# AESC Working Paper 9

# Managing the transition towards a low-carbon economy: A case study of Guangdong-Hong Kong Energy Collaboration on the Development of Renewable Energy

Daphne Mah[1], Jasper Ip[2] and Peter Hills[3]

Publication Date: Nov 2014
Original Publication date: Oct 2012

[1] Director and Assistant Professor, Asian Energy Studies Centre and Department of Geography, Hong Kong Baptist University
[2] Senior Research Assistant, Asian Energy Studies Centre and Department of Geography, Hong Kong Baptist University
[3] Chair Professor, The Kadoorie Institute, The University of Hong Kong; Fellow, Asian Energy Studies Centre, Hong Kong Baptist University

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Correspondence to lead author: daphnemah@hkbu.edu.hk

**Preface**

This working paper represents work in progress. It is a consolidation of preliminary outputs from two research projects. The first is a commissioned study titled "Hong Kong Sustainable Energy Future: Technological and Policy Options for Hong Kong-Pearl River Delta Energy Collaboration" which is a collaborative project between The Kadoorie Institute at HKU, the School of Energy and Environment at the City University of Hong Kong, and Greenpeace China (Study period: July 2010-June 2011). The second is a Public Policy Research Project titled "Managing the transition towards a low-carbon economy: stakeholder engagement for technological environmental innovation decision-making in Hong Kong" undertaken by The Kadoorie Institute for the Research Grants Council of Hong Kong to inform decision-making for a low-carbon economy transition (Study period: July 2010-September 2012).

**Abstract**

Technological innovations such as renewable energy, smart grids and electric vehicles can play a key role in low-carbon energy economies. However, the effectiveness of efforts to facilitate the diffusion of such environmental-related technological innovation has remained largely explored. Using a case study of the development of renewable energy in the Hong Kong-Guangdong region in China, this paper explores to what extent and how regional energy collaboration can contribute to technological innovation. First, we examine the relationships between regional energy governance and technological innovation. We identify three dimensions that might affect such technological innovation at a regional scale. These dimensions are the potential collaborative benefits, prioritised options and perceived barriers. Secondly, this study adopts a bottom-up engagment approach, using data drawn from a desktop study and a series of stakeholder engagement activities. Our analysis provides valuable insights into the perceptions of major stakeholders in this issue. Thirdly, our study offers policy recommendations on how to improve regional energy governance. A recognition of the need to adopt a regional and systemic approach, a joint vision, more effective regional energy institutions, and a review of the existing regulatory frameworks are prioritised areas for policy change.

## 1. INTRODUCTION

Renewable energy such as solar, wind, biomass, hydro, geothermal, wave action, and tidal power, is a key to low carbon economies. Such technologies can reduce air pollution, minimize future GHG emissions, reduce dependence on oil, promote economic growth and strengthen social cohesion (UNEP, 2011). Although at present renewable energy remains a relatively minor energy source in general, it has the potential to replace fossil fuels as a mainstream energy source. According to a study on renewable energy recently released by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2011), nearly 80 percent of the world's energy supply could be provided by renewable energy sources by 2050 if supported by appropriate enabling public policies.

Mainstreaming renewable energy in the context of sustainable energy however poses a major challenge to current energy governance systems. Barriers to the diffusion of renewable energy are many, involving factors that extend from the technological and economic to social and regulatory issues (IPCC, 2011). To create conducive conditions for such changes would require a structural shift away from energy systems which are currently based on fossil fuels (IPCC, 2011). Technological advancements, economic incentives, institutional structures as well as social acceptability have to be aligned to fully achieve the potential of renewable energy and to overcome the barriers (IPCC, 2011; Verbruggen et al., 2010). However, how to effectively facilitate such structural changes for the development of renewable energy requires further investigation.

These energy challenges are evident in both developed and developing economies, and Hong Kong is no exception. In Hong Kong, policies tend to rely on conventional energy options whilst the role of renewable energy in a sustainable future for this city has been comparatively neglected. In light of the energy challenges ahead, this working paper aims to explore whether and how a regional collaboration approach between Hong Kong and neighbouring Guangdong Province can better realise renewable energy options.

This study adopts a spatial perspective on regional energy governance. When compared with other geographical terms such as global, national and local, the "region" is a flexible concept that may refer to various scales of territories and spaces ranging from the super-region (e.g. Asia-Pacific) to the micro-region such as a sub-national territorial unit within a country (So, 2008). A regional perspective is of major relevance to our understanding of technological innovation systems. Regional collaboration appears to create some favourable conditions for knowledge exchange, learning, trust building and other important processes for technological innovation (Schienstock, 2005). In particular, due to their proximity and flexibility, regional networks may provide an effective platform for experimentation which often needs to involve intensive interactions between firms, consumers and governments (Schienstock, 2005). However, although there is a relatively abundant literature on renewable energy, a spatial analytical perspective that focuses on the regional level has been lacking.

Further to the concept of regional governance, another theoretical focus of this study is the concept of public engagement. Public engagement, which has been widely regarded as a central element of good environmental governance, is generally referred to as the process of involving the public for policy development (Mah et al., 2012; Rowe & Frewer, 2004). Technological innovations in large-scale energy systems involves a broad range of stakeholders including governments at various levels, firms, consumers, civil society and the general public. Effective processes for technological innovation therefore requires good stakeholder engagement. However, public engagement in energy decision-making has been relatively limited in practice and is particularly so in the Hong Kong context (Mah & Hills, 2010; Oxfam, 2010).

