IT ACADEMY

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SPRINT 10

UNDERSTANDING CATALUNYA'S ELECTRICITY DEMAND (JANUARY 2005 TO SEPTEMBER 2024)

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ABSTRACT

This study focuses on how energy is consumed in Catalunya from January 2005 to September 2024 and how it is priced from September 2021 to September 2024. Its main objective is to identify trends, such as when energy usage is high or low during different periods (January 2005 to September 2021 and September 2021 to September 2024, when small distributors were included), which days of the week have the most or least demand, and how energy costs fluctuate during these times, especially from September 2021 to September 2024. Understanding these patterns is key to encouraging people to use energy more effectively.

The data comes from two main sources: the Generalitat de Catalunya, which provided hourly electricity demand data measured at central busbars (in MWh), and Lumisa Energies, which supplied pricing information per kWh. To analyze the data, Power BI and Python were used. To make the data easier to work with, the original columns were reorganized using a process called unpivoting, and most of the graphs were generated using Power BI, such as bar and line plots. Moreover, to check if the data follows a normal distribution, the Shapiro-Wilk test was used, and to study the relationships between variables, Spearman's correlation was utilized in Python.

The results show that energy consumption tends to peak in the evenings in both periods, and from September 2021 to September 2024, the energy usage coincides with higher energy price rates, while off-peak hours occur after midnight. Moreover, weekends show lower energy usage and lower prices compared to weekdays.

Overall, this study provides valuable insights into how people in Catalunya use energy. These findings could be a use to guide the residents and businesses on how to consume energy that will benefit them and the autonomous region. Future research could look into other factors, like how renewable energy, seasonal changes or weather might influence these trends.

1- INTRODUCTION

1.1 Background

This study looks at energy consumption and pricing trends in Catalunya, a region where demand for energy has changed over time due to population growth, economic activity, and new energy policies. Understanding these changes is important because how we use energy reflects how society functions and also affects things like resource distribution, the environment, and economic efficiency.

This analysis is especially relevant right now, given the rising inflation that's affecting households and businesses. Catalunya's shift toward cleaner energy sources also makes it more important to find pricing strategies that can adjust to the changing balance of energy supply and demand.

1.2. Objective

The primary objective of this study is to investigate how energy usage from January 2005 to September 2024 has varied over time, with a particular emphasis on identifying the peak and off-peak hours as well as daily trends and providing insights on which days and hours have lower and higher price rates especially from September 2021 to September 2024. By understanding these patterns, the analysis aims to provide relevant data to residents, entrepreneurs and commercial entities to optimize energy usage and demand management.

1.3. Research Questions

This study seeks to answer the following questions:

1. E**nergy Consumption Patterns (January 2005– August 2021):**
- What are the peak and off-peak hours for energy consumption in Catalunya from January 2005 to August 2021?
- How does energy consumption differ across the days of the week during this period?

2.. **Energy Consumption Patterns (September 2021– September 2024):**
- What are the peak and off-peak hours for energy consumption in Catalunya from September 2021 to September 2024?
- How does energy consumption vary by day of the week during this period?

3. **Energy Costs Based on Lumisa's Price Rates:**
- During which hour(s) did residents in Catalunya pay the highest and lowest energy prices?
- On which day(s) did residents in Catalunya pay the highest and lowest energy prices?

By addressing these questions, the study aims to reveal important conclusions about energy consumption trends in two distinct timeframes and cost patterns from September 2021 to September 2024 in Catalunya contributing to more efficient and cost-effective energy use.

2. DATA DESCRIPTION

2.1 Source

The dataset used in this study was sourced from the network of the main electricity distributor in Catalonia. Specifically, the consumption data spans the years 2005 to 2024, covering two distinct periods: January 2005 to August 2021 and September 2021 to September 2024, when the electricity demand also included electricity transmitted to other distributors. Pricing data is based on Lumisa Energies' price rates per kWh, which were used to create a visualization of price and demand from September 2021 to September 2024.

