Large-scale rooftop solar photovoltaic technical potential estimation using Random Forests

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HIGHLIGHTS

- Rooftop photovoltaic potential is quantified in (200 × 200) m² pixels in Switzerland.
- Geographic Information Systems (GIS) tools are used for data processing.
- Random Forests are used to estimate solar and urban variables in the whole country.
- Prediction Intervals are computed to measure the uncertainty of the estimations.
- The rooftop PV production can cover 25% of Switzerland's demand in 2017.

ABSTRACT

Photovoltaic (PV) panels are a very promising technology that answers part of the increasing need for global renewable energy production, particularly in urban areas. We present a novel methodology combining Geographic Information Systems (GIS), solar models and a Machine Learning (ML) algorithm, Random Forests, to estimate the potential for rooftop PV solar energy at the scale of a country. We use a hierarchical approach which divides the computation of the final potential into several steps. Each step is reached by estimating multiple variables of interest using widely available data, and combining these variables into potential values. The method for estimating each variable of interest is as follows: (1) collect all the data related to the variable, (2) train a Random Forest model based on the collected data and (3) use the model to predict the variables in unknown locations. The variables of interest include available area for PV installation on rooftops, shape, slope and direction of rooftops, global solar horizontal and tilted radiations, as well as shading factors over rooftops. The study focuses on Switzerland and provides the rooftop PV technical potential for each (200 × 200) [m²] pixel of a grid covering the entire country. The methodology, however, is generalizable to any region for which similar data is available and could therefore be useful for researchers, energy service companies, stockholders and municipalities to assess the rooftop PV capacity of the region. Prediction Intervals are also provided for the different estimated variables, in order to measure the uncertainty of the estimations. The results show that Switzerland has a large potential for rooftop PV installations. More specifically, for roofs orientated at ±90° from due south, the total estimated potential PV electricity production is about 16.29 TWh/year, which corresponds to 25.3% of the total electricity demand in 2017.

1. Introduction

Switzerland has ambitious goals for increasing its use of renewable energy and reducing CO2 emissions. In particular, the Swiss Energy Strategy 2050 aims at phasing out of nuclear energy by 2035 and a possible 50–80% reduction in CO2 emission by 2050. These aims can partly be reached through a great increase in the production of renewable energy and associated development of grid and storage capacity. One way to do so is building large solar farms in rural areas. Another, and complementary way is to increase the on-site solar-energy production in urban areas, that is, decentralized electricity production through photovoltaic (PV) technology on the building rooftops. Decentralized PV electricity production widely regarded as contributing favorably to environmental, economic, and social aspects of urban
sustainability. Buildings rooftops within urban areas have always been interesting locations for PV system installation. However, developing an efficient method for finding and evaluating suitable roofs for the optimal placement of PV systems remains a challenge, particularly at a large scale. Taking the advantage of geospatial data and computational methods is the first step towards accurate solar potential estimation. Several methods, at different scale of study, have been proposed for estimating the rooftop solar PV potential. While many studies focus on...
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