BUAN 6V99.501 – Special Topics in Business Analytics

Title : Sustainability-focused data system to optimize electricity

Problem Definition and Data Selection

Problem Statement:
The main sustainability problem that the present project will be focusing on is the heavy reliance on non-renewable sources of energy, which are mainly at the form of fossil fuels, in the generation of electricity in Texas. The tremendous surge in the state's electricity demand, fueled by the growth of the population, economic growth, and the proliferation of digital technologies, simultaneously provides both a challenge and opportunity for transitioning to a more sustainable energy mix.

Data Preparation

Selection of data source:
The choice of data source for our project involved an intensive research process and careful consideration of different data sources concerning sustainability and electricity consumption in Texas. We began with brainstorming on key sustainability issues, including energy efficiency, carbon emissions, and renewable energy adoption.

This then led us to meticulous analysis of the consumption patterns of electricity and future demand in relation to effective solutions to these challenges.

Our research yielded us some excellent data sources, which mainly involve the US EIA website. The aim of this study was to develop a data system focusing on sustainability issues capable of optimizing electricity usage and aiding the adoption of renewable energy, and of course, minimizing carbon emissions in Texas.

Proposal Outline:

Problem Focus:
Analysis of the consumption patterns of electricity in Texas and predict future demand in relation to solving these sustainability challenges.

Proposed Data Sources:
Use datasets from US EIA website open data platforms, databases of governments, company reports, and relevant APIs.

Potential Value:
A data-driven system for optimizing electricity usage, improvement in renewable energy adoption, and reduction in carbon emissions in Texas.

Data Sourcing:

We collected our data from the US Energy Information Administration—EIA, an open source and often updated source and thus could obtain recent and accurate data over electricity consumption in Texas.

Data Cleansing and Transformation using Power BI and Python:

Missing Values, Inconsistencies and Errors:
We used Power BI techniques such as data profiling and filtering to find and fix missing values, inconsistencies, and errors in the raw data retrieved from the website of the EIA to obtain data for analysis with the integrity of the data.

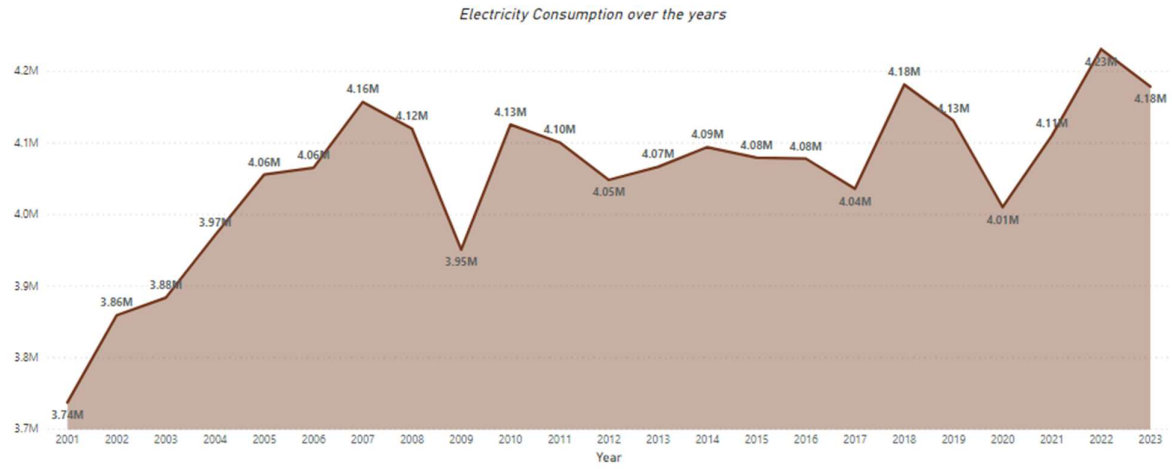
Data Transformations:
We applied some functionalities available in Power BI such as pivoting and unpivoting to restructure the raw data into forms more suitable for analysis.

Date Information Extraction:
We extracted the date component from the column containing date and time information using Power BI's functionalities—delimiters and column from examples. We are going to perform time-series analysis and trend identification.

Provisioning Data:
After data cleansing and transformation in Power BI, we organized the data into CSV files to provide it appropriately for further modeling and analysis.

