Renewable Energy Development in Hong Kong

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***Abstract*-- A two-stage consultancy study was commissioned by the Electrical and Mechanical Services Department of the Hong Kong SAR Government in November 2000 to investigate the feasibility of wide-scale application of renewable energy (RE) technologies in Hong Kong, with a view to further improving our air quality and reducing our greenhouse gas emissions.**

The Stage 1 Study evaluated the potential of various forms of RE technologies for wide-scale local use, and related legal, institutional and promotional issues. It also made recommendations for formulating an implementation strategy. The Stage 1 Study was completed in early 2003.

Upon reviewing current technological trends and applications, and taking into account Hong Kong's local characteristics, RE technologies that are considered potentially feasible for wide-scale application in Hong Kong include:

a. Solar power;
b. Wind Power; and
c. Energy from waste.

Public consultation on the findings and recommendations was conducted from February till April 2003, and the results indicated that the public are more receptive to RE than the consultant have envisaged.

The Stage 2 Study is a design and build project involving the installation of a building-integrated photovoltaic (BIPV) system in the Wanchai Tower. This is a pilot project which covers a total area of 500 m^2 PV panels with a peak power output of 55 kW.

This paper gives a brief account on the key findings of the two studies and discusses the technological performance of feasible RE resources in Hong Kong.

***Index Terms*— building-integrated photovoltaic, renewable energy, solar water heating, wind turbine.**

I. Introduction

When we discuss the topic of sustainable energy supply, there are actually many issues and problems surrounding us, and there is no single magic solution. The two important measures that policy makers in many countries usually have accorded high priority to are the promotion of energy efficiency and conservation and exploitation of renewable energy sources. These two measures, one addressing the demand-side and the other addressing the supply-side, working together still cannot solve all of our problems. We have yet to explore other measures. Nonetheless, they are ranked high in the list of .measures. That's why the Energy Efficiency Office of the Electrical and Mechanical Services Department, established in 1994, not only implements energy efficiency initiatives, but also looks into the potential for wide-scale application of renewable energy in Hong Kong.

Up to the present moment, renewable energy is only a secondary source of energy supply of the world, and fossil fuels are still the dominant fuels. The following figures illustrate the point:

TABLE I
YEAR 2000 FUEL SHARES IN WORLD TOTAL PRIMARY ENERGY SUPPLY (TPES) ACCORDING TO IEA

Oil	34.8 %
Coal	23.5 %
Gas	21.1 %
Non-fossil	20.6 %, of which :
Nuclear	6.8 %
Hydro	2.3 %
Combustible renewables and waste	11.0 %
Geothermal	0.442%
Solar	0.039%
Wind	0.026%
Tide	0.004%

In the recent decade, renewable energy has been accorded much greater attention amid the discussions at the World Summit on Sustainable Development in Johannesburg in 2002.

Many countries have been seriously considering increasing the share of renewable energy sources in their national energy supply. The European Community has adopted a very aggressive approach to the adoption of renewable sources. Directive 2001/77/EC required all their member states to set national indicative targets for the consumption of electricity produced from renewable sources and to achieve the overall European Community target of 22% of electricity to be produced from renewable energy sources by 2010. The national indicative targets in the Directive are not uniform, but

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differ widely. For example, the target for Austria is 78.1% (mainly hydropower), for United Kingdom 10%, and for Luxembourg 5.7%. Since the adoption of the Directive, the renewable energy market has been undergoing tremendous boom.

In Hong Kong, our electricity mainly comes from combustion of fossil fuels, supplemented with generation from the Guangdong Nuclear Power Station at Daya Bay.

The following table shows the mix of power plant types for the installed generation capacity of Hong Kong:

TABLE II
PLANT MIX FOR ELECTRICITY GENERATION

Plant type	Percentage
Coal fired	57.1 %
Oil fired	9.6 %
Natural-gas-fired	16.2 %
Nuclear	11.9 %
Pumped storage	5.2%

The burning of fossil fuels generates greenhouse gases and atmospheric pollutants. In 2001, 87% of all greenhouse gases emissions in Hong Kong were generated from energy use, the others were due to waste (11%) and industrial processes (2%), and minute amount from agriculture. Furthermore, almost all major atmospheric pollutants of particulate matters, SO_2, NOx, NMVOC, CO arise from energy use – whether from power plants, cars, ships, aircrafts, domestic or commercial and industrial premises.

Introducing more RE sources will help contain fossil fuel use, thereby alleviating the burden imposed on the environment and improving our quality of life.