2.2. Variables

The study utilizes the following key variables:

1. **Hourly Energy Consumption (MWh):**
- Description: The amount of energy consumed during each hour of the day.
- Purpose: To identify peak and off-peak hours and assess daily usage patterns.
2. **Day of the Week:**
- Description: Categorical variable indicating whether consumption occurred on weekdays or weekends.
- Purpose: To explore variations in energy consumption based on the day of the week.
3. **Time Period:**
- Description: The year or group of years to segment the analysis (January 2005– August 2021 vs. September 2021– September 2024).
- Purpose: To compare energy usage trends across different timeframes.
4. **Price per Megawatt Hour (€/MWh):**
- Description: The hourly energy rate, as defined by Lumisa's pricing policies.
- Purpose: To identify the hours and days with the highest and lowest energy costs.
5. **Energy Cost (€/Hour):**
- Description: The total energy cost calculated as consumption multiplied by the price per MWh.
- Purpose: To analyze the economic impact of energy usage patterns.

3.3. Preprocessing

The following preprocessing steps were undertaken to ensure data quality and consistency:

1. **Data Cleaning:**
- Unpivoted columns to rows for easier visualization, especially with hours.
- Added a column with assigned numbers to days for sorting.
2. **Feature Engineering:**
- Transformed kWh price rates to MWh to match the dataset, which is in MWh.
- Calculated the cost of the energy consumed by multiplying it by the price in MWh.
3. **Segmentation:**
- Divided the dataset into two timeframes (January 2005–August 2021 and September 2021–September 2024) to enable temporal comparisons and distinguish the difference in consumption amount before and after including the small energy distributors.

By thoroughly describing and preparing the data, this study ensures the reliability of its findings and provides a solid foundation for answering the research questions.

3. METHODOLOGY

3.1 Analysis Techniques

Descriptive Analysis:

- Used to summarize and visualize energy consumption and pricing trends across the dataset.
- Tools included line and bar graphs to identify patterns.

Time Series Analysis:

- Examined energy consumption patterns across different hours of the day and days of the week to identify peak and off-peak periods.
- Temporal variations were analyzed using line and bar graphs.

Statistical Testing:

- Shapiro-Wilk Test: Assessed the normality of the data to determine the suitability of parametric methods using Python.
- Trend Analysis: Applied to compare energy consumption and costs from September 2021 to September 2024.

Correlation Analysis:

- Spearman's rank correlation was used to measure the relationship between energy consumption and pricing, as the data did not meet the normality assumption.

Visualization:

- Heatmaps and scatter plots were employed to explore relationships between energy usage, time, and pricing. Seaborn and Matplotlib were used for enhanced visual clarity.
- Bar and line graphs were used to show trends in consumption and costs. Power BI was used to generate these graphs.

3.2. Assumptions

- The hourly energy consumption data is complete and representative of actual usage patterns.
- Time series data assumes consistency in measurement and recording practices over the years.
- The pricing data provided by Lumisa accurately reflects the energy rate structures for September 2021 to September 2024, as obtained from a single source.
- Correlation analysis assumes monotonic relationships between variables.

3.3. Tools/Software

- **Power BI:** Used for data cleaning, preprocessing, analysis and dynamic visualizations.
- **Python (Pandas, NumPy):** For statistical testing and relationship, exploratory analysis and visualization.

- **Seaborn and Matplotlib:** For relationships between variables.
- **Scipy:** For statistical testing, including normality assessments and correlation analysis.

These methodologies ensure a robust analysis framework, providing valuable insights into energy consumption and cost patterns in Catalunya over the studied periods.

4. RESULTS

4.1. Findings

Energy Consumption Trends (January 2005–August 2021):