Data Modelling
The electricity consumption data for Texas was first preprocessed as an important step in data modeling. The distribution of the data was tested for normality in order to determine whether there was any skewness or kurtosis, which might cause inaccuracies in future statistical analyses. Tests for stationarity were carried out to ascertain if the data was statistically stable over time, as is generally required for most time series forecasting techniques. The data was made non-stationary, by identifying elements such as trends or seasonality. Appropriate transformations, such as differencing or detrending, were applied to neutralize these elements so that the data could be properly modeled. These preprocessing steps are generally useful in normalizing the data and removing all underlying patterns that may cause confoundment for the forecasting models. This in turn allows the team to forecast true future trends in Texas' electricity consumption with much more precision.

Data Visualization



In order to represent the trends in electricity consumption over the years in the United States, we made a line graph comparing the years 2001 and 2023.

Key Observation

Comparing consumption:

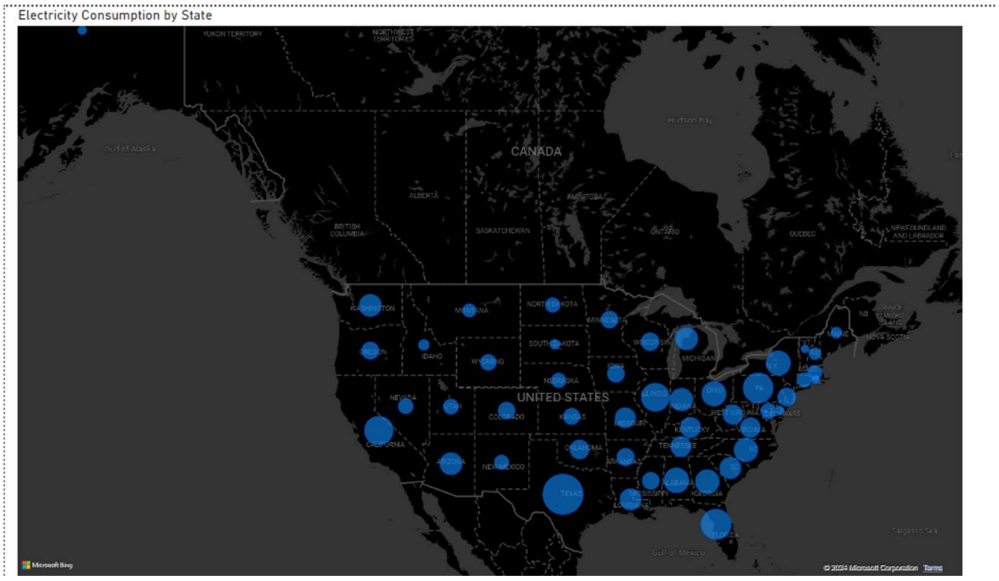
- 2001: Consumption was at 3.74 million units.
- 2023: Consumption had risen to 4.18 million units.

Growth in Consumption:

The line graph reveals a steady upward trend in electricity consumption during the years, and hence an increase in energy demand.

Magnitude of Increase:

The comparison between the years 2001 and 2023 reflects a remarkable increase in consumption, hence showing that the energy needs are changing and the emerging infrastructural developments.



We used a map visual to delve into electricity consumption over the United States with particular emphasis on Texas US-TX.

Key Observations:

High Electricity Consumption:

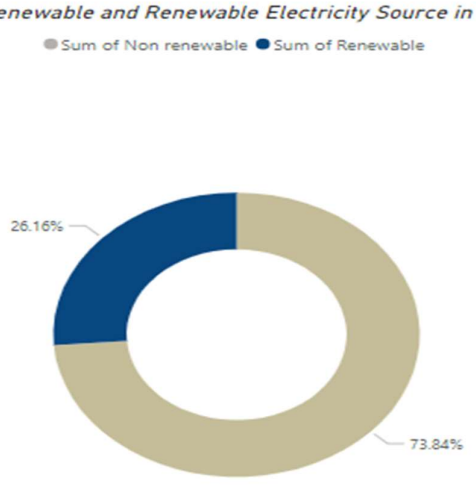
US-TX had the highest Sum of Electricity Consumption at 1,00,66,249.58 which is 3,57,057.55% higher compared to US-DC, which recorded the lowest Sum of Electricity Consumption 2,818.43.

Contribution of US-TX:

US-TX contributed significantly, 10.75% to the Sum of Electricity Consumption across the 51 states studied.