II. SITUATION OF RE UTILIZATION IN HONG KONG

Hitherto, RE has not yet been included into the energy supply portfolio of Hong Kong. RE has been utilized on the demand side to supplement the normal supply sources, and to provide independent sources of supply for isolated applications. The major types of RE installations that can be found in Hong Kong are:

(a) Solar water heating
(b) Solar photovoltaic
(c) Wind turbine
(d) Landfill gas generation

A. Solar Water Heating Installations

There are a number of solar water heating installations around Hong Kong, for low-rise houses in suburban areas, fire stations, prisons, etc. About 4500 m^2 of solar water heating panels have been installed in various places.

The largest solar water heating installation in the territory is the one installed in Sheung Shui Slaughter House, with 882 m^2 of panels and 312 kW heating capacity.

Fig. 1. Solar water heating installation at Sheung Shui Slaughter House

B. Solar PV Installations

There are many PV installations throughout Hong Kong at various locations – office buildings, hospitals, schools, fire stations, parks, and so on. Total capacity of PV installations currently in operation is about 250 kW.

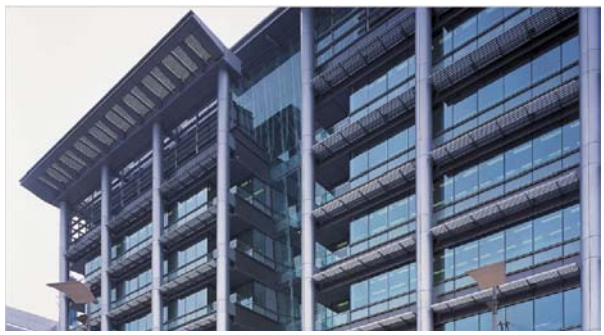

Fig. 2. BIPV installation at one of the Science Park buildings

One of the best-known projects is the Science Park PV project (Figure 2). The system currently includes photovoltaic panels with 138 kW electricity generation capacity. The additional capacity being planned will add an additional generation capacity of about 62 kW when completed.

Another well-publicized installation is the 55 kW photovoltaic system at Wanchai Tower. More details about this installation will be given in a later section.

The PV installation at the new EMSD Headquarters building currently under construction will have total installed capacity of 350 kW when completed, which will be the largest of its kind in the territory.

Another innovative PV project worth mentioning is an automatic slope irrigation system (Figure 3) at Kau Shut Wan Government Explosives Depot. The integrated system, which comprises an array of photovoltaic modules, a charger, an inverter and backup battery, and an irrigation system with pumps, water storage tank, piping and sprinklers, automatically extracts water from a nearby stream course sump pit and irrigates vegetation on a man-made slope at the Depot. This system was commissioned in July 2003.

Fig. 3. Automatic Slope Irrigation System

C. Wind Turbine Installations

Only small wind turbines have been installed in Hong Kong. The Hong Kong Observatory has successfully made use of small wind turbines along with photovoltaic panels to form hybrid systems to supply electricity to some of their weather monitoring stations in remote areas. These turbines are rated between 140 W to 500 W, each working in parallel with a 250 W PV panel.

The largest wind turbine installed is a single 2.5 kW machine (Figure 4) installed at Shek Kwu Chau Drug Rehabilitation Centre by CLP Research Institute. The turbine operates in parallel with a 3.3 kW PV installation forming a non-grid connected hybrid RE system.

Fig.4. Wind turbine at Shek Kwu Chau

D. Landfill Gas Installations

Landfill gas generation plants have been installed at most of the landfill sites in Hong Kong. The electricity outputs of the plants are mainly for on-site facilities. Total landfill gas generation capacity of about 7.4MW has been installed.

III. STUDY ON POTENTIAL APPLICATIONS OF RE IN HONG KONG

In view of the worldwide growing demand for cleaner energy, a consultancy study was commissioned by EMSD to investigate the viability of using RE technologies in Hong Kong and to make recommendations for formulation of an implementation strategy. The study commenced in November 2000 for completion in 2004.

The study evaluated the potentials of various forms of renewable energy for wide-scale local use, and the related legal, institutional and promotional issues. The Stage 1 Study Report [1] was published in February 2003.

Upon reviewing the current technological trends and applications, and taking into account Hong Kong's local characteristics, RE types that are considered potentially feasible for wide-scale application in Hong Kong include:

(a) solar power,
(b) wind power, and
(c) energy from waste

Other RE sources including biomass energy, geothermal energy, hydro power and tidal and wave power have limited potential for development in Hong Kong.

A. Solar Energy Potential in HK

According to the consultancy study [1], PV systems are mainly divided into 2 categories:

(a) BIPV type,
(b) non-BIPV type.

The BIPV type is usually mounted on rooftops, facades and external walls of a building, while the non-BIPV type is built along highway noise barriers, slopes and so on.

