Study Report of Photovoltaic (PV) Applications and PV Potential on Building Rooftops in Hong Kong

Executive Summary

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1. EXECUTIVE SUMMARY

1.1 Background

We (Meinhardt (M&E) Limited) were commissioned to carry out the Study on Photovoltaic (PV) Applications and PV Potential on Building Rooftops in Hong Kong ("the Study"). The main objectives of the Study include:

a) to review the current penetration of PV systems in Hong Kong;

b) to identify the barriers and restrictions for implementation of PV systems in Hong Kong;

c) to estimate the potential for installing PV systems at building rooftops in Hong Kong, after taking into account the barriers and restrictions identified; and

d) to recommend ways to overcome the barriers and restrictions.

1.2 Methodologies

The following methodologies have been adopted for acquiring data in the Study:

Objectives	Survey methodologies
(a) Current penetration of PV systems	• Questionnaire + Phone Interview + Object Recognition Technique[1](ORT)
(b) Barriers and restrictions for implementation of PV systems	• Questionnaire + Phone Interview
(c) PV potential on building rooftops after taking into account the barriers and restrictions identified	• Digital Map + Aerial Photo Analysis

Among all building types, the survey covered all government departments, utility companies, educational institutes, major public organisations as well as around 50% of the private buildings and 12% of the New Territories Exempted Houses ("NTEHs") to draw up the total estimated installed capacity of and the total estimated annual generated energy by PV systems in Hong Kong.

1.3 Current Penetration of PV Systems in Hong Kong

According to the results of the Study, the total estimated installed capacity of PV systems was around 6.29 MW in Hong Kong as at end of March 2017. The estimated annual generated energy by PV systems was about 6.29 GWh, and accounts for about 0.014% of the annual electricity consumption of Hong Kong in 2016. Most of the existing PV systems are installed by the Government, followed by the Utilities.

[1] ORT is an image processing technique to determine the identity of an object being observed in an image from a set of known tags. By using this technique, the PV panels could be recognised in the aerial photos.

1.4 Barriers and Restrictions for Implementation of PV Systems in Hong Kong

Through questionnaires and phone interviews conducted between April and end of 2017, the most commonly mentioned barriers and restrictions are highlighted below.

1.4.1 Cost Factors: According to the returned questionnaires, the average capital cost of PV systems from 2003 to March 2017 ranged from $44,000 / kW to $122,000 / kW and the payback period ranged from around 40 years to 110 years, depending on the capacity of PV systems. Based on the returns, it is observed that the capital cost of installing PV panels in Hong Kong is mainly contributed by the structural and labour costs, while the rest are by the cost of PV panels and other electrical hardware. It is also observed that there is a downward trend of the cost of PV installation in Hong Kong. According to the market survey conducted in early 2018, the average installation cost of PV systems was about $47,000/kW (for common PV systems without complicated builders / structural strengthening works) and the payback period was about 40 years. The calculation of the payback period has not taken into account the payment which can be received under the Feed-in Tariff Scheme, under which the power generated by participating RE systems can be sold to the power companies at a rate higher than the normal electricity tariff rate to help recover the costs of investment in the RE systems and generation.

1.4.2 Design Considerations: Questionnaire and telephone interview returns reflected that installation of PV systems on building rooftops requires large space, but it is common that building rooftops are occupied by electrical and mechanical facilities (e.g. air-conditioning plants, cooling towers, gondolas and satellite dishes) while some roof areas are used as sky gardens, amenity purpose or refuge area. Other key design considerations include nuisance to neighborhood (e.g. glare effect) and the need to conduct structural reinforcement owing to additional structural loading to the existing buildings, etc. For NTEHs, some owners expressed concern during the Study, which had been conducted before the relaxation of the buildings-related requirements on the installation of PV systems at NTEHs was announced by the Chief Executive in the 2018 Policy Address, that installation of PV systems may occupy substantial areas of their roof spaces, thereby depriving them such areas for other purposes.

1.4.3 Regulatory Issues: Under the Minor Works Control System, the installation height of PV systems (including supporting structure) is limited to 1.5 metres or less. Any installations exceeding the height limit or involving structural strengthening works will require prior approval from the Building Authority. As for NTEHs, PV system is one of the Green and Amenity Facilities items which do not require prior approval from the Building Authority if the installation is in compliance with the prescribed height and loading requirements. Any installation works that violate the prescribed height and loading requirements will be considered as unauthorized building works. Some respondents reflected during the Study, which had been conducted before the relaxation of the buildings-related requirements on the installation of PV systems at NTEHs was announced by the Chief Executive in the 2018 Policy Address, that the restriction in height limit of the PV installation would reduce their usable roof area.

