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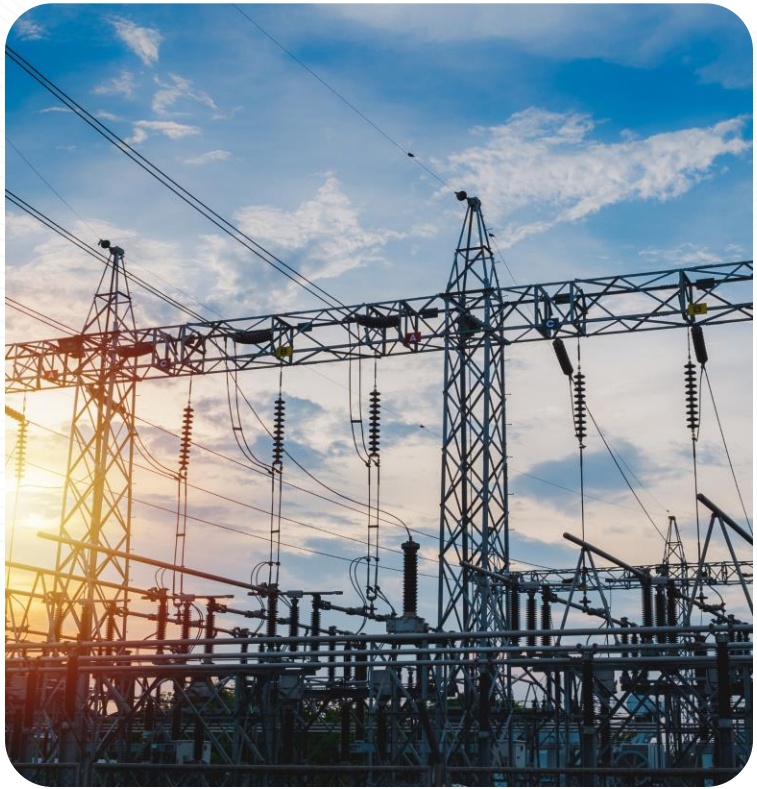


