University of Southern Queensland

School of Engineering

Optimising Power Usage for Homes with Solar Panel Systems

A dissertation submitted by

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ABSTRACT

The installation of residential photovoltaic systems is an entrenched and proliferating practice, as consumers strive to offset the growing cost of electricity. In the wake of reduced feed-in tariffs, grid export continues to be a less viable method for offsetting household energy costs. Energy conscious consumers must now look to increase self-consumption of generated electricity within their homes. A primary obstacle to increasing self-consumption is the temporal gap between peak solar system generation and household appliance usage patterns. This project was undertaken in order to lessen this time difference as much as reasonably practicable, through the design and implementation of an optimal control algorithm that automates appliance usage based upon the current energy yield from a typical PV system. In doing so, this algorithm would serve as the foundation for a wider home energy management system, monitoring and controlling the flow of electricity within a household between appliances, the grid, PV system and any potential Battery Energy Storage System (BESS) to maximise self-consumption and the economic benefit of the homeowner.

For this project, an extensive literature review was undertaken to identify appliance usage patterns in typical Australian households, the yield profiles of typical residential PV systems and existing Home Energy Management Systems (HEMS). In doing so a knowledge gap was identified in the literature, where limited research exists on the technical and economic benefits of consumers deviating from typical usage habits and the automation of appliances to close the temporal gap.

The literature review also identified the ideal structure for the algorithm as a statechart, a variation of a finite state machine that employs orthogonality to facilitate concurrent execution of states. This statechart was designed and constructed in the graphical programming environment Simulink, itself built upon the MATLAB programming language. Appliances were divided into controllable and uncontrollable groups, with controllable appliances denoted as those whose time of use is not expected to impact user convenience. These include hot water systems, pool pumps, washing machines, dryers and dishwashers. The inputs to the statechart consisted of manual uncontrollable appliance patterns for each season, as well as the seasonal yield patterns from a real-world PV system. In order to explore the viability of using BESS to further increase economic benefit, the algorithm was also modelled using input data from the Tesla Powerwall 2.

Results revealed that the algorithm was successful in automating controllable appliance usage based upon solar yield. Techno-economic analysis demonstrated a marked reduction in grid export, grid reliance and the per-kilowatt-hour cost of electricity. A significant improvement in self-consumption was identified for all scenarios tested and the feasibility of BESS installation was improved with the algorithm in place.

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NOMENCLATURE

A	=	Amperage (A)
Ah	=	Charge (Ampere-hour)
d	=	Discount rate (%)
i	=	Index
LCOE	=	Levelized Cost of Energy ($/kWh, ¢/kWh)
N	=	Final value of index
NPV	=	Net Present Value ($, ¢)
P	=	Power (w, kW, kWp)
PB	=	Payback Period (years)
P_{SH}	=	Site Specific Irradiance (kWh/m^2/day, MJ/m^2/day)
V	=	Voltage (V)
W	=	Work (Wh, kWh)

GLOSSARY

AC	=	Alternating Current
AEMO	=	Australian Energy Market Operator
AER	=	Australian Energy Regulator
BCA	=	Building Code of Australia
BESS	=	Battery Energy Storage System
BMS	=	Building Management System
BoS	=	Balance of System
DC	=	Direct Current
DIS	=	Department of Industry and Science
DNSP	=	Distribution Network Service Provider
DOD	=	Depth of Discharge
FSM	=	Finite State Machine
GPO	=	General Power Outlet
HEMS	=	Home Energy Management System
HVAC	=	Heating, Ventilation and Air Conditioning
HWS	=	Hot Water System
IT	=	Information Technology
LiFePo4	=	Lithium Iron Phosphate

LV	=	Low Voltage
MCB	=	Miniature Circuit Breaker
MEN	=	Multiple Earthed Neutral
MPP	=	Maximum Power Point
NEM	=	National Energy Market
NTESMO	=	Northern Territory Electricity System and Market Operator
PV	=	Photovoltaic
PWM	=	Pulse Width Modulation
RBS	=	Residential Energy Baseline Study
RCBO	=	Residual Current Breaker with Overcurrent
RCD	=	Residual Current Device
SLD	=	Single Line Diagram
SOC	=	State of Charge
SP	=	Single Phase
STC	=	Standard Test Conditions
WEM	=	Wholesale Electricity Market

1 INTRODUCTION

1.1 Background

Leading the world with solar uptake (energy.gov.au 2023), residential photovoltaic systems have become an ubiquitous addition to the Australian energy landscape. With over 3.4 million rooftop installations, consumers are becoming increasingly energy conscious, however reductions to feed-in tariffs and lower subsidies mean that homeowners are not reaping the same financial benefits as they once were (Ludlow 2023).

Technological advancement in equipment, such as panel or inverter efficiencies, can help to maximize generation, however optimization of energy usage to take advantage of peak solar yields is becoming increasingly important to offset regulatory changes, reduce grid reliance and ultimately save on household expenditure in a time where the cost of living is rising.

1.2 Problems

While solar still remains an economically sounds investment, with a typical return on investment of 3 to 5 years (energy.gov.au 2023), the primary issue still remains that generation can only be achieved when the sun is shining. These “full sun” hours do not align with the typical demand profiles of everyday Australians, with most usage occurring in morning and evening, outside the most potent irradiance periods of the day. While battery storage may be a potential solution to merge the gap between generation and demand time periods, the economic viability of this for the residential market is still poorly understood. Given these conditions, implementation of a home energy management system (HEMS) looks to be the logical solution. To explore implementation of a potential HEMS solution, the central problems of interest can be summarized as follows.

- Can a control algorithm be developed to automate appliance usage within a household, to minimize the time difference between generation and demand profiles?
- What is the feasibility of incorporating battery storage to further bridge the gap between generation and demand?

These problems form the core questions that were explored throughout the development of the project.

1.3 Aims & Objectives

The overarching aim of the project is to reduce reliance on the grid and maximise economic benefit for the homeowner as much as is practicable. The means to achieve this was proposed to be through the development and implementation of a control algorithm for eventual integration into a wider HEMS. The algorithm intent was to monitor and control appliance usage with respect to energy generation from a local solar generation installation. Such as system serves to minimise the time difference between solar generation and appliance demand as much as possible.

The objectives that were required to be undertaken in order to achieve the stated aims can be summarised as follows.

1. Research the existing literature to determine the current level of knowledge around residential HEMS, energy usage profiles for typical Australian homes, the configuration and performance of a typical residential solar system and the integration of battery energy storage systems (BESS) in these installations.
2. Identify a clear knowledge gap in the existing literature to justify the proposed research project.
3. Develop a clear methodology to develop and evaluate the HEMS control algorithm, analyse both its performance on a standalone system and a system with the implementation of a BESS, and draw a sound conclusion.
4. Develop a schedule and risk assessment to assist in the justification and delivery of the project.

Upon completion of the project, the expected outcomes as a result of the stated objectives were as follows.

1. Identification of typical power requirements and usage patterns of appliances for 2 person and 4 person households.
2. Recommendation of solar system and BESS capacity to maximise self-consumption of energy generated based on demand and generation patterns.
3. Development and simulation of an algorithm to automate appliance usage as much as practicable, to align usage with demand profiles, for the future implementation in a wider HEMS for a standalone solar system.
4. Development and simulation of an algorithm to automate appliance usage as much as practicable, to align usage with demand profiles, for the future implementation in a wider HEMS for a hybrid solar system with integrated BESS.
5. Provision of a techno-economic analysis to determine feasibility of both standalone and BESS integrated installations.

1.4 Project Benefits

Benefits of this research include decreased reliance on the grid, lower energy costs for homeowners and increased sustainability within Australia's energy generation industry. This research also serves to clear up existing questions around the economic viability of battery storage in residential installations, and potentially helps guide consumers towards the ideal residential solar generation topology with respect to the current market.

1.5 Outline

The project documentation consists of six distinct chapters, beginning with Chapter 1, which provides an introduction and overview of the project.

Chapter 2 consists of the literature review, which explores the nature of the current literature surrounding the topic, including economics, energy consumption and management, electrical installation topology, solar generation and battery systems within the context of residential installations. In addition to information gathering, this chapter also identifies potential applications for the existing literature, as well as identification of the knowledge gap, which serves to justify the undertaking of the project.

The project methodology is outlined in Chapter 3 and details project parameters and planning, before delving into two distinct design phases. The first schematic design phase employs the appliance energy consumption and solar generation data gathered in Chapter 2, to develop typical patterns that act as the input variables to the control algorithm. This phase also begins conceptual modelling of the system as a statechart by identifying the system states. The second phase of the methodology consists of the detailed design of the system and outlines the construction and implementation of the statechart within the Simulink environment.

Chapter 4 details the analysis of the results of the control algorithm, implemented as a statechart in the previous chapter. The method of analysis is described and undertaken for both standalone and hybrid solar installations. Whilst Chapter 4 is primarily concerned with analysing raw data, Chapter 5 discusses the implications of the results, determining the effectiveness of the control algorithm and presenting a techno economic analysis for each configuration.

The project documentation concludes with Chapter 6, which summarises the findings and works undertaken. The conclusion also includes brief reflection on the overall project and highlights the potential for future works in this area.

2 LITERATURE REVIEW

A thorough literature review is essential in order to assess the current state of knowledge, and to form the foundation on which an appropriate control algorithm for HEMS can be developed. Throughout this chapter, the following key areas are be explored.

- Economics within the Australian Energy Market
- Energy consumption within residential installations
- Residential electrical installations
- Residential solar generation installations
- Battery energy storage systems
- Home energy management systems

2.1 Economics of the Australian Energy Market

In order to appreciate the benefits of solar generation, it is crucial to gain an understanding of how the wholesale energy market operates in Australia.

The overarching public body that manages the energy market in the majority of Australia is the Australian Energy Market Operator (AEMO), operating both the electricity and gas markets across the country (AEMO 2024a). The electricity markets that the AEMO operate include the National Electricity Market (NEM) and the Wholesale Electricity Market (WEM). The NEM provides wholesale electricity to the Queensland, South Australia, Victoria and Tasmania regions, while the WEM services Western Australia (AEMO 2024b). A separate market operator, the Northern Territory Electricity System and Market Operator (NTESMO) is responsible for managing the market in the NT (AEMO 2024c). As this project focuses on the Queensland region, specifically South East Queensland, the NEM is the market of interest.

The NEM operates to generate and deliver electricity to consumers under the management of the AEMO in accordance with both National Electricity Law and the National Electricity Rules. The NEM monitors market demand and instructs generators of their output capacities to match in 5-minute intervals, a process known as a spot market. The current wholesale energy price is then calculated based on the spot market. This in then delivered via transmission lines, maintained by the regional transmission system operator, to large industrial customers and to local distribution networks for sale on to residential and commercial consumers (AEMO 2024d). The distribution lines for delivering electricity to consumers are maintained by the regional distribution network service provider (DNSP), with sales undertaken by local energy retailers. Energy retailers purchase electricity at the wholesale price from the NEM and sell it to the consumer in the form of a tariff over the distribution network. Energy retailers set the tariff prices according to network charges, the wholesale energy price and profit margins. The Australian

Energy Regulator assists in this by monitoring the market and setting a reference price known as the Default Market Offer in order to maintain transparency for consumers (AER 2024).

In South East Queensland, tariffs are structured around demand times across the network, with ‘peak’ high demand periods and ‘off-peak’ low periods of demand. Time of use tariffs offer lower costs in off-peak periods and higher costs in peak periods, charged per kilowatt hour (kWh) of electricity consumed. Demand tariffs are a per kilowatt (kW) charge for the highest consumption measure within a period or ‘charging window.’ These tariffs are examples of typical primary tariffs and are generally used for general light and power throughout all hours of the day (Energex 2024a). For high demand appliances that only require power intermittently, such as hot water systems, it is common to connect these to a secondary or ‘load controlled’ tariff. Secondary tariffs offer energy at a reduced cost compared to primary tariffs with the trade-off that the supply can be paused for up to six hours a day to alleviate heavy network demand (Energex 2024b). For consumers with solar generation on their premises, retailers also offer renumeration for excess generation in the form of a feed-in tariff. Table 1 below shows an example of the current tariff pricing structure from Origin Energy in the Sunshine Coast (Origin Energy 2024).

Table 1. Origin Energy Electricity Plans for Sunshine Coast

	Plan	
	Origin Go Variable	Origin Solar Boost
Supply Charge Units	Cents/day	
Daily Supply	131.14	138.03
Solar Meter Charge	9.57	9.57
Daily Supply - Controlled	3.69	3.89
Usage Charges Units	Cents/kWh	
General Usage (Primary Tariff)	32.27	33.96
Controlled Load Usage (Secondary Tariff)	20.06	21.11
Solar Feed-In	4.00	10.00 for first 14kWh/day 4.00 after 14kWh

Applications for Project

The application of controlled loads via secondary tariffs demonstrates the viability of automating appliance usage to take advantage of lower electricity prices during periods of “off-peak” demand. These secondary tariffs provide insight into typical appliance usages for intermittently operated equipment within a residential household such as hot water systems and pool pumps. An understanding of how the electricity market operates within Australia also provides a foundation to understand the economics of solar generation, which assists with identifying ideal system sizing and techno-economic analysis of battery energy storage systems.

2.2 Energy Consumption within Residential Installations

Key to development of an appropriate control algorithm, an understanding of typical power consumption within residential installations is required.

2.2.1 Typical Households and Total Consumption

According to a 2018 CSIRO survey on energy consumption and household types, total energy usage tends to closely correlate with the number of occupants within a household (CSIRO 2018), with usage increasing with each additional occupant.

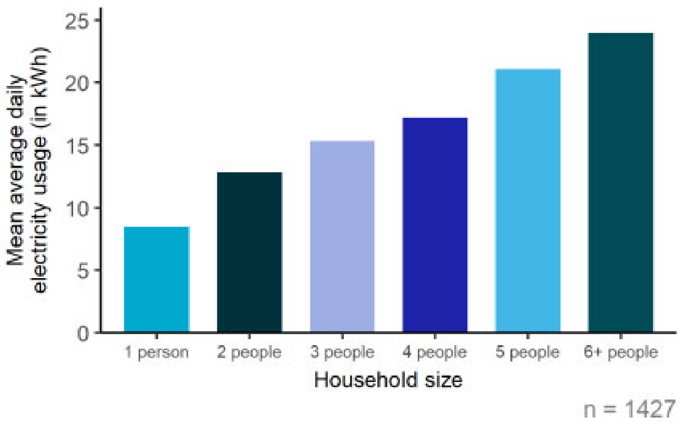


Figure 1. Electricity usage vs household occupancy (CSIRO 2018)

While it is worth noting that this survey only focuses on CSIRO volunteers, these observations are consistent with the findings from alternative sources. The 2020 Residential Energy Consumption Benchmarks (Frontier Economics 2020) published by the Australian Energy Regulator (AER) also show correlation between energy usage and household size, while also highlighting seasonal usage trends. Focusing on South East Queensland and Northern New South Wales, this correlation can be seen in table 1 below.

Table 2. Seasonal electricity usage vs household consumption

Occupancy Size	Electricity Consumption (kWh) per Season			
	Summer	Autumn	Winter	Spring
1	908	857	848	799
2	1393	1281	1250	1202
3	1644	1531	1545	1449
4	2074	1935	1873	1800
5+	2430	2182	2153	2038

Visual representation of the data as a bar graph allows the trend to be seen with greater clarity.

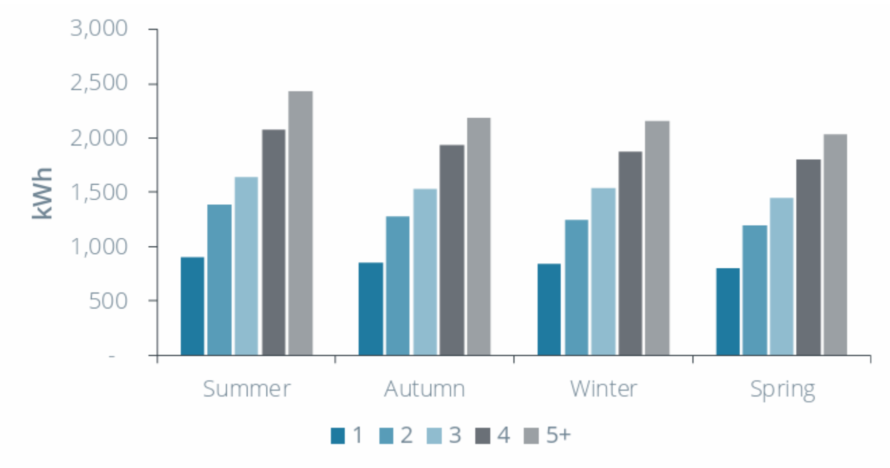


Figure 2. Seasonal electricity usage vs household occupancy (Frontier Economics 2020)

With regards to household composition, the CSIRO (CSIRO 2018) indicated that 2 and 4 people were the most common occupant number, and that couples with children and without children are the most common arrangement (at 40% and 33% respectively). Similar findings were reported by the Australian Bureau of Statistics during the 2021 Census (Australian Bureau of Statistics 2021), which found 70.5% of households were occupied by families, compared to 25.6% lone and 3.9% group occupancy arrangements. Within family households, 53% were reported to be couples with children and 47% as couples without children.

2.2.2 Consumer Habits and Appliance Usage

Beyond simple total energy expenditure, it is necessary to understand how electricity is utilized across a 24-hour period, so that a profile can be developed.

In 2012/2013, the CSIRO conducted a study of energy efficiency within Australian households across 209 premises in Melbourne, Brisbane and Adelaide (Ambrose et al. 2013). The purpose of this was to evaluate the effectiveness of the Building Code of Australia's (BCA) 5-star energy efficiency standard, with regards to reducing heating and cooling energy usage within Australian households. Though the authors note that the small sample size limits the definitiveness of the findings, it concludes that the BCA recommendations have had a positive effect. More importantly for this project, the sub-circuit monitoring provides a snapshot into appliance usage patterns for different houses. As part of this study, electricity consumption was measured in half hour intervals via monitoring of sub-circuits via an EcoPulse data logger. The data logger measured current and voltage of up to 8 circuits, which was summed together to also calculate total usage within the home.

Household composition and occupancy rates were accounted for with regard to energy usage throughout each premises. Retirees accounted for approximately 15%, 21% were working couples and approximately 64% were families with one or more children. In 20% of households, the premises were unattended during work hours, while approximately half of the households had an occupant home throughout the day.

The results of the energy logging undertaken as part of the evaluation were incorporated into the CSIRO online “Typical House Energy Use” dashboard (CSIRO 2013) for ease of analysis. Circuits were separated into four categories – plug in appliances (general power outlets), lights, HVAC, and ovens. Focusing on Brisbane, Queensland, hourly usage times per weekday in each season are assessed below. Note areas of higher consumption are warmer in colour (tending towards yellow and orange) while lower demands appear in darker shades of green.

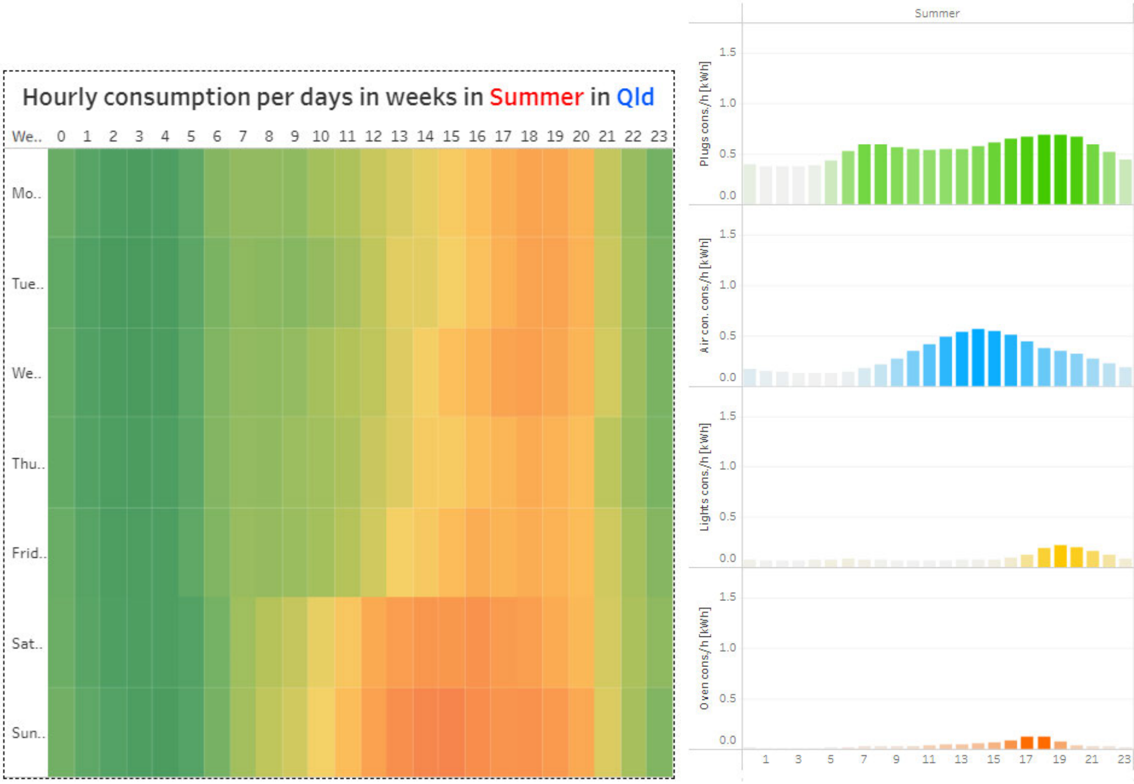


Figure 3. Summer hourly energy consumption (CSIRO 2013)

For summer weekdays, demand is low late at night and during the early morning, increasing throughout the day and peaking in the afternoon and early evening (approximately 13:00-21:00). Weekends are similar, though the demand begins to increase earlier in the day, around 10:00 compared to 12:00-13:00 on weekdays and the overall magnitude of consumption is higher. With reference to the circuit demand trending on the right, plug in appliances and oven consumption appear to be remarkably close when compared to other seasons. Lighting loads are focused around evening use, with negligible demand in the morning that can be attributed to earlier sunrise times in the summer months. HVAC loads are heaviest in the summer in comparison to other seasons, with significant usage throughout the heat of the day. Both magnitude of the demand and profile of its usage correlate with the rise in temperature throughout the day.

