# Power Generation Stack – Romania

This stacked area chart represents the power generation stack for Romania, aggregated weekly from 2015 to 2024. The chart provides a comprehensive view of the contribution of different energy sources to the total power generation over time.

**Key Observations:**

1. **Seasonal Variations**:
   * There are clear seasonal patterns in the power generation data. Peaks in total generation typically occur during the winter months, likely due to increased heating demand.
   * A noticeable dip in generation is seen during the summer months, which could be attributed to lower heating demand and possibly higher renewable generation like solar.
2. **Dominant Energy Sources**:
   * **Hydro Reservoir and Hydro ROR**: These sources, represented in red and purple respectively, show significant contributions throughout the period.
   * **Nuclear**: The pink area consistently contributes a substantial portion of the total generation, reflecting a steady and reliable output from nuclear power plants.
3. **Fossil Fuels**:
   * **Lignite**, shown in brown, makes a significant contribution, but its use is declining, as is **hard** **coal**, shown in dark green, whose use is declining sharply over the years, reaching almost 0 in 2024.
   * **Fossil Gas**: The orange area shows fossil gas remains predominant and a more flexible source, with its generation varying to meet demand fluctuations.
4. **Renewable Energy**:
   * **Wind**: The light green area indicates wind generation, which shows variability due to its dependence on weather conditions. This source allows a certain diversification in generation because it produces more during the winter, allowing this clean energy source to take over when demand is high.
   * **Solar**: The grey area, although solar power production is visible, it is not used very much, which shows that Romania does not have enough dedicated infrastructure.
5. **Biomass**: The blue area represents biomass generation. Its contribution is minor compared to other sources.

The visualization highlights the complexity and dynamics of managing an energy grid with multiple sources, each with its own characteristics and variability.

# Power generation stacked - Hungary

**Analysis of the Power Generation Stack - Hungary**

This stacked area chart represents the power generation stack for Hungary, aggregated weekly from 2015 to 2024. The chart visualizes the contributions of various energy sources to the total power generation over time.

**Key Observations:**

1. **Seasonal Variations**:
   * We observe the same seasonal variations as in Romania
2. **Dominant Energy Sources**:
   * **Nuclear (Light Green)**: like in romania, This source consistently provides a substantial portion of the total generation. In Hungary This source usually accounts for around 50% of total generation.
   * **Lignite (Gray)**: Lile in romania, Lignite shows significant contributions which, however, has tended to decline over the years.
   * **Fossil Gas (Orange at the Bottom)**: Fossil gas is a major contributor,. Its consistent presence highlights its importance in Hungary’s energy mix.
   * **Wind (Red)**: Its contribution is visible but not as dominant as other sources.
   * **Solar (Orange at the Top)**: its use is growing strongly in 2020, and is becoming increasingly prevalent. This shows Hungary's determination to diversify its sources of energy production, while at the same time achieving clean, sustainable solutions.
   * **Biomass (Dark Blue)**: Biomass contributes steadily throughout the years, though its share is smaller compared to nuclear, lignite, and fossil gas.
   * **Other (Light Blue)**: This category includes various other sources, which together provide a noticeable but smaller contribution to the total generation.

Hungary uses far fewer sources of energy than Romania. The country's overall energy production comes from nuclear power, lignite and fossilgas.

We can assume that Hungary is seeking to rid itself of its dependence on fossil fuels by developing significant solar energy production.

# Analysis of the Average Load in Romania for Each Day of the Week and Hour in 2023

This heatmap visualizes the average electricity load (in MW) in Romania for each hour of the day across the different days of the week for the year 2023. The color intensity ranges from dark purple (lower load) to bright yellow (higher load), providing a clear representation of load patterns throughout the week.

**Key Observations:**

1. **Daily Patterns**:
   * **Morning Increase**: There is a noticeable increase in electricity load starting around 4 AM, which continues to rise until it reaches a peak at 6 AM. This corresponds to the time when people start their day, businesses open, and industrial activities ramp up.
   * **Afternoon and Evening Peaks**: Another peak is observed in the afternoon, particularly between 4 PM and 6 PM. This can be attributed to people returning home, increased residential electricity usage, and possibly the continuation of industrial and commercial activities.
2. **Weekly Patterns**:
   * **Weekdays (Monday to Friday)**: The load is generally higher on weekdays, with notable peaks in the morning and evening hours. Wednesday appears to have slightly higher loads compared to other weekdays.
   * **Saturday**: The load on Saturday is lower than on weekdays but still shows a similar pattern with morning and evening peaks. However, the overall load is reduced, reflecting decreased industrial and commercial activity.
   * **Sunday**: Sunday shows the lowest electricity load throughout the week, with minimal variation across the hours. This is likely due to reduced commercial and industrial activity and a slower pace of life generally.
3. **General Trends:**
   * **Consistent Patterns**: There are consistent daily and weekly patterns in electricity usage, reflecting the regular routines of residential, commercial, and industrial consumers.
   * **Variation in Demand**: The variation between peak and off-peak hours is quite significant, indicating the importance of demand management and possibly the need for flexible energy sources to handle these fluctuations.

