Baseload smart regulation and carbon intensity reduction using innovative automation – pilot project

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DECLARATION OF ORIGINALITY AND APPROVAL OF REASEARCH ETHICS

I certify that this is my own work, and it has not previously been submitted for any assessed qualification. I certify that School research ethics approval has been obtained and the use of material from other sources has been properly and fully acknowledged in the text. I understand that the normal consequences of cheating in any element of an examination, if proven and in the absence of mitigating circumstances, is that the Examiners' Meeting be directed to fail the candidate in the examination as a whole.

Joseph Jacob 05/08/2023

ABSTRACT

Power consumption in the United Kingdom and its strain on the national grid is a growing concern that needs to be addressed immediately. Although the technological advances has helped increase the power consumption efficiency of electronic appliances, subsequently, there has been a considerable increase in appliances used in a commercial property which balances out or even worse increases the electricity demand even more. It has been identified that one of the biggest wastage when it comes to any infrastructure is the baseload (or passive load). As a countermeasure to address the baseload wastage, multiple smart metering solutions are introduced, which helps the consumers understand where the baseload wastages are and what measures can be taken to eliminate them. This has so far been proven successful but requires dedication and consistency from consumers to make sure these best practices are always followed. What if there was a way to eliminate human intervention which determines efficiency based on consistency?

A pilot experiment was run in an office property with two scenarios. Scenario 1 is business as usual where baseload is monitored but the counter measure to reduce baseload is left to the occupants to decide. Scenario 2 is when all sockets are monitored and automated using innovative intelligent cloud connected systems with commands provided for hard switch off from socket side during non-working hours.

In the end, the results were compared and the difference in value was quite dramatic. Scenario 1 obviously had higher readings when it came to average baseload consumption and power spikes. In addition to this detail, carbon intensity was also calculated which proved to be higher as compared to scenario 2. Scenario 2 showed a more optimized output especially when it came to baseload regulation which in-turn reduced the overall power consumption of the office, a saving of 60% was recorded when it come to power consumption and carbon intensity reduction of 40% was recorded as compared to scenario 1 results. So, from the overall data collected, it is recommended to have smart monitoring with an automated control system that requires zero human intervention to make sure that are no unnecessary baseload wastage and power spikes.

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PUBLICATION

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An oral presentation will be given on this date about the key aspects of this paper which will cover the aims, objectives, and end-result. The publication will be included in the Proceedings of the SET2023. But above all will have an opportunity to spread the message about baseload regulation.

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1. INTRODUCTION

In recent years, the United Kingdom (UK) has experienced a significant increase in electricity demand. This surge in demand can be attributed to various factors such as population growth, economic expansion, technological advancements, and changing lifestyles (van Vuuren et al., 2018). This increase in demand presents several challenges and concerns for the country. To address this issue, the UK government and electricity providers have implemented measures to rectify the increasing electricity demand. One measure taken to address the increasing electricity demand in the country is the adoption of the social norms approach (Harries et al., 2013). The social norms approach involves creating awareness and promoting energy-saving behaviors among consumers.

This approach acknowledges the role of consumer electronics and domestic appliances in driving up domestic electricity consumption. In order to reduce this consumption, the social norms approach focuses on influencing consumer behavior and encouraging energy-saving practices (Cotton, Shiel and Paço, 2016). By highlighting the social norms and behaviors of energy-efficient households, the approach seeks to create a norm where energy-saving practices are seen as the standard. Additionally, First Utility, a major electricity provider in the UK, has already adopted this approach in their operations. The social norms approach aims to influence consumer behavior and promote energy-saving practices in order to reduce domestic electricity consumption (Purtik and Arenas, 2017). Another measure taken to address the increasing electricity demand in the country is the promotion of renewable generation. Renewable generation is crucial in reducing the reliance on fossil fuels and mitigating the environmental impact of electricity production. The UK government and electricity industry are actively promoting the development and use of renewable energy sources such as wind, solar, and hydro power (Demirbaş, 2006). Incentives and policies have been put in place to encourage the adoption of renewable energy technologies, such as feed-in tariffs and renewable energy grants (Hain et al., 2005). These incentives aim to encourage individuals and businesses to invest in renewable energy generation, thereby increasing the overall capacity of renewable energy in the UK's electricity supply. Educating customers on energy demand and cost reduction opportunities is an essential aspect of addressing the increasing electricity demand in the UK (Bradley, Leach and Torriti, 2013). It involves providing consumers with information on how their energy usage impacts the overall electricity demand and cost.

Moreover, it educates them on practical steps they can take to reduce their energy consumption, such as using energy-efficient appliances, insulating their homes, and adopting energy-saving habits.

The government recognizes the need to formulate effective energy-saving policies that consider the social and economic factors associated with electricity demand. These policies aim to control the total consumption of fossil energy while minimizing the social costs. In order to achieve this, the government is utilizing social norms to promote energy conservation (Yang & Dian, 2022). This involves creating a social expectation of energy-saving behavior through campaigns, education, and social incentives. By promoting energy-saving practices as the norm, individuals are more likely to adopt these behaviors, leading to a reduction in electricity demand. Furthermore, the government has also recognized the importance of distributed electricity generation in meeting renewable energy targets (Miao et al., 2016). To achieve this, sustainable energy policies have been formulated to remove barriers and provide incentives for the development of distributed electricity generation. These policies include financial rewards, discounts, and penalties to incentivize households to change their energy consumption behavior and promote pro-environmental behavior. Collaboration between the government and electricity companies has led to the organization of programs aimed at promoting energy-saving behavior among consumers. This multi-faceted approach recognizes the importance of addressing both technical and social factors that influence electricity demand (Buys et al., 2015). In addition to these measures, it is crucial to guide the energy-saving behavior of new urban residents in order to reduce residential energy consumption. This can be achieved through the implementation of non-price interventions such as social norms and nudges. Overall, the government is taking a comprehensive approach to address the increase in electricity demand in the UK. They are implementing effective energy-saving policies that consider the social and economic factors associated with electricity demand. Moreover, measures such as promoting renewable generation, incentivizing energy efficiency, and educating customers on energy demand and cost reduction opportunities are being implemented (Buys et al., 2015)

Electricity demand in office buildings in the UK has become a critical issue in recent years due to the increasing concerns about energy consumption and carbon emissions (Menezes et al., 2012). To address this issue, various steps and policies have been implemented to reduce electricity demand in office buildings. One of the key steps taken to reduce electricity demand in office buildings in the UK is the implementation of energy performance regulations (Clarke et al., 2008). These regulations, such as the Energy Performance of Building Regulations, aim to improve the energy efficiency of buildings by setting standards and requirements for energy performance.

These regulations require office buildings to meet certain energy performance criteria, including the use of energy-efficient lighting technologies and the implementation of daylight harvesting strategies to reduce electricity demand for lighting and relevant cooling loads, which account for almost half of the total electricity demand in conventional office buildings (Shankar, Krishnasamy and Chitti Babu, 2020). Another step taken to reduce electricity demand in office buildings in the UK is the promotion of advanced lighting technologies. Advanced lighting technologies, such as LED lighting, are more energy-efficient compared to traditional lighting options. LED lighting consumes significantly less energy and has a longer lifespan, reducing the need for frequent replacements and maintenance. The implementation of daylight harvesting strategies has proven to be an effective way to reduce electricity demand in office buildings. Daylight harvesting strategies involve optimizing the use of natural daylight to supplement or replace artificial lighting, thereby reducing the need for electricity consumption during daylight hours. In addition to energy performance regulations and the promotion of advanced lighting technologies and daylight harvesting strategies, there are other steps taken to reduce electricity demand in office buildings in the UK. These steps include the installation of smart meters, which provide real-time information on energy consumption and enable building occupants to monitor and adjust their energy usage accordingly. Furthermore, building management systems are being implemented in office buildings to automate and control various energy-consuming systems, including lighting. These systems allow for more efficient scheduling of lighting usage, as well as the ability to dim or turn off lights when not needed.

Another step taken to reduce electricity demand in office buildings in the UK is the implementation of energy management systems (Hampton, 2018). Energy management systems are tools that help monitor and control energy consumption in buildings. These systems provide real-time data on energy usage and can identify areas of high consumption or inefficiency. By analyzing this data, building managers can make informed decisions and implement strategies to reduce electricity demand. Overall, the reduction of electricity demand in office buildings in the UK is being addressed through various measures

Similarly the household power consumption constitutes 38% of the total power consumption of the country. Power consumption in households has had a downward trend from 2005 to 2019. In 2005, the total power consumption for households was 126 terawatt hours and the value was reduced to nearly 100 terawatts by the year 2019. This change was brought about by having more energy-efficient equipment in dwellings compared to what was available back in 2005. Although this downward trend was disrupted in 2020 due to the COVID-19 pandemic which forced people to stay at home and increased the energy demand within dwellings dramatically. As of 2021, the total power consumption for households is about 109 terawatt hours (Alves, 2022). The national grid is at its maximum capacity and thanks to the COP26 declaration on accelerating the transition to 100% zero-emission cars and vans by 2035, electric vehicle demand is on an upward trend (UK, 2021), and the demand on the grid is going to increase much more. As a resolution factor, there are many smart monitoring services available for dwellings that give a clear indication of what the power consumption and the baseload are at every minute. The occupants of the dwelling are expected to have a detailed look at these readings and understand where the power wastages are and figure out a corrective action. The aim of this research is to prove that smart monitoring alone will not be effective, as long as human intervention is required for corrective action. To get optimum results, automation combined with smart monitoring is required.

From above mentioned cases when it comes to commercial spaces (like offices) and dwellings, we can see a huge dependency on consumers as part of social norm to take conscious decisions or lifestyle change to make sure power consumption is brought to a minimum. In my opinion, this is a gap if we are relying on consumers to achieve reduced power consumption especially when the nation is striving to achieve Net Zero targets. What if there was an option to overcome this social norm by automation? What if to reach desired result, we did not entirely depend on human intervention, instead rely on automation? This paper aims to address this issue.

While all the focus has been diverted towards alternate power source, power storage and modular power distribution system, very little attention has been provided to baseload wastage. Although, the value is small for individual dwellings, cumulatively this adds up to be a substantial value that contributes to the load on the national grid. Baseload for a dwelling is the amount of energy a house consumes in an idle mode which is otherwise mentioned as passive consumption. Study indicates that approximately 5% of the total electricity bill is contributed by baseload consumption in dwellings (Palmer, Terry and Kane, 2013) and for commercial space like an office, this percentage is between 25% and 30%. Since this baseload consumption occurs regardless of whether the residence is inhabited or not, it is seen as a unwanted wastage of resources. Most studies till now have reached the same conclusion, the advised correction is for residents to turn off all devices at the switch level. Although this is a workable option, there is no assurance that it will be carried out consistently on a regular basis.

1.1. GAPS, AIMS AND OBJECTIVES

This gap is addressed in my research by conducting an experiment to prove the impact of phantom power on total power consumption in a facility and how using automation this can be regulated to a great deal. This is done with help of intelligent self-learn capable sockets connected to individual devices of the office area which will be our project site. The sockets are network capable allowing it to communicate to a cloud-based software. The software will get in-depth readings of power consumption, carbon intensity and source of power information for each individual socket and for the entire facility. The sockets can be programmed to shut down remotely by applying time-based rules through the software, which should stop unnecessary wastage of passive power drawn by the devices connected to the socket even when device is not in use. This experiment proves that considerable amount of reduced power consumption can be achieved using automation in a small facility, thus the impact will be much greater in larger facilities.

The literature review chapter below points out numerous academic research done especially in the increase in electricity demand in the UK. The second section of literature review will focus on the area of work done to cater to the increase in the projected electricity demand and their gaps. A special focus will be given to baseload regulation for dwellings and partially addresses rectification by human intervention. The final part of the literature review will highlight the gaps and what this paper intends to do to close this gap. As an outcome of the literature review, the research design will aim to prove the advantages of baseload regulation using automation and bridge the gap of inconsistency due to human intervention.

2. LITERATURE REVIEW

2.1. ENERGY DEMAND IN THE UK

Electricity demand in the United Kingdom has been a topic of interest in recent years due to various factors impacting its growth. One major factor that has influenced the increase in electricity demand is the electrification of other sectors of the economy (Osei, Ghaffarpasand and Pope, 2021). This trend is expected to result in a rising demand for electricity in the UK. According to a study conducted by researchers, they assume a 1% year-on-year increase in electricity demand in the UK. This assumption is based on the observation that although demand in the UK has fallen in recent years, the increasing electrification of other sectors of the economy is expected to offset this decline and lead to an overall increase in electricity demand. The increasing electrification of other sectors of the economy is influencing the demand for electricity in the UK. The demand for electricity is influenced by various factors, including output or economic production growth, electricity tariff, weather patterns, population growth, and changes in technology (Motjoadi, Bokoro and Onibonoje, 2020). Economic production growth is a significant driver of electricity demand. As the output or economic production of a country increases, the demand for electricity also tends to increase. This is because increased production typically requires more energy-intensive processes, which in turn, leads to a higher demand for electricity. Additionally, technological advancements also influence how much electricity is demanded. Technology developments have led to the creation of more energy-efficient gadgets and appliances, which can lower the need for power. But technological development can also result in the uptake of new technologies that significantly rely on power, like electric cars and smart houses, which can raise the need for electricity. (Sorrell, 2015).

In addition to economic production growth and technology, weather patterns also have a significant impact on electricity demand. Weather patterns can influence electricity demand through their impact on heating and cooling needs. Higher temperatures, for example, can lead to increased demand for electricity for cooling purposes, as people rely more on air conditioning to stay comfortable (van Ruijven, De Cian and Sue Wing, 2019). Climate change is expected to exacerbate this effect, as it is projected to result in more frequent and intense heatwaves. According to the research conducted by Mideksa and Kallbekken, higher temperatures associated with climate change are expected to raise electricity demand for cooling, as people will increasingly rely on air conditioning to cope with hotter temperatures

(Mideksa and Kallbekken, 2010). Moreover, climate change is also expected to reduce the demand for electricity for heating purposes. As temperatures increase, the need for heating decreases, resulting in a lower demand for electricity for heating purposes. Furthermore, climate change is also expected to have an impact on electricity supply. Higher temperatures associated with climate change can also negatively affect electricity production from thermal power plants. According to Aroonruengsawat and Auffhammer, the increase in temperatures can reduce the efficiency of thermal power plants, leading to a decrease in electricity production (Auffhammer and Aroonruengsawat, 2011). The growing demand for electricity is driven by various factors, including population growth, economic growth, the spread of modern technologies, and climate change. According to Mideksa and Kallbekken, population growth is one of the main drivers of electricity demand increase (Mideksa and Kallbekken, 2010). Additionally, economic growth plays a crucial role in driving electricity demand. As economies grow, there is an increased demand for electricity to power industries, businesses, and homes. Moreover, the rapid spread of modern technologies also contributes to the growing demand for electricity. The adoption and use of modern technologies, such as smartphones, computers, and electric vehicles, require a significant amount of electricity to operate. According to Mideksa and Kallbekken, the rapid spread of modern technologies has been a significant factor in the increase in electricity demand (Mideksa and Kallbekken, 2010).

The UK's expanding population has put significant strain on its energy supply. Population expansion may have boosted domestic energy use, especially in the housing sector, according to studies (Smith et al., 2018). Rapid urbanisation and rising family sizes have increased the energy needed to run electrical and heating/cooling appliances.

2.2. INITIATIVES BY THE UK FOR POWER SURGE PROJECTION

The UK has taken a number of actions to cater to the expected increase in electricity demand in the future. These actions include:

- Investment in energy storage technologies: Recognizing the need to manage the increased demand and intermittent nature of renewable energy sources such as wind power, the UK has prioritized the development of energy storage technologies (Junior et al., 2021). ABB and UK Power Networks have developed a dynamic energy storage solution that supports power quality during disturbances and helps to manage the intermittency of wind power generation (Lang et al., 2012).