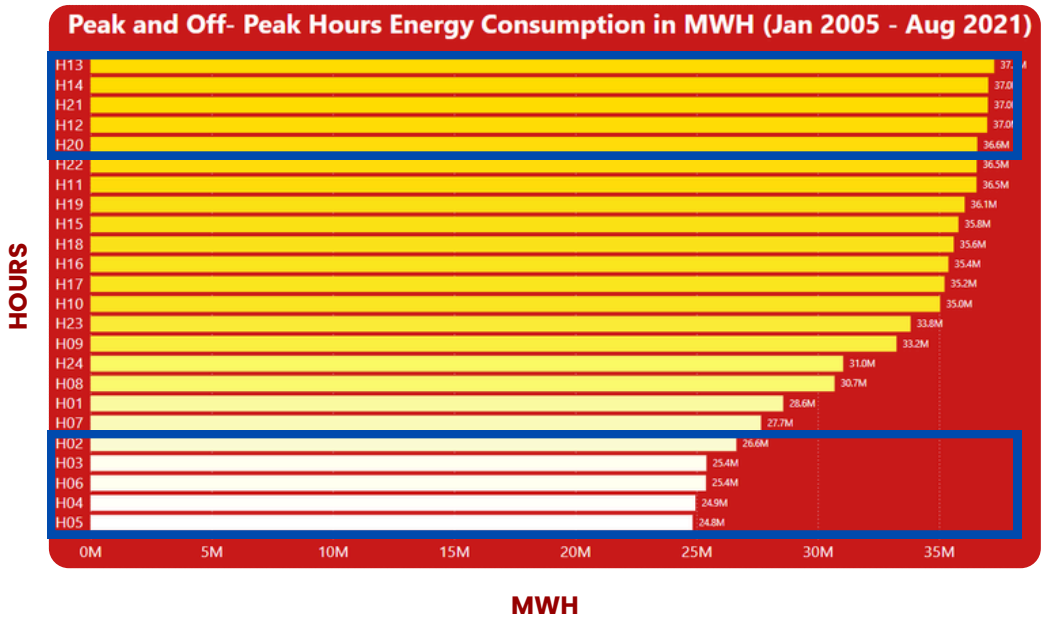

figure 1: **Peak and Off- Peak Hours from January 2002 to August 2021**

Peak energy consumption occurred from **12 PM to 2 PM** and between **8 PM and 9 PM.**. Off-peak consumption was observed from **2 AM to 6 AM.**

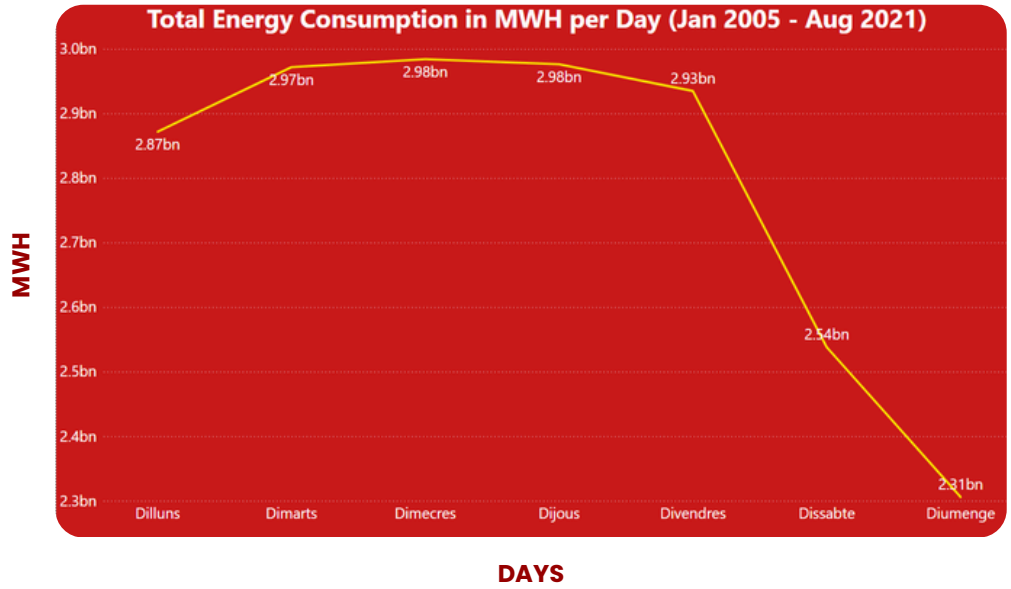

figure 2: **Total Daily Consumption in MWh from January 2002 to August 2021**

Weekday vs. Weekend: Energy usage was generally higher on weekdays, except on Mondays, and it significantly decreased on weekends. **The reasons for these fluctuations in consumption were not investigated, as they fall outside the scope of this study.**

Energy Consumption Trends (September 2021–September 2024):