Dominance of US-TX:

The data shows massive amounts of electricity consumption within the state of Texas, making it one of the key contributors to the national electricity consumption landscape.

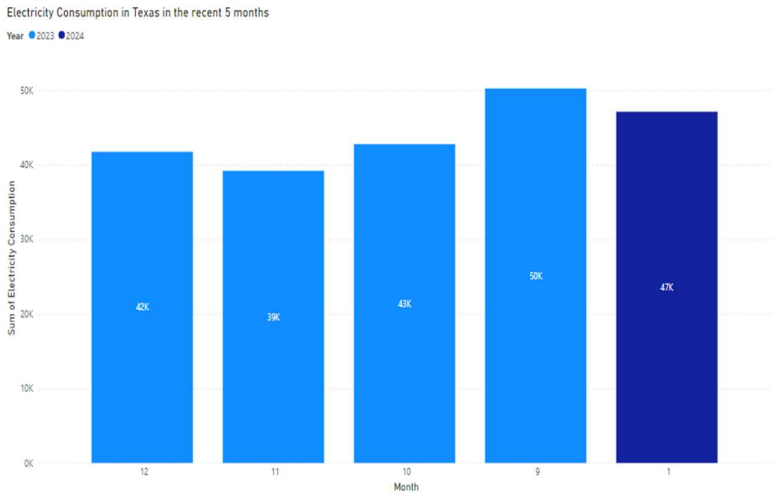


We illustrated data on the composition of electricity consumption in Texas using a donut chart that differentiates between non-renewable and renewable sources.

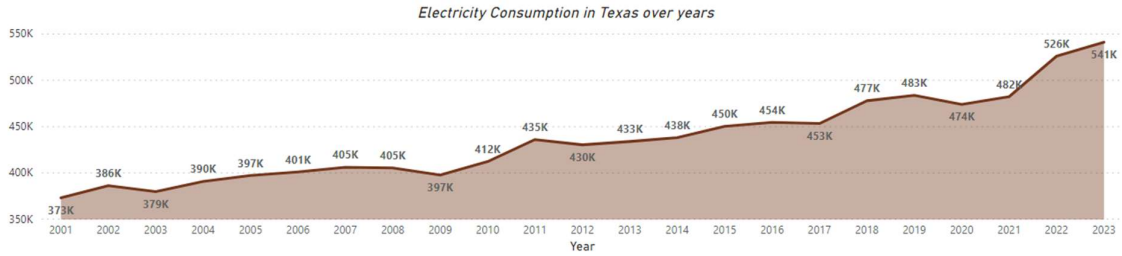
Key Observations:
Non-renewable vs Renewable Sources:

- Non-renewable electricity sources had been the largest, with 73.84% of electricity used being non-renewable.
- Renewable electricity sources were significant but relatively smaller, contributing 26.26% of overall consumption.

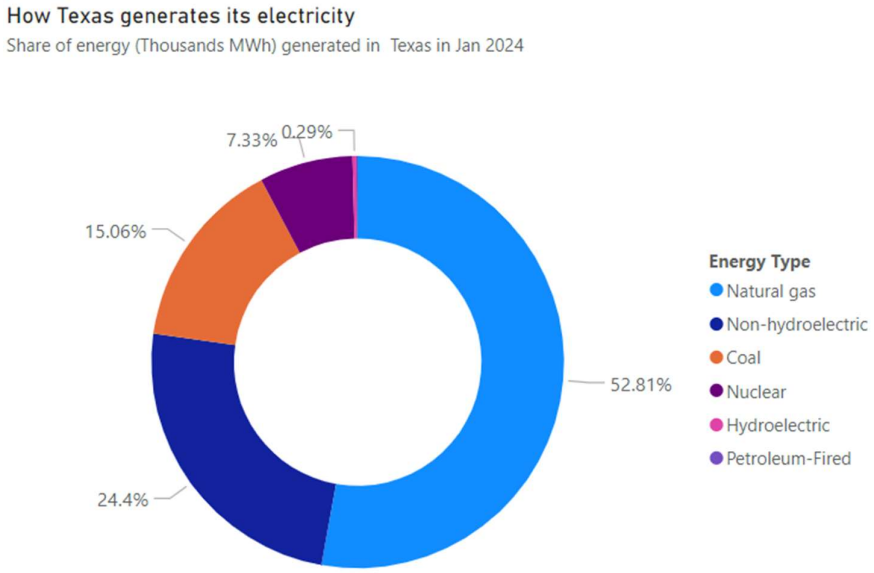
Reliance on Non-Renewable Sources:
Non-renewable sources dominated electricity consumption, thereby showing a high dependency on traditional sources of energy.