Final Report

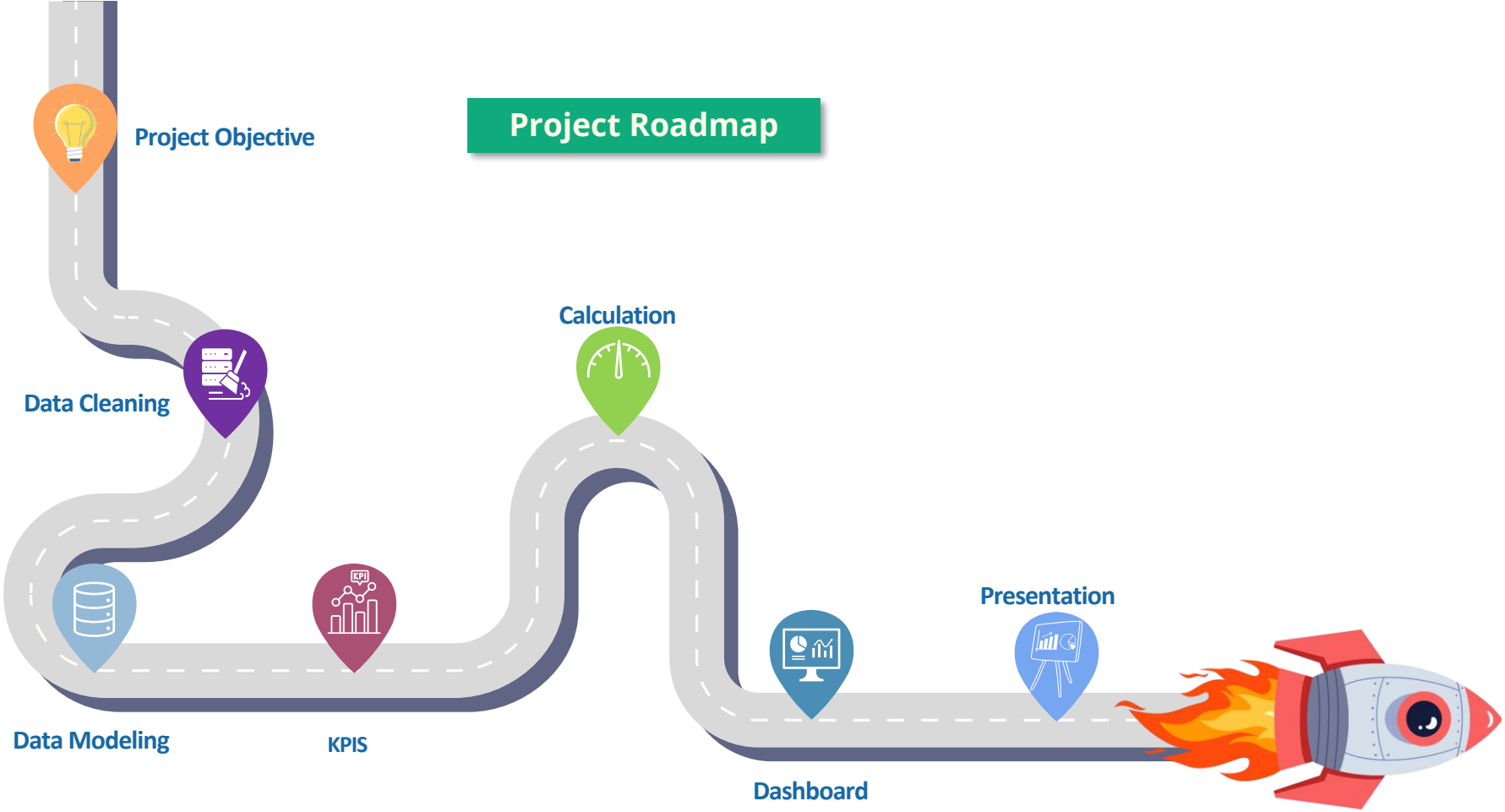
U.S. ELECTRIC GRID OUTAGE ANALYSIS

Presented to: Eng. Sherihan Ali

DEPI-GIZ1_DAT2_G1e
Group1

22/10/2024

Project Roadmap



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Brief overview of the project

The data set was about Information on electric disturbance events is collected using Form DOE-417 and published online in an annual summary. The dataset contains 4 files for download: An Excel spreadsheet containing the annual summaries, and 3 PDF documents for reference (the survey form, instructions, and documentation for online form submissions).

Electric outage incidents in the US power grid from January 2002 to July 2023, including details related to the event start and end time, location, alert criteria, demand loss, and estimated number of people affected.

Our objective was to act as a Senior Analytics Consultant hired by the U.S. Department of Energy to clean data and create a report/dashboard that showcases trends and key insights for 21 years' worth of event level power outage data.

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More Info about Electric outage

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Key Goals of the power outage Analysis

1 Identify Key Outage Trends

Analyze historical power outage data to uncover patterns, frequency, and common causes of outages.

2 Understand Outlier Events

Investigate significant or unusual power outage incidents that deviate from normal trends.

3 Pinpoint Significant Event Types

Categorize outages by event type, such as weather-related, operational issues, or fuel supply issues to target root causes.

4 Quantify the impact on Customer

Assess the scale and duration of power outages and their effect on resident customers.

5 Identify the impact on Demand Loss

This includes understanding changes in demand patterns during outages and how they affect the grid's ability to manage capacity efficiently.

6 Provide Recommendations

Suggest solutions to improve grid performance, reduce outage durations, Advanced threat detection systems and speeds up response to attacks.

Outage Trend Over Time

1 2015-2017

The number of reported outages remained relatively constant during this period.

2 2020-2022

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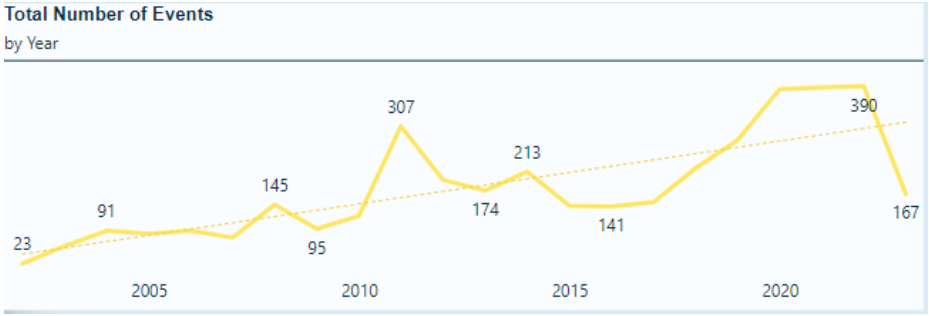

3 Comparing 2020 to 2017

Outage levels remained high, like the 2020 spike.

4 Comparing 2022 to 2023

Outages decreased significantly by **57%** compared to 2022, due to factors like grid investments, enhanced maintenance, and reduced extreme weather.

