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# Digitizing Renewable Energy Potential in Indonesia: A Strategic Map to Accelerate Investment

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**Abstract**

Indonesia is committed to achieving net-zero emissions by 2060 in response to the global climate crisis caused by dependence on fossil fuels. Achieving this goal depends on having reliable baseline data, especially field-validated and accessible maps showing renewable energy potential. Currently, these maps are only available in static formats, making them difficult to use. This study updates the static maps by creating an interactive geoportal to improve data transparency and accessibility. The process includes three main steps: development, integration, and validation. During development, the wind energy map is generated using the Weather Research and Forecasting Four-Dimensional Data Assimilation (WRF FDDA) model at a 5 km horizontal resolution and interpolated to a 1 km grid using ordinary kriging. The solar energy map uses a similar method, with added land suitability analysis. The hydropower map is based on the dependable flow Q90, in accordance with SNI 8396:2019. The bioenergy map includes urban waste biomass, using Net Caloric Value (NCV) data, and biomass from crops grown on degraded land. All these maps are combined into a single, publicly accessible interactive geoportal. What makes this study unique is the integration of diverse renewable energy data sources into a single national geoportal, and the first consolidated documentation and evaluation of an operational national system of this kind, something not offered by global platforms such as the Global Wind Atlas or the Global Solar Atlas, or Indonesian studies that mostly assessed a single resource type in isolation. This geoportal provides a centralized and accessible database of Indonesia's renewable-energy resources, improves the analytical basis for national and regional energy planning, is intended to reduce resource-risk uncertainty for investors, and supports Indonesia's transition from target-based renewable-energy policy toward data-driven implementation.

**Keywords:**
Critical land biomass, energy transition policy, geospatial data accessibility, investment decision-making, WRF FDDA modeling

## 1. Introduction

Energy remains a foundational input for economic activity, making the trajectories of energy demand and electricity demand increasingly interconnected, particularly as electrification expands across end-use sectors (Al-Irsyad et al., 2018). However, this growing demand is still largely supplied by fossil fuels, especially coal, oil, and natural gas, which continue to dominate the global and Indonesian energy mix and remain a principal source of greenhouse gas emissions (Muyasyaroh, 2024; Soemanto & Koestoer, 2023). Such dependence creates a dual challenge: fossil fuels provide energy security in the short term, yet their continued use intensifies climate risks, public-health burdens, and environmental degradation. In Indonesia, power-sector modeling shows that existing generation-expansion plans may remain cost-attractive in the short term but are insufficient to meet renewable-energy and emission-reduction targets without stronger decarbonization pathways (Al-Irsyad et al., 2019).

The Indonesian government has aligned its energy policy with the global emissions-reduction agenda by targeting net-zero emissions by 2060 (Pramudya et al., 2024). This commitment is reflected in national planning documents, including the National Energy General Plan (RUEN) and the National Electricity General Plan (RUKN), which emphasize reducing fossil-fuel dependence and accelerating the deployment of renewable energy (Government of Indonesia [GOI], 2017; KESDM, 2025). However, achieving this transition requires more than policy targets. It also requires reliable, spatially explicit, and accessible renewable-energy resource data to support project planning, grid integration, investment prioritization, and emissions-reduction pathways. Previous studies show that Indonesia's power-sector decarbonization depends on the ability to increase renewable generation while maintaining affordability and system reliability (Al-Irsyad et al., 2025; Umam et al., 2022). In this context, mapping renewable energy resources is not merely a technical exercise but a strategic prerequisite for translating national energy targets into bankable projects, regionally appropriate policies, and measurable decarbonization outcomes.

Indonesia's archipelagic geography makes direct and continuous resource measurement costly, fragmented, and difficult to standardize. This challenge is particularly important because renewable energy resources vary strongly by location, technology, grid condition, land availability, and local demand (Pristiandaru & Pambudi, 2019). For example, GIS-based solar assessment in Bali demonstrates the importance of spatial suitability analysis for identifying technically and environmentally feasible PV locations (Syanalia & Winata, 2018). Meanwhile, national wind-potential assessment using WRF modeling, GIS, and observational validation shows that wind-resource estimates can differ substantially depending on data source, spatial resolution, and validation method (Hesty et al., 2021a; Hesty et al., 2021b). Therefore, Indonesia needs a centralized, transparent, and regularly updated renewable-energy map that can consolidate resource information, accommodate ongoing environmental and resource-condition changes, and reduce uncertainty in national and regional energy planning.

The process of acquiring new and renewable energy data presents its own challenges because of Indonesia's territorial scale, uneven measurement infrastructure, limited human resources, and high costs of direct field measurement (IEA, 2021). These challenges can be addressed through the integration of Geographic Information System (GIS), remote sensing, modeling, and interactive web-based visualization (Nurliyanti et al., 2021). GIS has been widely applied in renewable-energy infrastructure planning, including resource-potential assessment, energy simulation, site selection, building energy-demand analysis, and impact assessment (Resch et al., 2014). Recent Indonesian energy studies further demonstrate the relevance of advanced geospatial and digital methods, including satellite-based energy-efficiency mapping, AI-driven carbon-stock estimation, and geospatial carbon-economic valuation for energy-transition planning (Briantiko et al., 2026; Inayah et al., 2026; Wijayanto et al., 2026). These studies indicate that spatial data systems can improve policy precision by linking energy-resource information with environmental, economic, and regional-development indicators.

Interactive renewable-energy maps have already been implemented globally, such as the Global Wind Atlas and Global Solar Atlas (Estima et al., 2013). These platforms provide important baseline information for wind and solar resource assessment. However, global-scale platforms often have limitations for national planning because their spatial resolution, parameter assumptions, and validation datasets may not fully represent local conditions (Davis et al., 2023). For Indonesia, such limitations are critical because project feasibility is shaped by local topography, land-use restrictions, grid access, electricity demand, permitting conditions, and technology-specific constraints.

