Electrical & Mechanical Services Department

Government of the Hong Kong Special Administrative Region

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Study on the Potential Applications of Renewable Energy in Hong Kong

Stage 1 Study
Executive Summary

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1 INTRODUCTION

1.1 BACKGROUND

As a small place with no indigenous energy resources such as oil, gas or coal, Hong Kong has been relying mainly on imported fossil fuels to support its energy sector[1]. In terms of electricity supply, two independent power companies, each providing generation, transmission, distribution and retailing of electricity, serve all major residential, commercial and industrial developments in the SAR. Coal and, more recently, natural gas are imported to generate electricity locally at three power stations.

Public awareness of energy efficiency and environmental protection has become more prominent recently. For example, Hong Kong has undertaken "*to contribute to international efforts to stabilise greenhouse gas concentrations in the atmosphere*". Greenhouse gas (GHG) emissions such as carbon dioxide are largely by-products of burning fossil fuels. The energy sector is the largest contributor to Hong Kong's carbon dioxide emissions, responsible for about 97% of the total carbon dioxide emissions, and most of which comes from electricity generation. At present, energy is untaxed, and there are no "eco-taxes" (e.g., carbon tax or SO_x/NO_x tax) to internalise local or global pollution costs associated with fossil fuel combustion.

Reduction of GHG emissions due to electricity generation may be achieved through several means, including use of alternative fuels and renewable energy sources. It is worthy to note that all new power plants commissioned in Hong Kong since 1996 have been using natural gas as fuel, which emits about 50% less carbon dioxide than coal. While renewable energy sources have been used in large-scale power generation in some overseas countries, it is unclear if this would be applicable in Hong Kong.

1.2 POLICY CONTEXT

At present, the two objectives under the energy policy are:

- ❑ Ensure the energy needs of the community are met safely, efficiently and at reasonable prices; and
- ❑ Minimise the environmental impact of energy production and use, and promote the efficient use and conservation of energy.

Increasing the contribution that renewable energy sources make to meeting local energy demand will support existing government policies aimed at minimising the environmental impact of energy production and promoting the efficient use and conservation of energy. It will contribute to international efforts to reduce greenhouse gas emissions into the atmosphere and improve compliance with air quality objectives.

Finally, increasing the proportion of energy needs met from renewable sources will also increase diversity of energy supply options, so helping to reduce reliance on imported energy or fuel, and increase security of energy supply.

Consistent with these policy objectives, the Government has considered it opportune to examine the potential for application of renewable energy in Hong Kong. Accordingly, the Electrical and Mechanical Services Department has commissioned this *Study on the Potential Applications of Renewable Energy in Hong Kong* (hereinafter referred to as the Study).

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[1] Energy sector includes electricity generation, manufacturing and construction, transport and other fuel combustion industries.

1.3 SCOPE OF STUDY

The Study is structured into two stages, consisting of:

Stage 1 of Study

- Review the latest developments in renewable energy[2] (RE) technologies world wide through a literature search and desktop study;
- Examine the potential for wide-scale[3] adoptions of suitable RE technologies in Hong Kong in the short and long term;
- Assess the feasibility and potential for wider application of new[4] and renewable energy technologies as alternative forms of energy sources in Hong Kong; and
- Devise a strategy for implementation.

Stage 2 of Study

- Conduct a pilot project to demonstrate the applicability of Building Integrated Photovoltaic (BIPV) systems.

This Executive Summary presents the principal findings of Stage 1 of the Study. Separate reports will be prepared for the Stage 2 BIPV demonstration project.

1.4 OBJECTIVE OF STAGE 1 STUDY

The Stage 1 Study is the first systematic assessment of the potential for renewable energy in Hong Kong. Its primary objective is to identify new and RE technologies that have a potential for wide scale application in Hong Kong and then formulate a "*strategy*" to facilitate their implementation. Key tasks in the Stage 1 study were:

- Technologies Review;
- Analysis of Issues and Barriers; and
- Strategy Formulation.

The findings are summarised in subsequent sections of this report.

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[2] The term "renewable energy" may be defined in several ways, and there is not at present a universally accepted definition. Generally speaking, renewable energy sources are secure and inexhaustible, in the sense that there is no problem of reserves being depleted.

[3] "Wide scale" use is taken to mean application of the technologies for community-scale use in centralised or distributed arrangement, with sufficient power and energy for distant transmission if they are located in areas remote from the loads.

[4] New energy technologies include "non-conventional" power generation as well as energy storage technologies. Note that these are not necessarily renewable energy technologies. An example is "fuel cells", some types of which can use fossil fuels such as natural gas to generate electricity.

2 TECHNOLOGIES REVIEW

The objective the Technologies Review is to identify new and renewable energy technologies that have a potential for wide scale application in Hong Kong, through a systematic process of technology identification, baseline conditions review, resource assessment, option evaluation and classification. This section summarises the findings of the Review, which is focussed mainly on technical issues. Non-technical constraints to the deployment of the identified technology options are further discussed in Section 3.

2.1 OVERVIEW

2.1.1 Resource Definition

In reviewing RE resources, it is important to note that the total amount of a particular form of energy that exists in nature is very often *not* the same as that can be extracted *in practice* after taking into account the many technical and non-technical factors. Recognising this, the following resource definitions are adopted in this Study:

- *Total Resource* – the total energy content of the RE source in a given time period;
- *Technical Resource* – the total resource, limited by our technical ability to extract it (i.e., technological limitations);
- *Potential Resource* – the technical resource, additionally limited by *basic practical incompatibilities* (e.g., roads) that reduce the opportunities of resource capture or technology deployment;
- *Accessible Resource* – the potential resource, additionally limited by institutional restrictions (e.g., country parks, sites of special scientific interests, etc);
- *Commercially Viable Resource* – the accessible resource, additionally limited by what the commercial sector considers financially viable; and
- *Acceptable Resource* – the viable resource, additionally limited by what is acceptable to society (e.g., visual impacts, planning permission, etc).

The first three (*total, technical* and *potential*) resource levels are related to essentially technical factors, while the last three (*accessible, commercially viable* and *acceptable*) are governed by non-technical constraints, related primarily to institutional, economical/financial and social factors.

2.1.2 Key Local Characteristics

Hong Kong has a total territorial area of about 2,757 km^2, consisting of 1,098 km^2 of land and 1,659 km^2 of sea. Land uses include a diverse range of developed areas, natural and managed habitats, and urban open space. However, land suitable for development is extremely limited, due to topographical constraints and existing developments. The marine waters of Hong Kong are used for a variety of beneficial purposes, including commercial shipping, fisheries, marine disposal sites, recreation (e.g., boating, beaches) and conservation (e.g., marine reserves). *Figure 1* summarises the major development constraints in Hong Kong.

A significant proportion of the land (815 km^2) is for open space, woodlands, grass, and shrubs, of which just over half (415 km^2) are designated as Country Parks or Special Areas. Built up areas (including commercial, residential, housing, industrial, vacant development land, institutional, community, roads, railways and airports) occupy only 167 km^2. Within these very densely populated and highly urbanised areas, there are many high-rise residential and commercial buildings consuming a significant amount of energy.