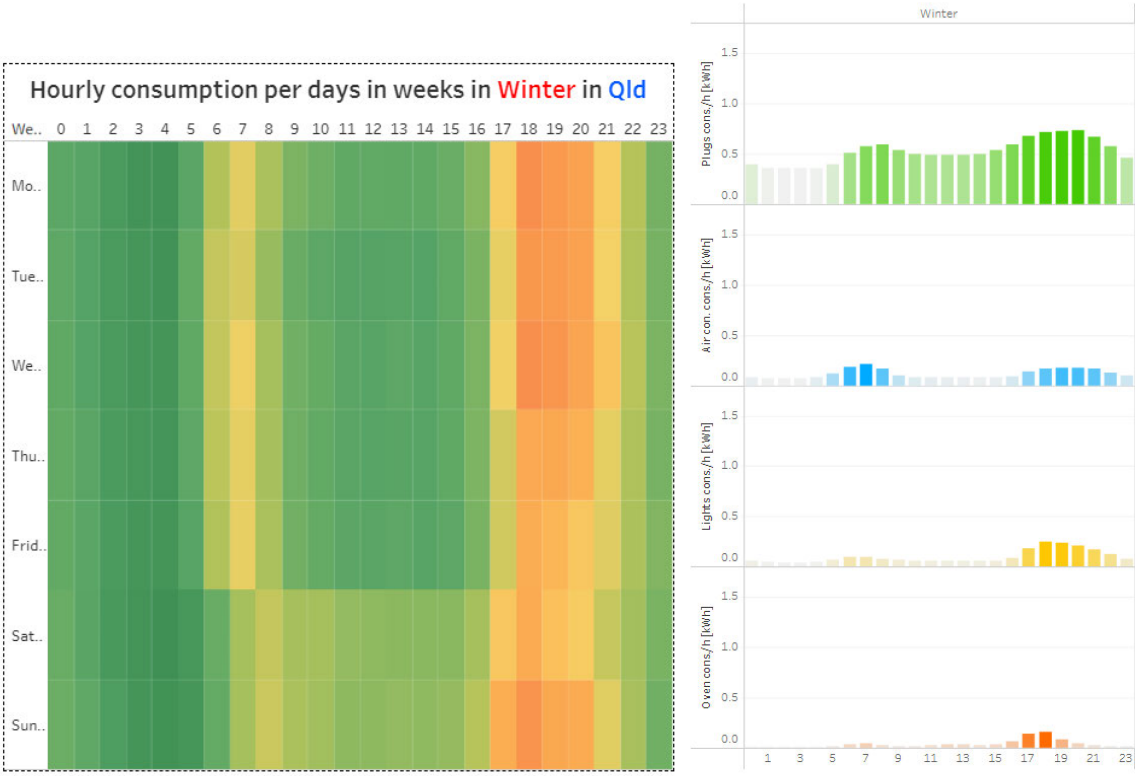


Figure 4. Winter hourly energy consumption (CSIRO 2013)

For winter weekdays, demand peaks in the mornings (approximately between 6:00 and 8:00) and evenings (approximately between 17:00 and 21:00), dropping throughout the night and early morning and through the middle portion of the day. Weekends follow a similar pattern, though the morning peak is shifted forward by approximately one hour (7:00-9:00) and is lower in magnitude. This may be accounted to later waking times on the weekends. Though consumption is lower between the morning and evening peaks again on weekends, demand is higher through this period than it is during weekdays, likely due to increased occupancy. With reference to circuit demand, general power and oven consumption is similar to other seasons, while cooler temperatures and later sunrises mean lighting and HVAC (heating) loads are present in the mornings.

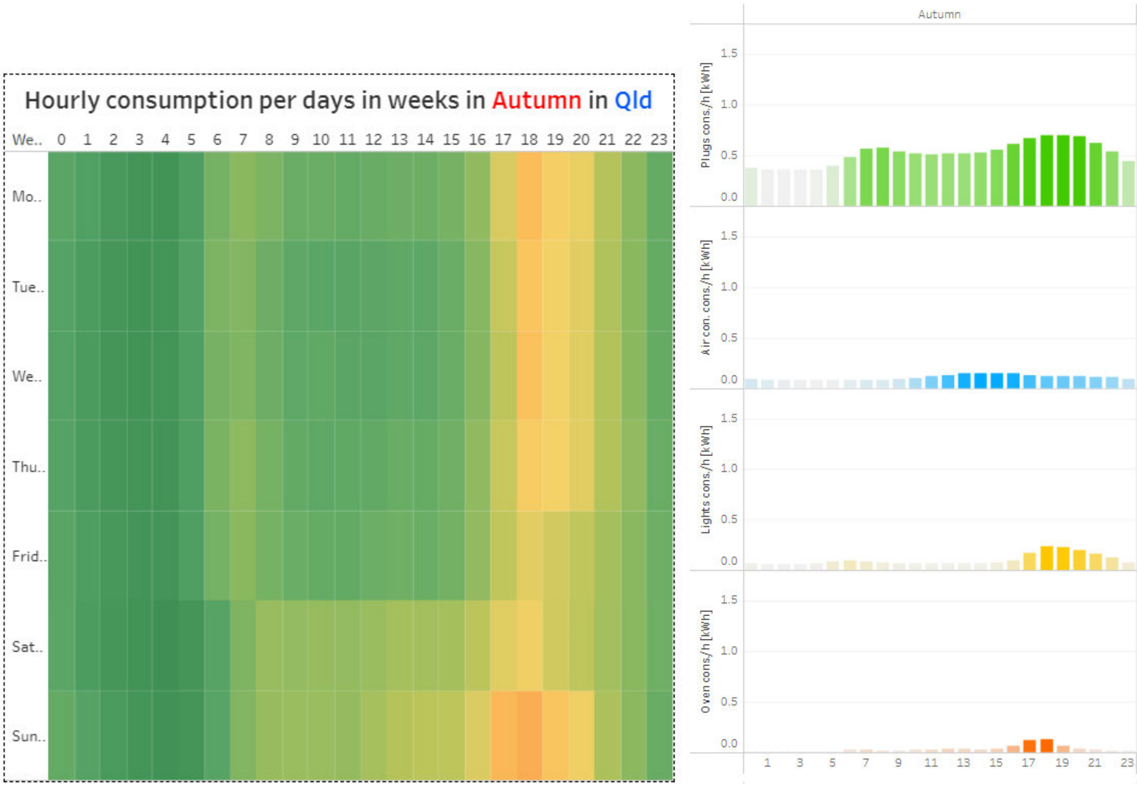


Figure 5. Autumn hourly energy consumption (CSIRO 2013)

For weekdays, the hourly consumption profile of autumn is similar to winter, though it has a less pronounced morning peak and lower peak demand in the evening. During weekends, the morning peak has smoothed, and the demand increases throughout the day in a similar fashion to summer, albeit with much reduced magnitude of demand. General power and oven consumption is similar to other seasons, with the lowest overall HVAC demand amongst the seasons reflecting the mild temperature. Morning usage of lighting is reduced from winter, though evening lighting is still greater than in spring and summer.

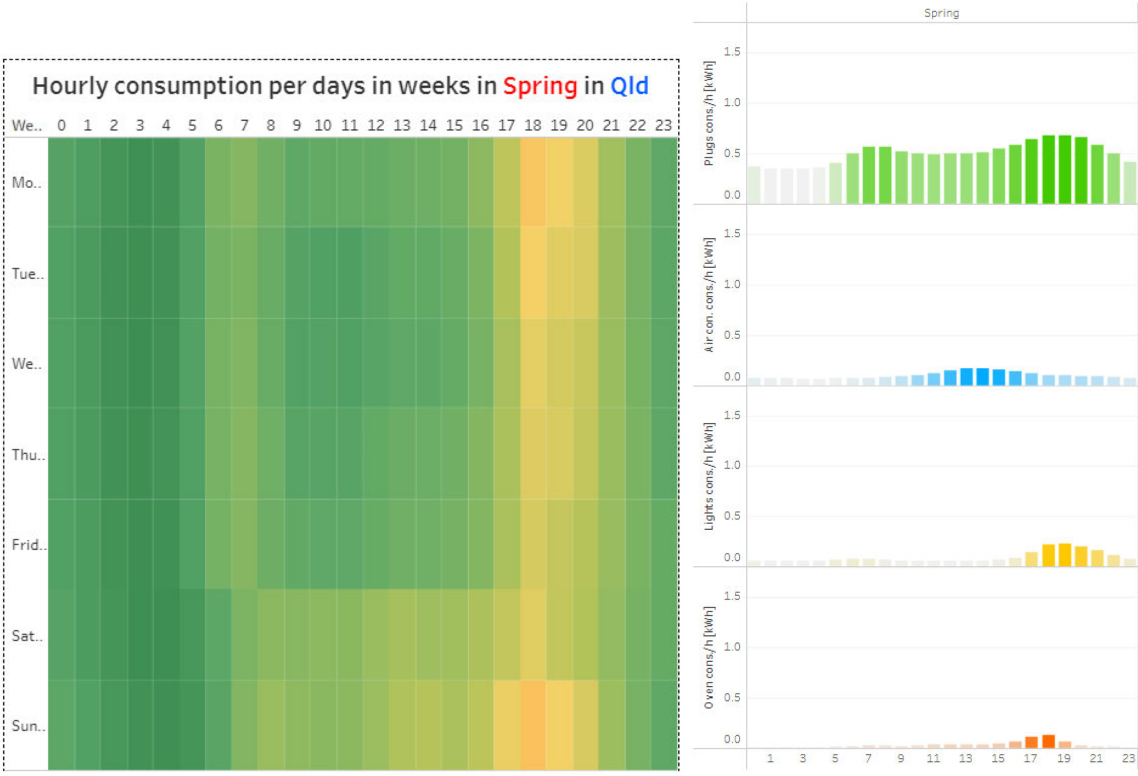


Figure 6. Spring hourly energy consumption per weekday (CSIRO 2013)

Weekdays in spring continue the trend set in autumn of a small morning peak (6:00-7:00), followed by a more substantial peak in the evening (17:00-20:00). Weekends are similar again, with the flattening of the morning peak giving way to a steady rise in evening demand. HVAC loads are still low in magnitude in comparison to summer, though nighttime usage is less than autumn evening and shifting more towards the heat of the day – around 14:00.

While general power consumption is consistently at a higher magnitude, there is limited difference in the pattern of usage between seasons. This is the same for oven consumption, which tends to be used around the same times regardless of seasons. HVAC looks to have the most impact in the differences in seasonal demand due to both the high-power consumption and the patterns of usage. While lighting demand magnitudes are overall lower than HVAC, in cooler months the patterns of light usage, particularly in the mornings, make a larger difference in seasonal profiles.

Overall, the results of the CSIRO study indicate that peak usage times for all appliances tend to be in early mornings, late afternoon and into the evening, with larger HVAC loads during the winter and summer months to offset temperature extremes.

The Residential Energy Baseline Study (RBS 2.0), prepared by EnergyConsult on behalf of the Department of Industry and Science (DIS) also predicted appliance usage trends in patterns similar to those found by the CSIRO (EnergyConsult 2022). The RBS 2.0 is an update of the previous tool developed for the DIS to model residential energy consumption at the appliance level and provide accurate projections up to the year 2040. The model was constructed using data from sources such as the 2016 Australian Census, the CSIRO, the Australian Energy Market Operator and demand data of residential appliances and equipment. Appliances were broken down into the following categories:

- Water heating – hot water systems
- Space conditioning - HVAC
- Lighting – Incandescent, halogen, fluorescent, LED
- Cooking – ovens, microwaves, cooktops
- White Goods – refrigerators, freezers, dishwashers, washing machines, dryers.
- IT and Home Entertainment – computers, televisions
- Other equipment – pool pumps, battery chargers, kitchen appliances

The RBS 2.0 model for weekday power consumption in 2024 is shown in Figure 7 below.

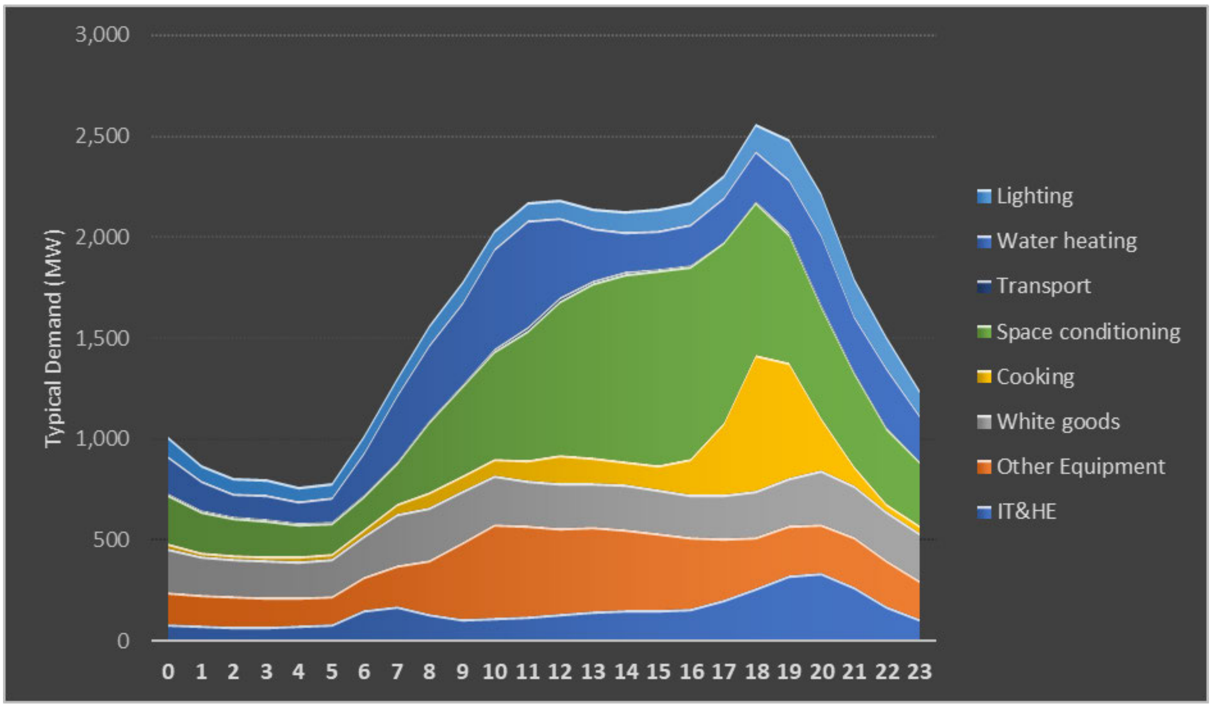


Figure 7. Summer 2024 weekday hourly energy consumption (EnergyConsult 2022)

The demand pattern for the summer weekday model output correlates closely with the usage found by the CSIRO, with consumption increasing throughout the day and peaking in the evening. An important note is the additional peak in the middle hours of the day due to water heating loads connected to off-peak tariffs. The model outputs of the remaining seasons show comparable results, closely aligning with the previous CSIRO results with the addition of water heating loads.

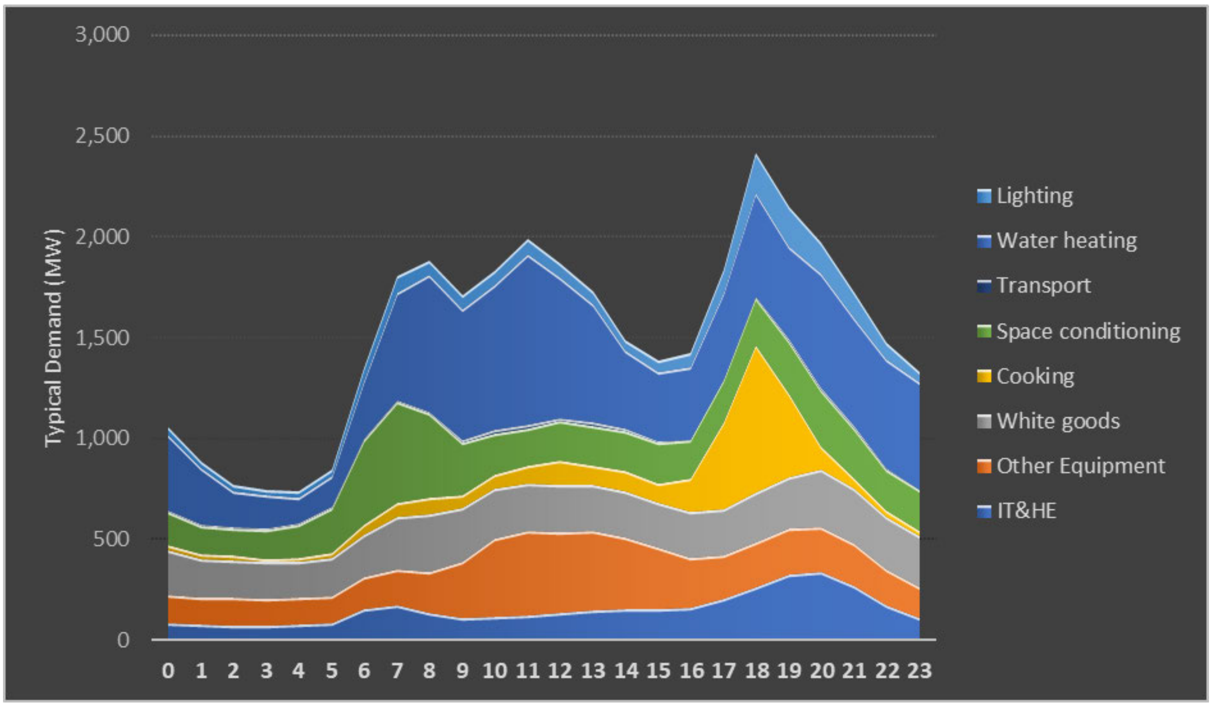


Figure 8. Winter 2024 weekday hourly energy consumption (EnergyConsult 2022)

Winter demand is similar to previous findings, with additional water loading.

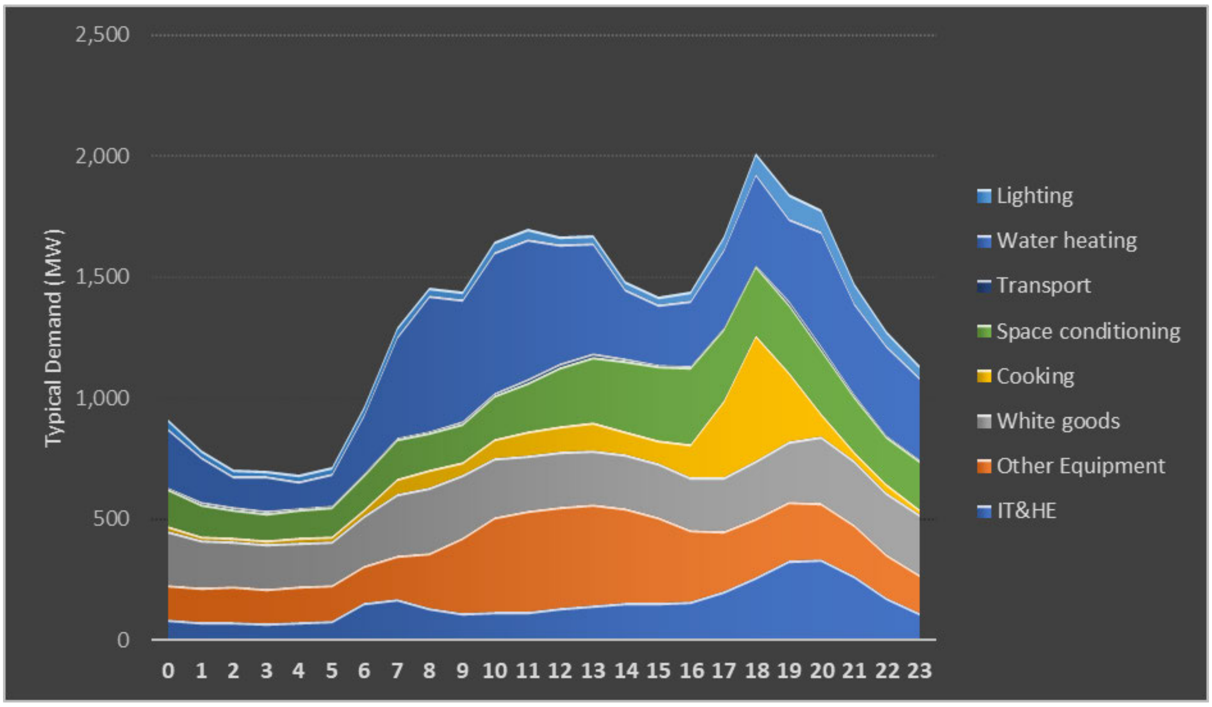


Figure 9. Autumn 2024 weekday hourly energy consumption (EnergyConsult 2022)

Autumn demand is similar to previous findings, with additional water loading.

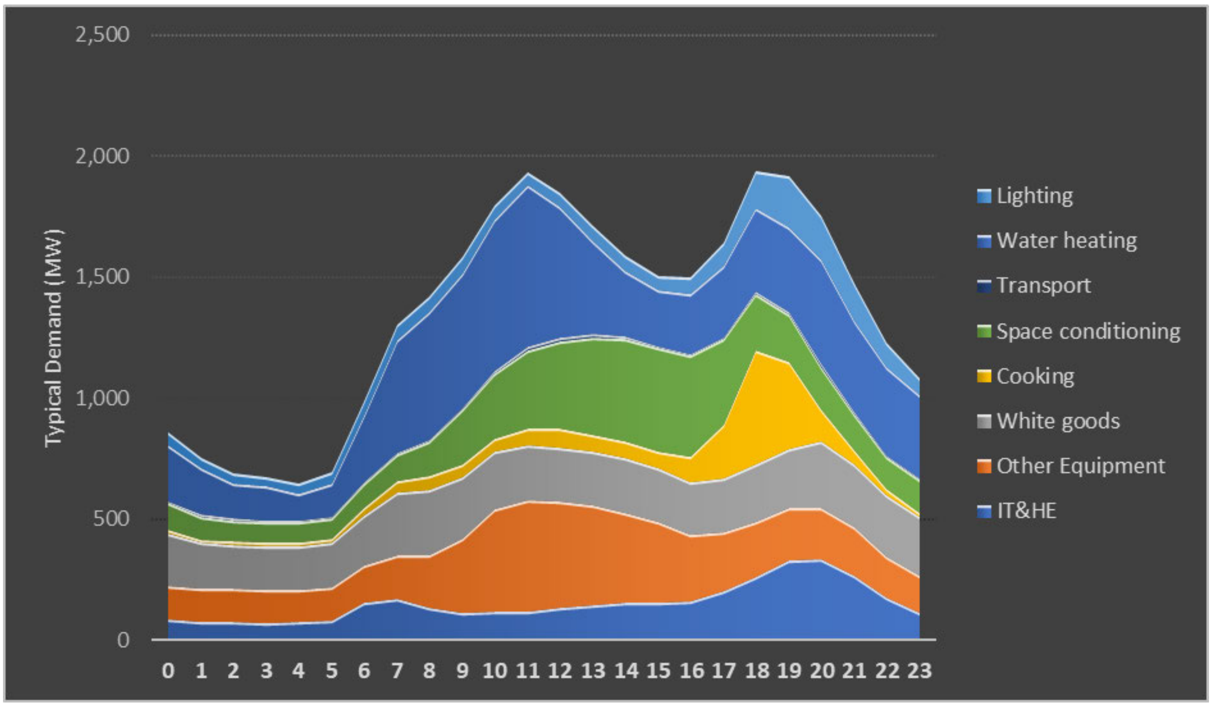


Figure 10. Spring 2024 weekday hourly energy consumption (EnergyConsult 2022)

Spring demand is similar to previous findings, with additional water loading. The model also predicts increased midday HVAC loading when compared to CSIRO findings, but the pattern of use (demand between autumn and summer) is consistent with the previous. Weekend profiles follow the same trend as weekday predictions.

Further exploration of the demand trends associated with hot water system (HWS) loading shows that the timing of usage with this appliance tends to correlate with secondary economy tariffs. In South East Queensland, Energex offers the volume controlled tariff 33, which operates for 18 or more hours each day outside if 4:00-9:00pm, as well as the night tariff 31 which operates from 10pm-7am (Energex 2024b). With reference to figures 7 to 10 above, the largest water draws tend to be in the middle of the day, with smaller demands outside the hours of tariff 33, indicating that economy tariffs are likely in place on a majority of homes. This reinforces Energex statement that loads such as HWS and pool pumps are typically connected to these types of tariffs and tend to operate outside the hours of 4:00-9:00pm. For a residential premises with both

Though the RBS is useful in confirming usage patterns observed from real world data, the typical demand is given from a generator's perspective, that is in megawatts for the entire state. Likewise, the 2013 survey undertaken by the CSIRO also provides valuable insight into usage patterns, however the small sample size and changing specifications of household appliances in the past decade warrant further investigation into the demand of typical household appliances.