To partially fill these knowledge gaps, this paper aims to examine the relationships between regional energy governance and technology innovation. Using a case study of the development of renewable energy in the Hong Kong-Guangdong region in China, we will explore to what extent and how regional energy collaboration can contribute to the development of renewable energy. We identify and discuss the potential collaborative benefits, prioritised options and perceived barriers relating to the development of renewable energy in the region.

This is a qualitative study. Our data and analysis are based on two research projects: a commissioned study funded by Greenpeace China (which is a collaborative project between the Kadoorie Institute, the City University of Hong Kong and Greenpeace China) and a RGC funded Public Policy Research Project relating to the low-carbon economy transition.

This study adopts a bottom-up approach for data collection. We use data drawn from a desktop study and a series of stakeholder engagement exercises conducted in a half day workshop in June 2012. The half-day workshop focused on three thematic areas relating to regional collaboration for renewable energy in the Hong Kong-Guangdong region. These three themes were major technological options, business and financing options, and policy and governance options. Some 44 stakeholders were included in these engagment activities which included a pre-workshop survey, presentation, focus group meetings and group reporting. Stakeholders from both Hong Kong and Guangdong were involved and they were drawn from the fields of government, utilities, academia, consultancy, a government-funded service company (i.e. Hong Kong Productivity Council), energy and environmental industries and environmental NGOs.

Our data are complementary. The desktop study provides generic background information for our investigation. A series of activities were designed for the June workshop to generate four types of complementary qualitative data from stakeholders. The first type of data were derived from pre-workshop questionnaires. 11 invited speakers and 20 invited participants were asked to complete a pre-workshop questionnaire which consisted of 4 themes and 12 open-ended questions about prioritised areas, critical barriers, knowledge gaps and their suggestions for innovative solutions. 13 completed questionnaires were collected. Data from these questionnaires provide a relatively structured and comprehensive assembly of the stakeholders' views on these aspects. The second type of data were derived from 12 presentations made by invited key informants and experts in the first section of the workshop. These speakers came from the government, academia and NGOs. Representatives from the power industry and the renewable energy industry were also invited and they had agreed to give presentations. However, on the date of the workshop they were not able to attend. The third type of data were derived from three co-current focus group discussion carried out in the second section of the workshop. Registered participants chose and joined a group according to their preferences. Each focus group discussion lasted for about 45 minutes. The three focus group discussions provided a friendly and facilitating environment for stakeholders to freely express views and debate in greater depth. The fourth type of data were derived from the reporting sections in which a representative from each focus group was invited to make a report of 10 minutes on their group discussion. The reporting session in front of the whole group allowed systemic conclusions that consolidate key themes and issues raised in the focus group discussions. A list of data derived from the workshop is provided in *Appendix 1*.

## 2. RENEWABLE ENERGY: GLOBAL TRENDS AND RECENT DEVELOPMENTS IN CHINA, GUANGDONG AND HONG KONG

*World trends of renewable energy*

Renewable energy can bring economic, social and environmental benefits, and is a key to a low carbon future. Renewable energy can be replenished in a short time in nature and are virtually inexhaustible. They also emit no or low emissions in the power generating process. Renewable energy can also make a major contribution to energy security at the global, national and local levels (UNEP, 2011).

Renewables contributed about 3900 TWh (19.5%) of electricity to global production in 2009. They were the third largest contributor behind coal (40.6%) and gas (21.4%) but ahead of nuclear (13.4%) and oil (5.1%) (IEA, 2011a, 2011b).

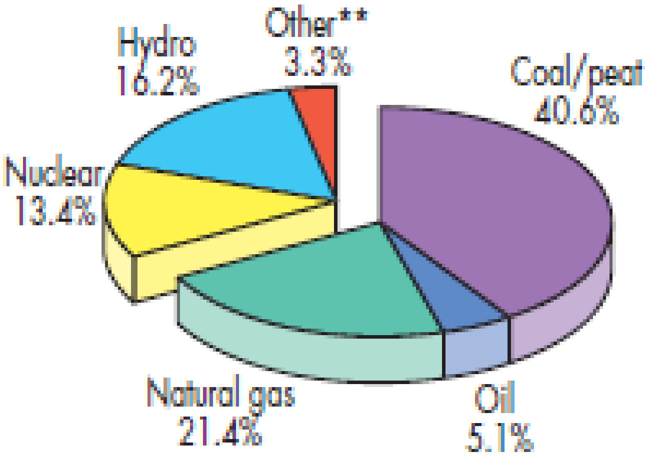
Global renewable power capacity reached 305 GW (of which wind power 159 GW; small hydro 60GW; biomass power 54 GW; grid connected solar PV 21 GW; geothermal power 10.7 GW) by the end of 2009 (REN 2010).[1] Wind, Solar PV and bioenergy have experienced rapid growth over recent decades. Grid-connected solar PV has grown by an average annual rate of 60 % over the past decade while wind and ethanol production recorded an annual growth rate of 27% and 20% respectively over the past five years (REN 21, 2010). Investment in renewable energy, led by wind and solar, is increasing substantially (IEA, 2010b).