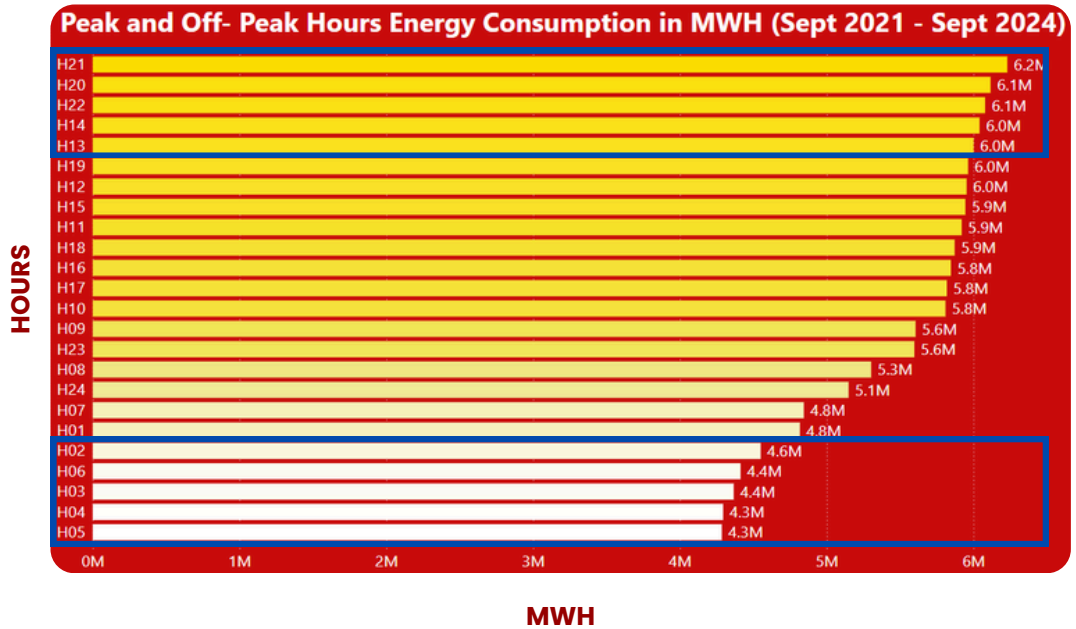

figure 3: **Peak and Off-peak hours for energy consumption in Catalunya (September 2021 to September 2024)**

Peak energy consumption during this period slightly differed from the first period, occurring between **1 PM and 2 PM** and from **8 PM to 10 PM.** Off-peak consumption remained consistent with the first period, observed from **2 AM to 6 AM.**

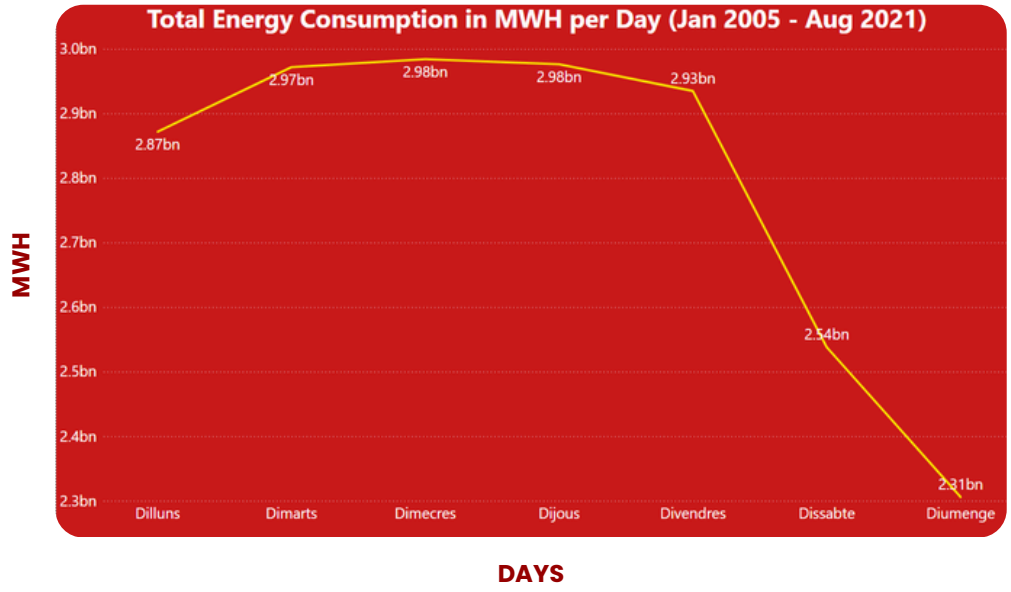

figure 4: **Total Daily Consumption in MWh from (September 2021 to September 2024)**

