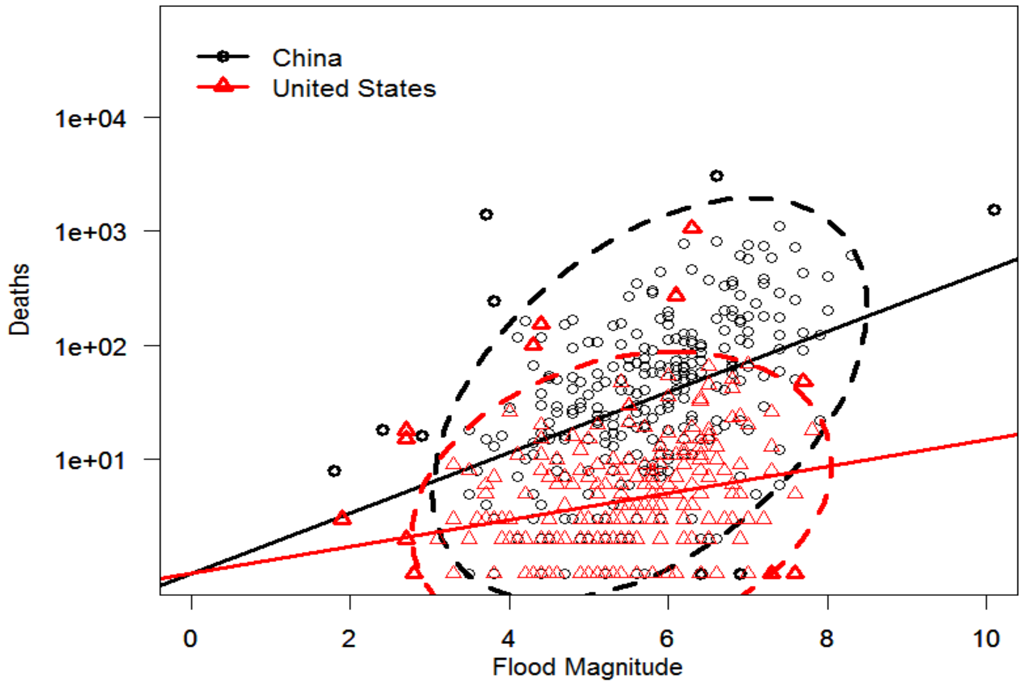

Figure 3: Logarithm of Number of Deaths as a Function of Flood Magnitude in China and US

Although Hong Kong government's Climate Change Strategy outlined adaptation options such as monitoring (flood warnings) and updating flood risk maps, detailed flood risk assessments are not available yet. However, Hong Kong depends on the PRD region in providing and supporting its essential services (including food, energy and water), adequate assessments for adaptation measures are necessary despite existing infrastructures for flood prevention and mitigation. In clear, although Hong Kong is relatively not physically flooded, a wide-spread and prolonged flooding in PRD region might cripple Hong Kong's ability in proper urban functionality. Hence, it is imperative for Hong Kong to pay more attention to flood risks over the PRD, and work with the PRD in climate adaptation and resilience planning [6].

3.2 Adaptation and Mitigation Strategies

The concept of climate resilience involves both mitigation and adaptation. There is a need to strengthen and empower a community's capacity and capability to reduce carbon emissions, as well as cope and absorb climate change related stresses and maintain the functional operation of public services, economic and social activities. The key focus of climate resilience efforts is to address the vulnerabilities that Hong Kong faces as a community with regards to the consequences of climate change [13].

(1) Hong Kong Government Commitment

Adaptation measures are based upon assessment of climate change risks and vulnerabilities that Hong Kong is likely to face in the coming decades. In considering how to expand the city's resilience, Hong Kong Government is collaborating with major public and private sector stakeholders to ensure efforts are well-coordinated. Security Bureau (SB) is coordinating Hong Kong's Contingency Plan for Natural Disasters, which is relevant for all extreme weather events that the community is used to encounter. Since 2008, Hong Kong climate adaptation response has been embodied in the Total Water Management Strategy. In the field of flood prevention, revitalizing water bodies has clear adaptation benefits, including integrating water bodies with urban landscapes to reduce heat island effect; turning "otherwise wasted" rainwater into useful resources; improving urban living environment, harmonizing human activity and nature; increasing resilience against the flooding brought about by climate change; and integrating drainage infrastructure with other land uses to improve carbon efficiency and reducing footprint.

Proper management of the mangrove habitat is also a priority. A mangrove management plan was developed to achieve the dual purposes of reducing flood risk and protecting habitat, which required multidisciplinary collaboration between government departments (DSD, AFCD and EPD) and with non-government ecological experts. Existing climate resilience capacity has been strengthened with strategic plan to be implemented over the coming years on specific aspects including conducting studies on information gaps and monitor changes; strengthening institutional capacity and policy focus; carrying out drills; updating disaster and emergency planning from to time; improving dialogue and coordination with private sector and raising community awareness [9;13].

In terms of climate mitigation, the greatest potential for sizable quantities of carbon emissions abatement in Hong Kong lies in the strategies of coal usage reduction for local electricity generation and maximization of energy efficiency, especially in buildings. Current targets are to reduce carbon intensity by 50-60% in 2020 (baseline 2005); and to reduce energy intensity by 40% in 2025 (baseline 2005). Changing the fuel mix of electricity generation will undoubtedly help Hong Kong to create a cleaner power sector, reach the lower-bound of our carbon intensity target by around 2020, as well as improve air quality and public health arising from lower pollutant emissions. Supply side efficiency could be further improved through co-generation and tri-generation [13].

Summarily, in collaboration with all stakeholders, Hong Kong Government is monitoring the implementation of climate mitigation measures on specific aspects including making public transport primary choice for mobility; expanding rail options and services; improvement of rail operation and vehicle fuel energy efficiency; testing low-carbon and zero emissions franchised bus technologies; recovery and use of landfill gas; recovering energy from sludge treatment; developing waste-to energy treatment for organic, yard and municipal solid waste; promotion of renewable energy such as solar power; improvement of power plant energy efficiency; promotion of co-and tri-generation; extension of lifespan of existing buildings with low carbon adaptive reuse; research on labeling and using low carbon construction materials and products; promotion of private electric vehicles; improvement of driving habits for fuel saving; promotion of biofuels use in government vehicles and non-road mobile machinery; capture and use of gas from wastewater treatment; and recovery of waste cooking oils for biodiesel production. Beyond 2030, the ambitious long term target is to achieve a reduction of Hong Kong's carbon emission by 80% in 2050.