Some countries have already adopted ambitious renewable energy plans, using renewables to replace fossil fuels as a mainstream energy source. In Denmark, wind energy currently accounts for about 25% of total electricity generation (MFA & Danish Wind, 2011). In the EU, for example, most of the new installed capacity of electricity generation is from new renewables such as wind energy while coal and nuclear power plants have been decommissioned (Figure 2).

Other promising renewables such as geothermal power, wave and tidal have also emerged as established technologies (REN 21, 2010).

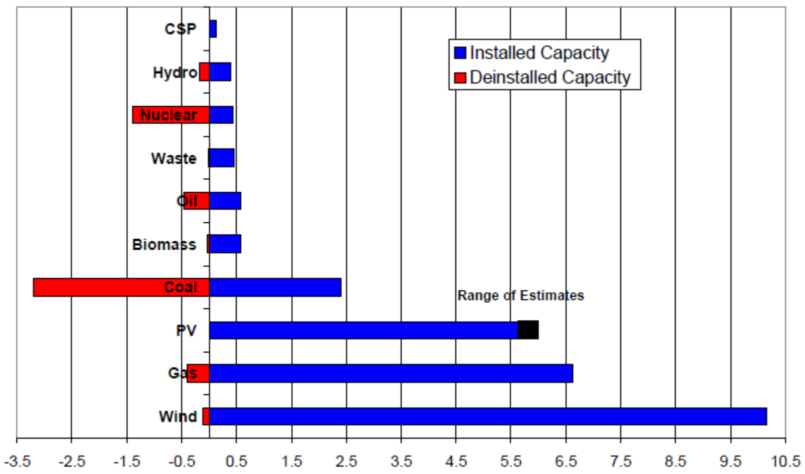
[1] Large-scale hydro is excluded.

Figure 1: The contribution of renewables to global electricity production (2009)




(Source: IEA, 2010b)

Figure 2: New installed or decommissioned electricity generation capacity (GW) in the EU in 2009




(Source: European Commission, 2010)

*Renewable energy in China*

In line with China's national policy for economic and industrial restructuring with science-based development, renewable energy has become a major element of economic and energy policies for both central and local government in recent years, particularly following the enactment of China's first renewable energy law in 2005.

Since the law was promulgated, China has issued more than 20 regulations and policies to support renewable energy. Major renewable plans include the China medium- and long-term renewable energy development plan and the 11th five-year plan for renewable energy development (Wang, Gu, & Zhang, 2010). A growing policy framework for renewable energy has been developed over the past few years. The policy framework covers renewable sources from wind energy to solar power and bioenergy, and involves a broad range of policy areas, from R&D to pricing and grid connection (Cherni & Kentish, 2007; Li et al., 2010).

In 2008, the supply of renewables in China was about 24,772 TWh contributing about 19% of total energy supply. Most renewables came from "renewable combustibles/ waste" (about 78%) while hydro amounted to about 19%. Geothermal, solar, wind and tidal represented a small share (2.5%) (IEA, 2010).

Several emerging trends of renewables in China are important to note:

- China has begun to play a central role in the global renewable energy market. China's wind energy sector, for example, overtook Germany and became the world No. 2 in terms of cumulative installed capacity in 2009. China also topped the world for newly installed capacity in 2009 (Li et al., 2010).
- Renewables are expected to experience substantial growth in coming years as China has introduced ambitious renewable energy plans including plans to build 7 wind bases and a number of offshore wind farms (*Box 1*).

Box 1: China's wind plans

China is planning to build mega on-land wind power bases, and go offshore.

1. ***Wind bases***: to build seven 10 GW-scale wind power bases in six provinces with a total installed capacity of 138 GW by 2020.
2. ***Offshore wind***: A number of provinces including Jiangsu, Shandong and Zhejiang has been formulating offshore wind plans for a total of 32.8 GW offshore wind farms.

Source: (Li et al., 2010)

*Renewable energy in Guangdong and Hong Kong*

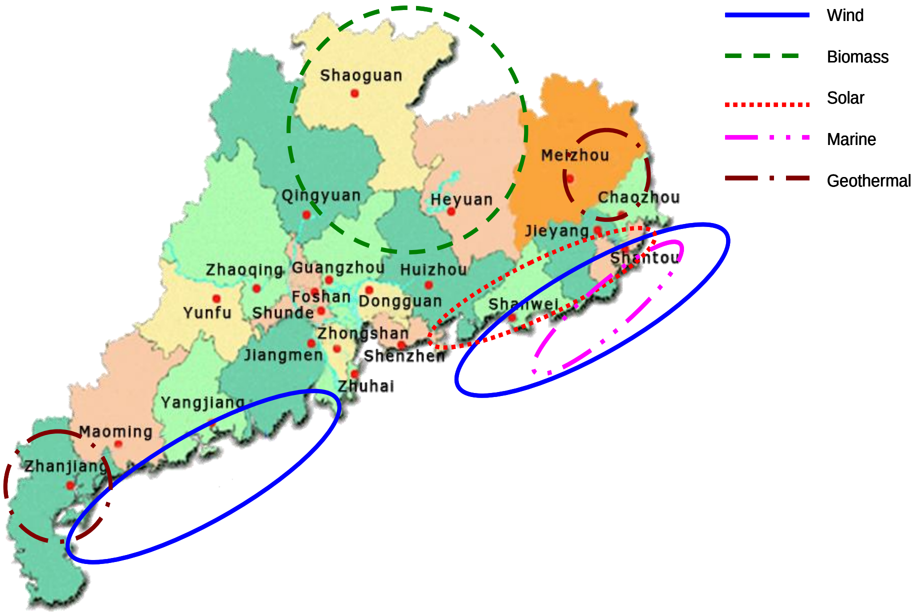
Guangdong and Hong Kong have developed renewable energy in very different ways and on different scales. Guangdong has a variety of renewable sources (*Table 1*) which are widely distributed geographically across the province (*Figure 3*). Guangdong has developed various sources of renewable energy, from wind to solar, to biomass and geothermal, although the total installed capacity is not particularly substantial.

