Solar Energy Potential Mapping around Yogyakarta Palace
As an Effort in Integrating Renewable Energy into Cultural Based Economic Development

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Abstract. The Yogyakarta Palace is the main heritage buildings in Yogyakarta Province. It is a main cultural symbol, which is also one of the main tourism objects. This research focuses on the Palace main buildings and surrounding area as an effort to integrate acceleration of renewable energy use into the cultural-based economic development. It considers cross-cutting issues in integrating engineering approach within a complex socio-culture context. The research applied distribution of solar energy potential mapping by using analysis of 3D buildings data in the Open Street Map (OSM), Digital Elevation Model (DEM) and solar intensity data. QGIS software was applied to analyze the 3D buildings data and geospatial aspect. The research also provides a classification of solar energy potential. The mapping shows valuable capacity of The Palace and its surrounding area to produce electricity by the PV technology. Implementing, for instance, the Building Integrated Photovoltaics (BIPV) method in selected buildings, could provide encouraging environment for green tourism in a city of culture melting point as well as increase of renewable energy role and economic development. However, in such delicate issue of PV implementation the mapping and installation works would be far simpler tasks compared to the required intensive socio-culture inclusive process.

1. Introduction
In recent years there has been substantial growth in two important renewable energy sources, which are wind and solar photovoltaic (PV) [1]. The government of Indonesia commits to increase targeted PV capacity. To reach that goal, the government has decided to increase the deployment of a PV grid-connected network through several systematic efforts.

Renewable energy is among the ways to build sustainable energy system. The achievement of several targets in renewable energy depends on whether or not the people with different cultures will accept the concept. Solar panels (along with other renewable power systems) are often opposed not
because they are a poor alternative to fossil fuels, but because people simply do not comprehend why such technologies may be needed [2].

Yogyakarta is one of the provinces that has no large electricity generation. Its electricity demand is mainly delivered from Yogyakarta-Central Java distribution network by State-Owned Electricity Company. Meanwhile, Yogyakarta Province has a distinctive culture full of noble values. The province involves cultural heritage objects in its tourism strategy. The Sultan Palace (Keraton) in Yogyakarta city, Indonesia is among the main destinations for tourists visiting Yogyakarta expressing a culture-based tourism approach.

This research is a part of comprehensive effort to increase use of renewable energy. It explores the opportunity in applying PV system in heritage area, by integrating engineering approach within a complex socio-culture context. The research conducted mapping. Then, several references were analyzed to describe cross-cutting consideration on various challenges.

2. Solar Energy Potential Mapping

Among the first steps prior to installation of the photovoltaics system is the solar energy potential mapping. This mapping provides important information not only in the detail technical activities of the installation, but also for feasibility study and policy development.

Several studies were performed using GIS techniques applied to application of solar energy [3],[4],[5],[6]. Those studies focused on an annual basis on the regional assessment of solar capacity. A model was applied in this study which analyzes the solar potential on an hourly basis at community level.

This work focuses on developing a modeling approach to 3D GIS at a fine spatiotemporal resolution to determine solar energy potential. The 3D GIS data is based on Open Street Map applications for 2D and 3D. The accuracies obtained allow for the case study to generate planimetric maps at a scale of 1:5000 or smaller using data from OpenStreetMap. However, the results obtained in this study are encouraging and show the possibility of using OpenStreetMap maps for applications such as general preliminary planning, and mapping the overall layout of potential construction sites, proposed transportation systems and existing facilities [7]. The Open Street Map data accuracy evaluation shows that Yogyakarta City has very good fitting to the reference data [8].

GIS is especially useful for such solar applications because it has the ability to track time and space and can precisely assess when and where an event or operation occurs [9]. In order to efficiently quantify and iterate the hourly solar modeling and mapping process over a simulated year, a model was developed in QGIS and ArcGIS Pro software. In ArcGIS Pro, the Calculate Solar Radiation method allows the simulation, visualization and analysis of solar radiation for different time frames over a geographic area. It takes into account the effects of the sun's atmosphere, latitude, elevation, slope inclination, direction, day-to-day and seasonal changes and the effects of shadows cast by local topography and buildings [10]. The research was carried out in an area of case study centered around Yogyakarta Palace.

The 3D GIS modeling approach developed for the analysis of fine-resolution community-based solar potential consisted of six main steps: (1) downloading Digital Elevation Model Data (DEM), (2) downloading 2D Open Street Map building data, (3) inputting 3D information based on the 3D Open Street Map website into QGIS software, (4) a 3D case study model in ArcGIS Pro software, (5) estimating solar potential, and (6) extraction. This technique was tested in the National Cheng Kung University buildings in Taiwan, on a case study area. This technique can be transferred to any location provided the data is available.

The solar radiation calculation tool can be used to calculate solar radiation maps for every month and the whole year, based on a Digital Terrain Model (DEM) as well as 3D features such as buildings and trees or a Digital Surface Model (DSM). This study is focused on the DSM and 3D buildings for whole year. The main results of this method are solar energy potentials that available on DEM and 3D building modeling. The output attribute table of the result shows the level of solar energy potential (kWh/m²/day), which provides a basis to calculate the total of solar energy potential.
3. Results
The mapping provides solar energy potency on DEM and 3D buildings/DSM for building area of 1,587,532 m². For the DEM, it is shown by blue to white colours representing low to high potential, respectively. While, yellow to red colours indicate low to high potential in the buildings, respectively.