Weekday vs. Weekend: The results for this period were the same as in the previous period. Energy usage was generally higher on weekdays, except on Mondays, and significantly decreased on weekends. **The reasons for these fluctuations in consumption were not investigated, as they fall outside the scope of this study.**

Pricing Analysis (Lumisa Energies Rates):

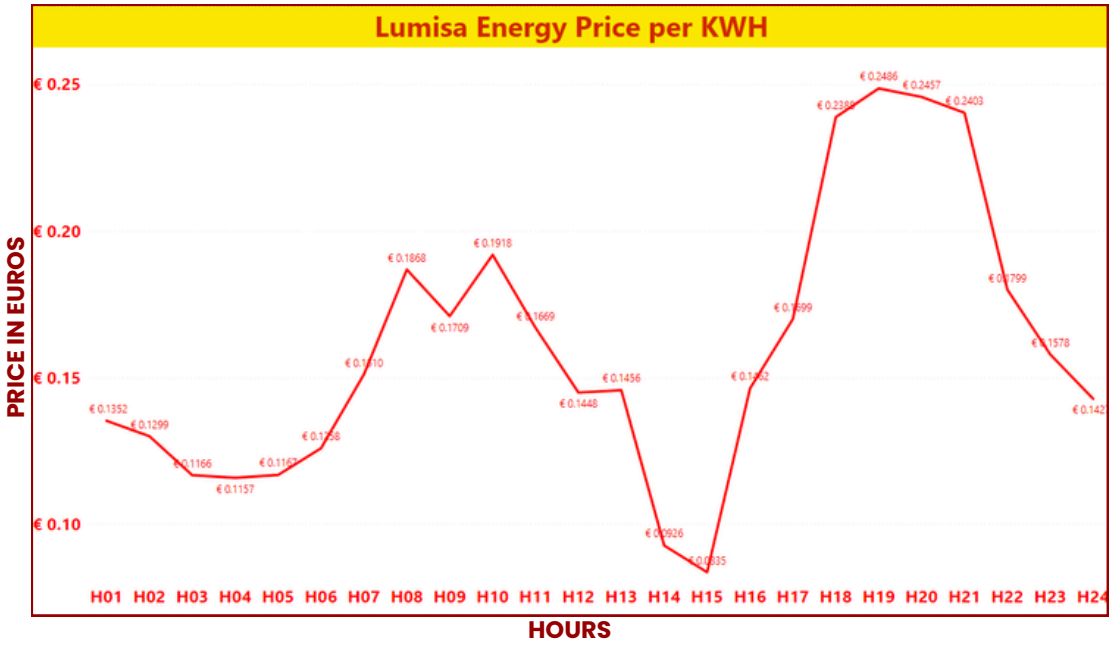

figure 5 : **Lumisa Energies Price Rates in KWh**

These are the price rates per kWh published by Lumisa Energies on their website. The prices vary by hour, and while there may be price ranges, no identical price was detected across the hours.

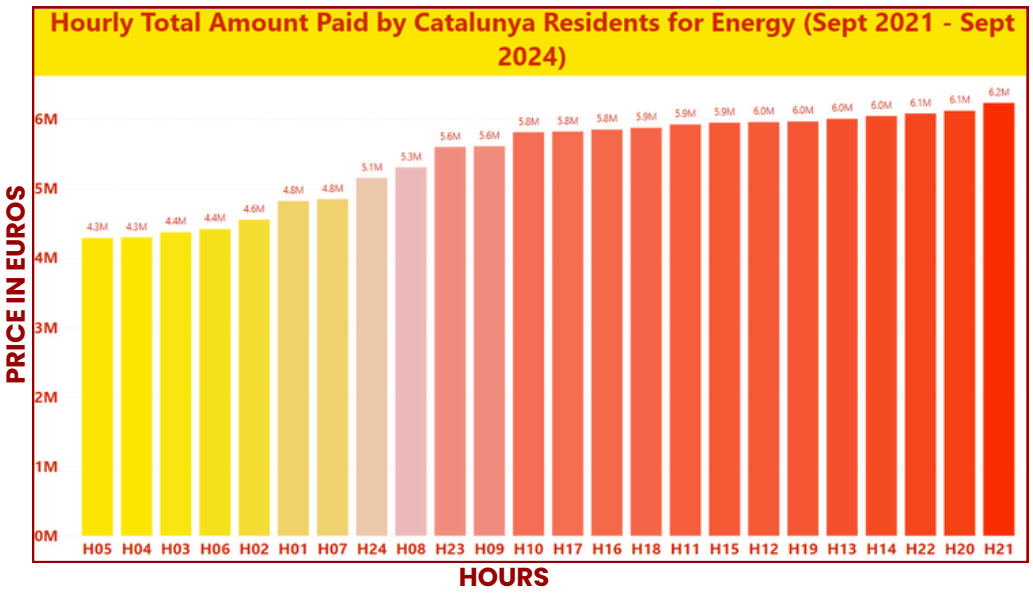

figure 5 : **Hourly Total Amount paid by Catalunya Residents (September 2021 to September 2024)**