Table 1: Potential and development plans of renewable energy in Guangdong

| **Technologies** | **Resources potential** | **Installed capacity (as of end of 2009)** | **2015 target** | **2020 target** |
|---|---|---|---|---|
| Wind | Onshore: 75 GW<br>Near shore: 20 GW | Onshore: 1,140 MW[@]<br>Near shore: N/A | Onshore: 2,000 MW<br>Near shore: 1,500 MW | Onshore: 2,000 MW<br>Near shore: 8,000 MW |
| Biomass | 618TWh | 300 MW | 800 MW [*]<br><br>1 million tonne[#] | 1,300 MW[*]<br><br>2 million tonnee[#] |
| Hydroelectric Power | 8.2 GW | Nil | Nil | Nil |
| Solar (PV) | Annual radiation: 4,200-4,000 MJ/Sq meter | 2 MW | 120 MW | 300 MW |
| Ocean & Geothermal | 8TWh[##] | Nil | 30 MW | 100 MW |

[@] Include 500 MW completed and 640 MW under construction
* In terms of electricity generation capacity; include waste to energy
\# In terms of liquid fuel
\## Geothermal energy only
(Sources: Guangdong NDRC 2010; Statistics Bureau of Guangdong Province, 2010)

Figure 3: Geographic distribution of renewable energy sources in Guangdong




(Sources: Guangdong NDRC, 2010; CMA 2011a; CMA 2011b; CHTSPTN 2011)

The Guangdong provincial government has been preparing major plans to further accelerate the development of renewable energy. Those include the "Exploitation and Development Plan of Emerging Energy Industries in Guangdong Province (Draft for Comments) 广东省新兴能源开发及产业发展规划(征求意见稿)》". By end 2015, 3.5 GW renewable electricity is planned to be added to the energy mix. Wind energy is the leading renewable energy source, with a total installed capacity of 500 MW at the end of 2010. Guangdong has set up ambitious renewable energy targets for 2015 and 2020 (*Table 1*).

In Hong Kong, according to a government study, wind and solar power could potentially contribute 39% and 17% respectively of the HKSAR's total annual power demand in 1999 when fully developed (EMSD, 2002). However large-scale deployment is severely constrained by a number of factors including the scarcity of flat land and planning approval procedures. Renewables amounted to 0.12 TWh in 2008, representing a minute 0.4% of Hong Kong's total energy supply. 99.8% of the renewables came from "renewable combustibles/ waste" (IEA, 2010) and the remaining 0.2% came mainly from wind energy.[2]

The Hong Kong government has proposed a modest renewable target of 3-4% of HK's electricity supply by 2020. Both the two power companies in Hong Kong have committed to setting up their own pilot commercial-scale offshore wind farms, with a planned total installed capacity of 300 MW (Environment Bureau, 2010).

Despite the modest progress made in Hong Kong, it is important to note that cross-border collaboration for renewable energy in this region has been given more attention from the national government in Beijing. In December 2008, the National Development and Reform Commission launched the "Outline of the Plan for the Reform and Development of the Pearl River Delta (2008-2020)" (NDRC, 2009) which has elevated Hong Kong-Guangdong regional environmental collaboration to a national strategic level. This Outline also echoed Hong Kong Chief Executive's 2008-2009 and 2011-2012 Policy Addresses which aspires to turn the Pearl River Delta Region into a green and quality living area (HKSAR Government, 2008; HKSAR Government, 2011).

More than three years later since the promulgation of the Outline, in June 2012 Hong Kong, Guangdong and Macau jointly announced "The Regional Cooperation Plan on Building a Quality Living Area"(HKSAR Environment Bureau *et al.*, 2012) – which is the first regional plan formulated for the implementation of the Outline. This Plan is of major relevance to regional collaboration for the development of renewable energy because the development and wider use of new and renewable energy in the greater Pearl River Delta is highlighted as one of the five areas that require long-term cooperation between the three governments. Specifically, the plan recommended the three governments to strengthen policy support for renewable energy, formulate energy plans to improve the regional energy structure and enhance collaboration in the renewable energy industry in the Pearl River Delta. It also recommended the governments to strengthen support for the renewable energy industry through tax and financing incentives and to establish industrial standards and accreditation mechanisms to ensure the healthy development of the industry.