With respect to our previous visualizations, we understood that Texas is the highest consumer of Electricity in the US and also the fact that almost 74% of the electricity in the US are from non-renewable sources. Now to get a fair understanding of the electricity consumption in the US over the recent 5 months we can refer the above bar chart which suggests that electricity consumption on an average in the recent few months is more than the average of the other states in the US and Texas is a good sample set to study the demand and supply of electricity in the US and for the system to predict the demand over the next few months which would in turn make us understand the steps to be taken to optimize electricity in Texas in the future months.



In the last ten years, the Texas power grid has been facing a steady and significant increase in its electricity demand. The consumption of electricity in the state has increased by an average of 6% on a year-to-year basis, and in the last ten years, the total consumption has increased by 17.2%. Such a trend is expected to continue owing to the state's ever-increasing population and economic development.

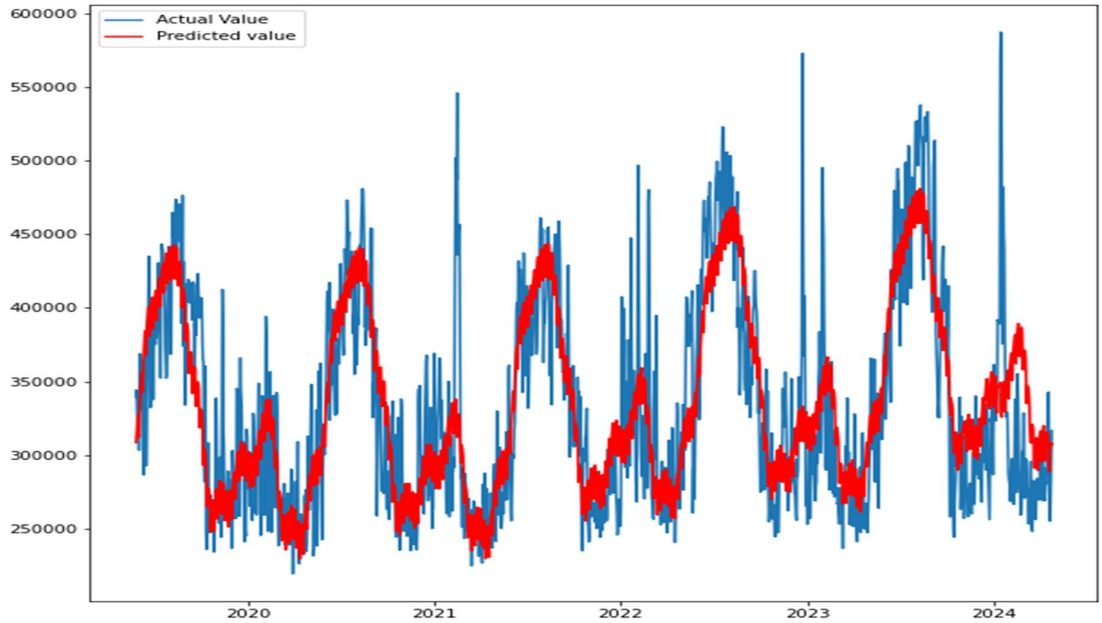


As against the conventional fossil fuels, Texas has adopted diversity in its energy mix, as the energy mix of the state includes both the conventional fossil fuels and renewable resources. In the United States of America, Texas ranks first when it comes to the highest production of wind energy. Wind-generated electricity in the United States of America accounts for 26% of the total electricity generated in 2022. Texas has also seen rapid growth in solar power capacity—more than double in 2021—and is on its way to be close to 18,000 MW by the end of 2023. The mix of such renewable and non-renewable resources has helped Texas grow and sustain its economy and population in an adequate way, thereby symbolizing the state's commitment to having a balanced and sustainable energy future.

Electricity demand trends will be very key to the design and investment of generation capacity, particularly of renewable energy resources. Higher levels of government investments in renewable energy projects require knowledge of trends in electricity demand so that the generation mix and supporting infrastructure can be optimally put in place to meet future demand sustainably. Better forecasting of electricity demand allows energy planners to better set priorities for the deployment of renewable over non-renewable alternatives, thus reducing stranded capacity and improving the overall system efficiency.