(2) Specific Climate Adaptation in Energy Sector: Experiences from CLP

In general, common changes in weather patterns include hotter and drier summer, heavy rainfall, more typhoons, heat waves, high winds, warmer autumns and springs, etc. Changes in weather condition could result in business disruption, unexpected maintenance cost, safety concerns, insurance claims by customers, loss of business opportunities, supply chain interruption, increase in raw material prices, etc. In the power sector, the physical assets, infrastructure, day-to-day operations and maintenance, logistics and supply chain could be sensitive to climate change. Therefore, adaptation typically includes measures that build power system resilience to resist and recover from impacts of extreme whether events, with flexibility, in order to enable the power system to be efficient and agile enough for stable generation and supply. Fig.4 below describes climate adaptation assessment methodology at CLP [3; 12].

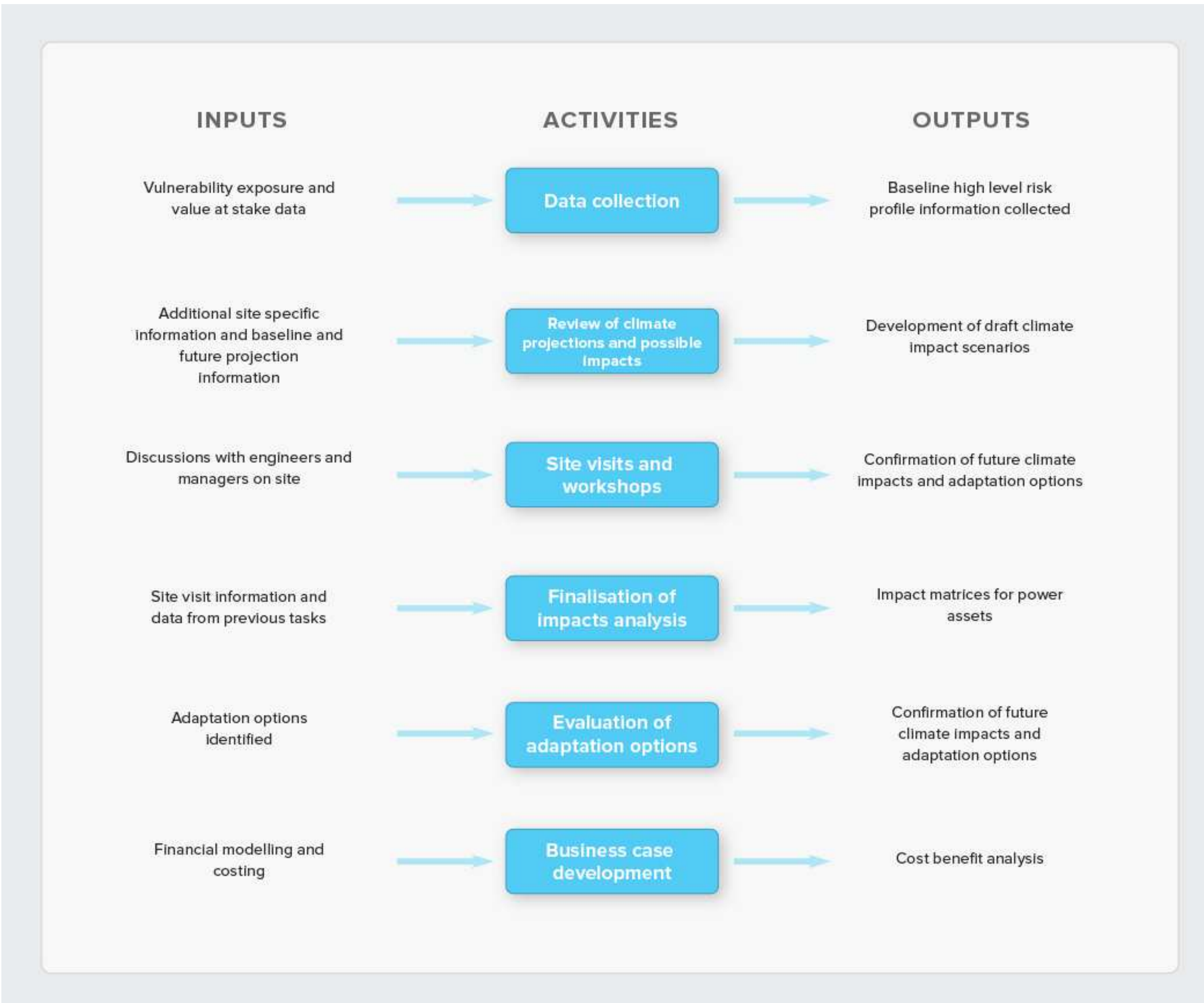

Figure 4: Typical Assessment Flow of CLP's Climate Adaptation

Basically, adaptation assessment process consists of review of climate change projection and possible impacts, risk and cost analysis, evaluation of adaptation capacity, and setting adaptation options. CLP has implemented in Hong Kong a number of measures to counter the potential impact of super typhoons since 2004. These include enhancing the structure of the 400kV pylon to withstand super typhoons with wind gusts up to 300 km/h, the creation of a typhoon response protocol and coordinating system. These measures, together with regular drills, aimed at constantly improving CLP's ability to respond to emergencies and to maintain a safe and reliable electricity supply. With incidents of super typhoons increasing globally, CLP has implemented an Emergency Restoration System to enable the rapid construction of temporary pylons, shortening the time it takes for power to be restored when an existing pylon is damaged from several months to just two weeks [3; 12].

Flood risk assessments are also conducted to determine whether further mitigation measures would be needed to cope with the possibility of increased severity of storm surges and the global trend of rising sea levels as a result of climate change. A number of preventive measures have been implemented at targeted CLP generation, transmission and distribution substations, including installation of flood gates, sealing of the cable inlets and equipping the substations with sump pumps and flood alarm systems.

Moreover, a flood calculator, which estimates the flooding risks at CLP substations based on the Hong Kong Observatory's latest information on estimated sea levels, was launched which would allow for timely supervision and coordination by operations centre to ensure supply reliability. In addition, Hong Kong has a large number of fast-growing tree species, and trees that make contact with power lines can interrupt the normal power supply. Thus, CLP has set up its vegetation management team in 2001 to perform regular checks on power lines, and to adopt vegetation management techniques such as pruning trees that might affect overhead power lines. The pruning of trees can be carried out even when the lines are carrying live electricity in order to reduce the disturbance to the customers. The number of power failure incidents caused by trees has been reduced by 80% since their work began [3; 12].

