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Estimation of solar energy potential in Fairview Park and Hong Lok Yuen

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Introduction

This paper aims to estimate the potential installed capacity of solar PV systems and solar electricity generation potential in Fairview Park and Hong Lok Yuen. The estimation makes reference to two main sources of data:

1. On-site solar energy potential assessment conducted with Fairview Park and Hong Lok Yuen households; and
2. Rooftop areas estimated utilising the measurement tools of the Lands Department's GeoInfo Map

Fairview Park and Hong Lok Yuen are chosen for conducting solar energy potential assessment. These two low-density communities possess, in principle, rich solar energy potentials and share the following features: (1) semi-detached and garden housing design with basically same building heights which minimise shading to each building; (2) tilted rooftops with ceramic tiles and non-competing uses that can maximise sunlight exposure and solar panel installation suitability; and (3) relatively flat and widening terrains (Figures 1-3).



Figures 1 and 2: Panoramic view of Fairview Park (FP; left) and Hong Lok Yuen (HLY; right).
Photo credits: (left) Chun-hei Wong and Bethel High School (2017);¹ (right) Mondo Ching (2019).

¹ A drone video of Fairview Park: <https://drive.google.com/file/d/1NdK4TzAMpo-zkS2aru00rGqTlVuUoPXb/view?usp=sharing> (Source: Chun-hei Wong and Bethel High School)



Figure 3: Tilted rooftops with ceramic tiles of Hong Lok Yuen (HLY).
Photo credits: Mondo Ching (2019).

The paper is divided into three parts following this introduction. The first part discusses the methodology in collecting data and conducting solar energy potential analysis. The second part discusses the formulas in use and calculations of solar energy potential. The last part discusses the assumptions and limitations which might affect the results of the analysis.

Methodology

A. On-site solar energy potential assessment

The City University of Hong Kong's Ability R&D Energy Research Centre (AERC), in collaboration with the Asian Energy Studies Centre, Hong Kong Baptist University, conducted on-site solar electricity generation assessment utilising hemispherical photography technique on the rooftops of 32 Fairview Park and 16 Hong Lok Yuen households between September 2018 and January 2019. The Meternorm software and Horicatcher tool are used to estimate the annual and monthly solar irradiation per area (kWh/m^2) of the rooftops and the shading effect based on historical climate data and the height of surrounding structures. The geographical distribution of the sample households are given in Figures 4 and 5. The assessment data of the sample households are used as references to project the solar potential of Fairview Park and Hong Lok Yuen.

