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Development and Strategy of New Renewable Energy Modeling for the Future

Suwarno[1]✉, Muhammad Fitra Zambak[1], Elvy Syahnur Nasution[1], Rohana[1], Catra Indra Cahyadi[2]
[1]Department of Electrical Engineering, Universitas Muhammadiyah Sumatera Utara, Denai Street 217, Medan20371, Indonesia, suwarno@umsu.ac.id
[1]Department of Electrical Engineering, Universitas Muhammadiyah Sumatera Utara, Denai Street 217, Medan20371, Indonesia, mhdfitra@umsu.ac.id
[1]Department of Electrical Engineering, Universitas Muhammadiyah Sumatera Utara, Denai Street 217, Medan20371, Indonesia, elvysahnur@umsu.ac.id
[1]Department of Electrical Engineering, Universitas Muhammadiyah Sumatera Utara, Denai Street 217, Medan20371, Indonesia, rohana@umsu.ac.id
[2]Department of Electrical Engineering, Politeknik Penerbangan Medan, Penerbangan Street 85, Medan20131, Indonesia, catraindracahyadi@gmail.com
✉Corresponding Author: suwarno@umsu.ac.id | Phone: +6282272732905

Abstract
Developing and modeling strategies for sustainable renewable energy always involve complex optimization problems including design, planning, and control, which are often computationally intractable for conventional optimization methods. Advances in artificial intelligence technology have provided many optimization methods to handle these complex problems effectively and inspired by their promising performance and becoming increasingly popular nowadays for future energy. In this paper, we summarize recent advances in optimization methods inspired by advances in artificial neural network technology, evolutionary algorithms, and hybridization applied to the field of sustainable energy development. Modeling for the prediction of operational solar radiation is very important for decision-making, resource variability, and energy demand. This paper presents an ANN-based method to generate DNI forecast operations using weather and aerosol forecasts of each data. The ANN model is designed to predict weather and aerosol variables at a certain time as input, while the other models use the DNI forecast improvement period before the instant forecast. The developed model uses observations of the North Sumatra location and the results of DNI forecasting are obtained every 10 minutes on the first day with DNI forecasting compared to the initial forecast that comes down based on modeling with R^2, MAE, and RMSE and provides a good fit to the experimental data. Energy modeling strategy is one of the basic concepts in maintaining security, comfort, and privacy by creating a green and emission-free environment. The concept of development and modeling strategy of new renewable energy for the future is increasingly attracting attention to be studied and observed more deeply to prepare for sustainable future energy.
Keywords: Development, modeling strategy, renewable energy, future energy

Introduction
The increase in energy demand is caused by people's need to carry out activities to meet daily needs [1]. The use of fossil fuels is decreasing due to dwindling production and will eventually run out which is the cause of air and environmental pollution [2], [3]. The development of environmentally friendly energy consists of energy saving, increasing efficiency, and changing fossil energy to new, renewable energy [4]. Therefore, the use of future green energy is an important thing to discuss. Green energy is one of the new renewable energy to continue to be investigated so that its use is more optimal to maintain a healthy environment for the achievement of future development [5]. The implementation of a sustainable energy optimization system or green energy consists of design, control, and strategy with the implementation of programs that support its success [4]. However, this is still a problem for optimizing new renewable energy systems which is complex and related to the problem of integrating green energy sources into renewable energy systems which are nonlinear and multiple local optima [6].

The concept of green energy development and modeling is a system that manages various energy sources to be utilized as technological and communication advances to integrate predictive and real-time control and respond to supply and demand to balance energy [7]. The application of environmentally friendly concepts and green energy has become a shared consensus built-in social society and has become the direction of development in various industries and other developments [8]. The environmentally friendly concept is integrated into housing construction without leaving a gap in modern social life [9]. Optimizing the development and modeling of electrical energy use in various life contexts is the focus of this research and is a priority discussion in saving electrical energy [10]. Some reasons are to meet the normal operating system, reduce electricity consumption, and improve the efficiency of domestic electricity utilization. The impact of reducing energy-saving emissions from sustainable operations and construction can be realized [11].