4 Promotion of Low Carbon Infrastructure in Hong Kong

4.1 Government Strategies

As mentioned above, Hong Kong Government, in collaboration with key stakeholders, is actively promoting low carbon schemes in various infrastructures such as energy (generation and supply infrastructures), transport (roads, bridges, rails, port and airport), waste treatment (landfill and sludge treatment facilities), sanitary (hospitals), educational (school, universities) etc.

In energy sector, application of co and tri-generation systems could further improve carbon reduction from existing and new energy supply side infrastructures in reinforcement of coal reduction and green technology programmes from generation side. Co-generation system generates power and makes use of the heat produced during the process whereas tri-generation takes this a step further by also producing cooling (using an absorption chiller) as part of the process. In near future, these technologies will be also integrated into buildings and new infrastructures construction planning for embodied carbon emission reduction.

Carbon labelling scheme for infrastructure construction materials has been also launched by Construction Industry Council (CIC) in January 2014. The scheme arose from research on carbon footprint of infrastructure construction products, which can be easily used by designers, contractors and diverse end-users in their selection of low-carbon materials. The Government makes reference to the labelling scheme for new public infrastructure projects (especially for new roads, buildings, bridges, drainage systems and pipelining facilities), while the scheme is gaining traction with the private sector.

Improvement of rail, port and airport operations for energy efficiency and carbon emission reduction significantly contributes to strengthen low carbon strategies in transport infrastructures (experiences from MTR, Modern Terminals Ltd., Hong Kong Airport International etc.). Recovery and use of landfill gas; recovery of energy from sludge treatment; development of waste-to-energy treatment for organic, yard and municipal solid waste, are also various strategies developed by Hong Kong Government and stakeholders to promote low carbon in existing and new waste treatment and management infrastructures [9; 13].

4.2 Experiences from Hong Kong International Airport

Greenhouse gas (GHG) emissions are commonly categorized into three different scopes according to the nature, ownership and level of control of the emission source as described in Table.2. The experience from Hong Kong International Airport Carbon Reduction Programme demonstrates how carbon footprint reduction can be achieved by engaging and collaborating with different stakeholders [8].

While Airport Authority accounts for about 40% of the airport-wide carbon emissions, the remaining 60% come from its business partners (BPs). In order to accelerate carbon reductions at Hong Kong International Airport, since 2008, AAHK has proactively worked with BPs through a number of initiatives under the Hong Kong International Airport Carbon Reduction Programme. The key milestones of the programme are summarized in Fig. 5 [8].

Table 2: Greenhouse Gas Emissions Scopes at Hong Kong International Airport

Scope 1: Direct GHG emissions from sources that are owned or controlled by the airport operator
Emission sources: • Power plants and/or emergency power generators • Vehicle fleets including ground service equipment (GSE) • Firefighting and maintenance equipment
Scope 2: Indirect GHG emissions from the off-site generation of electricity (heating and cooling) purchased by the airport operator
Emission source: • Electricity generation (heating and cooling)
Scope 3: GHG emissions from airport-related activities from sources not owned or controlled by the airport operator
Emission sources: • Aircraft main engines and auxiliary power units (APU) • Vehicle fleets, including GSE, owned or controlled by others • Ground transport to and from the airport (ie surface access)

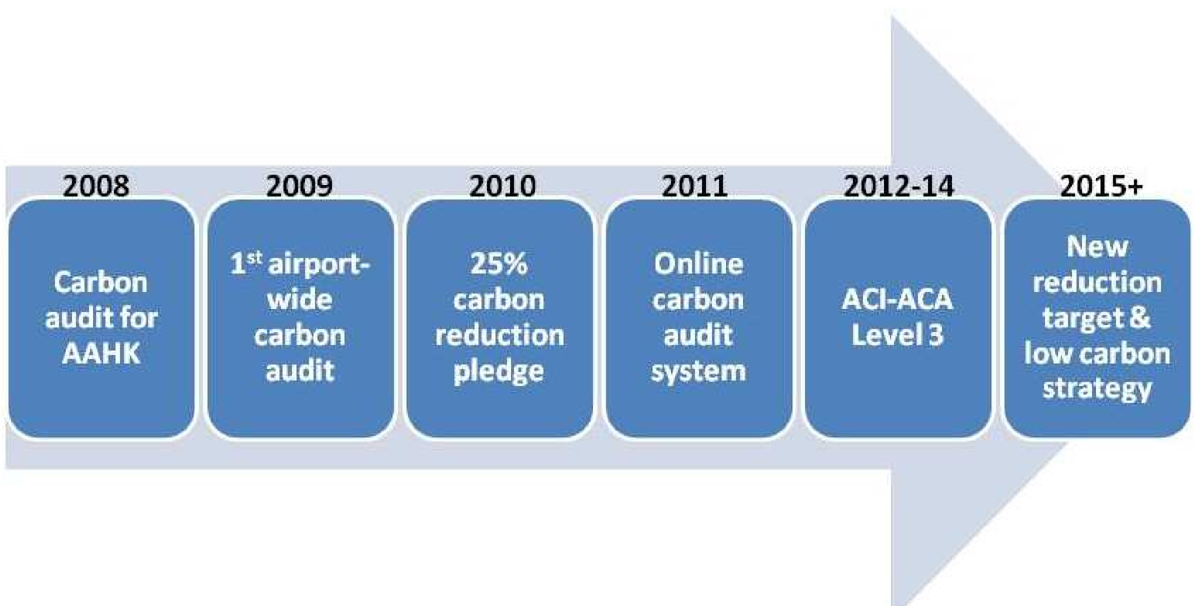

Figure 5: Carbon Management Roadmap for Hong Kong International Airport

AAHK completed in 2008 its first carbon audit of its own buildings and facilities and was EPD's first Carbon Reduction Charter signatory. In 2009, an airport-wide carbon audit was conducted in conjunction with BPs. In December 2010, AAHK, together with nearly 40 BPs, pledged to reduce carbon intensity by 25% per workload by 2015 (One workload unit refers to one passenger or 100kg of cargo) compared to 2008 emission levels. Figure 6 shows the ensemble picture of stakeholders' commitment [8].

