Institution Details

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| **Province** | Sindh | **City** | Karachi |
| **Institution** | National University of Computer and Emerging Sciences (FAST-NU) | **Campus** | Main Karachi Campus |
| **Department** | Computer Science | **Degree Level** | Undergraduate (BS Program) |
| **Degree Program** | BS Computer Science | **Telephone** |  |
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| **Project Title** | Energy Forecasting using AI for Smart Grids | |  |
| **Group Details** | **Member 1 Name: Zain Ali Siddiqui**  **Member 1 Roll #: 21K-4870** | **Member 2 Name: Abdul Rehman Arain**  **Member 2 Roll #: 21K-3364** | **Member 3 Name: Maaz Muhammad Khan**  **Member 3 Roll #: 21K-3365** |
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| **Project Area of** | Data Science,  Artificial Intelligence | | |
| **Specialization** |  |  |  |
|  |  |  |  |
| **Project Start** | August 2024 | **Project End Date** | May 2025 |
| **Date** |  |  |  |
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Project Details

**Introduction / Abstract**

The shift toward renewable energy is happening worldwide, but the challenge remains in how to effectively integrate these sources into power grids. Renewable energy sources like wind and solar are unpredictable, with varying outputs based on factors like weather conditions and time of day. In Pakistan, we face a growing gap between energy demand and supply, while our potential to harness wind and solar energy remains largely underutilized. This project, **“Energy Forecasting Using AI for Smart Grids,”** aims to tackle this challenge by applying machine learning techniques to accurately predict energy production from renewable sources like wind and solar power.

The use of AI in this context can greatly improve how we manage energy. For instance, grid operators will be able to better plan for energy production, ensuring there’s neither excess energy that goes to waste nor shortages that could lead to blackouts. By using real-time weather data, our system will be able to predict energy output from both wind and solar, which will help with planning and reduce the reliance on fossil fuels. In doing so, we can make Pakistan’s energy grid smarter, more efficient, and more environmentally friendly.

### ****Scope of the Project****

This project focuses on creating a system that forecasts the energy output from wind and solar sources. The system will utilize machine learning models to predict energy production in different regions, using both historical and real-time weather data. One of the key features will be the ability to compare the energy generated from renewable sources with the demand, allowing for better management of energy flows within the grid.

The project includes the following elements:

* **Wind Energy Component**: We’ll develop models that predict how much energy wind farms will generate, based on factors like wind speed, air density, and turbine efficiency.
* **Solar Energy Component**: Similarly, we’ll create models to forecast energy output from solar panels, taking into account variables like sunlight intensity and temperature.
* **User Interface**: We’ll design easy-to-use tools that visualize real-time and predicted energy outputs, making it easier for stakeholders to understand and act on the data.
* **Deficit Identification**: The system will analyze any shortfalls in energy by comparing production with demand, helping managers take preventative action.

This model will initially focus on Pakistan but can be expanded to other regions globally in future phases.

### ****3. Aims and Objectives****

The main goal of this project is to develop an AI-based forecasting system to optimize renewable energy’s contribution to smart grids. Specifically, we aim to:

1. **Predict Wind Energy**: Forecast energy production from wind farms based on real-time weather data.
   * Sub-goal: Assess the efficiency of different turbines under various wind conditions.
2. **Predict Solar Energy**: Build models to predict energy output from solar panels, considering factors like sunlight intensity and temperature.
   * Sub-goal: Evaluate solar panel performance based on factors like tilt, direction, and material.
3. **Match Supply with Demand**: Create a method to compare energy production with demand forecasts, helping identify potential shortages or surpluses.
   * Sub-goal: Provide recommendations to grid managers for balancing energy loads.
4. **User-Friendly Tools**: Develop dashboards and other tools that make it easy for non-technical stakeholders, like policymakers and energy suppliers, to interpret the forecasts.
   * Sub-goal: Highlight actionable insights that can guide decisions on energy policy and grid management.

By achieving these objectives, we hope to make renewable energy more reliable and increase its share in Pakistan’s energy mix.

### ****4. Success Criteria****

For this project to be successful, several criteria need to be met:

* **Prediction Accuracy**: The models must offer accurate predictions with minimal error, using metrics like Mean Absolute Error (MAE) and Root Mean Square Error (RMSE). We’re aiming for an accuracy rate of at least 85%.
* **Reliable Performance**: The forecasts need to be consistent and dependable across different weather conditions and seasons, with the ability to adapt to sudden changes.
* **Scalability**: The system must be able to handle larger datasets or expand to other regions without losing efficiency or accuracy.
* **User Satisfaction**: The dashboards should be intuitive and easy for users to understand, providing actionable insights for grid managers and policymakers.
* **Impact on Energy Management**: The tool should help reduce energy shortages or surpluses, increasing grid efficiency and reducing dependency on non-renewable sources.
* **Environmental Impact**: By improving the integration of renewable energy into the grid, the project should contribute to lowering carbon emissions.