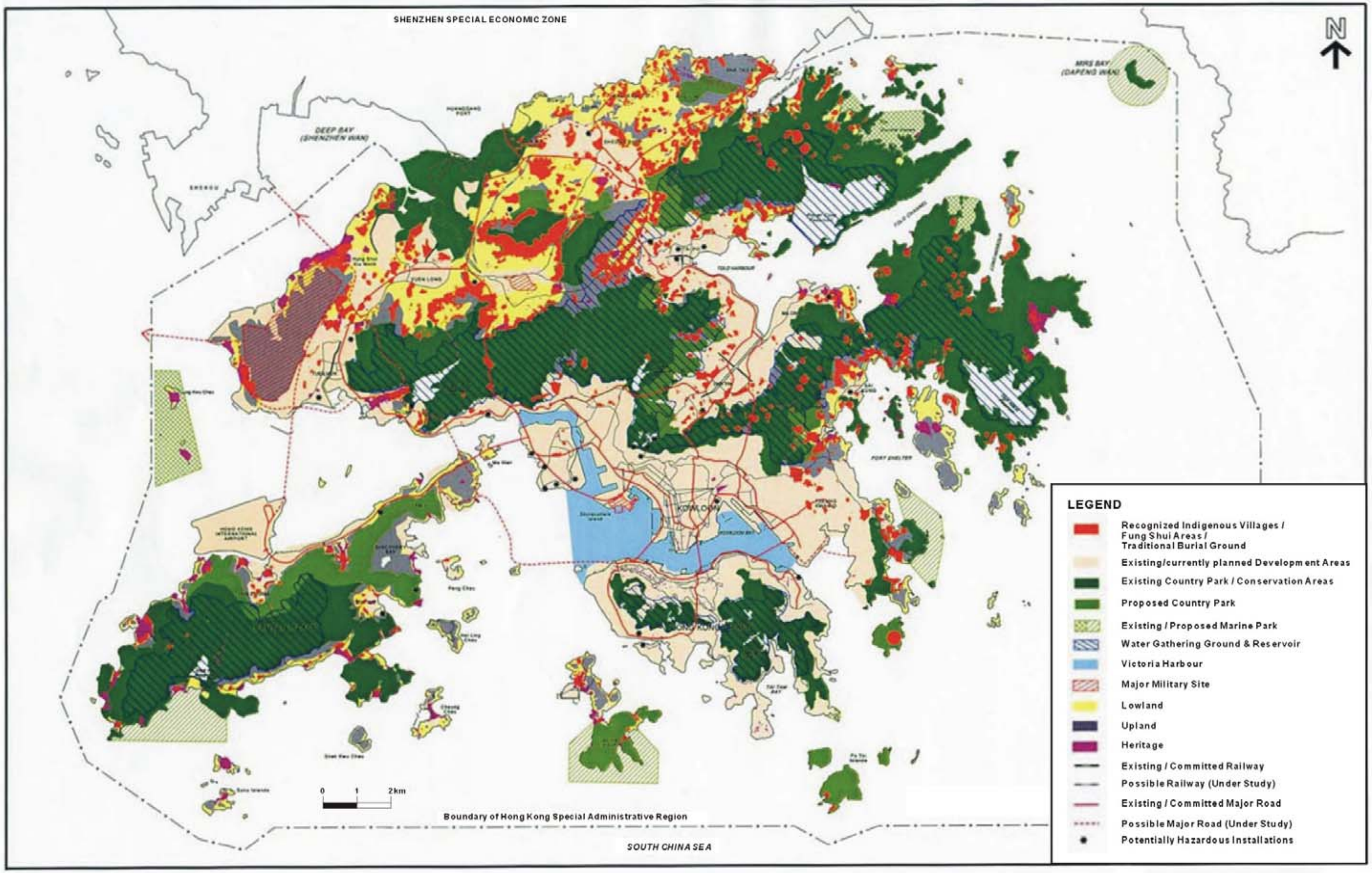

Figure 1 **Major Development Constraints in Hong Kong** (Source: Hong Kong 2030 web site)

Given Hong Kong's small size and densely populated nature, it is clear that deployment and siting of any new and renewable energy systems, particularly those involving large centralised generation facilities, must take into account a range of land and marine constraints. However, while there are likely many constraints to development of large scale facilities in urban areas, there are potential opportunities for deployment of distributed or embedded non-polluting renewable energy systems at individual localities, including new and redeveloped urban areas. This is particularly relevant given buildings are the most significant electricity users in Hong Kong.

2.1.3 Technology Classifications

Taking into account the fundamentals of Hong Kong's local characteristics, and other relative technical, cost, and environmental factors, the Study has reviewed a wide range of new and renewable energy resource or technologies, and classified the options into the following categories:

- **Technologies with Potential for Wide Scale Application**, including:
  - Photovoltaic systems;
  - Wind power (rural wind farms, near-shore wind farms, and individual urban wind turbines);
  - Building Integrated Fuel Cells; and
  - Energy-from-waste[5].
- **Technologies for Other Applications,** those that may be applicable at specific sites, subject to case-by-case evaluations. These include:
  - Solar water heating;
  - Small hydroelectric systems; and
  - Wave power systems.
- **Technologies that do not appear to have potential for wide scale application in Hong Kong**:
  - Solar thermal electricity generation;
  - Biomass (energy crops);
  - Geothermal energy; and
  - Tidal power.

2.2 PHOTOVOLTAIC SYSTEMS

Photovoltaic (PV) devices directly and silently convert light energy to electricity. PV power systems, consisting of solar panels or modules and ancillary equipment, are installed at locations with good sunlight exposure to maximise energy production. The Study has found that PV technologies could potentially be installed as building-integrated (BIPV) and non-BIPV generation systems. BIPV systems are particularly relevant to Hong Kong, given the large number of high-rise buildings and the fact that no additional land resource will need to be utilised.

[5] Please refer to Section 2.5 for a further discussion of energy-from-waste technologies.

2.2.1 Potential Resource

In Hong Kong, a typical horizontally mounted flat PV system is expected to generate about 121 kWh/year per m^2 of PV panel. If all of the land in Hong Kong were fitted with horizontal PV panels, the total electrical energy available would be 133,000 GWh[6] per year, which is 3.7 times of the SAR's annual electricity demand (35,500 GWh) in 1999. Obviously, the area that is technically available for PV panel installation would be much smaller after taking into account "*basic practical incompatibilities*" such as roads, natural areas, reservoirs, etc.

In assessing potential for deployment of PV systems, a fundamental issue is the allowable space for system installation. It is recognised that this is a very site-specific consideration, as the system may be located in different geographical settings, resulting in different efficiencies in sunlight capture. Also, PV panels may be installed in different configurations, e.g., horizontally, vertically, or tilted. All these factors affect the electrical energy that can be generated from the PV systems.

To estimate the *potential*[7] resource of PV energy in the long term, "*equivalent horizontal areas*[8]" that may be utilised for PV array installation has been assumed, as shown in *Table 1*, on the basis some building surfaces and land are or will be available for installation of PV systems at each land use category. Based on these assumptions, the *potential* resource (electricity generation) for each land use category was calculated. *Table 1* is therefore also an indication of the priority areas for PV deployment, which may be refined in the future by adjusting the assumed utilization ratios.