Figure 6: Ensemble Picture of Airport Community Pledge in 2010 for Carbon Intensity Reduction by 25% by 2015 (from 2008 levels)

To facilitate the tracking of carbon emissions, in 2011, Airport Authority developed a proprietary on-line carbon audit system to calculate and monitor carbon emissions for both Airport Authority and its business partners (Fig.7&8). In December 2012, Hong Kong International Airport achieved the "Optimization" level under the Airports Council International's Airport Carbon Accreditation (ACI-ACA) programme, making Hong Kong International Airport the first airport in Asia-Pacific region to achieve this standard.

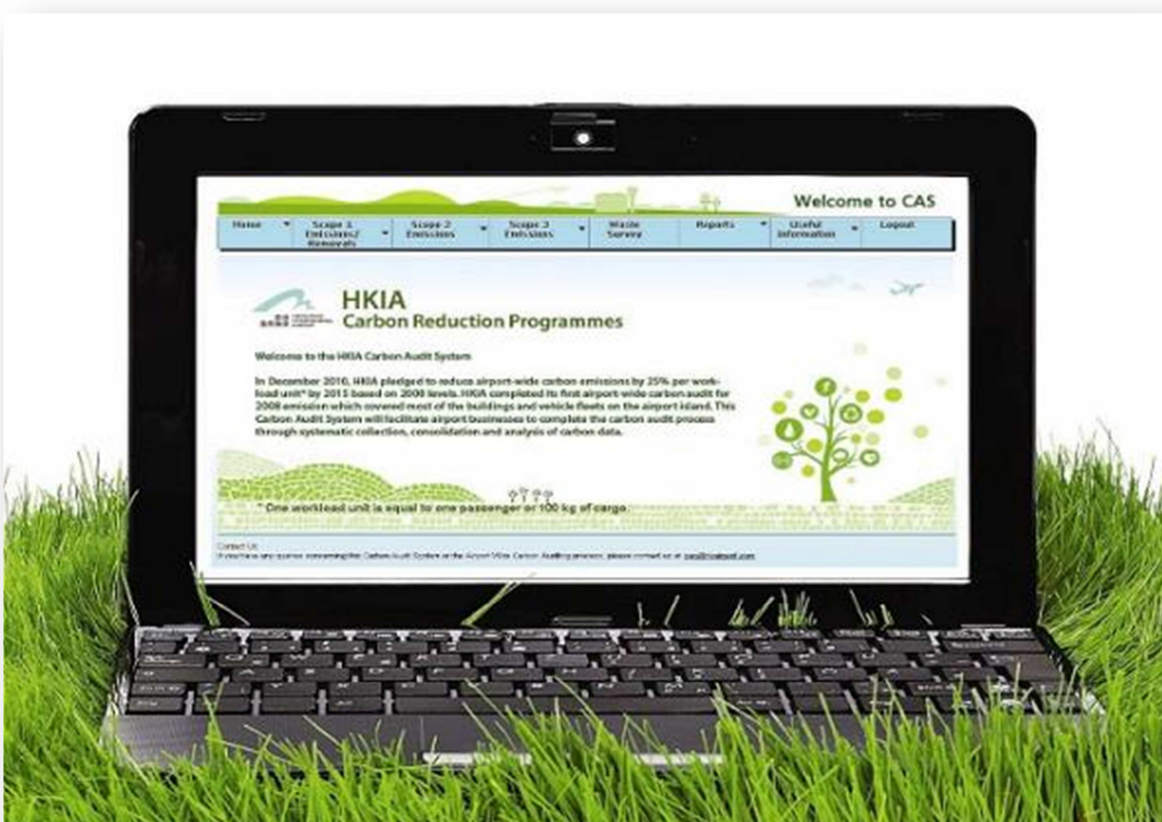

Figure 7: Carbon Audit System at Airport Authority

Figure 8: Platform for Close Collaboration between Airport Authority and its Business Partners for Carbon Footprint Reduction at Hong Kong International Airport

In order to ensure the BPs are equipped with the necessary knowledge and skills, AAHK has organized over 30 carbon workshops, sharing and training sessions since the launch of the programme. Moreover, AAHK trained a team of internal staff members as certified carbon auditors to conduct on-site carbon data checking for participating partners every year. In addition, external verification of HKIA's carbon footprint has been conducted annually which significantly increases the accuracy of carbon data and improves the robustness of the HKIA Carbon Reduction Programme [8].

In addition, AAHK conducts a quarterly Airport Community Environmental Forum to communicate with BPs on carbon-related issues. Attendees are encouraged to share their experience and best practices for carbon management with other business partners. With the concerted efforts of the airport community, HKIA remains on track to achieve the 25% target. As of end 2014, the carbon intensity was reduced by 22.4%, relative to 2008 levels. Figure 9 illustrates the carbon reduction performance between 2008 and 2014.