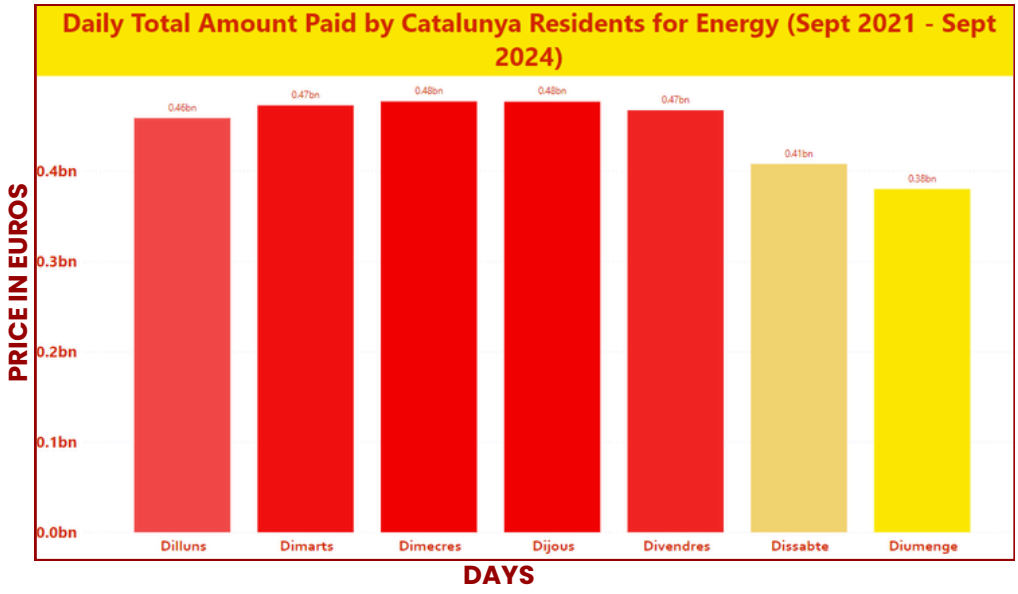

figure 6: **Daily Total Amount paid by Catalunya Residents (September 2021 to September 2024)**

Residents paid the highest rates during peak demand hours **(1 PM to 2 Pm and 8 Pm to 10 PM)**, which align with increased energy usage. Prices were lowest during off-peak hours **(2 AM to 5 AM)**. Since pricing data for weekends was not disclosed by the company; therefore, this study assumes that price rates remained consistent throughout the week (Monday to Sunday).

4.2.Statistical Tests

Shapiro-Wilk Test:

- The p-values in column MWH and price per MWH are extremely small, far below 0.05. This means the null hypothesis is rejected for every column, indicating that none of the columns follow a normal distribution.

Spearman Correlation Analysis:

- The Spearman correlation of 0.72 between energy consumption in MWh and price per hour in MWh displays an impressive positive relationship. This implies that as energy usage increases, the price per hour also tends to increase, but not in a perfect linear way.

