International Journal on "Technical and Physical Problems of Engineering" (IJTPE)
Published by International Organization of IOTPE
ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

September 2022 | Issue 52 | Volume 14 | Number 3 | Pages 221-228

ASSESSMENT OF POTENTIAL SURFACE FOR INSTALLING SOLAR PANELS ON ROOFS IN URBAN ZONE BY USING REMOTE SENSING TECHNOLOGY

W. Chokkuea [1] N. Kaewrawang [1] T. Laosuwan [1] J. Piamdee [1] S. Sirikaew [2]

1. Department of Physics, Faculty of Science, Mahasarakham University, Kantarawichai, Mahasarakham, Thailand
drwutthisat@gmail.com, nachapon.k@msu.ac.th, teerawong@msu.ac.th, jenjira@msu.ac.th
2. Department of Physics, Faculty of Science, Silpakorn University, Mueang Nakhonpathom, Nakhonpathom, Thailand
sattra_20@hotmail.com

Abstract- This research aims to assess potential surface of roofs in urban zone that were appropriate for installing solar panels by considering on shading occurred with roofs caused by nearby buildings by using remote sensing technology. The research methodology was divided into 3 parts including: (1) Analysis on data obtained from satellite of urban zone from Google Earth Pro; (2) Creation of 3D models of considered buildings with the height over 20 meters by using SketchUp 8 Program to study and analyze on occurred shading; and (3) Calculation of roof areas of those roofs based on consideration on shading of nearby buildings by using ArcMap 10.5 Program. The results revealed that urban zone used for consideration in this research was Chatuchak District in Bangkok with the approximate considered area of 254,000 square meters. The considered building was 27 buildings with the height over than 20 meters. The height was ranged from 20.50-132.65 meters. When considering on shading of buildings throughout the year, it was found that there were 7 and 13 buildings with the smallest roof areas with shading or with proportion ranged from 0-10% and the largest roof areas with proportion ranged from 91-100%, respectively, whereas other buildings had proportion of roof areas with shading ranged from 11-90%.

Keywords: Solar Rooftop, Remote Sensing Technology, Shading Effect, Partial Shading.

1. INTRODUCTION

Currently, demand on electric energy has been increasing continuously whereas sources of such energy (fossil fuel (are limited. Therefore, energy that is a kind of renewable energy has been used as alternative energy that could generate electric power by using solar panels as a device to transform solar energy into electric power that is operated by photovoltaic effect [1]. Generated electric power is based on 2 major factors including operational temperature and incident sun rays on solar panels [2-3]. When considering on uniform irradiance condition, generated electric power is equal to one another of very cell and electric power generated from solar panels is equal to sum of power electric of each cell. In the event of non-uniform irradiance condition or partial shading condition, sun rays would be various causing various values of peak *I-V* and *P-V* [4] leading to loss of electric power that can be generated by solar panels.

Generally used solar panels are connected in the form of series connection, parallel connection, or mixed connection. If there is any solar panel with shading, such panel will act as load according to Kirchhoff's voltage law (KVL) [1] causing mismatch. Shaded panel will act as reverse bias and distribute energy across the panel causing higher temperature and hotspot that is one of causes of fire on solar panel [5]. Shade on solar panels can be caused by many causes, for example, dust, trees, array of nearby solar panels, high buildings, etc.

With this reason, effects of shade on performance of solar panel have been studied extensively [6-8]. Therefore, assessment on shade on solar panels is important for reducing effects and avoiding occurred problems as well as improving performance of solar panels for full effectiveness. Moreover, appropriate PV array configuration under shading condition has also been studied extensively with the aim to reduce loss of electric power as much as possible. Belhachat and Larbes [9] studied, analyzed, and compared 6 formats of 6×4 array configuration including: (1) Series (S); (2) Parallel (P); (3) Series-Parallel (SP); (4) Total-Cross-Tied (TCT); (5) Bridged-Linked (BL); and (6) Honey-Comb (CB) under 8 cases of possible partial shading condition. The results of the research conducted by using modeling via MATLAB/Simulink Program and SimPower Program revealed that TCT array configuration had the highest performance level.

Bingol and Ozkaya [10] studied, analyzed, and compared 5 formats of 6×6 array configuration including: (1) S, (2) SP, (3) TCT, (4) BL, and (5) CB under 6 cases of possible partial shading condition. The results of the research conducted by using modeling via MATLAB/Simulink Program revealed that TCT array configuration caused the lowest level of loss of electric power.