### ****5. Features / Literature Review****

### Wind Energy Forecasting

Wind energy forecasting has come a long way thanks to advances in machine learning. Wind energy generation is influenced by multiple factors like wind speed and direction, and in the past, models based on physics were used to estimate outputs. However, data-driven approaches, like machine learning models (regression techniques, support vector machines, and neural networks), have proven to be more accurate.

* **Recent Developments**: Research by Zhang et al. (2020) shows that combining traditional physical models with AI can significantly improve prediction accuracy. Studies like those by Abdi and Afshar (2022) also point to deep learning as a game-changer in capturing complex weather patterns for better wind energy forecasting.

#### **Solar Energy Forecasting**

Solar energy forecasting has also evolved from using clear-sky models, which predict energy output based on ideal conditions. With machine learning, these models now account for real-world variables like cloud cover, air temperature, and even dust in the atmosphere.

* **Recent Developments**: Kuo et al. (2018) introduced SolarNet, a deep learning model specifically designed for solar irradiance forecasting, and recent studies by Ledmaoui et al. (2023) emphasize the effectiveness of AI in predicting energy production from photovoltaic systems.

### ****6. Proposed Methodology****

This project will use historical and real-time weather data to develop two separate models: one for wind energy and one for solar energy.

#### **Wind Model Development**

1. **Data Collection**: We’ll gather wind data from sources like the Global Wind Atlas, which provides information on wind speeds, directions, and other environmental factors.
2. **Data Preprocessing**: We’ll clean the data, handling outliers and normalizing it for better accuracy.
3. **Feature Engineering**: We’ll enhance the model by adding new features, such as seasonal trends and local weather conditions.
4. **Model Training**: We’ll experiment with machine learning algorithms (e.g., random forests, gradient boosting, deep learning) to find the best fit.
5. **Evaluation**: Once trained, the model will be tested using accuracy metrics like MAE and RMSE.

#### **Solar Model Development**

1. **Data Collection**: Solar irradiance data will come from local meteorological stations.
2. **Data Cleaning**: Missing values will be filled in using statistical methods, and data will be prepped for analysis.
3. **Model Training**: Neural networks and regression models will be applied to predict solar energy output.
4. **Evaluation**: The model’s performance will be measured using accuracy metrics, and the best model will be selected for final use.

### ****7. Work Plan****

This project is expected to span about eight months, with the following phases:

Phase 1

* **Month 1-2**: Data collection and preparation for wind and solar datasets.
* **Month 3-4**: Developing the wind energy forecasting model.

Phase 2

* **Month 5-6**: Developing the solar energy forecasting model.
* **Month 7**: Integrating the models into a single platform and creating dashboards.

Phase 3

* **Month 8**: Testing, evaluation, and refining the final system.

### ****8. System Design****

The system will include:

* **Data Processing Pipelines**: Separate pipelines for wind and solar data preparation.
* **Prediction Engines**: Different engines for wind and solar energy forecasts.
* **Deficit Estimation**: A module that compares predicted energy supply with demand to estimate any shortages.
* **Visualization Layer**: User-friendly dashboards that display energy forecasts and key metrics in real time.

### ****9. Tools and Technologies****

* **Programming**: We’ll primarily use Python due to its vast ecosystem of libraries for machine learning and data analysis.
* **Libraries**: Key libraries include scikit-learn (machine learning), TensorFlow/Keras (neural networks), and pandas/NumPy (data handling).
* **Databases**: A relational database like PostgreSQL will store both historical data and forecasts.
* **Visualization Tools**: Dashboards will be built using tools like Plotly and Matplotlib for visualizing the forecast data.

### ****10. References****

1. P.-H. Kuo and C.-J. Huang, "A Green Energy Application in Energy Management Systems by an Artificial Intelligence-Based Solar Radiation Forecasting Model," Energies, vol. 11, no. 4, p. 819, 2018.
2. Y. Ledmaoui et al., "Forecasting solar energy production: A comparative study of machine learning algorithms," Energy Reports, vol. 10, pp. 1004–1012, 2023.
3. X. Zhang et al., "Hybrid models for wind power forecasting: An overview," Renewable Energy, vol. 145, pp. 262-273, 2020.
4. H. Abdi and M. Afshar, "Deep Learning in Wind Power Forecasting: Techniques and Applications," Energy AI Journal, vol. 14, pp. 53-67, 2022.