[2] A 800-kW wind turbine is owned and operated by Hongkong Electric Company Limited on Lamma Island. http://www.epd.gov.hk/epd/textonly/english/news_events/other/comments_070321b.html

## 3. HONG KONG-GUANGDONG RENEWABLE COLLABORATION: CONTEXTUAL FEATURES, POTENTIAL COLLABORATIVE BENEFITS, POSSIBLE STRATEGIC OPTIONS AND PERCEIVED BARRIERS

### 3.1 Contextual Features of Hong Kong and Guangdong

For decades, Hong Kong and Guangdong have been closely linked in terms of economic and political development. Examples include the economic development of Shenzhen that benefited from Hong Kong's experience, the industrial relocation of Hong Kong factories to the Pearl River Delta in Guangdong, and the reliance of Hong Kong on food and water imports from Guangdong. It is also important to note that Hong Kong and Guangdong shares some similarities as well as differences in major contextual features as summarised in *Table 2*.

Table 2: Basic Features of Hong Kong and Guangdong (2010)

| | Hong Kong | Guangdong |
|---|---|---|
| Area (thousand km$^2$) | 1.1 | 179.8 |
| Population (million people) | 7 | 85.2 |
| Political status | A special administrative region | A provincial unit |
| GDP (billion USD)* | 224.8 | 723.7 |
| GDP per capita (USD), 2010** | 31,810.2 | 7036.7 |
| Primary Energy Consumption (Million tonne of standard coal Equivalent) 2010 | 19.0 | 21.8 |
| Total Electricity consumption (TWh) 2010 | 41.86 | 40.60 |
| Installed Capacity (MW) and power structure (2010) | 10,664 (Coal: 54%; Natural gas: 23%; Nuclear: 23%) | 71130 (Coal: 74.3%; Hydro: 17.7%; Nuclear: 7.1%; Wind: 0.9%) |

* GDP for Hong Kong HK$1,743.9 billion dollars; GDP for Guangdong Province RMB 4,601.3 billion Yuan. Currency converted to US dollars based on the exchange rates on 30 August, 2012.
** GDP per capita for Hong Kong HK$246,733 dollars; GDP for Guangdong Province RMB 44,736 Yuan. Currency converted to US dollars based on the exchange rates on 30 August, 2012.

(Sources for Hong Kong data: CSD, 2011a; CSD 2011b; Environment Bureau, 2010; ISD, 2011;
Sources for Guangdong data: GDSB, 2011; National Bureau of Statistics of China, 2011; SERC, 2011; GDSTS, 2011)

### 3.2 Potential collaborative benefits

In the context of the Hong Kong-Guangdong region, the differences between Hong Kong and Guangdong in terms of renewable resources and geographical and physical characteristics have created many opportunities for Hong Kong-Guangdong collaboration on renewable energy that can benefit both sides in some important aspects. Our analysis identifies four categories of regional complementarities. These relate to physical, technical, economic and market factors, and they are summarised in *Table 3*. These are areas where potential collaborative benefits and drivers for collaboration exist. These complementarities are illustrated with wind energy as an example.

Table 3: The four complementarities between Hong Kong and Guangdong in the development of renewable energy: an example of wind energy

| **Types of Regional Complementarities** | **Parameters** | **Hong Kong** | **Guangdong** |
|---|---|---|---|
| Physical Complementarities | ***Wind resources*** | 1 GW on land, 3 GW offshore | 75 GW on land, and 25 GW near shore |
| | ***Land resources*** | Land availability is a major constraint. Around 40% of its 1100 $km^2$ land areas is designated as country parks and conservation areas, building wind farm in these areas will need to address major planning constraints.<br>Public opposition can be a major constraint. The two proposed offshore wind farms have already caused some oppositions from environmental groups. | Land availability less a constraint. Potential wind sites are located along its 4300-kilometer-long coast line.<br>Public opposition to wind development is less a constraint generally |
| | ***Raw materials*** | Limited indigenous supply of raw materials | Rich in raw materials |
| Technical Complementarities | ***Capacity factor*** | Less than 12%[3] | As high as 25.6% for a land based wind farm in Nan'ao Island |
| | ***R&D capabilities*** | Strengths in absorptive capacity from global knowledge sources (Sharif, 2005)<br>Strengths in standardization and quality assurance | Strong manufacturing capacity |
| | ***Human resources*** | Good access to global expertise | Potential to mobilise a lot of graduates for R&D<br>Vocational training/ career development |
| | ***Managerial capacity*** | Excellent managerial skills which are up to international standards<br>Experience in transferring managerial skills to counterparts in Guangdong, e.g. the MTR system in Shenzhen | Relatively under-developed |
| Economic Complementarities | ***Investment*** | A 200MW off-shore wind farm to generate 1% of electricity for HK cost HK$ 5-8 billion (Environment Bureau 2010) | Land based wind farm (of a scale of 180 MW) to generate 1% of electricity for HK cost HK$ 2 billion (Huaneng 2006) |
| Market Complementarities | ***Market demand, market and financial systems*** | Relatively free market competition and level-playing-field<br>Innovation in financial options- drawing on the skills of international financial institutions<br>Expertise in attracting specialist investors to invest in renewable energy projects in Guangdong | State retains major influence in the economy through state-own enterprises. The government has great power to mobilize resources and direct industries and enterprises |

[3] This figure is based on the only commercially operating wind turbine on Lamma Island of Hong Kong. That turbine is operated by Hongkong Electric Company Limited (complied with the information released in the Hongkong Electric Company Limited Annual Report 2008).