Limited academic research exists on the most popular size, types, and availability of appliances in *residential premises in Australia*. As appliance models, energy efficiency and overall power demand change over time, so do the details of individual consumers appliances. Without access to retail data, consumer rating websites provide insight into popularity trends of household appliances. ProductReview is the largest consumer opinion website in Australia, with more than 3.3 million active users (ProductReview 2024). Table 3 below details the power demand of the most popular appliances as voted by the users of ProductReview.

Table 3. Typical appliance power demand

Appliance	Reference Data Sheet	Demand details
Hot water system (Heat Pump)	Evoheat EVO270 Series (Evoheat 2024)	Power: 0.94kW
HVAC (Bedroom)	Mitsubishi Heavy Industries Avanti 2.5kW (Mitsubishi Electric 2024b)	Power Cooling: 0.51kW Power Heating: 0.65kW
HVAC (Living)	Mitsubishi Heavy Industries Avanti 5kW (Mitsubishi Electric 2024b)	Power Cooling: 1.39kW Power Heating: 1.49kW
Downlight (LED)	Arlec 9W Tri Colour Dimmable LED Downlight (Arlec 2024)	Power: 9W
Oven	Bosch Series 8 Built-in Oven (Bosch 2024a)	Power: 3.6kW
Microwave	Ariston MWA25B (Ariston 2024)	Power: 1.75kW
Cooktop	Westinghouse WHC642BA 4 Zone (Westinghouse 2024)	Power Total: 6.5kW LHS front: 2.3kW RHS front: 1.2kW LHS rear: 1.2kW RHS rear: 1.8kW
Refrigerator/ Freezer	Mitsubishi Electric 700L Multi Drawer MR-WX700C Series (Mitsubishi Electric 2024a)	Power :2.4kW (~10A) Consumption: 425kWh/year 1.16kWh/day
Dishwasher	Bosch Series 8 SMS8EDI01A (Bosch 2024b)	Power:2.0-2.4kW Consumption: 230kWh/year (eco wash) 630Wh/day Cycle time: 210 mins (eco wash)
Washing Machine	Speed Queen AWNA62 (Speed Queen 2024)	Power: 375W

		Cycle time: 37 minutes (normal wash)
Clothes Dryer	Haier HDV40A1 (Haier 2024)	Power: 1.75kW Cycle times: 30,60,120,180 minutes
Computer	ASUS ROG Strix G15 G512LW-AZ003T (ASUS Australia 2024)	230W
Television	Samsung Q70C QLED Series 65 inch (Samsung Australia 2023)	Power: 145-245W Consumption: 532kWh/year
Pool Pump	Zodiac FloPro E3 Series 1HP (Zodiac Australia 2023)	Power: 0.75kW Consumption: 563kWh/year

2.2.3 Applications for Project

The research undertaken for this section has a direct correlation to the development of both the magnitude and pattern of appliance usage. Total energy consumption as well as daily, weekly, and seasonal demand has been explored for both two and four occupant households. The patterns of usage and the demand of typical residential appliances explored in this section will be used to develop the typical profiles in the methodology.

2.3 Residential Electrical Installation Topology

To appreciate how a solar system operates, it is necessary to understand the topology of a typical residential electrical installation.

In Australia, mains electricity is provided at a voltage of 230VAC (+10%, -6%), in accordance with *AS60038 Standard Voltages*. This falls within the range known as low voltage. The standard for the design and installation of low voltage electrical systems is *AS/NZS 3000:2018 Electrical Installations*, also known as the “Wiring Rules” (Standards Australia 2018). This standard outlines the requirements and general arrangement of components to enable the distribution and control of electrical elements within buildings and public spaces. The general arrangement of an electrical installation in this context consists of individual final subcircuits (or circuits for short) that reticulate from a central switchboard to items of electrical equipment within a residential premises. Equipment is typically either general power outlets (GPO) that enable the connection of plug-in appliances, or hard-wired appliances such as light fixtures, hot water systems or HVAC.

Figure 11. A residential switchboard showing individual protective devices and metering equipment.

Each circuit consists of a protective device that is housed in the switchboard, and conductor cabling that reticulates from this device out to equipment and appliances. Protective devices are typically either circuit breakers or residual current devices and protect people and property from the effects that arise during electrical fault conditions. Circuit breakers (commonly referred to as MCBs – miniature circuit breakers) protect against overcurrent and short circuit faults, to prevent conductors from exceeding their maximum current carrying capacity, which could otherwise result in a fire hazard. Residual current devices (RCDs) protect against earth faults, or the leakage of electrical current, which could cause exposed conductive fixtures to become 'live.' A live conductive fixture, such as a tap or the frame of a hot water system, presents a hazard known as touch potential, where the voltage between the fixture and the system ground is sufficient enough that contact between these points may result in electric shock. In modern installations, it is common to have a single device that acts as a combination of both an MCB and an RCD. This device is known as an RCBO, or a residual current breaker with overcurrent protection.

Figure 12. A residual current breaker with overcurrent protection (RCBO) manufactured by Clipsal (Clipsal 2024)

The conductor cabling consists of one to three active conductors, a neutral conductor, and a protective earthing conductor. The active and neutral conductors are 'current carrying.' They complete the electrical circuit, facilitating the flow of current to power appliances within the home. The earth, or ground, is a protective conductor that does not carry current in ordinary operating conditions and is connected to conductive parts of electrical equipment. This provides a reference to ground for the installation, via connection to the earth stake near the switchboard. The main earthing conductor attached to the earth stake, and the main neutral conductor in the consumers mains are joined together using a link between the earthing and neutral terminal bars in the switchboard. This arrangement is known as a Multiple Earthed Neutral (MEN). In the event of an earth fault, current will flow through the low resistance pathway created by the connection of the protective earth to the main neutral. This current will flow through the main neutral, back to the star point of the distribution transformer. The flow of this fault loop current will cause the protective device to operate, either by facilitating instantaneous trip of the overcurrent protection (in the case of an MCB) or by monitoring the difference in active and neutral current (in an RCD/RCBO). Figure 13 below shows the flow of current through this earth fault loop.

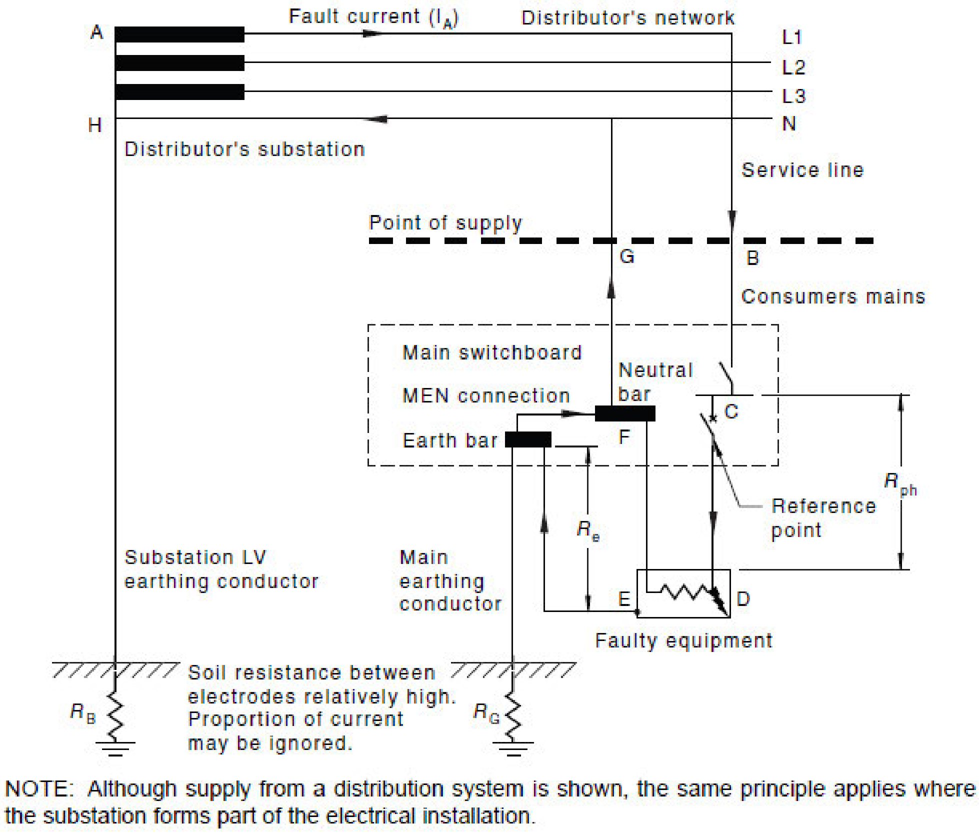


Figure 13. MEN system and earth fault loop as shown in AS/NZS3000 Figure B5 (Standards Australia 2018)

Upstream of the individual circuits, a main switch is installed in the main switchboard to enable the isolation of all circuits. This device can either be simply an isolator, which has no fault protection, or an MCB as described above. The switchboard also houses the energy retailers' metering equipment, to enable monitoring of energy consumption by the retailer for billing. The metering equipment and main switch function as the entry point for electrical connection between the local electrical installation within the premises and the wider electrical distribution network maintained and operated by the distribution network service provider (DNSP). This link is bridged by the consumers mains, larger conductors that are installed between the DNSPs fuses and the customers metering isolation links.

Figure 14 below is a single line diagram, highlighting the specific connections between components in a typical residential main switchboard.

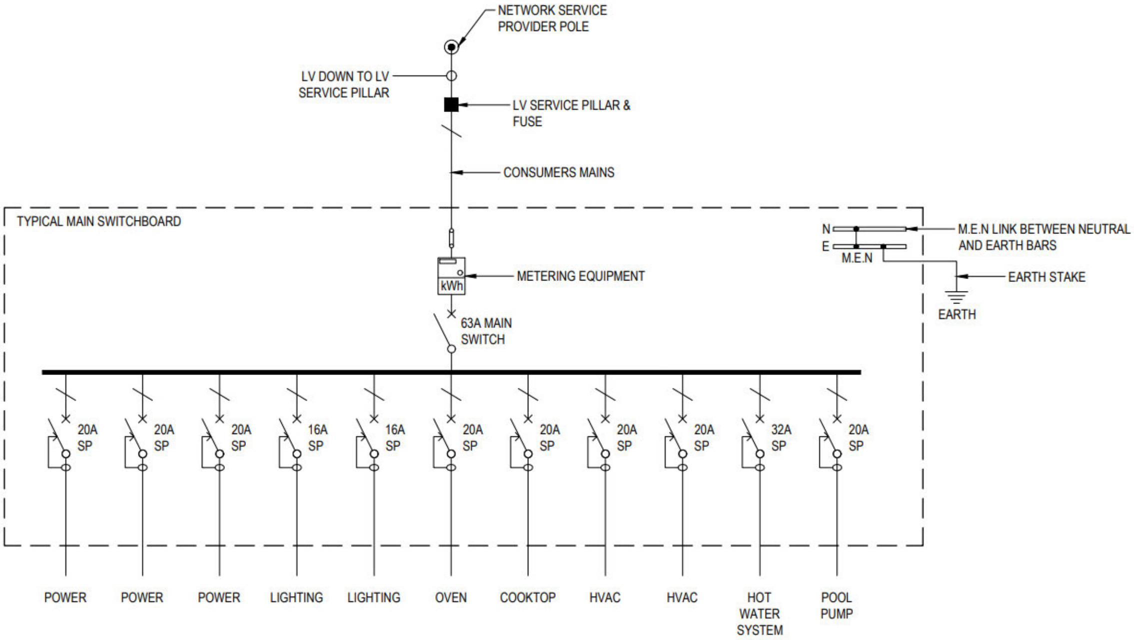


Figure 14. Single Line Diagram (SLD) of residential main switchboard.

AS/NZS3000 Clause 2.2.1 dictates that the arrangement of circuits takes into account the relationship of the connected equipment, including its operational requirements and the load characteristics in reference to the component ratings (Standards Australia 2018). Typical load groups per circuit include.

- Power – consisting of general power outlets of the same rating (10A)
- Lighting – consisting of light fixtures.
- Oven – single unit
- Cooktop – single unit
- HVAC – typically by groups of similar rated smaller units (2.5kW or below) or individual larger units (5kW and above)
- Hot water system (single unit)
- Other hardwired equipment such as pool pumps

For the loading of circuits, AS/NZS 3000 gives guidance on the number of consuming points to be connected to each circuit in Table C9, shown in Figure 15 below.

TABLE C9

GUIDANCE ON THE LOADING OF POINTS PER FINAL SUBCIRCUIT

Cable cross-sectional area[(1)] mm²	Rating of circuit-breaker[(1)] A	Contribution of each point (A) (sum not to exceed rating of circuit-breaker)						Maximum connected load for a range[(4, 5)] W
		Lighting points[(6)]	10 A single-phase or multiphase socket-outlets[(3, 7, 8, 9)]		15 A single-phase or multi-phase socket-outlets[(8, 9)]	20 A single-phase or multi-phase socket-outlets[(8, 9)]	Permanently connected fixed or stationary appliances[(6, 10)] or water heaters	
			Non-domestic installations without permanent airconditioning	All domestic installations and non-domestic installations with permanent airconditioning				
1	6	0.5	NP	NP	NP	NP	Connected load	NP
1	8	0.5	NP	NP	NP	NP		NP
1	10	0.5	NP	NP	NP	NP		NP
1	13	0.5	NP	NP	NP	NP		NP
1	16	0.5	NP	NP	NP	NP		NP
1.5	8	0.5	NP	NP	NP	NP		NP
1.5	10	0.5	NP	NP	NP	NP		NP
1.5	13	0.5	NP	NP	NP	NP		NP
1.5	16	0.5	NP	NP	NP	NP		5000
1.5	20	0.5	NP	NP	NP	NP		5000
2.5	10	0.5	NP	NP	NP	NP		NP
2.5	13	0.5	2	1	NP	NP		NP
2.5	16	0.5	2	1	15	NP		5000
2.5	20	0.5	2	1	12	20		8000
2.5	25	0.5	2	1	10	18		8000

(continued)

TABLE C9 *(continued)*

Cable cross-sectional area[(1)] mm²	Rating of circuit-breaker[(1)] A	Contribution of each point (A) (sum not to exceed rating of circuit-breaker)						Maximum connected load for a range[(4, 5)] W
		Lighting points[(6)]	10 A single-phase or multiphase socket-outlets[(3, 7, 8, 9)]		15 A single-phase or multi-phase socket-outlets[(8, 9)]	20 A single-phase or multi-phase socket-outlets[(8, 9)]	Permanently connected fixed or stationary appliances[(6, 10)] or water heaters	
			Non-domestic installations without permanent airconditioning	All domestic installations and non-domestic installations with permanent airconditioning				
2.5	32	0.5	2	1	8	16		10 000
4	16	0.5	2	1	15	NP		5000
4	20	0.5	2	1	12	20		8000
4	25	0.5	2	1	10	18		10 000
4	32	0.5	2	1	8	16		10 000
6[(2)]	20	0.5	2	1	12	20		10 000
6[(2)]	25	0.5	2	1	10	18		10 000
6[(2)]	32	0.5	2	1	8	16		13 000
10[(2)]	32	0.5	2	1	8	16		13 000
10[(2)]	40	0.5	2	1	8	16		>13 000

NP = denotes socket-outlets not permitted on these circuits

Figure 15. Guidance on the maximum loading of circuits (Standards Australia 2018)

Applications for Project

The information found undertaking this research highlights the specific arrangement of consuming devices in a typical residential installation. Understanding the physical construction of an electrical installation also provides a foundation to aid in understanding the connection of a generating device, such as a solar generating installation.

2.4 Residential Solar Generation

The primary goal of the control algorithm is to bridge the temporal gap between the peak period of generation of electrical energy by the rooftop solar system and the periods of usage of electricity by the occupants of the household. A multitude of factors affect the energy yield of a solar system, and an understanding of these factors is essential to the development of an appropriate control solution.

2.4.1 Solar System Topology

This project is primarily concerned with determining total power generation over a defined time period in each 24-hour cycle, however it is important to identify the main components that form a working solar system.

The equipment that collectively form the solar system includes:

- Photovoltaic (PV) Inverter/s
- PV modules/panels
- Balance of system equipment (BoS)

The components of a solar system that dictate its capacity to generate electricity are photovoltaic (PV) panels and an inverter, while the balance of system components serve to control and monitor electricity throughout the system. The balance of system components include DC and AC cabling, protective devices, metering and system monitoring equipment (GSES 2021, pp. 166-7).

Photovoltaic panels, also known as solar panels, convert sunlight into electricity, being responsible for power generation within the system. The output of each panel is dependent on both its electrical characteristics and performance characteristics (GSES 2021, pp. 86-7). Electrical characteristics are an intrinsic property of the panel itself and are dependent upon properties tied to the physical construction of the panel, such as the cell type (mono or polycrystalline). These include the panels maximum power, maximum voltage, maximum current, open circuit voltage, short circuit current and associated efficiency. Performance characteristics are variable to the environment and comprise of external factors such as irradiance and temperature. To account for the variable nature of external influences, manufacturers specify the electrical characteristics of panels under standard test conditions (STC) (GSES 2021, pp. 86-7).

The current for each panel is a small direct current (DC) and generated voltages are also small. To maximize voltage, multiple panels are arranged in series connected ‘strings,’ as series voltages are additive. Multiple strings are arranged in parallel with one another so that the currents in turn add together. This arrangement is known as a PV array maximizes power generation via the simple application of ohms law, power is equal to voltage multiplied by current.

Since the array produces DC at a voltage dependent on the size of the array, it is necessary to convert this to a 230VAC for usage within a typical household. This is achieved by connection of the array to a solar inverter. Inverters employ a combination of pulse width modulation (PWM), voltage control with DC-DC converters or transformers and commutation to match the frequency and voltage magnitude of the grid (GSES 2021, pp. 105-9). Inverters are specified according to the following characteristics.

- Input (DC) – the characteristics of the PV array into the inverter such as maximum power, voltage, and current inputs.
- Output (AC) – the characteristics of the output to either the grid or to loads, such as voltage, frequency, power, power factor and harmonics.
- Efficiency – the efficiency of the inverter to track the maximum power point (MPP) of the array and convert DC to AC.

Figure 16. A 5kW grid connected inverter adjacent a residential switchboard.

The total size of a typical solar system is rated as power in kilowatts (kW) and is dependent on the nameplate rating of the inverter. Residential inverters are typically 3kW, 5kW, 7kW and 10kW (Tushar et al. 2023), though the output specification can differ slightly between individual manufacturers. Inverters allow the input array power to be a degree larger than the nameplate rating, which improves efficiency of the inverter in lower levels of irradiance. This is known as oversizing the array, with the Clean Energy Council allowing a maximum of 1.33 times the inverter rating (CEC 2022). Total PV array sizes are typically 100-133% the rated inverter power output, and the common convention is to name the system size after the aggregate kW rating of the array.

To interconnect the overall solar system with the wider electrical installation, the output of the inverter is connected to the load side of an appropriately rated circuit breaker in the main switchboard. This arrangement can be seen in the single line diagram in Figure 17 below.

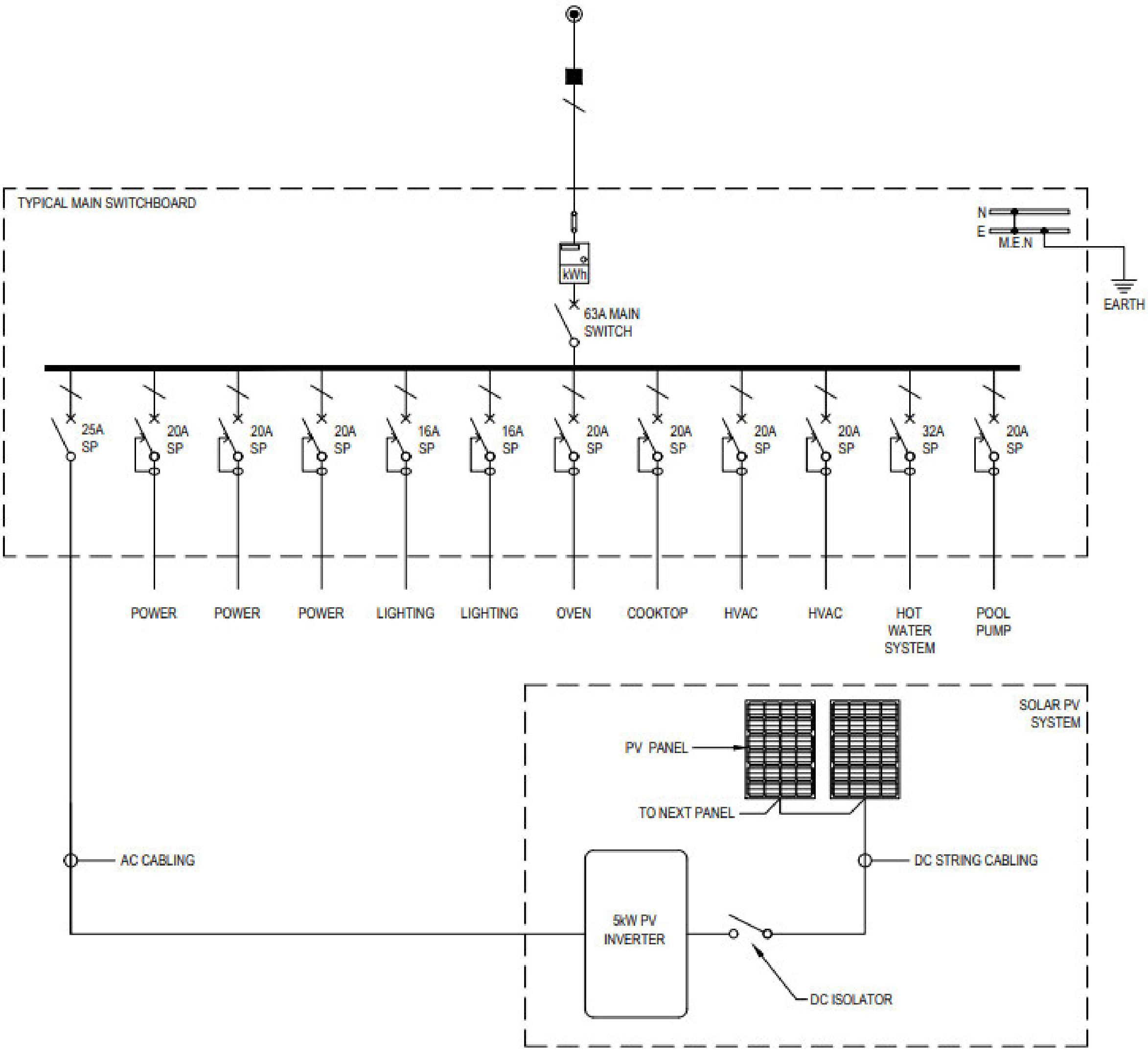


Figure 17. Single Line Diagram (SLD) of residential main switchboard with 5kW solar system.

2.4.2 Battery Energy Storage System (BESS) and Hybrid System Topology

Battery energy storage systems (BESS) allow for the storage of energy generated by the solar system in times where generation exceeds demand. This stored energy can then be utilized in periods of high demand when solar irradiance is low, increasing self-consumption and decreasing reliance on the utility grid. When installed as part of a grid connected solar system, these installations are known as a hybrid system.

As per the construction of a traditional PV solar system, hybrid systems include the PV inverter, modules, and balance of system components. However, additional infrastructure is required to facilitate the integration of a BESS. This includes.