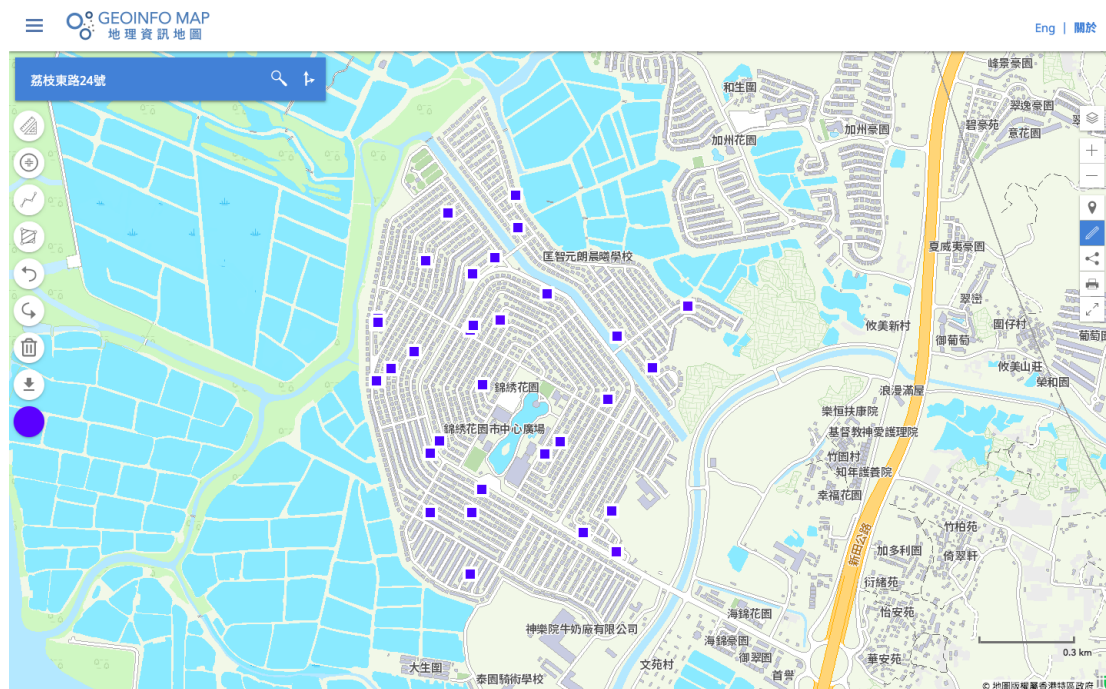


Figure 4: Geographical distribution of sample households in Fairview Park.

Source: Authors utilising GeoInfo Map

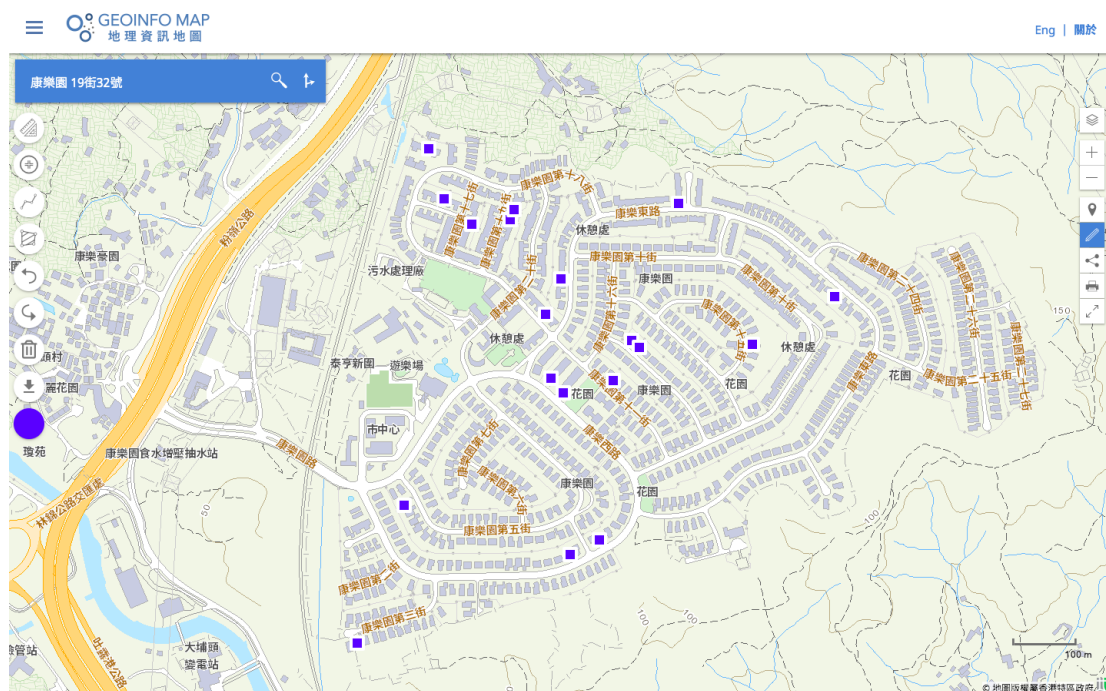


Figure 5: Geographical distribution of sample households in Hong Lok Yuen.