Rani, et al. [11] presented 9×9 TCT array configuration by using SuDoKu technique under 4 cases of partial shading condition. The results of the research conducted by using modeling via MATLAB/Simulink Program revealed that TCT array configuration by using SuDoKu technique could increase output electric power compared to TCT array configuration. Moreover, there were also other researches on array configuration under partial shading condition [12-14] and TCT array configuration using SuDoKu technique [15-16].

From the above results, it was found that loss of electric power or reduced performance of electric power generation is not based on shading areas only but it is also based on array configuration and shading formats. To assess appropriate potential surface of roofs in urban zone for installing solar panels, besides using data with roof area survey, it is also able to be studied based on data from remote sensing technology [17-19]. Remote sensing technology is able to survey data extensively with lower expenses than manual land surveying. Consequently, remote sensing technology has been applied to various dimensions, for example, forest fire, burned areas drought, flood, and Land Surface Temperatures, etc. [20-29] .As a result, this research aims to study on potential surface by assessing formats or characteristics of shadow occurred on roof areas caused by nearby buildings by using remote sensing technology. The research was conducted by selecting an urban zone as the case study and assessing shading fraction monthly throughout the year.

2. MATERIAL AND METHOD

Research methodology was divided into 3 parts including:

1) analysis on satellite image data of considered urban zone;

2) create 3D models of buildings in considered urban zone; and

3) calculate roof areas of such considered buildings affected by shading of nearby buildings.

The research methodology was shown in Figure 1 and could be explained as follows:

2.1. Analysis on Satellite Image Data

The researcher used Google Earth Pro Program for selecting urban zone with high buildings or large number of buildings. Buildings with the height of 20 meters and higher would be considered because such height could be primarily measured by using commands of programs.

2.2. Creation of 3D Model

The researcher used SketchUp 8 Program for creating 3D models of those buildings with the height of 20 meters and over that were obtained from analyzing above satellite image data. Subsequently, effects caused by shading of nearby buildings would be analyzed by considering on hourly shade occurred with buildings from 09:00 a.m. - 03:00 p.m. on the 15th day of every month. Obtained data would be used as data for analyzing on monthly results throughout the year.

2.3. Calculation of Roof Areas

The researcher used ArcMap 10.5 Program for finding appropriate roof areas for installing solar panels. Those appropriate roof areas would be used for considering on effects caused by shading of nearby buildings by assessing proportion of non-shaded areas and shaded areas. Such assessment was used for considering on monthly and yearly results.

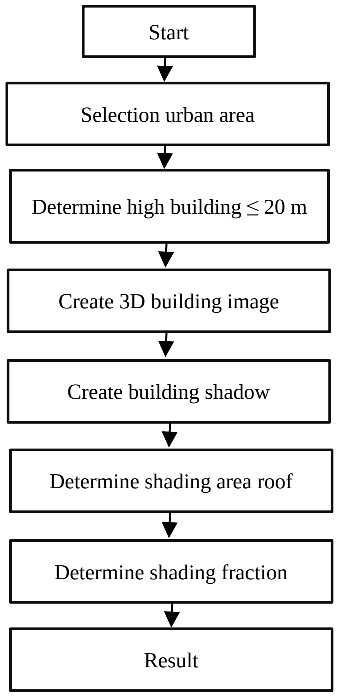


Figure 1. The research methodology

3. RESULT AND DISCUSSION

3.1. Results of Analysis on Satellite Image Data

The results of analysis on satellite image data revealed that considered urban zone was Chatuchak District in Bangkok (18.83 N and 100.56 E) with the considered area of 254,000 square meters (approximately). There were 27 buildings with the height of 20 meters and higher as shown in Figure 2. It was also found that the height of those buildings was ranged from 132.65-20.50 meters with mean of 47.72 meters as shown in Table 1.

