**SOUTHERN ALBERTA INSTITUTE OF TECHNOLOGY**

**SCHOOL FOR ADVANCED DIGITAL TECHNOLOGY (SADT)**

**An analysis of energy consumption in Alberta and strategies for sustainable energy practices**

**By**

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# **PART 5**

## **BUILDING THE ANALYTICAL SOLUTION**

ABSTRACT

The purpose of this project is to analyse energy consumption data provided by the Alberta Electric System Operator (AESO) to identify trends, patterns, and insights that can guide sustainable energy practices. The analysis encompasses eight years from January 1, 2015, to December 31, 2023, and focuses on both energy generation and demand. The objective is to create predictive models that can forecast future energy consumption, which will aid in proactive planning and decision-making.

According to stakeholder analysis, government and regulatory bodies have a significant interest in managing energy consumption for policy development and resource planning. Energy providers are directly impacted by consumption patterns and have the potential to influence consumer behaviour through pricing structures and energy efficiency programs.

The dataset includes over 1.2 million rows of data that undergo data preprocessing and analysis using various statistical and machine-learning techniques. The regional analysis identifies consumption patterns across different sectors and regions within Alberta, while predictive modelling and load forecasting provide insights into future energy demand.

The analysis reveals the impact of seasonality on energy consumption, with spikes during winter months and a shift in generation capacity towards cleaner energy sources. However, challenges remain in managing energy loss during the phase-out of coal-powered generation and optimizing generation from renewable sources, particularly during low wind and solar output periods.

Based on the findings, recommendations include increasing investment in wind, solar, and natural gas generation, as well as establishing more storage facilities to balance energy supply and demand throughout the year. Overall, this project emphasizes the importance of data-driven insights in shaping sustainable energy practices and addressing the evolving needs of Alberta's energy landscape.

**Risk and Reward**

In analysing AESO energy consumption data comes with both risks and rewards. Thorough understanding of the risks and rewards are crucial for effective decision-making. Below are an outline of the potential risks and rewards that may arise, along with how to effectively manage same.

**Table 1: Risks**

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Risk** | **Description** | **Management** |
| 1 | Market volatility | The energy industry can be highly volatile due to conditions such as natural disasters or events, weather condition, economic conditions and geopolitical. | Diversifying the energy mix and using major tools for risk management such as hedging, staying up to date on external factors which can eventually has an impact on the market and having systems and tools to forecast and predict to some degree of certainty natural event and some disasters. |
| 2 | Regulatory Changes | Regulatory policies and federal government can be changed, these will impact the energy sector's operations specifically investment in the sector and the direction of those investments. | There is the need to stay updated on regulatory developments, and all parties should be engaged in policy development and so that change in government will not lead to change in policy and investment priorities. |
| 3 | Technological advancement | Rapid technological changes can have a disruptive effect or impact on the energy landscape. For push for green technology such as electric vehicles (EVs) will require more generation capacity to meet demand. | Proper investment in research and development, staying up to date on technological trends, and having systems to adapt quickly to those changes will go a long way to help. This will lead to making use of advanced data analytics and predictive modelling. |
| 4 | Clean environmental push | The ever-growing environmental concerns and awareness will lead to stringent regulations, affecting traditional energy sources in the energy generation mix such as coal and oil. | Adequate investment in clean energy alternatives and sustainable, wide diversification of energy sources, and above all, proactively address environmental concerns will be the better approach to use. |

**Table 2: Rewards**

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Demands** | **Description** | **Management** |
| 1 | Innovation opportunities | With the ever-growing push for clean energy alternative sources and sustainable energy mis. The energy industry is poise for growth and offers a lot of opportunities for new technologies and innovation. | The era of working in silos are far gone, energy regulators and producers are to collaborate with technology partners, invest in research and development and promote a culture of innovation. |
| 2 | Demand for energy | The increasing population, high demand for EVs and industrialization will lead to high demand for energy to sustain the industry. | Proper assessment and dentification of high profitable areas with high growth potential to invest in, and adapt more agile strategies to meet such a increasing demand. |
| 3 | Energy transition effort | The shift globally towards sustainable and cleaner energy sources also offer an avenue for investment in renewable energy projects which can offer more generation capacity. | Proper evaluation and diversification into the renewable sources and exploring collaboration with existing companies in the green energy industry and adequately aligning strategies with global sustainability targets |

**Data Collection**

The dataset for the project is on Alberta Electric System Operator (AESO) public data source portal(<https://public.tableau.com/app/profile/market.analytics/viz/AnnualStatistics_16161854228350/Introduction>). Hence, the dataset is available, and access is not restricted. The downloaded data covers a period of 8 years (1st January 2015 to 31st December 2023).

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Source: <https://public.tableau.com/app/profile/market.analytics/viz/AnnualStatistics_16161854228350/Introduction>

Below is the structure of the downloaded data. Though the data is cleaned, the format is not suitable for analysis. Hence the need to move to the next stage our architecture overview which is the data preprocessing stage.