Overall, PV systems are estimated to have a *potential* resource of about 5,944 GWh each year, equivalent to about 17% of Hong Kong's annual electricity demand (in 1999). This estimate is based on the assumption that, in the long-term, approximately 49 million m^2 of equivalent horizontal PV panels could be installed ultimately. The majority of this (over 90%) is likely to be realised as BIPV systems, rather than non-BIPV installations.

The major opportunity for deployment would appear to be in future developments, because BIPV systems may be "designed into" buildings, facilities or new town infrastructure. The many existing buildings (particularly residential) and city infrastructure may also provide opportunities for retrofitting PV systems to capture solar energy.

[6] GWh = million kWh

[7] "Potential resource" is as defined in Section 2.1.

[8] The annual electrical energy output of a PV panel is related to the orientation it is installed. In Hong Kong, for example, a vertical PV panel mounted on the southern wall will generate only about 58% of electrical energy compared to a horizontally mounted PV panel. That is, 1 m^2 of such a vertically mounted PV panel would have an *equivalent horizontal area* of 0.58 m^2. In Table 1, the PV deployment goal is listed as *equivalent horizontal area,* but it is recognised that some BIPV panels will be installed vertically or in a tilted manner

Table 1 Long term PV Deployment Goals

Land Use	Area (km^2)	Assumed Equivalent Horizontal PV Surface Coverage	Equivalent Horizontal Area for PV Power Generation (km^2)	Potential Resource (GWh)
BIPV System Deployment				
Residential	45	30%	13.5	1,629
Public rental housing	14	30%	4.2	507
Commercial	2	50%	1.0	121
Industrial	11	50%	5.5	664
Government, institution and community facilities	21	20%	4.2	507
Temporary housing areas	1	0%	0.0	0
Vacant development land	27	60%	16.2	1,955
Non- BIPV System Deployment				
Roads/Railways	33	5%	1.7	199
Airport	13	10%	1.3	157
Open Space (e.g., urban parks)	17	10%	1.7	205
Woodlands	220	0%	0.0	0
Grass and shrubs	519	0%	0.0	0
Badlands, swamp and mangrove	44	0%	0.0	0
Arable	59	0%	0.0	0
Fish ponds	14	0%	0.0	0
Temporary structures/livestock farms	11	0%	0.0	0
Reservoir	26	0%	0.0	0
Other uses	21	0%	0	0
Total	**1,098**		**49**	**5,944**

2.2.2 Implementation Issues

Of the 5,944 GWh/year of electricity that could be *potentially* generated by PV systems in the long term, the actual resource that will be available *in practice* is subjected to several non-technical constraints, some of which are generic to all RE options (e.g., market issues) and some specific to PV technology. While a more detailed discussion of these generic constraints are presented in Section 3, it is useful to briefly outline the issues related to BIPV systems below:

2.2.2.1 Institutional Issues

The Buildings Department (BD) controls all private development in Hong Kong under the Buildings Ordinance and allied legislation. Any building-integrated new or renewable energy installations (PV for example) would have to comply with the codes of practice and standards in order for approval of the building plans to be obtained. While BIPV systems do not have significant environmental, health and safety issues, there are specific standards concerning PV systems, including those on wind effects, cladding and curtain wall systems requirements. These are not expected to be insurmountable, however.

Further, the BD recently released a practice note on green features for new building developments. This note sets out incentives provided by the government to encourage the design and construction of green and innovative buildings. The package of incentives includes a list of ‘green’ features that may be exempted from the Gross Floor Area (GFA) and Site Coverage (SC) calculations. There is an opportunity for BIPV systems to be included in this scheme.

2.2.2.2 *Commercial Viability*

The Study has estimated that the PV electricity generation cost is at between $2.2/kWh and $4.1/kWh[9], which is about an order of magnitude higher than conventional fossil fuel power generation technologies at present (which ranges from $0.2/kWh[10] to $0.4/kWh[11]). This high generation cost is due primarily to the high cost of solar panels. While custom-made solar panels may be promoted as alternative curtain wall materials with the added benefit of power generation, they are more costly than conventional building materials. Anecdotal evidence collected in the course of the Study suggests that the BIPV schemes adopted so far have tended to have a pay-back periods far longer than those usually considered acceptable by the private sector – a differential which, if it persists, is clearly a major barrier to the wider uptake of BIPV by the private sector.

2.3 WIND POWER

2.3.1 Wind Resource

Wind turbines are devices that convert the kinetic energy of the wind into rotational motion to turn an electrical generator and produce power. Since the kinetic energy available in the wind is proportional to the cube of the wind speed, the amount energy which can be captured by any given wind turbine is very sensitive to the wind speed encountered at the location in which it is installed. Using long-term historic meteorological data and a computer modelling technique, the wind resources in Hong Kong are mapped in *Figure 2*.

Figure 2 shows the high wind resource areas potentially suitable for wind power applications[12] in Hong Kong are essentially all the high grounds, as well as most of the offshore marine areas. It also shows that the highest wind resource areas (larger than 600W/m^2) are generally located at mountaintops in the eastern side of the SAR.

Methods of exploiting wind resources on land can be divided into two categories, either *wind farms* or *individual turbines*. The term "wind farms" refers to groups of large machines (typically 1 MW to 2 MW capacity each), usually installed in rural or marine locations. Wind turbines may also be installed individually. These are typically smaller than those installed in wind farms. Individual wind turbines may be sited in either rural or urban areas. The wind power options that have potentials for wide scale application in Hong Kong are outlined below.

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9 Cost (quoted here and in subsequent sections) covers both capital and operation & maintenance costs, and is the cost of electricity generation only (@ 4% discount rate at year 2001 price level). It does not include any allowances for commercial considerations such as financial charges, profits and risks.

10 For combined cycle gas turbine power plant

11 For coal-fired plants with flue gas desulphurisation

12 The higher the wind power density, the higher energy yield is expected. A "rule of thumb" is that sites with a mean wind power density below 150 W/m^2 are unlikely to be suitable for wind power application.