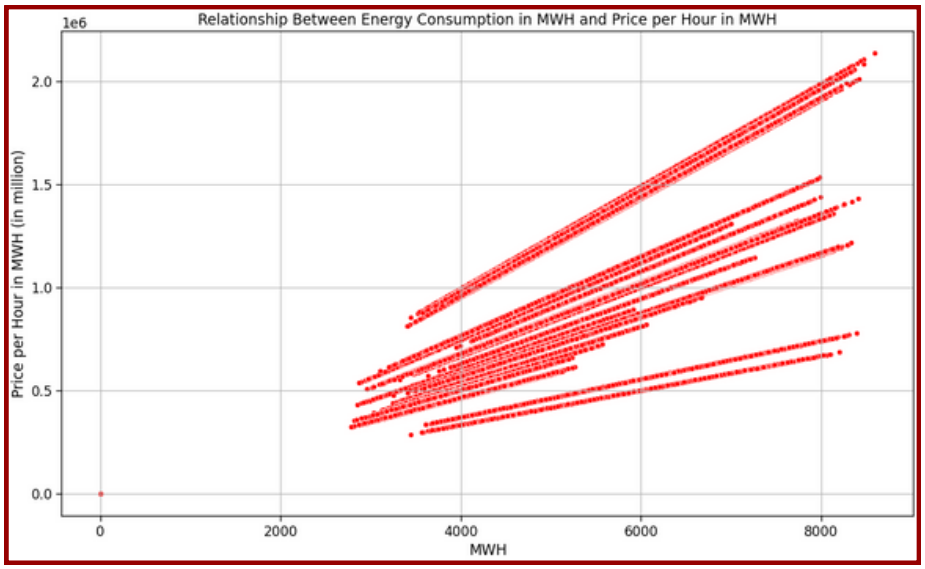

figure 7: **Scatterplot showing the relation of the consumption in MWh and Price per MWh**

The graph indicates a clear positive relationship between the two variables. As energy consumption (MWh) increases, the price per hour also tends to increase. The data points form a diagonal line that suggests a monotonic increase — meaning, as one variable increases, the other does too.

5. CHARTS AND GRAPHS

For the analysis, different types of charts, each chosen to highlight specific trends and relationships in the data.

Line graph

This graph was used to show energy consumption trends over the days of the week during different periods. It was ideal for illustrating how energy use changed over time, making it easy to identify days with high and low consumption. It helped visualize fluctuations in energy demand and observe patterns that may be linked to specific days, such as weekends or weekdays.

In addition, it was used to show the flow of energy consumption throughout each hour of the week, from Monday to Sunday. This graph helps observe how demand changes hourly across multiple days, revealing any clear patterns of increase or decrease in energy use throughout the week, as shown below:

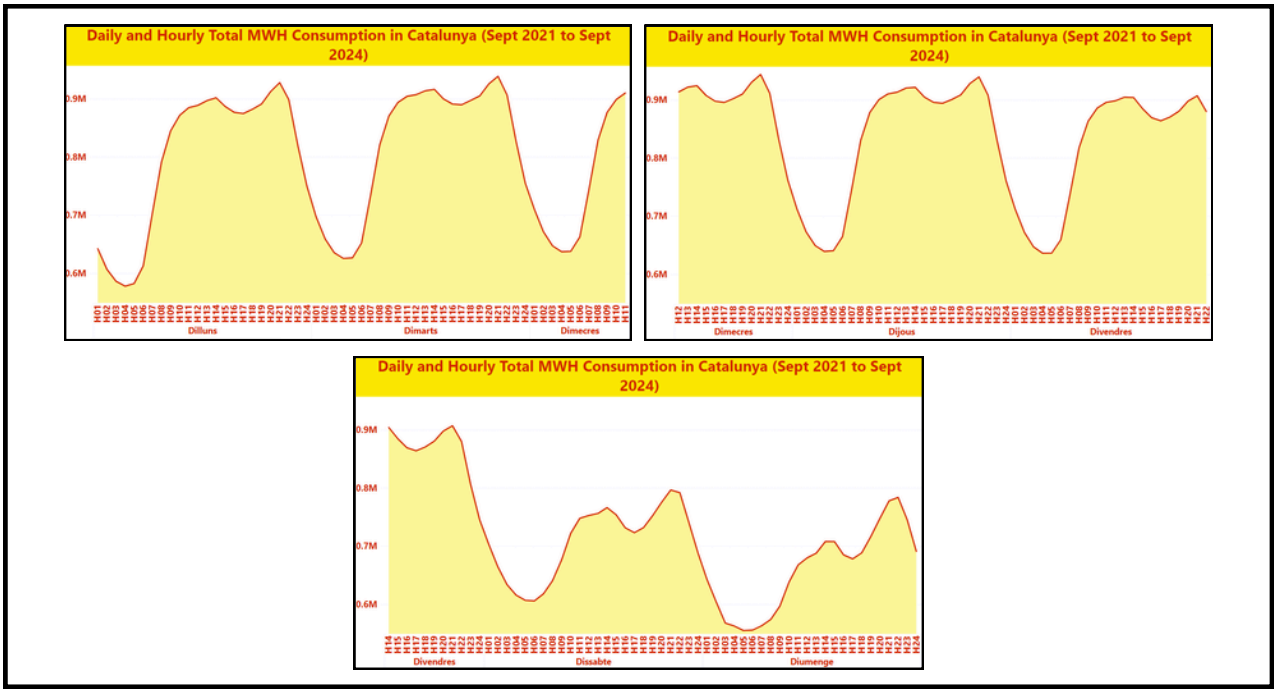

figure 8:**Daily and Hourly Total MWH Consumption in Catalunya (Sept 2021 to Sept 2024)**

Bar graph

This was used to compare energy consumption during peak and off-peak hours. This was used to compare different categories, and in this case, they effectively highlight the distinct differences between periods of high demand (peak hours) and low demand (off-peak hours). This visual representation makes it easier to grasp how energy usage varies across different times of the day.

Scatterplot

This was chosen to analyze the correlation between energy consumption and price per hour. It shows how the price tends to increase with energy consumption, highlighting a positive correlation.

6. FINDINGS

6.1 Interpretation

The findings reveal distinct patterns in energy consumption and pricing in Catalunya over the analyzed periods. Peak hours across the week are consistent, particularly during the evenings, confirming expectations of higher demand during these times. However, it can only be assumed that this is aligned with residential and business activities, as the reasons behind the peaks are not within the scope of the study. Off-peak hours occur late at night, when we assume activity is minimal.

Similar patterns are found during the week, Mondays, Saturdays and Sundays display low energy demand. These patterns suggest opportunities for demand-shifting strategies to optimize energy use and reduce costs for consumers.

The correlation between energy consumption in MWh and price per hour in MWh shows a strong positive relationship. This implies that as energy usage increases, the price per hour also tends to increase, though not in a perfect linear way.

6.2. Limitations

The study has a few limitations that should be considered.

1. The data only covers energy consumption and pricing from 2021 onwards, so any differences in energy patterns before that period weren't included.
2. The study doesn't break down energy use by sector, such as residential, commercial, or industrial, which means we don't know if these groups behave differently when it comes to consumption and pricing.
3. The study doesn't take into account factors like weather, economic activities, or special events, which can have a big impact on energy use and pricing.
4. The price data is based on just one energy company, so it may not fully reflect the pricing trends across the entire market, which could make the results less accurate for the broader population.

7. CONCLUSION

This study analyzed energy consumption and pricing trends in Catalunya across two periods: January 2005 to August 2021 and September 2021 to September 2024. The findings indicate consistent peak consumption hours during evening periods from 12 PM to 2 PM and between 8 PM and 9 PM, with off-peak hours observed late at night from 2 AM to 6 AM during the first period (January 2005 to August 2021). Additionally, from September 2021 to September 2024, peak energy consumption slightly differed from the first period, occurring between 1 PM and 2 PM and from 8 PM to 10 PM, while off-peak consumption remained consistent with the first period, observed from 2 AM to 6 AM.

Pricing trends showed that residents paid the highest rates during peak hours, particularly in the evening, and the lowest rates during off-peak hours.

Understanding these patterns can be really helpful for different groups.

1. For policymakers, knowing when energy consumption is highest can help them create strategies to encourage people to use less energy during peak times, like offering discounts for off-peak use or adjusting prices to balance demand on the grid.
2. For energy providers, this information helps them manage resources better and adjust prices to match consumption patterns, which can improve both efficiency and customer satisfaction.
3. For residents, knowing when prices are higher or lower allows them to change their energy habits, save money, and contribute to a more sustainable energy system.

Future Research:
Future research could explore how factors like weather, economic changes, and the use of renewable energy affect both energy use and pricing. It would also be useful to look at real-time energy changes and come up with methods to predict future demand and prices.

Practical Applications:
Development of apps or tools that help people track their energy costs and usage, making it easier to make smarter decisions. Moreover this could be useful to find ways to use renewable energy more effectively during peak and off-peak hours, which could help make energy use more sustainable.

In summary, this study provides a clear picture of energy consumption and pricing in Catalunya, showing opportunities to change energy costs by encouraging residents, entrepreneurs to change habits on energy use that will benefit them and Catalunya.

8. REFERENCES

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