There is the need to process the data and convert it to a format suitable for analysis. The essence is to clean and preprocess the data to ensure accuracy. Handle missing values, outliers, and any inconsistencies.

**Table 3: Raw demand data structure**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Hourly Profile | Season | Date (MST) | Calgary | Central | Edmonton | Losses | Northeast | Northwest | South |
| 01/01/2015 | OFF PEAK | WINTER | 01/01/2015 00:00:00 | 1028.338459 | 1326.524094 | 1375.897642 | 279.0501962 | 907.5675665 | 989.6784688 | 922.8939968 |

**Table 3: Raw generation data structure**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Fuel Type** | **Date - MST** | **Date** | **Date (MPT)** | **Date (MST)** | **Maximum Capacity** | **System Available** | **System Capacity** | **System Generation** | **Total Generation** |
| Coal | 08/10/2023 00:00:00 | 08/10/2023 | 08/10/2023 03:00:00 | 08/10/2023 02:00:00 | 820 | 195 | 820 | 273.1354 | 272.0294955 |
| Coal | 08/10/2023 00:00:00 | 08/10/2023 | 08/10/2023 06:00:00 | 08/10/2023 05:00:00 | 820 | 380 | 820 | 377.808 | 377.5864382 |
| Coal | 08/10/2023 00:00:00 | 08/10/2023 | 08/10/2023 23:00:00 | 08/10/2023 22:00:00 | 820 | 380 | 820 | 376.112 | 375.9049385 |

**Data Preprocessing**

The data was transformed and converted into a format suitable for analysis. The data was therefore loaded into Microsoft Power BI.

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Power Query was then launched to transform the data by deleting unnecessary columns such as totals (system load), dates in different regions and unpivoting the data in a format suitable for analysis. Below is the figure of the transformation process.

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After unpivoting, the two columns which names are not descriptive enough were renamed to Region and Load. This will therefore make them descriptive enough for analysis to be performed on them.

A screenshot of a computer

Description automatically generated

The table below is the output from cleaning and preprocessing, which is ready and are in the format for analysis. We then move to the next stage, which is how to save the clean data.

***Unpivoted data structure***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Date** | **Hourly Profile** | **Season** | **Date (MST)** | **Region** | **Load** |
| 01/01/2015 | OFF PEAK | WINTER | 01/01/2015 00:00:00 | Calgary | 1028.338459 |
| 01/01/2015 | OFF PEAK | WINTER | 01/01/2015 00:00:00 | Central | 1326.524094 |

**Data Storage**

To make the data available to all team members, a folder was created in OneDrive where the data in CSV was saved and shared for ease of collaboration with version control enabled.

**A screenshot of a computer

Description automatically generated**

**Data Analysis Tools**

As indicated in the proposal, Power BI and Python were the data analysis tools used in our analysis. Power BI was basically used for the initial data cleaning and preprocessing into a format suitable for analysis.

The cleaned data in a csv format was loaded into Jupyter Notebook using Python. Below is the loading process (python code to load the data) and print the first five (5) rows of data from the data frame.

**A screenshot of a computer

Description automatically generated**

To be sure the imported data was of correct format and datatype and suitable for analysis, we again converted the data type to appropriate format to avoid errors during the analysis phase. Below is the code and the output from the datatype conversion.

A screenshot of a computer

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**Exploratory Data Analysis**

Before we perform exploratory data analysis on the data, we first checked for missing values though we know the data is clean. This is to be sure we are working with data with no missing values of significance.

**A screenshot of a computer

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**A screenshot of a computer

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With the results above we are sure and confident that there are no missing values, and we are confident that we will be working with a very clean data when we proceed. Exploratory Data Analysis involves visualizing and understanding the data to gain insights. Here are some techniques we applied to the energy consumption data.

We used Histogram of Load to visualize the distribution of the 'Load' variable.

A graph of a number of blue and white lines

Description automatically generated with medium confidence

Box Plots by Region was explored to determine the load distribution in different regions including system or transmission loses.

**A screenshot of a computer screen

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Violin plot of Load by Season was utilized to visualize the distribution of load by season.

**A screenshot of a computer screen

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**Statistical Analysis**

We then proceeded to calculate summary statistics such as mean, median, standard deviation, minimum, and maximum for the 'Load' column to ascertain the spread of the data or values in there. Below is the code and output from that.

A screenshot of a data analysis

Description automatically generated

Descriptive analysis for the power generation dataset

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Grouped Analysis was conducted to group the data by 'Hourly Profile', 'Season', and 'Region' and calculate mean load for each group.

**A screenshot of a computer program

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**Presentation of Solution and Results**

#### **General objective**

The main objective of our project is to analyse energy consumption datasets from Alberta Open Data, identify trends and patterns in energy usage, and develop actionable insights to promote sustainable energy practices.