We address that need by developing an interactive renewable-energy map for Indonesia covering wind, solar, hydro, and bioenergy resources. Several studies in Indonesia and elsewhere have already developed similar web-based renewable-energy maps. Nizamuddin et al. (2017) built a Web GIS based on open-source software (GeoServer, PostgreSQL/PostGIS, QGIS, GeoExt) to display renewable-energy and mineral potential. Its functionality, however, remains limited to presenting and browsing information (geothermal and hydropower) within a single province, and does not extend to planning analysis or investment feasibility. Setyowati et al. (2018) described ESDM One Map Indonesia, the Ministry of Energy and Mineral Resources (MEMR)' WebGIS that integrates hundreds of thematic maps across subsectors (oil and gas, minerals and coal, electricity, renewable energy and energy conservation, geology) as an implementation of the One Map Policy. Its focus, however, is the standardization and integration of geospatial data across units and ministries rather than the analysis of renewable resource potential for planning and investment; the authors also noted problems of inconsistent data formats and the low responsiveness of data owners in updating their data. Fournier et al. (2023) developed the Community Solar Opportunities Map (CSOM) to identify and prioritize community solar sites in Los Angeles County. The map is built on utility grid-capacity data, which makes it difficult to replicate in other regions. Kiseleva et al. (2023) reviewed the global development of renewable-energy GIS and presented the "RES of Russia" GIS, which provides interactive maps of solar, wind, geothermal, and bioenergy resources at the national scale. For Lesotho, Pasanisi et al. (2021) produced wind, solar, and hydrological potential maps based on 30 years of WRF simulations at 1 km resolution, subsequently embedded in a WebGIS platform (QGIS Server + Lizmap) containing more than 120 data layers. Ramafikeng et al. (2025) developed a web platform integrating rooftop solar potential, urban wind, biomass, and wind-farm site suitability analysis (MCDA-AHP) for the Atlantis area of Cape Town. Fish and Calvert (2016) conducted a competitive analysis and content analysis of twelve interactive solar energy web maps in cities across the United States. Their findings recommend platforms that are scalable and plug-and-play, and that are designed for multiple stakeholder groups (utilities, urban planners, developers).

Previous studies reveal two consistent patterns. First, interactive GIS for renewable-energy analysis is generally built at the local or sub-national scale and for only one or two types of resources (Fish & Calvert, 2016; Fournier et al., 2023; Nizamuddin et al., 2017; Ramafikeng et al., 2025). As a result, such interactive GIS is difficult to use as a basis for national energy planning. Second, multi-resource integration at the national scale is generally undertaken by countries with small and homogeneous territories (Pasanisi et al., 2021). ESDM One Map Indonesia has integrated geospatial data across energy subsectors, but its orientation is one map policy standardization and cross-subsector thematic inventory (Setyowati et al., 2018). ESDM One Map Indonesia does not provide a ready-to-use analytical basis on renewable-energy potential for planners and investors.

Thus, the novelty of this study lies in its integration of multi-resource renewable-energy data into a centralized, accessible, and nationally relevant geoportal designed for planning and investment decision-making. Unlike static maps, which often require formal data requests, limit user interaction, and quickly become outdated as environmental and resource conditions change, the interactive geoportal allows stakeholders to explore renewable-energy potential directly through a web-based portal whose service-based architecture allows individual layers to be replaced or extended without rebuilding the platform. Our main contributions are fourfold. First, we provide a centralized and accessible database of Indonesia's renewable-energy resources. Second, we improve the analytical basis for national and regional energy planning. Third, we reduce resource-risk uncertainty for investors. Fourth, we support Indonesia's transition from target-based renewable-energy policy toward data-driven renewable-energy implementation.

## 2. Methods and Materials

### *2.1 Methodology*

The methodology for developing a renewable energy potential map consists of three main stages: the development stage, the integration stage, and the validation stage, as shown in Figure 1. Within the development stage, each energy type follows a sequential workflow of data collection, data processing, resource modeling (including dynamical downscaling for wind and solar), spatial interpolation, and visualization; these sub-steps are shown as connected boxes in Figure 1. The development stage includes the creation of five energy potential maps: wind energy, solar energy, hydropower, urban waste biomass, and biomass from crops on degraded land. Each type of energy has its own processing workflow, which ends with visualization using ArcGIS software, and all results are then combined in the integration stage.

The development of the wind energy potential map begins with dynamical downscaling of global climate data using the Weather Research and Forecasting Four-dimensional Data Assimilation (WRF FDDA) method to a spatial resolution of 5 km. The extracted wind speed data from WRF FDDA are then verified using field observation measurement data. The speed data were validated against field observation measurements for 2001–2015 prior to spatial (kriging) and vertical interpolation to 50 m. Field observation data used to validate the WRF FDDA wind and solar outputs were obtained from a total of 122 observation locations distributed across Indonesia, comprising 11 measurement sites operated by MEMR and 111 observation stations operated by the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG). The MEMR's observations covered the 2001–2015 period, while available BMKG records within the same modeling period were also used for verification. Each observation location was matched with the nearest WRF FDDA grid cell at hourly intervals. The model results and measured values were compared as aligned time series at the available temporal resolution. Qualitative verification was conducted by examining the agreement between the temporal patterns of the model results and observations, whereas quantitative model performance was evaluated using the root mean square error (RMSE) and correlation coefficient.

The dynamical downscaling process for solar energy uses a similar approach to wind energy, namely through WRF FDDA to achieve a spatial resolution of 5 km. The extracted solar radiation from WRF FDDA is then averaged over daytime periods based on local time in each region. The subsequent steps include spatial interpolation to a 1 km resolution using the kriging method, calculation of suitable land area for solar power plants, estimation of potential capacity, calculation of potential energy production, and visualization using ArcGIS.

The hydropower potential map focuses on calculating Run-of-River potential, while reservoir or dam systems are calculated separately. The potential is calculated using the dependable flow Q90 in accordance with SNI 8396:2019, with a minimum head of 10 meters and a maximum penstock length of 1,000 meters. Additional parameters include a minimum dependable discharge of 0.01 $m^3/s$, gravitational acceleration of 9.8 $m/s^2$, and system efficiency of 0.6, with results visualized using ArcGIS.

The bioenergy potential map is divided into two parts. The first part is urban waste biomass, which is determined based on waste generation data. Net Caloric Value (NCV) is used to calculate thermal potential, which is then converted into kWh. The next stage is converting kWh into MWe, assuming a capacity factor of 80% and thermal efficiency of 30%. The final estimated results are visualized using ArcGIS. The second part is biomass from crops on degraded land. The mapping process begins with extracting data on degraded land and forest estate areas. These two areas are overlaid by considering terrain contours, soil type, administrative boundaries, and crop growth conditions. The results of this spatial analysis are then visualized using ArcGIS.


**Figure 1.** Flowchart of the renewable energy potential mapping methodology.

The integration stage comprised data compilation, standardization, storage, map-service publication, and web-application development. API integration enables the front-end interface to dynamically request and render specific data layers from GeoServer based on user interaction, such as layer selection and location-based queries. It distinguishes the geoportal's interactive functionality from a static image or printed map even though the underlying resource data are not continuously changing. Before publication, datasets from different sources were transformed into a common spatial-reference framework using the Geographic Coordinate System with the WGS 1984 datum. The datasets were harmonized in terms of spatial format, attributes, classification, and geodatabase structure, with positional and topological consistency checks applied where relevant. The standardized datasets were then organized and stored in an enterprise geodatabase using PostgreSQL as the database management system. They were subsequently published through the ESDM geoportal's map-service infrastructure in formats such as WMS, WFS, and KML. ArcGIS Server and GeoServer served as spatial-service publishing components. Although the underlying renewable-energy potential layers were precomputed, the map-service integration enabled the web application to interactively display selected layers, adjust map views, inspect spatial information, and support simple spatial analyses.

