BDE Solutions: Bridging Energy and Analytics to Empower Smarter Communities

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1. INTRODUCTION

1.1 Abstract

This report presents a data analytics solution for the Itty-Bitty Electric Company (IBEC), a Southern California utility aiming to improve grid reliability by reducing Customer Minutes of Interruption (CMI). Through detailed analysis of internal outage data and regional circuit performance, we identify patterns in outage frequency, equipment failure, and environmental impact.

Despite challenges in aligning external datasets with internal records, our team applied regression modeling, visual analytics, and dynamic interactive dashboards to surface actionable insights. Key findings highlight circuits with the greatest impact on service reliability, and our recommendations focus on targeted upgrades, seasonal maintenance strategies, and opportunities for predictive modeling. The result is a set of prioritized, data-driven strategies to help IBEC allocate resources effectively and improve long-term operational performance.

1.2 Our Company

Big Data Energy Solutions is a California-based analytics consulting team dedicated to transforming complex utility data into clear, actionable insights. Founded on the principles of data transparency, grid modernization, and sustainability, we specialize in leveraging advanced analytics to help utility providers make smarter, more efficient decisions.

Our team operates at the intersection of energy and information, combining technical expertise with industry awareness to solve real-world challenges. With a strong foundation in predictive modeling, machine learning, and data visualization, we empower energy companies to optimize infrastructure, reduce service interruptions, and better serve their communities.

We are passionate about using data as a force for good – improving system reliability, supporting environmental resilience, and ensuring that every decision is backed by meaningful insights. Our mission is to bring clarity to complexity and help utility providers like IBEC deliver power more efficiently, reliably, and sustainably.

2. EXECUTIVE OVERVIEW

2.1 Current Understanding

At the core of IBEC's challenge is how to best deploy limited resources to reduce Customer Minutes of Interruption (CMI). Outages may stem from a variety of causes – aging infrastructure, adverse weather, vegetation interference, or wildfire threats – and not all circuits contribute equally to system-wide impact. Our task was to identify which circuits matter most, why outages are happening, and what actionable steps will yield the highest return in reliability improvement.

To ground our perspective, we conducted a SWOT analysis of IBEC's current outage management landscape:

Strengths

- Access to detailed internal outage data across multiple regions and circuits
- Established performance metrics like CMI, SAIDI, and SAIFI to guide infrastructure investment
- Strong motivation and organizational support for improving grid reliability

Weaknesses

- Inconsistent or missing data entries in key fields
- Difficulty integrating external datasets due to lack of standard identifiers
- Limited internal capacity for advanced analytics and predictive modeling

Opportunities

- Implement targeted upgrades in high-impact circuits to reduce CMI
- Use predictive analytics to proactively identify future outage risks
- Incorporate environment and geographic data to develop seasonal maintenance strategies
- Build customer trust by demonstrating transparency and data-driven action

Threats

- Increasing risk from environmental factors such as wildfire and extreme heat
- Potential misallocation of resources if outages are not properly prioritized
- Reputational risk if service reliability declines or customer expectations are not met
- Regulatory pressure to justify rate increases without clear data support

2.2 Our Focus

Our team's focus throughout this project was to support IBEC in identifying high-priority circuits and outage patterns that contribute most significantly to Customer Minutes of

Interruption (CMI). By analyzing the company's internal outage dataset, we aimed to uncover actionable insights that would guide strategic investment in infrastructure improvements.

We concentrated our efforts on understanding outage frequency, duration, and impact across IBEC's service regions. Using statistical analysis, regional comparisons, and performance metrics such as SAIDI and SAIFI, we were able to evaluate which circuits were most in need of attention and why. Our findings informed targeted recommendations to help reduce unplanned outages and enhance service reliability.

In addition to conducting the analysis, we also created dashboards, charts, and visual tools to present complex trends in a clear and digestible way. These visualizations are intended to support ongoing decision-making and allow IBEC to track improvements over time.

Ultimately, our focus is to deliver a data-driven strategy that empowers IBEC to optimize limited resources, improve operational efficiency, and take meaningful steps toward long-term grid resilience.

2.3 Our Goal

Our goal is to deliver a data-driven strategy that helps IBEC reduce unplanned outages and improve system reliability by identifying the circuits with the highest impact on Customer Minutes of Interruption (CMI). By analyzing outage trends and root causes within the internal dataset, we aim to guide IBEC in prioritizing infrastructure upgrades that maximize return on investment and community satisfaction. In addition to our analysis, we provide clear visual tools and actionable recommendations to support informed decision-making and long-term operational improvement.

3. DATA ANALYSIS PROCESS

Data analysis is a critical component of this project, serving as the foundation for identifying problems, uncovering patterns, and supporting data-driven decision-making. This chapter outlines the process we followed – from setting objectives and forming hypotheses to visualizing data, navigating limitations, and executing our strategy.

3.1 Identifying Objectives

Before conducting any analysis, it was essential to define clear goals. In this case, our objective was to help IBEC reduce Customer Minutes of Interruption (CMI) by identifying the circuits and outage patterns with the greatest impact on service reliability. Establishing specific objectives allowed us to focus our analytical efforts and ensure our findings aligned with IBEC's operational priorities. This clarity of purpose is what makes data analysis actionable – not just an exploration of data, but a pathway to measurable improvements.

3.2 Initial Hypotheses & Analytical Questions

To guide our analysis, we began by forming key hypotheses and analytical questions. We hypothesized that circuits with the highest frequency and longest duration of outages would contribute most significantly to total CMI. We also expected that certain outage causes – such as underground (UG) and overhead (OH) equipment failures – would appear more prominently in specific regions or seasons. These guiding questions helped us prioritize what to look for, such as:

- *Which circuits have the highest CMI?*
- *What are the most frequent outage causes, and where do they occur?*
- *Are there seasonal patterns that could inform targeted maintenance?*
- *How do different KV levels (e.g. 4, 12, 16) correlate with performance and failure rates?*
- *What is the average number of customers affected per outage?*

Determining the variables and factors to answer these questions will be a crucial component of our analysis. By framing our exploration with questions, we ensured our analysis stayed focused and goal-oriented.

3.3 Data Cleaning & Enrichment

A critical first step in our analysis was ensuring the dataset provided by IBEC was complete, consistent, and reliable for meaningful exploration. Raw data often contains errors, missing values, or inconsistencies that, if left unaddressed, could significantly distort analytical outcomes and lead to misguided recommendations.

Our data cleaning process focused on identifying and resolving missing or inconsistent entries, particularly within key fields such as outage duration, customers affected, outage causes, and circuit information. Where gaps existed, we made reasonable assumptions or excluded problematic entries based on their potential impact on the overall integrity of the analysis. Duplicated records were removed, and categorical values were standardized to maintain uniformity across outage cause codes and seasonal classifications.