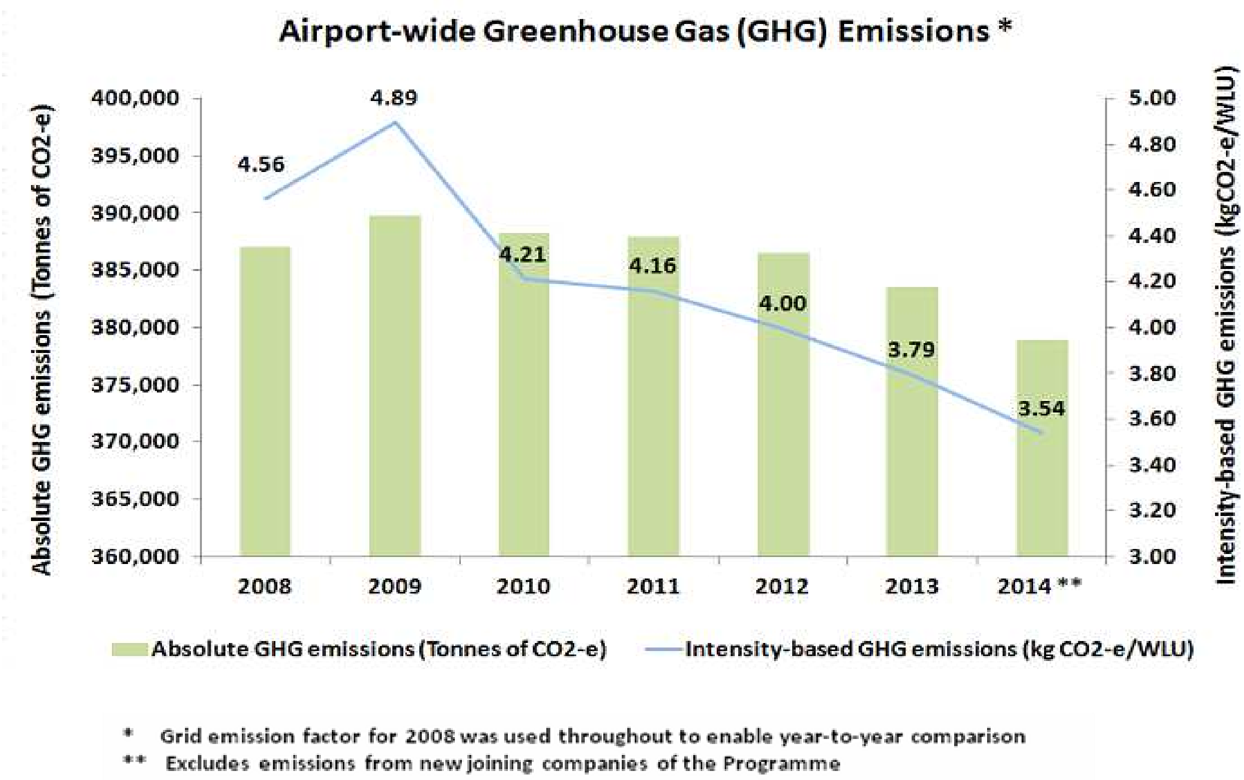

Figure 9: Carbon Emissions Reduction Performance at Hong Kong International Airport

Going forward, Airport Authority is developing a new airport-wide carbon reduction target and the associated strategies in 2016. The similar engagement models will be extended to other specific environmental aspects such as air quality, general waste management and water consumption, and also to other multi-tenants facilities operators [8].

4.3 Experiences from The Hongkong Electric Co., Ltd.

In close collaboration with stakeholders (Government, Stakeholder Liaison Group, Fisheries Review and Consultation Committee etc.), The Hongkong Electric Co., Ltd is engaged in reducing greenhouse gas emissions and investing in low-carbon energy infrastructures, in particular wind and solar energy installation as described on Fig. 9. The main objectives are to reduce dependency on fossil fuels, combat climate change and to improve air quality in Hong Kong. Subsequent to the introduction of the first wind turbine, Lamma Winds, of 800kW capacity on Lamma Island as a demonstration project in 2006, The Hongkong Electric Co., Ltd has been carrying out further studies for developing an offshore wind farm of capacity up to 100MW within the territorial waters in Hong Kong (Fig. 10) [7].

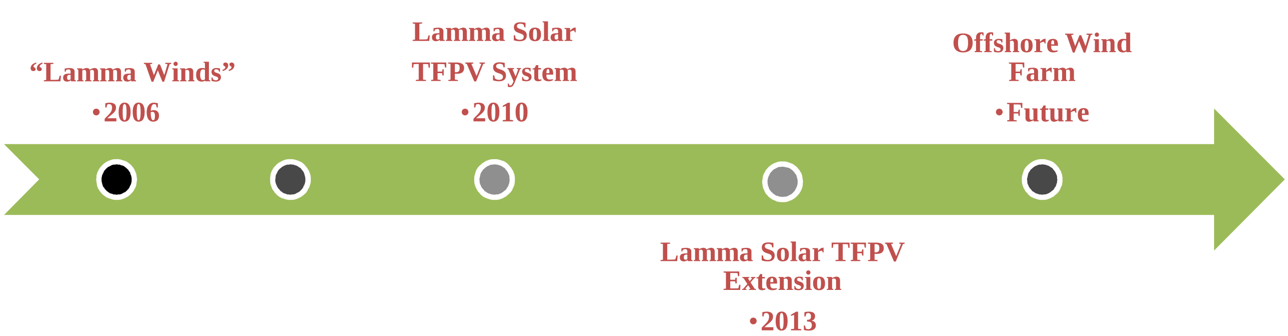

Figure 9: Renewable Energy Programme at The HongKong Electric Co. Ltd.

Among the studied sites for the wind turbine installation, the most preferable site was located at about 3.5km southwest of Lamma Power Station with less overall environmental impacts, shallower water depth and shorter transmission cables linking to Lamma Power Station compared with other potential sites in the eastern waters of Hong Kong. In addition, rapid logistic support can be offered from Lamma Power Station during construction phase of the project, as well as the maintenance support during operational phase. The average capacity factor of "Lamma Winds" over the last decade (2006-2016) was about 13%. The capacity factor of the offshore wind farm will be much higher with an estimated annual generation of more than 175 million units of electricity and would offset 150,000 tonnes of CO_2 emission [7].

To enhance and diversify such green infrastructure programme, The Hongkong Electric Co., Ltd commissioned a solar photovoltaic system (Amorphous Silicon Thin Film PV modules) of 550kW capacity on the roof tops of the station buildings in Lamma Power Station in July 2010 and upgraded to 1MW in 2013, representing the largest solar photovoltaic installation in Hong Kong. The advantages of silicon thin film PV panel include optimal power output at high temperature and better weak light performance. Installed solar PV infrastructure is expected to generate more than 1.1 million units of electricity annually with 915 tonnes of CO_2 emission reduction [7].

In short, installed green energy infrastructures generate about 9,000 MWh of green electricity from 2006 up to present. The Hongkong Electric Co., Ltd. will continue its efforts in exploring more opportunities of renewable energy applications for power generation in Hong Kong to move towards a sustainable and low-carbon development [7].

Figure 10: Lamma Winds

5 Strategies for Urban Mobility Decarbonizing

5.1 Promotion of Electric Vehicles in Hong Kong

With zero pollutant emissions, electric vehicles (EVs) are an ideal solution in phasing out greenhouse gas emissions and heavy air pollutants from road transport. Electric vehicles use an electric motor for traction and batteries for their electricity storage. The drive train of electric vehicles consists of three major sub-systems including electric motor propulsion system (vehicle controller, power electronic converter, the electric motor, and transmission), battery system (batteries, Battery Management System and charging unit), and auxiliary system (heating/cooling, electronic pumps, and other electronic auxiliaries).