- Promotion of electric vehicles: The UK government has announced a ban on the sale of new petrol-based vehicles after 2030, with a focus on encouraging the adoption of electric vehicles (Octopus, 2022). This shift towards electric vehicles is expected to contribute to a significant increase in electricity demand. With vehicle to grid (V2G) technology demand on the rise, it is expected that the vehicles will charge during off peak hours or get powered from a renewable charging station and the charge can be discharged to the grid when the grid is at its peak and needs support of additional power source to cater to demand.
- Expansion of renewable energy sources: In order to meet the growing electricity demand and reduce reliance on fossil fuels, the UK government has implemented a "National Renewable Plan" that targets approximately one third of all electricity consumption to come from renewable sources by 2020, which has so far proven to be wrong as desired result not reached (Upreti and van der Horst, 2004).
- Implementation of heat pumps for space heating: The UK has recognized the potential of heat pumps as an alternative to gas-driven technologies for space heating in buildings (Hewitt, 2012). These heat pumps can be decarbonized by utilizing technologies such as solar PV, wind farms, and carbon capture and storage.
- Improving energy efficiency: The UK has also focused on improving energy efficiency in order to reduce overall electricity demand. This includes initiatives such as promoting energy-efficient appliances, improving insulation in buildings, and implementing smart grid technologies that enable more efficient use of electricity (Chowdhury et al., 2018).

From the above points, I feel the crux of the problem is not touch based on. What about energy wastage within a dwelling or a commercial space or any kind of infrastructure? Why is there a focus shift on new forms of energy storage options, energy efficiency of infrastructure and products? The passive power drawn by devices in any infrastructure even when it is not in use (which is otherwise called phantom power) cumulatively adds up to be a huge loss and this is complete wastage of energy.

2.3. ENERGY COSUMPTION IN COMMERCIAL BUILDINGS

Despite the fact that a growing number of countries have been launching new policies to improve building energy performance, the average energy consumption per person in the global buildings sector has remained practically unchanged since 1990. Commercial buildings account for 11% of final energy consumption in the UK. Moreover, within the commercial buildings sector, certain sectors have been identified as major contributors to energy consumption. In the UK, retail buildings contribute up to 17% of commercial building energy consumption, while in the USA they account for 18% of total commercial building consumption, which is equivalent to 3.2% of the total energy consumed within the country. This highlights the significant impact of energy consumption in commercial buildings on overall energy consumption and the need for targeted efforts to improve energy efficiency in these sectors. The energy consumption in commercial buildings in the UK is a significant contributor to the overall energy consumption in the country. According to research done by Luis Perez-Lombard, Jose Ortiz and Christine Pout, commercial buildings account for 11% of final energy consumption in the UK (Pérez-Lombard, Ortiz and Pout, 2008). Additionally, statistics show that a quarter of total energy consumption by commercial buildings is contributed by electric lighting and office equipment (Masoso and Grobler, 2010). This indicates that there is a need for strategies and initiatives to improve the utilization efficiency of lighting systems in commercial buildings. The energy consumption in commercial buildings in the UK is not only significant in terms of overall energy consumption, but also in comparison to other sectors. For instance, the commercial and public sector in Thailand represented 35.2% of total electricity consumption in 2013, highlighting the substantial role of commercial buildings in energy consumption in different countries (Chaichaloempreecha, Chunark and Limmeechokchai, 2019). Furthermore, the share of energy consumption by each end-use group in commercial buildings can vary depending on factors such as climate, system efficiencies, and building structure (Jenkins, Liu and Peacock, 2008).

This means that the average energy consumption of commercial buildings in the UK may differ from that in other countries. For example, in Canada, the residential sector accounts for 17% of total energy consumption (Aydinalp-Koksal and Ugursal, 2008), while in some developing countries like China, the energy consumption of residential buildings may be even higher (Hu et al., 2017). Overall, the energy consumption in commercial buildings in the UK plays a significant role in the country's total energy consumption. In order to address this issue and reduce the energy consumption in commercial buildings, various strategies can be implemented. These strategies may include improving the utilization efficiency of lighting systems through the use of energy-efficient lighting technologies, implementing smart energy management systems to optimize energy use, and promoting energy conservation practices among building occupants (Wei et al., 2016).

The implementation of these strategies can lead to significant reductions in energy consumption in commercial buildings and contribute to overall energy efficiency in the country.

Commercial buildings in the UK account for 11% of the final energy consumption, with a quarter of that being contributed by lighting and electronic devices. This indicates the importance of addressing energy consumption in commercial buildings, particularly in terms of their lighting systems. To improve the utilization efficiency of lighting systems in commercial buildings in the UK, it is crucial to consider energy-efficient lighting technologies and smart energy management systems. These technologies and systems can help optimize energy use and reduce energy wastage, leading to significant energy savings. Additionally, promoting energy conservation practices among building occupants is crucial in reducing energy consumption. Building occupants can be educated about the importance of energy conservation and provided with energy-saving tips, such as turning off lights and electronic devices when not in use. Although personally I feel, this will be an inconsistent practice and not reliable as this is dependent on physical intervention.

2.4. ENERGY COSUMPTION IN DWELLINGS

Domestic power consumption in the UK has been a hot topic and there have been numerous studies done on this particular topic for the last 20 years. Yigsaw Yohanis did a study and published it in 2008 in which he did a detailed report to establish a relationship between total power consumed in a dwelling against the type of house against the total earnings of each household. The study that he performed in 27 dwellings showed some obvious results. The power consumption was directly proportional to the size of the dwelling. But along with that, there was also an interesting find which suggested that the same type of house can have 2 different types of power consumption depending on the earnings of each household (Yohanis et al., 2008). Human intervention here has been a major stake in determining the top power consumption.

Similarly, a more recent study by Araya Mejias and his team published in 2021, used energy smart meters in buildings using International Performance Measurement and Verification Protocol (IPVMVP). Readings were taken before and after the improvement was done and there was a considerable reduction in power consumption. Although the reduction was not up to the mark. The total energy savings obtained for all homes was 14%, but the predicted savings was supposed to be 88%. The reason for not reaching the desired savings was due to the habits and behavior of the tenants (Araya Mejias et al., 2021). Again, human intervention has played a negative role in this experiment to not achieve the desired target.

W. Kong and Z.Y. Dong take their study a few steps ahead to determine power consumption on individual device levels using Non-Intrusive Load monitoring technology (NILM). As an occupant or tenant, you receive real-time exact power consumption per device (Kong and Dong, 2020). Using this data, the occupant has to take a conscious decision on their way of life moving forward. This again raises the question of inconsistency and further falling short of desired target levels.

2.5. GAPS AND RECTIFICATION ACTIONS

From the above studies, we can see that there are many actions taken to make sure energy consumption is brought down in commercial and residential properties, although it is quite evident that little or no emphasis is given to baseload wastage and only rectification action mentioned in studies mentioned above is to teach occupants or bring about a behavior change for the desired result to be achieved with regards to the regulation of baseload wastage and carbon intensity reduction. It is expected that occupants have to study the readings captured and make necessary changes to the way of operation. Most importantly the new way of operation has to be followed consistently.

Department of Energy & Climate Change (DECC) and the Department of Environment, Food and Rural Affairs (DEFRA) approached Cambridge Architectural Research, Loughborough University and Element Energy to re-analyze the household Electricity Survey. One of the activities performed was measuring the baseload or least power drawing from all outlets in a period of 24 hours. The average drawn in the middle of the night was 110 watts. Keep in mind that this power consumed by the household is a complete waste, this power consumed did not contribute to any kind of thermal comfort or fulfill any set agenda of occupants. 110 Watts might seem extremely low, but since this consumption is round the clock, in a year this consumption adds up to an average of 201KWh for a single dwelling (Palmer, Terry and Kane, 2013). The report also published a financial term against this wastage which was between £20 and £30 a year. As per Office for National Statistics (ONS), in the UK there are a total 19.3 million families sheltered in dwellings (owned or rented). This data is collected in 2021 (Statistics,2019). If we assume a rounded figure of 19 million dwellings and an average baseload wastage of £25, the total wastage for the UK in a year is a staggering £475 million. Baseload, although very little for individual dwellings, now has cumulatively added up to be a bigger problem to deal with. Although the corrective action for this was to educate occupants about the wastage and instruct them to switch off devices before they go to bed. When it comes to occupants, they do not look at this issue as a £475 million per year issue, they look at this as a £1.6 per month of wastage which may not get their attention as worth looking into.

My research design will address this issue and replace human intervention with automation. By doing so, the window of human error or negligence is reduced dramatically, and the result will be consistent throughout the testing and monitoring period. My research will also go the extra mile to compare outcome of two scenarios. In scenario 1, all the power consumption is monitored at individual device level, but there is zero level of automation provided. This means the workflow will be identical to any commercial or residential property. In scenario 2, along with power consumption monitoring, there will be an additional feature of automation added to the equation which should help bring down unnecessary wastage of passive power especially during non-working hours. Once the readings for both scenarios are collected, the same will be compared and we should expect to see a considerable saving of baseload wastage and carbon intensity in scenario 2 as compared to scenario 1.

3. RESEARCH DESIGN METHODOLOGY

3.1. METHODOLOGY AND PRELIMENARY WORKS

The method used to indicate the effect of baseload wastage would be a short-term pilot phase experiment conducted in a small office space for a total period of 4 weeks. The aim of this experiment is to show the impact of baseload wastage and carbon intensity when automation is turn off and on for a small office space. If the same solution is implemented at a larger facility, which could be a bigger office building or a big site office, the impact of savings which is expected to come in when it comes to baseload wastage and carbon intensity reduction would be quite substantial.

The first meeting was held on the 21March2023 at measurable.energy (Measurable Ltd). During the meeting, the intend of the experiment was discussed to check if the products available are viable and has the capability to produce the desired results. Once this was confirmed, a complete site survey was conducted including listing down the equipment connected to the intelligent sockets. During the next one month, all devices with its operating power details were tabulated, and a plan of action was put in place as to how the experiment is expected to run. On 25May2023, second round of face-to-face meeting was conducted which commenced the first phase of the experiments which will be referred to as "Scenario 1" hereafter. The detail description of Scenario 1 will be explained in section 3.6 of this document. This phase of the experiment started on the 25May2023, 12.30 PM and completed on 08June2023, 12.30 PM. The third meeting which happened on the 08June2023 started off by concluding Scenario 1 and initiating the second phase of the experiment which will be referred to as "Scenario 2" hereafter. Scenario 2 experiment started on 08June2023 12.40 PM and ended on 22June2023 12.40 PM. The details on Scenario 2 are explained in detail in section 3.6. Over the course of one month starting 22June2023, all readings were collected by running a software report and the information gathered for Scenario 1 and Scenario 2 was compared resulting in the conclusion of this project. There are certain limitations which were recorded and same is explained in section 5.1, limitation of experiment.

3.2. OFFICE DETAILS, LAYOUT DESCRIPTION AND ITS DEVICES

The location of the office is as mentioned below:

measurable.energy (Measurable Ltd)

Reading, United Kingdom

The office is sub-divided in 3 sections:

- Lab and Test centre
- Office Space
- Conference Room

The Lab and test centre would be used only during new product test phase which could be not as frequent and consistent as compared to other two rooms. The office space (the room located in the middle) is the most frequently used area. This room has the greatest number of electronic devices which could possibly draw passive power even when equipment not in use. The conference room also is used frequently, but the frequency is not as much as the office space. The number of devices in the conference room is also less. The office is functional typically for 5 days a week (Monday to Friday) from 9 AM – 6PM.

While majority of the daily activity is concentrated around the office space area, there is moderate or average amount of activity in lab and test centre (when equipment are to be tested or calibrated) and in conference room (when there are client meetings, office meetings or presentations). From the readings collected below (refer to critical discussion section) it is quite evident that out of the total power drawn from the full office, a substantial amount is power is drawn from the office space area due to 2 reasons, one being the space is used considerably higher than the other 2 room sections of the office and the second reason being majority of the equipment are located in this area.

Below image (Figure 3.1) indicates the office layout:

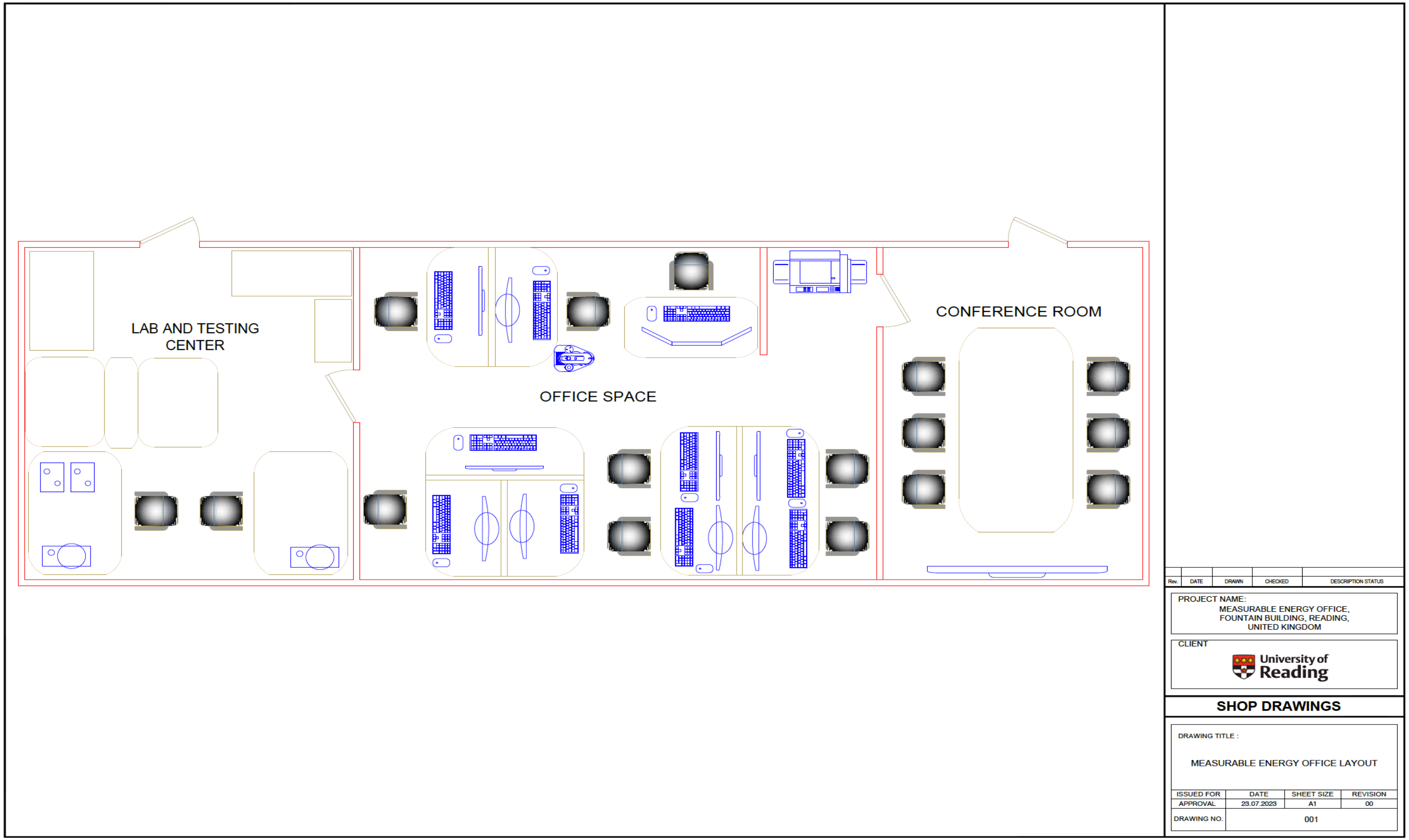


Figure 3.1: Measurable Energy office – Layout

3.2.1. EQUIPMENTS LOCATED IN LAB AND TEST CENTRE

The lab and test centres will have testing equipment, calibrating devices, and laptops. These are devices which are not used regularly and only used on demand basis. When they are in use, they do add to be quite substantial when it comes to wattage due to power consumption.