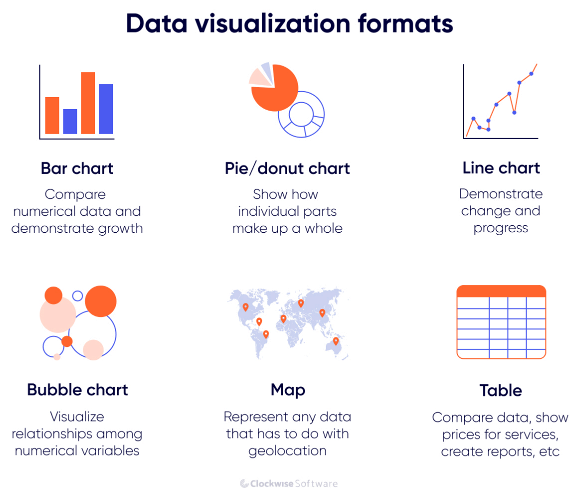
In the enrichment phase, we generated additional fields to enhance the dataset's analytical depth. New calculated metrics, such as average outage duration per customer and aggregated Customer Minutes of Interruption (CMI) by circuit, were created to provide a clearer view of performance trends. We also leveraged summary statistics – such as total outages per year and average SAIDI/SAIFI differences year-over-year – to enrich the dataset without altering its original integrity.

This thorough cleaning and enrichment process allowed us to move forward with confidence, ensuring that the insights and recommendations presented are both reliable and actionable.

3.4 Visualization Techniques

Data visualizations played a central role in both the analysis and communication of our findings. Visuals allow complex trends to be interpreted quickly, revealing patterns and outliers that might be overlooked in raw data.

Choosing Suitable Visualizations: Selecting the appropriate visualization type is critical, as it directly influences how insights are interpreted. For example, line charts are ideal for tracking trends over time, while bar charts help compare outage causes or performance across different regions. Geographic heat maps, on the other hand, allow us to spatially visualize where the most critical outage zones are located. However, due to the internal dataset being synthetic and lacking precise location data, we decided to withdraw from using any geographic/spatial maps to bolster our findings.



Since much of IBEC's outage data is categorical – such as outage cause, region, or circuit type – bar charts and line charts proved most effective. Scatter plots and linear regressions, while powerful in other contexts, were less useful given the structure of our dataset.

Tools and Methods Used: We used a combination of Python libraries to produce clear and interactive visuals. Libraries such as **Matplotlib**, **Plotly Express, Seaborn,** and the dashboard application, **Tableau,** allowed us to display outage trends, compare circuit performance, and overlay trending information. These tools helped us bring the analysis to life, offering IBEC an intuitive way to interpret and act on our findings.

3.5 Key Concerns

During the course of our analysis, we encountered several challenges that shaped our approach and informed our recommendations:

- **Data Completeness**: Some internal data fields contained missing, inconsistent, or duplicate entries, particularly in areas such as outage duration and customer impact. In these cases, we made informed assumptions to ensure continuity in the analysis while clearly documenting any adjustments made.

- **Risk of Misprioritization**: Without the context of external or environmental data, there is a risk that IBEC could invest in circuits that appear problematic on paper but may not represent the most urgent operational issues. Our prioritization framework was designed to mitigate this by weighing outage frequency, duration, and customer impact collectively.

- **Lack of External Data**: While external datasets such as wildfire risk maps or regional climate data could enhance the analysis, integration was limited by differences in data structure and availability. As a result, our findings are based solely on enriched internal data. Future efforts could benefit from incorporating spatial and environmental layers to refine prioritization even further.

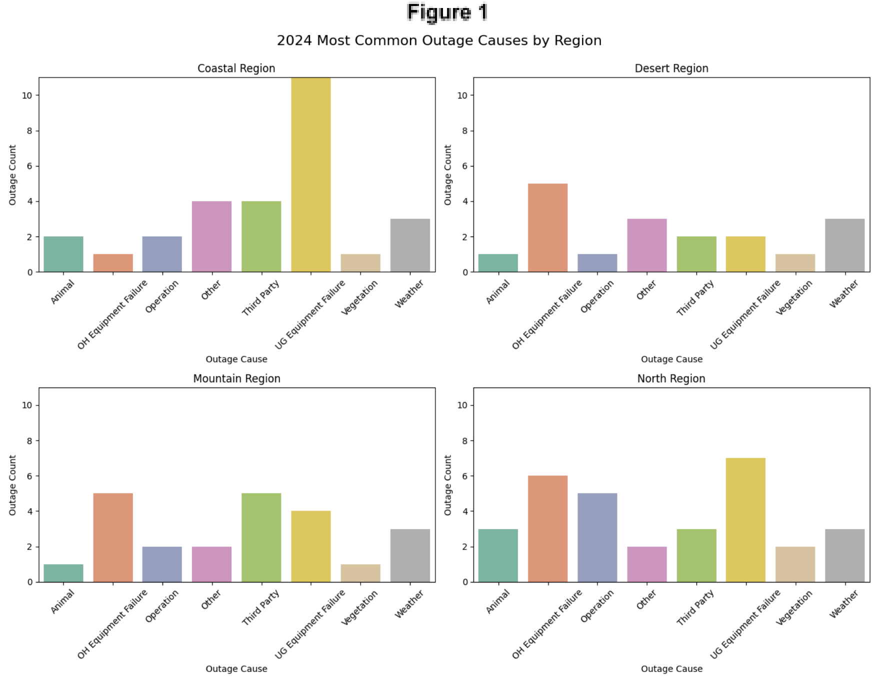
3.6 Our Preferred Approach & Strategy

To address the challenges in the dataset and extract meaningful insights, we adopted a data-driven and risk-aware strategy centered around exploratory data analysis (EDA). We began by cleaning and validating the dataset, resolving duplicates and addressing missing values where possible. From there, we performed targeted aggregations and trend analysis focused on CMI, outage causes, and seasonal patterns.

Rather than relying on complex modeling with weak assumptions, we prioritized interpretability and clarity—allowing our recommendations to be both defensible and actionable. By visualizing outage trends, ranking circuit performance, and isolating key patterns, we created a framework that supports confident decision-making. Our approach ensures that IBEC's investments are not only grounded in evidence but also aligned with the company's broader goal of improving reliability and operational efficiency.