### *2.2 Data*

The development of renewable energy potential maps utilizes various spatial and observational data sources that cover different time ranges for each type of energy. Input data for the WRF model in wind energy potential consist of three main sources. First, wind speed data from the National Centers for Environmental Prediction Final Operational Global Analysis (NCEP FNL) (NCAR, 2026) with a spatial resolution of 1° × 1° for the period 2001–2015. Second, wind speed data from the Cross-Calibrated Multi-Platform (CCMP) (Wentz et al., 2015) with a spatial resolution of 0.25° × 0.25° over the same period. Third, field observation measurement data for the period 2001–2015, which are used to validate the WRF model results. The WRF input data for solar energy potential use the same data sources as wind energy potential.

Additional data include annually updated land cover data from the Food and Agriculture Organization (FAO, 2025), monthly-updated World Database of Protected Area (WDPA) data from the United Nations Environment Programme (UNEP, 2026), and administrative boundary data from the Geospatial Information Agency (BIG, 2026). These additional datasets are used to calculate the area of land available for solar power plant development. Global datasets were used at this stage due to their consistent national-scale coverage and ready-to-use grid format; however, these do not carry the legal land-use status assigned under Indonesian spatial planning regulations. Mapping solar potential in a GIS environment by integrating irradiance estimates with land-suitability and protected-area constraints is consistent with prior Indonesian solar resource assessments (Rumbayan et al., 2012).

The development of the micro-hydropower potential map uses three main types of data. Elevation data are obtained from the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) by NASA (2026a), with a spatial resolution of 30 meters. Rainfall data are sourced from the Tropical Rainfall Measuring Mission (TRMM) 3B43, a joint mission by NASA and the Japan Aerospace Exploration Agency (JAXA), with a spatial resolution of 0.25° × 0.25° for the period 1983–2018 (NASA, 2026b). In addition, data on hydropower plant development plans from the Ministry of Public Works and Housing (PUPR) for the period 2015–2027, Pranoto et al. (2021), and Aminuddin et al. (2022) is used to identify dam locations that have been or will be constructed. Using slope data from SRTM DEM and rainfall data from TRMM as the main layers in a GIS overlay is the usual method for mapping micro-hydro potential across Indonesia. This is because there are not many ground hydro-meteorological stations available (Pranoto et al., 2021).

Bioenergy potential data are categorized into two types of potential maps. Mapping of urban waste biomass potential uses data on waste generation and composition from the Ministry of Environment and Forestry (MEF, 2025), along with Net Caloric Value (NCV) data obtained from laboratory tests. NCV data are used to determine the net calorific value of various types of waste as a basis for calculating the thermal energy potential of these wastes. Municipal solid waste and its caloric value represent key bioenergy sources prioritized for Indonesia. The assessment of biomass potential from crops on degraded land utilizes the official national LULC and forest-area reference, i.e., forest-area and degraded-land data from the same ministry, which serve as the foundation for spatial overlay analysis to identify areas suitable for bioenergy crop development. The application of spatial overlay to align production forest and degraded land with appropriate bioenergy species is consistent with the degraded-land mapping framework established for Indonesia (Jaung et al., 2018).

## 3. Results and Discussions

### *3.1 Static Map*

Figure 2 presents the wind energy potential map generated from a dynamical downscaling process using the WRF FDDA model at a 5 km horizontal resolution, interpolated to a 1 km grid, at a height of 50 meters. Wind speed outputs from WRF FDDA were validated against field observation measurements for 2001–2015 prior to spatial (kriging) and vertical interpolation to 50 m. This observational validation step allows the resulting speed classes to be interpreted as representative of near-surface wind conditions. Wind speeds are categorized into two categories: 4–6 m/s, shown in green, and above 6 m/s, shown in red. The highest wind potential is concentrated along the southern coasts of Java and Kalimantan, South Sulawesi, West Nusa Tenggara, East Nusa Tenggara, and several locations along the southern coast of Papua. Wind speeds of 4–6 m/s are more broadly distributed, encompassing most coastal regions of Indonesia's major islands, including Sulawesi and Maluku. These regions represent promising candidates for wind power plant development.

