ANALYSING PROJECT JUA'S ELECTRICITY DATA TO UNDERSTAND SYSTEM PERFORMANCE

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PROJECT JUA AND THE GOALS OF THE RESEARCH PROJECT

Project Jua, funded by the OVO Foundation and implemented by Energy 4 Impact, has provided more than £2m to support electricity access to more than 300 schools and health facilities in the most remote and underserved regions of Kenya. The goal of this project is to use off-grid systems, comprised of solar panels and battery packs, to help improve the quality and availability of education and healthcare services by providing access to affordable and clean electricity.

Designing solar off-grid systems correctly is essential for successful implementation: under-sizing could result in power being unavailable, while over-sizing can result in unnecessary costs and diverting funds that could be used elsewhere. To correctly size a system it is necessary to estimate the shape and size of the electricity demand profile of the end-user: the most common way to do this is to use electricity demand surveys and to consider the power rating of the appliances that will be used[1]. However, by using data recorded in similar systems which have been connected recently, significant improvements in this estimation can be realised[2]. The use of machine learning algorithms, that can exploit recorded data to predict future energy consumption of the site involved, offers promising results[3].

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To investigate the potential of using these methods to investigate appropriate sizing, systems installed as part of Project Jua were the subject of a thesis project on the MSc in Sustainable Energy Futures at Imperial College London[4].

The goal of this project was to inform improvements to the sizing of the systems by analysing electricity data gathered during the first phases of the project. All of the Project Jua installations are equipped with a remote monitoring system, providing a remarkable amount of data being collected and allowing for analysis of the performance of the systems and to make recommendations for future project phases.

This project aimed to clean and process the data monitored from the systems, to assess the sizing of the different installations, and to make recommendations to improve future sizing using demand forecasting. This report provides a brief summary of the methodology used by the thesis project, its key findings, and recommendations for stakeholders and future projects.

DATA AND METHODOLOGY

The available dataset contained 20 institutions of the first phase of the project (OVO1) and 150 institutions of the second phase (OVO2). Around two years of monitored data was available for OVO1 sites, and between eight and 12 months for OVO2 sites, depending on the installation date. For every institution the measured values include battery voltage, power production and consumption, and other technical data.

To analyse the data, the Python programming language was used for the following steps:

1. Assessing the quantity and quality of data.
2. Understanding the time evolution of the data.
3. Calculating system-level performance.
4. Using correlations and machine learning to make predictions.

FINDINGS AND DISCUSSION

UNDERSTANDING THE DATA

After exporting, cleaning and processing the available data, the OVO1 dataset contained 17 institutions (three health facilities and 14 schools) with data available for between three months and two years. The dataset for OVO2 contained 134 institutions (19 health facilities and 115 schools) with between two and 12 months of data. Processing and cleaning provided a usable dataset for further analysis. All schools have been closed or operating at reduced capacities since March 2020 and this likely subsequently affected the representativeness of the data for the usage of the energy systems, especially for the more recent OVO2 installations.

The next step was to understand the consumption and the production behaviour at each individual institution. Plotting the data over time provides an understanding of short-term behaviour (such as daily patterns and weekly effects), as well as medium or long-term effects as well (such as trends of energy usage, seasonal variations, and holidays). For example Lake Turkana School was found to have decreasing consumption over time from late 2018 to early 2020, and also lower consumption around Christmas and April likely due to school holidays, shown in Figure 1.