4. RESEARCH AND ANALYSIS

Figure 1



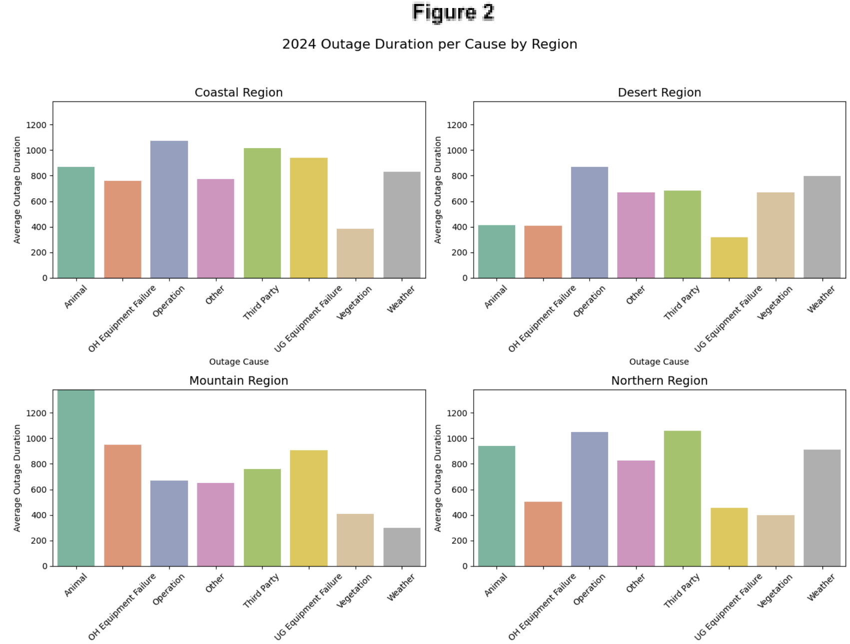
To make the analysis more granular, we split the visualizations into subsections by Region.

To make the analysis more granular, we split the visualizations into subsections by region to examine outage patterns more precisely.

Looking at **Figure 1: 2024 Most Common Outage Causes by Region**, we observe that *UG Equipment Failure* is nearly three times as common as any other outage cause in the Coastal Region. This suggests a possible underlying infrastructure issue that disproportionately affects this area.

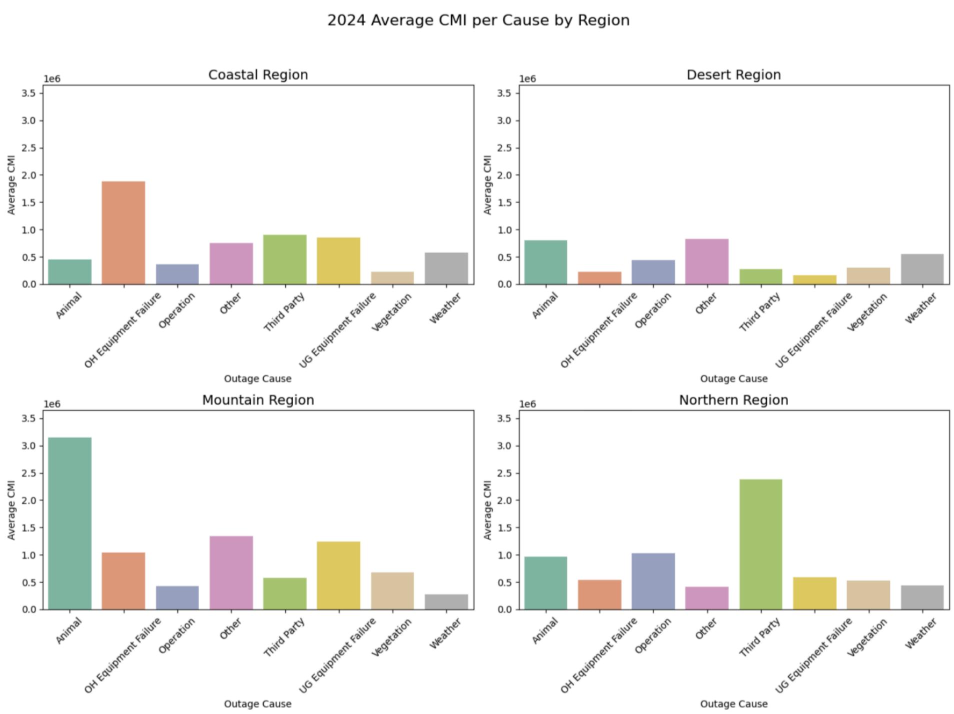
Next, **Figure 2** explores the **average outage duration by cause** across each region. A significant observation is that animal-related outages in the Mountain Region last considerably longer than those caused by other factors. Although this could be dismissed due to the possibility of fewer customers in the affected circuits, **Figure 3** adds crucial context.

Figure 2



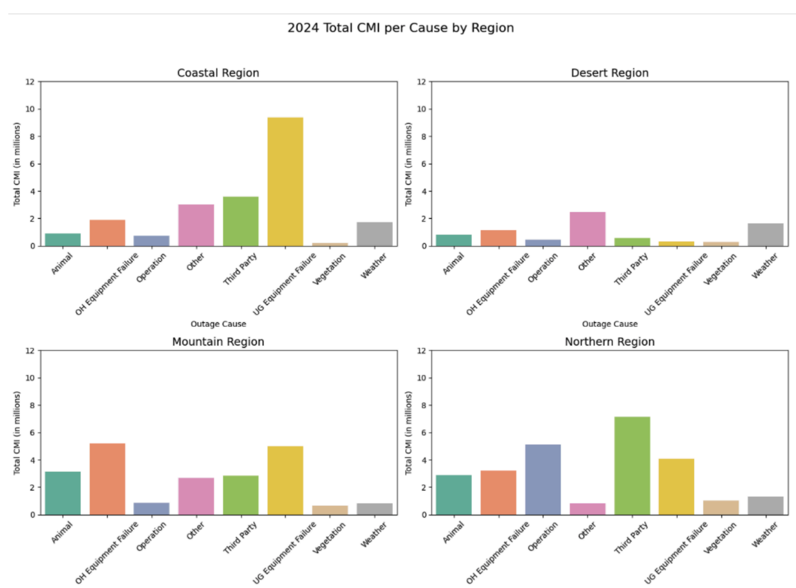
In **Figure 3**, we see that the **average CMI per outage** caused by animal interference in the Mountain Region is nearly three times higher than for any other cause. This confirms that these longer outages do, in fact, impact a significant number of customers and should not be dismissed as isolated incidents.

Figure 3



Further, **Figure 4** shows that although UG equipment failure was responsible for just one outage in the Coastal Region, the **total CMI for that outage** was at least twice as high as for any other cause. This highlights that even rare outages can be highly disruptive when they affect a large number of customers or last for an extended period. Despite having average durations similar to other causes, UG equipment failure stands out as particularly costly in terms of customer impact.

Figure 4



Seasonal patterns were then analyzed in **Figure 5**, which displays outage counts by cause across Winter, Spring, Summer, and Fall. *UG Equipment Failure* peaks during the Summer, almost doubling the next most frequent cause—likely due to heat stress and increased electricity usage. OH equipment failure and vegetation-related outages spike in the Spring, possibly due to rapid plant growth or seasonal storms. These seasonal differences suggest that proactive strategies should be aligned with seasonal conditions.