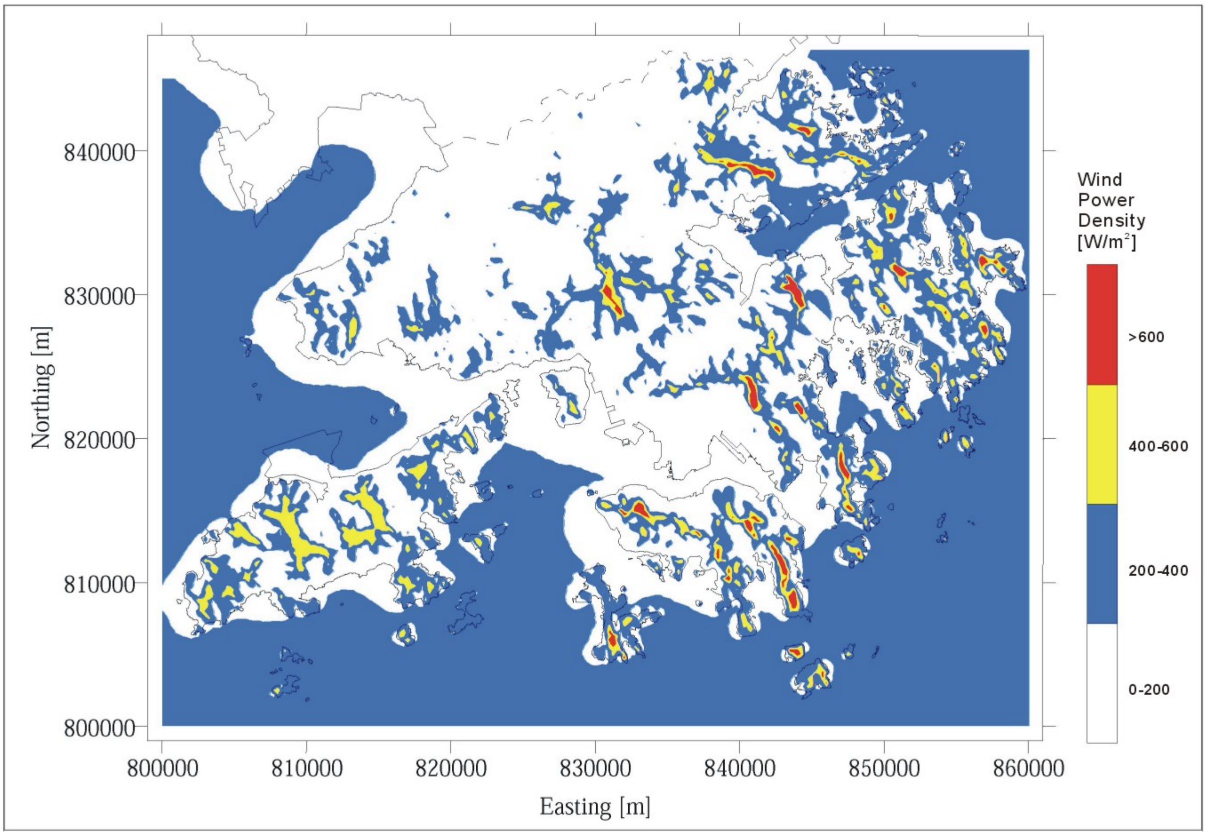

Figure 2 Hong Kong Wind Resource Map

2.3.2 Rural Wind Farms in Linear Arrangements

These are lines of large wind turbines sited along the ridge of hills and mountains in high wind resource areas. The technology is mature and reliable, as evidenced by many overseas examples. Large wind turbines are a sizable construction. For example, a 1 MW wind turbine has a rotor diameter of about 60 metres, and the entire structure would be the approximate height of a 30-storey building. It follows that large rural wind farms would need to be carefully sited to avoid significant impacts on sensitive ecology or natural areas of high conservation value. Also, their construction needs to be properly controlled to avoid any significant environmental (e.g., dust, soil erosion, water quality, etc) impacts.

2.3.2.1 Potential Resource

This option has an estimated *potential* resource of about 2,630 GWh (equivalent to 7.5% of annual electricity demand in 1999), assuming in the long term about 1,000 large (1 to 2 MW capacity each) wind turbines could be installed at high wind resource areas. In Hong Kong, the area of high wind resource (i.e., 200 W/m^2 or higher) on land has been estimated at about 393 km^2. For 1,000 wind turbines to be installed, this is equivalent to a density of 2.5 turbines per km^2, which is considered readily achievable from a technical point of view.

2.3.2.2 Implementation Issues

Obviously, the actual rural wind power that will be available in practice is related to the number of wind turbines that can be installed ultimately. As with PV systems, this is subjected to several non-technical constraints. Those specific to large rural wind farm projects include:

Commercial Viability

Though large wind farm developments are capital intensive, with a generation cost of about \$0.2/kWh to \$0.35/kWh, this technology is the least costly of the identified renewable energy options. Overseas experience has suggested that large land based wind farms are potentially cost competitive with conventional fossil fuel power generation technologies.

Institutional Restrictions

To maximise energy yield, the wind turbines will be best installed in the high wind resource areas shown in *Figure 2*. It is noted that most of these are located within Country Parks, where a project proponent must apply to the Agriculture, Fisheries and Conservation Department for development permission under the Country Park Ordinance.

The key objective of country park designation is "*to conserve areas of great landscape quality, recreation potential, and conservation value and open up countryside for greater enjoyment of the population*". Development of large wind farms in designated country parks may not be considered compatible with this objective, and development permission may not be secured. If so, the extent of deployment of rural wind farms will be greatly limited.

Social Acceptability

Community attitude towards large wind farms is not known in Hong Kong. Overseas experiences suggest that visual intrusion is probably the biggest planning issue for large wind farms. This is a very subjective issue, and has a wide range of effects on people. In Hong Kong, in addition to visual impacts, *fung shui* issues could also be a major consideration in wind farm developments. Social attitude is likely to play a key role in determining the amount of wind resource that can be extracted in practice.

2.3.3 Near-shore marine wind farms

This option would involve carefully placing of large wind turbines (typically 1 to 2 MW each) in the shallow waters (up to 30 metres deep) of Hong Kong. Each individual wind turbine in the farm could be founded directly on piles into the seabed. While the turbines are tall (about 90 metres from sea level for a 1 MW turbine), they are spaced wide apart in a geometric array (about 480 metres for 1 MW turbines). Overseas experiences have suggested that marine wind farms could co-exist with many other marine beneficial uses, including fisheries.

2.3.3.1 Potential Resource

This option has a long-term *potential* resource of 8,058 GWh (about 23% of annual power demand), assuming 744 km^2 (45%) of our sea area could be utilised, as shown in *Figure 3*.

In arriving at this estimate, it has been assumed that large marine wind farms are located in high wind resource marine areas (larger than 200 W/m^2) outside of major shipping channels. Although individual wind turbines in the farm will be spaced several hundred metres apart, it has been assumed that for the purposes of this assessment they are not compatible with *major* shipping channels due to operational and safety considerations. In other words, major navigation channels are considered a *basic practical incompatibility* with respect to marine wind farms.