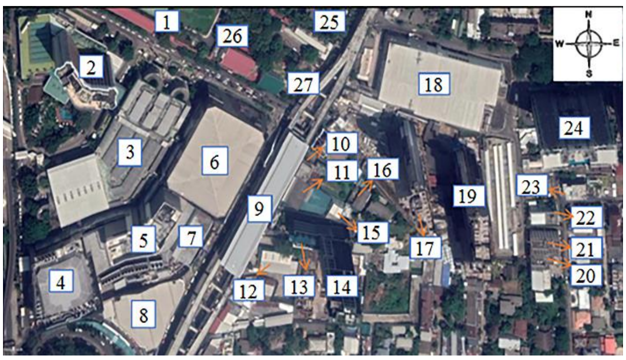


Figure 2. Chatuchak District in Bangkok, Thailand

Table 1. Building, Building height (m), and Roof area (m^2)

Building	Building height (m)	Roof area (m^2)
1	20.95	2,383.63
2	84.50	2,582.09
3	49.15	12,102.41
4	60.40	3,190.73
5	98.38	4,001.74
6	66.17	10,460.70
7	60.70	1,494.79
8	65.80	5,326.72
9	30.80	5,014.76
10	27.55	293.83
11	27.28	611.42
12	21.26	881.88
13	29.60	1,037.35
14	132.65	1,776.29
15	21.04	229.96
16	27.67	301.96
17	80.87	1,711.18
18	33.35	11,792.69
19	80.50	1,735.98
20	40.00	385.81
21	40.26	387.10
22	30.70	581.46
23	20.50	810.85
24	70.90	2,741.55
25	20.90	490.83
26	20.87	887.10
27	25.56	547.35
Average	47.72	2,731.93

3.2. Results of Creation of 3D Models

From analysis on satellite image data and selection of studied area, it was found that 3D models could be created from all of 27 buildings as mentioned above as shown in Figure 3. When Show/Hide Shadows commands and specification of time and date were used, it could represent shading occurred with buildings as shown in Figures 4 and 5. When using commands to show hourly shading of buildings, the examples of January (January 15th) were shown in Figure 4 and the examples of June (June 15th) were show in Figure 5. It was found that shading of buildings at the same period of time was different in each month because the direction of the sun in the key was to the south from December to January [30].

As a result, shading of buildings was occurred in the north in the highest level. On the other hand, the direction of the sun in the key was to the north from June to July [30]. As a result, shading of buildings during those months was different from shading from December to January. Consequently, direction and shading of building was based on height, location, position of buildings alignment, and order of days in the year. Such occurred shading was caused by axial tilt of the earth's axis and earth's orbit around the sun [30]. The example of monthly shading of buildings at 10:00 a.m. is shown in Figure 6.

3.3. Results of Calculation of Roof Areas

When considering on shading of buildings, the example is shown in Figure 7 representing proportion of non-shaded roof areas and monthly shaded roof areas throughout the year of each building as shown in Figure 8. It was found that the months with the large's shaded areas were November, December, January, February, October, March, September, April, August, May, June, and July, respectively. When considering on proportion of shaded roof areas throughout the year of each building, it could be represented as shown in Table 2.

It was found that there were 7 buildings that their roof areas were shaded by 0 -10% including buildings 8, 12, 14, 19, 20, 21 and 24. There were 13 buildings that their roof areas were shaded by 90-100% including buildings 1, 3, 6, 9, 10, 11, 13, 15, 16, 17, 18, 26 and 27. On the other hand, other buildings had proportion of shaded roof areas ranged from 11-90%. When considering on total roof areas of 27 buildings, it was found that proportion of roof areas that were shaded throughout the year was ranged from 5.41% (July) - 60.53% (November).

Table 2. The proportion of the roof area that is covered by shadows throughout the year

Proportion of the shadowed area	Building
0-10%	8, 12, 14, 19, 20, 21, 24
11-20%	4
21-30%	5, 7
31-40%	-
41-50%	-
51-60%	2
61-70%	22
71-80%	23
81-90%	25
91-100%	1, 3, 6, 9, 10, 11, 13, 15, 16, 17, 18, 26, 27

4. CONCLUSIONS

This study on potential surface for installing solar panels in urban zone was conducted to study on appropriate potential surface for installing solar panels by considering on shading occurred with roofs caused by nearby buildings. This research was conducted by using remote sensing technology that was one of methods with high level of correctness and accuracy. Data would be processed with computer programs used in architecture, engineering, landscape design, and Geographic Information System management. Urban zone used in this research was Chatuchak District in Bangkok with considered area of 254,000 m^2 (approximately). Considered buildings were 27 buildings with the height of 20 meters and over. When considering on shading of those buildings throughout the year, it was found that there were 7 buildings (buildings No. 8, 12, 14, 19, 20, 21, 24) with the smallest shaded roof areas or with the proportion of shaded roof areas ranged from 0-10%. There were 13 buildings (buildings No. 1, 3, 6, 9, 10, 11, 13, 15, 16, 17, 18, 26 and 27) with the largest shaded roof areas or with the proportion of shaded roof areas ranged from 91-100%. Other hand, other buildings (building No. 2, 4, 5, 7, 22, 23 and 25) had shaded roof areas ranged from 11-90%.