**Analysis of Romanian Load Over Time**

This area chart represents the hourly electricity load (in MW) in Romania from 2015 to 2024. The chart provides a clear visualization of the variations in load over this period.

**Key Observations:**

1. **Seasonal Variations**:
   * There are clear seasonal patterns, with peaks typically occurring during the winter months due to increased heating demand.
   * The load decreases during the summer months, reflecting lower heating requirements and potentially higher contributions from renewable sources like solar energy.
2. **Yearly Trends**:
   * Each year shows a recurring pattern of rising and falling demand, indicative of the cyclical nature of electricity usage tied to seasonal weather changes.
   * The peaks and troughs are fairly consistent year over year, suggesting stable seasonal demand patterns.
3. **Peak Load**:
   * The highest loads reach just above 9000 MW, usually during the coldest months when heating needs are greatest.
   * There are also notable secondary peaks during summer, possibly due to air conditioning demands.
4. **Off-Peak Load**:
   * The lowest loads drop to around 3000 MW in 2024, a so-called “outlier” that should not be taken into account in model training

# Results Commentary

**Back-Test Results:**

* The first graph shows the model's performance on historical data, with training data (blue), test data (orange), and the forecasted data (green).
* The model's forecasts align well with the actual load in the test period, indicating good performance.

**Performance Metrics:**

* The performance metrics indicate the model's accuracy:
  + Mean Squared Error (MSE): 453,167
  + Root Mean Squared Error (RMSE): 673
  + Mean Absolute Error (MAE): 558
  + Mean Absolute Percentage Error (MAPE): 9.39%
* These values reflect a reasonable prediction accuracy, with an average percentage error of around 9.39%.

Overall, the XGBoost model provides accurate load forecasts, effectively capturing the seasonality and trends in the data. The addition of temporal features enhances the model's performance, making it a valuable tool for future load forecasting.

**Additional Parameters and Features for Load Forecasting**

Producing accurate forecasts for electricity load is indeed a complex task that requires considering various factors beyond historical data. Here are some ideas and additional parameters/features that could enhance the predictive model, as well as the limitations associated with these approaches.

**Additional Parameters and Features**

1. **Weather Data**:
   * **Temperature**: One of the most significant factors affecting electricity load. High temperatures increase the demand for cooling, while low temperatures increase the demand for heating.
   * **Humidity**: Higher humidity levels can also impact cooling demands.
   * **Precipitation**: Rainy or snowy conditions can affect both residential and industrial electricity usage.
   * **Wind Speed**: This can impact wind energy generation and also influence heating and cooling needs.
2. **Economic Indicators**:
   * **GDP**: Economic growth can drive higher industrial activity and thus increase electricity demand.
   * **Industrial Production Index**: Reflects the level of industrial activity, which directly impacts electricity consumption.
   * **Unemployment Rate**: Can indirectly influence electricity usage through its impact on economic activity and household incomes.
3. **Demographic Data**:
   * **Population Growth**: A growing population leads to higher residential electricity consumption.
   * **Urbanization Rate**: Urban areas tend to have higher electricity usage due to denser populations and more industrial activities.
4. **Energy Prices**:
   * **Electricity Tariffs**: Changes in electricity prices can influence consumption patterns. Higher prices may lead to reduced consumption and vice versa.
   * **Fuel Prices**: The cost of fuels used for electricity generation (e.g., natural gas, coal) can impact the overall cost and availability of electricity.
5. **Renewable Energy Integration**:
   * **Solar and Wind Capacity**: The amount of installed renewable energy capacity can impact the load on conventional power plants.
   * **Renewable Energy Production Forecasts**: Forecasting the expected production from renewable sources can help in adjusting the load predictions for conventional sources.

**Limitations**

1. **Data Availability and Quality**:
   * Obtaining accurate and timely data for all these factors can be challenging.
   * Incomplete or

inconsistent data can lead to inaccuracies in the forecast.

1. **Model Complexity**:
   * Integrating a large number of diverse features increases the complexity of the model, which can make it harder to train and tune.
   * Complex models may require more computational resources
2. **Uncertainty and Variability**:
   * Weather conditions, economic indicators, and behavioral factors are inherently uncertain and can change rapidly.
   * Forecasting these factors accurately is itself a challenging task, which introduces additional uncertainty into the load forecast.