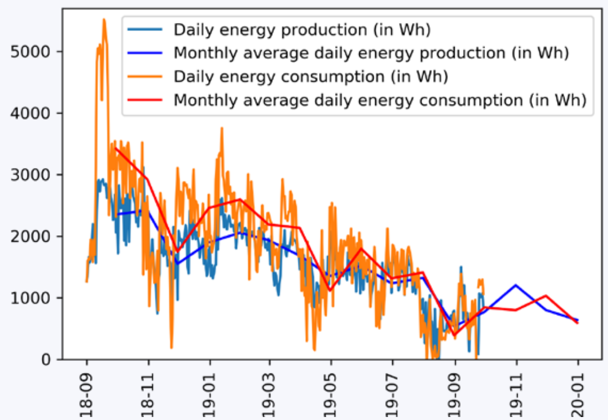

Figure 1: Time evolution of the energy production and consumption for Lake Turkana School (OVO1)

Using the 24-hour profile is a useful way of comparing the patterns of the different institutions by giving an overview of the behaviour over a typical day. Figure 2 presents the hourly profile of the power production and the power consumption for 18 schools selected from the OVO2 database as an illustration of the overall dataset.

For the energy production all the profiles have a similar shape, with no production during the night (from 6pm to 6am) and with a peak in production in the morning. Most of the sites reach peak production at around 10am. This is before midday, when the sun is highest and where the peak in production would be expected. The reason for the earlier peak is that the production is limited by the capacity available in the battery. Once the battery is full, the production is reduced. When the battery is fully charged the system limits the production to prevent the battery from being overcharged and damaged; if the consumption is relatively low, the system energy production will also be limited.

The energy consumption profile is more complicated to analyse. Figure 2 shows that the consumption is more constant than production, with maximum values around 200 Watts (W), and more consistent throughout the day. The maximum production, however, was between 300 W and 500 W. An interesting insight is that the night consumption seems higher than the day consumption, most likely due to the need for lighting during hours of darkness. The higher consumption from 7 pm to 5 am, which is entirely supplied by the battery because there is no sun at this time, highlights the importance of correctly sizing the energy storage to meet the needs of the users at the right times.