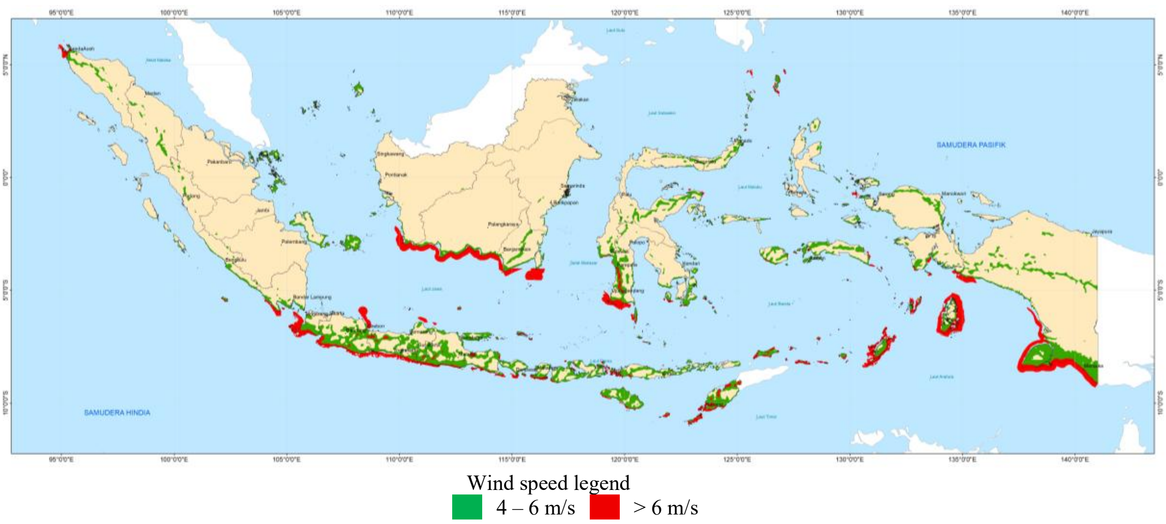


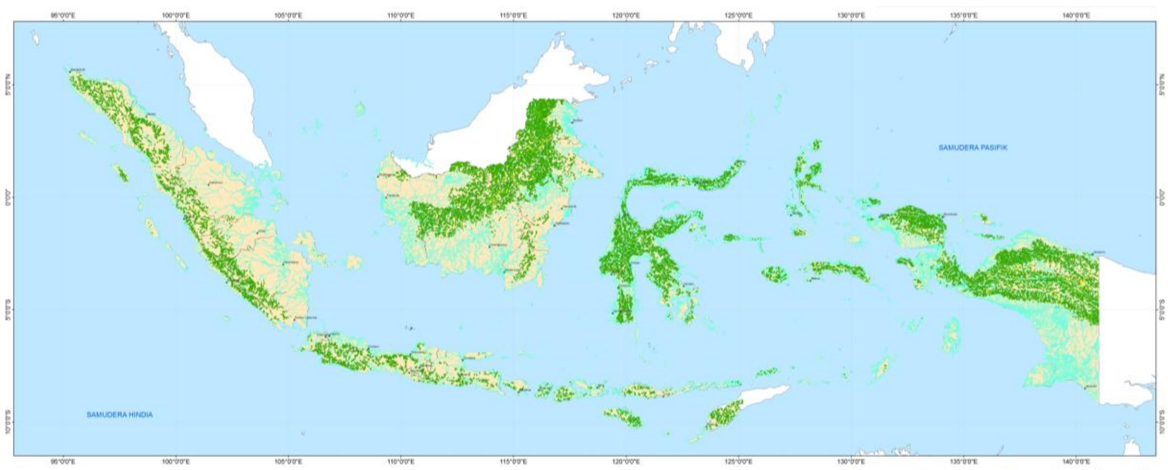

**Figure 2.** Wind energy potential map.

Figure 3 presents the solar energy potential map. Solar radiation values were derived from the same validated WRF FDDA outputs used for the wind assessment, averaged over daytime hours per local time zone, then constrained by land-suitability and protected-area exclusion (FAO land cover; WDPA). The spatial distribution of solar radiation across the country, under the specified scenario, begins at 3.75 kWh/m²/day in residential areas, bare land, and savanna that are not classified as protected areas. Solar radiation is categorized into five classes, ranging from 3.75–4.20 kWh/m²/day up to a maximum of 5.01–5.27 kWh/m²/day, with the highest value indicated in red. Regions with the highest solar radiation potential, exceeding 5.00 kWh/m²/day, are located in East Nusa Tenggara, parts of South Sulawesi, and several regions in Papua. Overall, eastern Indonesia exhibits higher solar radiation intensity compared to the western regions, suggesting it is a priority for large-scale power plant development. Because the land-suitability screening relies on global land-cover and protected-area datasets, this layer should be read as a resource-screening indicator.

Solar intensity legend (in kWh/m$^2$/day)
3.75 – 4.20 | 4.21 – 4.60 | 4.61 – 4.80 | 4.81 – 5.00 | > 5.01 – 5.27

**Figure 3.** Solar energy potential map.

Figure 4 presents the hydropower potential map, integrating data on river discharge potential for Run-of-River systems and possible dam locations. Potential is estimated from the dependable flow Q90 (SNI 8396:2019) derived from SRTM DEM slope and TRMM 3B43 rainfall data (1983–2018), applying a minimum head of 10 m, maximum penstock length of 1,000 m, and system efficiency of 0.6. Known/planned dam locations were cross-checked to avoid double-counting ROR and reservoir potential. Hydropower potential is categorized by power output in kilowatts, from less than 100 kW to more than 5,000 kW, with a color gradient ranging from light yellow to dark green. Areas with the highest hydropower potential are identified in Kalimantan and Papua Islands, as indicated by the dominance of dark green on the map, which corresponds to the presence of large rivers with high discharge in these regions. Sumatra Island also shows significant hydropower potential, especially within the Bukit Barisan mountain range, where significant topographic relief supports the development of both large-scale and micro-hydropower plants.



Hydro power legend (in kW)
5 – 100 | 100 – 200 | 200 – 600 | 600 – 1,000 | 1,000 – 10,000 | 10,000 – 50,000 | > 50,000

**Figure 4.** Hydro energy potential map.

Figure 5 presents the biomass potential map for production forest development on critical and very critical land. Potential locations were identified by spatially overlaying KLHK production-forest boundaries with KLHK critical-land classification (critical and very critical categories), following the degraded-land mapping framework of Jaung et al. (2018). No independent field validation was conducted for this layer, so results should be read as a spatial screening indicator. It maps production forest areas overlapping with critical and very critical lands as potential locations for bioenergy crop development. Very critical land is indicated in red, while critical land is shown in green, with both distributed across various provinces in Indonesia. Areas with significant land potential for biomass crop development have been identified on Sumatra Island, particularly in Riau and South Sumatra, as well as on Kalimantan and Sulawesi Islands, where extensive production forest areas overlap with critical land.

Figure 6 presents the urban waste biomass map. Point-based potential values were calculated by converting waste generation and NCV data into thermal energy (kWh), then into electrical capacity (MWe) assuming an 80% capacity factor and 30% thermal efficiency. These conversion assumptions were not independently validated against operating waste-to-energy plants and represent theoretical potential. Urban waste biomass potential is visualized based on city/regency locations using point symbols whose sizes represent the magnitude of energy potential, while critical land biomass potential is displayed as area distributions. Java Island dominates urban waste biomass potential due to its very high population density and large volume of waste generation, with major cities such as Jakarta, Surabaya, and Bandung as key contributors.