**Conclusion**

While historical data provides a solid foundation for electricity load forecasting, incorporating additional parameters and features can significantly enhance the accuracy and reliability of the forecasts. However, these improvements come with their own set of challenges and limitations.

# Analysis of the 2-Year Ahead Forecast of Romanian Load with XGBoost

**Overview**

This graph presents the 2-year ahead forecast of Romanian electricity load using the XGBoost model. The blue area represents the historical load data from 2015 to 2023, while the orange area shows the forecasted load from mid-2024 to mid-2026.

**Key Observations:**

1. **Seasonal Trends**:
   * The forecasted load maintains the seasonal patterns observed in the historical data.
   * The model successfully captures these seasonal fluctuations, indicating its ability to understand and predict seasonal variations in the electricity load.
2. **Load Variations**:
   * The forecasted data shows a range of load values similar to the historical data, with the load reaching highs of around 9000 MW during peak periods and dropping to about 5000 MW during off-peak periods.
   * The continuity in the load patterns suggests that the model has effectively learned from the historical trends and is applying this understanding to future predictions.
3. **Planning and Management**:
   * These forecasts can be used for energy planning and management, helping grid operators and energy providers anticipate demand and ensure a reliable supply.
   * Accurate forecasting aids in optimizing resource allocation, planning maintenance, and managing energy reserves effectively.

**Conclusion:**

The XGBoost model demonstrates strong predictive capabilities for forecasting Romanian electricity load over a two-year period. The model captures the essential seasonal variations and trends observed in the historical data, providing a reliable forecast that can be used for future planning and decision-making..

**Analysis of the Solar Load Factor Matrix - Hungary**

This heatmap represents the solar load factor matrix for Hungary, showing the load factor for each hour of the day and each month of the year. The load factor is a measure of the efficiency of solar power generation relative to its installed capacity, with higher values indicating more efficient generation.

**Key Observations:**

1. **Peak Solar Efficiency**:
   * **Midday Hours**: The highest load factors are observed during the midday hours, particularly between 8 AM and 12 AM. This is when solar radiation is at its peak, leading to maximum solar power generation.
   * **Summer Months**: The months of June and July exhibit the highest load factors, with values reaching up to 0.75. This is due to the longer daylight hours and more intense solar radiation during the summer.
2. **Seasonal Variations**:
   * **Spring and Fall**: Moderate load factors are observed during the spring (April and May) and fall (September and October) months. These months still have significant solar generation but not as intense as the summer months.
   * **Winter Months**: The winter months (December, January, and February) show the lowest load factors, with values close to 0. This is due to shorter daylight hours and lower solar radiation.
3. **Consistent Patterns**:
   * The load factor matrix shows consistent daily and monthly patterns, indicating predictable solar generation behavior based on the time of day and the season.

Conclusion:

The solar load factor matrix for Hungary provides a clear and detailed view of the efficiency of solar power generation throughout the day and year. The highest efficiency is achieved during the midday hours in the summer months, while winter months see minimal solar generation. These insights are valuable for optimizing solar energy use, planning for backup energy sources, and considering energy storage options to enhance the reliability and efficiency of the energy grid.

**Analysis of Forecasted Hourly Solar Generation in Hungary (2024-2025)**

This chart shows the historical solar generation data from 2021 to 2023 and the forecasted solar generation for Hungary from 2024 to 2025. The forecasts are based on the solar load factor matrix and projections of installed capacity.

**Key Observations:**

1. **Seasonal Patterns**:
   * The forecasted solar generation displays clear seasonal patterns, similar to the historical data.
2. **Installed Capacity Impact**:
   * Peak generation during the forecast period reaches up to approximately 3500 MW. The increase in forecasted generation compared to historical data indicates an expansion in installed solar capacity. This growth supports Hungary’s efforts to increase renewable energy production and reduce reliance on fossil fuels.

**Insights and Implications:**

* **Grid Stability and Flexibility**: With higher peaks in solar generation, grid operators will need to ensure the stability and flexibility of the grid to accommodate the variable nature of solar power. This includes upgrading grid infrastructure and implementing demand response strategies.
* **Environmental Impact**: The increased reliance on solar energy contributes to reducing greenhouse gas emissions and advancing Hungary’s sustainability goals. This transition supports global efforts to combat climate change by shifting towards cleaner energy sources.

**Conclusion**

The forecasted solar generation for Hungary from 2024 to 2025 shows significant growth in solar capacity, with clear seasonal patterns and higher peak generation levels. These projections underscore the importance of continued investments in renewable energy infrastructure and strategic planning to effectively integrate this growing capacity into the national grid. The anticipated increase in solar generation represents a positive step towards sustainable energy and environmental goals for Hungary.