(a) Physical complementarities.

According to the recent IPCC report on renewable energy (2011), combining different types of variable renewable sources and sources from larger geographical areas will be beneficial in smoothing the variability and reducing overall uncertainty for the power system.

(b) Technical complementarities

Technical capabilities across the border also differ. As shown in Table 3, the capacity factor for a wind turbine in Hong Kong is substantially lower that in Guangdong (more detailed illustration please refer to *Box 2*). In terms of R&D capabilities, whilst Guangdong has strengths in the manufacturing sector, Hong Kong has its strengths in absorptive capacity from global knowledge sources as well as in standardisation and quality assurance. Hong Kong also possesses high managerial capacity which can be transferred to Guangdong.

(c) Economic complementarities

Cross-border collaboration has the potential to reduce the cost of Hong Kong to use more renewable energy. The costs of renewable energy are highly site-sensitive, depending on a number of factors including the availability of renewable resources, land resources and labour costs. The geographical and technology mixes of renewable energy can be better optimised on a regional basis rather than at a city-scale.

Regional collaboration may allow Hong Kong to take advantage of the relatively more abundant renewable resources, low-cost labour and the availability of cheaper land across the border. For instance, rather than building costly renewable energy facilities within Hong Kong, it may be more cost-effective for Hong Kong to build or invest in for example wind farms in Guangdong and then import renewable electricity to Hong Kong, rather than building offshore wind farms in Hong Kong (Box 2).

**Box 2. Why is it more cost-effective for Hong Kong to build wind farms in Guangdong rather than in Hong Kong?**

While the actual costs of a specific wind farm would depend on a number of site-specific factors, generally it may be more cost-effective for Hong Kong to build wind farms in our neighbouring province rather than building wind farms within Hong Kong boundary for a number of reasons:

1. Because wind resources are greater in Guangdong (the full operation hours/ capacity factor of a land based wind farm in Guangdong can be as high as 25.6%, which doubles that of the only existing wind turbine in Hong Kong (<12%), investment in wind farm projects in Hong Kong generally would have lower investment return and longer payback period. A 200MW offshore wind farm to generate 1% of electricity from wind built in Hong Kong will cost 5 – 8 billion Hong Kong Dollars (Environment Bureau, 2010). While the investment for 4 land-based wind farms, with an installed capacity of 45 MW each, in Guangdong to generate the same amount of electricity is only about 2 billion Hong Kong Dollars (1.7 billion Yuen RMB) (UNFCCC, 2009).
2. If Hong Kong is to adopt more flexible approaches to developing renewable energy, e.g. through purchasing renewable electricity certificates to meet its renewable energy targets,[4] Hong Kong utilities would not need to build additional backup capacity, which is costly, to maintain secure energy suppliers. Such flexible approaches would help minimise the cost of using more renewable electricity in Hong Kong.

Economic benefits of regional renewable collaboration can also be achieved through the development of a Guangdong-Hong Kong renewable technology hub. Although Hong Kong has limitations in developing some large-scale renewables such as wind farms, it has a strategic role to play in the regional development on renewable energy. Hong Kong has unique strengths in quality assurance, standardization, financing and project management. The regional capacity for developing renewable energy may therefore be enhanced through combining the strengths in R&D and production capacity in Guangdong and the strengths in quality assurance and financing in Hong Kong. Hong Kong for example can also serve as the financing hub for renewable facilities in Guangdong.

(d) Market complementarities

Regional collaboration may also create opportunities for emerging green electricity markets. An opportunity of renewable energy collaboration is that rather than building renewable energy projects, Hong Kong can purchase renewable electricity across the border through

[4] Renewable electricity certificates provide flexibility that physical transmission of renewable electricity is not a must.

green electricity market systems – voluntary electricity markets in which electricity consumers can choose to pay a premium on their electricity bill to support renewable energy.

The cross-border energy trade between Hong Kong and Guangdong has been in place for decades. CLP Power has been importing nuclear power from the Daya Bay Nuclear Power Station and the pumped storage power station at Conghua since the 1990's through a long-term electricity purchase agreement. It is in the regional common interest to adopt a similar long-term purchase agreement for renewable energy.

Aggregating demand from Hong Kong's electricity consumers for renewable energy can stimulate investment of more renewable projects in the region, e.g. in Guangdong, where it will be more cost-effective to build new renewable energy facilities.

In Hong Kong, some big consumers can easily absorb the renewable electricity if a local renewable target is set at 5% of electricity generation. The Hong Kong government, utilities (e.g. MTR and Hong Kong Airport) are key potential large users of renewable electricity. The Hong Kong government is a major electricity consumer in Hong Kong, consuming 5% of total electricity generation in 2008, about 2 TWh. The MTR Corporation Limited (MTR) is another major electricity consumer, consuming about 3% of total electricity consumption in this city (Cheng, 2010). Individual electricity consumers can also be mobilised through green marketing and education to subscribe to renewable electricity on a voluntary basis. Aggregate demand from individual consumers can be substantial.