(1) *Researches on Electric Vehicles and Batteries*

In order to contribute to technological advancement of EVs, the Power Electric Research Center of Polytechnic University of Hong Kong, in partnership with other stakeholders, conducted substantial studies on specific technical aspects in linkage with the comfort of drive, traction, performance of the battery and safety. Achieved technical innovations are summarized below [2]:

-Active Suspension: with regards to the slow dynamic response of the conventional hydraulic suspension traditional conceived with no self-learning, researches are performed on new active suspension based on a linear motor that is able to adjust its vertical force to cancel the vibration due to the uneven road Surface (a system designed based on switched-reluctance principle).

-In-wheel motor: the main innovation here is to embed the motor inside the wheel to create more space and room in order to eliminate the transmission, gear box, shaft and crutch. The design is benefited from the elimination of mechanical loss as compared to the conventional system. The motor is designed with four sets of stator windings and each winding gives a quarter of the torque. Such innovation enables the control of the steering by wiring. No physical connection between the steering wheel and the in-wheel motors. Part of the braking can be provided by the in-wheel motor through motor drive control [2].

-Integrated motor drive and charger: electric motor drive and the charger do not operate simultaneously for conventional EVs. They are both based on an inverter circuit. Therefore an improved design of the circuit topology has been done, so that these two parts can be consolidated into a simple component to provide the same function. Part of the inverter legs is used for motor drive and also as the battery charging in form of the H-bridge converter.

-Battery management system: the key achievement here is the improvement of the battery management system (BMS) in connection with other components of EVs to optimize the battery performance and safety.

-Battery Balancing: power electronic circuit has been designed to develop a list of the active circuits. The circuits enable energy transfer from higher to lower charged cells. The voltage is connected to a corresponding capacitor to achieve balancing. The circuits can operate without voltage sensors and provide active and high efficiency method of cell balancing.

-Super-capacitor: proposed super-capacitor in replacement of battery offers longer life time and higher safety factor than battery. It has better thermal stability, wider temperature range and higher robustness under thermal and mechanical stress condition. However, the energy density of super-capacitor is lower than that of battery. Therefore presently, it is used for short distance or as a support to EVs battery. Another new concept, the body integrated super-capacitor, is being developing with installation of the balancing and protection system inside the panel to improve the energy density of the system [2].

(2) Government Incentives

Aiming at cleaning up roadside air pollution and reduce greenhouse gas emissions, Hong Kong Government is proactively promoting the EVs to build up confidence and provide impetus for further advancement of the technology. Accordingly, a Steering Committee on the Promotion of EVs led by the Financial Secretary has been set up. To date, the key measures that have been introduced include taking the lead in using EVs as example (so far, 245 EVs have already joined the Government vehicle fleet, accounting for about 4% of the Government fleet); tax incentives for acquiring EVs (waiving the first registration tax for EVs till end March 2017, and allowing enterprises which procure EVs to have 100% profits tax deduction for the capital expenditure on EVs in the first year of procurement); setting up chargers and parking in collaboration with private stakeholders and subsidy for the trial of EVs; establishing a Pilot Green Transport Fund since March 2011(HK$300 million) for application by transport operators and non-profit-making organizations providing services to their clients and goods vehicle owners, encouraging them to try out innovative green and low carbon transport technologies [10].

These measures are also expected to encourage EVs suppliers to increase the performance of EVs on the local market. As a result, the number of EVs increased to 4,629 at the end of February 2016 with over 50 EV models (including private cars, light goods vehicles, taxis and buses) on the local market. Vehicle vendors are also sourcing commercial EVs such as electric buses and light goods vehicles. The growing interest in promoting the use of EVs worldwide will encourage EV manufacturers to advance the technology.

(3) Persistent Challenges

While significant progress has been made in developing and promoting EVs, major challenges underlined below have to be overcome.

-EVs battery cost reduction: currently the cost of Li-ion battery with 35 kWh storage capacity is still too high at manufacture. Reducing the cost of battery packs is therefore the key challenge for EVs development;

-Safety improvement: current nickel and cobalt-based oxide Li-ion cathode materials have potential issues with overcharging, clearly, and voltage control at cell, module and battery level is critical to prevent overcharging of automotive Li-ion batteries, but these are all factors that will inevitably increase Li-ion battery cost further. Lithium iron phosphate cathodes offer a promising future but with lower specific energy and power density;

-Battery charging time: shortening the charging time to a matter of minutes, and providing better and more charging facilities;

-Battery reliability: EVs have uncertainty on the reliability of batteries, which is costly to replace. Cruising range for most EV models is still limited;

-Charging protocol: EVs have no unified charging protocol;

-Battery environmental pollution: studies on Tesla's vehicles conducted by the Environmental Protection Agency and the U.S. Department of Energy have showed that batteries designed with nickel and cobalt, as well as solvent-based electrode processing, can have serious environmental impact including ecological toxicity and contribution to global warming among other factors;

-EVs are not suitable for intensive application: another challenge for EV adoption is that it's not suitable for one of the most fuel-intensive applications: heavy-duty vehicles. It's estimated that the 2 million to 3 million heavy-duty trucks operating in the U.S. alone consume more than 35 billion gallons of fuel annually. On a per-vehicle basis, these heavy haulers consume 30 times as much fuel as the average automobile, thus, reducing consumption in this segment would go a long way towards reducing oil dependence, and also offer huge cost savings for the trucking industry.

5.2 Development of Low Carbon Fuel

In sight of invested efforts in transport greening, heavy duty transportation still relies on diesel in Hong Kong. Moreover, extension of the rail system and improvement of the pedestrian experience will not have an impact on goods vehicle emissions. Electrification of the heavy duty vehicles is strongly challenging due to the high demand on the battery system in terms of power and capacity. In such context, biodiesel appears as an alternative for conventional diesel engines. Waste-based biodiesel is a natural and renewable fuel made from vegetable oils (soy and corn) or animal waste. It holds no petroleum, biodegradable and nontoxic. Compared to other alternative fuels, biodiesel fuel supports some unique features and qualities [11].