Eco-friendly energy has become an extension of the concept of green and environmentally friendly buildings [12]. The strategy of implementing environmentally friendly and green energy management is an interesting topic to discuss and needs to be studied to realize it. In this process, logical management is needed, such as saving water, electricity, and other resources to achieve the goal of protecting the environment and preserving natural resources. Residential energy consumption is analyzed comprehensively because it is the main need for housing and the environment. In the process of building green and environmentally friendly housing, it is used as a basic job in complex construction and planning to improve management and meet the needs of residential development [13]. Electrical energy management has been carried out routinely but requires human resources and a management system that is not effective and efficient, so it does not meet the specified standards [14]. For that, personnel are needed to be professional and detailed in handling this. Some references regarding the electrical energy management model such as in industry, housing, and others, so that the electrical energy management system is actively built to realize environmentally friendly residential energy management information and automation [15].

One of the new renewable energies is the solar energy system which has variability as a renewable energy source and in general, the equatorial region has very large potential as an energy source in the future [16]. North Sumatra is a tropical area with very large solar radiation potential and needs to be utilized as a renewable source to improve energy efficiency, electrification, and energy policies [17]. Solar radiation is a clean and environmentally friendly source used for transformation and other purposes. However, this energy source has variability that can affect other electricity generation, so it can disrupt the optimal balance between electricity generation and consumption due to the limited and unreliable availability of large-scale electrical energy storage systems [18].

Solar energy sources rely only on direct solar radiation and diffuse radiation, thus producing accurate estimates of variables and tending to influence more certain estimates [19]. The solar radiation predictive approach model can be carried out using a numerical weather forecasting (NWP) model and by weather and climate conditions at the research location [20]. This NWP model provides weather information with a focus on meteorological variables including weather and climate to predict solar radiation for the next 4 hours to several days [21], [22]. This variability forecasting model is obtained from the weather where the research was conducted and is used as a model to estimate it. [23]. This model is an accurate approximation of the global solar radiation components and energy balance on earth, but the Integrated Forecasting System (IFS) model developed at the European Centre for Medium-Range Weather Forecasts (ECMWF) is the global NWP model that has been developed and used in Europe for a long time with the best performance as found by researchers [24], where 24-hour global solar from IFS and American Global Forecasting System (GFS) are compared with observations made at several research stations. The researchers found that the combined IFS and ECMWF models performed better than the GFS model for all-sky conditions based on the average bias error and correlation coefficient. In the study from [25], the hourly Global Horizontal Irradiance (GHI) estimates from the IFS and ECMWF global models as well as the Weather Research Forecasting (WRF) model used by the GFS are compared with observations over the US and European countries showing that the ECMWF model performs significantly better across all locations and different climate conditions.

The accuracy of solar radiation variables in research using the NWP model has been obtained for the needs of developing solar energy systems [26], [27]. Direct Normal Irradiation (DNI) is very difficult to predict because it is highly dependent on the presence of clouds and the type and concentration of aerosols in the atmosphere [28]. For the NWP models produced by IFS and ECMWF, monthly climatology averages are compared with more detailed approaches to reduce computational time. Researchers using the NWP models have produced excellent results under certain weather and climate conditions, as reported by [29]. The Copernicus Atmospheric Monitoring Service (CAMS) and Goddard Earth Observing System Version 5 (GEOS-5) global models have been of particular interest, as noted by [30], and achieved a 4.3% reduction in relative mean square error (RMSE) for the hourly IFS and ECMWF GHI estimates based on aerosol estimates and experimental data, as suggested by [31], while other researchers obtained between the NWP and WRF models combined with chemistry to modeling aerosol and solar radiation data were compared with observations showing shortwave radiation powers 2 to 5 times higher during dust storms compared to values on dust-free days proposed by [32].

Knowledge of all the complex phenomena in the Earth's atmosphere, including the interactions between solar radiation and the atmosphere, and between solar radiation and the Earth's surface, is a constraint, and its representation in the most complex and detailed NWP models is limited by data availability and computational limitations [33]. Several techniques have been developed and evaluated to further improve the solar radiation estimates made by NWP models consisting of classical statistical methods [34]And Machine Learning (ML) methods [35]. *Support vector machine model*(SVM), Random forest (RF), or*Artificial Neural Network* (JST), and focus on global solar irradiance prediction has been studied by [36].