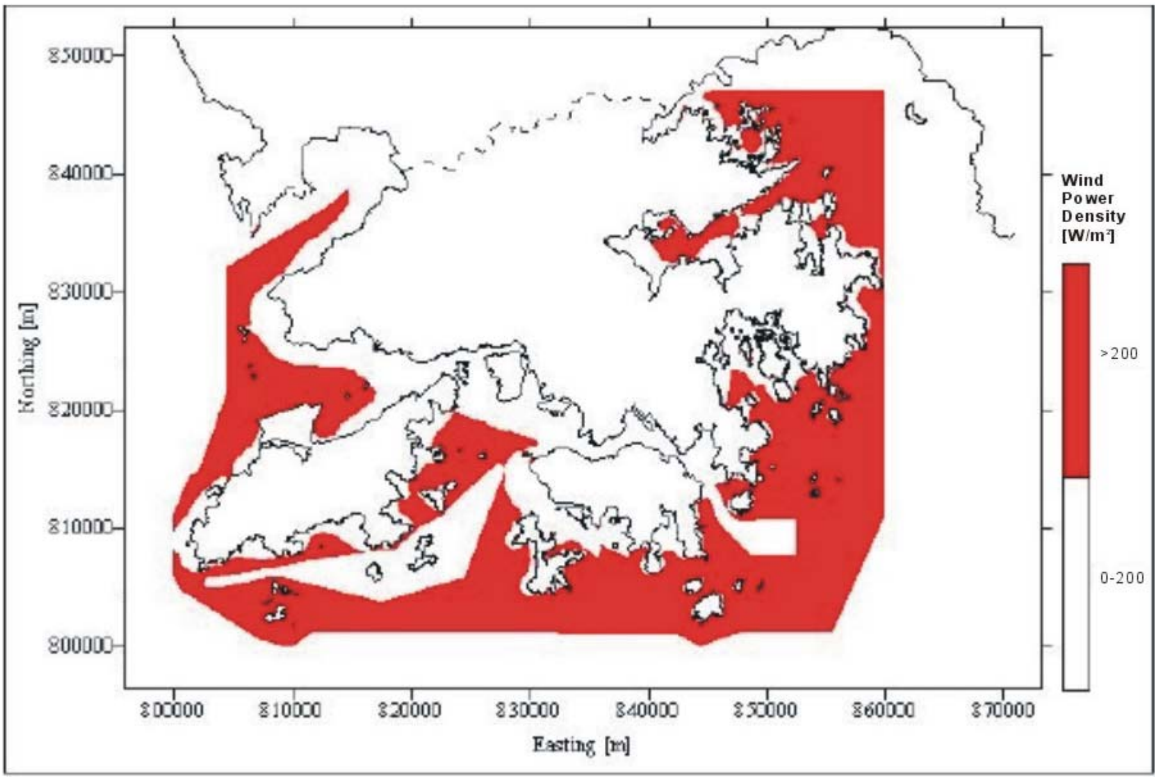

Figure 3 Potential Marine Wind Farm Deployment Areas

2.3.3.2 *Implementation Issues*

As with land based wind farms, the actual number of marine wind turbines that can be installed ultimately will be influenced by several non-technical constraints. Those specific to large marine wind farm projects include:

<u>Institutional Restrictions</u>

Placement of marine wind turbines clearly involves development and "occupancy" of the seabed, both for the turbines themselves and for the cables connecting the turbines to the main electricity grid. Within the SAR boundary, the seabed is owned by the government, which may grant rights for development. The Lands Department may consider the project as reclamation, and prepare a gazette notice for the proposed development under the Foreshore and Seabed (Reclamations) Ordinance. Authorisation of a development right under the Foreshore and Seabed (Reclamations) Ordinance will be granted only when all issues have been resolved. Public views will be solicited in the gazettal process. It is understood that there are precedents for power companies to pay a premium to the government for use of the seabed for submarine cables.

The Marine Parks Ordinance provides for the designation, control and management of marine parks and marine reserves. In marine parks, a multiple-use approach is adopted to allow activities compatible with the objectives of marine parks and non-destructive to the marine environment. In marine reserves, there are more stringent controls and only scientific studies and educational activities will be allowed. Development of marine wind farms in a marine park/reserve may or may not be acceptable to the Director of Agriculture, Fisheries and Conservation, who is the designated authority under the Ordinance.

Commercial Viability

At about $0.36/kWh to $0.64/kWh, marine wind power is more costly than rural one, due to the need for marine construction. Marine wind farms are therefore unlikely to be cost competitive with conventional fossil power plants at present, unless specific support measures are provided to project developers by the government.

Social Acceptability

The move towards marine wind farms in overseas countries has been driven largely by the desire to stay away from population centres to minimise visual impacts and planning objections. However, Hong Kong is small compared to many overseas countries. Therefore, if visual impacts of wind turbines *were* a major concern to the public, it is likely that only the remote eastern waters would be considered "visually" acceptable - greatly reducing the extent of sea area available for turbine installation.

Also, while marine wind farms could "technically" co-exist with other beneficial uses (such as fisheries and recreational boating), community attitude in this respect is not known.

2.3.4 Individual Urban Wind Turbines

Wind turbines on rooftops of high-rise urban buildings would be attractive in that they are building integrated and therefore close to the electrical load. The technology is currently under development, and is likely to be more costly compared to other wind energy technologies. Technical issues with respect to safety, stability, noise and vibration, though not insurmountable, will have to be resolved before rooftop wind turbines can be implemented in the future. Owing to the urban setting, these wind turbines are likely to be small, say, around 40 kW each, which would have a rotor diameter of 10 to 15 metres.

2.3.4.1 Potential Resource

Assuming that technical issues with respect to rooftop wind turbines can be overcome, new urban developments or redevelopment of old urban areas would provide opportunities for installation of rooftop wind turbines in the future.

Assuming that there are approximately 30,000 high-rise buildings, and that on average one small wind turbine may be installed on the rooftop of each, it has been estimated that approximately 30,000 wind turbines could be installed. It is important to note that this is an estimate based on average conditions. Depending on site-specific conditions, it is possible that some buildings are not suitable for wind turbine installation, while some could accommodate multiple turbines.

On this basis, this option has an estimated long-term *potential* resource of about 3,000 GWh (about 8% of annual power demand), assuming 30,000 small wind turbines could be installed ultimately.

2.3.4.2 Implementation Issues

Any building-integrated new or renewable energy installations (such as rooftop mounted wind turbines) would have to comply with building codes of practice and standards in order for approval of the building plans to be obtained from the Building Department. Given the developmental status of this technology, there are at present no established technical standards for rooftop mounted wind turbines. The opportunity of retrofitting small wind turbines on rooftop of existing high-rise buildings is therefore very limited at present. However, in the long term, as this technology is further developed in the future, there could be opportunities for small wind turbines to be "designed into" the building structure.

More so than other wind turbine installations, visual impacts of rooftop mounted wind turbines could be even a bigger concern, due to the location and prominence of such installations at densely populated urban areas. Social acceptance of this technology will be critical for its implementation, and will determine how much of this resource can be harvested in practice.

2.4 BUILDING INTEGRATED FUEL CELLS

Fuel cells are a new energy technology, rather than a renewable energy source. Fuel cells produce direct current (DC) electricity from the electrochemical potential created by a fuel (e.g., hydrogen) and an oxidiser (e.g., oxygen). Fuel cells are similar in construction and operation as batteries, but are designed to minimise sacrificing of electrodes and are fed reactants continuously. Fuel cells are identified by their electrolyte. The main types of fuel cells are: alkaline (AFC), proton exchange membrane (PEM), phosphoric acid (PAFC), molten carbonate (MCFC) and solid oxide (SOFC). Each fuel cell uses specific electrochemical reactions to produce electricity, operate at different temperatures and use different catalysts.

Building Integrated Fuel Cells (BIFC) is attractive as it is located in buildings. They are beneficial by reducing electric demand on the grid, improving electric service reliability to the building, and reducing air pollutants compared to conventional fossil fuel generators. Overseas experience has suggested that fuel cells emit only 1/15 to 1/600 of total air pollutants (e.g., NOx, CO, SOx, hydrocarbons and particulates) compared to fossil fuel power plants for the same kWh of electricity generated.

2.4.1 Resource Potential

The resource potential of fuel cells is only limited by the supply of raw fuels. Several raw fuels suitable for fuel cells are available in Hong Kong, though only town gas and LPG are currently supplied to the urban areas. Natural gas is supplied to the power stations only. For all types of fuel cells, natural gas or LPG would be preferable than town gas, due to the formers' higher energy value. Town gas can be used, recognising that the efficiency of the fuel cells would be reduced.