Below table (table 3.1) will indicate the type of device and the associated power requirements:

Bronson ++ VC1000	
Power Input	AC 100-240 V (50/60 Hz)
Power Capacity (Max)	1000 Watts
Max Current	4 Amps
Pi-Top Pi Laptop	
Power Input	AC 240 V (60 Hz)
Screen Power	3W
Power consumption (Typ)	50W
Duratool D03233	
Power Input	220–240 V / 50/60 Hz to adaptor
Power Rating	54W

Table 3.1: Lab and test centre – equipment list

3.2.2. EQUIPMENTS LOCATED IN OFFICE SPACE

The office space will have the maximum number of devices compared to any other section of the office. The office space has a series of computers with associated type of display screens, keyboard, and mouse. In addition to this there are coffee machines, printers, and routers as well. Please refer to table 3.2 to table 3.4 to capture complete information of all devices connected to power sockets:

Dell 27 Curved Monitor – S2721HGFA	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	27 Watts
Power Consumption (Max)	46 Watts
Power Consumption (Standby)	0.5 Watts
Power Consumption (Off Mode)	0.3 Watts
Dell Docking Station	
Power Input	Power Adapter 180 Watt
Power consumption (Typ)	up to 130 Watts power delivery
Dell Latitude 5000 Series Laptop	
Power Input	220–240 V / 50/60 Hz to adaptor
Power consumption (Typ)	65W adapter, 7.4mm barrel

Table 3.2: Office space equipment list – Part 1

Below table 3.3 indicates devices located on the left section of the office space and its associated power. Majority of the devices shown below are never turned off, they would either be in use and draws power ranging between typical and max power consumption value mentioned below or during non-office hours they draw a power value similar to idle or sleep mode.

Printer/Scanner - Konica Minolta	
Power Input	220–240 V / 50/60 Hz
Power consumption	1500 Watts
Dell 27 Flat panel Monitor – P2719H X 5 times	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	19 Watts
Power Consumption (Max)	58 Watts
Power Consumption (Standby)	0.3 Watts
Power Consumption (Off Mode)	0.3 Watts
24" Flat panel Monitor X 2 times	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	16 Watts

Power Consumption (Max)	52 Watts
Power Consumption (Standby)	0.3 Watts
Power Consumption (Off Mode)	0.3 Watts
19" Flat panel Monitor	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	15 Watts
Power Consumption (Max)	48 Watts
Power Consumption (Standby)	0.3 Watts
Power Consumption (Off Mode)	0.3 Watts
Dell Docking Station X 4 times	
Power Input	Power Adapter 180 Watt
Power consumption (Typ)	up to 130 Watts power delivery
Dell Latitude 5000 Series Laptop	
Power Input	220–240 V / 50/60 Hz to adaptor
Power consumption (Typ)	65W adapter, 7.4mm barrel
PCSPECIALIST Vortex G30 CPU	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	230 Watts
Power Consumption (Max)	600 Watts
Dell 27 Curved Monitor – S2721HGFA	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	27 Watts
Power Consumption (Max)	46 Watts
Power Consumption (Standby)	0.5 Watts
Power Consumption (Off Mode)	0.3 Watts

Table 3.3: Office space equipment list – Part 2

Below table 3.4 indicates devices located in the middle section of the office space and its associated power. Majority of the devices shown below are never turned off, they would either be in use and draws power ranging between typical and max power consumption value mentioned below or during non-office hours where they draw a power value similar to idle or sleep mode. In addition to this, this section of the office also includes coffee machine which draws huge power when in use but does not draw phantom power when not in use.

Dell 27 Flat panel Monitor – P2719H X 3 times	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	19 Watts
Power Consumption (Max)	58 Watts
Power Consumption (Standby)	0.3 Watts
Power Consumption (Off Mode)	0.3 Watts
Dell Docking Station X 6 times	
Power Input	Power Adapter 180 Watt
Power consumption (Typ)	up to 130 Watts power delivery
Dell Latitude 5000 Series Laptop X 4 times	
Power Input	220–240 V / 50/60 Hz to adaptor
Power consumption (Typ)	65W adapter, 7.4mm barrel
Dell 27 Curved Monitor – S2721HGFA X 2 times	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	27 Watts
Power Consumption (Max)	46 Watts
Power Consumption (Standby)	0.5 Watts
Power Consumption (Off Mode)	0.3 Watts
Philips SPA 2300 Subwoofer	
Power Input	220–240 V / 50/60 Hz to adaptor
Power consumption (Typ)	38 W (Subwoofer: 12 W)
Russell Hobbs 20680 Buckingham Filter Coffee Machine	
Power Input	220–240 V / 50/60 Hz to adaptor
Power consumption (Typ)	1000 Watts

Table 3.4: Office space equipment – Part 3

3.2.3. EQUIPMENTS LOCATED IN CONFERENCE ROOM

The conference room has the least number of devices, although it does have high power consuming devices which cumulatively add to the total power demand of the entire office.

Please refer to table 3.5 below to get a break down of what kind of equipment are in use and what is their operating power:

85" Flat screen monitor	
Power Input	AC 100-240 V (50/60 Hz)
Power consumption (Typ)	1200 Watts
Power Consumption (Max)	2050 Watts
Power Consumption (Standby)	5 Watts
Power Consumption (Off Mode)	1 Watts
Dell docking station	
Power Input	Power Adapter 180 Watt
Power consumption (Typ)	up to 130 Watts power delivery
Dell Latitude 5000 Series Laptop	
Power Input	220–240 V / 50/60 Hz to adaptor
Power consumption (Typ)	65W adapter, 7.4mm barrel

Table 3.5: Conference room equipment list

3.3. INTELLIGENT SOCKET FEATURES

In a typical office or a commercial building, the switch boards sockets are passive devices which distributes power from power distribution board to individual device level supplying a standard of 220-240Vac at an amps rating of either 5 Amps or 15 Amps depending on what type of equipment is plugged in. The only way to grab information about the power consumption would be to get a cumulative power demand chart which will only give an information of what is the total power that is drawn for the complete establishment. In the case of this project, all sockets are a special type with machine learning technology and with the capability of measuring power at individual device level. In addition to the measuring capability, the socket has an added advantage to control the power demand as well. Since the sockets are Wi-Fi enabled, they have a full duplex communicating capability to a central software. Through the software, we can monitor what is the power drawn at any given time and in addition to that, there are certain rules that can be set to individual sockets with regards to power distribution. For example, through the software, we can set a rule on an individual socket which states that the power shall be distributed from 9AM to 5PM on a weekday and zero power is transmitted from 5:01 PM to 8:59 AM on a weekday and the whole of weekends. This command can be overridden in 2 ways, one way would be the switch off the rule at software level and the other way would be press the override button on the switch board which manually overrides the rule and works on manual mode for the next 2 hours, like any conventional switches available in the market today.

To summarize the features and outputs of this technology:

- Detailed in-dept reading of power consumption of any socket at any given time
- Carbon intensity details at any given time (Figure 3.2)
- Energy cost (Figure 3.2)
- Comparison details of 2 periods
- Option to provide rules from the software to automatically switch ON/OFF the sockets at any required time schedule.
- Power source indication on sockets – if power that the socket is getting at any given time is generated using renewable or non-renewable resources.

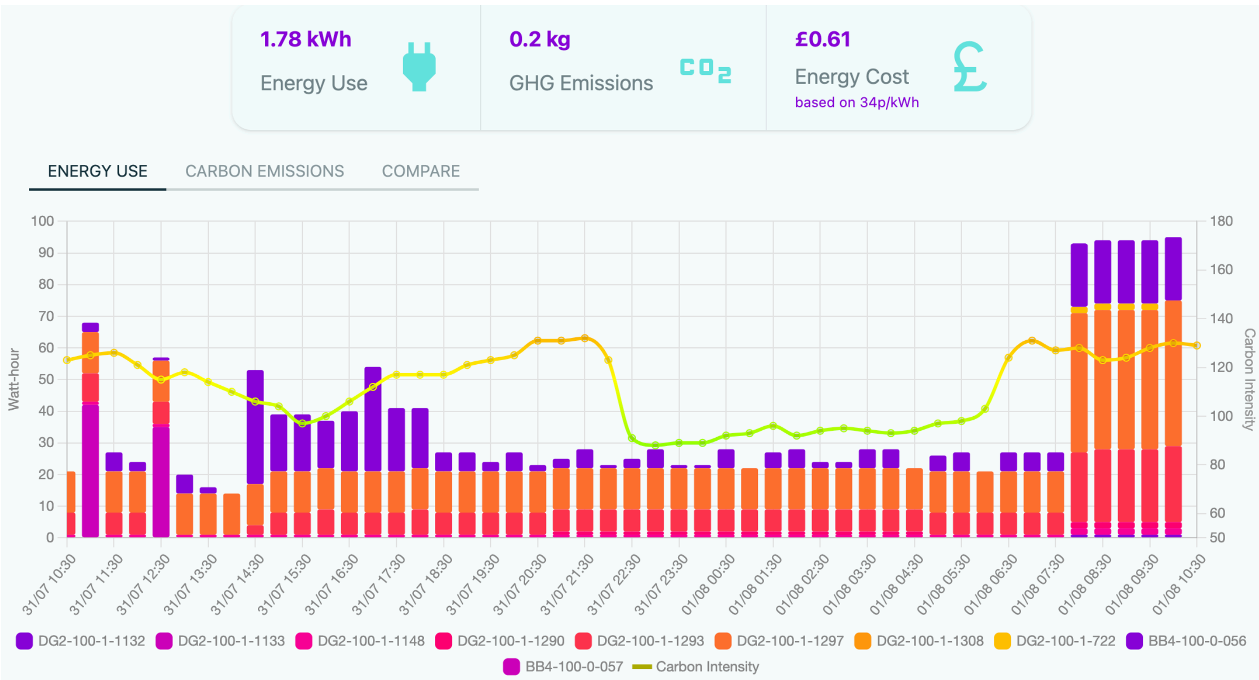


Figure 3.2: Measurable energy software reading graphical user interface

Below image (figure 3.3) shows how an intelligent measurable-energy switch board would look like:

Figure 3.3: Measurable-energy sockets

The sockets connect to your existing Wi-Fi network to operate and will still have power even if your internet goes down. They also have an inbuilt memory so that any rules that are usually applied will still work and they'll continue to monitor your energy usage.

Another feature of these sockets is that it indicates the source of power as well. This is indicated with the color of on the LED light on the switch board. Below image (figure 3.4) indicates the light source:

Figure 3.4: Measurable-energy socket light source

There are 3 colors which will indicate the source of energy. When it's green, this means your energy is mainly coming from renewable sources, like wind and solar. When it's amber, your energy is a mix of renewable and non-renewable sources, like fossil fuels (coal, natural gas and oil) and nuclear energy. When it's red, your energy is coming from non-renewable sources. The consumer is given a clear indication of the source of power if it is generated from renewable or non-renewable resources. Below table 3.6 indicates the LED status of the sockets and its associated meanings.

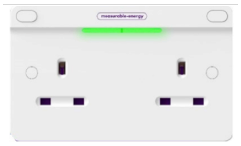
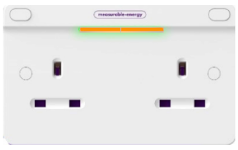
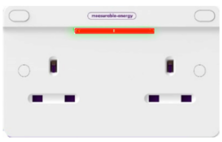
Measurable Energy - Socket LED Indication	
Socket LED Status	Description
	LED light code: Green
	Power Source: Renewable energy
	Source of power at grid: Wind or Solar
	LED light code: Amber
	Power Source: Renewable and or non-renewable energy
	Source of power at grid: Wind, Solar, Gas, Coal
	LED light code: Red
	Power Source: Non-renewable energy
	Energy: Gas or coal

Table 3.6: LED Status indication of sockets

A typical example would be that of a consumer who would like to operate the coffee machine or the printer, can decide if switching on the devices is absolutely required or not looking at the LED light code. The same applies for a dwelling which could possibly be installed with these intelligent switches allowing the consumer of the dwelling to decide if they want to run their high-power consuming device like a washing machine or a dishwasher looking at the LED light code. In addition to this feature, using the software we can populate the carbon intensity for a preferred period as well. The carbon intensity reading would depend on the type of device that is most frequently used and the power source while the device was running. As an example, if a high-power consuming device was used when the LED status was showing as red or amber, you can expect the carbon intensity to increase. National Grid Electricity System Operator (ESO), in partnership with Environmental Defense Fund Europe and WWF, has developed a series of Regional Carbon Intensity forecasts for the GB electricity system, with weather data provided by the Met Office. The national grid's carbon intensity API provides an indicative trend of carbon intensity for the electrical grid of Great Britain up to 48 hours ahead of real-time (carbonintensity, 2023). The measurable energy software has the capability to access this data and convert this into tangible information which is reflected on the graphs as indicated in figure 3.2.

Since all sockets are connected to the cloud, the sockets use a combination of hardware-based and cloud encryption which is essential for data security. The sockets are actively monitored and assessed for all security threats and encryption protocol developments, following the UK government's Code of Practice for IoT (Internet of Things) Security (Department for Digital, Culture, Media & Sport, 2018).

3.4. MEASURABLE-ENERGY SOCKET SPECIFICATION

Below table (table 3.7) show the details specification of the measurable-energy sockets used for the experiment:

Category	Description
Amp rating	13 A
Power voltage supply	100-250 V AC
Power consumption	<0.5 W
Operating temperature	-10°C to +40°C
Operating humidity	0-95% RH, no condensation
Number of earth terminals	2
Number of gangs	2
Dimensions	150 x 92 x 29.3 mm
Switched/unswitched	Switched - single pole
Screwed/screwless	Screwed
Wi-Fi support	2.4 GHz
Wi-Fi security	WPA2/WPA3 PSK
Certifications	BS1363, UKCA and CE
Guarantee	10-year guarantee for manufacturing faults and defects

Table 3.7: Measurable-energy socket specification

3.5. MEASURABLE-ENERGY SOCKET LOCATION AND UNIQUE ID

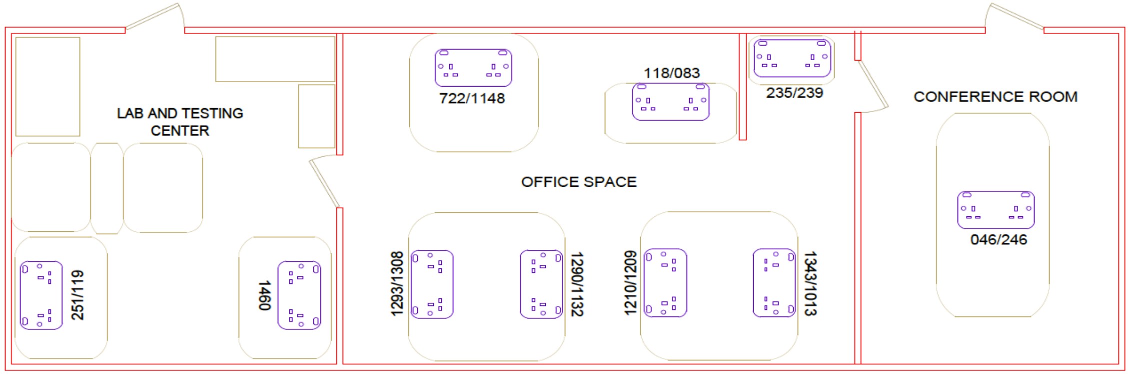
The office facility where the experiment was conducted has these intelligent sockets located in strategic locations to provide connectivity to all devices listed section 3.2.1/3.2.2/3.2.3. Below shown layout (Figure 3.5) indicates the location of sockets. Each socket points have a unique ID for reference purposes which is indicated in the drawing as well.

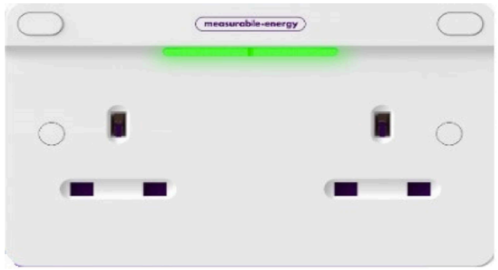
One very important point to be noted in this experiment is that none of the heating or cooling or building services other than those mentioned in section 4.1.1/4.1.2/4.1.3 are monitored or connected to the sockets.