The development and modeling of GHI forecasting with four ML models resulted in an accuracy of 81%. This model can find out the systematic errors of the NWP model output and relevant variables in historical and observational data estimates by comparing the basis of the two data and providing the best assessment with a short time and a more detailed model [37]. In several studies on forecast Hourly GHI, DNI, and DHI with several machine learning models and solar radiation as input, as well as aerosol observations against wind and aerosol forecasts, are evaluated to obtain the best ANN model performance [38], while the comparison of models with feed-forward artificial neural networks and recurrent neural networks to estimate global solar radiation at the research site shows that, artificial neural networks can improve prediction performance, but incur additional computational costs [39]and the results are getting closer to the solar radiation one day ahead through SVM with NWP data from the Meteorology, Climatology, and Geophysics Agency scale model producing an RMSE of 15.98%, while the use of artificial neural networks to approach solar radiation with NWP from the WRF model, there is a reduction in model bias obtained, MSE and RMSE [40]. Meanwhile, ML models have been developed to be applied to solar irradiance forecasting with a focus on GHI which is used to obtain an approximation of the power output of a solar energy system with a temporal resolution and forecast time horizon that is not synchronized with the real-time forecast [41].

The proposed development and modeling method for operational DNI forecasting consists of specific locations and times used for IFS/ECMWF and aerosol forecasts; ANN models are used for specific weather and aerosol forecasts; and ANN models are used to refine DNI before the prediction time step at specific seasons and times. The results of the observation of the development and evaluation of the proposed research show that this method is applicable and generalizable and contributes to findings that can be applied at specific locations and times.

Due to the above problems, it is necessary to develop and model the solar radiation. This paper is proposed as a forecast of solar radiation in North Sumatra with an iterative combination model between two parameters, namely weather and climate obtained from the Meteorology, Climatology, and Geophysics Agency of Medan City. Two models are designed with weather and climate predictions at a certain time as input, and one model is proposed to improve solar radiation forecasts based on operational data. The application of this proposed model with an approach time of 10 minutes and the results are obtained with the R^2, MAE, and RMSE model statistics, then this model is evaluated at different periods and locations in North Sumatra which can provide equivalence with experimental data [42].

Research contributions This is a proposal for the development and modeling strategy of new and renewable energy for green energy and saving energy use so that it can meet energy needs and become the right choice in the use of new and renewable energy in the future without emissions and environmental pollution.

Research Methods

Developing models to forecast IFS/ECMWF and CAMS model data and solar radiation observation data from a network of stations in Medan, North Sumatra, Indonesia. Some models are operational and models are developed to allow operational use of daily data. Weather data for forecasting are obtained from the IFS/ECMWF model, while the NWP model is a wave-range radiation scheme in 1D radiation, estimating temperature, humidity, effective cloud radius, and monthly average climatology of aerosols, CO2, ozone, trace gases, albedo, land surface temperature, and emissions at different spectral bands and solar zenith angles with radiative transfer at different wavelengths in 14-16 spectral bands [43]. The *McRad* model has shortcomings that require the development of a new ECMWF radiation scheme, namely *ecRad*, and its development consists of, First, flexibility: scientific development requires the ability to exchange each component of the radiation scheme with a faster, more efficient, and more accurate component, but the non-modular design of *McRad* makes this very difficult. Second, efficiency: the spectral interval (252) required for RRTM-G makes *McRad* 3.5 times slower than previous findings. The results obtained with the radiation scheme are run on a much coarser grid than the other models, and in all operational model configurations except the high-resolution forecast (HRES), only record the radiation scheme every 3 hours, while in HRES with hourly scheme calls. Schematic illustration of the five main components of *ecRad* (different colors) and the data flow between them (arrows). Data were taken for maximum grid point density and temporal forecast horizons up to 72 hours to obtain hourly average values of direct and normalized global horizontal radiation in W/m^2, convert air temperature (T) to ^{o}C, and calculate wind speed (WS) in m/s and wind direction (WD) in degrees North at the wind speed at the time of the study [44].

1. Aerosol forecasts and scale models

The proposed development of CAMS provides estimates of the global atmospheric composition based on the IFS model with additional modules enabled for aerosols, reactive gases, and greenhouse gases taking into account phenomena such as emissions and trace gases and aerosols, uptake and release by vegetation, soil and ocean-atmosphere with dry precipitation on the surface of precipitation, chemical conversion and aerosol microphysics. This component generates atmospheric variables, and aerosol optics at different wavelengths in 3D with a horizontal spatial resolution of 40 km and a time step of 1 hour [45].