Figure 1 shows the distribution of energy potential in at Yogyakarta Palace and its surrounding area. The white colour distribution representing high potential is shown at Alun-Alun Utara (The North Square) and Alun-Alun Selatan (The South Square). A unique result was detected in the 3D solar energy distribution, showing the red colour distribution which are concentrated in the inner circle of Yogyakarta Palace.

More detail information on solar energy potential can be seen in the attribute table. Table 1 shows the classification of solar energy potential at Yogyakarta Palace and Surrounding Area. The highest percentage area has low solar energy potential ranging from 0.502 to 1.503 kWh/m²/day. Meanwhile, the second biggest percentage area has 5.919 - 10.801 kWh/m²/day.

| Solar Energy Potential Classification (kWh/m²/day) | Percentage (%) |
|-------------------------------------------------|----------------|
| 0 - 0.501                                       | 26.69          |
| 0.502 - 1.503                                   | 22.59          |
| 1.503 - 3.494                                   | 12.39          |
| 3.494 - 5.919                                   | 15.11          |
| 5.919 - 10.801                                  | 23.22          |

4. Discussions
One of the rising trends in solar PV module power generation is building integrated photovoltaic (BIPV). It showed that the Yogyakarta Palace and its surrounding area has valuable capacity to produce the electricity by the PV technology. Using PV in this area, for instance by applying the BIPV, could provide encouraging environment for green tourism, which is in Yogyakarta a melting point of culture, increase of renewable energy role and economic development. Intensive innovation in the BIPV in the form of various types of roofing materials, such as solar tiles, shingles or metal roofing sheets is currently coming on the market. In terms of aesthetics and function, they can meet even the stringent requirements of heritage conservation [11]. The integration of renewable energy into envelopes of historical buildings can be conducted at material, system, and building level. Although the integration of solar energy in historical buildings is usually difficult due to the lack of space or the need to preserve the exterior architecture, successful examples can be found in the use of PV tiles or PV panels, placed in buildings [12].
However, installation of the PV in this heritage area should be conducted by seriously considering architectural aspect and related regulation. Installing PV in a cultural heritage area which is center of culture deeply rooted representing religious, philosophies and cultural values will face delicate challenge. The Yogyakarta Palace (Keraton Yogyakarta) is one of the prime cultural centers of Java. It was placed according to the concept of integrity between macro and micro cosmologic values, covering physical and mental spatial dimension and beginning-ending time space. Various symbols at its building represent religious, philosophies and cultural values [13]. The palace is cultural heritage area and protected by the Heritage Act. Especially the philosophical axis, in which the palace is one of its main components, is protected by the Provincial Regulation number 6/2012. Following the protection, the government uses the heritage for various purposes: the source of education, economy and identity. As tourism activities increase, currently the Yogyakarta Palace and its surrounding area becomes a melting point between local people, visitors, locality and globalization [14].

Presently, many cities spend more and more in cultural program as well as large infrastructure projects, which are supposed to be drivers of sustainable development. Cities allocate budget in cultural facilities and events, and in the preservation of their historical heritage. Some cities have progressed more than others to develop their cultural sectors into full stimulants for economic growth [15].

Modern tourists are becoming more mindful of the necessity of applying the principles of sustainable development in daily life, so they will express same preferences during their stay in chosen tourist destinations. Except for its ecological and financial advantages, use of renewable energy sources in the hospitality industry and tourism directly plays important role to increase competitive advantages of tourist suppliers [16]. There are many positive synergies between hotel industry and renewable energy sources producing many economic, environmental and social benefits. Development of energy tourism provides differentiation of the current tourist product attracting more environmentally sensitive tourists. The energy tourism has been already successfully developed in some European territories [17]. Renewable energy sources can be considered an inviting element within the industrial tourism and, in some cases, have ability to increase the number of visitors to the
area, mainly due to its modern design, proportions, eco-image and, in certain regions, due to its uniqueness [18].

There are worthy examples that demonstrate the enormous potential of integrating PV elements into historical buildings. However, the situation could be problematic when PV systems will be installed in such buildings due to their cultural and social value, which is likely to be higher than its market value [19]. Historically significant buildings are listed on local, national or international register providing certain degree of protection. Any physical alteration, including repairs, additions, refurbishment, energetic renovation, etc. to these important properties require review and approval by the corresponding official body. Furthermore, this option has not been often properly utilized yet because of psycho-social barriers and lack of information [20]. Refurbishment of historic dwellings is a complex task which requires implementation of highly aesthetical and functional techniques to comply with heritage protection law requirements. Renewable energy and particularly PV technology seem controversial in terms of integration into the historic building envelope.

The use of solar energy in a building of cultural-heritage value is an issue bringing the trade-off between aspects of use and preservation to a head. The management of the built cultural heritage should strive to ensure its posterity to future generations. Since the value categories of buildings are mutually dependent, long-term use and preservation require a management process that takes their economic, ecological and social values into consideration [21].

Among the first steps to overcome barriers, is to better understand the processes for both, historic preservation and solar PV project implementation, and to encourage working with professionals in each sector to receive appropriate support and guidance [20].

5. Conclusions
The Yogyakarta Palace and its surrounding area has valuable capacity to produce the electricity by applying the PV technology. Installation of the PV in this heritage area should be conducted by seriously considering architectural aspect and related regulation. It will also probably need zonation which determining buildings which can be equipped by the PV. Moreover, installing PV in a cultural heritage area which is center of culture deeply rooted representing religious, philosophies and cultural values will face complex challenges. In such delicate issue of PV implementation, the mapping and installation works would be far simpler tasks compared with the required intensive socio-culture inclusive process. Considering these delicate issues, the PV could be installed not in main buildings of The Palace, but in other surrounding buildings.

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