In addition, when comparing the results of this research with similar research, it was found that they were in the same direction. For example, research by Cascone et al., [31] "Calculation procedure of the shading factor under complex boundary conditions", and research by Joachem, et al., [32] titled "Automatic Roof Plane Detection and Analysis in Airborne LIDAR Point Clouds for Solar Potential Assessment". Both studies have identified that shadows and building obscuring affect the installing solar panels on roofs. As a result, this research can be used as the guidelines for assessing potential surface of other buildings considered by using shading of nearby buildings that will help to assess incident solar energy and electric power generated from installing solar panels on building roofs.

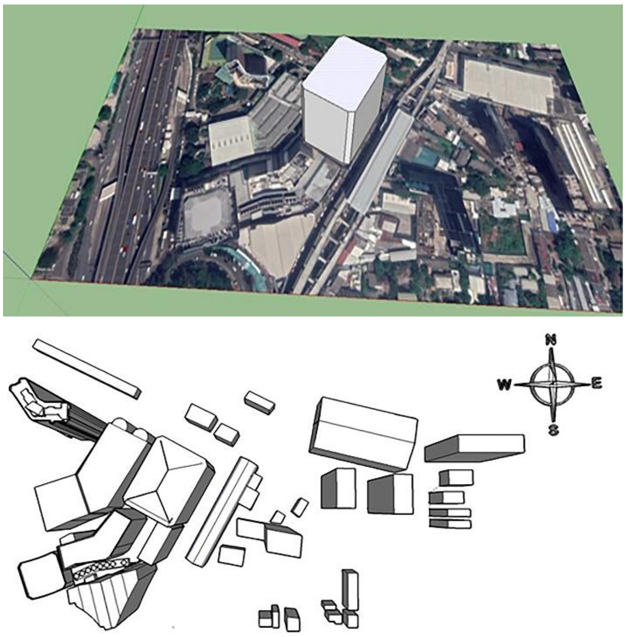
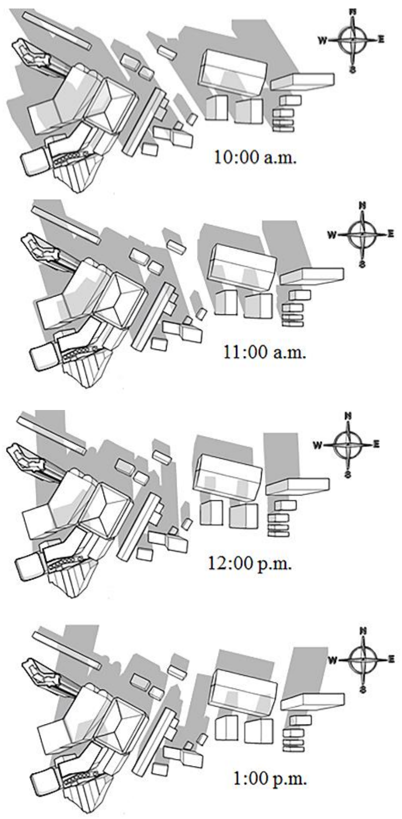