Figure 5

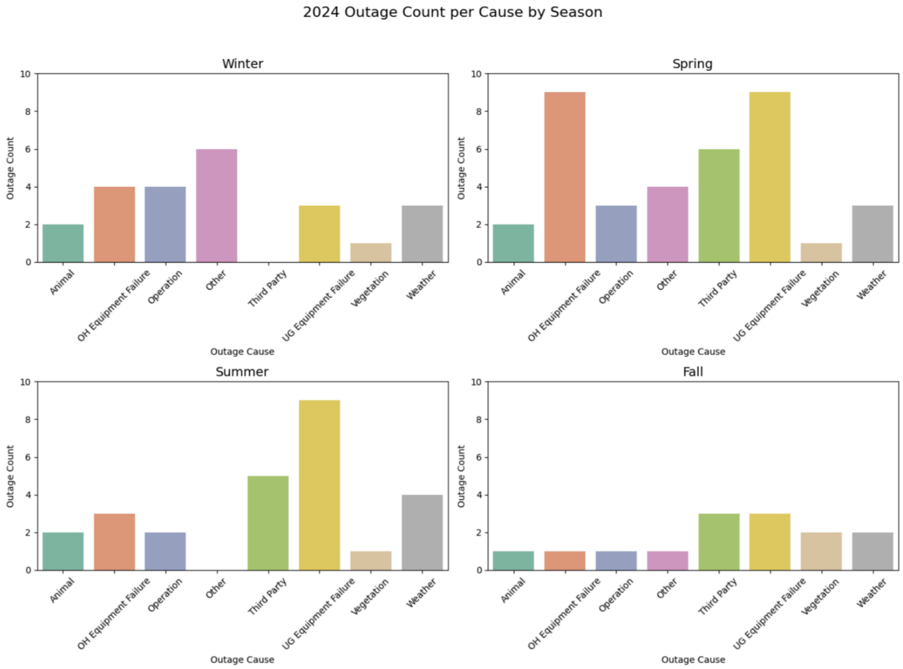


Table 1 further validates this pattern. Spring recorded **37 outages**, nearly **three times more** than Fall (14 outages), which had the fewest. This underscores the need for heightened preventative maintenance before and during the Spring and Summer seasons.

Table 1

Metrics by Season

Season	Total Outage Count 2024	Total Outage Time 2024	Total CMI 2024
Fall	14	8,935	9,914,374
Winter	23	20,075	17,813,559
Summer	26	22,358	24,039,742
Spring	37	24,130	24,202,316

Shifting focus to circuit-level reliability metrics:

In **Figure 7**, the **Roosevelt circuit** in the Coastal Region clearly stands out with a **SAIDI of 20.92**, while all other circuits remain below 3. This single data point demands attention.

In **Figure 8** , we see that the Roosevelt circuit also had the biggest percent increase in SAIDI with 53.26% from 2023. Then, in **Figure 9**, we see that the Roosevelt circuit has the highest total outage time in 2024 with 153.75 hours. And in **Figure 10**, we see that the roosevelt circuit also serves the least amount of customers of all circuits with 441 customers. Thus, the combination of high outage time and low customer count leads to a high SAIDI.

Figure 7

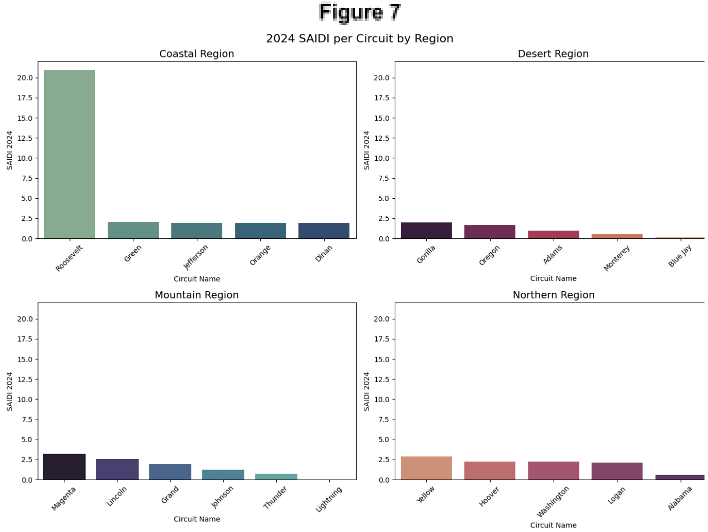


Figure 8

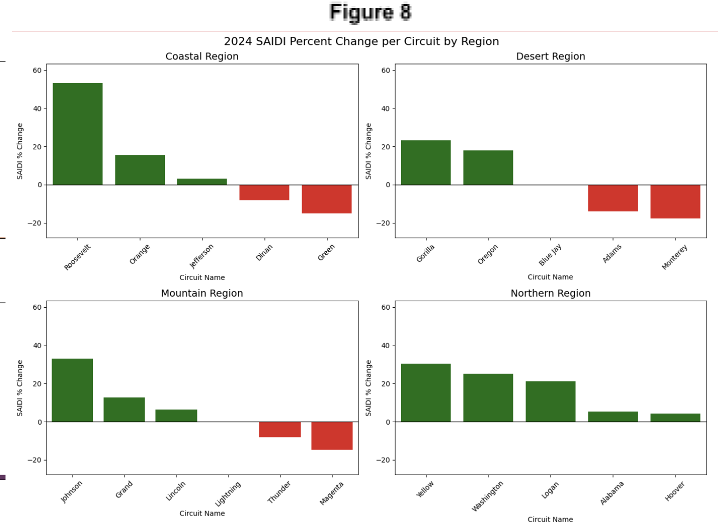


Figure 9

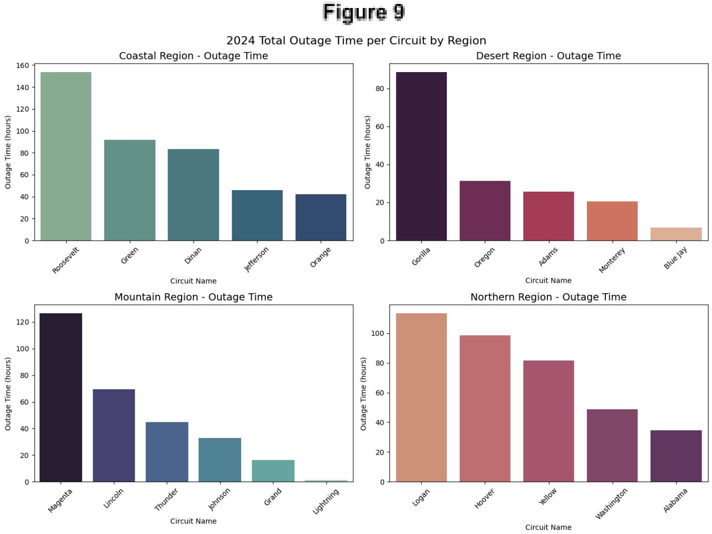
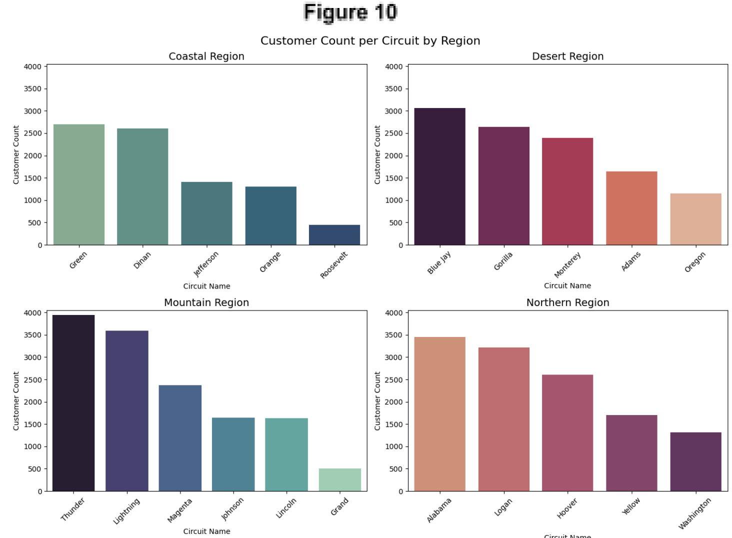