The GHG emissions benefits of biodiesel are especially significant, over conventional gasoline and diesel. Active policies to promote greenhouse gas emission reduction in transport through the use of waste based biodiesel are cost effective. Hong Kong Government recognized biodiesel as a low carbon choice and reaffirmed its commitment to actively promote it. Depending on the type of waste used, GHG reduction of used cooking oil/grease trap/inedible lard biodiesel is in the range of 85% to 90% per unit of energy. This means that for every unit of fossil fuel diesel energy replaced with its biodiesel equivalent, emissions are reduced to as little as 10%-15%. In terms of absolute reduction, a B7 mandate (7% biodiesel content is the limit in EN590 diesel specifications, that can be used in all diesel engines without modifications) on the entire diesel consumption in Hong Kong (1.4M tons a year) results in reduction of approximately 270-290 kilotons of CO_2eq per year. Another of advantages of biodiesel fuel is that it can be blended with other energy resources and oil. Biodiesel fuel can also be used in existing oil heating systems and diesel engines without making any alterations. The lubricating property of the biodiesel may lengthen the lifetime of engines [11].

(1) Government Commitment

Commitment of Hong Kong in promoting biodiesel resulted in a number of initiatives including use of B5 in the majority of the governmental departments; pilot scheme run by Development Bureau requiring its contractors to use B5 with an expansion plan to all works/departments in near future; use of B5 in all vehicles at Airport Authority within the Statutory Corporations; appointment of major consultancy by the Government to carry out a management study for the objective of promoting wider use of biodiesel in Hong Kong; promotion of franchises public bus services (all bus companies have B5 available from at least Shell and Chevron, who have already adapted their terminals to deliver blends, and are offering listed prices for B5 together with Euro V diesel) and active communication campaign, addressing key stakeholders [11].

(2) Abroad Successful Experiences and Challenges

Although Hong Kong government has launched an aggressive scheme to promote the use of biodiesel, there are a number of policies (successfully implemented internationally), that could enhance and speed up the expansion of biodiesel in Hong Kong as specified below [11]:

-Setting mandatory blending targets: the Europe Union Renewable Energy Directive requires a 10% share of renewables in transport by 2020. In Southeast Asia, Indonesia is moving to a B20 mandate, and Malaysia to B10. This policy has the advantage of simple regulatory implementation and enforcement, although care has to be taken to specify only biofuels with high environmental performance (waste based low GHG footprint biofuel), in order to achieve the volume based target with maximum GHG reduction.

-GHG reduction targets in transport fuels: since January 1, 2015, Germany's mineral oil sellers must reduce the greenhouse gas emissions of their products by 3.5% (4% in 2017 and 6% in 2020). These targets have to be achieved through the incorporation of alternative fuels. The final 6% requirement in 2020 is the final target set by the Europe Union Fuel Quality Directive.

-Price on GHG emissions through a proper carbon tax scheme (Canada), or introducing taxes/tax waivers on fuels based on their GHG saving.

-Another example of GHG savings target is the Californian low-carbon fuel standard (LCFS), enacted in 2007. The LCFS requires oil refineries and distributors to ensure that the mix of fuel they sell in the Californian market meets the established declining targets for GHG emissions. The final target is the reduction of 10% in the carbon intensity of California's transportation fuels by 2020.

Hong Kong could follow above same path, including requirements in GHG savings in the specification of their fuels in the Air Pollution Control (Motor Vehicle Fuel) Regulation. This policy of tightening fuel specifications has already proven successful for the reduction of sulphur. Biodiesel would be the best and quickest way of mitigating heavy duty vehicle GHG emissions, offering 85-90% GHG reduction for every unit of energy replaced. An installation of 100,000 tonnes of biodiesel in Hong Kong, using the entire production of biodiesel for blending in B7, is associated with a reduction of 270-290 kilotons of CO_2eq per year. Thus, active policies from the Government are required to "level the playing field" in terms of GHG emissions. A mandate could be easily implemented and that, alternatively, a change in the specification of Euro V, including a minimum quantity of biodiesel, would be the most efficient voluntary measure to achieve a rapid change. While these policies are implemented, a number of short term incentive schemes could be implemented to help the growth of the local biodiesel production, blending infrastructure and consumer confidence.

These schemes require the active participation of public transportation companies, the government, the government contractors, statutory corporations [11]. In clear, biodiesel from waste offers the rare opportunity to alleviate several of Hong Kong's major development challenges at once, without requiring significant trade-offs. With the right support, Hong Kong can make greater use of this solution as potential axe within low carbon development process.

6 Carbon Pricing and Market Setting

6.1 Definition and Mechanism

A carbon price is a cost applied to carbon pollution to encourage polluters to reduce the amount of greenhouse gas they emit into the atmosphere. Economists widely agree that introducing a carbon price is the single most effective way for countries to reduce their emissions.

A carbon price not only has the effect of encouraging lower-carbon behavior, but also raises resources that can be used in part to finance a clean-up of polluting activities (investment in research on green technologies).

There are two main ways to establish a carbon price. First, government can levy a carbon tax on the distribution, sale or use of fossil fuels, based on local carbon content. This has the effect of increasing the cost of those fuels, goods and associated services, encouraging business and consumers to switch to greener production and consumption. Typically, the government will decide how to use the revenue, though in one version, the so-called fee-and-dividend model. The tax revenues are distributed in their entirety directly back to the population [5].

The second approach is a quota system called cap-and-trade. In this model, the total allowable emissions in a country or region are set in advance ("capped"). Permits to pollute are created for allowable emissions budget and either allocated or auctioned to companies. The companies can trade permits, introducing a market for pollution, ensuring that the carbon savings are made as cheaply as possible. The carbon price tips consumers and businesses economic interests towards cleaner options. Under tax system, the carbon price is invariant with uncertain quantity emitted, while under cap and trade system, the allowable emissions are set with certainty (unless or until the regulator changes it) and the price is uncertain. Theoretical work has demonstrated an efficiency preference for a fixed price (i.e. tax) over cap and trade when there is uncertainty and the abatement cost is more sensitive to that uncertainty than the damages from the pollution. The “benefits” of carbon pricing are as an alternative to “command and control”. With less flexibility, costs are higher “by definition” unless the government knows every detail of abatement options open to polluters.

