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GIS-based Dimensionless Assessment of Distributed Rooftop PV in Chinese Residential Communities

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Abstract

For the purpose of applicable regional assessment of the residential roof-mounted PV, a di-mensionless estimation based on the multi-criteria database is carried out in this paper. With Energy-Economic-Environment relevant factors incorporated in GIS, a dimensionless index was protocoled as the regional substitution rates of distributed rooftop PV (RSR-DRPV) for typical residential communities. This model reveals the potential quantitatively and spatially in forms of queryable interpolated GIS mappings, considering both supply and demand sides. Results indicated that the distribution of urban RSR-DRPV was in accord with that of solar resources. However, the rural RSR-DPVR tended to be equally distributed in China mainland, except for the eastern coastal regions with higher ranges. Policy implications were also given regarding quantitative magnitude and subsidy levels. This evaluation was conducted at community scale, and it can be taken as reference when establishing located subsidy levels for urban and rural areas respectively at planning stage.

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Keywords: distributed rooftop PV; substitution rate; GIS mapping; residential communities

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1. Introduction

On request of the U.S. - China Joint Announcement on Climate Change [1], China promises to increase the share of non-fossil fuels occupied in primary energy consumption to around 20% by 2030. Due to the advantages of short energy payback period (0.8 - 3 years) and steady per-formance, the distributed rooftop PV (DRPV) systems are intensively considered in both the newly-built and existed residential buildings, especially when considering the benefits of lowering down the peak power demand and avoiding the transmission procedures [2]. However, there are no applicable referenced indicators for planners to decide the potential of DRPV applied in a certain community [3].

Researches of DRPV potential focus more on the regional potential instead of a stand-alone PV generator [4]. For a DRPV, attentions are paid mostly on two aspects namely: 1) how to identify the application area; 2) what indicators can be used. Firstly, in terms of the area iden-tification, Horváth [5] classified buildings based on roof characteristics and other geometric factors on building typology. Ayompe et al. [6] assessed the energy generation potential of PV by satellite-derived solar radiation datasets. Secondly, when it comes to the assessment indicators, however, many researches were confined to aspects of power generation potential, radiation levels or fitting suitability, such as the indicators of stability degree, optimal period, peak sunshine hours and solar radiation. For example, Sun et al. [7] evaluated regional potential by an indicator of electricity generation, with the help of a solar radiation tool embedded in GIS. Castillo et al. [8] identified the potential mismatches between fund allocations and actual regional suitability, with solar radiation and other geographical factors. Moreover, due to the powerful abilities of spatial management and multi-criteria superposition, GIS (Geographic Information System) has been adopted as a crucial tool to illustrate the assessment results [9]. Thus, solar resource evaluation and adaptability can be achieved with high-resolution mappings [10].

It should be noticed that an indicator considering only the supply side, could not provide suf-ficient references for policy decision-makers and the planners of PV projects. This is because for a planned community, the planning indexes are usually defined as occupied proportions of energy gained from renewable energy and low-carbon technologies, in order to go with the regional sustainability regulations in LEED ND [11], BREEAM Communities and so on. In this paper, with Energy-Economic-Environment (3E) factors, the community-scale models were established for urban and rural communities, based on GIS platform.

Nomenclature

$\eta_{PV}(t)$	real-time conversion efficiency , %
$E_{PV}(t)$	real-time monitored real-time electric power generation, kWh
A_{PV}	area of panels, m^2
η_{mono}, η_{poly}, η_{thin}	conversion efficiencies of monocrystalline silicon, polycrystalline silicon and thin film panels
RQ_M	modified annual radiation quantity, kWh
RSR-DRPV	regional substitution rates of distributed rooftop PV
3E	Energy-Economic-Environment factors

2. Methods

2.1. Auxiliary experimental testing and modification

In order to estimate the modified hourly radiation quantity ($\sum_j \sum_k RQ_{jk}$), an experimental platform was performed to find out the dynamic relationship between the conversion efficiency and the solar radiation intensity (RI) of three kinds of PV panels namely: Monocrystalline silicon (MS), Polycrystalline silicon (PS) and Thin film (TF). The real-time data series were dealt with by Eq. (1), and formulas of conversion efficiency were fitted as Eq. (2) [12]. Thus the real electric power generation (EPG) can be obtained.