Guangdong has the potential to act as the renewable energy base for Hong Kong. If 5% of the supply of electricity in Hong Kong comes from renewable sources, about 900 MW capacity of installed renewable facilities will be needed. Guangdong has a wind energy potential of 75 GW onshore and 20 GW nearshore, and the province has been planning to build 9 GW of new wind farms between 2010 and 2020 (Guangdong NDRC 2010). 10% of Guangdong's planned wind farms would be sufficient to produce renewable electricity for Hong Kong to meet the market demand of 5% renewables.

### 3.3 Prioritised options for renewable energy collaboration

Stakeholder views on the prioritised areas for collaboration in terms of technological options, financing options and governance options were collected and analysed.

(a) Technological options

Solar, wind, biomass, biofuels and energy storage are the prioritised energy options identified (P01; P04). Other suggestions include offshore wind energy (P01; P01). Decentralised technologies which are more applicable to cities like Hong Kong and Shenzhen (S01; P04 ); Plug-in EV(smart grid) to store wind power (P05) are also identified as potential areas. Some participants also note that in the light of the Hong Kong context, gas fired power plants can be used to balance variable wind power (P05) and priorities should be given to areas that are close to or already been commercialized and receiving government subsidies (S01).

Some participants highlighted the importance of infrastructural support on a regional basis. These include resource assessments at the regional scale (P01), grid connection for wide-scale renewable energy (P05), and smart grids in terms of grid planning, operation, maintenance and control (S01; GD01; P04; P06). Flagship projects of common interest and potential collaborative benefits for Guangdong and Hong Kong can be another prioritised area (S01).

(b) Financing options

In relation to developing viable financing models for renewable energy in this region, our analysis shows that government intervention, particularly in the form of tax reductions, subsidies, carbon tax and seed funding, is perceived as desirable.

Factors beyond government direct spending are also important. Public-private partnership for project development, consolidating and co-funding of grants, developing innovative financing services, are some of the potential areas where the region can collaborate (S01). Cross-border financing is also perceived as a potential area for collaboration. For example, enterprises in Hong Kong may invest in renewable projects across the border.

It is important to note that some participants suggested that regional collaboration may open up some new financing options. Such new options include emission trading and achieving cost reduction through economics of scale (P09; S01; GP02).

(c) Governance options

Our participants identified several areas where Hong Kong and Guangdong may collaborate to develop more effective governance arrangements for regional collaboration. These include the development of a joint vision for renewable energy, the formation of joint regulatory and policy frameworks, and the formulation of a clear and directional energy policy (S01). A regional energy plan and roadmap is also identified as important (GP03). Other governance options include the establishment of effective collaborative institutions (S01), the introduction of renewable portfolio standards (S01), and the setting up of regional emission reduction targets. In addition, the establishment of regional R&D and policy research centres through regional collaboration is also important (P04).

### 3.4 Perceived Barriers

Various barriers need to be overcome before Hong Kong and Guangdong can collaborate and fully realise their renewable energy potential. Our analysis identifies five categories of barriers: physical, technical, economic and market, political and institutional, and social.

*Physical* Barriers. The availability of renewable resources and land for siting renewable facilities is identified as the major physical barrier. Renewable energy tends to be land-demanding and site specific (S01). The availability of land is perceived as a particular key issue in Hong Kong because of its scarcity (P07).

*Technical* Barriers. Intermittency, technical reliability, grid integration, transmission considerations and energy storage systems are the major technical barriers identified by our workshop participants. These barriers have also been commonly identified in other countries and cities. But our participants also highlight infrastructural issues as a major barrier. Some raised concerns relating to the major changes in the existing electric infrastructure which would be required for wide-scale deployment of renewable energy in this region. Such infrastructural changes will require major investments in infrastructure. Our participants also raised concerns relating to the over-development of renewable energy in China in ways that the required R&D inputs, human resources and quality assurance may be unable to match the rapid pace of development and may jeopardise the long-term healthy growth of these emerging industries (GD01).

*Economic* and *market* barriers. High up-front capital costs and high financial and investment risks tend to result in a lack of funding opportunities for renewable energy projects, and it is particularly so in SMEs projects. In addition, the reducing carbon price and the depressing global economy is adding to the funding cost and government support (S01; GD02). The lack of actual investment in renewable energy in this region has created barriers for renewable projects to benefit from economies of scale (S01).

*Political and institutional* barriers. Our participants highlighted the lack of a comprehensive regulatory and policy framework for regional development of renewable energy as a key barrier. Specifically, they highlighted the Scheme of Control Agreements (SCAs), the existing regulatory framework for the electricity sector in Hong Kong, as major institutional barriers that do not provide sufficient incentives for renewable investment (S01; P01; P03; P10). The lack of coordination across government agencies is also perceived as a barrier for collaboration (S01).

In addition, power relationships, most notably natural coalitions that oppose emerging energy technologies, are also identified as key barriers. Some participants raised concerns about the perceived monopoly of the electricity industry in the mainland China (S01), and the difficulties for SMEs to compete with incumbent companies for funding (S01).

