Towards Net Zero Carbon: An Intelligent Dashboard to Promote Pro-Environmental Behaviour

Project PI: Dr Ahmad Taha; Project Research Assistant: Mr Rory Nesbitt – JWS of Engineering, University of Glasgow

Introduction

The climate change race has been a great challenge and the UK government has taken serious steps towards achieving the 2050 net zero carbon target. One of the government's main focal points is modifying the behaviour of buildings' occupants to reduce energy consumption.

The aim of this project was to develop an interactive dashboard that implements a traffic light system to visualize the energy consumption and some environmental parameters of a research lab at the University of Glasgow (UofG). The traffic light system is implemented as a persuasive measure to indicate to users whether their consumption is low/medium/high with respect to the base consumption.

The rest of the document will report on the fulfilled objectives, that were set out in the proposal form, the problems encountered, and future considerations.

Objective 1: Testbed Development (Sensor Network)

The first objective was set to scale up the existing testbed, i.e., the Persuasive Energy Conscious Network (PECN), which constitutes smart plugs that monitor and report energy consumption of individual workstations, every 15 minutes. The LoRaWAN protocol is a Low Power Wide Area Networking (LPWAN) communication protocol for Long Range (LoRa) communication. With the UofG having access to the IoT Scotland Network, the data from the sensors can be collected and forwarded directly to our Multi-access Edge Computing (MEC) server via the MQTT protocol. Through the SICSA and the matched funding, the testbed was scaled up to include the following contextual monitoring sensors:

- An environmental sensor that monitors CO_2, temperature, and humidity levels
- A light level sensor hat also monitors motion.
- A sound level sensor.

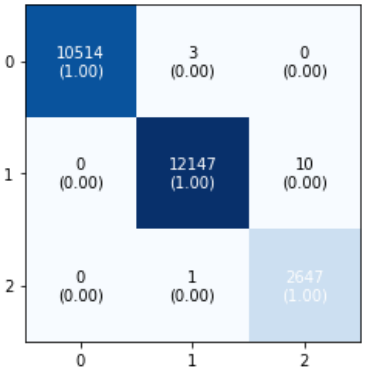
The purpose of the procured sensors was to collect contextual data and establish relationships between them and the energy consumption patterns. All new sensors were deployed, and data is now being saved to an InfluxDB database, every 15 minutes, since 01st of August 2022.

Problems Encountered with Testbed Development

The testbed was meant to have a people counter sensor as detailed in the proposal. The agreed upon sensor to count people was not procured due to supply chain issue. Given the short period of the project, it was disregarded from the data analysis. To mitigate this, the environmental sensors are used to provide insights on the occupancy and its impact on energy consumption.

Objective 2: Artificial Intelligence Stage

The main objective here was to utilize Machine Learning (ML) for classification and multi-feature forecasting of the energy consumption data. The random forest classifier was used on the energy consumption data to classify the data into low, moderate, and high energy consumption levels. The low classes spanned values 0 to 10 kWh, 10 to 20 kWh, and 20 to 30 kWh, for the low, moderate, and high classes, respectively. The data used to train the classifiers covered a period of 11 months, from October 2021 to End of August 2022, at a resolution of 15 minutes.



Machine Learning Classification Results

The results showed high classification accuracies of 99% for the RF. The main purpose of training the classifiers was to assess the overall energy consumption of the research lab and see where it sits on the low/moderate/high scale. As can be seen in the figure on the right, the consumption is skewed towards the low and moderate classes (labelled 0 and 1 in the Figure), with 48% of the energy data being

classified as moderate consumption and 10% classified as high (labelled 2 in the Figure).

Problems Encountered with the AI Algorithms

The objective relating to developing a multi-feature algorithm to forecast the energy data was not fulfilled in this project due to delays in procuring, deploying, and testing the new sensors. Hence, not enough reliable data were generated to build efficient forecasting algorithms.

Objectives 3 & 4: Dashboard and System Integration

The data from all the testbed sensors are recorded on the InfluxDB and updated every 15 minutes. Grafana platform was used to develop a dashboard that visualises the current usage as a green/amber/red guage, hence implementing the traffic light system, to notify the users of the current level of consumption in comparison to the base levels. The rest of the dashboard shows the energy consumption vs the environmental parameters data, collected from the testbed.