6.2 Key Lessons from Emission Trading Systems

(1) Lessons from Hong Kong’s Successful Textile Quota Market

Hong Kong’s successful operation of a textile quota market in the 1970s and 1980s is a ‘concrete’ example of the benefits a market in permits. Textile quotas were imposed under the Multi Fiber Agreement between 1974 and 2005 to limit the export of clothes to the US and Europe. They were designed to protect textile industries in Developed Countries from being driven out of business by imports from Developing Countries. Each Developing Country was given a quota of garments that it could export to a given Developed Country. If the Developing Country did not use all its quota in one year then it received less in the next year. The Hong Kong Government initially allocated the quota based on past sales and then set up an excellent mechanism for companies to sell quota to each other. Thus, a profitable business could buy quota for expanding sales while a weak business could sell quota. The trading system allowed the companies which could get the most value from the quota to use it. It also led to Hong Kong using its quota in full each year and thus gaining quota share over time [4].

(2) Lessons from Europe Emission Trading System

Although carbon pricing experience is still on-going in Europe, analysis of the system results in following key lessons:

-Cap-setting: the system is characterized by a protection of local industries against integrity; this seems to negatively impact the effectiveness of the scheme.

-Allocation: political haggling enables gradually moving away from free allocation.

-Control of the market: carbon prices in Europe have been undermined by the implementation of overlapping energy and environmental policies including renewable energy subsidies (esp. in Germany) and energy efficiency mandates.

In clear, the carbon pricing system in Europe is not effective due to combined policies that curb its liberalization and free development either way [5].

(3) Lessons from Swiss Experience

Switzerland is an interesting case study for Hong Kong to consider as it is a small territory looking to trade carbon emissions with the much larger European Union. Switzerland has committed to reduce GHG emissions by 20% in 2020 and 50% in 2030 (baseline 1990). It has introduced carbon pricing is steps [4]:

1. From 2007, it put a price on GHG emissions through a ‘carbon levy’ paid by about 1,900 firms. The proceeds of this levy funded building energy efficiency upgrades and reduced individual health insurance and business payments for social security.

2. From 2009, permitting firms to voluntarily join its carbon trading scheme to allow them to find lower cost means of abatement than the carbon levy.

3. In parallel, it has been negotiating to link its scheme with the European Emission Trading Scheme (EU-ETS). These negotiations have been going slowly, perhaps due to the EU-ETS’s current surplus of credits and hence low carbon price. The negotiations, however, position Switzerland to link with the EU-ETS once conditions are favorable.

This three step process is low risk as it is based on the merit of ‘*crossing the river by feeling the stones’*. It is an interesting path Hong Kong can start down [4].

(4) The Way Forward

Points Hong Kong should learn from existing abroad experiences:

-Start slowly: one way to do this is for Hong Kong to pursue its own emission trading system pilot, work out the kinks, and progressively explore linkages with Mainland China and global system.

-Start soon and set a flexible system: be able to adjust the cap if the price is inappropriate.
-Auction allowances: avoid free allocation of allowances despite inevitable political pressure.

-Ensure the predictability of changes: while the system should be flexible, changes in policy must also be predictable. Policy should be designed with flexibility mechanisms upfront so people can predict the circumstances under which change might occur.

-Assure the transparency of the system: the carbon pricing is more likely to be supported by stakeholders if the process and input for policy design and development is transparent.

-Don't combine policies: avoid diluting the effectiveness of carbon pricing with overlapping renewable energy subsidies, energy efficiency or fuel economy standard mandates.

-Cover as many sectors as possible and minimize exceptions.

6.3 Potential Benefits for Hong Kong from China's National Carbon Market

As part of the 12th Five-Year Plan, the Chinese government selected seven cities (Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangzhou and Shenzhen) to establish pilot emissions trading systems from 2017 covering power generation, steel, cement and other key industrial sectors. The system will impose caps on almost 10,000 companies with regulation on 3-4 billion tons of CO_2. The government expectation is to unify the carbon market in China based on a national standard of quota allocation.The emission trading systems in Guangzhou and Shenzhen have long sought to be linked to Hong Kong due to existing economic and environmental agreements between Hong Kong and Guangdong Province [5]. Hong Kong, given its good governance and entrepreneurial traders, could make a success out of a carbon market in the same way as it benefited from the textile quota system. Its combining with the carbon emissions market in China has the following advantages [4]:

1. It is likely to be more cost effective to save carbon emissions in the Mainland than Hong Kong. Buying credits which pay for projects in the Mainland would thus reduce Hong Kong's cost of meeting part of its emissions target.

2. Hong Kong earns substantial income providing services. Part of the arrangement for Hong Kong participating in the China's National carbon trading scheme should be access for its engineering and financial services to work on carbon reduction projects in China. Further, Hong Kong's stock exchange should be able to trade the carbon credits for China's National carbon trading scheme.

It is appropriate, given its high standard of living and dependence on trade, for Hong Kong to commit to carbon neutrality by 2050 as its contribution to the Paris Agreement's target of global carbon neutrality in the 2nd half of this century. Putting a price on its carbon emissions and trading emissions credits both reduces the cost of meeting this commitment and should allow Hong Kong to earn income from its engineering and financial service industries contributing to carbon reduction projects in Mainland China and elsewhere. The first steps for Hong Kong to achieving this objective are to [4]:

1. Put a levy on its own carbon emissions through a revenue neutral switch from property taxes to a levy on the carbon content of energy and building 'shadow carbon prices' into infra-structure investment decisions.

2. Follow Switzerland's example of setting up its own carbon market as a voluntary alternative to paying a carbon levy and then explore linking this to China's National Carbon Trading scheme.

7 Conclusions and Perspectives

In line with China's pledge at the COP 21, Hong Kong is actively developing strategies (green energy, infrastructure, building and mobility, smart technologies, responsible investment, and business sustainability) for moving towards low carbon future. There is an imperative to significantly scale up action. This provides Hong Kong with strong opportunities to develop local environmental market, green consumption and to diversify its economy.

However, persistent challenges hinder low carbon strategies in Hong Kong. Technical and economic obstacles are associated with sustainable cost-effectiveness, comfort, safety, performance, and competitiveness of existing technologies, in particular in the fields of mobility and energy where further innovations are needed to make low-carbon options economically attractive. Policy challenges mainly include the way long-term low carbon investment and green consumption are regulated, climate risk is predicted and valued, corporate sustainability outcomes are regulated and promoted, and the way public-private partnerships will be coordinated for research on sustainable emerging green technologies.

Overcoming these challenges requires commitment of all stakeholders on reforms to unlock emission reduction opportunities for Hong Kong and avoid economic failures. Action is needed on regulations on low carbon technologies, climate finance facilitation, carbon pricing and market setting, mandatory carbon labelling, and effective public awareness campaigns on low carbon business opportunities.

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