Figure 10



The CMI and SAIFI metrics are examined in **Figures 11 to 14**. In **Figure 11**, we see that the Green circuit, despite only having **6 outages**, had a very high total outage time. **Figure 12** confirms that this led to over **8 million minutes of customer impact (CMI)** in 2024 due to a combination of high duration and a relatively large customer base.

In **Figures 13 and 14**, the Roosevelt circuit is again an outlier. It has the **highest SAIFI** value in 2024 and also shows the **largest increase in SAIFI** from the previous year, reinforcing the need for intervention.

Figure 11

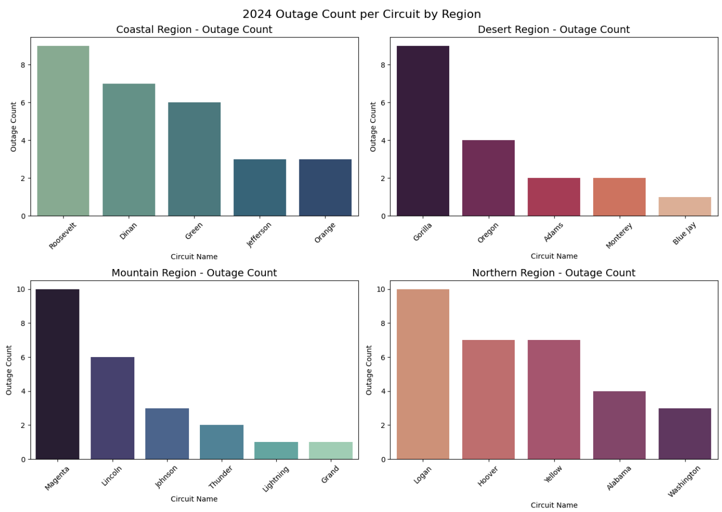


Figure 12

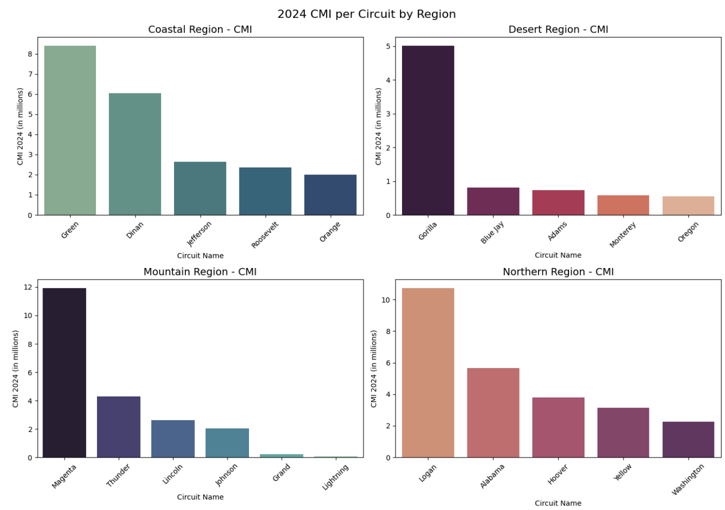


Figure 13

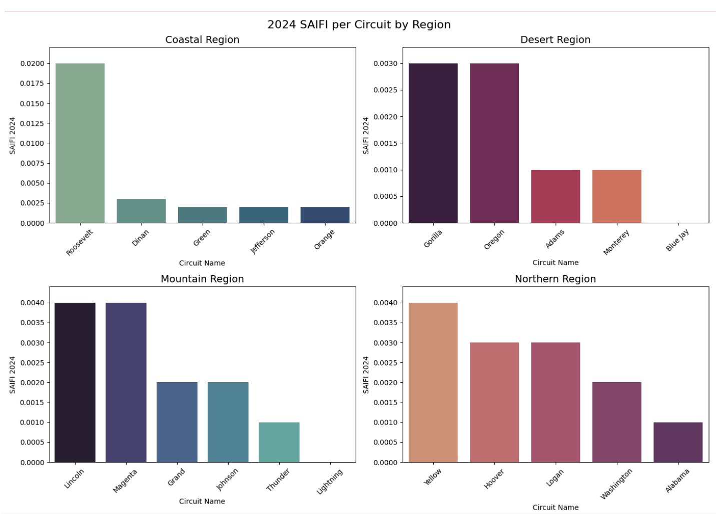
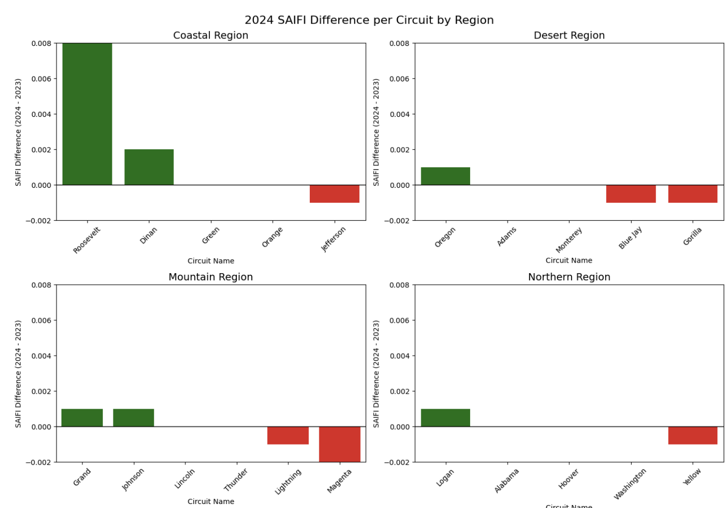


Figure 14



Next, we examine **monthly trends** in **Figures 15 and 16**. May saw the **highest number of outages (15)**, while **CMI peaked in July**, exceeding **12 million minutes**. This decoupling suggests that not all outages are equal—some months have fewer but more impactful outages.

Figures 17 and 18 break this down regionally. The **Northern Region** had the **highest total CMI and number of outages**, while the **Coastal Region** had the **highest total outage time**, suggesting fewer but longer outages. These contrasts are summarized in **Table 2**.