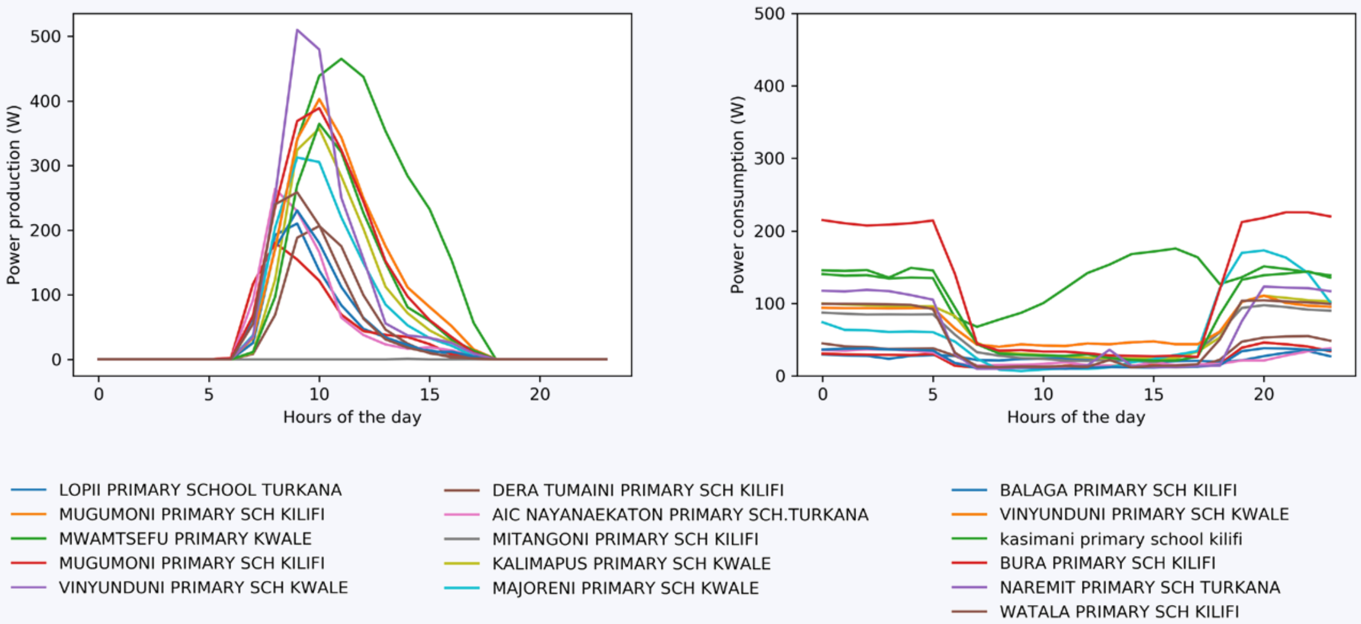

Figure 2: Hourly profile of the power production and of the power consumption, for 18 schools selected from OVO2 database for illustrative purposes (115 schools in total).

CONSUMPTION COMPARISON AND SIZING ASSESSMENT

The average daily mean power production and consumption were considered to compare the different sites, and the utilisation rate was used to assess the sizing of the different installations. The average consumption is 837 Watt-hours (Wh) per day for the OVO1 institutions, 955 Wh per day for OVO2 schools and 2685 Wh per day for OVO2 health facilities. On average, the consumption of health facilities is twice as high than for the schools. Figure 3 shows the distribution of the average daily mean energy consumption for the schools and health facilities: while schools typically have consumption centred around 1 kilowatt-hour (kWh, 1000 Wh) per day, whilst there is a much wider range for the health facilities with consumption between 1 kWh to 9 kWh per day.

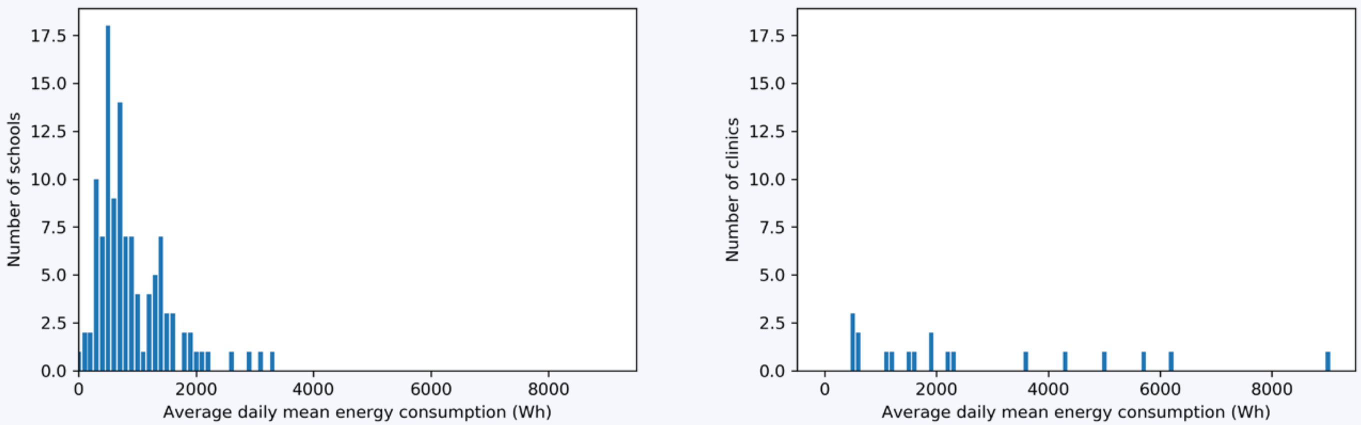

Figure 3: Distribution of the average daily mean energy consumption for the schools (left) and for the health facilities (right)

Most of the institutions do not exploit the whole potential of their systems: the average utilisation rate is just 26% for OVO1 institutions, 21% for OVO2 schools and 27% for OVO2 health facilities. This is likely a result of reduced usage during the COVID-19 crisis when many schools were closed or operating at reduced capacities, but before this period systems still had the potential for greater energy usage. The utilisation could be increased by providing more appliances, as was planned by the government before being affected by COVID restrictions, or by user training to increase the energy usage.