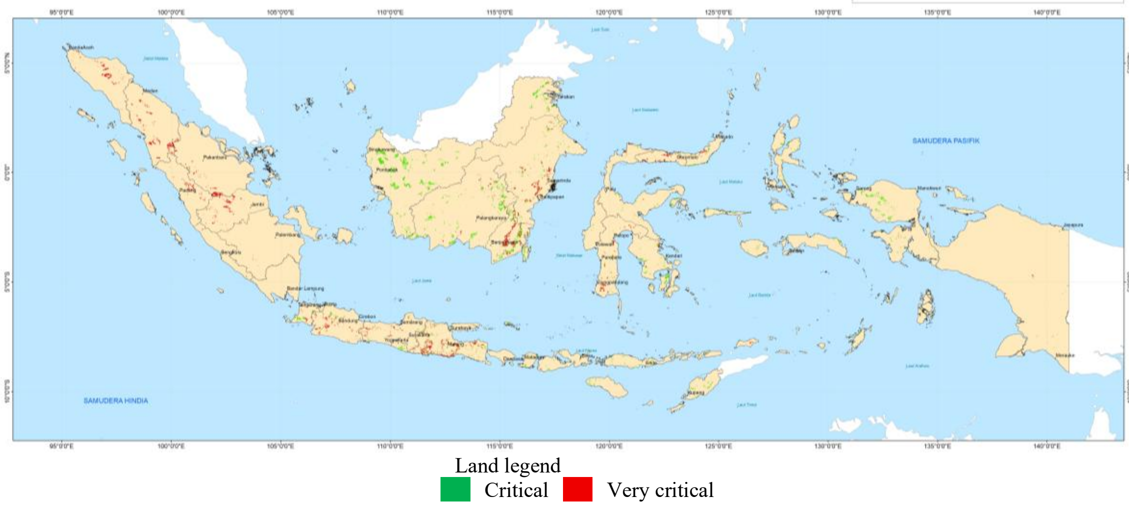



**Figure 5.** Potential map of biomass from crops on critical and very critical production forest land.

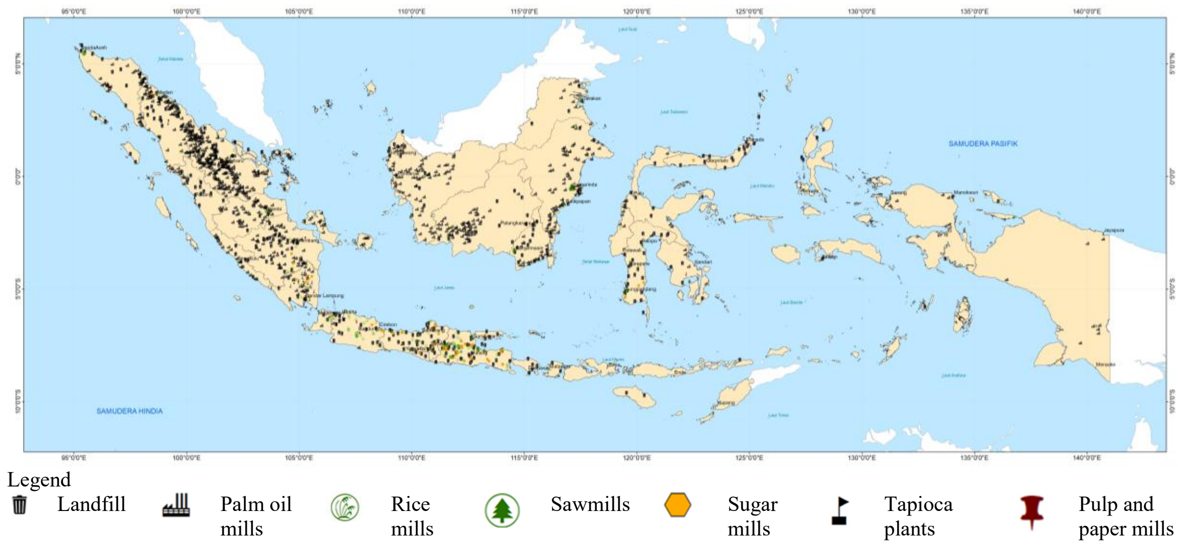



**Figure 6.** Potential map of waste biomass.

Across all five maps, different verification and validation approaches were applied according to the characteristics and availability of reference data for each energy resource. For the wind and solar components, WRF FDDA outputs were verified against available field observations through qualitative time-series comparison and quantitative statistical assessment using the RMSE and correlation coefficient. For the hydropower component, the calculation procedures and parameter selection followed the Indonesian national standard SNI 8396:2019. The bioenergy components and cross-cutting aspects of the maps were reviewed through Focus Group Discussions involving relevant experts and stakeholder institutions.

These results also indicate what a nationally modeled and locally validated dataset adds relative to global platforms. The Global Wind Atlas and the Global Solar Atlas provide single-resource layers derived from global reanalysis without assimilation of Indonesian ground observations, and without the land-suitability and protected-area screening applied to the solar layer in this study. The wind and solar layers reported here, by contrast, were produced with four-dimensional data assimilation and verified against 122 MEMR and BMKG observation stations, so that the resulting classes can be interpreted as representative of observed near-surface conditions at the validated sites. The two sources would be expected to diverge most in areas of complex terrain and in coastal transition zones, where global-resolution parameterization cannot resolve local acceleration effects. That expectation has not been tested quantitatively in this study, and a grid-cell comparison of both atlases against the validation stations is recommended as part of the next update cycle.

### *3.2 Interactive Geoportal*

All renewable energy potential maps produced in the form of static maps are then integrated into an interactive geoportal that can be accessed online by the public through the ESDM Geoportal at https://geoportal.esdm.go.id/ebtke/. The geoportal in Figure 7 displays all layers of renewable energy potential data, covering wind, solar, hydropower, and bioenergy, in a single integrated map interface overlaid on an ESRI basemap. Users can choose to display all data simultaneously or select only the specific layers needed for their analysis, for example, displaying only hydropower or bioenergy potential. This layer selection feature allows users to easily explore and compare the spatial distribution of different types of renewable energy potential in their areas of interest.

The geoportal has been validated through a series of processes involving stakeholders. From 2014 to 2015, three Focus Group Discussions (FGDs) were conducted, involving the National Institute of Aeronautics and Space (LAPAN), the Meteorology, Climatology, and Geophysics Agency (BMKG), the Geospatial Information Agency (BIG), the Bandung Institute of Technology (ITB), the Research Center for Water Resources (PUSAIR), LEN Industri company (LEN), the Indonesian Renewable Energy Society (METI/EBT Association), and the Ministry of Research and Technology (KEMENRISTEK). In this process, the basic concept was further developed based on inputs obtained through the series of FGDs. In 2016–2017, result testing was carried out in collaboration with the National Energy Council (DEN), the MEMR Planning Bureau, and the Minister's Special Staff. This stage included an evaluation of both the methodology and the technical aspects of map development. After completing the testing phase, the map was soft launched by the Minister of Energy and Mineral Resources in December 2015 in Aceh and officially launched by Vice President Jusuf Kalla at the Bali Clean Energy Forum (BCEF) event in February 2016 in Nusa Dua, Bali. Moreover, the map has been used as a basis for energy planning, as stipulated in Presidential Regulation Number 22 of 2017, and as a reference for selecting development locations by the State Electricity Company (PLN) and investors.