Figure 15

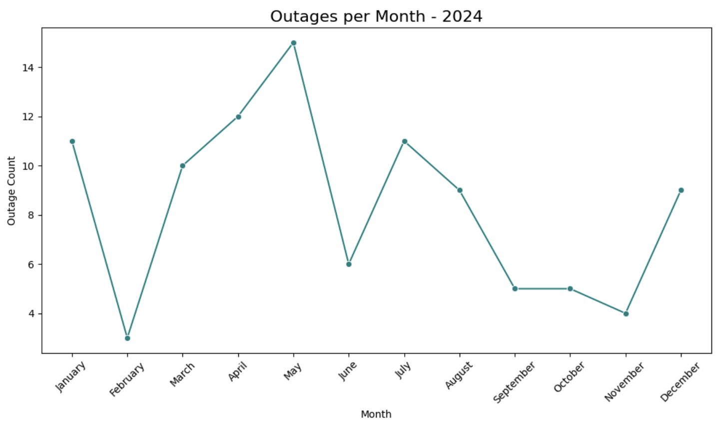


Figure 16

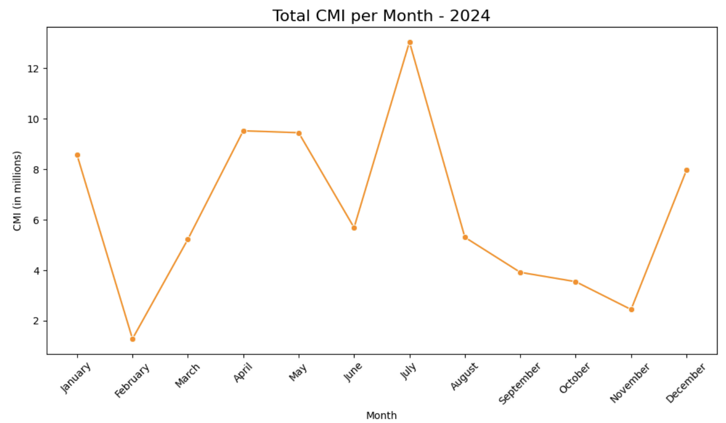


Figure 17

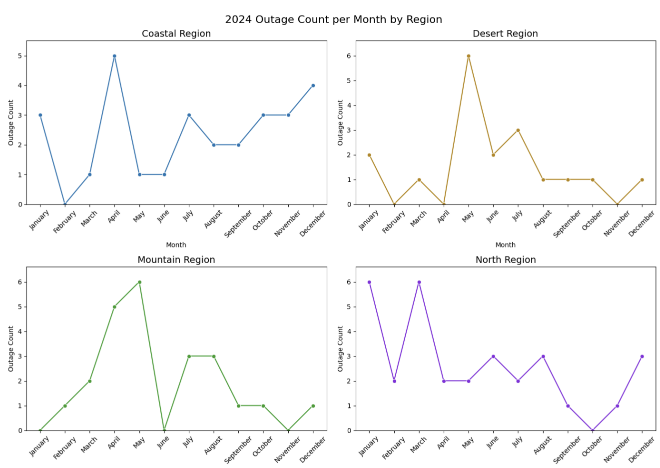


Figure 18

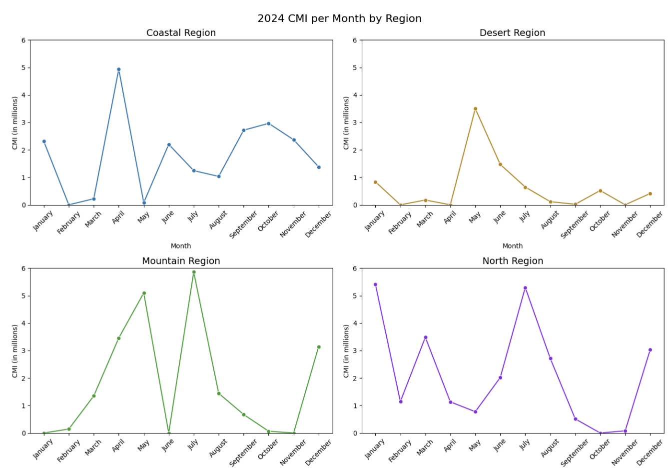


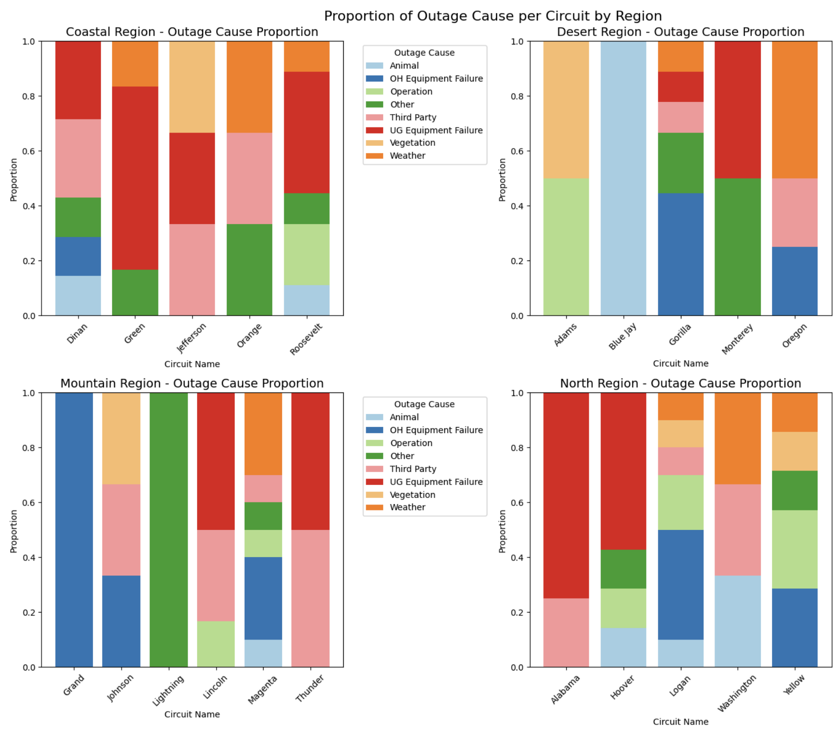
Table 2

Region Metrics 2024

Region	CMI	Total Outage Time	Total Outages
Coastal	21,451,249	25,000	28
Desert	7,696,578	10,378	18
Mountain	21,224,894	17,480	23
North	25,597,270	22,640	31

Finally, **Figure 19** analyzes the **proportion of outage causes per circuit**. In the Coastal Region, Roosevelt's issues stem predominantly from *UG Equipment Failure*. In the Desert Region, Gorilla was affected primarily by *OH Equipment Failure*. Magenta and Logan circuits were heavily impacted by *OH Equipment Failure* and *Third Party* causes. Understanding these circuit-specific root causes is essential for forming actionable, localized strategies.