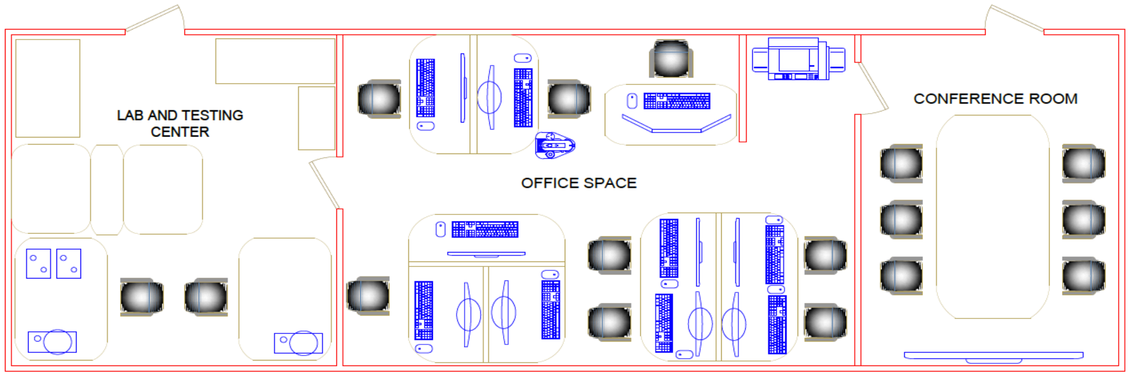
Below table (Table 3.8) indicates the unique ID number of individual sockets located across the office layout as pictorially indicated in figure 3.

Measurable Energy - Socket Details			
Lab Test Centre		**Office space**	
Socket Number	Category	Socket Number	Category
251	Group 1	722	Group 2
119	Group 1	1148	Group 2
1460	Group 2	1293	Group 2
		1308	Group 2
Conference room		235	Group 2
Socket Number	Category	239	Group 2
46	Group 1	1210	Group 1
246	Group 1	1209	Group 1
Office Space		1013	Group 1
Socket Number	Category	1343	Group 1
118	Group 1	1290	Group 2
83	Group 1	1132	Group 2

Table 3.8: Measurable-energy socket unique ID and category







Lab Space		Office Space			
Soicket Number	Status	Soicket Number	Status	Soicket Number	Status
251	Staging	722	Live	1290	Live
119	Staging	1148	Live	1132	Live
1460	Live	1293	Live	118	Staging
		1308	Live	83	Staging

Printer & Office		Conference Room	
Soicket Number	Status	Soicket Number	Status
235	Live	46	Staging
239	Live	246	Staging
1210	Staging		
1209	Staging		
1013	Staging		
1343	Staging		

Rev.	DATE	DRAWN	CHECKED	DESCRIPTION STATUS

PROJECT NAME:
MEASURABLE ENERGY OFFICE,
FOUNTAIN BUILDING, READING,
UNITED KINGDOM

CLIENT
University of Reading

SHOP DRAWINGS

DRAWING TITLE :
MEASURABLE ENERGY OFFICE
ELECTRICAL SOCKET LAYOUT

ISSUED FOR	DATE	SHEET SIZE	REVISION
APPROVAL	23.07.2023	A1	00
DRAWING NO.	002		

Figure 3.5: Measure-energy socket location and unique ID

3.6. EXPERIMENT RULES AND TIME FRAME

The experiment was conducted in 2 phases, which is referred to as “scenarios” in this report. The data was collected for scenario 1 and scenario 2 separately and compared to understand the delta in power consumption and carbon intensity. Below sections 3.6.1 and 3.6.2 will indicates the rules applied to scenario 1 and scenario 2 respectively.

3.6.1. SCENARIO 1 – AUTOMATION OFF - RULES AND DURATION

The aim of scenario 1 is to replicate how a convention switch board would work in a normal office or dwelling set up. To make this happen, one rule was provided that the switch will be always “ON” including weekdays and weekend. This would mean that all automation is OFF for the complete duration of test phase of scenario 1. Scenario 1 rule setting was assigned, and test phase started on 25May2023 at 12.30 PM for a period of 2 weeks. The scenario 1 test phase ended on the 08June 2023 at 12.30 PM. Below figure (Figure 3.6) shows the rule (Always ON) set on the software which was assigned to all switch ID’s.

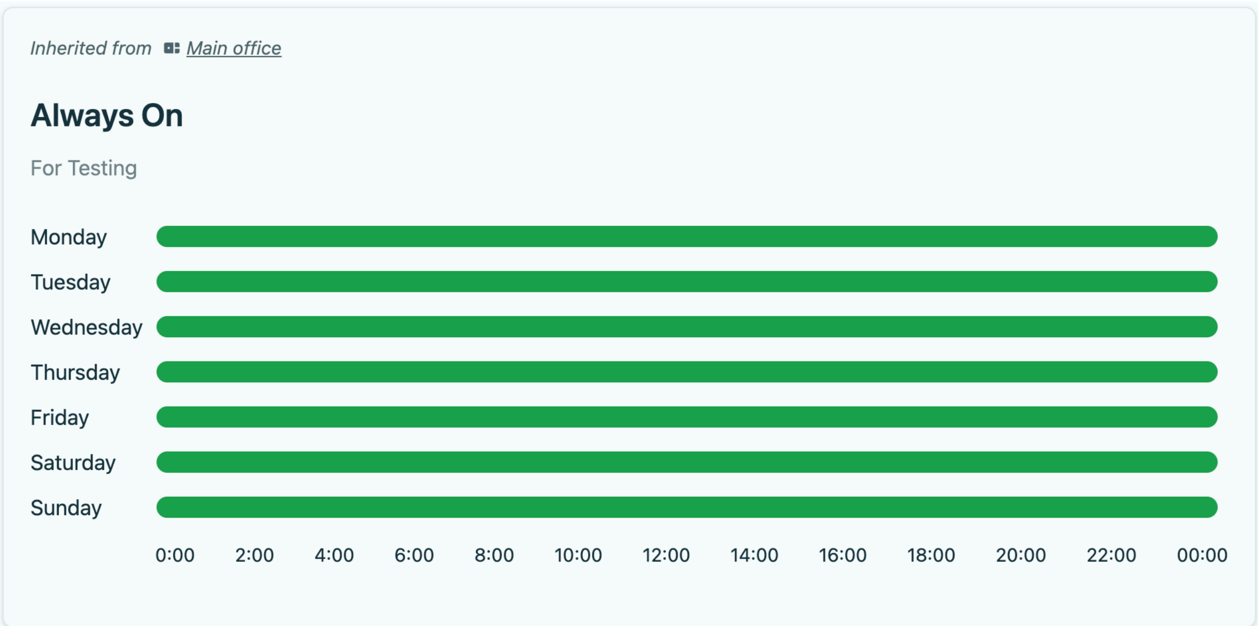


Figure 3.6: Scenario 1 rule – automation OFF – 25May2023 to 08June2023

This scenario replicates the switch status that is currently been done in majority of the offices, commercial building and even dwellings. In this scenario, the power drawn when the office is functional should be identical or close to power drawn during in scenario 2. Although the major difference can be identified during non-operational hours where all equipment is off or in standby mode will continue to draw passive power even when these devices are not in use. This passive power drawn will have impact on total power demand and carbon intensity. This comparison will be done in detail in section 5 – results and critical discussion.

3.6.2. SCENARIO 2 – AUTOMATION ON - RULES AND DURATION

For scenario 2, the real features of measurable-energy intelligent switch boards are put to use. A total of 3 rules and an instruction was provided for this test phase. Scenario 2 assigning, and rules and test phase started on the 08June2023 12.40 PM and the same was concluded on the 22June2023 12.40 PM.

The first rule applied was that all switch board will be fully OFF during weekends (Saturday and Sunday) for the duration mentioned above. This would mean that during weekends, none of the devices would be able to draw any kind of passive power from the switches and hence the carbon intensity during this period would be "zero". Below image (figure 3.7) is a snapshot of the rule assigned for the weekends. During the test phase, there were 2 weekends.

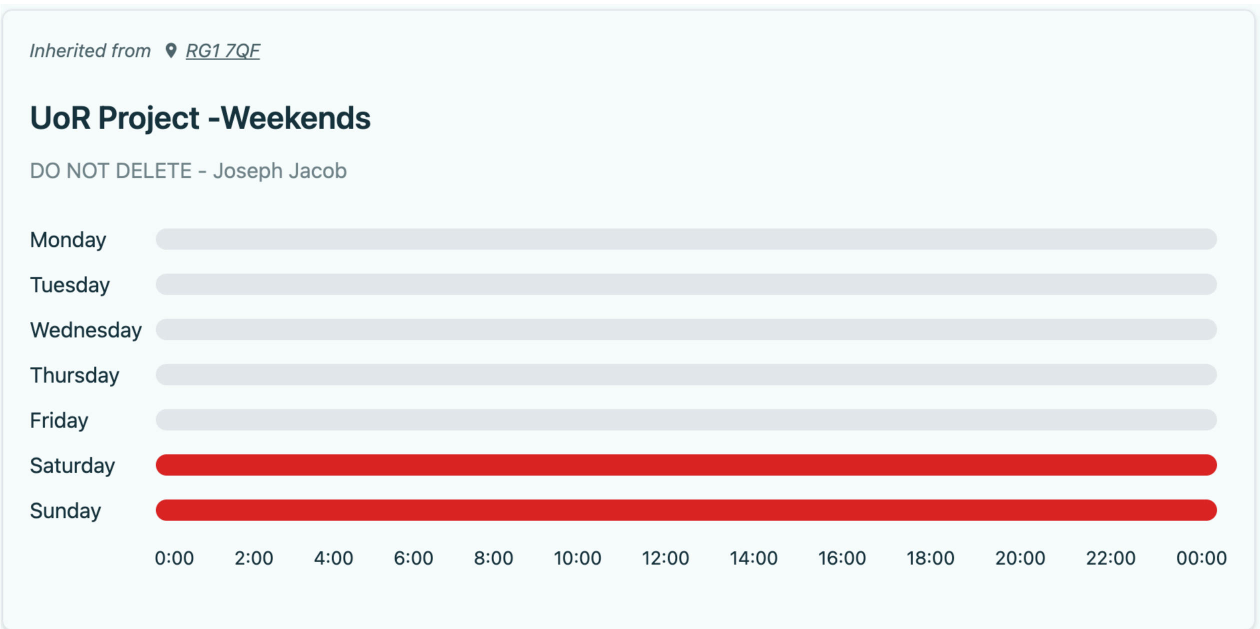


Figure 3.7: Scenario 2 – Rule 1 – Weekends always off

The second rule applied was that all switch board will be full OFF prior to office opening hours. The time period assigned was from 12 midnight to 9 AM during weekdays. Below image (Figure 3.8) is a snapshot of rule applied for prior office hours.

Figure 3.8: Scenario 2 – Rule 2 - Weekdays off – 12 midnight to 9 AM

The third rule applied was that all switch board will be full OFF during after office working hours. The period assigned was from 8 PM to 12 midnight during weekdays. Below image (Figure 3.9) is a snapshot of rule applied for after office hours.

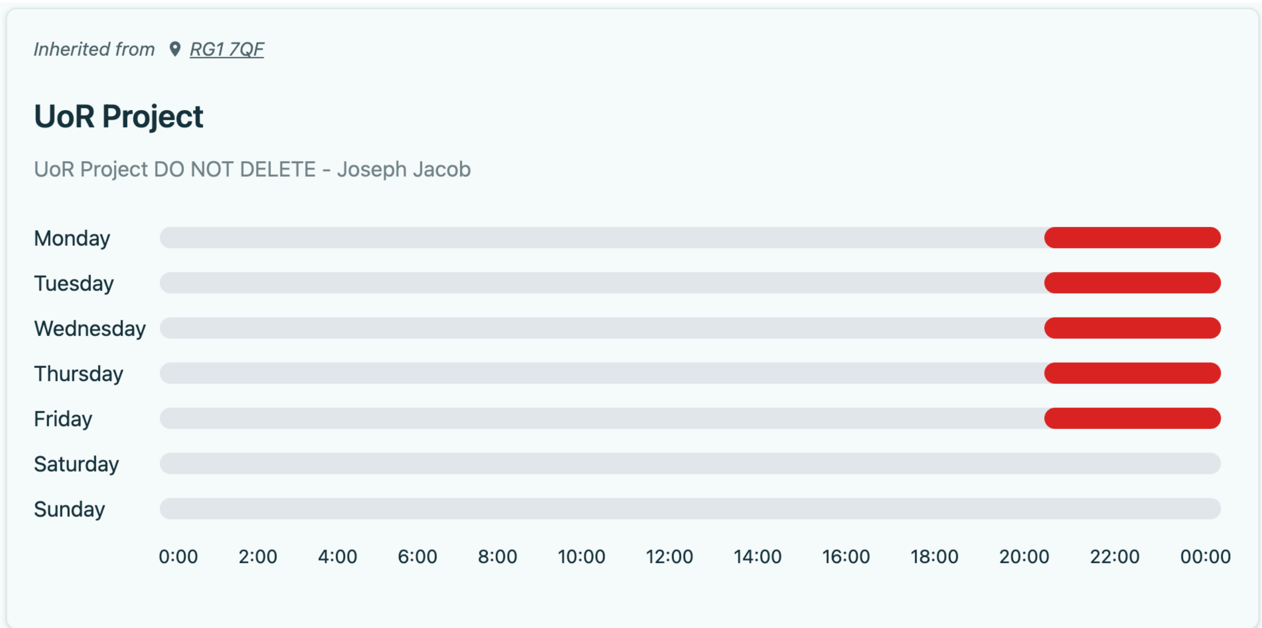


Figure 3.9: Scenario 2 – Rule 3 – Weekdays off – 8PM to 12 midnight

In addition to above mentioned rules, instruction was provided to the employees of the office to be mindful about the power source which is indicated as LED light on the face of the switch board. The employees were requested not to use inconsequential devices if the LED light on the socket indicated "red" or "amber". Although this control measure requires human intervention, it is important to spread the awareness of power source to consumers as impact of carbon intensity cumulatively could be quite substantial. The LED light code is designed to be a visual trigger for the consumer to make a conscious decision on their next action when it comes to using the device connected to the socket. In the case of this office, it could possibly be the coffee machine or the printer or the 85" flat screen monitor.

Below table (Table 3.9) is a tabular indication of rules applied for scenario 1 and 2.

Description	Scenario 1	Scenario 2
Duration	2 Weeks	2 Weeks
Experiment Timeline start	25May2023 12.30 PM	08June2023 12.40 PM
Experiment Timeline End	08June2023 12.30 PM	22June2023 12.40 PM
Weekend & Public Holiday rule	ALWAYS ON	ALWAYS OFF
Weekday rule	ALWAYS ON	OFF - 8PM to 9AM

Table 3.9: Scenario 1 & 2 – rules and duration

4. RESULTS AND ANALYSIS

Both scenarios were run for a period of 2 weeks and the results were compared. Scenario 2 showed a considerable reduction on total power consumption and carbon intensity as compared to scenario 1. In the below section, we will deep dive into individual scenario to understand the impact and the delta between both. As per table 3.8 in section 3.5, the switches were divided into 2 categories, Group 1 and live. Although both were recorded similarly, the readings were taken separately.

4.1. SCENARIO 1 – GROUP 1 CATEGORY READINGS

In the Scenario 1 – Group 1 category, the below graph (figure 4.1) indicates the power consumption and carbon intensity of Group 1 category sockets from 25May2023 12.30 PM to 08June2023 12.30PM. As per data gathered, during this period, a total power consumption of

11kWh and carbon intensity of 1.3kg was recorded. This reading should ideally replicate how a normal office floor would function. All automations are OFF which mimics how a conventional socket would operate.