Source: Authors utilising GeoInfo Map

B. Categorisation of shading ratio

A shading ratio (S) is calculated for each sample household which has conducted solar potential assessments:

$$S = \frac{H_{Gkhor}}{H_{Gh}}$$

where

H_{Gkhor} refers to the assessed irradiance taking azimuth (direction of rooftop surface where north = 0°), rooftop inclination and surrounding building heights into account; and

H_{Gh} refers to the irradiance received taking rooftop inclination equal 0° and heights of surround buildings are 0° in all directions

The shading ratios (S) of the sample households are categorised into groups based on the directions (γ). In Fairview Park, since most rooftops usually face two opposing directions and the basin terrain of Fairview Park minimises the shading effect of rooftop solar potential, two board categories (North side and South side) are used. In Hong Lok Yuen, since there are multiple shapes of rooftops and the valley terrain of Hong Lok Yuen contributes to a great shading effect to the rooftops in different directions, four categories (Northeast, Southeast, Southwest, Northwest) are used. Where rooftop directions for a roof in Hong Lok Yuen cannot be determined, a “All” category is used. The categories and range of shading ratios for each category in Fairview Park and Hong Lok Yuen are given in Tables 1 and 2 below. The number of sample roofs and their corresponding categories are given in Table 3.

Table 1: Categories of shading ratio of Fairview Park

Categories	Direction	S (Min - Max)
N	North side ($0^\circ \leq \gamma \leq 90^\circ, 270^\circ \leq \gamma \leq 360^\circ$ (i.e. 0°))	0.92026825633383 - 0.961251862891207
S	South side ($90^\circ < \gamma < 270^\circ$)	0.96274217585693 - 1.02384500745156

Note: 0° denotes North.

Table 2: Categories of shading ratio of Hong Lok Yuen

Categories	Direction	S (Min - Max)
All	Direction of rooftop cannot be determined	0.919402985074627 - 1.01268656716418
NE	0° - 90°	0.937313432835821 - 0.972388059701493
SE	90° - 180°	0.92089552238806 - 1.01268656716418
SW	180° - 270°	0.947014925373134 - 1.01193139448173
NW	270° - 360°	0.919402985074627 - 0.959701492537313

Note: 0° denotes North.

Table 3: Number of sample roofs in Fairview Park and Hong Lok Yuen

Fairview Park: 62*		Hong Lok Yuen: 32*	
North side	30	NE	4
		SE	12
South side	32	SW	6
		NW	10

Note (*): The figures do not include the outlining roofs with exceptionally low irradiance.

C. Area estimation

Rooftop areas of houses in Fairview Park and Hong Lok Yuen are estimated by using the GIS measurement tools of the Lands Department's GeoInfo Map on the digitalised rooftops from satellite images. According to the address information provided by GeoInfo Map, we identify 4,996 houses in Fairview Park and 1,163 houses in Hong Lok Yuen. The sum of rooftop areas of these houses constitute the ***working rooftop areas*** in Fairview Park and Hong Lok Yuen.

In addition to working rooftop areas, the ***useable rooftop areas*** of each identifiable houses in Fairview Park and Hong Lok Yuen are calculated. Taken into consideration that a standard 300W solar panel has an area of about 1.7 m², the useable area is calculated as follows:

$$\text{Useable area} = \frac{\text{Rooftop area}}{1.7} \text{ (round down to the nearest integer) } \times 1.7$$

D. Estimation of maximum solar panel installed capacity and solar energy potential

The maximum solar panel installed capacity is calculated as follows:

$$\Sigma \text{Installed capacity (kW) of rooftop} = \frac{0.3\text{kW}}{1.7} \times \text{Area (working or useable)}$$

The total solar energy potential is calculated as follows:

$$E = \Sigma(S \times H_{Gh} \times A \times eff \times PR)$$

where

S is the shading ratio;

H_{Gh} is the irradiance received assuming rooftop inclination is 0° and surround building heights are 0° in all direction (the H_{Gh} values in Fairview Park and Hong Lok Yuen are $1,342 \text{ kWh/m}^2$ and $1,340 \text{ kWh/m}^2$ respectively based on Meternorm);

A is the working area/useable area;

eff is the efficiency of solar panel (17% is used assuming monocrystalline silicon solar panels are used); and

PR is the performance ratio of the PV system (82% is used assuming the PV system would lost part of the generation for various reasons excluding shading).