Figure 19



In summary, the analysis reveals multiple critical insights:

- Certain circuits (e.g., Roosevelt and Green) disproportionately contribute to poor reliability.
- UG and OH equipment failures are major contributors to high CMI and SAIDI.
- Spring and Summer bring significant increases in outage count and impact.
- Monthly and regional breakdowns highlight varying needs for attention and investment.

These findings inform our forthcoming recommendations for improving reliability and minimizing customer impact in future years.

4.4 Predictive Modeling and Future Risk Assessment

We had decided from the first dataset sheet titled "Circuit Outages" to create new variables of Average time wait per customer affected per outage, measured in minutes. We would calculate this new variable by getting the total duration of the outage divided by the customers affected by the outage. We applied multiple linear regression models to model the expected value of average weight time experienced per customer affected (minutes) using total customers affected by outage, total outage duration(min), KV circuit type, and outage causal code. Utilizing the multiple linear regression model, we get a multiple R-squared of .4083, which means 40.83 percent of the variance in the average wait time per customer can be explained by the number of customers affected, outage duration in minutes, type of KV cricut, and the outage cause code.

Focusing on the second dataset labeled "Lookup," we will now do multiple linear regression to model the expected value of 2023 SAIDI using circuit KV type(1=4, 2=12, 3=16), region type (1=Coast, 2=Desert, 3=Mountain, 4=North), customer count, and circuit miles. We get these results. Utilizing the multiple linear regression model, we get a multiple R-squared of 0.428, which means 42.8 percent of the variability of 2024 SAIDI can be explained by the customer count, circuit per miles, region where the circuit was located, and circuit KV type.

Now that we have found the best regression models for SAIDI in 2023, we should also find the best regression model for SAIFI in 2023.Now we are going to apply multiple linear Regression on 2023 SAIFI using dummy variable KV(1=4, 2=12, 3=16), dummy variable region type(1=Coast, 2=Desert, 3=Mountain, 4=North), customer count, and circuit.miles. Using multiple linear regression to find the expectation of 2023 SAIFI given the independent variables, we have a multiple R-squared of 0.3007, which means 30.07 percent of the variability of SAIFI in 2023 can be explained by KV circuit type, region, total customer count, and circuit in miles.

For our second machine learning method, we decided to use a logistic regression model using a Generalized Linear Model (GLM) to find the probability of an outage occurring on a holiday, post-holiday, or regular day within a year that we consider in 2024. We consider a "holiday" to be 01/01/2024 (New Year's Day), 01/15/2024 (Martin Luther King Jr. Day), 02/19/2024 (Presidents' Day), 02/14/2024 (Valentine's Day), 03/31/2024 (Easter Sunday), 05/27/2024 (Memorial Day), 06/19/2024 (Juneteenth), 07/04/2024 (Independence Day), 09/02/2024 (Labor Day), 10/14/2024 (Indigenous Peoples' Day), 10/31/2024 (Halloween), 11/11/2024 (Veterans Day), 11/28/2024 (Thanksgiving Day), and 12/25/2024 (Christmas Day). A "post-holiday" is considered the day after a holiday that we just listed. Then, a "regular" day is considered a day that is not a holiday or a post-holiday. In our GLM, we used a binomial family to indicate that we have 3 different types of days to track the frequency of an outage happening on those days, with a yes or no.

This is the correct frequency table of the type of day with yes and no, since we had 100 outage cases, and calculating the total, it equals 366. In 2024, there were 366 days because it was considered a leap year. Based on the GLM, we get an intercept of -1.1074, post-holiday has an estimate of -0.1919, and regular has an estimate of 0.1911. Then, calculating the odds and probabilities of each of the categories, we get the following interpretation. We are 95 percent confident that the probability of an outage happening on a holiday is between 15.42% and 37.15 % . We are 95 percent confident that the probability of an outage happening on a post-holiday is between 24.16% and 68%. Post-Holidays has 17.46 %(.1746) lower odds to get an outage compared to Holidays. We are 95 percent confident that the probability of an outage happening on a regular day is between 33.02% and 74.82%. The odds of an outage when it is a Regular day is 21.05 percent higher than the odds when it is a Holidays

5. STRATEGIC RECOMMENDATIONS AND KEY INSIGHTS

5.1 Priority Actions for Circuit Upgrades

Based on our analysis, UG and OH Equipment failures account for a high percentage of the outage causes across IBEC's network. This frequency combined with relatively high average CMI per outage leads to over 30 million Customer Minutes Interrupted in 2024. We should prioritize upgrades for circuits most affected by these causes in order to obtain the highest return on IBEC's investment.

Top 5 UG Circuits by CMI:

	Circuit Number	Circuit Name	Outage Cause	Total_CMI	Incident_Count	Avg_Duration	Avg_Customers	SAIDI	SAIFI
1	3	Green	UG Equipment Failure	6056750.0	4	858.500000	1920.750000	2.40	0.002
11	15	Thunder	UG Equipment Failure	3999518.0	1	1291.000000	3098.000000	0.74	0.001
12	17	Hoover	UG Equipment Failure	2673298.0	4	607.500000	1016.750000	2.18	0.003
0	2	Alabama	UG Equipment Failure	1425615.0	3	255.333333	2203.666667	0.57	0.001
8	12	Jefferson	UG Equipment Failure	1351376.0	1	1424.000000	949.000000	1.88	0.003

UG Failure Circuits:

- **Green** had the highest total UG-related CMI (6,056,750) and one of the longest average durations (858.5 minutes), impacting nearly 2,000 customers per incident. We recommend deploying underground fault detection and beginning a root cause assessment of past failures.
- **Thunder** experienced a single UG failure that resulted in almost 4 million CMI, indicating high customer density and extended downtime. This may be an outlier, the circuit should still implement underground infrastructure inspection and sensor deployment to prevent these types of incidents from reoccurring.

Top 5 OH Circuits by CMI:

	Circuit Number	Circuit Name	Outage Cause	Total_CMI
6	9	Magenta	OH Equipment Failure	3602257.0
16	21	Dinan	OH Equipment Failure	1876050.0
14	19	Logan	OH Equipment Failure	1807594.0
3	5	Yellow	OH Equipment Failure	1404964.0
5	8	Johnson	OH Equipment Failure	1349760.0

	Incident_Count	Avg_Duration	Avg_Customers	SAIDI	SAIFI
6	3	849.00	1534.333333	3.77	0.006
16	1	758.00	2475.000000	2.09	0.001
14	4	449.25	947.000000	1.75	0.002
3	2	605.50	1163.000000	2.20	0.005
5	1	1216.00	1110.000000	0.91	0.001

OH Failure Circuits:

- **Magenta** ranked highest in OH-related CMI (3,602,257), with long average outages (849 minutes) and frequent incidents. Targeted overhead equipment inspection and condition-based maintenance should begin here.
- **Logan** had four outages with a total CMI of 1.8M. Due to consistent failures, it should be prioritized for preventive upgrades or equipment replacement.