1.4.4 Other concerns: At the time of the Study, there was no single guideline or consolidated reference for the application procedures to government departments and power companies for installation of PV systems and connecting to the grid. Some respondents indicated that they had limited knowledge on the application procedures, and regard this as one of the factors which discouraged them from PV installation. Other key concerns include the availability of reliable service providers to provide one-stop service for PV installations, the quality of PV system components and the frequency of maintenance of PV systems, etc.

1.5 Estimation of PV Potential on Building Rooftops in Hong Kong

1.5.1 Total roof area

By using the Geographic Information System (GIS) technique, the estimated total rooftop areas of all buildings in Hong Kong is around 42.6 $km^{2.}$.

Based on the land usage distribution[2] and building densities for different land uses[3], the roof areas are classified into the following categories:

a) Public housing – rental blocks

b) Public housing – sale flat blocks

c) Private residential – more than 25-storey

d) Private residential – less than or equal to 25-storey

e) Commercial

f) Industrial land

g) Industrial estate

h) GIC

i) Cottage and temporary structures

j) Airport (including all buildings at Chek Lap Kok)

1.5.2 Roof Area Suitable for PV installation

According to a local study[4], around one-third of the roof areas in Hong Kong is not worthy of installing PV systems. Those rooftop areas are of low solar irradiance, at perimeter zone of the building roof or pitched roof with slopes over 40°. Therefore, the roof area suitable for PV installation is estimated at around 25.7 km^2 [5].

[2] According to the Hong Kong Annual Digest of Statistics 2017, the major classifications of the land uses with buildings are: residential (public residential, private residential and rural settlement), commercial, industrial (industrial estates and industrial land), Government, institutional and community facilities (GIC), and Airport.

[3] The building densities of each land use are checked from the digital maps from the Lands Department and the Map of Land Utilisation in Hong Kong from the Planning Department.

[4] Estimation of Hong Kong's solar energy potential using GIS and remote sensing technologies, Charles WONG Man-sing et al., The Hong Kong Polytechnic University (2016)

[5] The area has not taken into account the occupied roof area for other purposes. Please see paragraph 1.5.3.

1.5.3 Available Roof Ratio

The available roof ratio is the ratio of the available roof area to the total roof area. The available roof area can be calculated by deducting the occupied area for other purposes from the total roof area through the aerial photo analysis.

After consolidating the information from the stakeholders from the building industry, the following areas are considered as occupied area for other purposes:

a) Building services components such as plant rooms, pipework, air conditioner outdoor units and gondola;

b) Other uses such as landscaping, recreational area, architectural features or other green features; and

c) Refuge roof area.

The average roof ratios for different building types are summarised as below:

Building Types	**Available roof ratio* (%)**
Public housing – rental blocks	6 - 11
Public housing – sale flat blocks	6 - 11
Private residential	
a) More than 25-storey	7 - 11
b) Less than or equal to 25-storey	12 - 18
Commercial	8 - 10
Industrial land	19 - 38
Industrial estate	8 - 27
GIC	10 - 15
Airport (includes all buildings at Chek Lap Kok)	8 - 10

**The upper limit of the available roof ratio represents the roof ratio in the scenario where inaccessible roof is also considered for PV installation*

Remarks:

1) The private residential buildings are divided into two groups, i.e. > 25-storey (with refuge floor requirement in general) and ≤ 25-storey (no refuge floor requirement in general).

2) Owing to the small footprint of NTEHs, separate analysis was performed.

3) Cottage and temporary structures are neither permanent nor legal buildings / structures, and therefore they are not considered in the estimation.

1.5.4 Utilisation Factor

The area and number of the PV panels which can be placed on available roof area are affected by the inter-row spacing between two arrays of PV panels and the spacing requirement is subject to the tilting angle of the PV panels. The utilisation factor is used to define the ratio of installed PV panel area to the available roof area. In order to get the optimum annual electricity generation, south-facing PV panel with tilting angle of 14° was adopted for analysis. After considering the separation distance of the front and back rows of PV panels to avoid the partial shading effect during the winter solstice in Hong Kong, the inter-row spacing is calculated and the utilisation factor is taken as 0.7.

1.5.5 Estimated PV Panel Area

After taking into account the available roof ratio for different building types and the utilisation factor, it is estimated that the PV panel area in Hong Kong is around 3.246 – 5.010 km^2.