Dashboard and System Integration Results

The dashboard is the interface between the user and the testbed and it was designed to update the current usage automatically, every time data is recorded in the database. Through the dashboard, insights into the current and historical energy consumption behaviour can be extracted. For instance, over the period shown on the graphs, which spans one full day, the energy consumption patterns did not change much, even though the lab is empty outside of the normal working hours. This also evident by the sound and light levels, which are only significant from the morning, till about 8 pm which is when some PhD students and post-docs finish work

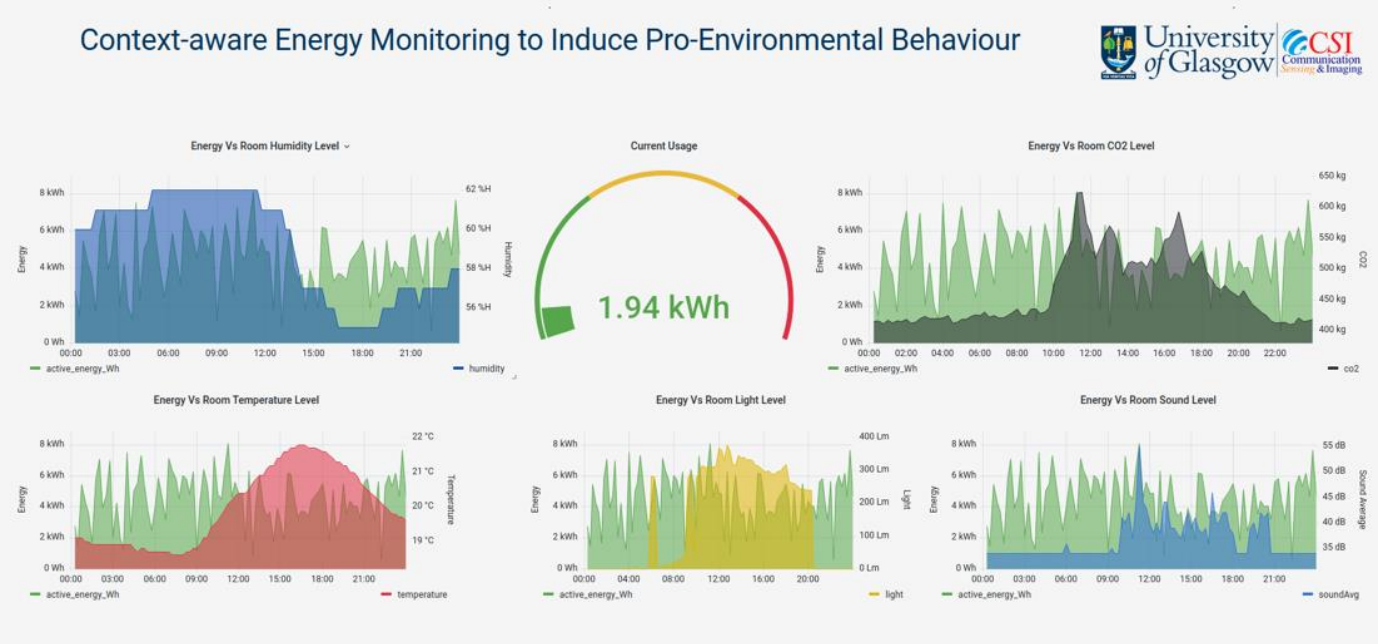


Figure 1: The Energy Dashboard Displaying Consumption vs Environmental Parameters

Conclusions and Future work

The results shown in the dashboard indicates the potential presence of a negative behaviour amongst the users of the lab given the constant energy levels, even outside of normal working hours. Nevertheless, the classification results have shown that the lab is a moderate user of energy. More data from the environmental sensors is needed to make stronger conclusions on the current status of the behaviour within the research lab.

The development of the testbed will continue to grow, even after the course of the project, by integrating more sensors to the existing ones, this primarily includes the people counter sensor. All the data will be used to train forecasting algorithms. This will enable creating behavioural interventions to influence and encourage users to adopt a green behaviour. With all this done we would be able to apply for external research funding such as EPSRC, EPSRC IAA for impact case studies and we would attract industrial engagement for innovate UK and KTP projects.