- Batteries
- Battery Inverter/s
- Battery charger/s

The most common battery chemistry for residential solar systems in Australia are deep cycle lead-acid and lithium-ion (GSES 2022). Lead acid batteries trade offer a low-cost entry to storage at the expense of size, increased maintenance, and a maximum depth of discharge (DOD) in the region of 70% (GSES 2022). Depth of discharge is a measure of the battery capacity in amp-hours (Ah) that is available for discharge and has an inverse relationship with the with the life of the battery – as DOD increases, the remaining charge/discharge (duty) cycles available over the lifetime of the battery decrease. To maximise lifespan, DOD of a lead acid battery is typically kept to 20% (GSES 2022). A combination of the small DOD and lower energy density means that the physical dimension of a lead acid battery bank is larger when compared against lithium ion. Ventilation in the area that these batteries are stored is also required to account for the release of gas, and more regular maintenance (such as the topping up of electrolyte) is required (GSES 2022).

In comparison to lead acid, lithium-ion batteries are a more recent chemistry, offering increased energy density and deeper DOD with a longer life cycle, at the expense of higher cost. Unlike lead acid technologies, lithium-ion batteries have the ability to achieve 100% DOD, with typical DOD kept to 80% for longevity (GSES 2022). These systems are fully sealed and do not require ventilation for emissions. As a result, maintenance of lithium-ion batteries is significantly less than that of lead acid, however a battery management system (BMS) is required to monitor conditions and prevent cell over-charging/discharging (GSES 2022).

Figure 18. Tesla Powerwall 3 Lithium Ion (LiFePo4) battery (Tesla Inc. 2024)

Batteries are DC components which require additional devices to manage both their charge and discharge. Multimode inverters are used to convert the DC output of the BESS to a 230VAC signal for consumption by household loads or export to the grid and typically include a built-in charge controller. In an AC coupled system, the inverter is connected between the batteries and the output (AC) side of the PV inverter (GSES 2022).

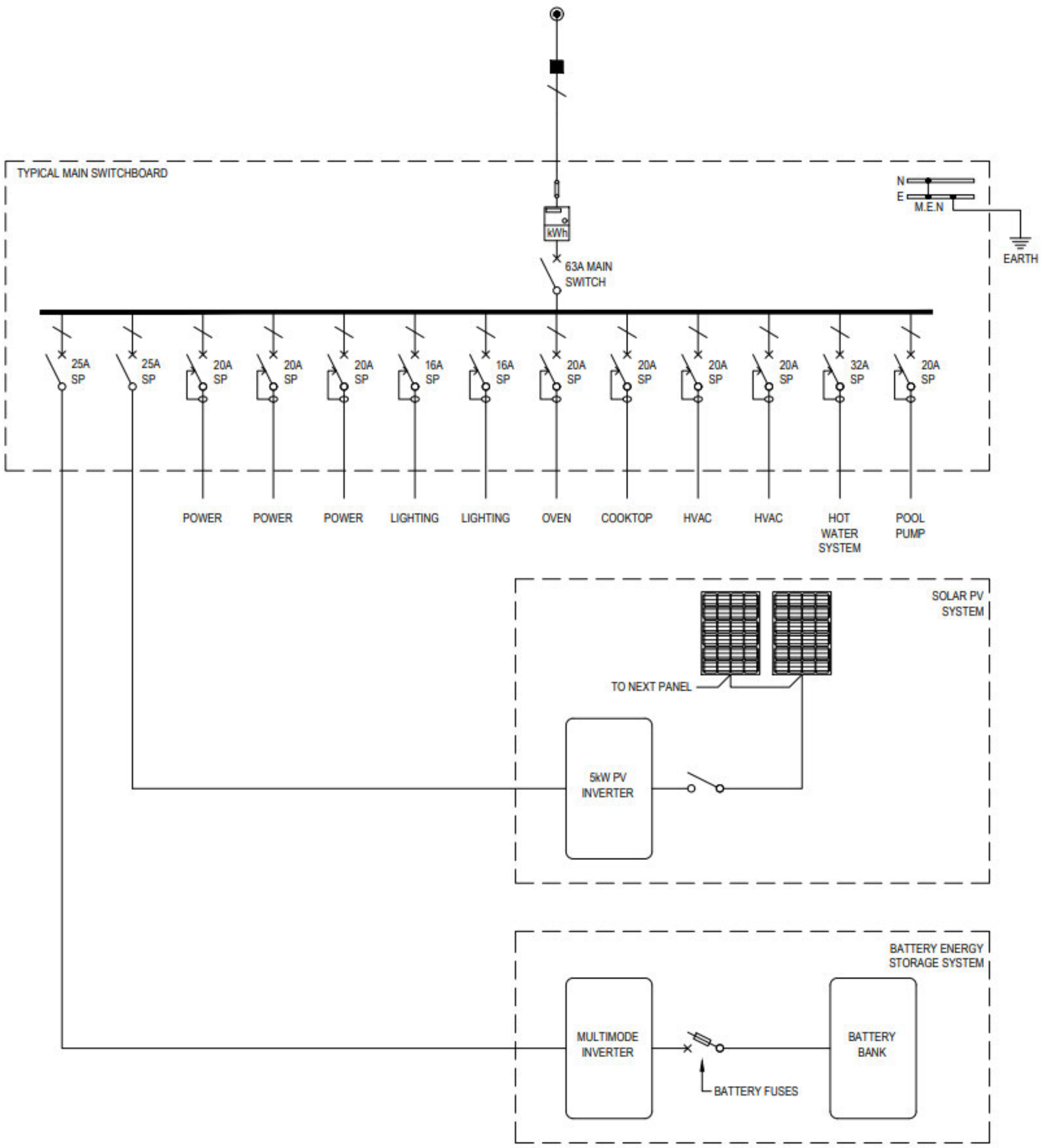


Figure 19. AC coupled battery energy storage system.

For a DC coupled system, the battery bank is connected directly to the PV array on the DC side of the grid inverter. In this case, a separate multimode inverter is not required, however a standalone charge controller is required.

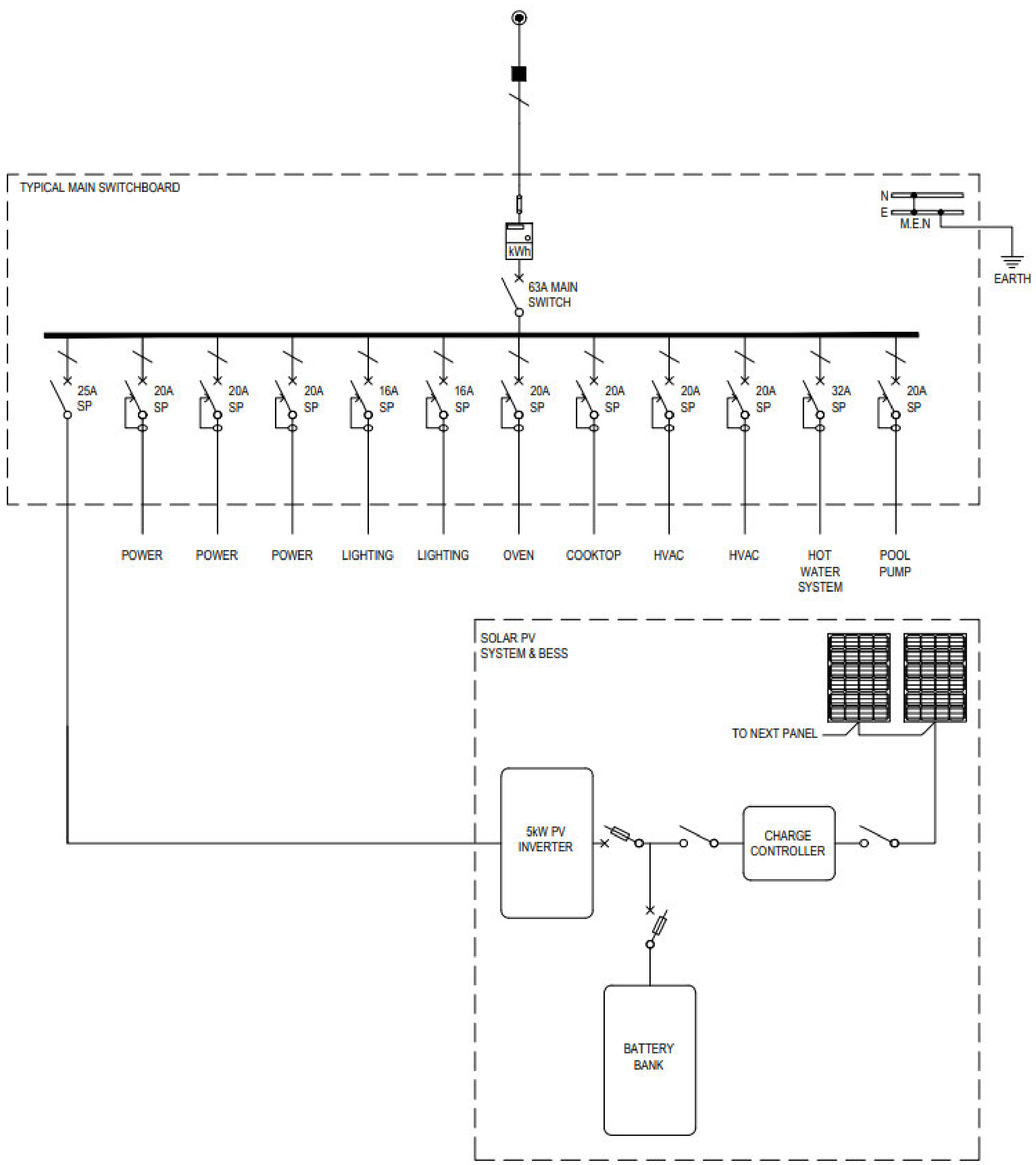


Figure 20. DC coupled battery energy storage system.

DC coupled systems are typically more efficient than their AC coupled counterparts, as the conversion between AC and DC only happens a single time. However, most lithium-ion solutions are AC coupled, as the BESS is complete unit with battery, inverter, charger and BMS built in. This can be seen in products such as the Tesla Powerwall (Tesla Inc. 2024) and LG Chem Resu (LG Corporation 2024).

2.4.3 Solar Generation Profiles

Given the inherent advantages of self-consumption, the alignment of a customer's load profile with their solar system generation profile becomes imperative to maximize the benefit (Nicholls et al. 2015). Similar to the consumer energy usage patterns found by the CSIRO (CSIRO 2013), Nicholls also found that demand tends to peak in the early morning and evening, with HVAC contributing to larger morning demand in winter months.

When analysing solar generation of a 3kW inverter with a matching 3kW array in Queensland, generation matched or exceeded demand in summer between the hours of ~6:00AM and ~5:00PM. During winter, this trend was observed between ~8:00AM and ~4:00PM.

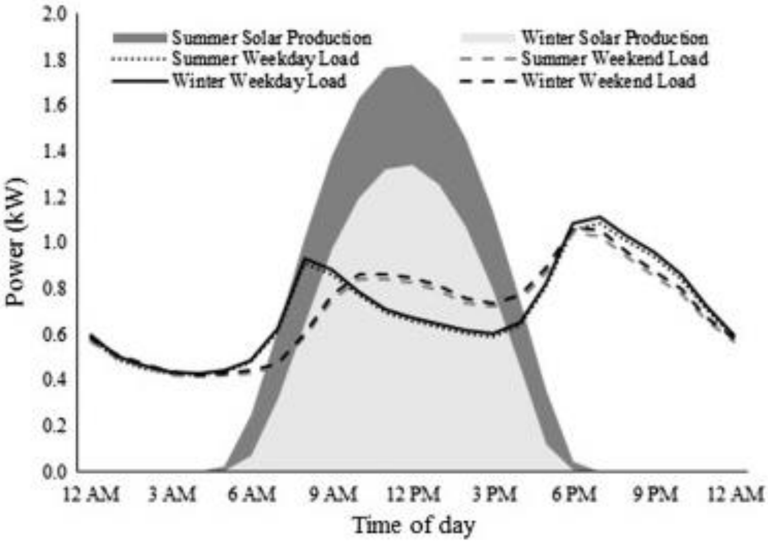


Figure 21. Solar generation vs demand (Nicholls et al. 2015)

Similar solar generation patterns can also be observed through the analysis conducted by the Australian PV institute, through their live PV generation tracking tool. This tool estimates the output across the state as a percentage of the system capacities by analysing data from Solar Analytics and PVOutput (APVI 2023).

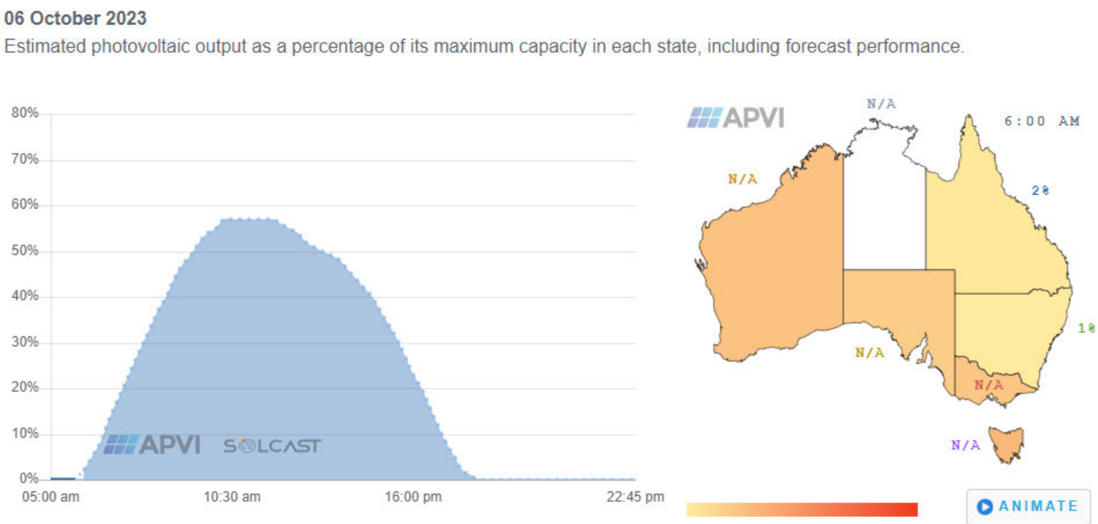


Figure 22. Average solar generation in Queensland on 06/10/23 (APVI 2023)

With reference to Figure 22, output does not exceed 30% of its rated capacity until between 8:00AM and 4:00PM, a time where a large section of Australians residents are at their place of employment. Analysis of lowest and highest yield days through the Australian PV Institute reveals that this bell curve pattern is typical of solar generation.

Though the above resources provide valuable insight into the patterns of generation, PVOutput.org provides a database of past and live performance of actual systems. Figure 23 below shows the generation of a 6.37kW system in a Brisbane suburb (postcode 4055) on the 12th of March 2024.

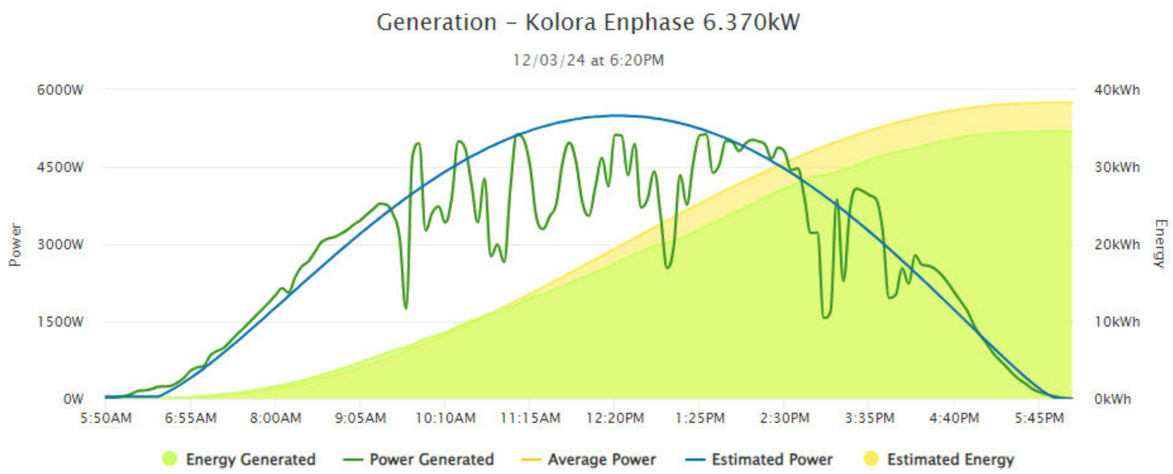


Figure 23 Solar generation in Brisbane, Queensland on 12/03/24 (PVOutput 2024)

The average power generated correlates with both the previous generation patterns and the estimated generation pattern overlaid. However, the actual power does vary through the day, which is likely due to clouds shading the array from the sun as they traverse the sky throughout the day.

It is important to also weigh total energy generation against total demand across the day. The actual output is dependent upon the system sizing and the solar irradiance or exposure (Tam et al. 2017). For analysis, the annual mean exposure is sufficient.

Table 2
Daily electricity produced by the photovoltaic solar systems (in kWh/m^2) [30].

Solar system capacities	Sydney	Canberra	Melbourne	Brisbane	Hobart	Adelaide	Darwin	Perth
1.5 kW	7.05	7.35	6.45	7.95	6.00	7.35	9.00	8.25
2 kW	9.40	9.80	8.60	10.60	8.00	9.80	12.00	11.00
3 kW	14.10	14.70	12.90	15.90	12.00	14.70	18.00	16.50
4 kW	18.80	19.60	17.20	21.20	16.00	19.60	24.00	22.00
5 kW	23.50	24.50	21.50	26.50	20.00	24.50	30.00	27.50

Figure 24. Annual mean daily solar production (Tam et al. 2017)

Figure 24 highlights the annual mean daily electricity generated from common solar system sizes. Note the increase in generation for higher system capacities, for the same value of irradiance. Comparison for Brisbane irradiance against the average 4 person household usage of 17kWh (CSIRO 2018), a minimum system size of 4kW would be required for self-consumption.

2.4.4 Economics of Solar Generation and Ideal System Sizing

In order to determine the ideal system size, it is crucial to understand the economics of solar generation. As touched on in section 2.4.4, two primary methods exist for return on investment for consumers with a solar system. The first is renumeration from feed-in tariffs – exporting generated electricity back to the utility grid. The second method is self-consumption of the generated electricity. Both of these are valid strategies, though further analysis can reveal a preference for renumeration.

A techno-economic analysis was undertaken by Tushar et al to quantify the viability of the four most common solar system capacities in the Australian, considering the economic, environment and electrical retail market in 2023. As part of the study, the average per kWh and solar feed in tariff prices within Australia were compared. With reference to Figure 24 below, self-consumption of generated electricity has clear economic advantages when compared to export and renumeration via a feed-in tariff.

City	Grid electricity rate (cents per KWh)	Solar feed-in rate (cents per kWh)	Benefits of self-consumption (cents per kWh)
Adelaide	35	12	23
Brisbane	26	9	17
Canberra	17	8	9
Darwin	26	26	0
Hobart	26	9	17
Melbourne	26	11.3	14.7
Perth	27	8	19
Sydney	24	6	18
Mean	**26**	**11**	**15**
Std	**4.88**	**6.28**	**7.14**

Figure 25. Average per kWh and feed-in tariff prices 2023 (Tushar et al. 2023)

With the objective of maximizing economic benefit via self-consumption, the study considered 3kW, 5kW, 7kW and 10kW systems, both with and without battery storage, analysing their net present value, benefit cost ratio, internal rate of return and payback period (Tushar et al. 2023).

Solar Components	The rank score for financial indicators				Total score R	Weighting (R/∑R)	Rank position
	NPV	IRR	PB	BCR			
3 kW SS	6	4	4	4	18	0.125	4th
3 kW SSWB	8	8	8	8	32	0.222	8th
5 kW SS	3	3	3	3	12	0.083	3rd
5 kW SSWB	7	7	7	7	28	0.194	7th
7 kW SS	2	1	1	1	5	0.035	1st
7 kW SSWB	5	6	6	6	23	0.160	6th
10 kW SS	1	2	2	2	7	0.049	2nd
10 kW SSWB	4	5	5	5	19	0.132	5th

Figure 26. Ranking of common PV system capacities with and without BESS (Tushar et al. 2023)

The resultant findings indicated that the ideal system size from an economic perspective is a 7kW system without battery storage. The study also revealed that in the current Australian market, the inclusion of battery energy storage is still less viable than a standalone grid connected system, with the highest ranked hybrid installation a 10kW system as the fifth most attractive economic option (Tushar et al. 2023).

2.4.5 Applications for Project

The research undertaken for this section has a direct correlation to the development of energy yield profiles for typical residential solar systems, both with and without a BESS. Ideal PV system sizing for both grid-connected and hybrid systems has been identified, and the pattern of energy generation within the selected area of South East Queensland has been explored. Battery chemistries and the usable energy based upon their recommended depths of discharge have also been found. The information in this section will be used to develop the typical generation profiles in the design for modelling against the typical appliance usage patterns.

2.5 Home Energy Management Systems and Control Algorithms

Though the scope of this project concludes with the development of a preliminary control algorithm, an appreciation of the current state of home energy management systems (HEMS) and control strategies is crucial to understanding how this software will integrate into the wider framework.

A 2015 systematic review of the literature for modelling approaches on HEMS undertaken by Beaudin and Zareipour highlights that energy management systems are fundamentally a tool for demand response. For the purposes of energy management systems, demand response is defined as “intentional electricity consumption pattern modifications by end-use customers that are intended to alter the timing, level of instantaneous demand, or total electricity consumption” (Albadi & El-Saadany 2008). While historically these pattern modifications have primarily been driven by consumers altering their own usage based upon awareness of their own consumption, the implementation of autonomous control within home energy management systems is a growing area of research. An effective system now serves to both limit demand as much as reasonably practicable, while also shifting demand patterns to take account of favourable conditions in terms of “energy costs, environmental concerns, load profiles and consumer comfort” (Beaudin & Zareipour 2015) and does so with a level of autonomy independent to the consumers own conscious decisions.

In order to manage demand response, residential appliances are defined under typical load groups. Beaudin and Zareipour note that certain appliances differ in the group they are classified under in the wider literature, though the most common groupings are.

- Uncontrollable loads – loads that should not be altered because they provide high value to the occupants, such as lighting, television, and computers.
- Curtailable loads – Loads that are responsive to tariff changes, such as dimming of lighting during peak times to reduce kWh consumption.
- Uninterruptible loads – Loads that require sequential, uninterrupted cycles to complete their given task. This includes clothes dryer/washers and washing machines.
- Interruptible loads – Loads that can be interrupted through their cycle and resume at a later time with no ill effects. This includes charging appliances such as laptops, phones, and electric vehicles.
- Regulating loads – Loads that are thermostatically controlled to maintain a desired state, such as hot water systems or HVAC.
- Energy Storage – Loads similar to regulating loads to store and dispense energy such as batteries.

The ideal model for scheduling within HEMS is a moderately recent area within research. Complexity in modelling forecasting uncertainty and multi-objective scheduling results while still balancing the limitations of computational power and timing means that identification of the ideal algorithm is difficult (Beaudin & Zareipour 2015). As this project has a known set of inputs and outputs, and the scope is limited to a known pattern of appliance usages, the number of operational states is finite. For this reason and due to the limited time in which to develop a solution, the development of a finite state machine to implement a prototype control algorithm is deemed to be appropriate, with one specific caveat. Finite state machines (FSM) allow the representation of a complex system as a series of operational states, with transition between states enabled by temporal or triggered inputs. This can be visualized through the use of a state diagram, serving both as a graphical representation and tool to begin algorithm development. FSMs can be one of two types, a Moore machine where outputs are dependent on the state only or Mealy machines where outputs are a function of both the state and the trigger/input. As Mealy machines require less states than a Moore machine for the same system, they are the preferred FSM for this project. The traditional state diagram is described as follows (ELE3307 2022).