2.4.2 Implementation Issues

The key issue with respect to application of BIFC would be space constraints. Fuel cells take up more room than equivalent capacity engine and gas turbine generators. Because of this, careful consideration of the location of the plant must be made prior to fuel cell installation.

In addition to adequate space, the fuel cell power plant must have access to fuel gas, building electric circuits, and thermal load (if co-generating[13]). Analysis of the various fuel cell types indicates that, on average, they require about 0.42 m^2/kW of area. Therefore, for a 200 kW fuel cell, a space of 84 m^2 is required. The most likely location for space-congested applications is in basement parking lots or mechanical equipment areas, or on rooftops. It should be noted that fuel cells are quite heavy pieces of equipment, so roof mounting would require special structural considerations.

Fuel cells are costly compared to conventional generation technologies. The cost of FC electricity could be as high as $2.4/kWh, and is an order of magnitude higher than conventional fossil fuel technologies. Cost is a significant factor affecting the extent of fuel cell technologies being adopted in Hong Kong.

[13] Co-generation means production of both electricity and heat.

2.5 ENERGY-FROM-WASTE

Energy-from-waste (EfW) technologies including landfill gas utilisation and other thermal and biological processes have also been reviewed, and these could potentially meet up to a few percent (about 3%[14]) of the annual power demand. Landfill gas is presently utilised on site, but there is excess available. As the Government is already pursuing integrated waste management facilities separately under the Waste Reduction Framework Plan, EfW technologies are not considered in detail in this Study, though it may be considered as a renewable energy resource or technology.

2.6 TECHNOLOGIES FOR OTHER APPLICATIONS

The Study has found that the following RE technologies may be applicable at specific sites, subject to case-by-case evaluations by interested parties:

- *Solar water heating* at building developments, particularly at buildings (e.g., hotels, hospitals, sports centres) where a large centralised hot water system is available;
- *Small hydroelectric* systems, particularly retrofit schemes at water treatment facilities where excess hydraulic energy is available; and
- *Wave power* systems for remote areas, particularly at offshore islands in the southern part of the SAR.

[14] The estimated energy-from-waste contribution is "*potential*" resource in that it is technically achievable by harvesting the energy content of the waste materials.

3 ISSUES

The Technologies Review has suggested that RE sources that are "*technically*" available locally could satisfy a proportion of Hong Kong's power demand, and therefore help to minimise air quality impacts and greenhouse gas emissions associated with power generation. However, it is also clear from the Review that successful resolution of several non-technical constraints is critical, as it will determine how much of the *potential* resource can be extracted *in practice*. Consistent with international experience, for a local RE market and a supply side industry to emerge, it is necessary to address a set of non-technical barriers, covering both *generic* and *technology-specific* issues.

3.1 GENERIC ISSUES

"Generic" market barriers are those that affect the development of the RE sector as a whole, as opposed to individual. Collectively these can reduce the financial viability of RE projects and discourage investment. These are elaborated below.

3.1.1 Pricing of Conventional Power

At present, energy is untaxed, and there are no "eco-taxes" (e.g., carbon tax or SO_x/NO_x tax) to internalise local or global pollution costs associated with fossil fuel combustion. This tends to disadvantage RE power, which is generally more costly than convention electricity, but does not generate air pollutants or GHG emissions. Coupled with the requirement under the Scheme of Control Agreements[15] (SCAs) to supply power at the lowest cost, this tends to drive investment towards conventional generation (rather then RE) as the *least* cost option.

3.1.2 Grid Access

Each of the two power companies provides: generation, transmission, distribution and retailing of electricity in two spatially differentiated areas. In addition to the power stations, each company owns the transmission and distribution infrastructure within its given geographical area of supply.

The SCAs set out the relationship between the government and the power providers. In essence, the Government recognises that the companies and their shareholders are entitled to earn a return which is reasonable in relation to the risks involved and the capital invested in and retained in their business, and in return, the Government has to be assured that service to the consuming public continues to be adequate to meet demand, to be efficient and of high quality, and is provided at the lowest cost which is reasonable in the light of financial and other considerations.

The SCAs are not franchises and do not provide exclusivity of generation, distribution or supply to the power companies within their geographic areas. In principle, a third party power producer would, subject to due process, be free to build generating capacity and distribute power to consumers. In practice, given the vertically integrated nature of the electricity sector, there are at present significant barriers to entry into the market, for example the cost of building a viable, alternative distribution system.

The ability of third party RE power generation projects to access the electricity grid (so as to distribute power to customers) is therefore an important issue to be addressed, if multiple

[15] Each of the two power companies in Hong Kong operates under a Scheme of Control Agreement with the Government. The latest SCAs date from 1993/1994 and expire in 2008. An interim review is scheduled for 2003.

investors are to be encouraged. In relation to this, concerns regarding *standards* and *charges* applied to such third parties, simply with respect to access to the grid, and the *power purchase prices* available to RE projects, and the *security* of such power purchase agreements are also important issues to be addressed for promotion of renewable energy projects.

The 2003 Interim Review of the SCAs will provide an opportunity for the Government to discuss with the two power companies on the question of renewable energy development. It is clear that the requirements of renewable energy markets need to be taken into account if changes to the structure and regulation of the energy market are contemplated in the future, whether in the context of the SCAs or more generally.

3.1.3 Public Awareness

This has two aspects:

- *Awareness* and understanding of RE technologies in the commercial sector (as potential investors); and
- *Awareness* and understanding of the *benefits* of RE in the community.

3.2 TECHNOLOGY SPECIFIC ISSUES

Technology specific issues have been discussed previously. In summary, these include:

- *Availability* of suitable sites, particularly for large wind farms;
- *Community concern* at the visual, noise and possibly safety impacts of wind turbines (farms); and
- *Unfamiliarity* of building developers and professionals (e.g., architects, engineers) with the properties and performance of BIPV systems.

The identified issues are multi-disciplinary in nature, involving many social, economic, financial, legal, regulatory and institutional considerations. This means that not only the Government and the power industry but also the public must play a part, if Hong Kong were to realise more of her RE potential.

4 A STRATEGY FOR RENEWABLE ENERGY

4.1 OBJECTIVE AND APPROACH

To secure the wider use of RE sources in Hong Kong, a strategy and action plan is proposed. Specifically, the RE Strategy is designed to:

- Build public understanding of, and support for, RE technologies;
- Align policies, institutional arrangements and technical standards relevant to RE so as to promote RE;
- Create a positive environment for investment in RE technologies; and
- Create a market in which RE can be sold to consumers.

It is recognised that there has been relatively little local experience in the application of RE technologies. A period of learning is required to allow experience to accumulate and policies to develop. The approach is therefore to progress in phases, to accommodate such learning and to reflect the parallel development of environmental and energy policies, and key changes in the existing regulatory regime. Importantly, the RE strategy should encourage positive change within the existing regulatory framework, promoting participation by both power companies and third parties.

Consultations with key stakeholders in the course of the Study has found that there is already some interest in and support for the RE agenda in government, in the power utilities, in Non-Governmental Organisations and in some segments of the corporate sector. However, the right incentives need to be in place before significant investment in RE technologies can be expected. The RE strategy is intended to create those incentives, and address the various identified barriers. In particular, it seeks to identify and capitalise on '*win-win*' outcomes that will satisfy the key requirements of the major stakeholders. In summary, the RE strategy provides:

- Proposals for *awareness raising* and *promotional* activities to raise the profile of NRE sources and to promote learning from local and international experience in RE project development;
- Proposals for a set of *enabling measures* to address supply and demand side barriers to the development of RE sources; and
- Proposals for a set of *technology-specific* actions designed to support renewable energy project development.