It is important to note that some participants from Hong Kong expressed concerns about the non-consistency of government policies and the lack of a good understanding of the policy-making processes in Guangdong relating to renewable energy (S01).

*Social* Barriers. Public acceptability and consumer responses to foster markets for renewable energy are a key factor. However, some participants raised concerns about the lack of public knowledge and acceptance of renewable energy and the NIMBY problem relating to the siting of renewable energy facilities are also potential social barriers in this region (S01; GD02).

## 4. CONCLUSIONS

This paper adopts a regional governance perspective for analysing technological innovation, with specific reference to a case study of the deployment of renewable energy in the Hong Kong-Guangdong region. This spatial perspective partially closes the gaps in the literature on technological innovation. We have made three contributions.

Firstly, this study offers a systemic perspective on regional governance analysis in current debates relating to technological innovation. We have built the linkages between the concepts of regional complementarities, types of strategic options for regional collaboration as well as categorization of barriers. Our result shows that regional collaboration for renewable energy depends on these three dimensions.

Specifically, we identify four dimensions of regional complementarities which are of major relevance for this region to realise collaborative benefits. Whilst physical and technical complementarities are important, we found that economic and market complementarities are also a key. We also found that three types of options, technological, financing and governance, are prioritised areas for renewable collaboration across the border. However, our results show that five dimensions of barriers need to be overcome before Hong Kong and Guangdong can fully realise the renewable energy potentials. Whilst physical and technological barriers are important, a diverse range of non-technical factors are also critical. These include economic and market barriers, political and institutional barriers, and social barriers. Our results show that these dimensions were viewed as particularly important in facilitating regional collaboration for renewable energy.

Secondly, this study adopted a bottom-up engagment approach for analysis. Whilst stakeholder engagement has been increasingly recognised as an important strategy for effective energy decision-making, how and to what extent such an approach works is still unexplored. This study provides valuable insights into the perceptions of major stakeholders in this context. Our reflection on the engagment process in our workshop opens up a critical area for further research. We observed that there was a major gap between stakeholder interests and the actual development of regional collaboration in the area of renewable energy. Some participants showed great interest in learning more about the policy-making processes from their counter-parts across the border. But these participants appeared to have little knowledge and access to such information. The processes, mechanisms and institutions that should be in place for closing these gaps should be an important area of future research.

Thirdly, our study also offers policy recommendations on how to improve regional energy governance, particularly in the area of renewable energy. Many solutions to overcome the barriers towards a low-carbon future in Hong Kong and Guangdong can be found only on a regional basis. The complementarities in diverse dimensions across the border define Hong Kong and Guangdong as highly interdependent on energy development. Our analysis has demonstrated that this regional approach requires a recognition of the need to move away from relying on local solutions to one with a regional, systemic approach. Major changes are needed in regional energy governance to enable these collaborative benefits to be realized. A joint vision, a high-level policy framework, the establishment of more effective regional energy institutions for planning and implementation are some of the prioritised areas for policy change. It is also important to note that a review of the existing SCAs has been widely regarded as critical. Electricity tariff reforms and market structures are two critical areas for review. Furthermore, engaging stakeholders on a regional scale seems to be a crucial component of effective governance system. However, the current energy decision-making systems in this region have provided limited opportunities for inviting engagement. How to enhance the inclusion of stakeholders is another critical area for policy change.

Appendix 1: A list of data derived from our workshop in June

| Code | Types of activities | Themes |
|---|---|---|
| P01 | Presentation | Renewable Energy Options for Hong Kong and their Developments in Guangdong |
| P02 | Presentation | Renewable energy options |
| P03 | Presentation | Building-integrated-photovoltaic |
| P04 | Presentation | Wind power |
| P05 | Presentation | Wind power |
| P06 | Presentation | Smart Grid |
| P07 | Presentation | Smart Grid |
| P08 | Presentation | Green Financing Tools and Business Models |
| P09 | Presentation | Green Electricity Market and Emissions Trading |
| P10 | Presentation | Innovation in governance |
| P11 | Presentation | Governance and Institutional Innovations |
| GD01 | Group discussion | Technological options |
| GD02 | Group discussion | Financing models and mechanisms |
| GD03 | Group discussion | Governance options |
| GP01 | Group presentation | Technological options |
| GP02 | Group presentation | Financing models and mechanisms |
| GP03 | Group presentation | Governance options |
| S01 | Pre-workshop survey summary | |

Acknowledgements

The work described in this working paper was partially supported by a commissioned study by Greenpeace China and a grant from the Central Policy Unit of the Government of the Hong Kong Special Administrative Region and the Research Grants Council of the Hong Kong Special Administrative Region, China (Project No. HKU7004-PPR-10).

We would like to acknowledge the contribution of Dr Josie Close at the City University of Hong Kong's School of Energy and Environment and Ms Gloria Chang from Greenpeace China who collaborated with the authors in a commissioned project "Hong Kong sustainable energy future: technological and policy options for Hong Kong-Pearl River Delta collaboration", which was completed in 2011. Some of the ideas of this working paper are developed from the findings of this commissioned project.

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