Figure 3. 3D modeling using SketchUp 8



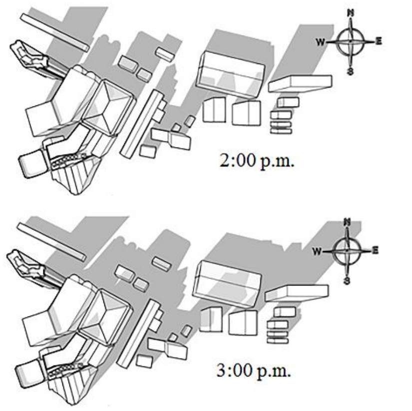


Figure 4. Shadow of the hourly building in January

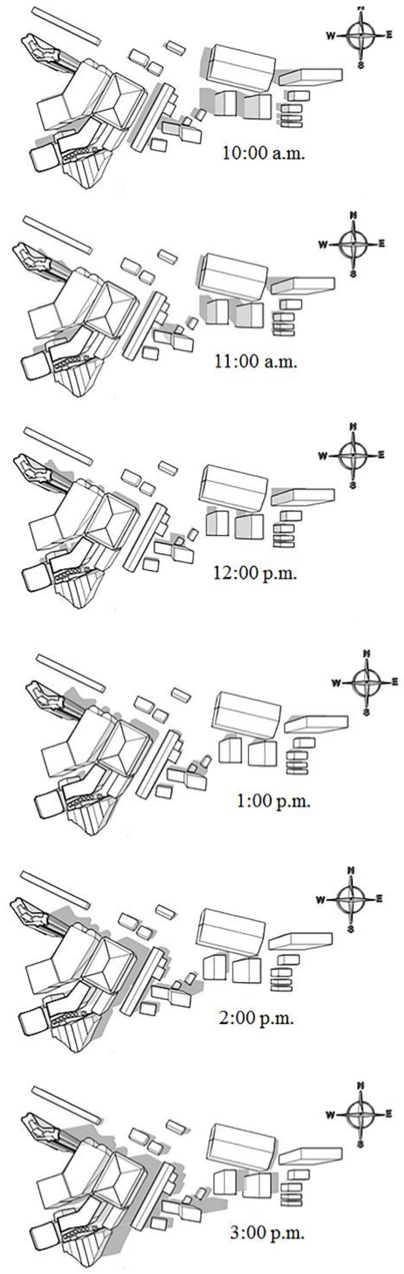


Figure 5. Shadow of the hourly building in June