- Circle: represents a state, or the starting state in the case of a double circle.
- Arrows: transitions between states.
- Transition labels: condition to trigger change in state and the associated output. The '/' separator is used between the trigger and output.

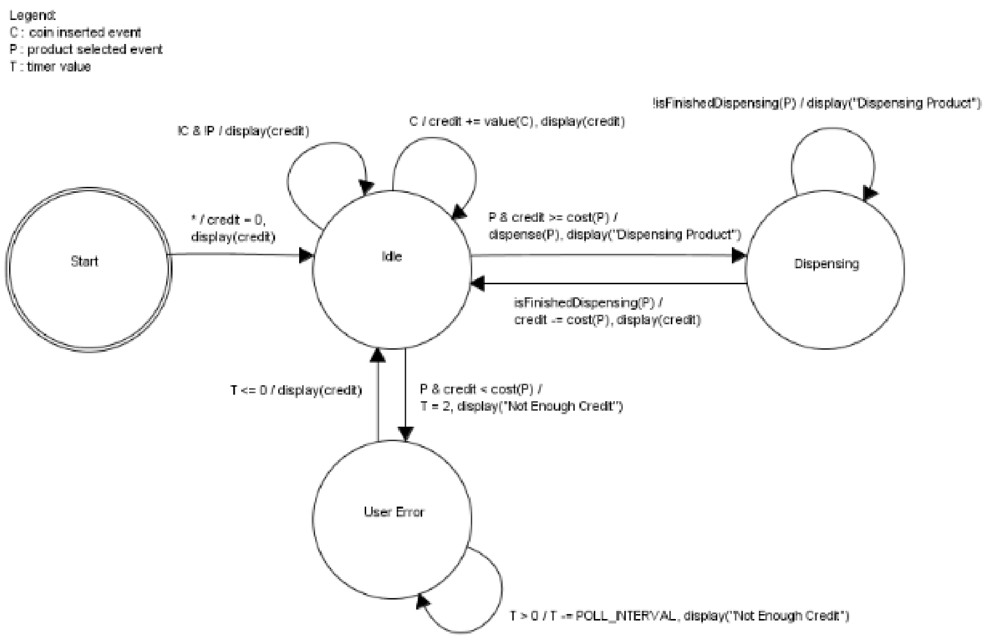


Figure 27. Mealy Machine – State Diagram of coin operated vending machine (ELE3307 2022).

Though the FSM enables ease of visualization and development of a control algorithm, they can become unwieldy when multiple processes are required for each state. If these processes are required to occur in several combinations, an ever-increasing number of states is required to quantify the combinations. In this instance, it is better to represent these in a manner where each separate process belongs to a specific state at any given time. This allows parallel operation of the processes, known as orthogonality, to enable a more intuitive representation of complex state machines. The design technique described is called a statechart, which builds upon the previous concepts of the finite state machine and utilize the following graphical representations (ELE3307 2022).

- Rounded rectangle: represents a state. Rectangles encompassing the states represent a process.
- Dashed line: used to separate concurrent processes.
- Arrows: transitions between states within a process. Arrows from a black circle are the initial state.
- Transition labels: condition to trigger change in state or process. The '/' separator is used as 'broadcast communication' between processes to enable events to change concurrent processes.

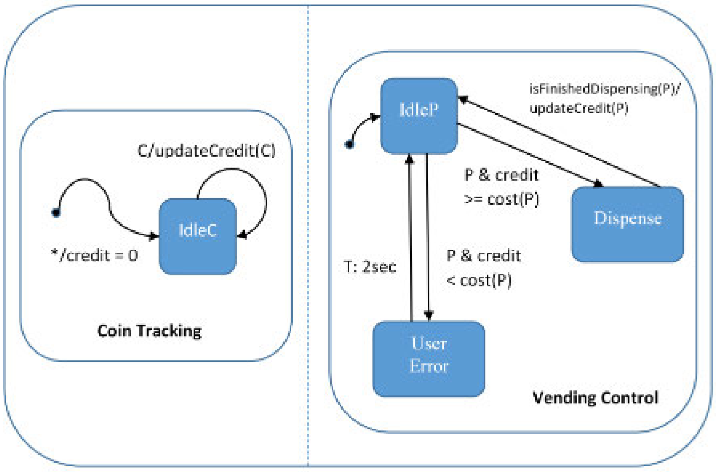


Figure 28. Statechart of coin operated vending machine (ELE3307 2022).

Applications for Project

The literature reviewed as it pertains to home energy management systems and control strategies has provided clarity with regards to the load groupings of home appliances. This will enable modelling of the loads in a manner that is consistent with the current state of research, as well as providing two clear objectives – limiting demand and shifting demand to take advantage of periods of high energy production from solar generation. The implementation of the system as a statechart will enable prototype algorithm development in an efficient manner, to achieve the desired goals within the time constraints of the project.

2.6 Knowledge Gap

A great deal of literature exists within this field, with extensive research having been undertaken into the technology of rooftop generation system and the battery storage system components, as well as techno-economic studies that account for modern feed-in tariffs, yields and payback periods. Though self-consumption has been highlighted as the most economically sound usage profile for consumers, and battery systems appear to be less desirable from a financial standpoint, the arguments for both of these points are based upon existing patterns of usage, with peak times in early morning and the evening. Limited research exists outside these typical patterns of usage, and advice to consumers is to simply move their usage patterns to align with the generation yields more closely, not accounting for the working and lifestyle habits of consumers. In addition to this, patterns of usage tend to be analysed on a macro level, without understanding how individual appliance usage (such as washing machines, dryers, dishwashers) impact demand periods. Without meaningful research into how to close this temporal gap between generation and usage, there is only so much that can be done.

There currently exists no automated solution to close this gap – this project presents a viable opportunity to further align the generation and usage profiles, increasing self-consumption and limiting reliance on the grid. Higher scrutiny will be placed upon changing consumer habits as they relate to individual appliance usage and how these appliances can be operated autonomously based upon current irradiance. It will also present an opportunity to reevaluate the techno-economic viability of battery energy storage systems within an ecosystem that is not constrained by historical usage patterns.

3 METHODOLOGY

This chapter outlines the methodology undertaken to develop and deliver the project. There are four distinct sections within the chapter that detail the requirements to complete the project.

- Section 3.1 is project planning, detailing the resources required and highlighting potential limitations.
- Section 3.2 details the project parameters, including the scope and tasks required to achieve a satisfactory outcome.
- Section 3.3 details the concept design stage. This includes identifying the selected method of computational modelling, a schematic design of the model and the inputs and outputs to the system.
- Section 3.4 outlines the detailed design stage. This details the design and implementation of the model utilizing computer software to begin analysis of the system.

3.1 Project Planning

The primary goal of the project is the development and optimization of a preliminary control algorithm; therefore, software licensing fees are the primary contributor of cost to the project. The University of Southern Queensland currently provides student access to programs such as Office 365 and MATLAB, including the required addon Simulink environment. Table 4 below outlines the expected resources required to complete the project.

Table 4. Project Resources

Resource	Cost	Comment
Computer with Internet Access	N/A	Already acquired. Access to reputable sources through the likes of Google Scholar and the IEEE is already sourced through UniSQ.
Stationary	$20	Already have notebooks and pens. May require additional but majority of notetaking will be electronic.
MATLAB	N/A	Access is already sourced through UniSQ student licensing
Microsoft Excel	N/A	Access is already sourced through UniSQ student licensing

The major limitations on the project were time and uncertainty around the new format of the overarching Professional Engineer Research Project delivery subject ENP411. The University of Southern Queensland begins its transition from a two semester to a three-trimester format throughout 2024. As the development of the dissertation has not been undertaken in this manner before, both students and faculty will be navigating this change together for the first time. To assist with delivery of the project, the overarching subject ENP4111 consists of seven individual submissions, with the submission of the final project due on the 4$^{th\ of}$ November 2024. In addition to the above, to ensure that the project reaches a definitive conclusion, the following limitations have been implemented.

- Economic analysis is undertaken on the impacts for the typical yields and usage patterns developed within the project methodology only, with reference to the Origin Energy tariff pricing structure identified within the literature review.
- Due to difficulties in determining upfront BESS and PV system costs, without sourcing multiple quotes across different system sizes, the economic analysis will assume a ‘rule of thumb” of $1000/kW for each.

3.2 Project Parameters

This section outlines the parameters of the project in order to bound the scope and define the expected outcomes for delivery.

Scope and Tasks

The scope of the project includes distinct research, modelling, implementation, and analysis phases. Tasks for the project are as follows.

1. Undertake literature review to ascertain the current state of knowledge within the area of interest, including economic and technical aspects of residential energy consumption, solar generation, arrangement of electrical, solar and battery installations, and existing home energy management systems.
2. Analyse power requirements and usage patterns for individual appliances, including but not limited to
    a. Lighting
    b. Cooking appliances – oven, cooktop, microwave
    c. Refrigerator and freezers
    d. Dishwasher
    e. Clothes Washing Machine
    f. Drier
    g. HVAC – Air conditioning and space heating
    h. Entertainment and lifestyle devices – television, computer, phones and tablet charging.
    i. Hot water system
    j. Pool/irrigation pumps

3. Develop typical daily usage patterns based upon these devices. Expand to weekly, monthly, seasonal and annual usage. Undertake usage pattern development for two most common household occupancy types (2 person and 4 person).
4. Analyse solar generation for typical solar system capacities in the South East Queensland area. Determine system capacities required to maximize self-consumption for 2 and 4 person households. Develop typical daily, weekly, monthly, seasonal and annual generation profiles for each system.
5. Develop an algorithm to automate appliance usage as much as practicable, to align usage and generation times. Prioritize freedom of usage around low draw, on demand appliances (e.g. entertainment) and scheduling of high draw, intermittent use appliances (e.g. pool pumps, washing machines).
6. Simulate the algorithm as part of a wider home energy management system for both the 2- and 4-person household. Analyse the results.
7. If time permits, repeat algorithm development and simulation, this time for a hybrid system including a BESS.
8. Undertake a techno-economic analysis on both the standard and hybrid system to determine feasibility.
9. Present results and suggest next steps.

Following the literature review in chapter 2, analysis for the first four tasks has been completed. Chapter 3 focuses upon the development of typical generation and consumption profiles based upon the gathered data, and the development of an algorithm (task 5) that will serve as a concept level home energy management system.

3.3 Project Schematic Design - Concept

Before modelling of the algorithm can be undertaken, it is crucial to develop a concept level design to clearly identify the system variables. Schematic design for the concept encompasses the completion of tasks 2, 3, and 4 as noted in section 3.2.1. The outcomes of the concept design are as follows.

- Spreadsheets (.xl file extension) to model typical appliance demand and usage patterns for 2- and 4-person households over daily, weekly, monthly, seasonal and annual time periods.
- Spreadsheets (.xl file extension) to model optimized appliance demand and usage patterns for 2- and 4-person households over daily, weekly, monthly, seasonal and annual time periods.
- Spreadsheets (.xl file extension) to model typical solar system generation patterns and performance daily, weekly, monthly, seasonal and annual time periods.
- Identification of system states and schematic design to implement modelling of a finite state machine.

3.3.1 Appliance Demand and Usage Patterns

As identified throughout the literature review, Table 5 below details the typical appliance demands identified from product data sheets.

Table 5. Typical appliance power demand details

Appliance	Details
Hot water system (Heat Pump)	Power: 0.94kW
HVAC (Bedroom)	Power Cooling: 0.51kW
	Power Heating: 0.65kW
HVAC (Living)	Power Cooling: 1.39kW
	Power Heating: 1.49kW
Downlight (LED)	Power: 9W
Oven	Power: 3.6kW
Microwave	Power: 1.75kW
Cooktop	Power Total: 6.5kW
	LHS front: 2.3kW
	RHS front: 1.2kW
	LHS rear: 1.2kW
	RHS rear: 1.8kW
Refrigerator/Freezer	Power: 2.4kW (~10A)
	Consumption: 425kWh/year
	1.16kWh/day
Dishwasher	Power:2.0-2.4kW
	Consumption: 230kWh/year (eco wash)
	630Wh/day
	Cycle time: 210 mins (eco wash)
Washing Machine	Power: 375W
	Cycle time: 37 minutes (normal wash)
Clothes Dryer	Power: 1.75kW
	Cycle times: 30,60,120,180 minutes
Computer	230W
Television	Power: 145-245W
	Consumption: 532kWh/year
Pool Pump	Power: 0.75kW
	Consumption: 563kWh/year

Though the literature review identified typical consumption patterns, these were across a multitude of consumers and therefore a range of different appliance providers. The granularity of appliance usage was also lacking in the literature, with multiple appliances grouped together. The project is focusing on the creation of an algorithm that aligns solar generation and appliance usage with clearly defined products, and due to time constraints, it is not feasible to account for variability of usage between each day in a typical year. As a result, it is necessary to make certain assumptions regarding appliance usage, in order to simplify the development of the usage profiles and begin modelling of the algorithm as soon as possible. Assumptions as they apply to the appliances can be seen in the following list, with specific assumptions for each appliance identified in their respective sections.

- Appliance usage patterns in each group shall assume the minimum amount of diversity and the maximum demand during all periods of usage. The only exception to this will be the cooktop. This is to ensure that that the final control algorithm is optimized for the heaviest practical loading.
- The pattern of appliance usage shall be assessed over 15-minute periods.
- The pattern of appliance usage across each day of a given week shall be identical.
- The pattern of usage across each week of a given season shall be identical, with variation occurring between seasons only.

3.3.1.1 Hot Water System

It is assumed that the ambient temperature of the environment will have negligible effect on the heating of the system. Time for the hot water system to reach temperature is 3 hours, based on its documented 270L capacity and 89L/hour recovery rate. It is assumed that the system will hold temperature until the following day. It is assumed that the hot water system will be supplied by tariff 31 and operate overnight.

Equation 1

$$Hourly\ consumption: 0.94kW * 1 = 0.94kWh$$

3.3.1.2 HVAC

It is assumed that each season shall utilise a single mode of operation for HVAC only. Summer and spring shall use the demand details for cooling, while winter and autumn both utilise demand for the heating cycle. The HVAC shall consist of the nominated split systems in the following locations.

- Bedroom 1: 2.5kW split system
- Bedroom 2: 2.5kW split system
- Bedroom 3 (4-person household only): 2.5kW split system
- Bedroom 4 (4-person household only): 2.5kW split system
- Living area: 5kW split system

3.3.1.3 Lighting

It is assumed that the entirety of the lighting within the premises consists of the nominated LED downlights. Reflecting the minimum amount of diversity all lighting is assumed to be operational during periods of use. The spread of downlights throughout the premises shall be as follows.

- Bedroom 1: 2x fixtures
- Bedroom 2: 2x fixtures
- Bedroom 3 (4-person household only): 2x fixtures
- Bedroom 4 (4-person household only): 2x fixtures
- Living area: 4x fixtures
- Dining area: 4x fixtures
- Kitchen: 4x fixtures
- Bathroom: 2x fixtures
- Toilet: 1x fixture
- Ensuite (4-person household only): 2x fixtures
- Halls: 3x fixtures
- Laundry: 2x fixtures

3.3.1.4 Cooking Appliances – Oven, Microwave and Cooktop

For a 2-person household It is assumed that morning periods of cooking consist of the usage of the microwave only, while evening periods utilize the oven, microwave and cooktop. For the 4-person household, it is assumed the cooktop is also used in morning and lunch periods to account for the preparation of meals for children and closer align the expected demand identified in the literature review. The microwave and oven are both assumed to operate at their maximum demands for each period of usage. The cooktop is assumed to operate utilising the two largest hobs for any given period of usage.

Equation 2

$$Hourly\ consumption\!:= 2.3kW + 1.8kW = 4.1kWh$$

3.3.1.5 Refrigeration

It is assumed that the load of the refrigerator compressor is spread uniformly across a 24-hour period. Equation 1 below determines the hourly consumption of the refrigerator.

Equation 3

$$Hourly\ consumption\!: \frac{1.16kWh}{24\ hours} = 48.33W$$

3.3.1.6 Dishwasher

It is assumed that the dishwasher operates a single full cycle each day. The cycle is assumed to be the eco wash identified in the product data sheet, operating for a period of 210 minutes. The hourly demand is determined by the following.

Equation 4

$$Hourly\ consumption: 2.4kW * 1 = 2.4kWh$$

3.3.1.7 Washing Machine

It is assumed that the washing machine operates a single full cycle each day. The cycle is assumed to be the normal wash identified in the product data sheet, operating for a period of 37 minutes. The hourly demand is determined by the following.

Equation 5

$$Hourly\ consumption: \frac{375Wh}{60} * 37 = 231.25Wh$$

3.3.1.8 Clothes Dryer

It is assumed that the clothes dryer operates a single full cycle each day. The cycle is assumed to be operating for a period of 60 minutes. The hourly demand is determined by the following.

Equation 6

$$Hourly\ consumption: 1.75kW * 1 = 1.75kWh$$

3.3.1.9 Television

It is assumed that there is a single television within the premises. The data sheet for the selected television specifies a maximum demand of 245W and an estimated annual consumption of 532kWh, or 1.458kWh/day. Based on this estimated consumption, the television would have to be operating at its maximum demand for a period of six hours each day. Conversely, the Australian Viewing Report published by Neilson reports that Australians spend on average 2 hours and 27 minutes watching television per day (Regional TAM et al. 2018). Noting the annual consumption figure given in the data sheet is for the EU, the consumption for this project will be based on the approximate 2.5-hour time reported by Neilson and the maximum demand.

Equation 7

$$Daily\ consumption: 245W * 2.5 = 0.6125kWh$$

$$Hourly\ consumption: 245W * 1 = 0.245kWh$$

Usage is assumed to be consistent across each day, with the period of usage shared between all occupants.

3.3.1.10 Computer

The Neilson report also that consumers average 22 hours per month viewing video on devices that include desktop and laptop computers, tablets and smart phones. For the purposes of this project, it is assumed that the reference laptop computer is the only device in the household that is used for this purpose.

Equation 8

$$Daily\ usage\colon \frac{22\ hours}{30.44\ days} = 0.7227\ hours$$

$$Hourly\ consumption\colon 230W * 0.7227 = 0.1662kWh$$

3.3.1.11 Pool Pump

It is assumed that the pool pump will operate for 8 hours each day of the year, regardless of the season. The given estimated annual consumption for the pump is 563kWh/year or 1.5424kWh/day.

Equation 9

$$Hourly\ consumption\colon \frac{1.5424kWh}{8} = 0.1928kWh$$

Though the pump is rated for a maximum output of 0.75kW, the manufacturer information specifies that it is designed to operate at less than its maximum output to improve the longevity of the pump. It is assumed that the pool pump will be supplied by tariff 33 and operate during the day outside the hours of 4-9pm.

3.3.1.12 Typical Usage Patterns

Incorporating the findings of the literature review and the assumptions made for appliance usage, typical usage patterns have been developed. These typical patterns will be used to baseline the performance of the solar generation for the chosen PV system, to ascertain the level of self-consumption without any controls in place. Distribution of appliance usage has been based upon the “Typical House Energy Use” dashboard (CSIRO 2013) while total daily consumption has been based upon the findings from the 2020 Residential Energy Consumption Benchmarks (Frontier Economics 2020). Due to the minimum amount of diversity being used for appliances, overall consumption within the model is higher than the averages given in the literature review. It has been chosen to maintain these higher-than-average consumption values in order to minimise change to the typical appliance usage patterns. As the primary objective of the project is the development of an algorithm that modifies the patterns of appliance usage, the patterns themselves have been weighted higher than the values of consumption.

Figure 29 to Figure 32 below are graphical representations of the typical daily usage patterns for a 2-person household across each season. The Excel spreadsheet to be used to create these graphs are located in Appendix D. Further input spreadsheets for each appliance are derived from the graphical spreadsheet and are used as inputs for the computational model - also found in Appendix D.

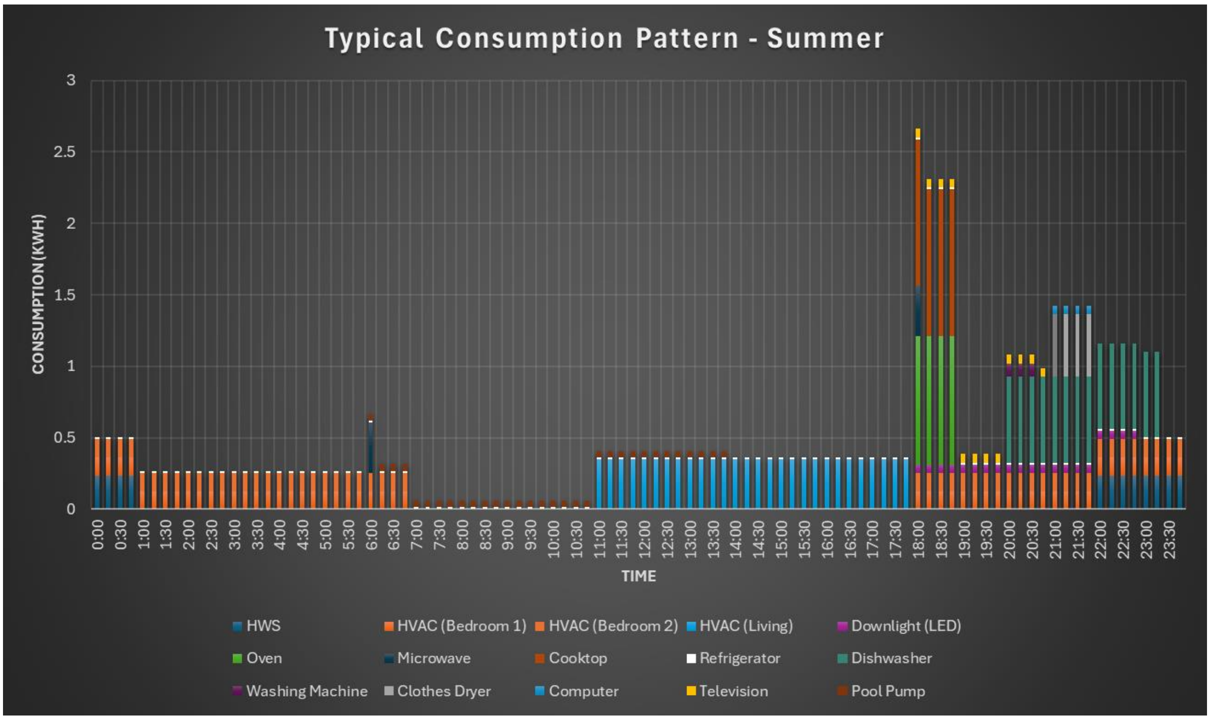


Figure 29. Typical daily usage patterns per season for 2-person household (summer)