Spatial and temporal degradation models are commonly used for simulation, while bilinear interpolation for grid points is different. The development of a model to validate solar radiation measurements at the study site is essential. For the model in the temporal scale, it is calculated using hourly average radiation scaling interpolation. This method aims to obtain data during the study period that can represent solar radiation data as input for a more complex machine learning model to improve DNI estimation. This proposal is a compromise between developing a more complex physical downscaling method to maintain hourly energy predictions that input the original hourly radiation values into the machine learning model directly and developing a model for each desired time step. This model has deviations caused by the downscaling method on the input energy prediction values and assimilated by the machine learning model.

The development and modeling of energy in the world is very rapid to meet and save the use of electrical energy. The support of the energy sector and local market structure regulations in the development of the contract energy market are analyzed. The strategy of encouraging the development of energy modeling and stakeholder support is a reference in making green and emission-free energy a success [46]. This support can promote the development of energy service companies in several Asian countries and beyond. The development trends and performance of the energy service industry are analyzed. Some research results show that appropriate financial and non-financial policy support can effectively promote the development of the energy service industry. Based on the draft energy efficiency law the energy management financing model is introduced to support the implementation measures of energy management. There are financing and risks in the electric energy management market in Asia. To ensure the competitiveness of the energy-saving service market, competitiveness of the energy-saving market and services in Asia can be guaranteed if the growth rate is maintained at 5% in the next decade while introducing the necessary capital flow to ensure economic stability and solve structural reform problems [47]. Energy-saving projects based on the electric energy integration and management system model help realize the application of green energy and free from environmental pollution. Based on quantitative data analysis, the issue of using financial derivative trading to stabilize energy-saving income has been discussed by several researchers such as [48]. This is the most important factor in public policy and business strategy to encourage the development of electrical energy management.

2. Load estimation

Based on previous research, optimizing green energy is a complex problem according to local conditions, therefore several parameters need to be considered, such as economy, location, environment, load demand, and the availability of new and renewable energy [49]. Load estimation based on the above parameters as a model applied in this study. Modeling with HOMER is the best choice because it is a model that can accommodate these parameters. Some researchers use the LCOE, NPC, and minimum generation cost models. However, decision-making in RET becomes complicated due to economic and MCDM aspects. Therefore, the selection of the research model with the most optimal hybrid energy system, considers economic aspects, environmental aspects, and so on.

3. System design

The system design for this study with new and renewable hybrid energy sources is located in North Sumatra. The parameters are entered into the HOMER simulation system to determine the energy mix and energy needs as shown in Figure 1. Design with HOMER software, based on consideration of local conditions, cost parameters, energy resources, and other important simulation parameters. Optimization in HOMER is simulated for one year using hourly steps to meet electricity needs with the lowest NPC. Several combinations of electricity grid, solar PV, wind, and battery are proposed. This combination of energy sources is simulated to see the load needs.

4. Components of the model system

The electrical network as in the HOMER simulation with electricity costs for a particular month to see the expenditure. Based on available sources a modeling design is as follows.

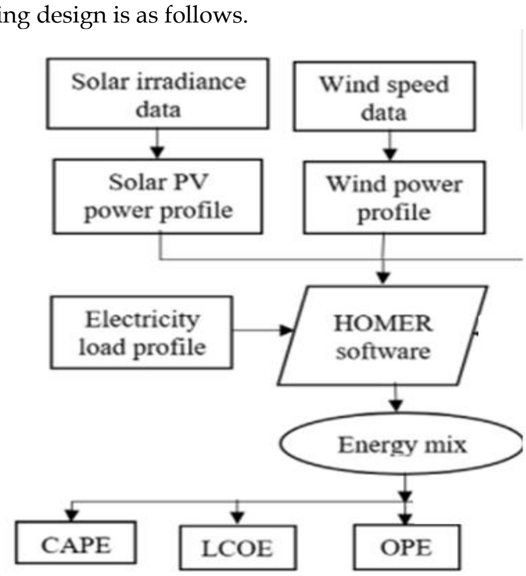

Figure 1. System design.

Renewable Energy Resources and Load Demand

Meteorological data of the research location were obtained from NASA's surface meteorology and solar energy database. In addition, wind speed data were also obtained from NASA's database at an anemometer height of 50 m above the earth's surface for terrain such as airports for 10 years. Meteorological data for annual average daily radiation, wind speed, and temperature.