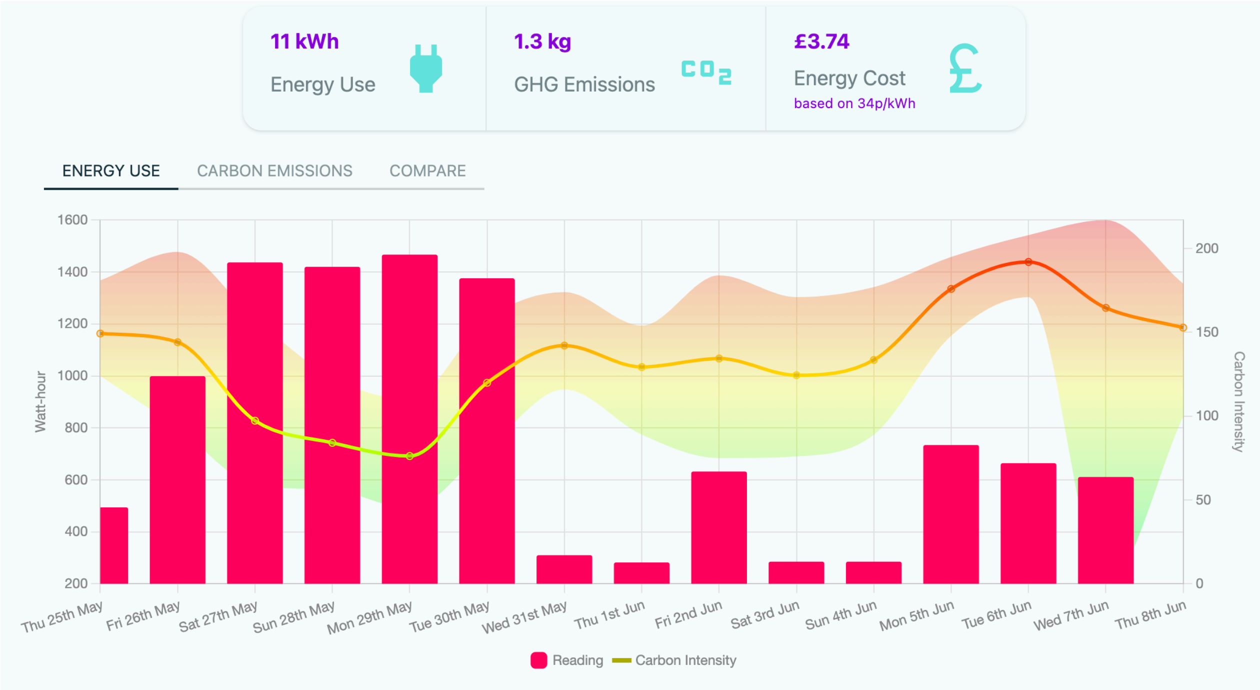


Figure 4.1: Scenario 1 – Group 1 category

Below graph (figure 4.2) is the carbon data which is isolated of the same scenario – Group 1 category. From the graph you can see that carbon intensity is recorded on 27May 2023, 28 May 2023, 03June 2023 and 04June 2023. These days are weekends, and the office is expected to be non-functional. The power consumption recorded during the weekend could be due to equipment testing happening at the lab & test centre. A special attention has to be given for 05June 2023 to 07June2023, where the power consumption dropped dramatically as compared to all other weekdays, but at the same time, the carbon intensity shot up. This is a typical example of usage of power generated from non-renewable resources which raises the carbon intensity. It can be suspected that there was very little wind or solar during these days and a possible power source could have been Natural gas or coal.

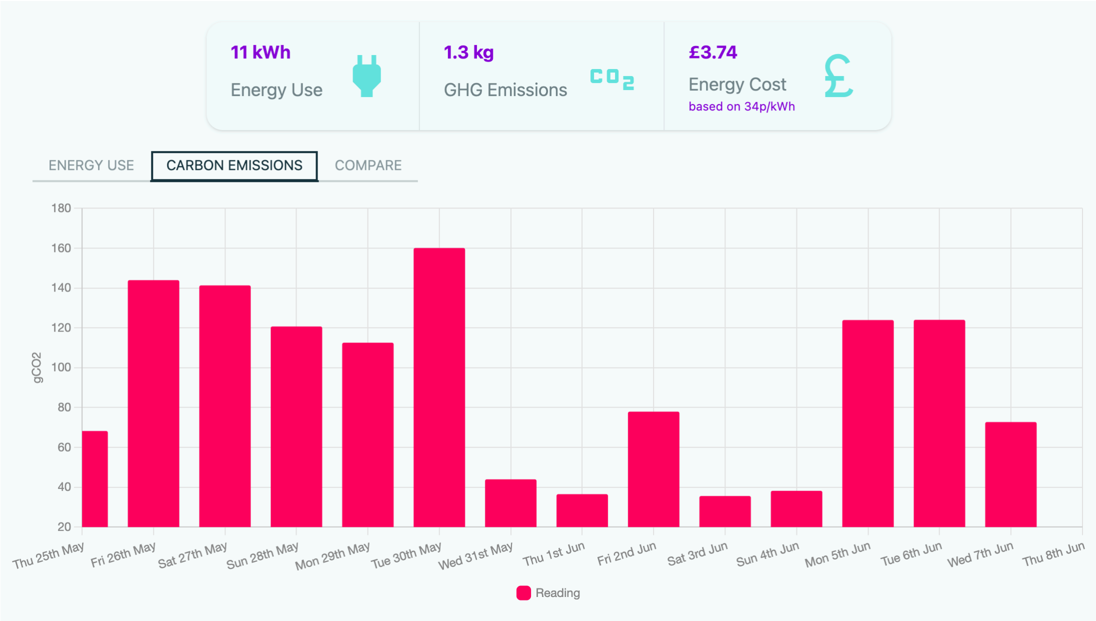


Figure 4.2: Scenario 1 Group 1 sockets – Carbon intensity isolated information

Upon investigating the energy dashboard energy mix it is quite evident that from the 05June2023 to 07June 2023, the primary source of energy was gas and hence resulting in carbon intensity even though the power consumption was comparatively low compared to other weekdays (Dashboard , 2023). Below image (figure 4.3.1) is a graphical representation of energy generation mix on 05June2023.

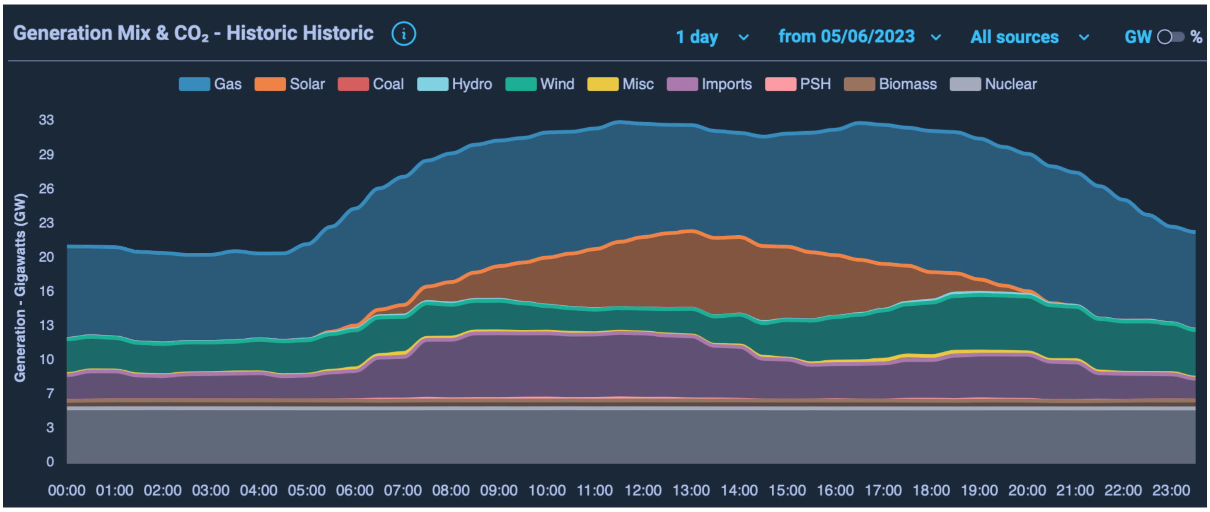


Figure 4.3.1: Energy generation mix – 05June2023

Source: https://www.energydashboard.co.uk/historical

Below image (figure 4.3.2) is a graphical representation of energy generation mix on 06June2023 which again proves that gas was the highest producer of power.

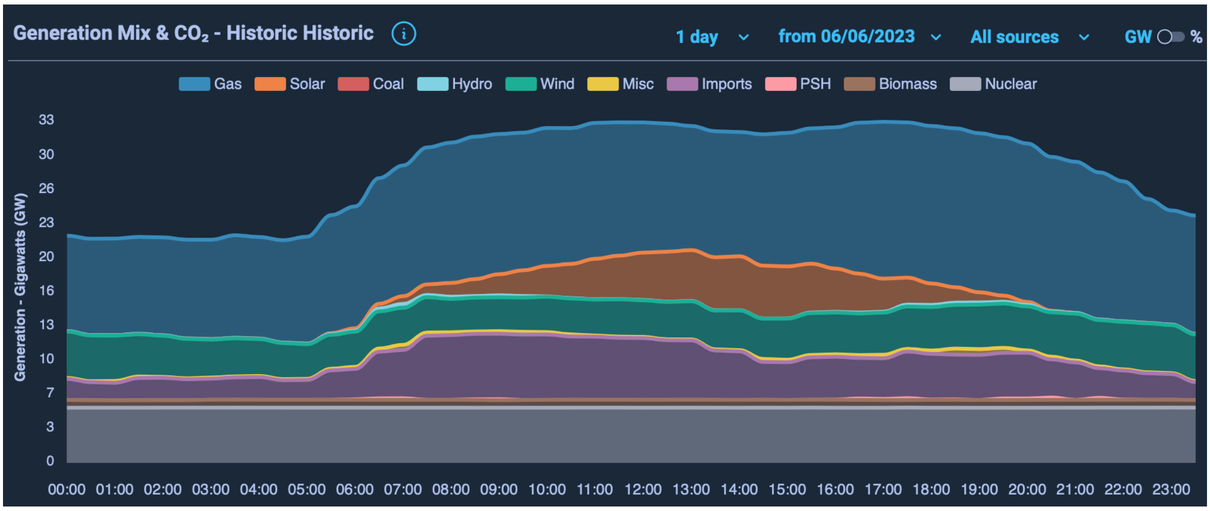


Figure 4.3.2: Energy generation mix – 06June2023

Source: https://www.energydashboard.co.uk/historical

Below image (figure 4.3.3) is a graphical representation of generation mix on the 07June2023 which again proves that gas was the highest producer of power.

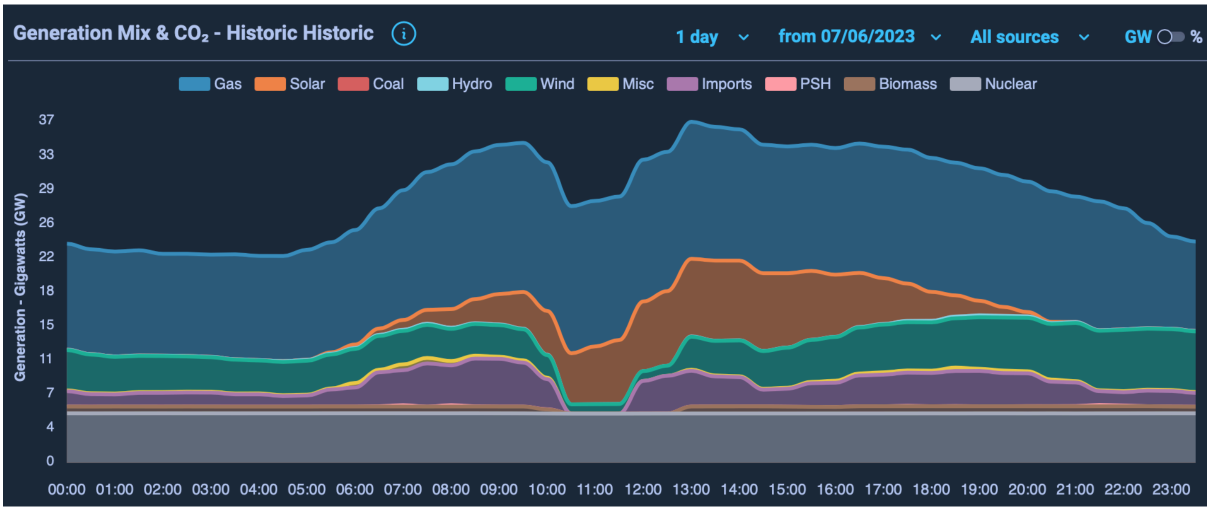


Figure 4.3.3: Energy generation mix – 07June2023

Source: https://www.energydashboard.co.uk/historical

On the contrary, on 28May2023, power consumption was higher than usual, but the carbon intensity was less compared to the week after. Upon investigating it was clear that wind and solar was the biggest contributor of power to the energy mix. Below image (figure 4.3.4) shows the graphical representation of energy generation mix for 28May2023.

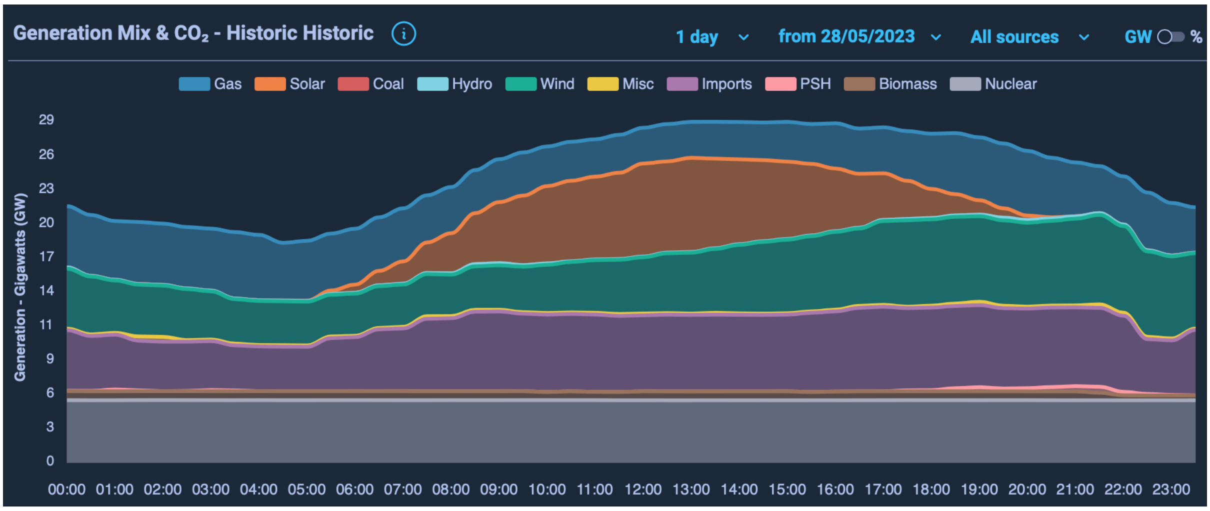


Figure 4.3.4: Energy generation mix – 28May2023

Source: https://www.energydashboard.co.uk/historical

4.2. SCENARIO 1 – GROUP 2 CATEGORY READINGS

In the Scenario 1 – Group 2 category, the below graph (figure 4.4) indicates the power consumption and carbon intensity of Group 2 category sockets from 25May2023 12.30 PM to 08Jun2023 12.30PM. As per data gathered, during this period, a total power consumption of 93.44kWh and carbon intensity of 12.7kg was recorded.