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we can address the rise in reported power outages through the following points

- **Investments in strengthening the power grid**: Upgrades to critical infrastructure, such as transmission lines and transformers, improved grid resilience.
- **Enhanced Preventive Maintenance**: More rigorous maintenance schedules and better equipment monitoring helped prevent potential failures.
- **A reduction in extreme weather events**: Fewer severe weather incidents in 2023 compared to 2022 contributed to the decrease in weather-related outages.
- **Improved operational strategies**: Utilities enhanced response times, optimized demand forecasting, and better managed resources, leading to fewer outages.

Reported Outage Duration

After tracking number of power outages over time ,we need to know about the duration for reported Outage:

4. Outage Duration:

- Most power outages fall into the category of lasting more than 8 hours, with many even exceeding 24 hours. This is a critical issue for both residential customers and businesses, as longer outages can lead to major economic losses, public health risks. Most of the long duration are caused by Weather related events.

- Shorter-duration outages (1 - 8 hours) are less frequent, but their occurrence suggests that many events are quickly resolved, possibly due to less severe underlying causes.

- **Extreme: T**he longest outage duration occurred in **2013**, with an event lasting **131.23** days, mainly attributed to the **MRO** region Due to **Cyber events** then the total outage duration according to cyber events started to decrease with **66%** when comparing **2014 to 2013**

- (RF) region is considered the region with the longest Total Duration in both Normal & Extreme events

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Organizations likely enhanced their cybersecurity infrastructure, implementing better firewalls, intrusion detection systems, encryption

Companies may have developed more robust backup and disaster recovery systems, allowing them to restore services more quickly following a cyber incident.

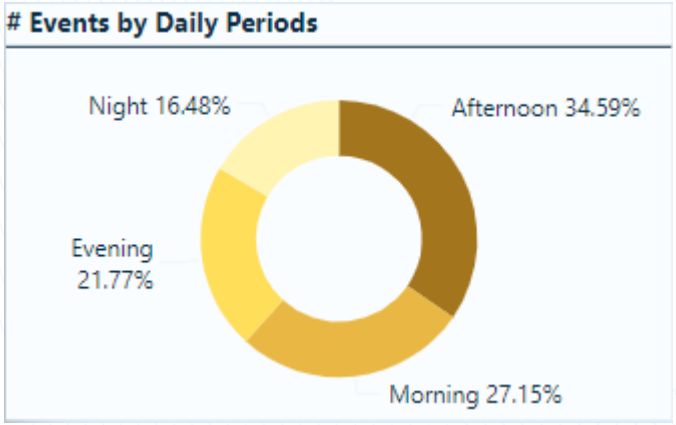
The decrease in outage duration associated with cyber events can be attributed by

increasing in cybersecurity awareness, with companies investing in employee training to avoid phishing

The use of advanced threat detection systems like machine learning-based anomaly detection could have helped organizations detect and respond to attacks more quickly.

Daily Trends: Outages were most frequent in the afternoon and morning with total **61.47%** of total events.

several measures can be taken to mitigate these occurrences and reduce their impact:

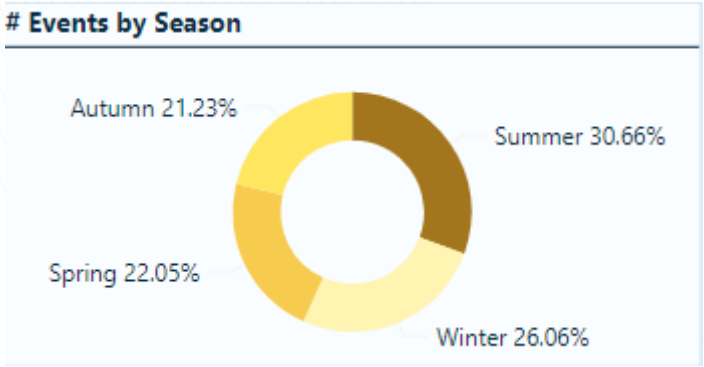


- **I**mplementing load-shedding strategies or demand response programs can reduce stress on the grid during these hours.
- **U**tilize load balancing techniques to distribute the demand more evenly throughout the day. Shifting non-critical loads to off-peak times could reduce the frequency of overloads leading to outages

Seasonal Trends: Outages were most frequent in Autumn (21.23%) and winter (26.06%), accounting for a total of 47%,

while summer (30.66%) and spring (22.05%) made up 53%. This indicates a fairly even distribution of outages between the autumn-winter and spring-summer seasons.

So we need to know the other causes that effect on events otherwise the weather



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After knowing that not only the weather effect on outage , here we will know about the other events types

Fuel Supply Issues caused the most significant impact, with the longest average outage duration of 196 hours and the highest number of reported outages (1,692). This suggests that disruptions related to fuel supply are both frequent and prolonged.