1.5.6 Rooftop PV Potential Estimation

If the PV potential can be fully exploited, the estimated annual electricity generated by PV panels on building rooftops in Hong Kong would range from 505,326 to 880,733 MWh, accounting for around 1.1% - 2.0% of the total electricity consumption of Hong Kong in 2016.[6] However, it should be noted that whether all the PV potential at building rooftops can be exploited depends on a number of factors, including buildings' structural integrity and willingness of building owners (especially for those buildings with multiple ownership) to install PV panels taking into account various considerations including their preference over the use of their roofs and plans of redeveloping their buildings, etc., which may not be easily resolved.

[6] The upper limit of PV potential represents that (a) PV panel efficiency of 20% is adopted (as compared to the 17.5% adopted in calculating the lower limit); (b) PV potential at inaccessible roof has been taken into account (for non-NTEH buildings); and (c) assuming that PV panels are projected beyond the external wall (for NTEHs).

Detailed breakdown of PV potential at rooftops by building types is as follows:

Land use	Roof area (km^2)	Roof area suitable for PV installation (km^2)	Available roof ratio (%)	Utilisation factor for PV installation	Estimated PV panel area (km^2)	Potential PV installation capacity (kW)	Annual electricity generation (MWh)	Annual electricity generation as a percentage of the total electricity consumption in 2016 (%)
Public housing - rental blocks	2.306	1.537	6 - 11	0.7	0.064 - 0.118	11,299 - 23,675	9,040 - 18,940	0.021 - 0.043
Public housing - sale flat blocks	2.351	1.568	6 - 11	0.7	0.066 - 0.121	11,526 - 24,149	9,220 - 19,319	0.021 - 0.044
Private residential >25 storey	1.188	0.792	7 - 11	0.7	0.039 - 0.061	6,789 - 12,193	5,431 - 9,754	0.012 - 0.022
Private residential ≤ 25 storey	10.689	7.126	12 - 18	0.7	0.599 - 0.898	104,749 - 179,570	83,799 - 143,656	0.190 - 0.326
Commercial	2.409	1.606	8 - 10	0.7	0.090 - 0.112	15,741 - 22,488	12,593 - 17,990	0.029 - 0.041
Industrial land	5.271	3.514	19 - 38	0.7	0.467 - 0.935	81,782 - 186,929	65,425 - 149,543	0.149 - 0.340
Industrial estate	1.265	0.843	8 - 27	0.7	0.047 - 0.159	8,264 - 31,876	6,611 - 25,501	0.015 - 0.058
GIC	8.353	5.568	10 - 15	0.7	0.390 - 0.585	68,213 - 116,936	54,570 - 93,549	0.124 - 0.212
NTEH	2.600	2.600	22-30 PV panels for each 65m^2 NTEH		1.452 - 1.98	254,100 - 396,000	254,100 - 396,000	0.577 - 0.899
Cottage and temporary structures	5.300	0.000	NA	NA	0	0	0	0
Airport (including all buildings at Chek Lap Kok)	0.868	0.579	8-10	0.7	0.032 - 0.041	5,671 - 8,101	4,537 - 6,481	0.010 - 0.015
Total	42.600	25.733			3.246 - 5.010	568,135 - 1,001,917	505,326 - 880,733	1.148- 2.000

The above estimations are based on the following assumptions:

a) Monocrystalline PV panels with panel efficiency of 17.5% to 20.0%.
b) Performance ratio of 0.75 is taken.
c) The PV panels are facing south and tilted at 14°.
d) 22 to 30 PV panels (each 1.65 m^2) can be installed at the main roof and roof above the stairhood of NTEH.
e) The average annual solar irradiance is 1,350kWh/m^2 for NTEH and 1,075kWh/m^2 for other buildings.
f) The cottage and temporary structures are neither permanent nor legal buildings nor structures, and therefore their roof areas are not considered.

1.6 Recommendations

To promote the development of PV systems on building rooftops in Hong Kong, the following measures are recommended:

1. Financial subsidies: Consideration should be given to developing incentive measures to attract investment in PV systems by the private sector.

2. Training of professionals: Training for PV systems service providers will help expand the PV industry.

3. Grid-connection arrangements: The Government and the power companies should increase the public awareness of PV applications in Hong Kong and provide support and make the grid-connection process for PV installations more transparent.

4. PV applications in new buildings: Consideration should be given to setting PV application as one of the pre-requisite items of green feature in granting the GFA concessions for new buildings.

5. Guidelines and specifications: Establishment of guidelines on the statutory submission requirements for PV installations and product specifications for PV systems can facilitate the development of PV technology in Hong Kong.