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Photovoltaic techno-economical potential on roofs in regions and islands: The case of the Canary Islands. Methodological review and methodology proposal

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ABSTRACT

The literature review shows a wide range of methodologies aiming at determining the photovoltaic (PV) potential. Very often, the methodology scale is too large (continents, countries or large regions) or too small (cities) or it is based on specific and non-commonly available software tools. This is why the proposed methodology to determine the PV roof potential in regions and/or islands can be useful. This methodology has been applied to the Canary Islands. Firstly, the available roof area for PV systems is determined, based on the total roof surface (using real data from the Spanish Cadastre) and utilization factors according to the municipality type. The methodology proposed to calculate the available roof surface is then compared to other well-known methods, including potential improvements using Geographical Information Systems. Secondly, the mean annual global solar radiation per municipality on inclined surfaces has been determined. To do so, a review of different methodologies has been assessed in a comprehensible manner, seeking for the ones that provide accuracy and simplicity. Thirdly, the yearly PV production per municipality has been calculated. For this, a step-by-step method to calculate the PV system efficiency, based on existing literature, has been detailed. Three different scenarios depending on the shared use of the available roof surface are defined and the corresponding PV production is calculated. A sensitivity analysis is also included, analyzing PV production in two cases: depending on back ventilation of the roof-mounted PV systems and on PV cell type (poly-crystalline to mono-crystalline). Finally, an economic assessment based on cost-resource curves is carried out. The spirit of the paper is to develop a methodology based on accuracy and, at the same, simplicity, understanding such as a method where all the calculations can be easily done using pen and paper, calculator and common office software programs.

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1. Introduction

There is a double motivation that led to this research. On the one hand, the need to determine the building integrated photovoltaic (PV) potential in the Canary Islands and, on the other hand, the need to develop a methodology adapted to the regional/island scale that can be carried out utilizing commonly available software programs.

1.1. Methodological review

One of the most important aspects to be considered to determine the PV building potential is the size of the area to be studied. Very often the same techniques cannot be applied at local, regional or continental scale [1]. For instance, it may be possible to quantify the shadow effects among buildings of a city with a digital three-dimensional model [2] but this is not a practical option when the scope of the study is a whole continent. For similar reasons, homogeneous or average data are usually considered a first approach [3] for large-scale studies, which is obviously inaccurate but inexpensive indeed.

Several authors have developed different methodologies to determine the PV potential on roofs [1,4–21]. One of the key points to determine which methodology should be used is the scale of the study. For small regions or islands, the literature review does not provide accurate and inexpensive methods that could be applied obtaining reasonable results. Very often the scale considered in the articles is too large: continents [10,11,18,19], countries [1,12,20] or large regions [1,4,8,21]; or too small: cities [9] or urban areas [5–7,13–17]. This is why the methodology proposed within this study can be useful to estimate the PV potential on roofs in territories as small regions/islands.

Another important aspect to determine the method to be applied is the analysis of the data that are available. Therefore, scale and available data will determine which method can be used.

The main difference among the methodologies in the literature review concerns the method used to determine the roof area. Mainly three different types of methods could be identified.

1. Methodology based on the determination of the ratio roof surface per capita. The total roof area is calculated then by multiplying this ratio by the total population of the targeted area. The ratio is calculated examining a sample of the targeted area. These methodologies usually differ on how to determine and/or analyze the sample.
2. Methodology based on establishing a correlation between the population density and the roof area (a minor part of the articles reviewed uses this method).
3. Methodology based on computing the total roof area of the target region. There are some examples of this type of methodology in the literature review. However, this methodology is being increasingly used in the last years, particularly since GIS has become a common tool.

1.2. Regional considerations

The Canary Islands are seven islands belonging to Spain but located in front of the Western coast of Africa (parallel 28). This Archipelago is highly dependent on external energy sources; nearly 98% of the primary energy consumption is based on imported oil brought to the islands by ships. Speaking about electricity, this percentage reached the 94% [22] in 2010. The Canary Islands have no conventional energy sources, but they have plenty of renewable energy resources, mainly wind and solar.

For the Canary Islands it is really important to increase the level of energy self-sufficiency. This can only be reached through the deployment of renewable energy sources (RES). RES are