Cyber Events had a much shorter average outage duration of 128.42 hours and a significantly lower number of reported outages (42). Although less frequent, cyber events still pose a substantial risk, with outages lasting over five days on average

This highlights that while fuel supply issues are more common and have a higher impact, cyber events, though fewer, can also result in extended outages.

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Strategies that must been implemented to reduce reported outages from Fuel Supply Issues

1. Invest in alternative energy sources (e.g., renewables, biofuels) to decrease reliance on a single type of fuel.
2. Maintain optimal fuel inventory levels and use predictive analytics to anticipate demand surges, ensuring adequate supply during peak periods.
3. Increase storage capacity for fuel to buffer against supply disruptions and fluctuations in demand.
4. Implement real-time monitoring systems to track fuel supplies and identify potential disruptions early.
5. Collaborate with industry stakeholders to share best practices and resources for managing fuel supply issues

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Then we need to dig deep more in NERC regions and know more about the Customer Affected and Demand loss

NERC Region	WECC	RF
Reported outages	1,105	807
Customer affected	70M	87M

This suggests that RF outages might be more widespread or that they occur in areas with higher population density, leading to greater customer impact.

The highest number of outages in **WECC** indicates potential vulnerabilities in that region's infrastructure or fuel supply, necessitating further investigation into the underlying causes and mitigation strategies

7. Demand Loss:

- Outages lead to substantial demand loss, with significant variations by year and region. The highest losses were reported in **2019-2020**.
- Regions such as **SERC** and **WECC** report higher total demand loss, which could be indicative of their heavier reliance on electric power in both residential and industrial sectors.
- Demand loss also correlates with the duration of outages, with longer-lasting events having a more profound economic and operational impact on power providers and consumers. The most cause of demand loss is the weather- related events.
- Extreme demand loss occurs during outlier events, disrupting entire regions and severely affecting economic activities due to prolonged power cuts.

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5. Total #Customer Impact:

- Millions of customers are affected by power outages, with **ERCOT** (Texas), **SERC** (Southeast), and RF(Midwest and Northeast) experiencing the largest average number of affected customers.
- Some years, particularly **2011, 2012 and 2020** saw high numbers of impacted customers due to large-scale weather events.
- **Extreme events** such as hurricanes or major operational failures cause massive spikes in affected customers. Outliers indicate rare but highly impactful disruptions requiring emergency interventions.

WECC experiences the highest number of outages **1,105** but doesn't lead in customer impact or demand loss, suggesting that these events might be more frequent but less severe.

RF&SERC having fewer events **807,788** respectively than WECC, cause significantly larger customer impacts and demand loss, suggesting larger-scale outages.

SERC has the most severe outages in terms of energy loss **413K,** and the **RF** region leads in terms of the number of customers affected.

ERCOT &NPCC have a moderate number of events, but the impact on customers and demand loss is relatively lower, indicating better mitigation or less widespread outages.

This analysis suggests that frequency and severity don't always correlate directly across regions, and further investigation might be needed to understand the specific factors contributing to these difference

We analyzed the different event types to determine whether they influence the number of customers affected and the demand loss, rather than just the number of reported outages.

The primary event type in the WECC was physical attacks, whereas the main event types for RF and SERC were weather-related incidents. This indicates that **weather** has a more severe impact compared to physical attacks.

3. Outage Causes:

- Weather-related events (particularly in winter and summer) are the leading cause of power outages, followed by equipment failures and other natural disruptions.

- Outlier outages are driven by severe weather events (hurricanes, ice storms), natural disasters, or major technical failures. These causes are rare but have a far-reaching impact, requiring extensive restoration efforts and preparation for extreme conditions.

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So, we need to set some solutions to reduce weather event type impact

1. **Advanced Weather Monitoring Systems**: Invest in real-time weather tracking and forecasting systems to anticipate severe weather events and their potential impact on the grid.
2. **Vegetation Management**: Implement programs to trim trees and manage vegetation near power lines to reduce the risk of outages caused by falling branches
3. **Emergency Response Training**: Ensure that utility crews are trained and prepared for rapid response during severe weather events.
4. **Smart Sensors and Automated Systems**: Deploy smart grid technology to detect outages quickly and reroute power automatically to minimize disruption.
5. **Partnerships with Weather Services**: Collaborate with meteorological agencies to improve forecasting accuracy and receive timely alerts about severe weather.


LUMA
"Addressing the vulnerabilities in the electric grid is no longer an option, but a critical responsibility. With strategic improvements and proactive measures, we can ensure that power outages become rare, brief, and less disruptive, securing a reliable energy future for everyone."