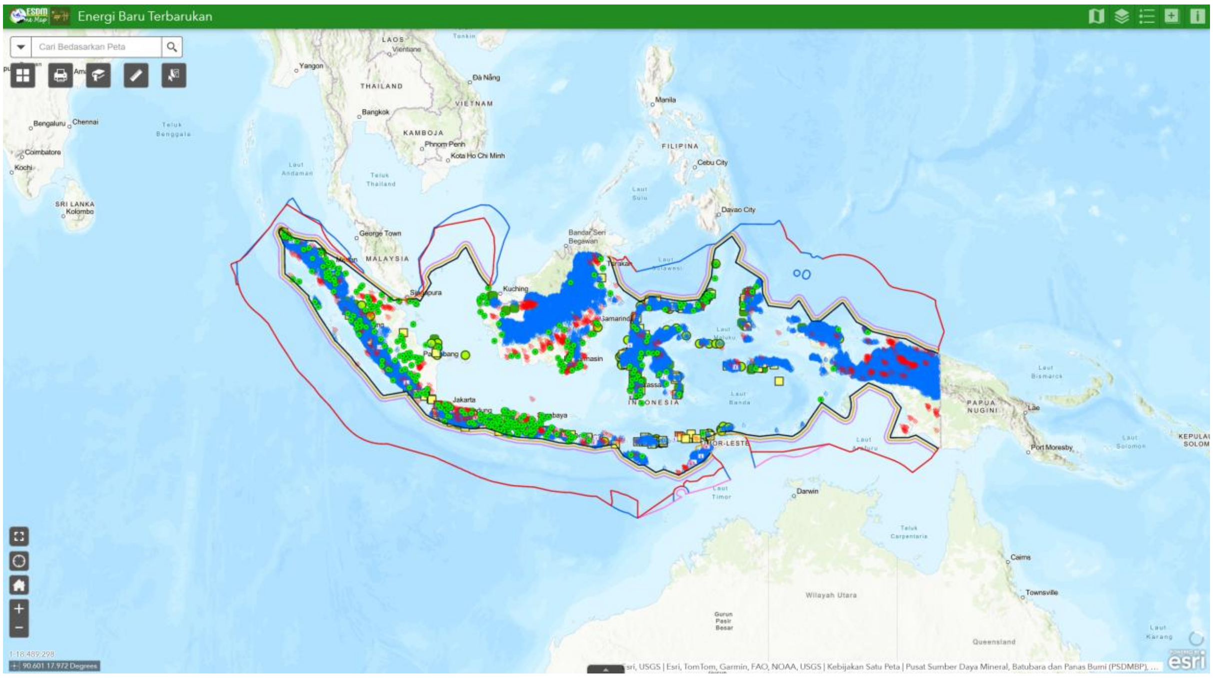



**Figure 7.** Renewable energy interactive map.

The geoportal significantly improves accessibility to renewable energy potential data by providing it in an interactive digital format. This platform enables investors and developers to efficiently identify suitable locations for renewable energy projects, thereby reducing initial investment costs and accelerating project initiation, thereby enhancing investor confidence. Several utility-scale projects have subsequently been developed in areas the geoportal identifies as high-potential, including the Sidrap Wind Power Plant (75 MW + 50 MW), the Jeneponto Wind Power Plant (72 MW), the Tanah Laut Wind Power Plant (150 MW), and the Sumbawa Solar Power Plant (1 MW). These cases are presented as chronological illustrations, since siting decisions also reflect grid access, land acquisition, tariff arrangements, and developer-commissioned measurement campaigns. In addition, community groups, including grant recipients, also utilize the geoportal to more effectively plan infrastructure that addresses local energy requirements.

The utilization of renewable energy potential maps is evaluated using several indicators, including time and frequency, program aspects, and activity aspects. From the time and frequency perspective, user profiles and the purposes of map usage are periodically monitored. From the program perspective, monitoring and evaluation include publication on the MEMR website and geoportal. Meanwhile, from the activity perspective, detailed map development is continuously carried out based on requests from local governments, non-profit organizations through grant programs, and private developers or Independent Power Producers (IPPs).

The geoportal is protected by intellectual property rights, including 16 copyrights related to thematic maps of micro-hydro, solar, and wind energy potential registered between 2014 and 2017, each valid for 50 years. In addition, three patents have been granted: (1) Method for Developing a Solar Energy Potential Map of Indonesia with a 5 km Resolution (P00201702638), (2) Method for Developing a Wind Energy Potential Map of Indonesia with a 5 km Resolution (P00201702639), and (3) Method for Developing a Micro-Hydro Energy Potential Map Using Rainfall Data with a Hydrological Distribution Model (P00201705315). The dataset generated from this geoportal serves as a basis for the preparation of the National Energy General Plan (RUEN), especially for wind, hydro, and solar energy maps, and is formally recognized in Presidential Regulation Number 22 of 2017.

### *3.3 Policy Implications*

The geoportal assists both central and regional governments in addressing energy needs. Policymakers leverage the platform to inform national energy planning using location-specific data. It facilitates the government's role, as policymakers, in setting regulations and targets for the deployment of renewable (non-fossil fuel) power plants, while also supporting the private sector and Independent Power Producers (IPPs) in making investment decisions in the renewable energy sector. By streamlining these processes, the geoportal accelerates the expansion of Indonesia's renewable energy sector, thereby supporting economic growth and job creation. Furthermore, it aligns with the government's open data objectives for the energy sector and advances the transition towards renewable energy in Indonesia.

The relationship between data accessibility and renewable-energy investment has been widely discussed in the literature. Accessible and transparent data can reduce information asymmetry, improve investor confidence, and support early-stage project screening, especially in sectors exposed to curtailment risk, policy reversal risk, price risk, resource risk, and technology risk (Egli, 2020). In Indonesia, renewable-energy investment studies emphasize that private-sector participation depends not only on financial incentives but also on credible information along with stable policy instruments and clear project-development pathways (Boediman et al., 2021; Durohman & Khoirunnisa, 2026). Thus, renewable-energy maps can function as an investment-enabling infrastructure by allowing developers, policymakers, researchers, and financiers to verify resource potential before committing to more expensive feasibility studies.

## 4. Conclusions

This study aims to improve the accessibility of renewable energy potential data in Indonesia. First, static maps for wind, solar, hydropower, and bioenergy potential were developed using validated modeling approaches (WRF FDDA, Q90 dependable flow, and NCV-based thermal conversion) consistent with methods applied in prior Indonesian resource assessments (Rumbayan et al., 2012; Pranoto et al., 2021; Hesty et al., 2021a). Second, these static maps were integrated into an interactive web-based geoportal that is publicly accessible at https://geoportal.esdm.go.id/ebtke/. The novelty of this study lies in the integration of multi-resource renewable energy data into a centralized, accessible, and nationally relevant geoportal, and in the first consolidated documentation and evaluation of the methodology behind an operational national system. Unlike single-resource platforms or studies that address wind, solar, or hydro potential separately, this geoportal consolidates multiple renewable-energy resources into one nationally relevant and publicly accessible system, allowing stakeholders to explore renewable-energy potential directly without formal data requests. This work provides a centralized and accessible database of Indonesia's renewable-energy resources, improves the analytical basis for national and regional energy planning, is intended to reduce resource-risk uncertainty for investors, and supports Indonesia's policy transition from a target-based approach to a data-driven implementation approach.

The availability of this geoportal has significant policy implications in accelerating Indonesia's energy transition toward achieving net-zero emissions by 2060. For both central and regional governments, the geoportal can serve as a foundation for spatially informed national and regional energy planning. For the private sector and Independent Power Producers (IPPs), the geoportal is expected to support more efficient preliminary identification of renewable energy project locations, which may in turn contribute to reducing initial investment costs and shortening project initiation time. This is illustrated, though not causally established, by recent renewable energy projects developed in regions identified as high potential in the geoportal, such as the Sidrap, Jeneponto, and Tanah Laut wind power plants and the Sumbawa solar power plant. A more rigorous, quantitative assessment of the geoportal's effect on investment decisions, for example through investor surveys or project-timeline analysis, is recommended for future research.