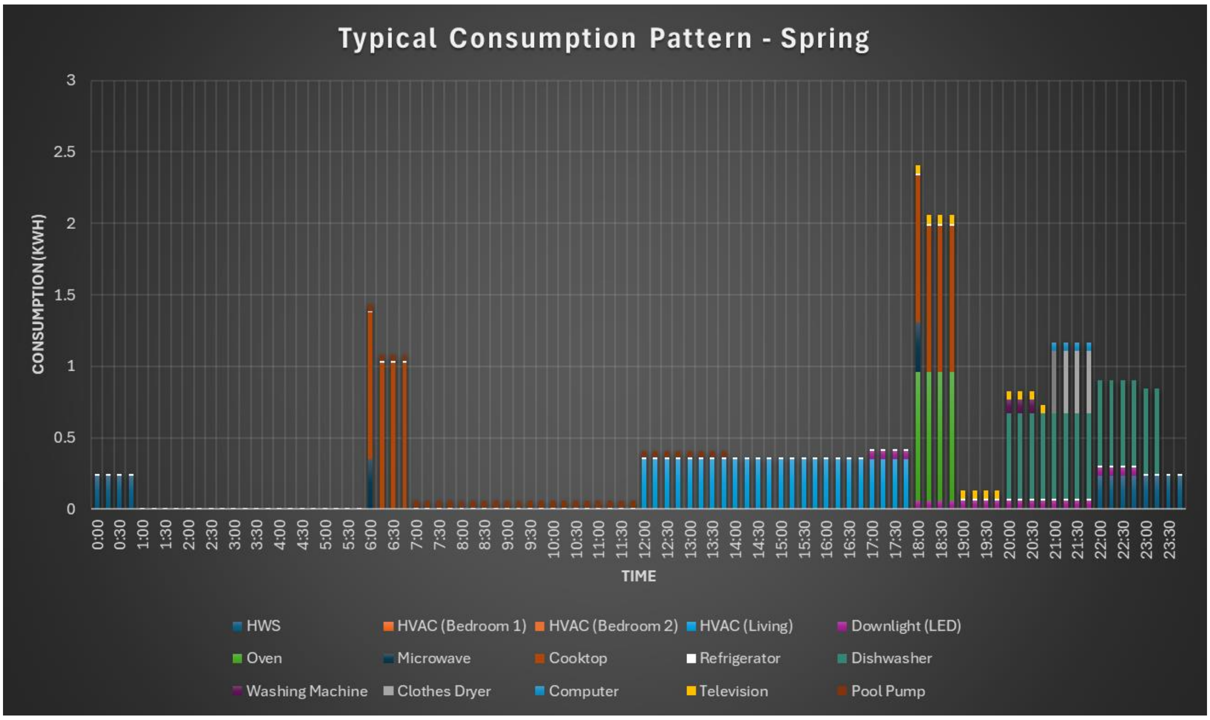


Figure 30. Typical daily usage patterns per season for 2-person household (spring)

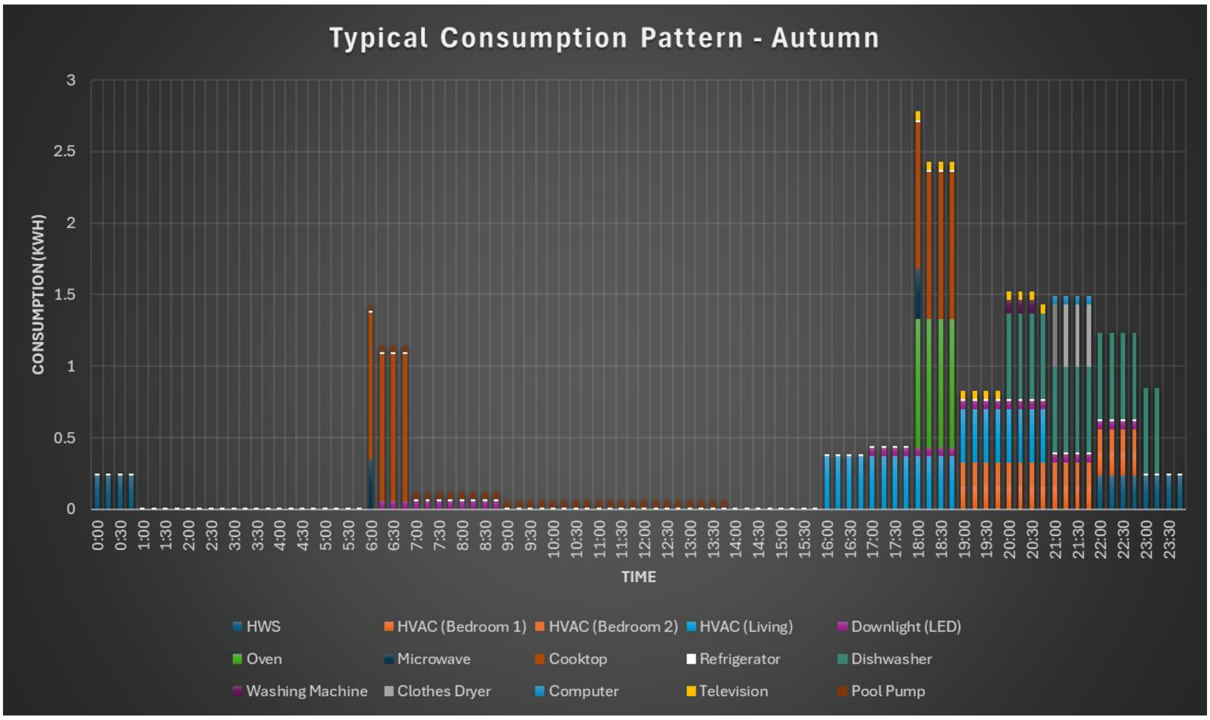


Figure 31. Typical daily usage patterns per season for 2-person household (autumn)

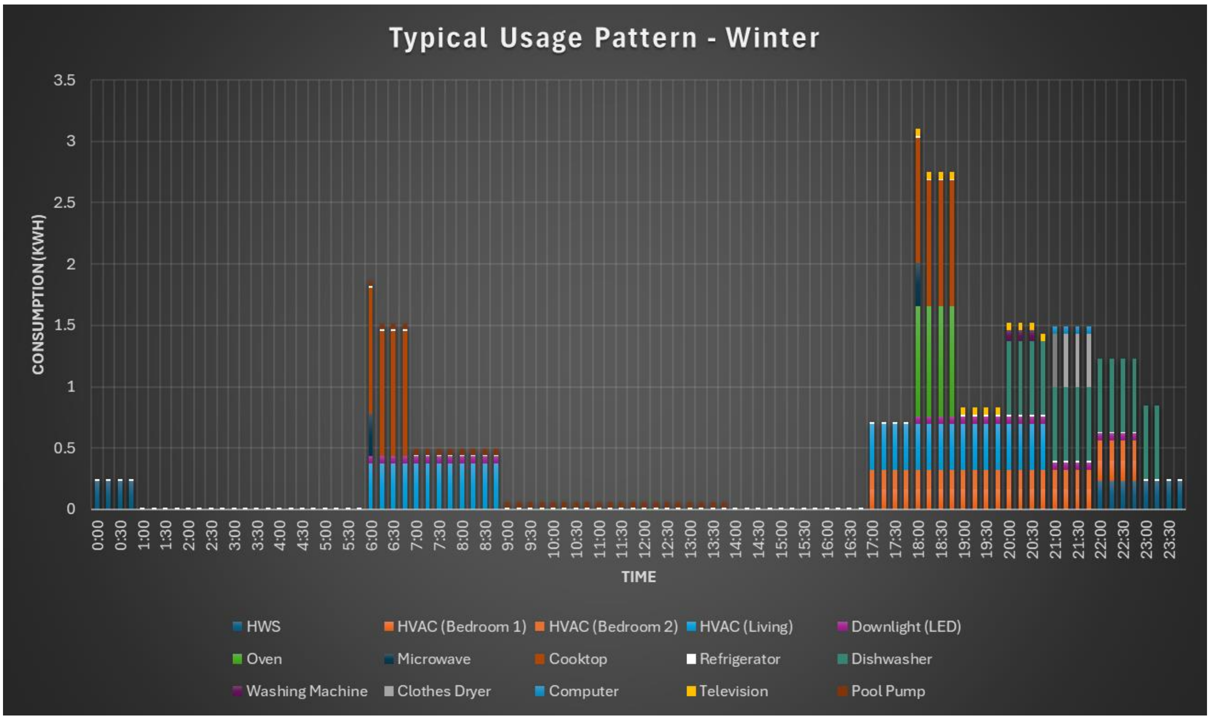


Figure 32. Typical daily usage patterns per season for 2-person household (winter)

Figure 33 to Figure **36** below is a graphical representation of the typical daily usage patterns for a 4-person household across each season. The Excel spreadsheet for the graphs as well as the derived input spreadsheets are located in Appendix D.

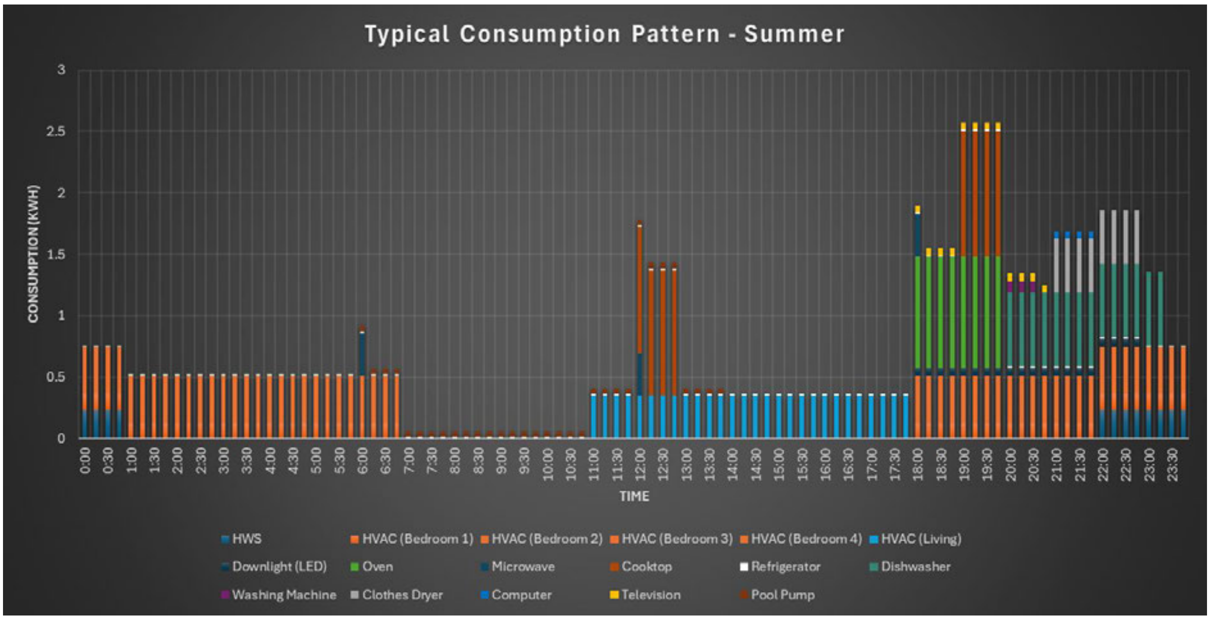


Figure 33. Typical daily usage patterns per season for 4-person household (summer)

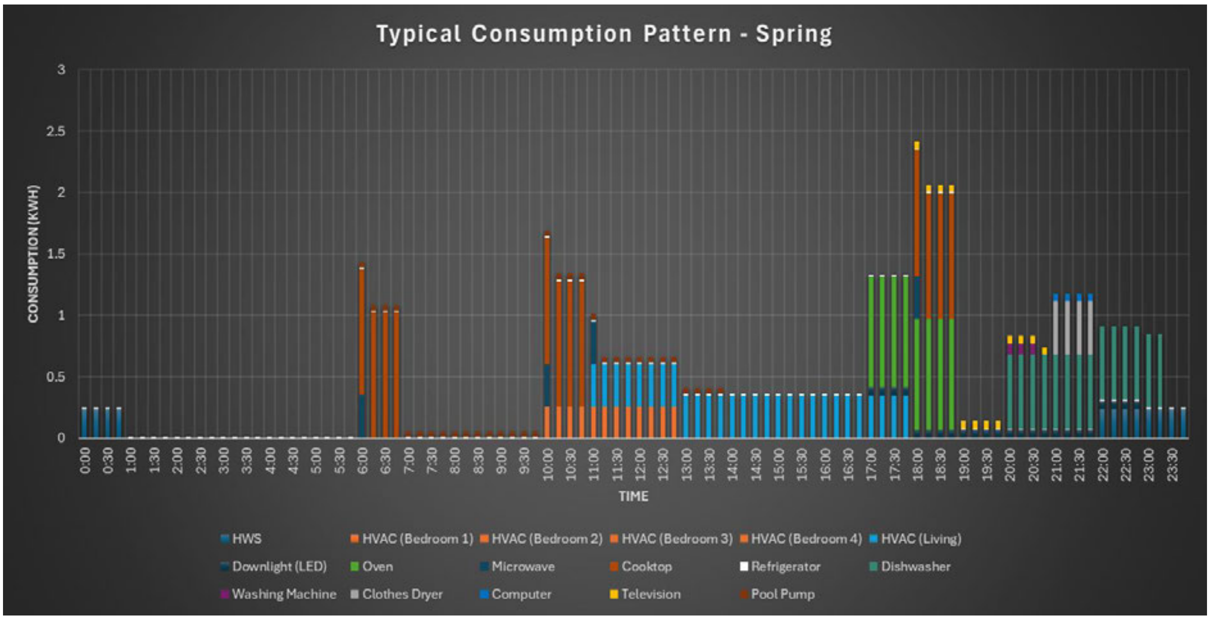


Figure 34. Typical daily usage patterns per season for 4-person household (spring)

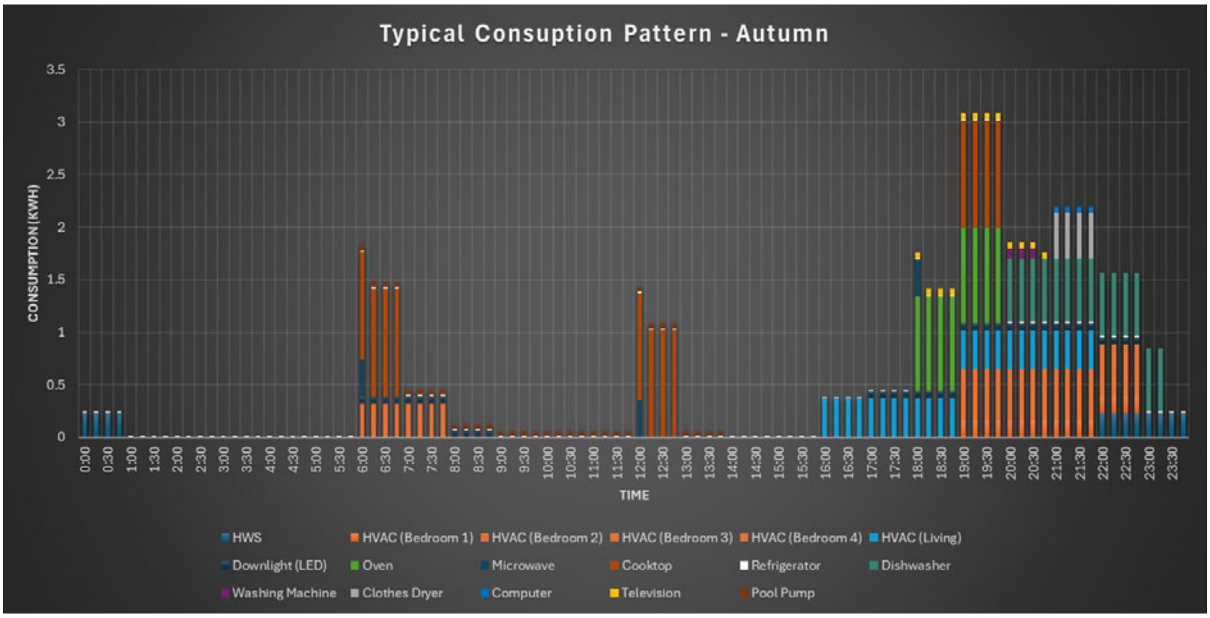


Figure 35. Typical daily usage patterns per season for 4-person household (autumn)

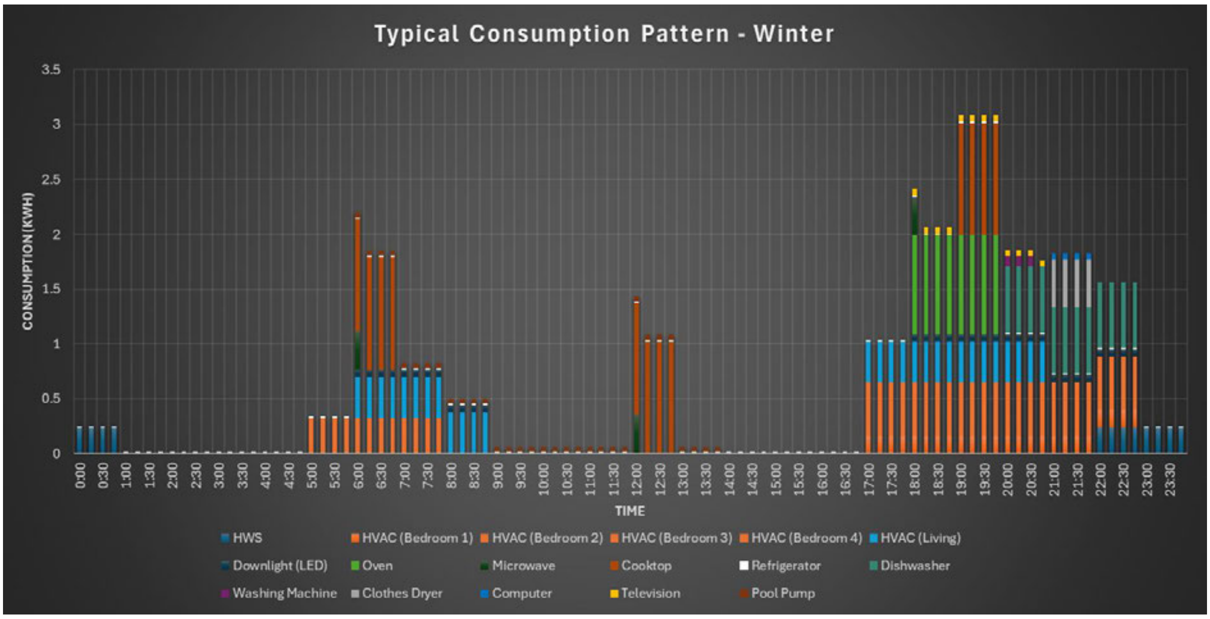


Figure 36. Typical daily usage patterns per season for 4-person household (winter)

3.3.2 Solar System Generation Patterns and Performance

Though the literature review identified a 7kW standalone solar system as the most cost-effective option, development of the typical appliance usage patterns highlights the following key operational requirements.

- For the 2-person occupancy household, the highest total daily consumption is 49.48kWh in summer. The peak demand is 12.42kW on a winter afternoon.
- For the 4-person occupancy household, the highest total daily consumption is 72.72kWh in summer. The peak demand is 12.32kW on a winter afternoon.

N.B. as consumption is represented in 15-minute intervals, peak demand is determined by taking the highest consumption value in kilowatt hours and multiplying this value by a factor of four.

In order to maximise self-consumption, the system will require an inverter with a maximum output of at least 12kW and the ability to generate 50kWh to 75kWh daily depending on occupancy size. The yield can be estimated as a product of the site specific irradiance (kWh/m^2/day or P_{SH}) and the size of the array (kWp) (GSES 2021, pp. 330-3).

$$kWh = P_{SH} * kWp$$

Average daily irradiance across the year in Australia can be determined from the Bureau of Meteorology's solar exposure maps, shown in Figure **37** below.

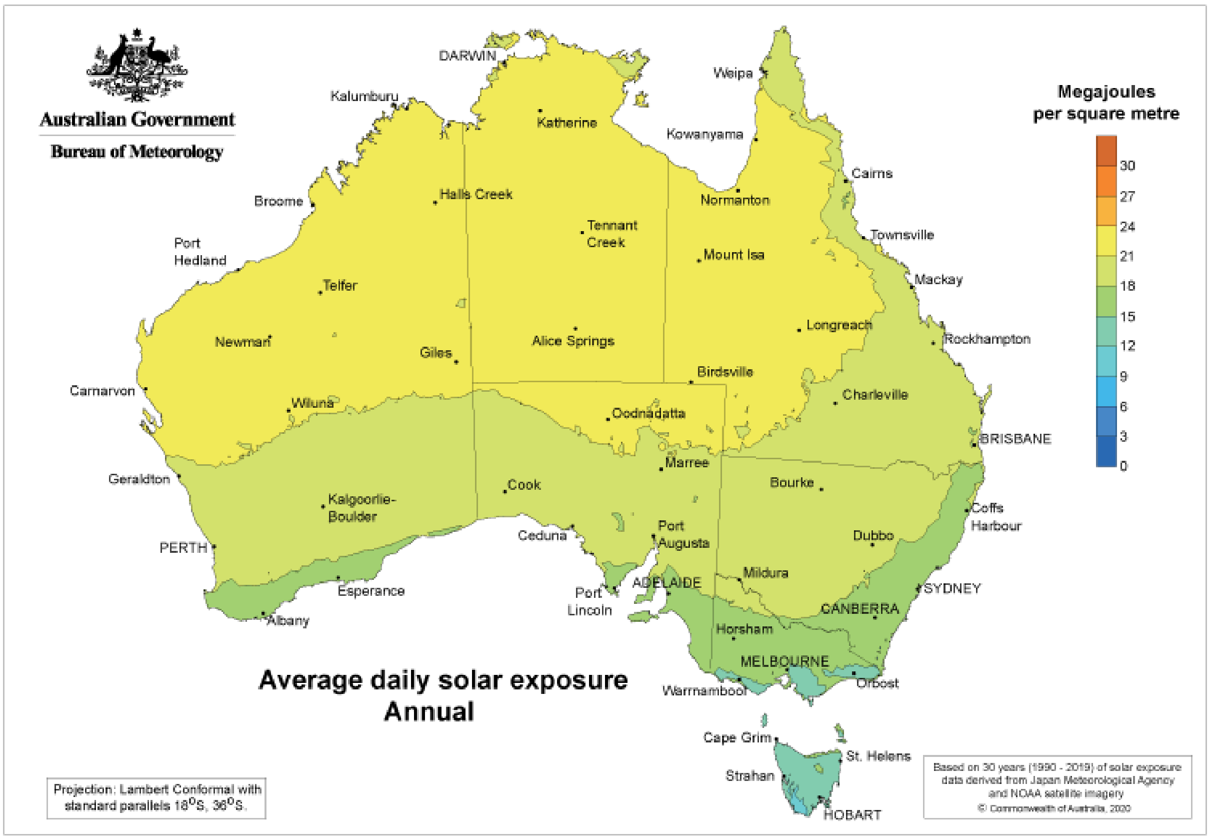


Figure 37. Bureau of Meteorology Average Daily Solar Exposure (Bureau of Meteorology 2024)

For the South East Queensland area, the average daily irradiance is between 18 to 21 MJ/m^2, or 5 to 5.83 kWh/m^2. To account for the lowest average, a P_{SH} of 5 can now be used to estimate the yield for the expected minimum inverter output.

$$2 - person\ house: 12kW * 5 = 60kWh$$

$$4 - person\ house: 15kW * 5 = 75kWh$$

In order for the data to be as accurate as possible, real installation yields in the Brisbane area will be used, as recorded on PVoutputs. The project will focus on ideal conditions only, as the primary objective is the development of a prototype control algorithm rather than the optimisation of solar system outputs in less-than-ideal conditions. As both household occupancies require a peak output higher than 10kW, a single 15kW inverter system will be used, as this is the next most common inverter size. The Anstead Fronius Installation will be used (PVOutput 2024). This system consists of a 10kW an 5kW Fronius inverter with 50x 327kW panels. Typical seasonal outputs for this system in ideal conditions are as follows.

- Summer - Maximum recorded yield on a fine day is approximately 95kWh and a peak generation of 12.59kW (recorded 28/12/23)
- Spring - Maximum recorded yield on a fine day is approximately 97kWh and a peak generation of 12.73kW (recorded 30/11/23)
- Autumn - Maximum recorded yield on a fine day is approximately 90kWh and a peak generation of 13.2kW (recorded 10/04/24)
- Winter - Maximum recorded yield on a fine day is approximately 82.1kWh and a peak generation of 12.26kW (recorded 19/08/23)

Figure 38 to Figure 41 below are graphical representations of the daily yields of the solar system across each season. The Excel spreadsheet to be used as a reference input for the computational model can be found in Appendix D.