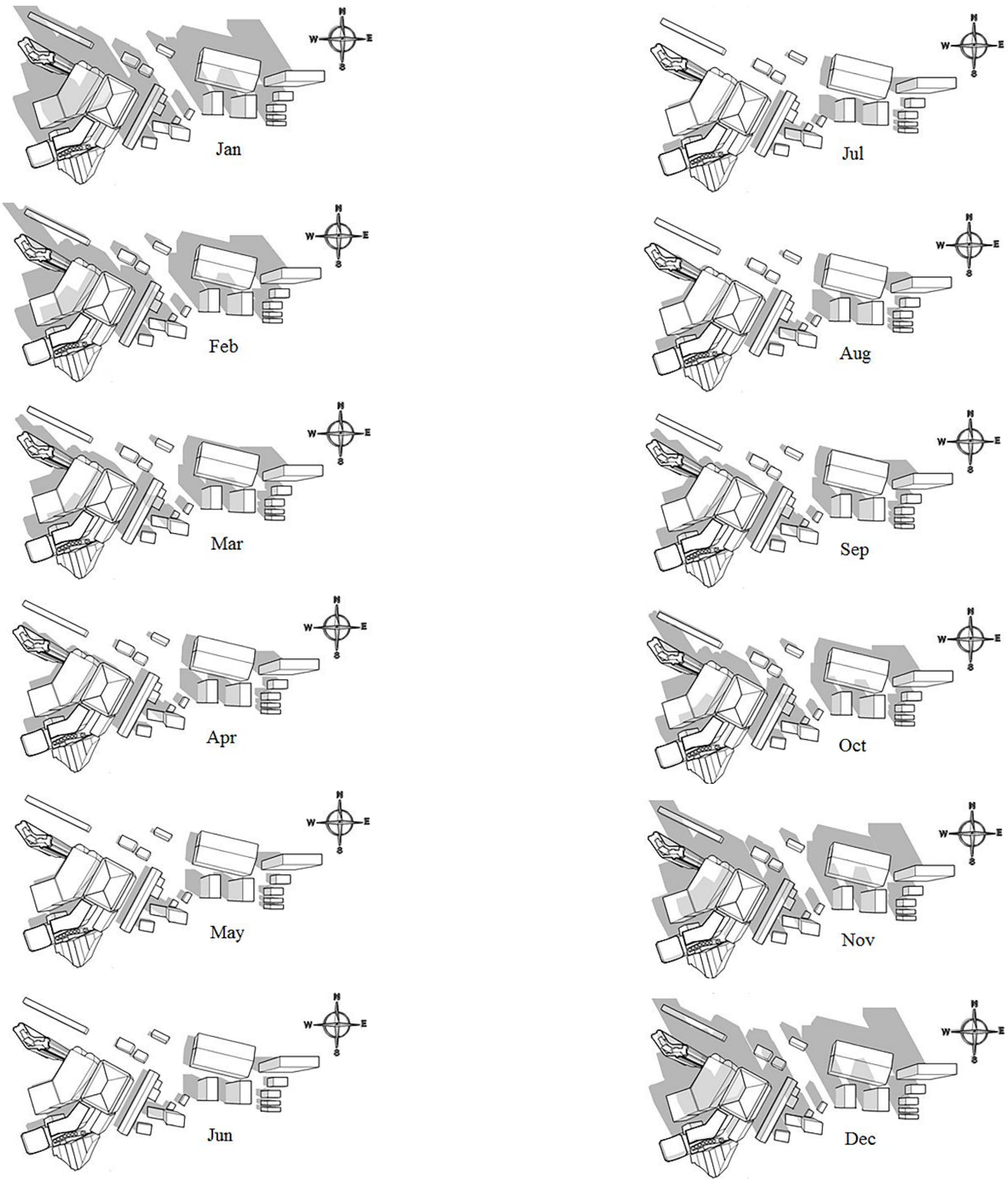


Figure 6. Monthly building shadow at 10:00 am

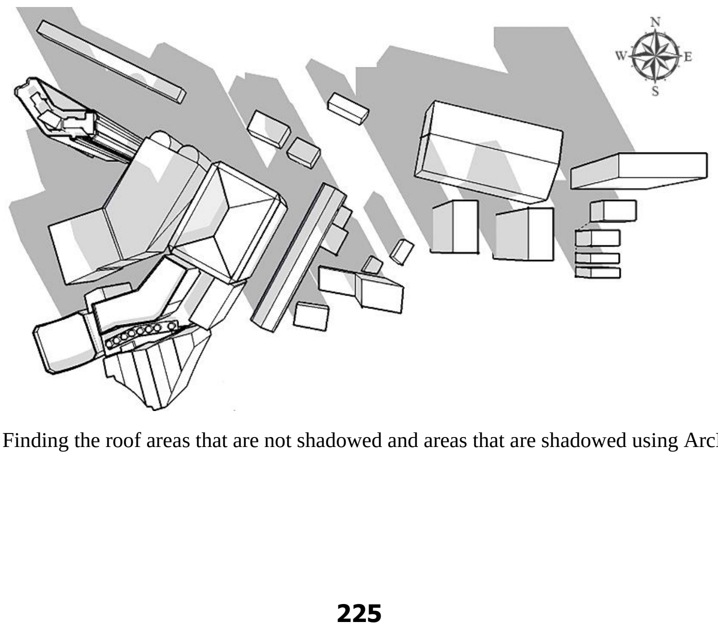


Figure 7. Finding the roof areas that are not shadowed and areas that are shadowed using ArcMap 10.5