High SAIDI/SAIFI Circuit: Roosevelt

Although the Roosevelt circuit wasn't one of the largest contributors to CMI, its high SAIDI and SAIFI values were concerning. As shown below, the Roosevelt circuit had the highest SAIDI and SAIFI values in 2024 by a large margin, with nine outages and over 9000 minutes of downtime. The CMI is low due to the small customer base of 441 customers, but these numbers indicate major issues with reliability. We recommend a complete failure analysis for this location, with this location possibly being used as a test site for solutions in other areas with higher CMI contribution.

5.2 Contextualizing Findings with Industry Research

To strengthen the validity of our findings and identify additional opportunities for IBEC, we investigated external sources related to utility infrastructure reliability, outage management strategies, and environmental risk factors. Our goal was to ensure that the patterns and recommendations we identified were not only rooted in internal data but also aligned with broader industry best practices.

Through our external research, we confirmed that many leading utilities prioritize circuits based on metrics like Customer Minutes of Interruption (CMI), SAIDI, and SAIFI — the same approach we adopted in analyzing IBEC's data. Additionally, research highlights that outages caused by underground (UG) and overhead (OH) equipment failures are among the most common and disruptive events across utility networks, reinforcing the focus areas we identified internally.

We also found that predictive maintenance strategies, including the use of environmental factors like seasonal weather trends and wildfire risk indicators, are increasingly being used by modern utilities to anticipate and prevent outages. Although IBEC's current dataset limited our ability to fully integrate external environmental data, our findings suggest that incorporating these sources in the future could further refine outage prevention efforts.

By validating our insights externally, we can confidently recommend that IBEC continue investing in targeted upgrades for high-CMI circuits, prioritize predictive maintenance efforts ahead of seasonal risk periods, and explore opportunities to enhance situational awareness by integrating environmental and geographic data over time. Our external research not only reinforces the direction of our current recommendations but also provides IBEC a clear path forward for evolving into a more resilient and proactive utility.

5.3 Proposed Visualizations and Dashboards

To help with decision-making and monitoring data in real time, we suggest the following visualizations or dashboards:

- **Top Circuits By CMI**
  - Displaying worst-performing circuits with various criteria like average duration and outage cause.

- **UG/OH Failures Over Time**
  - Pie/bar chart showing frequency of UG/OH failures over time. This would also help track any changes after suggested improvements.

- **SAIDI/SAIFI Tracker**
  - Monitors reliability based on certain thresholds.

- **Risk Prediction**
  - Incorporate failure probability and recommendations for maintenance based on factors such as historical trends or external factors. Machine learning could also be used for dynamic prediction.

Depending on internal resources these can be implemented through Tableau, Power BI, etc.

6. IMPLEMENTATION PLAN

6.1 Short-Term Strategy (Q2–Q4 2025)

In the coming months, IBEC has an opportunity to take several high-impact, low-barrier actions that can deliver quick wins and build momentum toward long-term grid improvements:

- Install underground fault detection sensors on the Green and Thunder circuits, where outages are both severe and time-consuming to resolve.
- Begin targeted inspections of overhead equipment on the Magenta and Logan circuits, focusing on early signs of wear, environmental damage, or recurring fault types.
- Launch a Roosevelt Circuit Diagnostic Initiative, aimed at identifying and resolving the root causes behind its unusually high SAIDI and SAIFI metrics.
- Develop and pilot a reliability dashboard, giving internal planners and engineers real-time access to CMI and SAIDI performance data across the system.
- Strengthen data quality, and establish internal standards for how outage events are recorded, categorized, and validated.
- Implement LiDAR-based vegetation management surveys in the Mountain and North regions to identify and address tree growth near overhead lines ahead of peak spring growth, reducing the likelihood of vegetation-related outages.
- Begin thermal imaging inspections in May–June to detect overheated underground components, install passive cooling systems or improved conduit ventilation to mitigate heat buildup, and map flood-prone zones using FEMA data to deploy sealable junction enclosures that protect UG infrastructure from water intrusion.

6.2 Long-Term Strategy (2026-2028)

In the future, IBEC should focus on improving their grid to adapt to environmental and operational obstacles.

- Expand predictive maintenance efforts to cover additional circuits showing early signs of declining reliability, as measured by rising SAIDI/SAIFI trends.
- Begin grid modernization, investing in technologies like remote monitoring and automated fault isolation to reduce downtime and improve visibility.
- Try to bring select overhead circuits underground, prioritizing areas with repeated outages and risk exposure from weather or vegetation.
- Integrate external datasets such as wildfire risk maps, climate forecasts, and FEMA flood zones into outage analytics, allowing IBEC to better prioritize maintenance and reduce risk from environmental threats.

7. CONCLUSIONS

7.1 Data Insights

- ➢ UG and OH equipment failures are the leading contributors to IBEC's CMI
- ➢ Green, Thunder, and Magenta circuits had the largest CMIs
- ➢ Roosevelt circuit needs targeted monitoring due to its SAIDI/SAIFI being an outlier compared to the rest
- ➢ UG equipment failure contributed to at least twice as much total CMI in the coastal region when compared to any other outage cause.
- ➢ UG Equipment Failure is almost three times as common as any other outage caused in the Coastal Region.
- ➢ Outages caused by an animal in the Mountain region last significantly longer than outages with other causes
- ➢ UG equipment failure in the summer is almost twice as high as any other cause

Our analysis confirms that UG and OH Equipment Failures are the leading contributors to Itty-Bitty Electric Company's CMI. Circuits like Green, Thunder, and Magenta had some of the largest CMIs, while Roosevelt needs to be considered due to the circuit being a SAIDI/SAIFI outlier.

7.2 Strategic Insights

IBEC should focus on a strategy that addresses two main challenges: reducing the impact of high-CMI circuits and improving overall system reliability. By focusing on these challenges IBEC will be able to make meaningful progress with limited resources while enhancing customer satisfaction and reducing maintenance costs.

Based on our analysis, we recommend the following targeted actions:

- Prioritize high-CMI circuits for infrastructure upgrades and enhanced monitoring. These circuits account for a disproportionate share of service interruptions and represent critical opportunities for reducing overall CMI.
- Investigate circuits with high SAIDI and SAIFI values. Persistent reliability issues on circuits may indicate that there are systemic problems that must be addressed through diagnostic analysis or pilot remediation programs.
- Optimize seasonal maintenance planning by aligning inspection and mitigation efforts with known risk patterns. IBEC should focus particularly on UG circuits in the Coastal region ahead of summer and OH circuits in the Mountain and North regions prior to spring.

- Integrate predictive maintenance strategies, leveraging historical outage trends, vegetation proximity data, and seasonal environmental factors to proactively identify and address at-risk circuits before failures occur.

By executing these strategic priorities, IBEC can begin to resolve its most pressing reliability concerns while building a more resilient, data-informed, and customer-focused grid for the future.

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