1. Solar PV

The solar panel used is a Monocrystalline Silicon type in Indonesia of 5,530 Rp/watt. However, according to the cost of solar panels per Kw of around Rp 5,083,000., with solar PV technology not yet perfect, then the replacement is around Rp 6,100,000., with the cost being quite large, but will decrease in the future. The assumption of operational and maintenance costs is estimated at Rp 14,200,000 per kW per year with a service life of 25 years is considered the lifetime of the solar module with a derating factor of 90%.

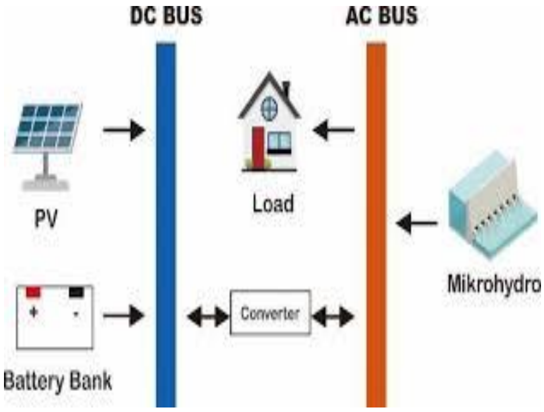

Figure 2. Hybrid research model scenario

2. Wind Turbine

In Iran, Baneshi et al. considered the cost of a wind turbine to be $2,000/kW. In China, a 3 kW wind turbine costs $3,000. Due to the geographical location, logistics, and installation challenges associated with a 3 kW wind turbine, it was set at $6,360 ($2120/kW) while the annual replacement and O&M costs were set at $5,088 and $127.2, respectively. The hub height is 12 m and the turbine life is 20 years. The charge controller and battery system require a charge controller to ensure the regulation of power to and from the battery. It detects whether the battery is fully charged or needs to be recharged. This protects the battery from damage. When the battery is fully charged, the charge controller diverts excess power to the discharge load, preventing the battery from overcharging.

3. **Power Converter**

The designed system consists of DC and AC components including the power grid, generator, battery, and solar PV making the converter a useful component in hybrid systems.

Results and Discussion

This section presents the results of the proposed hybrid system through simulation in HOMER Pro. Considering six proposed scenarios in this regard. In this study, the best scenario is selected by utilizing the CRITIC-PROMETHEE approach. The scenario results are categorized into economic, technical, and environmental practicalities as the main criteria in MCDM. Based on economic practicalities, Net Present Value (NPC), Levelized Cost of Electricity (LCOE), Initial Capital (IC), and Operating Cost (OpC) are considered for each scenario. Similarly, technical practicalities include Energy Production (EP), Unmet Electricity Load (UL), Excess Electricity (EE), and Shortage of Capacity (CS). Environmental practicalities include Carbon Dioxide, Carbon Monoxide, Unburned Hydrocarbons, Particulate Matter, Sulfur Dioxide, and Nitrogen oxide emissions. Figure 3 provides a summary of the simulation results for the scenarios.

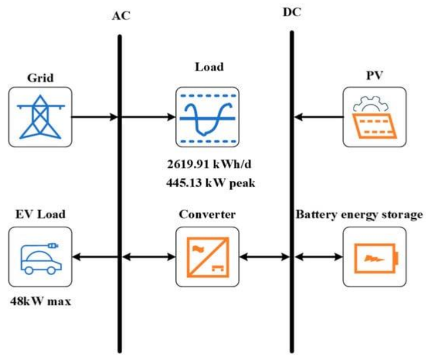

Figure 3. Simulation with HOMER

A. Approach model

For economic practicality, large NPC values are considered as the best scenario while for LCOE, initial capital, and operating costs, small values are considered as the worst scenario. For technical practicality, large energy production values are considered as the best scenario, while unmet electricity load, excess electricity, and shortage of capacity, small values are considered as the worst scenario. For all environmental practicalities, small values are considered the best scenario. This study considers the weight equation of economic, technical, and environmental practicality, the weight calculation of all sub-criteria using the CRITIC approach gives results by giving large weights to energy production, NPC, sulfur dioxide, and operating costs. The CRITIC approach is one of the MCDM methods. The CRITIC approach is used to calculate the weight of the HOMER hybrid system combination criteria.