However, this study has several limitations that should be considered. First, most of the data used to develop the potential maps are outdated and need updating to reflect changes in land cover, weather patterns, and infrastructure development. This gap is institutional: although the platform was designed so that individual layers can be replaced without rebuilding it, no funded and scheduled update cycle has been established. In particular, the land-cover and protected-area layers used for the solar potential assessment (FAO, WDPA) are global datasets that do not carry Indonesia's legal land-use designations. Thus, replacing these with official LULC and forest/protected-area data from the Ministry of Environment and Forestry is recommended to ensure the dashboard accurately reflects current and legally recognized national land-use conditions. Second, the current geoportal does not yet include all types of renewable energy, such as geothermal and ocean energy. Third, the field observation data used for verification cannot be considered statistically representative of all regions due to the limited density and uneven spatial distribution of ground-based wind, solar, and hydro-meteorological monitoring stations relative to Indonesia's national extent. Validation is therefore stronger in areas with denser station coverage and comparatively weaker in areas with sparse or no ground stations. Expanding the ground-monitoring network or supplementing it with additional independent satellite-derived or reanalysis datasets for cross-validation is recommended to strengthen the statistical robustness of future updates to the geoportal. Given the dynamic nature of wind, solar, hydrological, and land-cover conditions, sustaining the long-term relevance and reliability of this geoportal requires that its input data be periodically and systematically updated, its range of mapped energy types expanded, and additional parameters, such as local energy demand, grid conditions, and socio-economic factors, integrated. These improvements would result in a more comprehensive and operational potential map to support Indonesia's energy transition planning.

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## References

Al-Irsyad, M. I., Halog, A., & Nepal, R. (2018). Exploring drivers of sectoral electricity demand in Indonesia. *Energy Sources, Part B: Economics, Planning, and Policy, 13*(9-10), 383–391. https://doi.org/10.1080/15567249.2018.1538271

Al-Irsyad, M. I., Halog, A., Nepal, R., & Koesrindartoto, D. P. (2019). The impacts of emission reduction targets in Indonesia electricity systems: An energy-economy-environment model simulation. *Indonesian Journal of Energy, 2(*2*),* 118–130. https://doi.org/10.33116/ije.v2i2.42

Al-Irsyad, M. I., Quist, J., Rahayu, H. P., & Blok, K. (2025). A strategic plan for renewable energy transition in a coal dependent region using participatory backcasting: The case of South Kalimantan province in Indonesia. *International Journal of Sustainable Energy Planning and Management*. https://doi.org/10.54337/ijsepm.9826

Aminuddin, Pranoto, B., Al Irsyad, M. I., Sihombing, A. L. S. M., & Nurliyanti, V. (2022). Hybrid floating photovoltaic-hydropower potential utilization in Indonesia. *IOP Conference Series: Earth and Environmental Science, 1105*(1), 012004. https://doi.org/10.1088/1755-1315/1105/1/012004

BIG. (2026). *Batas wilayah administrasi [Administrative boundaries]*. https://geoservices.big.go.id/portal/apps/webappviewer/index.html?id=49bda2cefd3f4b92aa726300bcdb40f7

Boediman, A., Rahadi, R. A., & Nugraha, B. A. (2021). An overview of Indonesian renewable energy studies and its investment opportunities. *Indonesian Journal of Energy, 4*(2), 87–100. https://doi.org/10.33116/ije.v4i2.123

Briantiko, Z. O., Nurkarim, W., Wahyuddin, E. P., & Zulkarnain, M. (2026). Monetizing carbon emissions: Advanced strategies for optimizing carbon economic value using machine learning and geospatial analysis. *Indonesian Journal of Energy, 9*(1), 38–55. https://doi.org/10.33116/ije.v9i1.296

Davis, N. N., Badger, J., Hahmann, A. N., Hansen, B. O., Mortensen, N. G., Kelly, M., Larsén, X. G., Olsen, B. T., Floors, R., Lizcano, G., Casso, P., Lacave, O., Bosch, A., Bauwens, I., Knight, O. J., Potter van Loon, A., Fox, R., Parvanyan, T., Krohn Hansen, S. B., Heathfield, D., Onninen, M., & Drummond, R. (2023). The Global Wind Atlas: A high-resolution dataset of climatologies

and associated web-based application. *Bulletin of the American Meteorological Society, 104*(8), E1507–E1525. https://doi.org/10.1175/BAMS-D-21-0075.1
Durohman, H., & Khoirunnisa, A. N. (2026). Exploring smart renewable investment in green financial mechanism for achieving carbon neutrality: An empirical analysis of the ASEAN economy. *Indonesian Journal of Energy, 9(*1), 96–115. https://doi.org/10.33116/ije.v9i1.281
Egli, F. (2020). Renewable energy investment risk: An investigation of changes over time and the underlying drivers. *Energy Policy, 140*, 111428. https://doi.org/10.1016/j.enpol.2020.111428
Estima, J., Fichaux, N., Menard, L., & Ghedira, H. (2013). The global solar and wind atlas: A unique global spatial data infrastructure for all renewable energy. *Proceedings of the 1st ACM SIGSPATIAL International Workshop on MapInteraction*. https://doi.org/10.1145/2534931.2534933
Food and Agriculture Organization (FAO). (2025). *Land cover*. https://www.fao.org/faostat/en/#data/LC
Fish, C. S., & Calvert, K. (2016). Analysis of interactive solar energy web maps for urban energy sustainability. *Cartographic Perspectives*, (85), 5–22. https://doi.org/10.14714/CP85.1372
Fournier, E. D., Federico, F., Cudd, R., & Pincetl, S. (2023). Building an interactive web mapping tool to support distributed energy resource planning using public participation GIS. *Applied Geography, 152*. https://doi.org/10.1016/j.apgeog.2023.102877
Government of Indonesia (GOI). (2017). *Peraturan Presiden Republik Indonesia Nomor 22 Tahun 2017 tentang Rencana Umum Energi Nasional [Presidential Regulation of the Republic of Indonesia Number 22 of 2017 concerning the National Energy General Plan]*. Government of Indonesia. https://www.esdm.go.id/assets/media/content/content-rencana-umum-energi-nasional-ruen.pdf
Hesty, N. W., Cendrawati, D. G., Nepal, R., & Al Irsyad, M. I. (2021a). Wind energy potential assessment based-on WRF four-dimensional data assimilation system and cross-calibrated multi-platform dataset. *IOP Conference Series: Earth and Environmental Science, 897*(1), 012004. https://doi.org/10.1088/1755-1315/897/1/012004
Hesty, N. W., Cendrawati, D. G., Nepal, R., & Al Irsyad, M. I. (2021b). *Energy potential assessments and investment opportunities for wind energy in Indonesia* (CAMA Working Paper No. 31/2021). https://ssrn.com/abstract=3811064
International Energy Agency (IEA). (2021). *Renewable energy market update—Outlook for 2020 and 2021*. https://iea.blob.core.windows.net/assets/9ee2be30-de3f-4507-940c-ae4726c78845/Renewable_Energy_Market_Update.pdf
Inayah, I., Dzikra, K. G., Al Irsyad, M. I., Kastaman, R., Irawan, I., & Halog, A. (2026). A preliminary assessment of sustainable aviation fuel potentials from municipal, agricultural, and plantation wastes in Indonesia. *International Journal of Sustainable Energy Planning and Management*. https://doi.org/10.54337/ijsepm.10615
Jaung, W., Wiraguna, E., Okarda, B., Artati, Y., Goh, C. S., Syahru, R., . . . Baral, H. (2018). Spatial assessment of degraded lands for biofuel production in Indonesia. *Sustainability, 10*(12), 4595. https://doi.org/10.3390/su10124595
Kementerian Energi dan Sumber Daya Mineral (KESDM). (2025). *Rencana umum ketenagalistrikan nasional (RUKN) [National Electricity General Plan (RUKN)]*. https://gatrik.esdm.go.id/assets/uploads/download_index/files/28dd4-rukn.pdf
Kiseleva, S. V., Lisitskaya, N. V., Popel', O. S., Rafikova, Y. Y., Tarasenko, A. B., Frid, S. E., & Shakun, V. P. (2023). Geoinformation systems for renewable energy (Review). *Thermal Engineering, 70*(11), 939–949. https://doi.org/10.1134/S0040601523110071
Ministry of Environment and Forestry (MEF). (2025). *Sistem informasi pengelolaan sampah nasional: SIPSN [National Waste Management Information System (SIPSN)]*. https://sipsn.menlhk.go.id/sipsn/public/data/timbulan
Muyasyaroh, A. P. (2024). Rethinking energy security in Indonesia from a net zero perspective. *Indonesian Journal of Energy, 7(*1), 16–26. https://doi.org/10.33116/ije.v7i1.197
National Aeronautics and Space Administration (NASA). (2026a). *NASA SRTM digital elevation 30m*. https://developers.google.com/earth-engine/datasets/catalog/USGS_SRTMGL1_003