#### **Specific objectives**

The various specific objectives of our project are to:

1. analyze historical data can reveal long-term trends, such as increasing or decreasing energy consumption patterns, which can influence future planning.
2. develop predictive models based on historical data can assist in forecasting future energy consumption, supporting proactive planning and decision-making.
3. investigate the correlation between weather patterns (temperature, humidity, etc.) and energy consumption can assist in forecasting and adapting to seasonal variations.
4. understand when energy demand is highest can help in optimizing resource allocation and planning for increased capacity during peak times.
5. identify regional variations can help tailor energy policies and initiatives to address specific needs and challenges in different areas.
6. based on the analysis, propose actionable strategies and recommendations to encourage sustainable energy practices among consumers, businesses, and industries.

#### **Business questions**

The business questions of our project are as follows:

1. Are there noticeable trends in energy consumption over the years?
2. Can predictive modelling be used to anticipate future energy consumption trends?
3. How do weather conditions impact energy consumption?
4. What are the peak hours and seasons of energy consumption?
5. Are there specific regions with notable differences in energy consumption patterns?
6. What strategies can be implemented for promoting sustainable energy practices?

***Solution***

Based on the specific objectives above and the business questions, we hereby present our solution below.

***Are there noticeable trends in energy consumption over the years?***

From the figure 1 below, there are noticeable trends in energy consumption over the years in Alberta. There are some levels of seasonality noticed as well. Both load and generation experienced variation and seasonality over the years as depicted in figure 2 below.

A graph showing a number of orange lines

Description automatically generated

Figure 1: Daily total load for the last 5 years.

A graph of energy generation

Description automatically generated

Figure 2: Daily energy generation vs load for the last 2 years.

A graph showing a number of data

Description automatically generated with medium confidence

Figure 3: Daily total load for the last year (2023)

The trends are same for energy generation over the years. Per the figure 4 below, there are noticeable trend for power generation for all the fuel types.

A graph of blue lines

Description automatically generated

Figure 4: Daily total generation for the last 5 years.

A graph of energy generation

Description automatically generated with medium confidence

Figure 5: Daily energy generation vs load for the last year (2023)

The above figures confirm there are variations or seasonality in both energy consumption and demand within Alberta over the years. This could be attributed to weather conditions and seasons within the year.

***How do weather conditions impact energy consumption?***

The dataset has column for season, though only two seasons such as Winter and Summer were recorded, it was enough to perform some meaningful analysis on same. From the figures below, we can deduce that weather conditions have an impact on consumption. There were noticeable trends in demand, especially high loads were recorded during the winter season.

A graph with a line and a red line

Description automatically generated

Figure 6: Daily total load by Season for the last year (2023)

The average demand by season over the years also showed some impact by weather conditions. Only 2020 saw a huge decline in demand. This could be attributed to Covid-91 lockdown.

A graph of different seasons

Description automatically generated

Figure 7: Average demand by season over the years.

This again collaborates with the finding in the above figure. It also proves weather conditions affecting generation and demand have been influenced by the seasons.

***Are there specific regions with notable differences in energy consumption patterns?***

Per the demand trend below, Edmonton has the highest load over the last 5 years, followed by Central. It must be noted that, AESO classification/division of Alberta is different from the standard division by Alberta.

A graph of different colored lines

Description automatically generated

Figure 8: Demand trend for each region over the last 5 years.

A graph of different colored lines

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Figure 9: Daily demand trend for each Region in the last year (2023)

***What are the peak hours and seasons of energy consumption?***

From the figures below, we have noticed that the load start to pick from 4pm to 8am. Around this time families are back from School and work, and probably turn on electric equipment such as cookers, blenders, microwave etc.

From 9pm demands start to drop, by which time we expect families to retire to bed. The drop continues and rise briefly in morning till they leave house for school and work around 9am.

A graph of a graph

Description automatically generated

Figure 10: Average hourly demand profile over the years.

A graph of a line

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Figure 11: Average hourly demand profile for the last month of 2023.

***Predictive modelling to anticipate future energy consumption trends.***

Predictive modelling can be used to predict both demand and generation. From the figure below, we expect the trend to continue for both demand and generation. In 2025, and 2026, there will be spick in consumption, however, from the 3rd quarter of same year there will be a decline.

***A graph of a graph showing the price of a stock market

Description automatically generated with medium confidence***

Figure 12: Demand Forecasting with SARIMAX.

***A graph of a graph showing the growth of a stock market

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Figure 13: Generation Forecasting with SARIMAX.

**Conclusion & Recommendations**

Alberta is pushing to eliminate coal powered energy generation. However, there is no corresponding increase in generation from other fuel types to cater for the energy loss from coal as the figure below.

A graph of a graph showing the number of fuel types

Description automatically generated with medium confidence

Figure 14: System generation by Fuel type over the years.

Energy generation throughput from other fuel types such as Wind and Solar is very low duration the winter season. Demand/load on the other hand increases significantly during the winter and especially during on-peak hours.

We understand the push for green and environmentally friendly energy generation; however, this must be managed such that significant energy is not lost during the coal powered generation phase-out.

More investment should go into wind powered, natural gas and solar energy generation. Lastly, more storage facilities should be established to store energy from these generation mix during Summer for subsequent use in the winter.