DEMAND FORECASTING

Machine learning methods require a large number of examples to successfully train the algorithms, usually several hundred or thousands of cases. For Project Jua some quantitative predictions of the power consumption based on objective data about the institution (such as the number of students and size of the school) were possible using machine learning, but the scale of the datasets – in terms of numbers of institutions for OVO1, and duration of data collection for OVO2 – was not sufficient to have conclusive findings.

The relationship between power consumption and objective data is not linear, so neither correlation coefficients nor multivariable linear regression gave suitable results. Multi-class classifications and neural network approaches offered more promising results but remained inconclusive, with an accuracy rate of around 20%, due to the volume and the quality of the data available. In addition the OVO2 data, which accounts for the majority of the sites, contains a smaller amount of monitored measurements as these systems have been installed recently. As more data is recorded these methods will likely become more viable.

RECOMMENDATIONS

FOR IMPLEMENTING ORGANISATIONS

While the final institutions under OVO2 are currently being equipped, delayed by the COVID-19 crisis, the next challenge for Energy 4 Impact will be to operate and manage 320 installations. During the operation phase, the data being collected could be used in several ways to help the development of future off-grid projects.

Data analysis has an amazing potential for off-grid electricity access and the data collected during Project Jua are particularly valuable due to the number of sites for comparison. However, to be meaningful, analyses have to be based on reliable data. Processes for ensuring the quality and consistency of the data should be implemented throughout the project lifetime as the gaps in the existing datasets limit their potential.

Real-time data analysis and error detection could be implemented to predict or identify system faults. If user behaviour differs significantly from previous records, it could be detected by an algorithm and flagged for manual follow-up to identify the reason for the change. Alternative business models could also be explored to utilise the energy currently being wasted when the system is oversized: quantifying the energy going unused is critical in identifying a suitable alternative use that would be beneficial for the wider community. These could depend on government policies and approvals, and the interest and buy-in of the local communities, and would likely require support from implementing organisations in the forms of lobbying, demand stimulation, user training, and lobbying.

FOR DONORS, SUPPORTING ORGANISATIONS AND GOVERNMENTS

The consumption is driven by the appliances owned by the institutions. At present all Project Jua institutions are connected to electricity systems but they cannot maximise the benefits of this access because they do not own enough appliances to fully utilise the energy. It may be challenging, however, for the same organisation to finance both systems and appliances given that it requires considerable amounts of time and resources and because the two activities require different expertise and support. Furthermore, it is important to ensure that systems are appropriately sized, based on the anticipated energy usage required to achieve the goals of the project, to use resources effectively and maximise the number of beneficiaries and sites that can be reached.

Establishing and coordinating partnerships with organisations that supply appliances and training to schools and health facilities may be a mutually beneficial solution to increase the impact of electrification initiatives. Government agencies can play a role by supporting broader electricity access initiatives and donor- and private sector-led projects: providing legislative and financial endorsement to such programmes would further support community engagement and wider economic development opportunities.

FOR FUTURE RESEARCH

The utilisation data analysis has great potential to improve system sizing. By studying the OVO2 data over a longer period, for example between one and five years, it may provide insights that can help with the future electrification of similar institutions. For now the connections are very recent, especially for OVO2, and the utilisation has not yet reached a steady state. In a few years' time, however, if the data is collected and stored correctly then there is great potential to apply the knowledge gained from Project Jua to new projects aiming to bring electricity access to schools and health facilities in remote and rural areas of developing countries.

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Right now, we're installing solar panels in Kenya through Project Jua, bringing hundreds of thousands of people clean, green energy to power schools and medical centres. We're teaching kids about fighting the climate crisis through our Climate Changers programme, as well as making schools more energy efficient and planting Tiny Forests across the UK – these will become outdoor classrooms and have a massive impact, absorbing up to 7,200 tonnes of carbon each year. We're working with young people at risk of homelessness to construct homes through our Future Builders project, where they'll learn new skills and get support in education and employment.

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