National Aeronautics and Space Administration (NASA). (2026b). *TRMM 3B42: 3-hourly precipitation estimates*. https://developers.google.com/earth-engine/datasets/catalog/TRMM_3B42

National Center for Atmospheric Research (NCAR). (2026). *NCEP FNL operational model global tropospheric analyses, continuing from July 1999*. https://gdex.ucar.edu/datasets/d083002/

Nizamuddin, Hizir, Ardiansyah, P. D., & Handayani, P. (2017). Development of Web GIS for information of renewable energy in Aceh Province after rehabilitation and reconstruction process. *IOP Conference Series: Earth and Environmental Science, 56*(1), 012016. https://doi.org/10.1088/1755-1315/56/1/012016

Nurliyanti, V., Ahadi, K., Muttaqin, R., Pranoto, B., Srikandi, G. P., & Al Irsyad, M. I. (2021). Fostering rooftop solar PV investments toward smart cities through e-SMART PV. *2021 5th International Conference on Smart Grid and Smart Cities (ICSGSC)*. https://doi.org/10.1109/ICSGSC52434.2021.9490406

Pasanisi, F., Righini, G., D'isidoro, M., Vitali, L., Briganti, G., Grauso, S., . . . Seitlheko, M. (2021). A cooperation project in Lesotho: Renewable energy potential maps embedded in a WebGIS tool. *Sustainability, 13*(18), 10132. https://doi.org/10.3390/su131810132

Pramudya, I., Al Irsyad, M. I., Phoumin, H., & Nepal, R. (2024). The role of battery energy storage systems and market integration in Indonesia's zero emission vision. In *Large-scale development of renewables in the ASEAN: Economics, technology and policy* (pp. 121–143). Springer. https://doi.org/10.1007/978-981-99-8239-4_6

Pranoto, B., Soekarno, H., Cendrawati, D. G., Akrom, I. F., Irsyad, M. I. A., Hesty, N. W., . . . Aman, M. (2021). Indonesian hydro energy potential map with run-off river system. *IOP Conference Series: Earth and Environmental Science, 926*(1), 012003. https://doi.org/10.1088/1755-1315/926/1/012003

Pristiandaru, D. L., & Pambudi, N. A. (2019). Wind energy in Indonesia: Current status, potential, challenge, opportunities, and future policy. *Indonesian Journal of Energy, 2*(2), 65–73. https://doi.org/10.33116/ije.v2i2.37

Ramafikeng, M., Ajayi, O., & Adeleke, A. (2025). A web-based decision support tool for multifarious renewable energy systems. *Renewable Energy Focus, 54*. https://doi.org/10.1016/j.ref.2025.100702

Resch, B., Sagl, G., Törnros, T., Bachmaier, A., Eggers, J.-B., Herkel, S., . . . Gündra, H. (2014). GIS-based planning and modeling for renewable energy: Challenges and future research avenues. *ISPRS International Journal of Geo-Information, 3*(2), 662–692. https://doi.org/10.3390/ijgi3020662

Rumbayan, M., Abudureyimu, A., & Nagasaka, K. (2012). Mapping of solar energy potential in Indonesia using artificial neural network and geographical information system. *Renewable and Sustainable Energy Reviews, 16*(3), 1437–1449. https://doi.org/10.1016/j.rser.2011.11.024

Setyowati, H., Dwinugroho, M., Sigit Heru Murti, B., Yulianto, A., Ajiwihanto, N., Hadinata, J., & Sanjiwana, A. (2018). ESDM one map Indonesia: Opportunities and challenges to support one map policy based on applied Web-GIS. *IOP Conference Series: Earth and Environmental Science, 165*(1), 012021. https://doi.org/10.1088/1755-1315/165/1/012021

Soemanto, A., & Koestoer, R. H. T. (2023). Scenario insight of energy transition. *Indonesian Journal of Energy, 6(*1), 48–59. https://doi.org/10.33116/ije.v6i1.158

Syanalia, A., & Winata, F. (2018). Decarbonizing energy in Bali with solar photovoltaic: GIS-based evaluation on grid-connected system. *Indonesian Journal of Energy, 1*(2), 5–20. https://doi.org/10.33116/ije.v1i2.22

Umam, M. F., Selia, S., Sunaryo, A. F., & Al Asy'ari, M. R. (2022). Energy storage applications to address the challenges of solar PV and wind penetration in Indonesia: A preliminary study. *Indonesian Journal of Energy, 5*(1), 42–65. https://doi.org/10.33116/ije.v5i1.110

United Nations Environment Programme (UNEP). (2026). *WDPA - World database of protected areas*. https://www.arcgis.com/home/item.html?id=ae78aeb913a343d69e950b53e29076f7

Wentz, F., Scott, J., Hoffman, R., Leidner, M., Atlas, R., & Ardizzone, J. (2015). *Remote sensing systems cross-calibrated multi-platform (CCMP) 6-hourly ocean vector wind analysis product on 0.25 deg grid, Version 2.0.* https://www.remss.com/measurements/ccmp/

Wijayanto, A. W., Putri, S. R., Putra, Y. C., Natasya, A., Anggita, F. F., & Aziz, J. H. (2026). AI-driven carbon pricing optimization: A geospatial analysis framework for Indonesia's energy transition. *Indonesian Journal of Energy, 9*(1), 17–37. https://doi.org/10.33116/ije.v9i1.289