Results

The results of the calculation are as follows:

Table 4: Solar energy potential of Fairview Park and Hong Lok Yuen

Result	Fairview Park	Hong Lok Yuen
Total working rooftop area (km^2)	0.24	0.10
Total usable rooftop area (km^2)	0.23	0.09
Maximum installed capacity based on working rooftop area (MW)	42.51	17.21
Maximum installed capacity based on useable rooftop area (MW)	41.01	16.72
Total estimated annual solar energy potential based on total working rooftop area (MWh)	42137.95 - 44423.73	16926.09 - 18093.03
Total estimated annual solar energy potential based on total useable rooftop area (MWh)	40655.19 - 42860.57	16443.94 - 17579.17

Assumptions and Limitations

Various assumptions and limitations are highlighted which may affect the estimation of solar energy potential.

1. Not all the households are involved in our database

Referring to the official data from two case communities, the total number of houses/buildings in Fairview Park and Hong Lok Yuen is 5,024 and 1,202. During the GIS analysis of rooftop areas, we only observed 4,996 digitalised rooftops in Fairview Park and 1,163 digitalised rooftops in Hong Lok Yuen from the satellite images and based on the address information provided by GeoInfo Map. Potential reasons of this discrepancies may include, but not limit to:

- a) Counting errors;
- b) Unidentifiable address from the GeoInfo Map;
- c) Roofs which belong to two or more houses are counted as one roof;
- d) The official data is not updated.

These potential errors might lead to underestimation of total solar energy potential of the two communities.

2. Limitation on the number of samples

Owing to the limited number of interviewees who permitted the research team to conduct rooftop solar assessment, we were able to conduct 32 solar assessments in Fairview Park for 70 roofs (62 valid samples) and 19 solar assessments in Hong Lok Yuen for 44 roofs (32 valid samples). While the samples are distributed over the case communities, the limited number of samples might be representative to cover the range of solar irradiance received for all the roofs.

3. Limitation of conducting solar assessments in the highest and largest roofs

The inclined roofs in Fairview Park and Hong Lok Yuen increased the difficulties to conduct onsite solar potential assessment or at optimal roof locations. While the highest and largest roofs with multiple roof surfaces (in Hong Lok Yuen) are the optimal sites for placing solar panels, these roofs are less possible for conducting solar potential assessment. Under such circumstances, we conducted solar assessment in other accessible roofs (usually smaller or lower) to serve as substitutes for the optimal ones. In some extreme cases, the research team had to use own judgement to evaluate the surrounding building heights in the Horicatcher tools on the panoramic rooftop photos. Such limitation might contribute to the underestimation of the solar energy potential.

4. Outliers taken out from the data

As we observed, some of the roofs have stronger shading effect because of the obstacles such as trees or lamp posts. Hence, some roofs would receive fewer irradiance than other houses. Therefore, we took out four solar assessment samples in Fairview Park and seven solar assessment samples in Hong Lok Yuen (outliers) to prevent underestimation of the solar potential in two targeted communities.

5. Distortion from satellite images in GeoInfo Map

Due to the quality and coloration of ortho maps in GeoInfo Map, the shapes and directions of some roofs are difficult to be identified. Some roofs in Hong Lok Yuen also have complex shapes. Hence, the area and direction of roofs analysed from the GeoInfo Map might inherit observable errors.

6. The willingness of solar PV system installation

The willingness of residents in the two case communities are not taken into consideration. The results assume that (1) all roofs are fully equipped with solar PV systems and (2) Monocrystalline Silicon PV panels which have at least 17% efficiency will be the sole type of solar panels.

7. The maximum installation number of PV panel in household roof

We assume the maximum installation number of PV panel in each roof based on its total roof area instead of the shape of the roofs. In reality, residents might not be able to install solar PV panels to cover the entire roof areas on roofs with irregular shapes.