Electricity Consumption Behavior in CBCA Ndosho

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Introduction

While much of the developed world take access to a stable and reliable electricity grid for granted, many communities in developed countries do not have this luxury. CBCA Ndosho is a hospital in Ndosho in the outskirts of Goma, Democratic Republic of the Congo. Powered by the pre-paid electricity system Virunga, power quality is often not reliable, forcing the hospital to rely on generator usage to source their electricity for parts of the day. This research project attempts to visualize the hospital's electricity sourcing habits and find trends in grid and generator sourcing. The time period being studied is from March 14, 2020 to February 4, 2023. Understanding the power infrastructure struggles of CBCA Ndosho and similar low-resource facilities proves key to recognizing how to best understand and support these communities.

Preprocessing

The original form of the data explored in this study was in the form of written records that were manually transcripted onto a spreadsheet. After transcription, the dataset was cleaned through an extensive process of removing duplicates, filling in missing dates with averaged-out values, and other anomaly detection strategies using intuition to fix anomalies. Any and all manual changes to original data was logged with a note about why the change was made. Grid and generator "usage" was calculated by differencing one day's kWh balance and generator total hours, respectively. In addition to daily, averages of grid and generator usage data was explored weekly and monthly to remove granularity in data and to see if visible trends could be made apparent.

Model Selection and Statistical Methods

Since the goal of this study was to observe whether there were trends in grid and generator usage at the facility, rather than compute exact trend statistics, a model was not used. However, since all the data is based on a time series, a time series model can be used to model the data and accurately predict future behavior.

Limitations

An issue with the main dataset was occasional missing data points. Since removing dates from the dataset would be undesirable as it would appear that subsequent dates utilized more hours than in actuality, it was essential that these dates were to be estimated by averaging out the general behavior around the missing dates and ensuring that the total sum over a time period continued to sum to the value known in the nearest-following valid data point. However, it is known that the missing data from April - June, 2022 for Generator 2 was due to the generator being broken for that time period.

Additionally, since data was only known on the number of hours each generator was active per day, a challenge was finding an appropriate coefficient to use to convert generator hours used to kWh produced. Knowing that the generators were 80 kVa and 20 kVa respectively, a standard power factor of 0.8 was assumed, resulting in ratios of 64 and 16 respectively. Changes in this power factor will affect the results, but the overall trend behavior of the data will remain the same.

Data Overview

Initially on SNEL since construction in 2002, the facility disconnected around 2010 due to unreliability and operated off-grid on diesel, solar PV & batteries until connected to the Virunga SARL grid in mid 2020.

The study centered on two main datasets: grid data, and generator data. For the grid data, each row was a timestamp, with a log of how much electricity in kWh was remaining in the facility's energy balance (the grid operates on a balance-based system), alongside how much, if any, electricity was purchased at that time.

For the generator data, each row was a timestamp, logged each time any one of the two generators was turned on or turned off, alongside a log of the cumulative total hours that generator had been utilized for (presumably since manufacturing). The data also included how much, if any, generator fuel was purchased at that time, in dollars.

Bias in the data analysis might result from rounding values, imputing values in the initial transcription, and misreading handwriting. Reliability of the data additionally depends on the accuracy of the meter it was read from. Most possible bias would likely be the result of human error.

Figure 1: Facility technician points out kWh consumption in his logbook. Photo: J. Kersey 2024, Goma

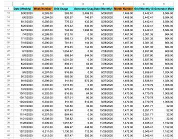

Figure 2: Transcribed Records with Analysis

Results

The full spreadsheet with all data analysis in this project an be found here.

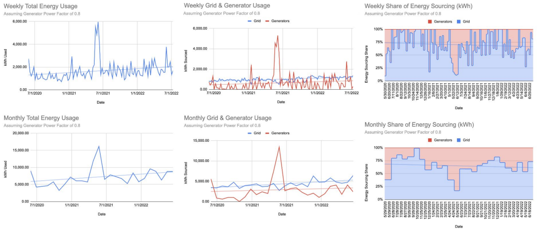

Figure 3 - mashup of hospital grid & generator usage data depicting total energy usage, individual energy sourcing, and the share between the two over the time period from 05/30/2020 to 07/09/2022.

Figure 4 - mashup of hospital grid & generator expenditure data depicting total energy expenditure, individual energy expenditures, and the share between the two over the time period from 05/30/2020 to 07/09/2022.

The drop in grid usage and large peak in generator usage seen in late-May to early-June 2021 was triggered by the eruption of Mount Nyiragongo starting May 22, 2021. The eruption caused the displacement of 25,000 residents, damaging of power lines, evacuation orders, a surge in hospitalizations, and a steep spike in total energy consumption for mitigation efforts (ACAPS 2021).

Over the grid monitoring period from 05/30/2020 to 02/04/2023, the hospital drew an average of 4,726.67 kWh/month from the grid, paying an average of $945.79/month at $0.20/kWh.

Over the generator monitoring period from 03/14/2020 to 07/09/2022, the hospital spent an average of 115.45 hours/month running either of their two generators, paying an average of $385.69/month on diesel fuel. Assuming a standard power factor of 0.8, the hospital produced an average of 4,500.76 kWh/month from its generators, paying an average of $0.086/kWh.

Conclusions

For the time period from 05/30/2020 to 07/09/2022, total electricity consumption at the facility grew at a rate of 23.63% per year. Growth in both grid consumption and generator usage drove this growth, while generator usage appears to increase in relative share to the grid over time. Total energy expenditure also increased over the time period. It is seen that, in general, when grid sourcing decreases, generator usage increases.

An additional key finding revealed through this work is how generator usage is fundamentally related to grid usage. Specifically, when the grid has outages or poor power quality, the facility activates its generators as an alternative source of reliable electricity. An in-depth study on this concept is explored in the DRC 6 research paper, "IoT data for managing the Energy-Health Nexus: Experimental Insights from Health Facilities in Rwanda & the Democratic Republic of Congo", which this project was a part of. The generator hours used from this study is found to be very similar to the generator hours predicted from the AI model in the paper, indicating a highly accurate model and suggesting the observation that the hospital's generators are predominantly used to counteract an unreliable grid.

Further research can be done on finding ways to displace generator usage for cleaner energy from the grid. Additionally, since this analysis is only on one hospital, more analysis needs to be done on other facilities to reveal a comprehensive picture of the energy struggles and behaviors of the region. Furthermore, the data and conclusions from this study can be combined with public health data to see how community health is related to electricity reliability—a key motive being investigated by the broader research team.

In the long term, this project can provide background for how to best support the energy needs of under-resourced communities.

Collaboration

The original data in photograph form was collected from CBCA Ndosho in the DRC by Samuel. The context for the project, as well as details on the goals of the broader research team, were provided by Samuel. Data analysis, visualizations, and conclusions were made by Charlie.