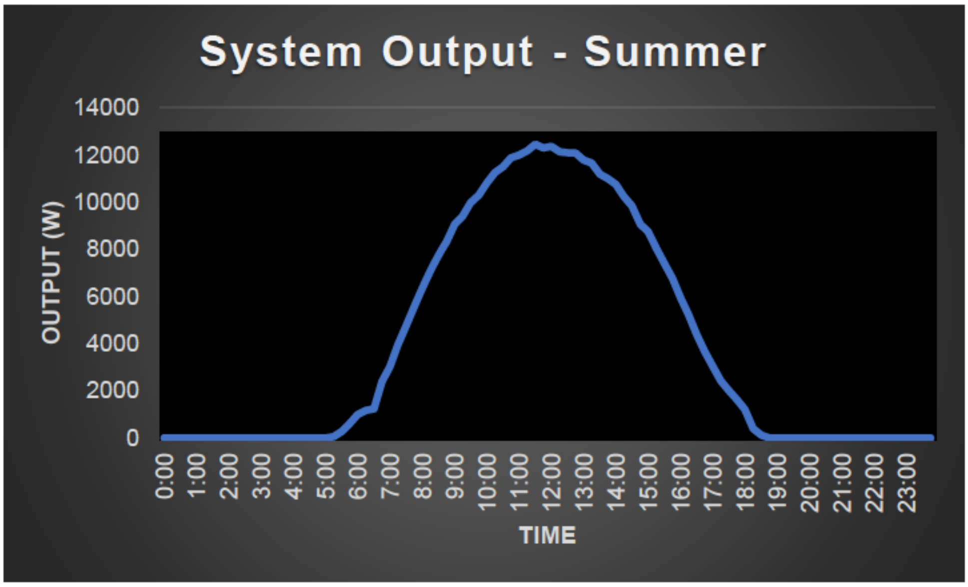


Figure 38. Reference system output (summer)

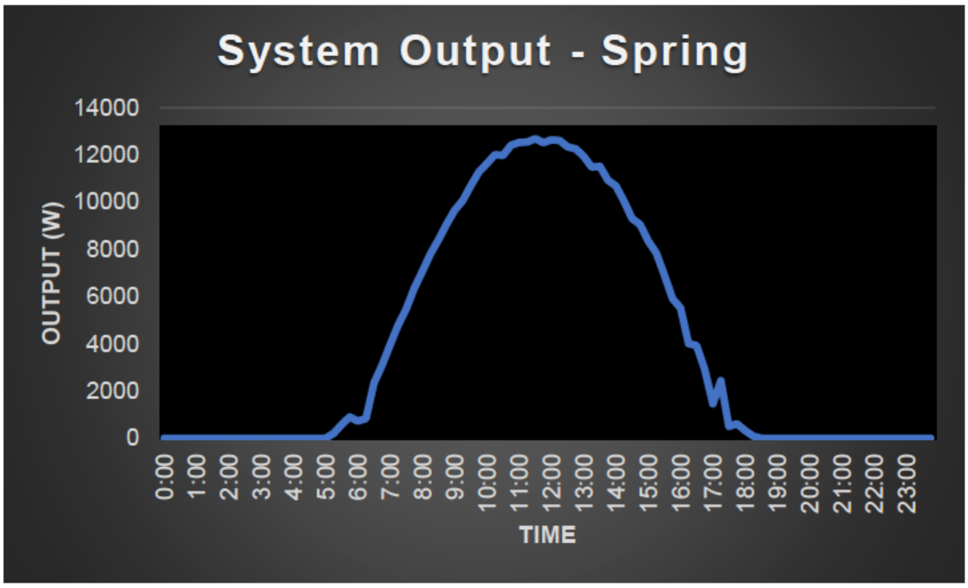


Figure 39. Reference system output (spring)

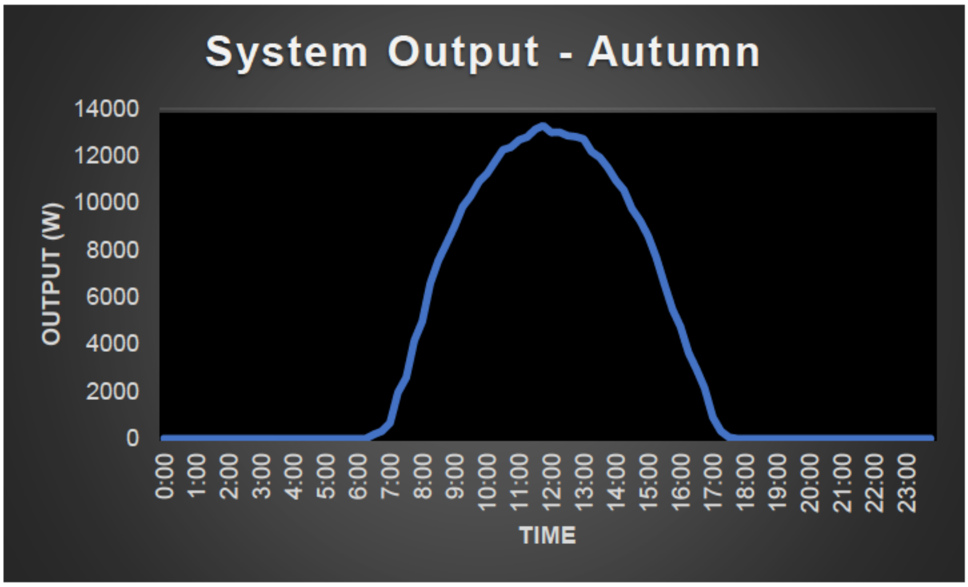


Figure 40. Reference system output (Autumn)

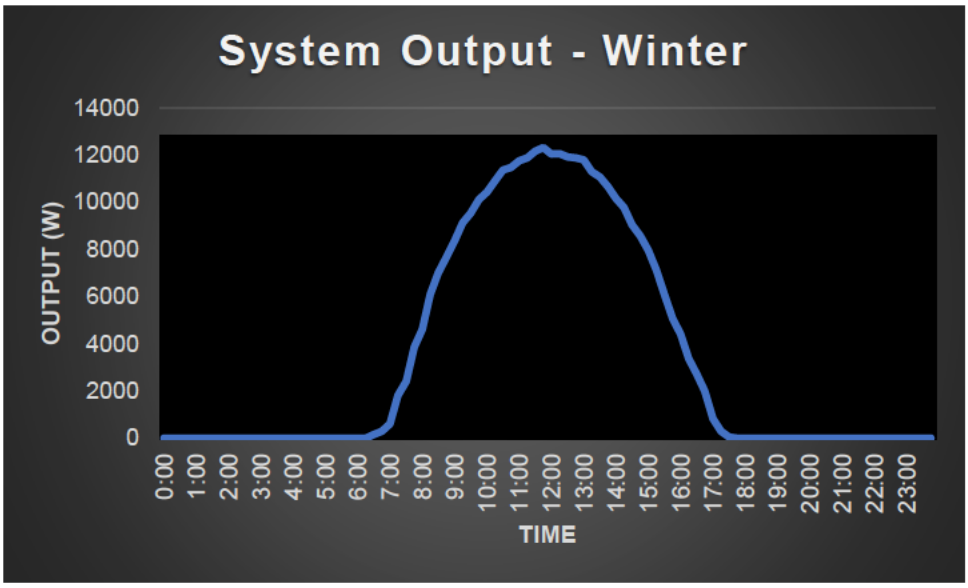


Figure 41. Reference system output (Winter)

3.3.3 Optimized Usage Patterns

Now that the typical solar system generation patterns are understood for each season, optimized appliance usage patterns can be developed. These optimized patterns represent a desired output of the prototype algorithm and provide an example of the expected output of the computational model. These patterns provide an insight into self-consumption, with regard to the solar system output. When analysing these patterns, it is important to note that the flexibility in shifting appliance usage time is impacted by the type of usage. Usage will be broadly defined into 2 categories, based upon groupings reference Beaudin and Zareipour in section 2.5 (Beaudin & Zareipour 2015).

Uncontrollable loads are 'on demand' appliances used at the consumers discretion, with likely time of use dictated by consumer habits. While small changes can be made to usage time, the controller should not exert such a level of control over these devices that would negatively affect the user's experience. Appliances that fall into this category are.

- Lighting – usage will largely be dictated by the consumer and will primarily be used in the evenings and winter/autumn mornings when ambient light is low. These periods have zero or close to zero solar production so self-consumption is limited.
- HVAC – usage will largely be dictated by the consumer and will primarily be used in the evenings and winter/autumn mornings. Usage is during both periods of high solar production (midday summer and spring) and low production (all season times of rest and autumn/winter mornings). Self-consumption will be achieved for times of production only. In the case of overnight usage for HVAC, it is assumed that self-consumption cannot be achieved without the implementation of a BESS.

- Oven, cooktop and microwave - usage will largely be dictated by the consumer and will be centred around mealtimes. Usage times are presumed to be morning, midday and evening. Cooking appliances are not assumed to be used for the 2-person household for lunch preparation, however the 4-person household is assumed to use appliances during this time for the preparation of food for children. Self-consumption will be achieved for times of production only.
- Television and computer - usage will largely be dictated by the consumer and will primarily be used in the evenings. Solar production during these periods is zero, therefore self-consumption will not be possible with these appliances.
- Refrigerator/freezer shall not be controlled at all due to health and safety concerns. This will present a small 24-hour load from the compressor.

Controllable loads are time independent appliances are those whose time of use is not expected to impact user experience. As a result, self-consumption can be maximised by allowing the controller to schedule operation only during times of solar production. Appliances that fall into this category are as follows.

- Hot water system
- Dishwasher
- Washing machine
- Clothes dryer
- Pool Pump

Figure 42 to Figure 45 below is a graphical representation of the optimized daily usage patterns for a 2-person household across each season. The Excel spreadsheets used to generate the patterns can be found in Appendix D.

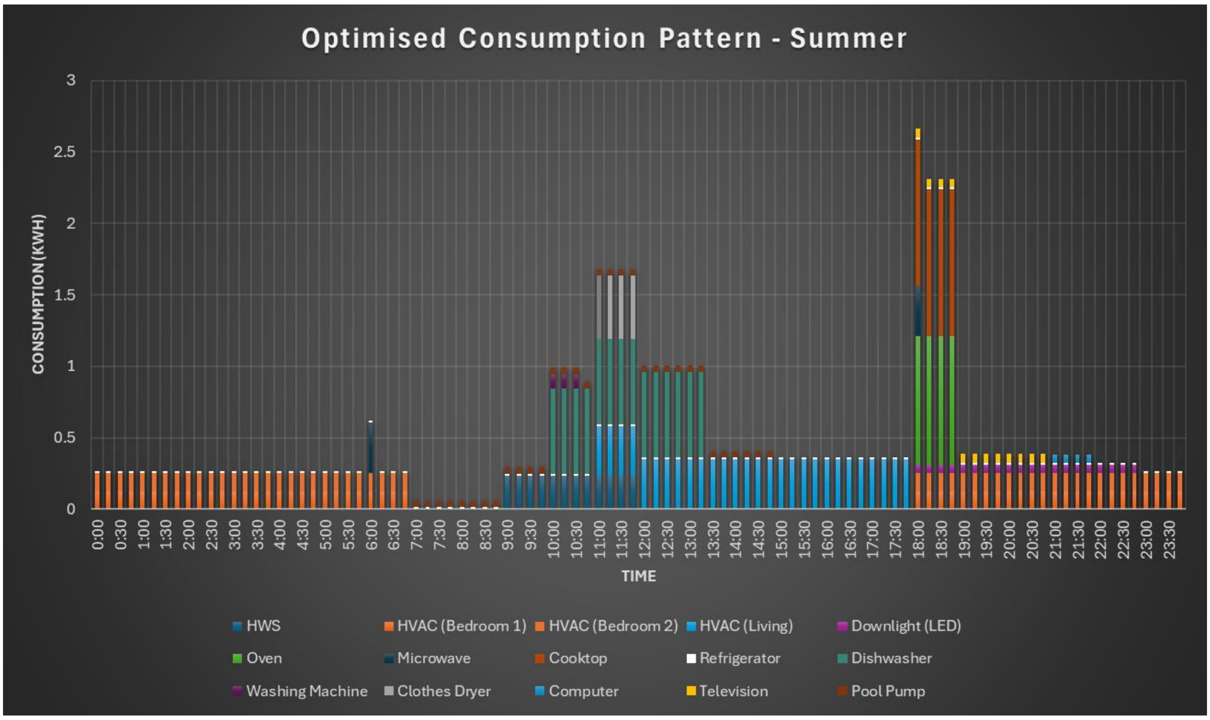


Figure 42. Optimized daily usage patterns per season for 2-person household (summer)

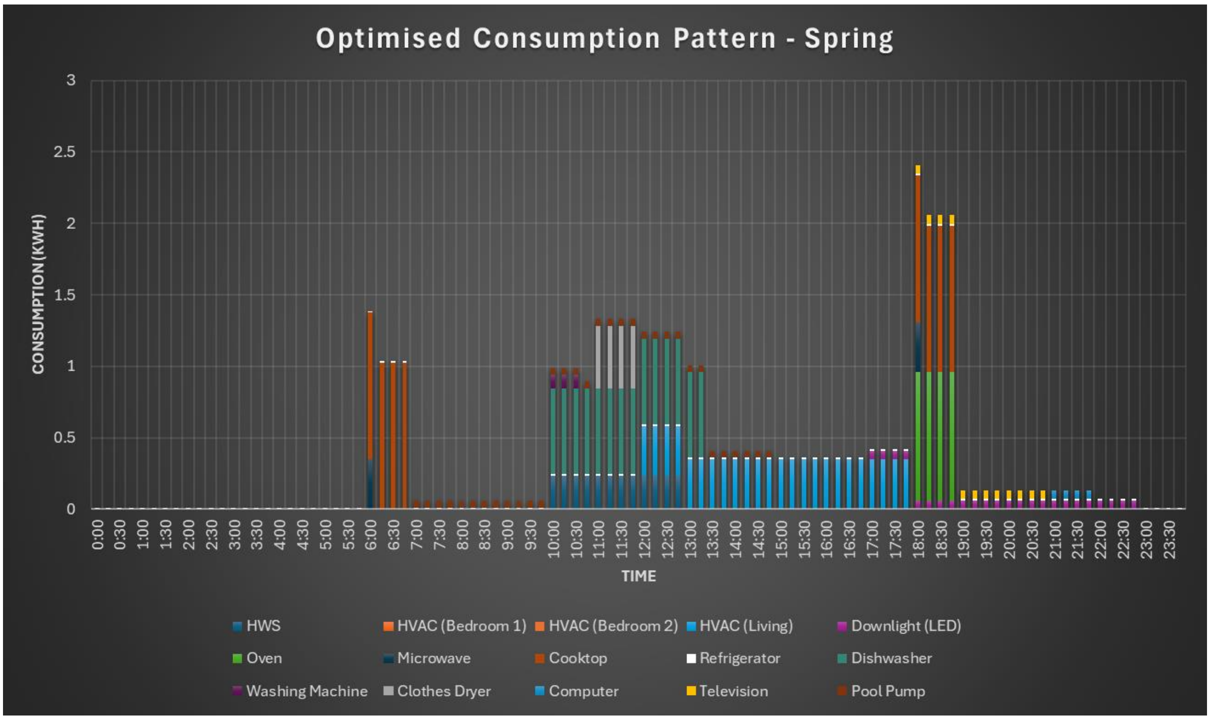


Figure 43. Optimized daily usage patterns per season for 2-person household (spring)

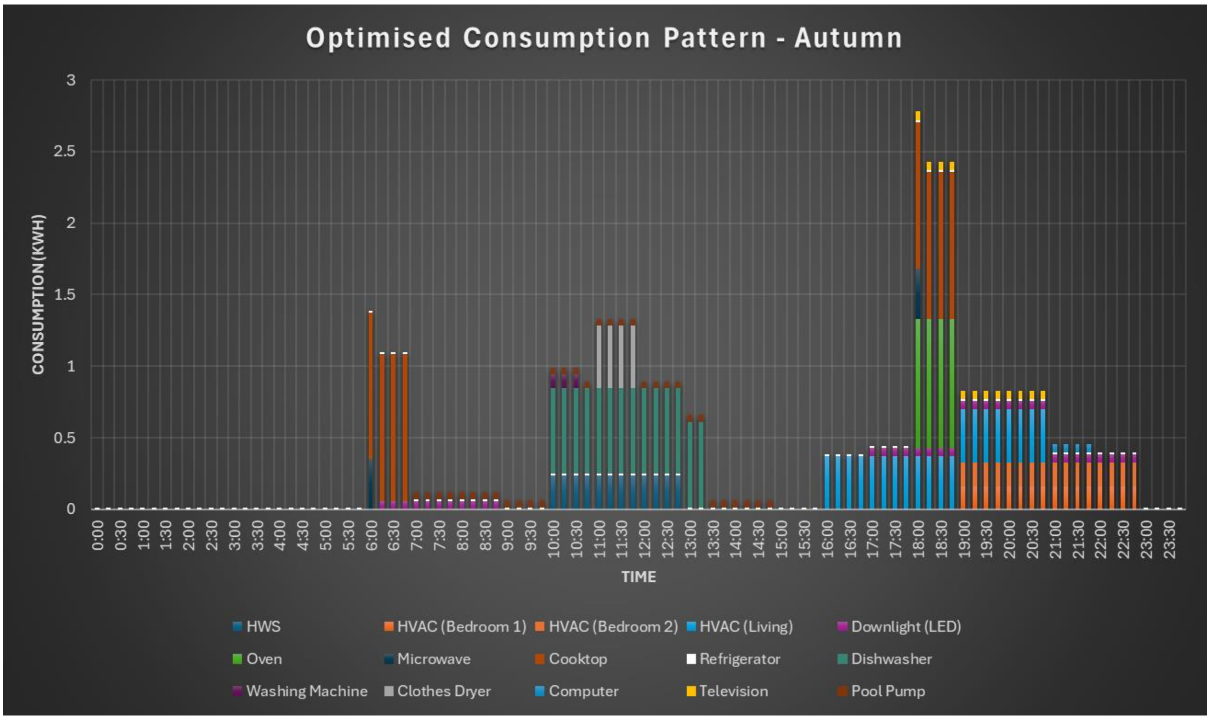


Figure 44. Optimized daily usage patterns per season for 2-person household (autumn)

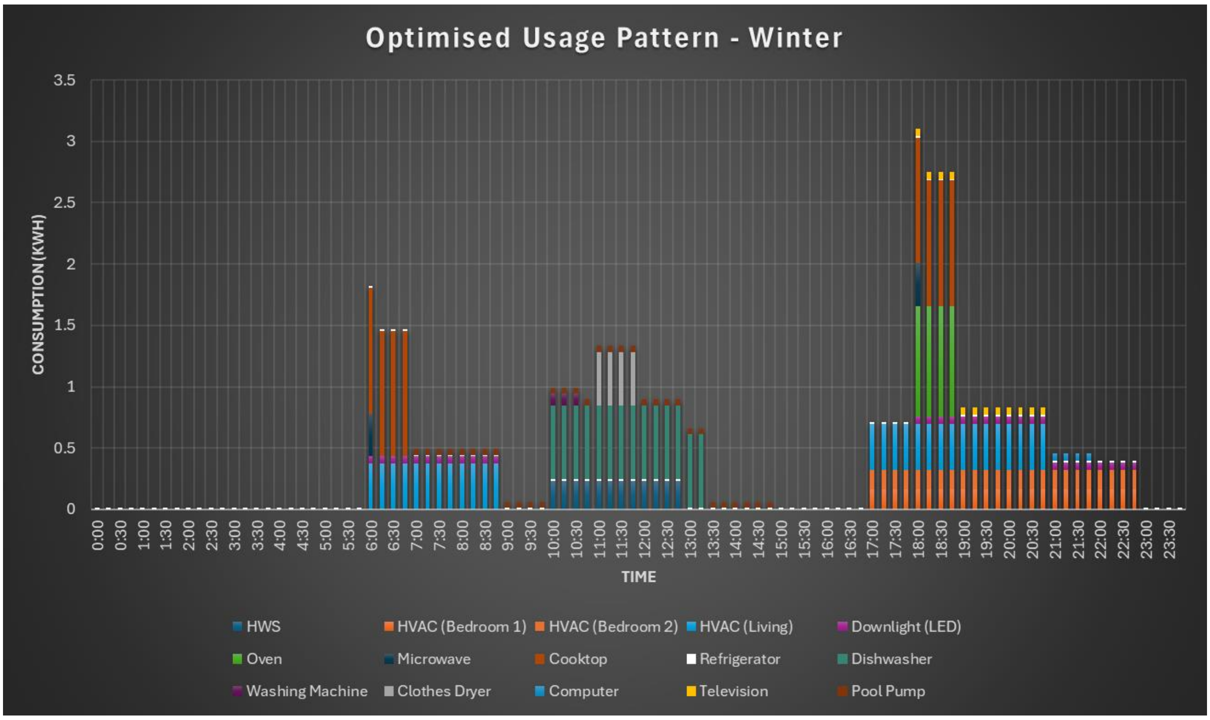


Figure 45. Optimized daily usage patterns per season for 2-person household (winter)

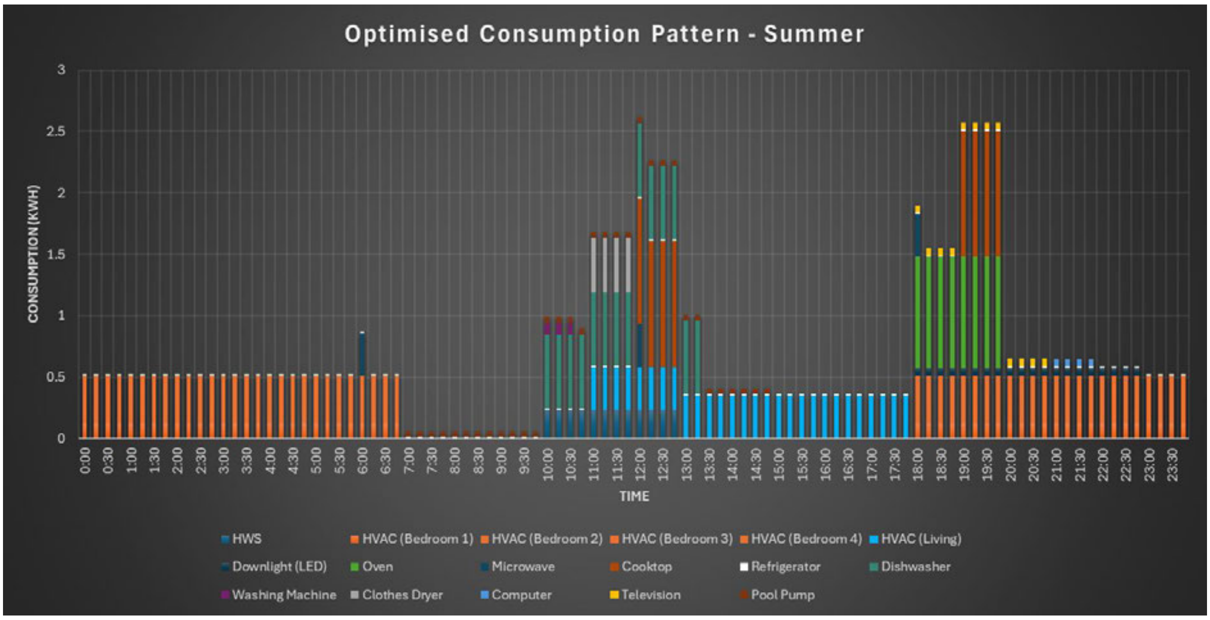


Figure 46 to Figure 49 below is a graphical representation of the optimized daily usage patterns for a 4-person household across each season. The Excel spreadsheet to be used as an input for the computational model can be found in Appendix D.