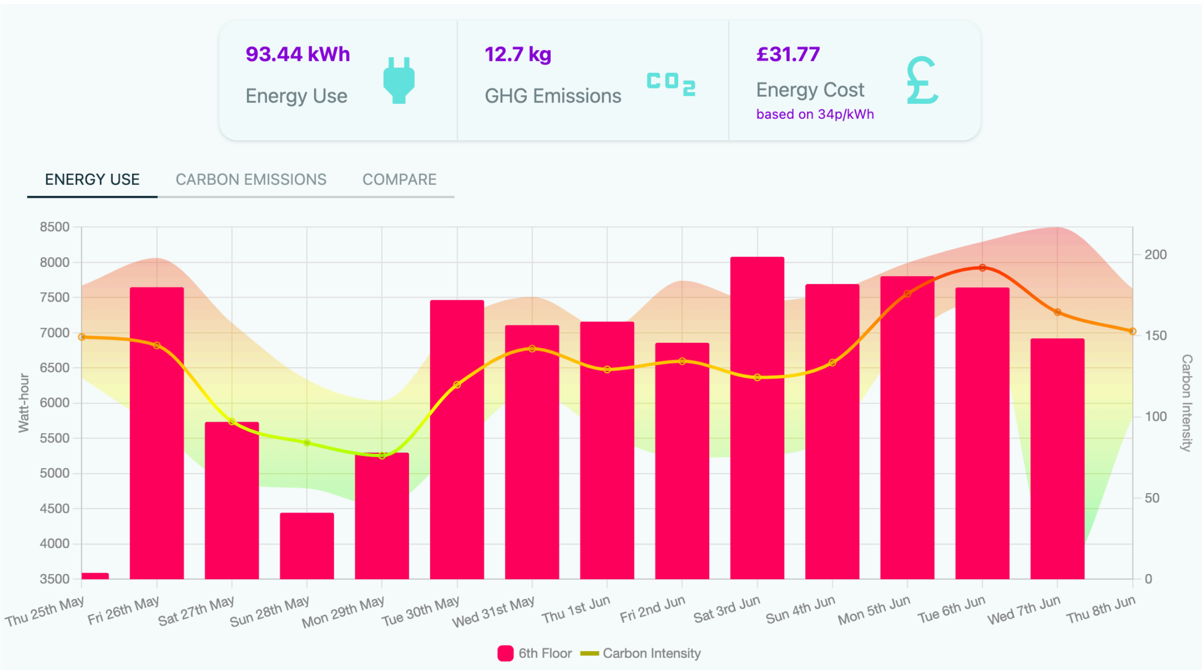


Figure 4.4: Scenario 1 – Group 2 category

Below graph (figure 4.5) is the carbon data which is isolated of the same scenario – Group 2 category. From the graph you can see that carbon intensity is recorded on the 27May2023, 28May2023, 03June2023 and 04June2023. These days are weekends, and the office is expected to be non-functional. This carbon intensity during weekends could be due to passive power drawn by the devices especially when the power source was generated using non-renewable resources.

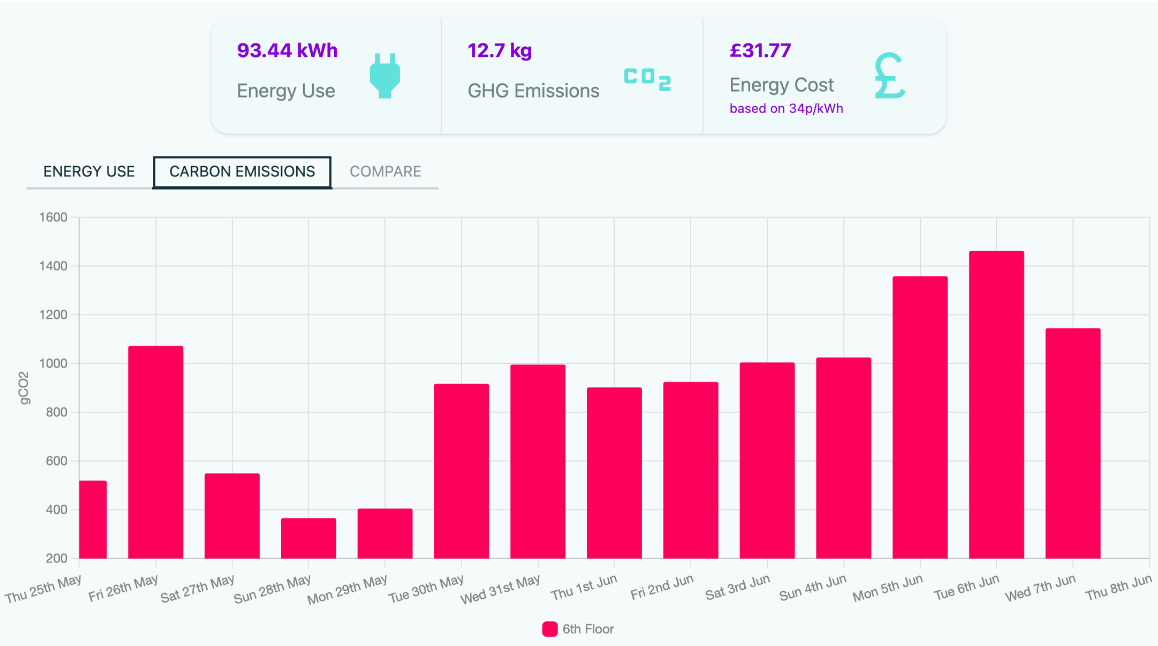


Figure 4.5: Scenario 1 Group 2 sockets – Carbon intensity isolated information

4.3. SCENARIO 2 – GROUP 1 CATEGORY READINGS

Now that we have established the power consumed and carbon intensity for scenario 1, it is time to investigate the scenario 2. Although it is vital to understand that scenario 1 is a similar situation at which majority of the offices, commercial spaces, industries, and dwellings operate. In Scenario 2, automation is turned ON. This would mean that the sockets are automatically turned off from 8PM to 9AM on weekdays and off completely during weekends. This should mean that devices are not capable of drawing any kind of power from the grid during this period.

In the Scenario 2 – Group 1 category, the below graph (figure 4.6) indicates the power consumption and carbon intensity of Group 1 category sockets from 08June 2023 12.40 PM to 22June2023 12.40PM. As per data gathered, during this period, a total power consumption of 4.39 kWh and carbon intensity of 0.8 kg was recorded.

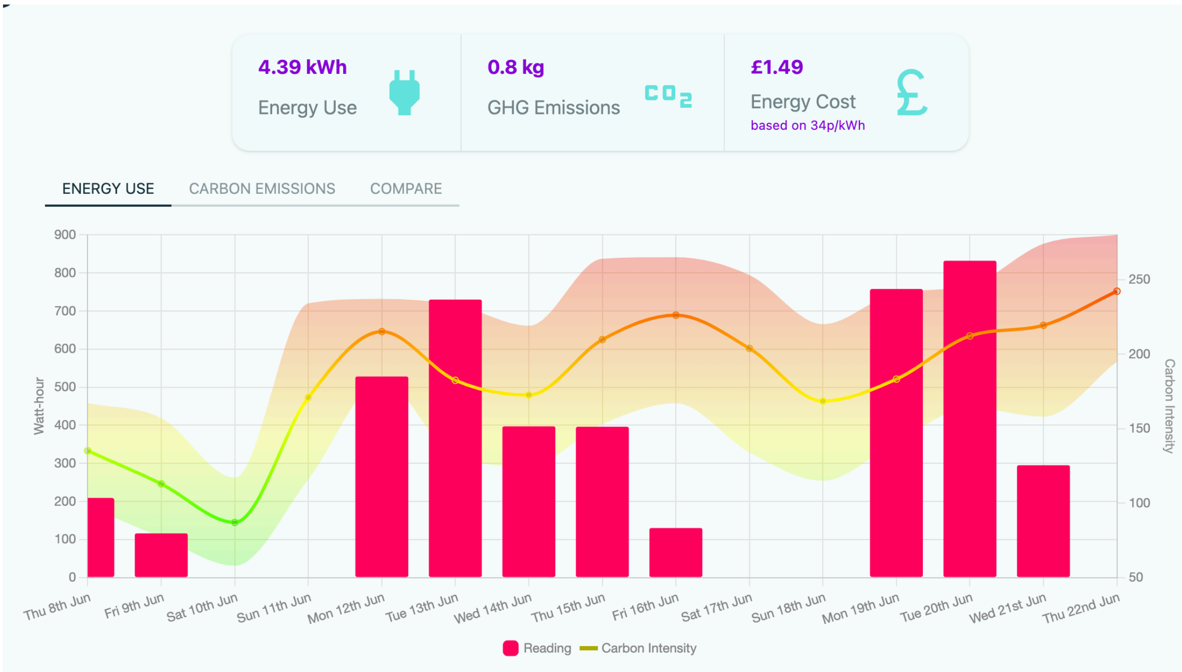


Figure 4.6: Scenario 2 – Group 1 category

Below graph (Figure 4.7) is the carbon intensity isolated information for the same scenario. The keys dates to look at are 10June2023, 11June2023, 17June2023 and 18June2023 which has a carbon intensity of "Zero" kilograms. This is clearly because the devices were not able to draw any kind of baseload or passive power from the sockets as they were programmed to be completely off during weekends. It is also good to note that the overall carbon intensity dropped dramatically as compared to scenario 1 Group 1 carbon intensity readings.

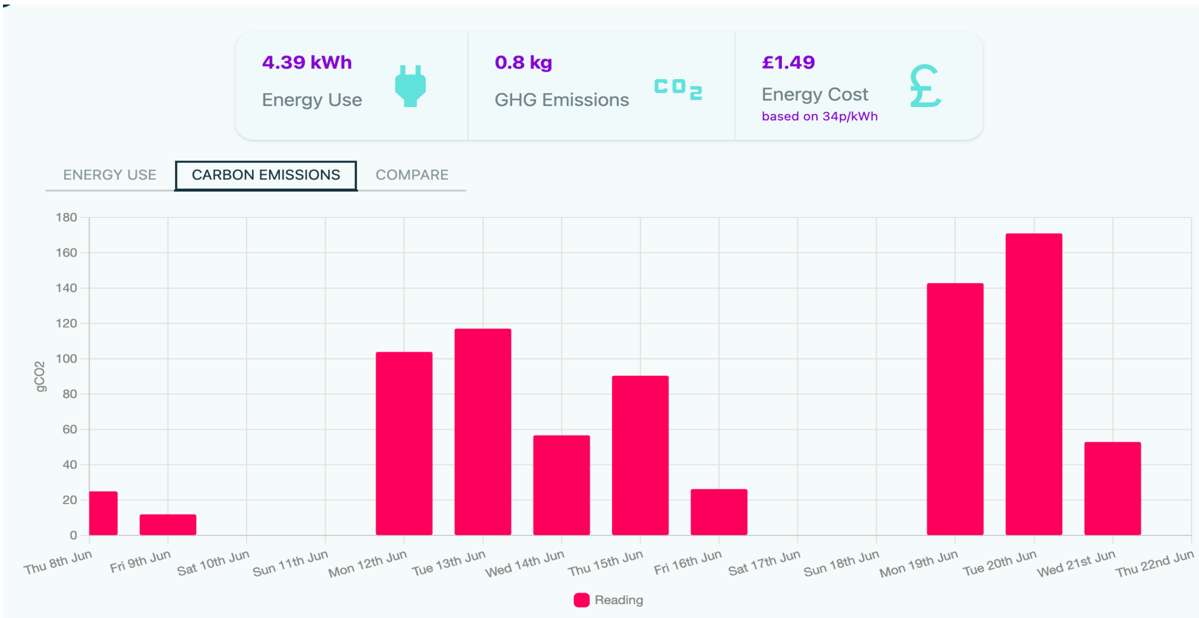


Figure 4.7: Scenario 2 Group 1 sockets – Carbon intensity isolated information

4.4. SCENARIO 2 – GROUP 2 CATEGORY READINGS

In the Scenario 2 – Group 2 category, the below graph (figure 4.8) indicates the power consumption and carbon intensity of Group 2 category sockets from 08June 2023 12.40 PM to 22June 2023 12.40PM. As per data gathered, during this period, a total power consumption of 37.09 kWh and carbon intensity of 6.5 kg was recorded.

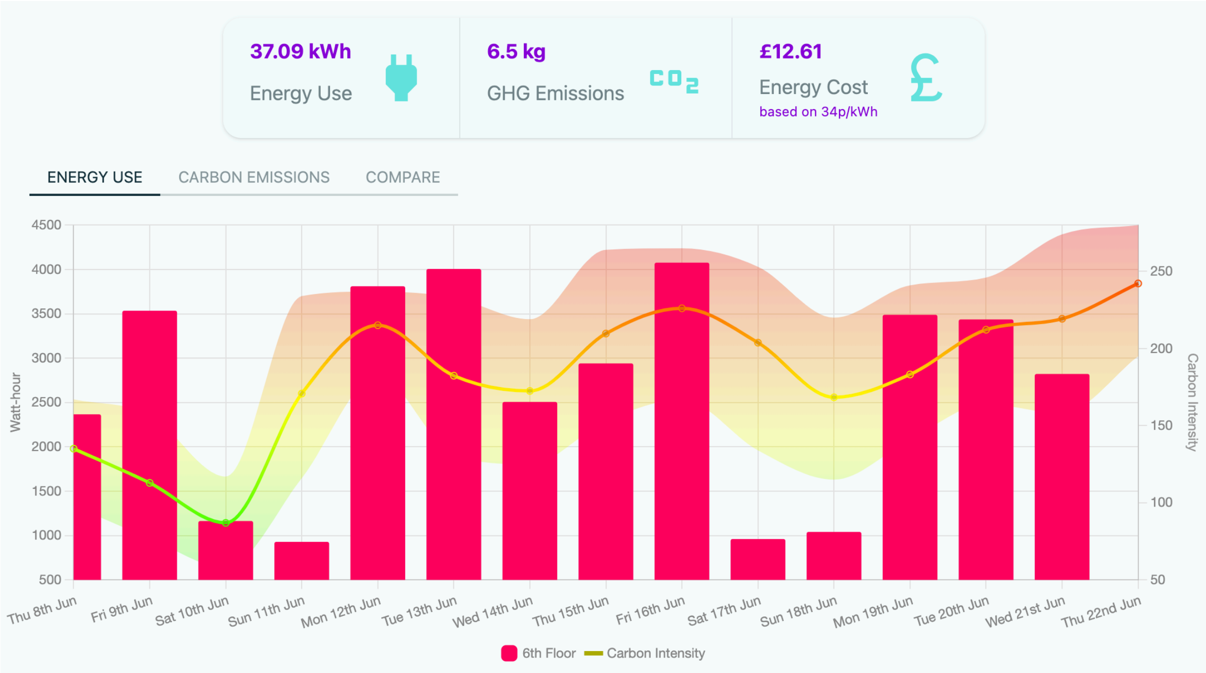


Figure 4.8: Scenario 2 – Group 2 category

Below graph (Figure 4.9) is the carbon intensity isolated information for the same scenario. The keys dates to look at are 10June2023, 11June2023, 17June2023 and 18June2023 which has a carbon intensity much lesser than scenario 1 carbon intensity reading of Group 2 category sockets. They are not "zero" like Group 1 category and a possible explanation could be that these switches were manually overridden by employees over the weekend resulting in minor readings. Due to override feature, work was not disrupted, and switches are turned on only for a period of 2 hours (unless override is initiated again).

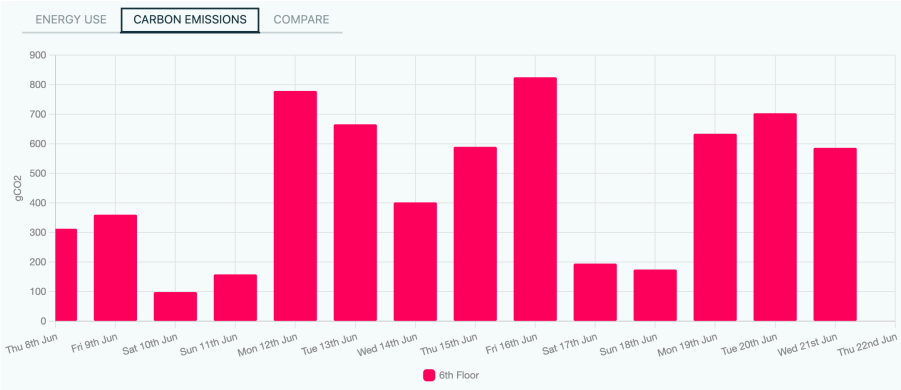


Figure 4.9: Scenario 2 Group 2sockets – Carbon intensity isolated information

4.5. CRITICAL DISCUSSION

Below table (Table 4.1) indicates the power consumption and carbon intensity readings collected from measurable energy software of scenario 1 and scenario 2 which was collected between 25May2023 and 22June2023. Scenario 1 is the part of the experiment which is meant to replicate how majority of the offices, commercial spaces, industry and dwelling operate at this present period. All sockets are programmed as Always on and automation off, which means power can be drawn from these sockets at any given time. Even if the devices are turned off or are in idle or sleep mode, they will continue to draw power which is referred to as passive power or phantom power which decides the level of what the baseload should be for that facility.