4.2 ENABLING MEASURES

Two issues critical to the wide-scale adoption of RE technologies are (a) the access of RE schemes to the electricity grid; and (b) ability of investors in RE schemes to earn a reasonable (or reasonably attractive) return for the power generated.

4.2.1 Grid Access

To address the grid access issue, it is recommended that the government:

- Should take steps to maintain a *level playing field* for the electricity supply sector if the grid owners (i.e., the two existing power companies) have to allow third party access to the grid;
- Should facilitate development of *technical* and *safety* standards for grid access, ensuring that standards are appropriate for the scale of generation envisaged;

- Should help remove the barriers, both *institutional* and technical, as far as practicable in the long run with a view to facilitating RE projects accessing the grid; and
- Should encourage full *transparency* in charging by the power companies.

It is suggested that a dialogue between the Government and the existing power companies regarding grid access by third party RE power suppliers should be established as soon as possible. The 2003 SCA interim review provides a good opportunity for conducting such a dialogue.

4.2.2 Market Creation and Power Prices

Investors in RE schemes could include the two existing power companies as well as independent power producers (IPPs). There are specific market and pricing issues related to each of these groups of investors.

Historically, the power companies in Hong Kong have been directed towards investment in cost-effective conventional power sources providing electricity at "lowest reasonable cost". However, electricity generated from renewable energy sources will often be more expensive on a $/kWh basis. Generation approved under the SCAs has not, to date, included renewable power schemes, so they have not invested in such capacity. In any case, there is no agreed mechanism by which the additional costs of renewable energy can be recovered from consumers, even if the power companies were to develop projects themselves.

For independent power producers, even if the existing power companies (as grid owners) do allow third party generators to access the grid, there is still no mechanism by which the power can be sold. There is at present no obligation on the two existing power companies to purchase third party power.

To this end, a range of financial instruments is available to encourage participation of the two existing power companies in the RE market, and to provide an intermediary market for future IPPs. Key options include:

- ***Option A*** - *Reviewing the existing regulatory framework with a view to, after modifying it if necessary, encourage the two existing power companies to invest in RE generation facilities*. This approach is restricted to projects that are owned by the two existing power companies;
- ***Option B*** - *Establishing a RE fund or account to purchase renewable energy* at an agreed margin over a specified base load marginal cost of power, the fund being topped up from a *general levy* on electricity tariffs. This approach has the advantage that the fund could support purchase of RE power generated by future IPPs (assuming grid access is secured) and "internal" RE projects developed by the power companies. However, a general levy would be non-elective in participation, i.e., individual electricity customers could not choose whether or not to help fund RE power projects;
- ***Option C*** - A voluntary *Green Electricity Scheme*, under which consumers could elect to contract with their power supplier to purchase electricity from certified renewable sources. The GES tariff could be set either freely by the power supplier (i.e., the existing power companies or a future IPP assuming that grid access is secured) or defined on the basis of an agreed formula. If uncertainty of demand was a barrier, or for the early phase, this approach could be underwritten by a government purchase guarantee[16], noting that the Government is the largest electricity consumer and its own demand is more than sufficient to absorb power from all RE projects that could conceivably be developed in the near future.

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[16] Individual government departments or agencies currently procure their power separately. There would be a need to review the current procurement policy if the option of a government purchase guarantee were to be pursued.

It is acknowledged that these options will need to be considered further by the Government, industry and the public, especially where impact on tariff levels is involved.

4.3 TECHNOLOGY SPECIFIC MEASURES

In addition to the enabling measures that will apply to all RE technologies, there are specific ones for:

- *Wind Energy.* Given the nature and likely scale of wind energy systems, it would be helpful for the Government to commission a study to identify possible sites for wind projects on the basis of an agreed site selection criteria, and to evaluate the more promising sites in greater detail. To facilitate acceptance by the public, it will be necessary to develop and promulgate planning policy and guidance for wind turbine installations, and provide stakeholders in the land use planning system with guidance about the benefits of wind energy, and international experience in the various impacts of wind farm development;
- *Building Integrated RE Systems.* BIPV, BIFC and building-mounted wind turbines have the potential to reduce buildings' net energy demand, though they are essentially small power generators. For these embedded systems to be established, it is necessary to create a framework in which small-scale generators can contribute directly to meeting the electrical loads of the building on which they are located. Recommended measures include definition of technical and safety standards for connection of 'small scale' generation into a building's electrical systems and certification or accreditation of individual products and/or suppliers/installers.

4.4 PROMOTION AND AWARENESS RAISING

Deployment of RE projects will be greatly facilitated by a wider awareness of RE sources and technologies, and the contribution that they can make to Hong Kong's environmental and energy objectives. The promotional strategy action plan is therefore an integral part of the overall RE Strategy, and will include both *general awareness-raising* and *specific promotional actions* triggered by the successful implementation of actions under the broader RE strategy. The proposed promotional strategy involves:

- *Short-term* (from the present to the introduction of the enabling measures to address grid access and pricing) actions, aiming to secure political and institutional support for the RE Strategy and to alert the public and consumers to the benefits offered by RE. These would include presentations to the legislature and decision-makers, demonstration projects to raise public awareness, attitude survey of commerce and industry, setting up of RE website, as well as networking with interested Mainland and overseas parties;
- *Medium-term* (for a period of about five to seven years after the previous phase) actions, aiming to capitalise on the implementation of the enabling measures (or launch of the RE market) and technology-specific programmes for wind, solar, etc. These could involve a keystone launch event, such as a RE fair, and other school educational programmes, consumer awareness campaigns, departmental briefings, as well as publicising the results of earlier demonstration projects;
- *Long-term* actions. The promotional agenda will inevitably evolve as circumstances change. The focus and content of the strategy will be reviewed periodically to ensure its relevance.

4.5 TARGETS

4.5.1 Approach

It is common for RE policies to incorporate targets for the contribution that RE technologies to meeting the overall energy demand. These targets act as reference points against which progress can be measured, and can be used to stimulate progress away from the 'business-as-usual' scenario.

Targets can be defined on a top-down or bottom-up basis. In markets that are not yet well developed, it is generally most appropriate to set targets on the basis of the projects that are likely to come "on stream" within a given period and under a specific scenario for market support (bottom up approach). As the market matures, it becomes possible (and more appropriate) to set overall targets, using a top down approach, leaving it to the market to determine how that target will be met.

The small size of Hong Kong and the early state of development of the RE market implies that initially targets should be based on a "bottom up approach", or the contributions that individual technologies (and, in the short term, individual projects) can realistically be expected to make. This approach is highly sensitive to the assumptions that are made, since (for example) the deferral or loss of one major project can have a measurable, and possibly irrecoverable, impact on progress towards the overall target that has been set.

4.5.2 Proposed Targets

Given the sensitivities of the assumptions, and the many as yet unresolved issues and barriers identified earlier, it is recommended that a cautious approach to target setting should be adopted. Based on a 'bottom-up' approach focusing on known and feasible individual projects, *Table 2* summarises the projected contributions from various **local** RE sources.