Solar energy resource in Hong Kong is regarded mildly rich. Hong Kong has an "annual average global horizontal solar irradiance" of 1,290 kWh/m^2. According to the consultancy study, the potential of solar energy in Hong Kong is 5,944 GWh/year, which is equivalent to around 16% of the 2002 electricity consumption in Hong Kong. This was derived by assuming that all feasible land areas for solar energy application were covered up by both BIPV and non-BIPV systems. The overall conversion efficiency of PV system was conservatively assumed as 9.3%. The shares of energy potential for BIPV and non-BIPV are 5,383 and 561 GWh/year respectively.

In the study, solar heating has also been reviewed and is considered suitable for site-specific applications, such as hotels, hospitals, etc., and its potential in Hong Kong is regarded insignificant.

B. Wind Energy Potential in H.K.

Wind farms can be classified principally into land-based wind farms and marine-based wind farms. Large-scale wind turbines are usually rated over 1 MW with a "hub height" of 50 to 70 m and the total height (including the blade) of over 100 m.

The wind energy potentials in Hong Kong are estimated at 2,630 GWh/year for rural wind farms, 3,000 GWh/year for small urban wind turbines and 8,058 GWh/year for marine wind farms, again under the assumption that all feasible locations are employed for installing wind turbines.

High wind resource areas in H.K. are mainly located at mountain tops on the eastern side of Hong Kong and most of the offshore marine areas. However, most of these mountain top areas are within country parks, which may not be suitable for building wind farms.

More promising locations for wind farms appear to be outlying islands and off-shore marine areas, even though electricity generation and transmission costs are higher.

C. Generation Costs

"Levelised Cost of Electricity" (LCE) is a term commonly used to compare the cost of alternative power generation systems. LCE adopts a life-cycle costing approach and uses net present value calculations (for the capital cost and operation and maintenance costs) as a means of comparing the average unit cost of electricity generated. The study revealed that LCE for PV power is between HK$2.2 to HK$4.1 per kWh, whilst that for rural wind farm is between HK$0.20 to HK$0.35 per kWh. The LCE for conventional fossil fuel power generation is between HK$0.2 to HK$0.4.

D. Barriers to RE Development

Major issues that may hinder wide-scale development of RE in H.K. include :

(a) Availability of suitable sites for large-scale RE projects;
(b) Concerns over the visual and noise impact of RE systems (for example wind turbines);
(c) Relatively higher cost of RE; and
(d) Access to the existing electricity grids by third party RE producers.

E. Proposed RE Targets

After seriously considering all the constraints including Hong Kong's geographical limitations, legislation and institutional restrictions, commercial viability and social acceptability, the RE targets (i.e. contributions to electricity supply) for H.K. were initially proposed as 1% in 2012, 2% in 2017 and 3% in 2022, taking 1999 as the base year.

F. Public Consultation

Subsequent to releasing the Study Report to the public, a two-month public consultation exercise was then conducted from 7 February to 6 April 2003, during which members of the public and relevant stakeholders were invited to offer their views on the study.

28 submissions were received from all walks of life including the following groups:

(a) Green Groups and Non-governmental Organisations;
(b) Professional Institutions and Trade Organisations;
(c) Political Parties;
(d) Power Utilities;
(e) Business Interests;
(f) Consulting Companies; and
(g) Individuals.

Public support is the most critical factor for the successful development of RE. According to the views collected [2], most respondents considered the targets recommended conservative. This may indicate that the public are more receptive to RE than the consultant has envisaged. In this context, the proposed RE targets are currently under review to meet the latest aspiration of the public.

G. Solar Energy measurements

Under the RE consultancy study, a 55 kW building-integrated photovoltaic (BIPV) system was installed at Wanchai Tower, as a pilot project. The installation was completed in end 2002.

The performance of the BIPV system is being monitored by EMSD until mid 2004. A sophisticated on-line computerized monitoring system has been installed in order to closely monitor the performance of the BIPV panels. Key monitoring parameters include solar radiation, wind speed, PV panel temperature, power output, cumulative energy output, power quality, etc.

H. Wind Measurements

General wind measurement work has been done by the Hong Kong Observatory, as part of their routine measurements. However, for evaluating wind power generation potential, measurements at greater heights and at specific locations are necessary. Some work in this respect has been undertaken by the private sector. Following a site survey and environmental impact assessment study, two outlying island sites, one on Po Toi and the other on Lamma, were chosen for wind power monitoring and measurement stations by one of our power companies. The data collection for a period of 12 months has been completed. The collected data, including wind speed and directions, will be used to build up a wind atlas for assessment of wind energy potential in the southern part of Hong Kong.