	Scenario 1		Scenario 2	
Socket Category	Group 1 Category	Group 2 Category	Group 1 Category	Group 2 Category
Start date and time	25May2023 12.30 PM		08June2023 12.40PM	
Stop date and time	08June2023 12.30 PM		22June2023 12.40PM	
Power Consumption	11 kWh	93.44 kWh	4.39 kWh	37.09 kWh
Carbon Intensity	1.3 kg	12.7 kg	0.8 kg	6.5 kg

Figure 4.1: Data collected – Scenario 1 and Scenario 2

Scenario 2 is the part of the experiment where automation without human intervention is put in place which allows power to the socket only during certain time of the day (in the case of this experiment, during office working hours). This would mean that devices connected to the socket has no option but to draw zero power from sockets (in the form of passive/phantom power) during non-functional hour of the office as the sockets are powered down using automation via measurable energy software rules or commands unless the rules are manually overridden by consumer on individual socket on need to use basis.

Scenario 2 has proven to bring down the total power consumption of the office facility. In Group 1 category, the power consumption of scenario 2 was reduced by 60.091% and the carbon intensity dropped by 38.462% as compared for scenario 1. Similarly, for Group 2 category the power consumption of scenario 2 was reduced by 60.308% and the carbon intensity dropped by 48.819% as compared for scenario 1. Due to zero or close to zero consumption of power during weekends and non-working hours of office, the baseload was regulated by eliminating the need of devices drawing passive power or phantom power from sockets. The criteria also proved to be effective when it came to carbon intensity of the office floor as well providing similar reduction results.

Below graphical representation (Figure 4.10 and Figure 4.11) indicates the difference in power consumption between scenario 1 and scenario 2 for Group 2 and Group 1 category.

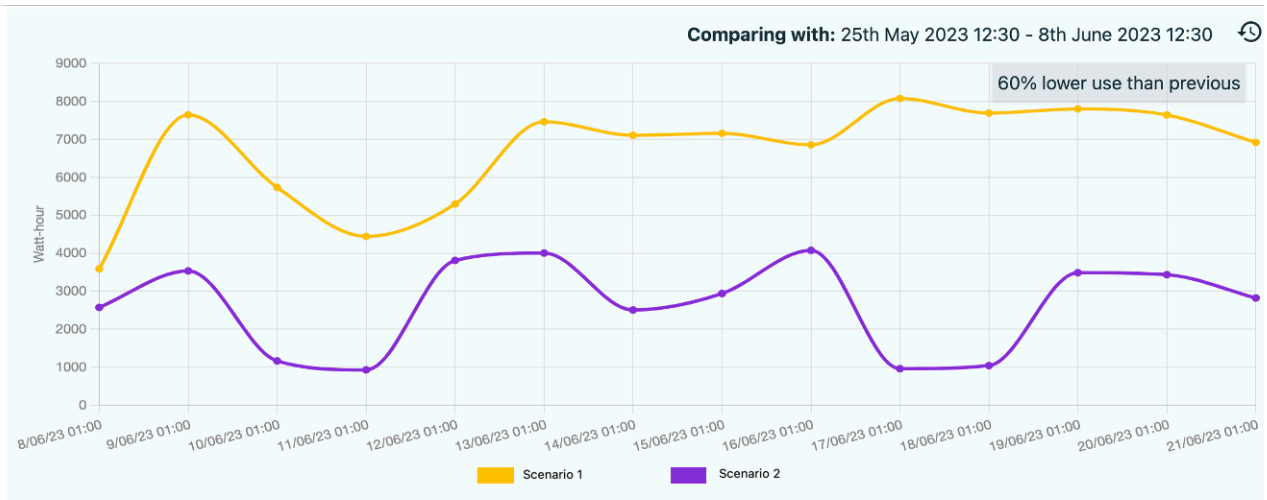


Figure 4.10: Data comparison – Group 2 category – Scenario 1 and Scenario 2

The above graph (figure 4.9) is self-explanatory as there is considerable decrease in power consumption and good reduction in baseload consumption as well.

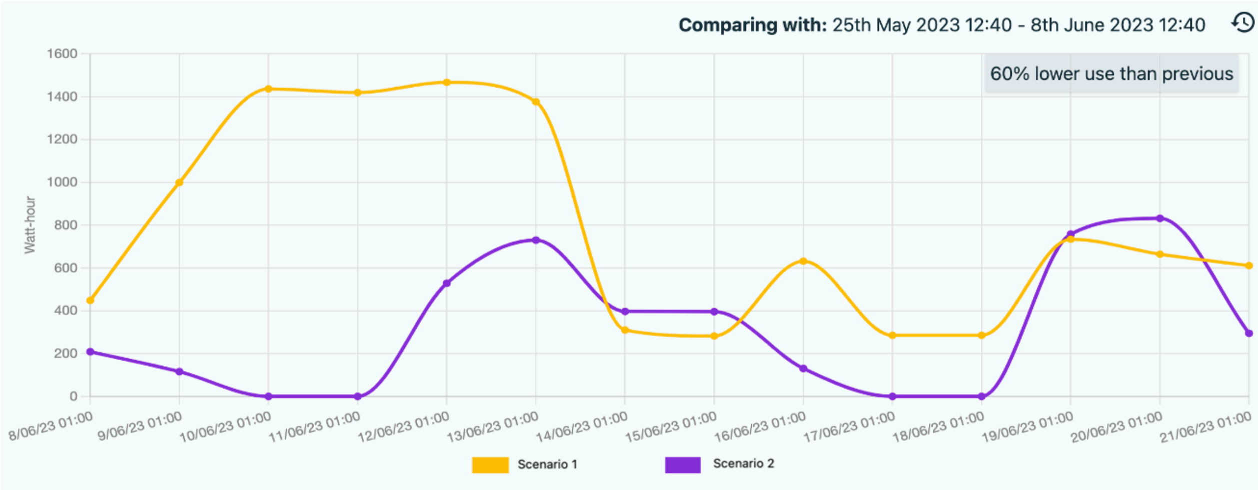


Figure 4.11: Data comparison – Group 1 category – Scenario 1 and Scenario 2

It is quite evident from the above 2 graphical representations, Scenario 2 (the purple line) has very less baseload as compared to Scenario 1 (the yellow line) in both Group 2 and Group 1 category. Although the readings are fluctuating in this scenario especially from an exact week before 09June 2023 to 12June2023. A possible explanation could be the fact that these sockets are assigned to the lab and test centre and there was continuous testing going on in scenario 1 which reflects as an unusual spike in readings. But during the second week readings, scenario 1 and scenario 2 readings are more streamlined, and consumption is low, which should mean that 2nd week of each scenario, there was very little activity happening in lab and test centre.

One key aspect to be considered is the fact that business continued as usual in the office and there was no downtime recorded. All devices were used in the same frequency as it was used for both scenarios and the only difference in scenario 2 was the fact that the need to draw passive power during non-functional hours of the office was eradicated which led to considerable savings when it came to baseload, power consumption and carbon intensity. Below image (figure 4.12 to figure 4.15) indicates the response received from employees of the office where the experiment was conducted which goes to prove that there was no impact in overall comfort of the employees or any downtime or disruption of work when automation was turned on.

Below response (figure 4.12) from questionnaire response received from employees of measurable energy indicates that all employees were aware that automation was switched on between 08June2023 and 22June2023. The complete questionnaire response can be found in appendix section 7.1.

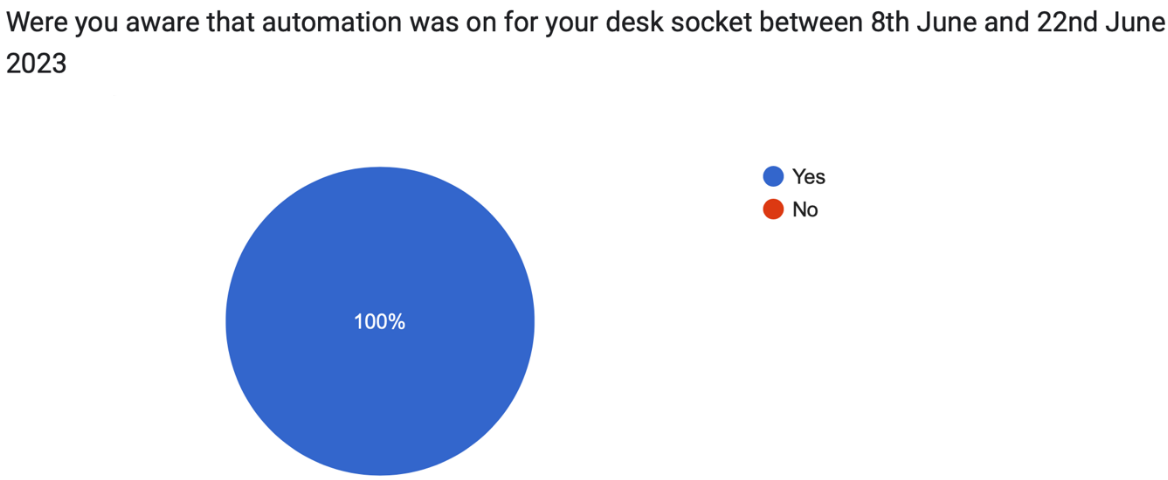


Figure 4.12: Measurable Energy employee - automation on status acknowledgement

Below response (figure 4.13) from questionnaire response received from employees of measurable energy indicates that there was no business interruption noticed when automation was turned on. This means the employee comfort levels were maintained as per their normal working conditions. There was no alteration required in their normal work routine to abide to the automation rules applied.

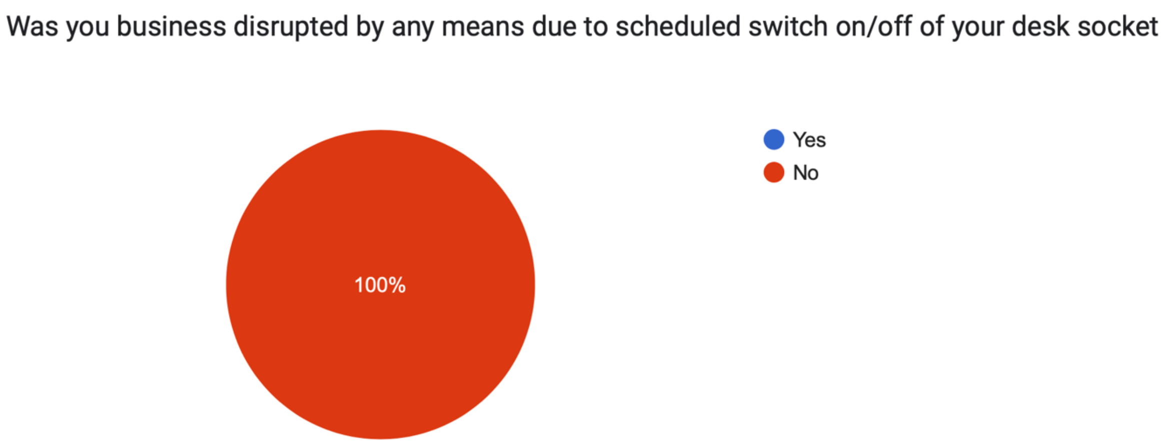


Figure 4.13: Measurable Energy – work disruption record

Below response (figure 4.14) from questionnaire response received from employees of measurable energy indicates that all employees noticed the LED light status on their assigned sockets which indicated if the source of power was coming from a renewable or non-renewable source.

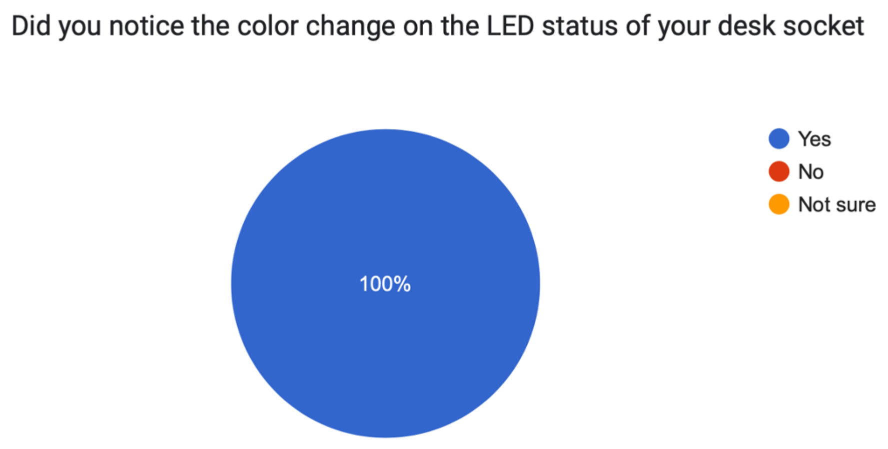


Figure 4.14: Measurable Energy employee acknowledgement of socket LED indication

Below response (figure 4.15) from questionnaire response received from employees of measurable energy indicates that 50% of the employees decided to change their course of action as the LED light indication stated that the power source was originating from a non-renewable source. This conscious effort was one of the contributions to reduction of carbon intensity. This explains the 40% reduction of carbon intensity in scenario 2 as compared to the carbon intensity recorded in scenario 1.

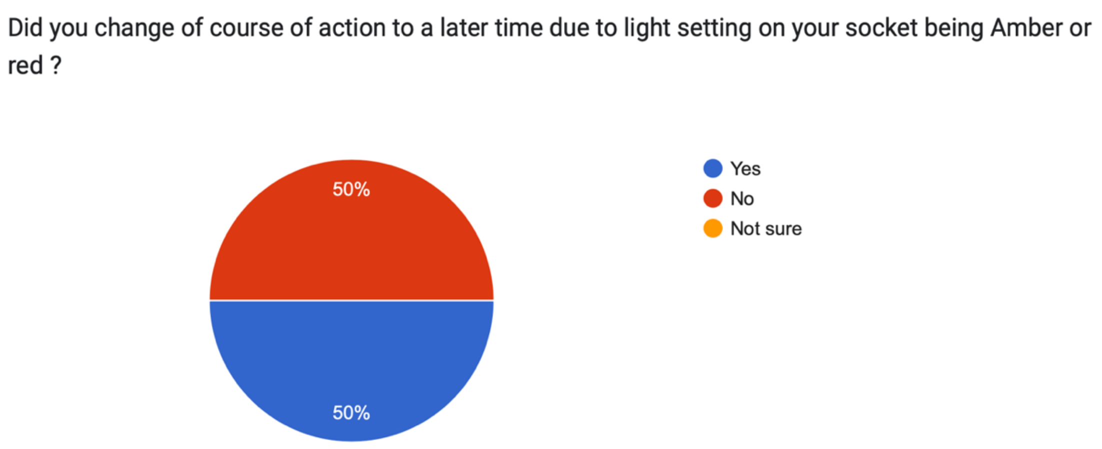


Figure 4.15: Measurable Energy employee – behaviour change acknowledgement

5. CONCLUSION & FUTURE WORKS

From the above experiment conducted and results analysed, it is evident that achieving baseload regulation using automation and avoiding human dependency to promote regulation is the right way moving forward to make sure there is no unnecessary wastage of energy and increment of carbon intensity. Above all baseload is brought to a minimum using automation. There was a saving of 60+% in power consumption recorded in the experiment conducted in an office floor with just 3 rooms. Imagine if this solution of baseload regulation using automation is replicated in a much bigger office or a commercial building, the savings recorded when it comes to power consumption and carbon intensity will be quite substantial. As per the literature review, it is quite evident that there are numerous papers and studies done which substantiates the importance of reduction of power consumption to reduce the load on the national grid. Although relying on human intervention to cut power at socket level as suggested by many papers and studies would not be the right approach as this is not reliable or consistent. In our technology driven times, where everything is linked into the IoT, we need to capitalize on this technology to make sure consumption in multiple disciplines of industries are regulated using existing infrastructure and automation. As this experiment has never been attempted before (or at the least not documented), this experiment should be considered as a pilot phase and should be used as a baseline. While today's attention has been diverted towards renewable energy generation and energy storage options to cater to future spike in energy demand, I strongly feel equal importance should be given to the crux of the problem, which is energy wastage and unnecessary increase of baseload due to passive or phantom power demand originating from ever growing devices in any infrastructure. Necessary steps are to be taken into consideration to make sure baseload regulation is given as much importance as all other initiatives that are being pursued by stakeholders.