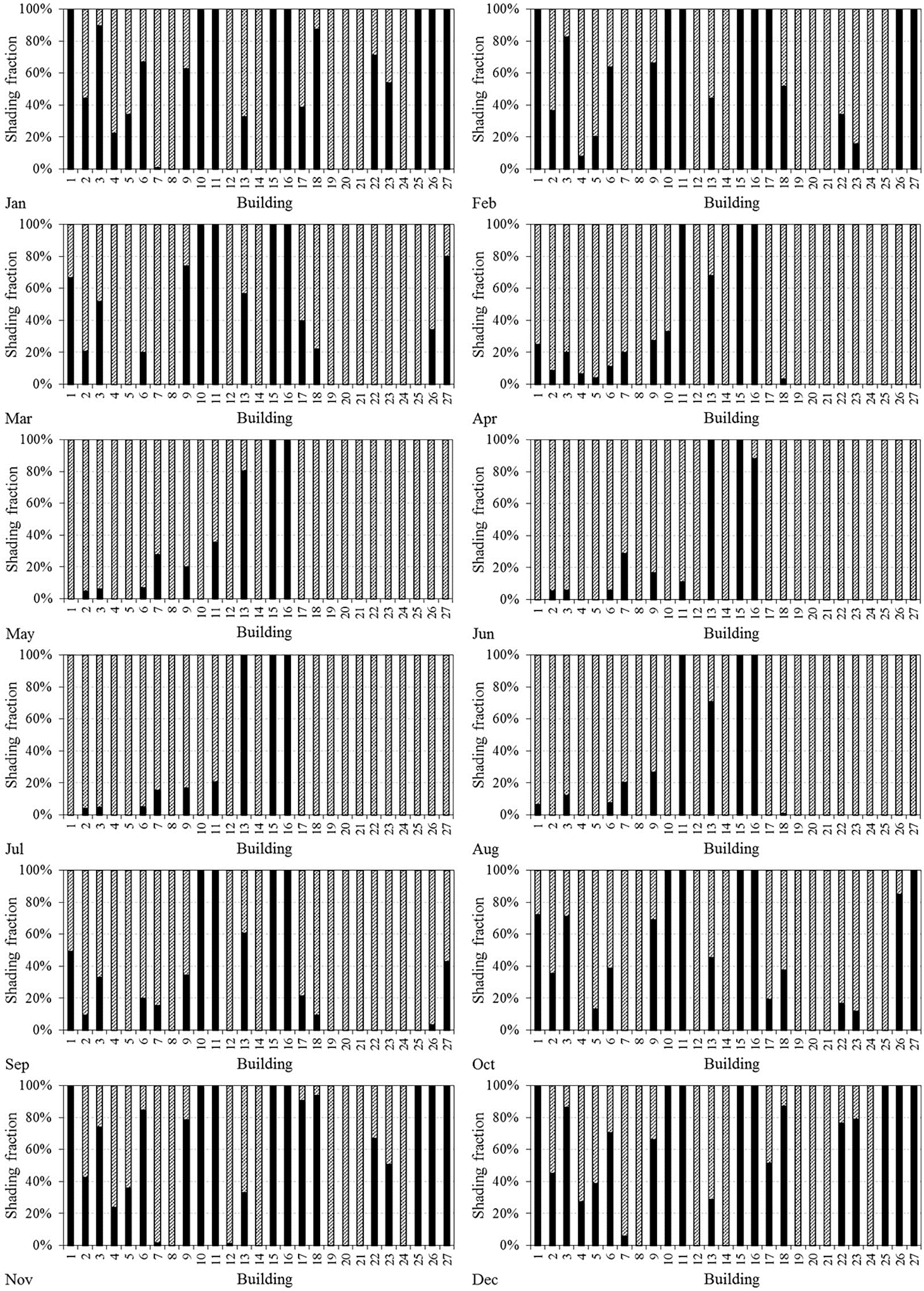


Figure 8. The proportion of building area by ▨ is the area that is not obscured by shadows and ■ is the shadowed area

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BIOGRAPHIES

Wutthisat Chokkuea was born in Mahasarakham, Thailand in 1979. He received the Ph.D. degree in Mechanical Engineering from Mahasarakham University, Thailand in 2014. Currently, he is an Assistant Professor at Department of Physics, Mahasarakham University, Mahasarakham, Thailand. His research interests are in the renewable energy, energy conservation, energy modeling, etc.

Nachaporn Kaewrawang was born in Nakhon Ratchasima, Thailand in 1998. She received the B.Sc. degree in Applied Physics (Energy) from Mahasarakham University, Thailand in 2020. She currently runs her own business in renewable energy. Her research interests are in the renewable energy, energy conservation, energy modeling and economics, environmental impact etc.

Teerawong Laosuwan was born in Hat Yai, Songkhla, on October 2, 1971. He received the Ph.D. degree in Electrical and Computer Engineering from Mahasarakham University in 2012. Currently, he is an Associate Professor at Department of Physics, Mahasarakham University, Maha Sarakham, Thailand. His research interests are in the remote sensing, geo-informatics, GIS modeling, mobile application development, energy technology and drone surveying and mapping, etc.

Jenjira Piamdee was born in Nongkhai, Thailand in 1977. She received the D.Eng. degree in Energy Engineering from Chiang Mai University, Thailand in 2013. Currently, she is a Lecture at Department of Physics, Mahasarakham University, Mahasarakham, Thailand. Her research interests are in the renewable energy, energy conservation, energy modeling and economics, environmental impact etc.

Sattra Sirikaew was born in Mahasarakham, Thailand, in 1993. He received the B.Sc. degree in Applied Physics, and the M.Sc. degree in Physics both from from Mahasarakham University, Thailand. Currently, he is a Ph.D. student at Faculty of Science, Silpakorn University, Nakhon Pathom, Thailand. His research interests are in the renewable energy, energy conservation, energy modeling, etc.