Table 2 Summary of Projected Contributions from Local RE Sources (GWh/year)

Source	**2012**	**2017**	**2022**
Large Scale Systems			
Onshore Wind	6	43	116
Offshore Wind	7	84	245
Energy-from-Waste (Landfill Gas)	231-184	254-161	273-178
Energy-from-Waste (Thermal Treatment[17])	0-472	0-932	0-932
PV Power Stations	6	12	17
Sub-total:	**250 – 675**	**393 - 1,232**	**651 - 1,488**
Small scale (distributed) systems			
Building Integrated PV	7	16	32
Building Integrated Fuel Cells	4	8	16
Sub-total	**11**	**24**	**48**
TOTAL	**261 – 686**	**417 - 1,256**	**699 - 1,536**
Percentage of 1999 electricity consumption	**0.735% - 1.932%**	**1.175% - 3.538%**	**1.969% - 4.327%**

[17] It is noted that development of energy-from-waste technology is still under a separate study, and no decision has been made as to whether such technology will be adopted in future.

On this basis, it is suggested that, at least initially, targets of **local** RE (including energy-from-waste) contribution to annual power demand (against the baseline year of 1999) should be set at:

- 1% by 2012;
- 2% by 2017; and
- 3% by 2022.

These targets may seem modest in the light of the estimates of the *potential* local RE resources, but are regarded by the team as prudent, given the many identified constraints and barriers. Credible targets are better than those that are unattainable, and even this level of local RE supply is contingent on addressing the barriers described above, which may in itself take longer than assumed in the Study.

Hong Kong is at a very early stage in the evolution of its RE sector and has yet to see demonstration of the key technologies. Projects take time to bring to fruition, especially where they bring new challenges in approval and consultation. More might be achieved faster if large investment capital were available, but equivalent environmental gains are likely to be achievable more cheaply by other means, and it is necessary to raise awareness and build support over time. Selection of viable demonstration projects, and their successful implementation will lay the groundwork for a more ambitious expansion of the RE programme after the initial years. Costs of RE technologies are expected to fall further with time, helping to bring a greater proportion of the possible resource within reach without excessive additional costs.

4.6 SUPPLEMENTARY STRATEGY

The above sections outline key components of the recommended RE strategy to secure wide-scale adoption of RE technologies. That is, a set of enabling measures to create the basic conditions for a RE market to operate, plus a number of technology-specific actions focused on barriers associated with wind, solar PV, etc. Grid access and market creation have been identified as key issues requiring action and support from the government to promote wide-scale adoption RE in Hong Kong.

Noting the issues and constraints associated with the current regulatory regime with respect to grid access, however, it is recommended that the government should also investigate the feasibility of standalone RE power supply schemes for district-based or specific applications. This supplementary strategy makes use of government's position as a large electricity consumer as well as the procurement agent for the planned waste treatment facilities.

As noted earlier, the government is evaluating technical options for large-scale integrated waste treatment facilities, including possibly thermal treatment technologies coupled with power generation in the order of tens to hundreds of MW. Given that energy-from-waste (which is a biomass technology) would have relatively stable output, there is the possibility for this to be used in conjunction with other intermittent or variable renewable energy sources (e.g., solar, wind) in particular applications. For example, a new development (e.g., industrial estate) may be supplied by such an integrated district-based RE supply system. Another option would be to co-develop an integrated RE generation system with future energy-intensive (government owned) facilities (e.g., water treatment plants) such that an end user(s) of the RE power can be assured.

Further, while this Study focuses on renewable energy resources that are available **locally**, the Government may consider requesting power suppliers to import (from the Mainland, for example) electricity generated from renewable sources, if deemed desirable. This and the other supplementary strategy options mentioned above may be further investigated.

5 CONCLUSIONS

The Study has found that RE resources could make a meaningful contribution to meeting Hong Kong's long-term power demand. If the set of (mostly) non-technical barriers identified in this Study are addressed, RE technologies could offer useful environmental benefits and provide alternative energy sources for Hong Kong.

There are opportunities for development of renewable energy projects under the current regulatory framework for electricity, and there is also interest in the greater use of the technologies concerned. These opportunities may involve grid-connected or standalone systems, and include 'quick wins' such as making productive use of large quantities of landfill gas that are currently collected but flared off for want of a market for the energy. It was also found that the **government** could exercise a powerful and positive influence in the RE market by virtue of its position as Hong Kong's **largest** electricity purchaser and as the procuring agent for major waste management facilities that may feature energy recovery.

However, for any of these opportunities to be realised on a meaningful scale, especially those involving grid-connected systems, there is a need for the government, electricity companies and project developers to work together on a set of **enabling** actions to create a supportive and profitable business environment in which RE projects can operate. These actions focus on defining terms for third party access to the grid, and on creating a mechanism by which power companies and promoters can recover the incremental costs of RE. The same issues have been addressed in many other countries and both lessons of experience and technical guidance are available.

With an enabling framework and the right incentives in place in the near term, the following period can be used effectively to:

- Demonstrate a wide range of alternative energy technologies,
- Educate the public about their benefits, and
- Build community support for future expansion.

Without such a framework or a means of selling the power generated, it is unlikely that RE in Hong Kong will develop far beyond a few small-scale grid-connected projects, or possibly one or two district-based standalone supply schemes. There is therefore a necessary role for government in **creating** the market for renewable energy. A RE Strategy has been presented that include various options, including those that need **not** be tied into the existing regulatory framework (e.g., Voluntary Green Power Scheme). There are also choices in the extent to which government wishes to back its stated support for RE or alternative energy sources with the purchase of power from these sources.

In a favourable business climate, alternative **local** energy sources could meet the equivalent of 1% of 1999 energy demand in 2012, 2% in 2017 and 3% by 2022.

6 RECOMMENDATIONS

It is recommended that:

- Government should adopt a formal policy position with respect to renewable or alternative energy. In particular, targets of local RE contribution to electricity demand (against baseline year of 1999) of 1%, 2% and 3% for 2012, 2017 and 2022, respectively, are proposed;
- The proposed near term awareness raising and promotional activities should be implemented as soon as possible. Key action items would include:
  - Presentations to the legislature and other decision makers to secure political and institutional support;
  - Demonstration projects (e.g., wind, BIPV, etc) to raise public awareness; and
  - Attitude survey of commerce and industry as potential investors.
- Technology specific support measures should be initiated at the earliest opportunity, including:
  - A comprehensive study to identify possible sites for wind projects, and to evaluate the more promising sites in greater detail;
  - Development of technical and planning guidelines for RE project developments, including wind and building integrated systems.
- A dialogue between Government and the power companies should be established as soon as possible (one way is to take the opportunity of the 2003 SCA interim review) about the creation of the necessary enabling conditions. Key issues to be addressed would include:
  - Grid access; and
  - Power purchase agreements.
- Government undertakes an extensive public consultation exercise (involving consumers as well as power suppliers) on the proposed financing options (e.g., general levy, voluntary green power schemes, etc) so as to:
  - Reach a decision on the preferred option; and
  - Constitute a funding mechanism to meet the incremental cost of RE.
- The RE Strategy and action plan be regularly updated to reflect evolving conditions and changing circumstances.