5.1. LIMITATIONS

Although the experiment provided the desired results, being a pilot phase, there are some limitations which had to be considered as mentioned below:

- The duration of the experiment for each phase had to brought down to 2 weeks each due to time constraint. This means total experiment readings were collected over a period of 4 weeks.
- We had to assume that the work pattern and intensity of devices used during the period of the experiment was same for apple-to-apple comparison. If actual work pattern was studied in detail, we would have noticed that there were minor differences in work patterns in scenario 1 and scenario 2 of the project.
- 4 weeks data collected would not give an accurate estimate for annual prediction, hence annual prediction is not considered for this pilot phase experiment.
- The office layout is small and the number of devices in the office is minimal. This does not affect the final result, but a bigger office with lot more devices connected should have provided a more substantial report.
- The readings collected are limited to electronic devices connected to the intelligent sockets. None of the lighting or HVAC devices are considered in this report even though they are one of the major contributors towards power consumption.

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7. APPENDIX

7.1. EMPLOYEE SURVEY REPORT

Timestamp	Were you aware that automation was on for your desk socket between 8th June and 22nd June 2023	Did the software give you notification prior to socket switching off its power	Was your business disrupted by any means due to scheduled switch on/off of your desk socket	Did you notice the color change on the LED status of your desk socket	Did you change of course of action to a later time due to light setting on your socket being Amber or red ?
2023/07/27 06:18:17 PM GMT+1	Yes	No	No	Yes	Yes
2023/07/28 11:27:02 AM GMT+1	Yes	Not sure	No	Yes	Yes
2023/07/28 12:07:13 PM GMT+1	Yes	No	No	Yes	No
2023/07/28 01:22:13 PM GMT+1	Yes	No	No	Yes	No
2023/07/28 01:23:02 PM GMT+1	Yes	No	No	Yes	No
2023/07/28 01:23:23 PM GMT+1	Yes	Not sure	No	Yes	Yes
2023/07/28 02:27:09 PM GMT+1	Yes	No	No	Yes	No
2023/07/28 06:34:45 PM GMT+1	Yes	No	No	Yes	Yes
2023/07/30 10:15:23 PM GMT+1	Yes	No	No	Yes	No
2023/07/30 10:15:23 PM GMT+1	Yes	No	No	Yes	Yes
2023/07/31 10:24:40 AM GMT+1	Yes	No	No	Yes	No
2023/07/31 5:20:39 PM GMT+1	Yes	No	No	Yes	No
2023/08/01 10:03:22 AM GMT+1	Yes	Not sure	No	Yes	Yes
2023/08/01 10:25:14 AM GMT+1	Yes	Not sure	No	Yes	Yes
2023/08/01 10:37:12 AM GMT+1	Yes	No	No	Yes	No
2023/08/01 11:00:17 AM GMT+1	Yes	No	No	Yes	Yes

7.2. REPORT GENERATED – MEASURABLE ENERGY SOFTWARE

Device ID	Reading date and time	Energy Use (Wh)	Device ID	Reading date and time	Energy Use (Wh)
dev_0CDC7E3D08B4	2023-05-26 17:00:00.000 +0100	2.11111E-05	dev_0CDC7E3D08B4	2023-05-30 13:00:00.000 +0100	10.22938056
dev_0CDC7E3D08B4	2023-05-27 18:00:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-05-30 13:30:00.000 +0100	1.01487E+01
dev_0CDC7E3D08B4	2023-05-28 08:00:00.000 +0100	2.11111E-05	dev_0CDC7E3D08B4	2023-05-30 14:00:00.000 +0100	7.830353611
dev_0CDC7E3D08B4	2023-05-30 10:30:00.000 +0100	8.411638333	dev_0CDC7E3D08B4	2023-05-30 14:30:00.000 +0100	1.659273056
dev_0CDC7E3D08B4	2023-05-30 11:00:00.000 +0100	13.75961194	dev_0CDC7E3D08B4	2023-05-30 15:00:00.000 +0100	8.595985833
dev_0CDC7E3D08B4	2023-05-30 11:30:00.000 +0100	13.69245944	dev_0CDC7E3D08B4	2023-05-30 15:30:00.000 +0100	19.81586111
dev_0CDC7E3D08B4	2023-05-30 12:00:00.000 +0100	13.65983	dev_0CDC7E3D08B4	2023-05-30 16:00:00.000 +0100	19.51911639
dev_0CDC7E3D08B4	2023-05-30 12:30:00.000 +0100	13.6646325	dev_0CDC7E3D08B4	2023-05-30 16:30:00.000 +0100	10.63853472
dev_0CDC7E3D08B4	2023-05-30 13:00:00.000 +0100	13.67316639	dev_0CDC7E3D08B4	2023-05-30 17:00:00.000 +0100	9.626585556
dev_0CDC7E3D08B4	2023-05-30 13:30:00.000 +0100	13.65992556	dev_0CDC7E3D08B4	2023-05-30 17:30:00.000 +0100	6.554056389
dev_0CDC7E3D08B4	2023-05-30 14:00:00.000 +0100	13.636785	dev_0CDC7E3D08B4	2023-06-03 09:00:00.000 +0100	1.05556E-05
dev_0CDC7E3D08B4	2023-05-30 14:30:00.000 +0100	0.901615556	dev_0CDC7E3D08B4	2023-06-06 08:30:00.000 +0100	1.05556E-05
dev_0CDC7E3D08B4	2023-05-30 15:00:00.000 +0100	13.69798194	dev_0CDC7E3D08B4	2023-06-07 09:00:00.000 +0100	0.000377222
dev_0CDC7E3D08B4	2023-05-30 15:30:00.000 +0100	13.6894475	dev_0CDC7E3D08B4	2023-06-07 09:30:00.000 +0100	14.15607417
dev_0CDC7E3D08B4	2023-05-30 16:00:00.000 +0100	13.69899528	dev_0CDC7E3D08B4	2023-06-07 10:00:00.000 +0100	13.28415139
dev_0CDC7E3D08B4	2023-05-30 16:30:00.000 +0100	13.70544333	dev_0CDC7E3D08B4	2023-06-07 10:30:00.000 +0100	10.64173333
dev_0CDC7E3D08B4	2023-05-30 17:00:00.000 +0100	13.63311444	dev_0CDC7E3D08B4	2023-06-07 11:00:00.000 +0100	6.124324167
dev_0CDC7E3D08B4	2023-05-30 17:30:00.000 +0100	10.34325083	dev_0CDC7E3D08B4	2023-06-07 11:30:00.000 +0100	14.40783111
dev_0CDC7E3D08B4	2023-06-01 07:00:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-07 12:00:00.000 +0100	0.349232778
dev_0CDC7E3D08B4	2023-06-03 09:00:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-07 12:30:00.000 +0100	8.076985833
dev_0CDC7E3D08B4	2023-06-07 09:00:00.000 +0100	0.134225833	dev_0CDC7E3D08B4	2023-06-07 13:00:00.000 +0100	5.444097778
dev_0CDC7E3D08B4	2023-06-07 09:30:00.000 +0100	8.263130833	dev_0CDC7E3D08B4	2023-06-07 13:30:00.000 +0100	5.170489722
dev_0CDC7E3D08B4	2023-06-07 10:00:00.000 +0100	13.70941472	dev_0CDC7E3D08B4	2023-06-07 14:00:00.000 +0100	5.023093056
dev_0CDC7E3D08B4	2023-06-07 10:30:00.000 +0100	18.20896222	dev_0CDC7E3D08B4	2023-06-07 14:30:00.000 +0100	5.245112222
dev_0CDC7E3D08B4	2023-06-07 11:00:00.000 +0100	9.148474444	dev_0CDC7E3D08B4	2023-06-07 15:00:00.000 +0100	5.078485278
dev_0CDC7E3D08B4	2023-06-07 11:30:00.000 +0100	19.11457694	dev_0CDC7E3D08B4	2023-06-07 15:30:00.000 +0100	0.625243056
dev_0CDC7E3D08B4	2023-06-07 12:30:00.000 +0100	12.95403222	dev_0CDC7E3D08B4	2023-06-08 12:30:00.000 +0100	6.47222E-05
dev_0CDC7E3D08B4	2023-06-07 13:00:00.000 +0100	2.504261667	dev_0CDC7E3D08B4	2023-06-09 09:00:00.000 +0100	0.000129444
dev_0CDC7E3D08B4	2023-06-07 15:30:00.000 +0100	2.138567778	dev_0CDC7E3D08B4	2023-06-12 09:00:00.000 +0100	0.001348056
dev_0CDC7E3D08B4	2023-06-08 12:30:00.000 +0100	2.191580278	dev_0CDC7E3D08B4	2023-06-12 13:30:00.000 +0100	1.05556E-05
dev_0CDC7E3D08B4	2023-06-09 09:00:00.000 +0100	2.190824444	dev_0CDC7E3D08B4	2023-06-13 09:00:00.000 +0100	0.000129167
dev_0CDC7E3D08B4	2023-06-12 09:00:00.000 +0100	2.192424722	dev_0CDC7E3D08B4	2023-06-14 08:30:00.000 +0100	0.000442222
dev_0CDC7E3D08B4	2023-06-13 09:00:00.000 +0100	2.190251111	dev_0CDC7E3D08B4	2023-06-14 10:30:00.000 +0100	6.740434444
dev_0CDC7E3D08B4	2023-06-14 08:30:00.000 +0100	0.009059722	dev_0CDC7E3D08B4	2023-06-14 11:00:00.000 +0100	6.705074167
dev_0CDC7E3D08B4	2023-06-14 09:00:00.000 +0100	2.183833611	dev_0CDC7E3D08B4	2023-06-14 11:30:00.000 +0100	7.7642125

Device ID	Reading date and time	Energy Use (Wh)	Device ID	Reading date and time	Energy Use (Wh)
dev_0CDC7E3D08B4	2023-06-14 10:30:00.000 +0100	6.278332778	dev_0CDC7E3D08B4	2023-06-14 12:00:00.000 +0100	7.736735556
dev_0CDC7E3D08B4	2023-06-14 11:00:00.000 +0100	13.68232778	dev_0CDC7E3D08B4	2023-06-14 12:30:00.000 +0100	7.458988333
dev_0CDC7E3D08B4	2023-06-14 11:30:00.000 +0100	13.56752639	dev_0CDC7E3D08B4	2023-06-14 13:00:00.000 +0100	7.859125833
dev_0CDC7E3D08B4	2023-06-14 12:00:00.000 +0100	13.73819972	dev_0CDC7E3D08B4	2023-06-14 13:30:00.000 +0100	7.898309444
dev_0CDC7E3D08B4	2023-06-14 12:30:00.000 +0100	13.68155444	dev_0CDC7E3D08B4	2023-06-14 14:00:00.000 +0100	9.282286667
dev_0CDC7E3D08B4	2023-06-14 13:00:00.000 +0100	13.70125528	dev_0CDC7E3D08B4	2023-06-14 14:30:00.000 +0100	13.20527389
dev_0CDC7E3D08B4	2023-06-14 13:30:00.000 +0100	13.66816778	dev_0CDC7E3D08B4	2023-06-14 15:00:00.000 +0100	21.39948083
dev_0CDC7E3D08B4	2023-06-14 14:00:00.000 +0100	13.75144111	dev_0CDC7E3D08B4	2023-06-14 15:30:00.000 +0100	20.78590944
dev_0CDC7E3D08B4	2023-06-14 14:30:00.000 +0100	13.66061639	dev_0CDC7E3D08B4	2023-06-14 16:00:00.000 +0100	11.49633
dev_0CDC7E3D08B4	2023-06-14 15:00:00.000 +0100	13.72135806	dev_0CDC7E3D08B4	2023-06-14 16:30:00.000 +0100	7.4662325
dev_0CDC7E3D08B4	2023-06-14 15:30:00.000 +0100	13.65430667	dev_0CDC7E3D08B4	2023-06-14 17:00:00.000 +0100	7.728696944
dev_0CDC7E3D08B4	2023-06-14 16:00:00.000 +0100	13.7167875	dev_0CDC7E3D08B4	2023-06-14 17:30:00.000 +0100	3.02946
dev_0CDC7E3D08B4	2023-06-14 16:30:00.000 +0100	13.66823167	dev_0CDC7E3D08B4	2023-06-15 08:30:00.000 +0100	0.000474167
dev_0CDC7E3D08B4	2023-06-14 17:00:00.000 +0100	13.77646333	dev_0CDC7E3D08B4	2023-06-15 12:30:00.000 +0100	2.11111E-05
dev_0CDC7E3D08B4	2023-06-14 17:30:00.000 +0100	6.128211389	dev_0CDC7E3D08B4	2023-06-15 13:00:00.000 +0100	8.44444E-05
dev_0CDC7E3D08B4	2023-06-15 08:30:00.000 +0100	0.002771667	dev_0CDC7E3D08B4	2023-06-16 09:00:00.000 +0100	0.000485278
dev_0CDC7E3D08B4	2023-06-20 09:00:00.000 +0100	7.52778E-05	dev_0CDC7E3D08B4	2023-06-19 08:30:00.000 +0100	0.001337222
dev_0CDC7E3D08B4	2023-06-22 12:00:00.000 +0100	7.52778E-05	dev_0CDC7E3D08B4	2023-06-19 11:00:00.000 +0100	19.03106083
dev_0CDC7E3D08B4	2023-06-23 08:30:00.000 +0100	2.13889E-05	dev_0CDC7E3D08B4	2023-06-19 11:30:00.000 +0100	10.74282722
dev_0CDC7E3D08B4	2023-06-27 08:30:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-19 12:00:00.000 +0100	7.652904444
dev_0CDC7E3D08B4	2023-06-27 12:00:00.000 +0100	0.264301389	dev_0CDC7E3D08B4	2023-06-19 12:30:00.000 +0100	7.280201944
dev_0CDC7E3D08B4	2023-06-27 12:30:00.000 +0100	0.174729444	dev_0CDC7E3D08B4	2023-06-19 13:00:00.000 +0100	10.57148389
dev_0CDC7E3D08B4	2023-06-27 13:00:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-19 13:30:00.000 +0100	11.59853389
dev_0CDC7E3D08B4	2023-06-28 18:30:00.000 +0100	1.891566944	dev_0CDC7E3D08B4	2023-06-19 14:00:00.000 +0100	10.72821361
dev_0CDC7E3D08B4	2023-06-29 15:30:00.000 +0100	8.61111E-05	dev_0CDC7E3D08B4	2023-06-19 14:30:00.000 +0100	10.75848667
dev_0CDC7E3D08B4	2023-05-26 20:30:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-19 15:00:00.000 +0100	10.68348389
dev_0CDC7E3D08B4	2023-05-27 18:00:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-19 15:30:00.000 +0100	8.088731389
dev_0CDC7E3D08B4	2023-05-28 08:00:00.000 +0100	3.19444E-05	dev_0CDC7E3D08B4	2023-06-19 16:00:00.000 +0100	7.990753333
dev_0CDC7E3D08B4	2023-05-28 10:30:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-19 16:30:00.000 +0100	8.777600278
dev_0CDC7E3D08B4	2023-05-29 08:00:00.000 +0100	1.05556E-05	dev_0CDC7E3D08B4	2023-06-19 17:00:00.000 +0100	9.502808333
dev_0CDC7E3D08B4	2023-05-30 10:30:00.000 +0100	15.70147528	dev_0CDC7E3D08B4	2023-06-19 17:30:00.000 +0100	7.310166389
dev_0CDC7E3D08B4	2023-05-30 11:00:00.000 +0100	13.49619194	dev_0CDC7E3D08B4	2023-06-20 09:00:00.000 +0100	0.00014
dev_0CDC7E3D08B4	2023-05-30 11:30:00.000 +0100	9.195185278	dev_0CDC7E3D08B4	2023-06-21 09:00:00.000 +0100	9.69444E-05
dev_0CDC7E3D08B4	2023-05-30 12:00:00.000 +0100	9.630233611	dev_0CDC7E3D08B4	2023-06-22 08:30:00.000 +0100	0.000463611
dev_0CDC7E3D08B4	2023-05-30 12:30:00.000 +0100	14.92460139	dev_0CDC7E3D08B4	2023-06-22 12:00:00.000 +0100	3.22222E-05

7.3. COMPLETE ENERGY REPORT – GROUP 1 & 2

Please refer to attachment names:

- Energy readings - 25th May to 22nd June - Group 1.csv
- Energy readings - 25th May to 22nd June - Group 2.csv

END