Recognizing the potential contributions of wind energy, the Government is now implementing a wind measurement programme. By installing wind monitoring equipment at potential sites for measuring their site specific wind characteristics, more accurate assessment of the electricity generation potentials can be done. Sites at Tung Lung Chau, Town Island, Miu Tsai Tun, Pottinger Peak, and the Government Logistics Centre Building have been selected for the wind measurement programme. For most of the sites, measurements will be taken at as far up as 50 metres above ground level. The programme started in end 2003 and will end by early 2005.

IV. BIPV INSTALLATION AT WANCHAI TOWER

The BIPV pilot project at Wanchai Tower was implemented through a design-and-build contract, and was completed in end 2002. Wanchai Tower is a high-rise government office building located in a busy commercial area. The project serves as a demonstration to the public and at the same time it will provide useful in-situ electricity production data for further analysis and evaluation.

Three types of PV sub-systems have been installed at Wanchai Tower, which together cover a total area of 500 m^2 with a peak power output of 55 kW. These three types of sub-systems are:

(a) rack type, on the roof top,
(b) sunshade type, from 1st to 12th floors, and
(c) skylight type, at the front entrance hall.

A. Rack Type Sub-system

The "Rack" type sub-system is installed on the rooftop of the building (Figure 5). Over 160 m^2 of poly-crystalline silicon PV panels with a peak power of 20 kW are installed. The PV panels are tilted optimally at 10^o to the horizontal plane after considering the shading effect due to adjacent buildings. Each PV panel is rated at 80 W (peak) with an open circuit voltage of 21.5 V and a short circuit current of 5.3 A. A computer software called "Array Shading Evaluation Tool" together with the fisheye photographic technique have been used for the shading analysis.

Fig. 4. Rack Type Sub-system

B. Sunshade Type Sub-system

The second sub-system is called the "Sunshade Screen" sub-system, comprising double-glazed panels completed with integrated mono-crystalline PV cells. Each panel is rated at 76.8 W (peak) and with an open

circuit voltage and short circuit current of 19.8 V & 5.46 A respectively. They are externally mounted on the building facade to provide shading for the upper portion of all south-facing windows from 1st to 12th floors of the building (Figure 6). The total area of installed panels is about 230 m^2 and the installed peak power is 25 kW. By using the sunshade type PV panels, the solar heat gain into the building through the windows is effectively reduced.

Fig. 6. Sun-shade Sub-system – Interior View

C. *Skylight Type Sub-system*

The third sub-system is the "Skylight" sub-system comprising PV panels similar to those of the Sunshade type but much larger. The panels are used to replace some of the vertically mounted glass-infill of the existing glass atrium at the southbound front entrance hall. About 100 m^2 of PV panels, each rated at 288 W (peak) with an open circuit voltage and short circuit current of 74.4 V & 5.46 A, are installed with a peak power slightly over 10 kW (Figure 7).

Fig. 7. Skylight Sub-system – Interior view

D. *Monitoring System*

There is a one-year monitoring and evaluation period to assess the performance and reliability of this BIPV system. Solar radiation, wind speed, PV panel temperature, power output, cumulative energy output, power quality etc. are logged by a computer system.

In addition, an information display panel has been installed at the building main entrance to disclose real time operational data to the general public. The data include solar irradiance, power output, cumulative energy generated and CO_2 avoided by the BIPV system. The information, which is also accessible through Internet (Figure 8) at the IP address of "202.130.116.90", will help the general public to better understand the applications of PV technology.

Fig. 6. Sun-shade Sub-system – Interior View

E. *Design Performance*

The design performance of the BIPV system was calculated basing on the solar irradiance recorded at King's Park in 1999 by the Hong Kong Observatory. The expected annual energy yield for the whole system is around 30,000 kWh.

V. CONCLUSIONS

The public consultation exercise on the findings and recommendations of the Stage 1 Study on potential applications of renewable energy in Hong Kong has recently been concluded. Most respondents considered the targets recommended by the consultants conservative (i.e. 1% in 2012, 2% in 2017 and 3% in 2022). The RE targets are being reviewed by the Government with a view to meeting the latest aspiration of the community.

Through the two monitoring projects currently being undertaken by EMSD (one to monitor the performance of the building-integrated photovoltaic system at Wanchai Tower, the other to monitor the wind characteristics at different locations in the territory), the renewable energy power generation potentials in Hong Kong can be more accurately assessed. These monitoring exercises can serve as the foundation work for more ambitious exploitation of renewable energy resources in Hong Kong.

VI. REFERENCES

[1] EMSD, "The Stage I study report on the potential applications of renewable energy in Hong Kong", Nov 2002, http://www.emsd.gov.hk/emsd/e_download/wnew/stage1_report.pdf

[2] EMSD, "Public Consultation on Stage I Study Findings – Summary of Comments Received", May 2003, http://www.emsd.gov.hk/emsd/e_download/wnew/RE_PC_Report_Eng.pdf