B. Sensitivity analysis

In this study, sensitivity analysis is used to validate the MCDM results and robustness of the technique. The main objective of this sensitivity analysis is to determine a new ranking of the Scenarios using the net outranking values. This is done by varying the initial weights of the categories in different cases and comparing them with the current case. All categories are given equal weights (33.3%) in Case 1, the Baseline Case. For Case 2, the economic and technical categories are given 35% each, while the environmental category is given 30%. For Case 3, the economic, technical, and environmental categories are given weights of 40%, 35%, and 25% respectively. For Case 4, the economic, technical, and environmental categories are given weights of 50%, 25%, and 25% respectively. For Case 5, the economic, technical, and environmental categories are given weights of 25%, 50%, and 25% respectively. For Case 3, the economic, technical, and environmental categories are given weights of 25%, 25%, and 50% respectively. The sensitivity results in this study show that the results in this study are consistent and robust. Although there are some fluctuations in the net rating for some cases, such as in case 1. In addition, the rating scenario remains constant in all cases.

C. Best scenario analysis

Six scenarios were simulated using HOMER pro and the results were further analyzed using the CRITIC-PROMETHEE II MCDM approach. The MCDM approach uses economic, technical, and environmental categories. The results showed that Scenario 3 is the best scenario consisting of grid, biogas, and solar panels without storage units. The winning system architecture has a grid capacity, a 20 kW biogas generator, 13.1 kW solar PV, and a 9.19 kW system converter. The system does not have battery storage which may be beneficial considering the battery life. The results showed that the AC load consumption throughout the year is 60,386 kWh. The annual contribution of solar panels is 23,917 kWh, the biogas generator is 10,850 kWh, and the grid is 32,184 kWh.

The results of the study illustrate that most of the electricity is obtained from the electricity grid with a contribution of 48%, but the combined contribution of solar panels and biogas is greater than the electricity grid. This microgrid requires 165 kWh/day of power and has a peak power of 17 kW. The annual excess electricity generation for this system is 5,590 kWh which represents 8.35% of the total generation. This excess electricity is beneficial because it can provide additional load. This is because there is no shortage of capacity or unmet electricity load in the system.

Conclusions

Based on the above analysis, it can be concluded that the Hybrid Renewable Energy System has proven to be more reliable and provides continuous electricity supply despite its intermittent nature. In this study, a hybrid energy system connected to the electricity grid is intended to overcome electricity problems and reduce costs in the consumer environment. Renewable energy resources (solar, wind, biogas), solar, and batteries are considered for design and simulation in the consumer environment. Biogas generation is mostly from human waste. The HOMER Pro modeling tool is used in the simulation of all scenarios. The results obtained from HOMER on the simulation of the hybrid system are classified into three perspectives. The results are further analyzed to determine the best combination for the location using the approach proposed. The most likely scenario has a combination of electricity grid, biogas, and solar PV without storage units.

The development system and integration strategy of new and renewable energy will be produced by using energy saving and scheduling the use wisely and according to needs. To maintain clean and green energy for housing residents, it can be combined with experience in housing management in the construction and operation of the electric power energy management system to obtain an effective electric power energy management system construction model. The use of safe, comfortable, reliable, economical, efficient, and scientific electric energy can be achieved with the development of environmentally friendly housing, the housing electric energy management system will play an increasingly important role in future life.

This study contributes to the development of a model for better DNI estimation based on data from NWP models in operational environments. The model is applied to forecast data from IFS/ECMWF and CAMS with atmospheric variables and aerosol data that affect solar radiation through the atmosphere. To calculate spatial and temporal forecasts for a desired location and time resolution using bilinear interpolation of the values of four surrounding grid points and cubic interpolation with hourly average variables. Two different models based on artificial neural networks are designed and optimized to produce better DNI forecasts with a desired temporal resolution and for a forecast period of 72 hours. To determine the accuracy of the results, it is necessary to perform the configuration of the tested models and the selected configuration using ANN. The model is run daily when the operational forecasts of ECMWF and CAMS are available for retrieval and the results for the next two days can be used by solar energy producers and grid operators to estimate energy production and make better decisions. This model is also applied to other locations spread around the research location that was developed showing an increase in DNI forecasts on day 1 of the forecast based on the R2, MAE, and RMSE models when compared to ECMWF estimates and field measurements at each research location. With better forecasts, more accurate estimates of energy generation in solar energy systems can be achieved and this is very important for solar power plants.

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