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Geo-enabled decision support system for potential clean energy mix for Bali, Indonesia

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Abstract

Five types of clean energy sources have been assessed, and spatial distribution mapped for energy mix analysis using *desa*, a village or the smallest government administrative unit in Indonesia, as the unit of analysis. The results show that the total technical potential of clean energy in Bali is 100,664 GWh/yr. They show that there is great potential to enhance the share of clean energy in electricity generation, and meet demand projected to be 4,993 GWh/yr. in Bali in 2019. These results can be used for policy analysis to help Indonesia to meet, and even exceed, the targeted 23% share of clean energy in total power generation by 2025, establish mini/micro gird power generation plants, and formulate feed-in tariffs for the main electricity grid.

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Keywords: Clean Energy, Potentiality, Decision Support System, GIS, Mini/micro Grid

1. Introduction

The Government of Indonesia aims to expand energy access to all citizens, with the provision of up to 1,200 kWh/yr per capita by 2019 from the current level of 843 kWh/yr per capita (ADB, 2015) [1]. The Government also has a plan to bolster domestic energy security by increasing the utilization of clean energy and scaling up energy efficiency. The current target is to increase the share of clean energy to 23% of all energy generated/used/distributed by 2025. The local government in Bali is particularly promoting increased clean energy use, which is one of Indonesia's tourism hubs.

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There is appetite among developers, investors, and researchers to develop viable solutions to tap clean energy from both the technical and economic aspects to fulfill the ever-increasing demand in Indonesia for electricity (ADB, 2015) [2], (Lopez et al., 2012) [3]. The availability and amount of clean energy on hand depend on the location, geophysical, and climatic conditions of a given area, among other things. It is therefore important for development and utilization of clean energy sources to quantify and map their spatial distribution. In this study, the technical potential of five energy sources – solar, wind, biomass, hydropower, and geothermal – have been estimated.

2. Materials and Methods

Geospatial and statistical data, for Bali, which is the study site, collected from secondary sources comprise the bulk of data and materials used in this study. Software employed included Quantum GIS (QGIS), a free and open source geographic information system and Geographic Resources Analysis Support System (GRASS), a plugin tool for raster data processing. These software were used for (i) data compilation, integration, and processing for the extraction of the required data, and (ii) geospatial analysis and development of required plugin tools for specific energy potentiality and suitability calculations. Topographic, accessibility, and land cover constraints were applied in the analysis of technical potential.

2.1. Topographic, political boundaries and statistical data

The base topographic data include land cover, contour and digital terrain models, road and river networks, and political boundaries (i.e., province, district, and *desa*) collected from the *Badan Informasi Geospasial* (BIG) or geospatial information agency, Indonesia. The number of households connected to the grid was obtained for each *desa* from the *Perusahaan Listrik Negara,* or state electricity company. The tabular statistical data on agriculture, plantation and forestry production, and their area in hectares was extracted and computerized from the Badan Pusat Statistics, or statistics Indonesia agency, reports from the year 2013. All the data were checked and integrated into the GIS database after editing. A *desa* is the smallest administrative unit for which population and other statistical data are available.

2.2. Energy source data

The *Energi dan Sumber Daya Mineral* (ESDM), or ministry of energy and mineral resources, has identified the existence of five sources of clean energy in Bali. These are solar, wind, hydropower, geothermal, and biomass. Data for the first four energy sources were obtained from ESDM.

For solar and wind energy, ESDM used one-degree Global Data Assimilation System data from National Oceanic and Atmospheric Administration/National Centers for Environmental Prediction and utilized the atmospheric general circulation model (AGCM) for interpolation followed by further downscaling to a 5-km resolution, with the technical assistance from the National Research Center of the Bandung Institute of Technology, Indonesia. By utilizing 1:25,000 scale topographic datasets, and with input from the Department of Public Works, Indonesia, ESDM estimated the run-of-river hydropower potential from potential-head of the delineated basins. Data for the geothermal energy technical potential for Bali was extracted from ESDM's Geological Agency estimation dataset conducted across the country.

For biomass energy, computerized tabular data on agricultural, plantation and forest production, and biomass residuals were integrated with *desa* political boundary data. Typographical errors in the names of *desas* were corrected based on the names and identification numbers of corresponding *desas* in the desa boundary layer.