This helps the energy system to improve its transition to one that has a greater renewable-based energy system that satisfies future electricity needs generated from factors such as population growth and economic development. As long as investment in renewable energy is aligned appropriately with projected demand, policymakers and stakeholders can ensure that generation and transmission capabilities are developed to ensure the success of transitioning to a low-carbon energy future.

Modelling:



This forecasting model uses the historical data from 2019 to April 2024 for Texas to predict future electricity demand. This could be useful in the allocation of the renewable energy capacity that will meet the future demand and reduce carbon emissions in Texas. The forecasting model was accurate: predicted values were within 3% of actual values during testing. In addition, it had an overall low error rate; this is evidence of the reliability of the model. The specific forecasting technique used was the Facebook Prophet model, which showed seasonality trends in Texas' electricity demand. By accounting for these seasonal trends, the model was able to accurately forecast future consumption patterns. The presentation stresses that constant improvement of the model is expected to ensure there is added realism due to other factors affecting the demand trends. This would make the forecasts even more accurate and reliable for long-term energy planning and integration of renewable energy. In summary, this forecasting model was essential in this project to permit the optimization of renewable energy capacity to meet the future electricity needs in Texas in a sustainable manner while accurately capturing the seasonal variations in demand patterns. Ongoing model refinement will further improve the reliability of these demand forecasts.

Our thoughts and Conclusion:

The data-based analysis in this project has identified highly invaluable insights that would guide Texas through the path for the future on sustainable energy. The advanced forecasting techniques made by the team of experts were able to forecast future electricity

demand accurately and precisely in the state. Such an essential step helps optimize the generation mix and infrastructure investment.

The demand forecasting models show that a high percentage of non-renewable alternatives can be substituted using renewable energy sources. There will be a high reduction in the unutilized capacity and overall system efficiency. According to online carbon footprint calculators, substituting just 1 megawatt-hour of non-renewable electricity generation with renewable sources can avoid 0.6 to 1.0 metric tons of CO2 emissions. With such a considerable potential of reducing emissions, it is clear that the alignment of Texas' generation portfolio with projected demand will bring considerable environmental benefits. However, to tap into the value of such benefits, plenty of investment will be required in long-term transmission infrastructure. The availability of sound transmission networks to carry renewable energy from generation to the demand centers will be essential in avoiding curtailments and amplifying the utilization of these clean energy resources. Demand response programs and energy efficiency standards would also have a complementary role in managing peak electricity demand, thus reducing the demand for additional generation capacity.

Texas has already become one of the key players in the field of renewable energy sources. With an installed capacity of around 35,000 megawatts of wind capacity and around 10,300 megawatts of solar capacity as of 2021, the state had reached the top ranks in the renewable energy race. In the record-breaking heatwaves of summer 2023, renewable sources of energy such as wind and solar were providing 30-40 percent of the electricity needed to meet the skyrocketing demand of the state. On some days, renewables were given more than 50 percent of the total generation. Such a large stride in transitioning to a more sustainable energy mix attests to the state's significant progress.

These presented results also revealed that the use of Texas' renewable energy capacity also depends on weather conditions and sometimes on transmission constraints, with periodic bottlenecks in the distribution of these clean sources at peak demand hours. The successful integration of renewables into the Texas energy system will critically depend on resolving the infrastructure challenges related to this.

This data-driven project has given policymakers, energy planners, and industry stakeholders in Texas new insight into how best to optimize the generation mix to make informed decisions regarding investment in necessary infrastructure and demand-side strategies complementary to renewable generation. A comprehensive approach will be instrumental in guiding the state's transition toward a renewable energy future, with a resulting reduction of its carbon footprint and the growing electricity needs of its population and economy being met.

References:

- 1 U.S. Energy Information Administration (EIA) analysis on Texas energy profile
- Wikipedia article on Energy in Texas
- 2 Statista data on Texas electricity generation mix by source in 2021
- 3 Baker Institute article on Electricity in Texas
- U.S. Department of Energy article on energy production by state
- CALCULATE THE CO2 YOUR ELECTRICITY CONSUMPTION GENERATES
- Yang, S.; Zhang, D.; Li, D. A Calculation Model for CO_2 Emission Reduction of Energy Internet: A Case Study of Yanqing. *Sustainability* **2019**, *11*, 2502. https://doi.org/10.3390/su11092502