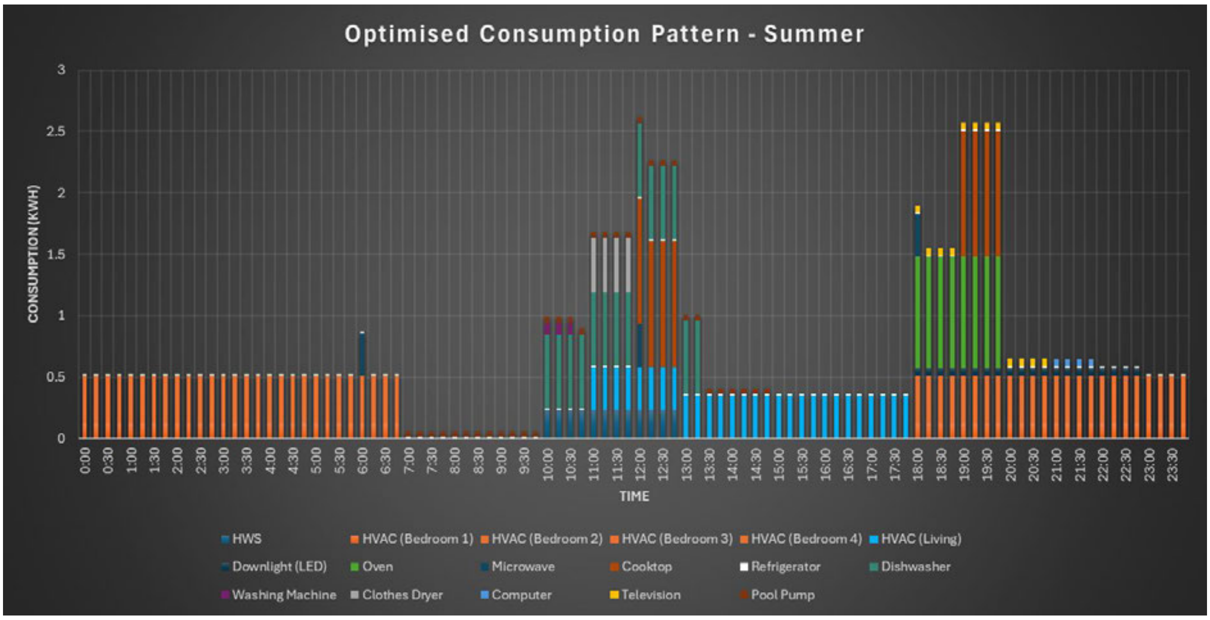


Figure 46. Optimized daily usage patterns per season for 4-person household (summer)

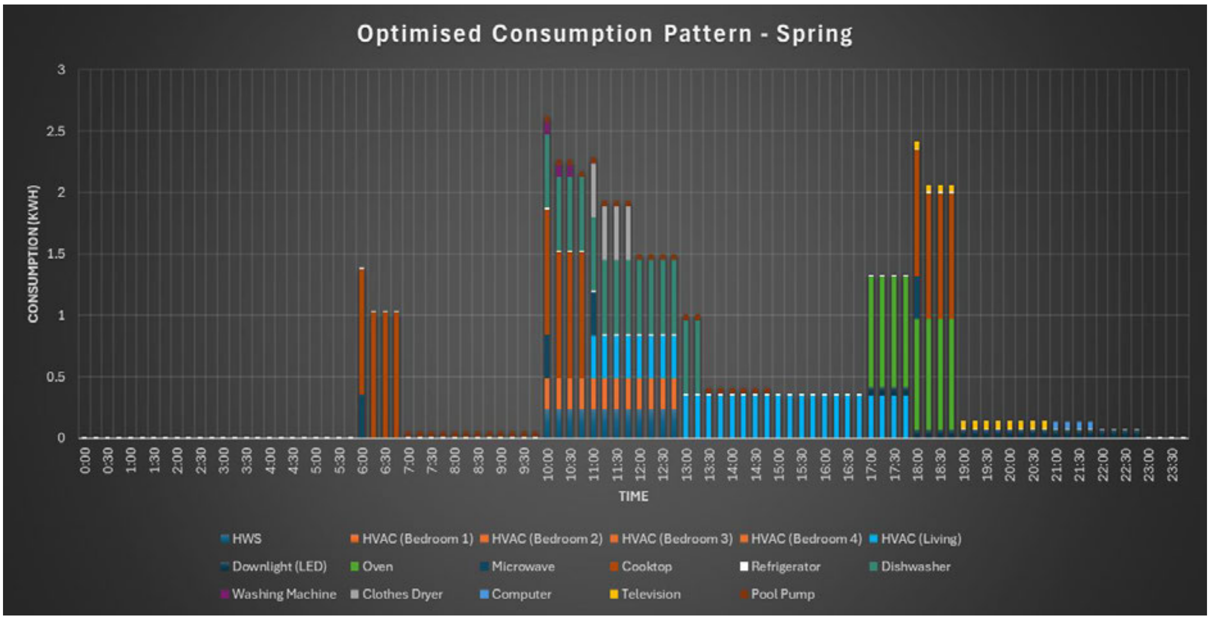


Figure 47. Optimized daily usage patterns per season for 4-person household (spring)

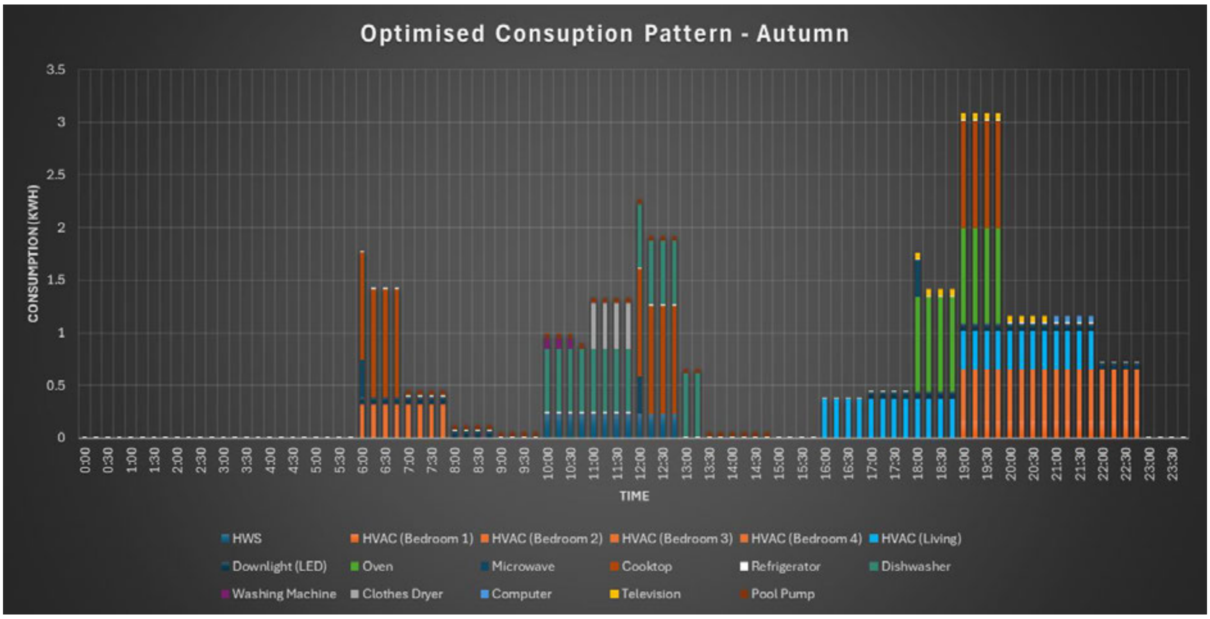


Figure 48. Optimized daily usage patterns per season for 4-person household (autumn)

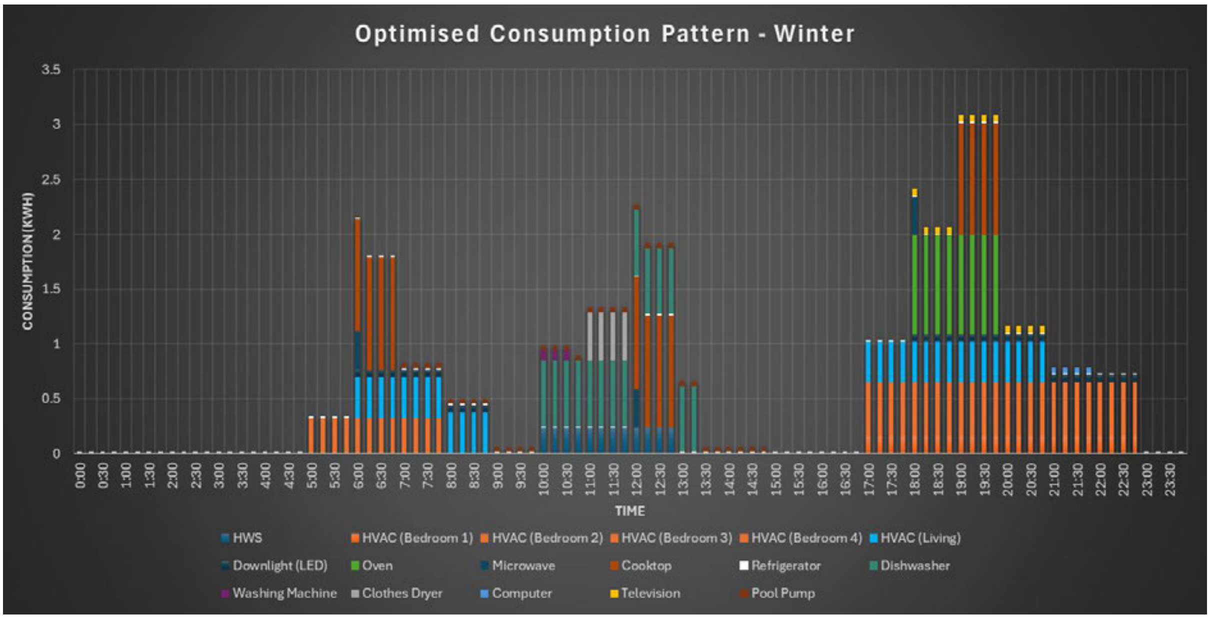


Figure 49. Optimized daily usage patterns per season for 4-person household (winter)

3.3.4 Battery Energy Storage System

As mentioned in the above section regarding solar system sizing, typical peak demands are approaching 12kW and occurring in the afternoon and early evening when solar yields are low. The appliances responsible for these peak demands are primarily what would be classed as uncontrollable loads, such as those used for cooking and heating. If self-consumption is to be maxmised, it is crucial to select a battery energy storage system that has the following features.

- High output power to meet as much of the appliance demand as reasonably practicable.
- High battery capacity to supply power to appliances for as long as possible.
- High depth of discharge to maximise the amount capacity available for consumption

The literature review identified the Tesla Powerwall as a preferred option with a continuous power output of 5kW, with 13.5kWh of capacity and a depth of discharge of 100%.

3.3.5 Computation Model Conceptual Development

Having the system input (solar generation patterns) and desired output (optimized usage patterns) defined, a conceptual framework can be developed, to be implemented as the prototype control algorithm in the subsequent detailed design stage.

As discussed in section 2.5, the system lends itself to modelling as a type of finite state machine known as a statechart. The statechart characteristic orthogonality will allow for parallel operation of processes, simplifying the design by limiting the number of states required. For clarity, the graphical representation of the statechart is reiterated here from the literature review.

- Rounded rectangle: represents a state. Rectangles encompassing the states represent a process.

- Dashed line: used to separate concurrent processes.
- Arrows: transitions between states within a process. Arrows from a black circle are the initial state.
- Transition labels: condition to trigger change in state or process. The '/' separator is used as 'broadcast communication' between processes to enable events to change concurrent processes.

Through detailed design, these graphical tools will be utilised to build the model in MATLAB using the graphical programming environment Simulink. Through usage of the extension Stateflow, Simulink provides the ability to program statecharts graphically. This greatly simplifies the design process as the traditional flowcharting stage of software design can be undertaken simultaneously with scripting and debugging. As part of the concept design stage, the inputs to the system have already been developed. Prior to detailed design in Simulink, the states of the system must be defined. The following sections describe the behaviour of the preliminary states to begin development.

3.3.5.1 Master Controller State

The master controller state will evaluate the current solar generation input to the system, simulated by reading the yield spreadsheet and the current time. Simultaneously the controller will evaluate each substate within it, with each substate being the respective appliances defined by the project. The master controller will then 'schedule' the appliances, operating the appliance substates by order of priority and available solar generation. At the end of an operational period (defined in the prototype program as a single day), the controller state will export the yield and appliance pattern schedule to Excel.

3.3.5.2 Lighting

The lighting substate will be triggered to energise the lighting loads within the household. As an uncontrolled load, transitions into and out of this substate will not be directly controlled by the master controller state but instead be user selected.

3.3.5.3 Hot Water System

Entry into this substate will energise the hot water system. As a controllable load, transitions into this substate will be triggered by the master controller state. As an interruptible load, transitions out of this substate will be triggered either by the thermostat (simulated using a 3-hour timer) or by the master controller state if solar yield drops below its operational threshold.

3.3.5.4 HVAC

Each HVAC system in the household will have its own substate, with entry energising the respective system. Between the hours of 6:00 and 00:00, these will be uncontrolled loads, operated by the user. From 00:00 to 6:00, they will be interruptible by the master controller state, dependent on the ambient temperature.

3.3.5.5 Refrigerator

The refrigerator is an uncontrollable load, controlled neither by the user or the master state. The master state will monitor usage of the refrigerator substate to help determine overall self-consumption of the system.

3.3.5.6 Oven

Entry into this substate will energise the oven. As an uncontrolled load, transitions into and out of this substate will not be controlled by the master controller state but instead be user selected. The master controller state will provide user prompts during period of low solar generation to help shift operating habits but will have no actual control over the load.

3.3.5.7 Cooktop

Entry into this substate will energise the cooktop. As an uncontrolled load, transitions into and out of this substate will not be controlled by the master controller state but instead be user selected. The master controller state will provide user prompts during period of low solar generation to help shift operating habits but will have no actual control over the load.

3.3.5.8 Microwave

Entry into this substate will energise the microwave. As an uncontrolled load, transitions into and out of this substate will not be controlled by the master controller state but instead be user selected. The master controller state will provide user prompts during period of low solar generation to help shift operating habits but will have no actual control over the load.

3.3.5.9 Dishwasher

Entry into this substate will energise the dishwasher. As a controllable load, transitions into this substate will be triggered by the master controller state. As an uninterruptible load, transitions out of this substate will be triggered by the master controller state once the wash cycle has completed. Intent of operation will be for the user to load the dishwasher in the morning and operation to begin autonomously via the master controller state.

3.3.5.10 Washing Machine

Entry into this substate will energise the washing machine. As a controllable load, transitions into this substate will be triggered by the master controller state. As an uninterruptible load, transitions out of this substate will be triggered by the master controller state once the wash cycle has completed. Intent of operation will be for the user to load the washing machine in the morning and operation to begin autonomously via the master controller state.

3.3.5.11 Clothes Dryer

Entry into this substate will energise the clothes dryer. As a controllable load, transitions into this substate will be triggered by the master controller state. As an uninterruptible load, transitions out of this substate will be triggered by the master controller state once the wash cycle has completed. Intent of operation will be for the user to load the dryer in the morning and operation to begin autonomously via the master controller state.

3.3.5.12 Pool Pump

Entry into this substate will energise the pool pump. As a controllable load, transitions into this substate will be triggered by the master controller state. As an interruptible load, transitions out of this substate will be triggered either by the pump controller (simulated using an 8-hour timer) or by the master controller state if solar yield drops below its operational threshold.

3.4 Project Detailed Design - Modelling

Now that preliminary design has been undertaken, the detailed design phase will focus on the development of the mathematical model.

3.4.1 Model Structure and Parent State

The model consists of a statechart embedded in the Simulink environment utilizing the Stateflow extension in MATLAB. This facilitates a streamlined design process where flowcharting stage is undertaken simultaneously with scripting and debugging of the algorithm.

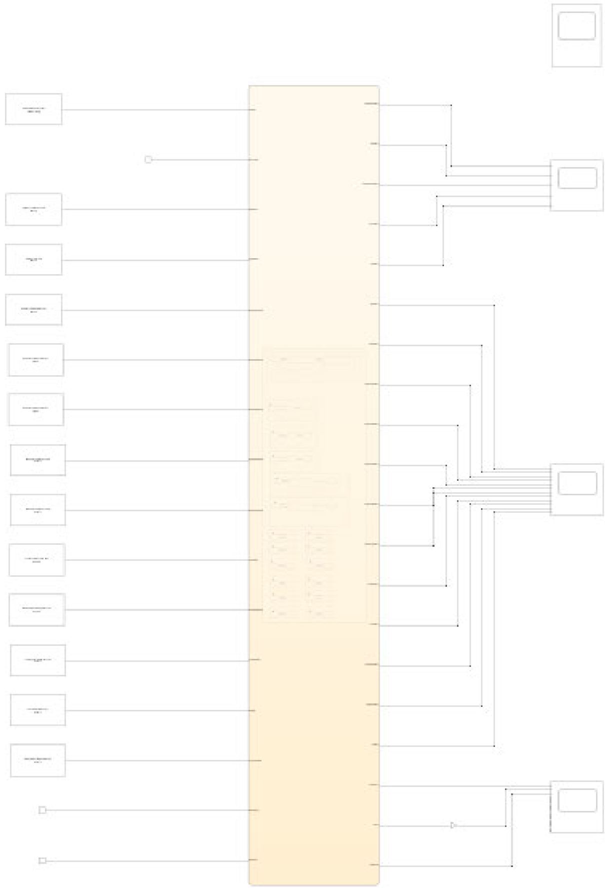


Figure 50. Simulink model with central statechart

Figure 49. highlights the statechart in the centre of the model. To the left of the statechart are the system inputs as follows.

- Spreadsheet for the solar yield profile – refer section 3.4.2 for details.
- Spreadsheets for uncontrollable load manual usage profiles – refer section 3.4.3 for details.
- Simulink constant blocks for battery capacity and battery output – refer section 3.4.4 for details.

- Simulink clock block to output current simulation time. The system clock is assigned to the input variable *currentTime* and outputs the current time at each simulation step.

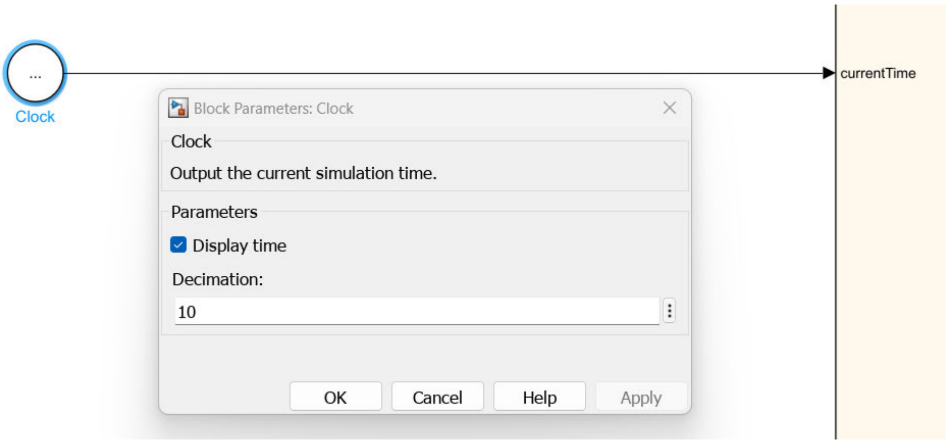


Figure 51. Clock providing simulation time to *currentTime* input variable.

To the right of the statechart, the system outputs can be seen. Three scopes and one floating scope are utilized to monitor changes in the output variables. The top scope is used to display the status of the controllable appliances through their respective output variables. This is vital both as a tool for debugging the behaviour of the controllable appliances and interrogation during analysis. This will be discussed in further detail in sections 3.4.3.2 and 3.4.3.3.

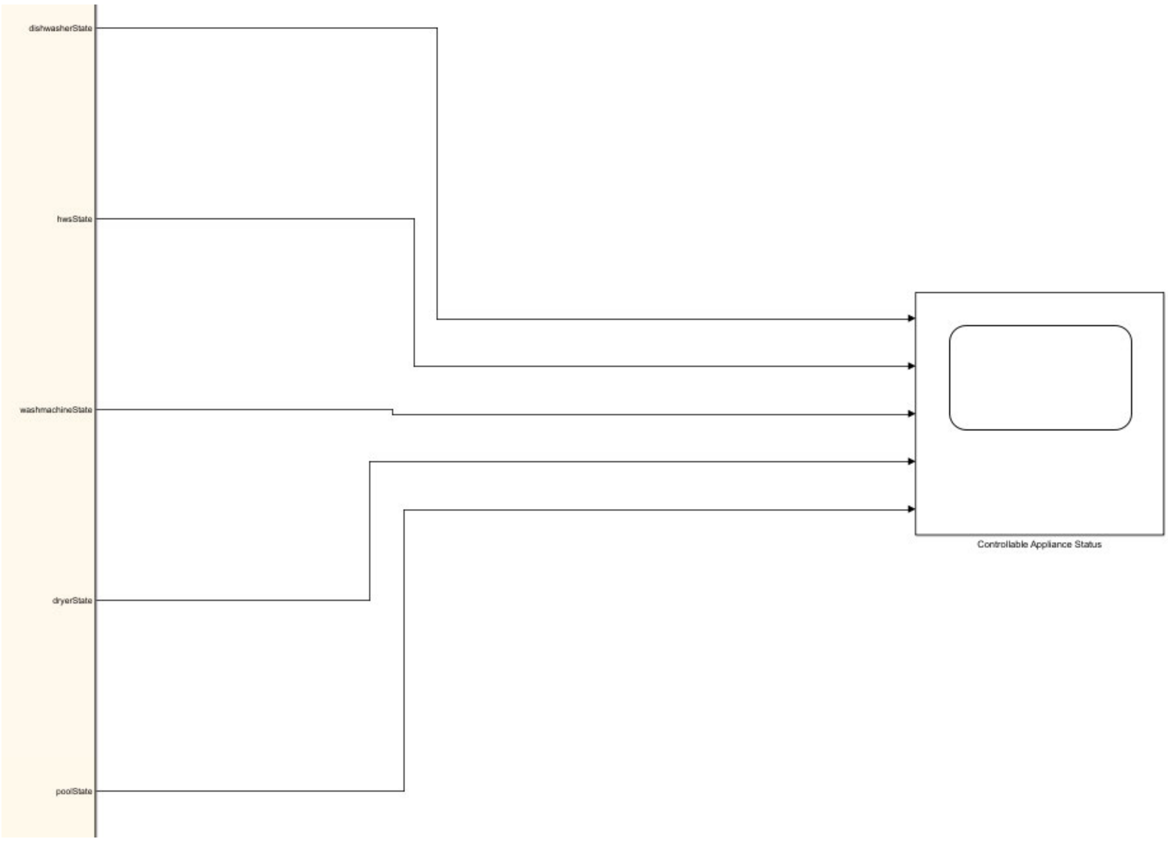


Figure 52. Controllable appliance status scope

The middle scope is used to display the status of the uncontrollable appliances through their respective output variables. This scope is used both as a visual aid for debugging and during analysis. This will be discussed in further detail in section 3.4.3.1.

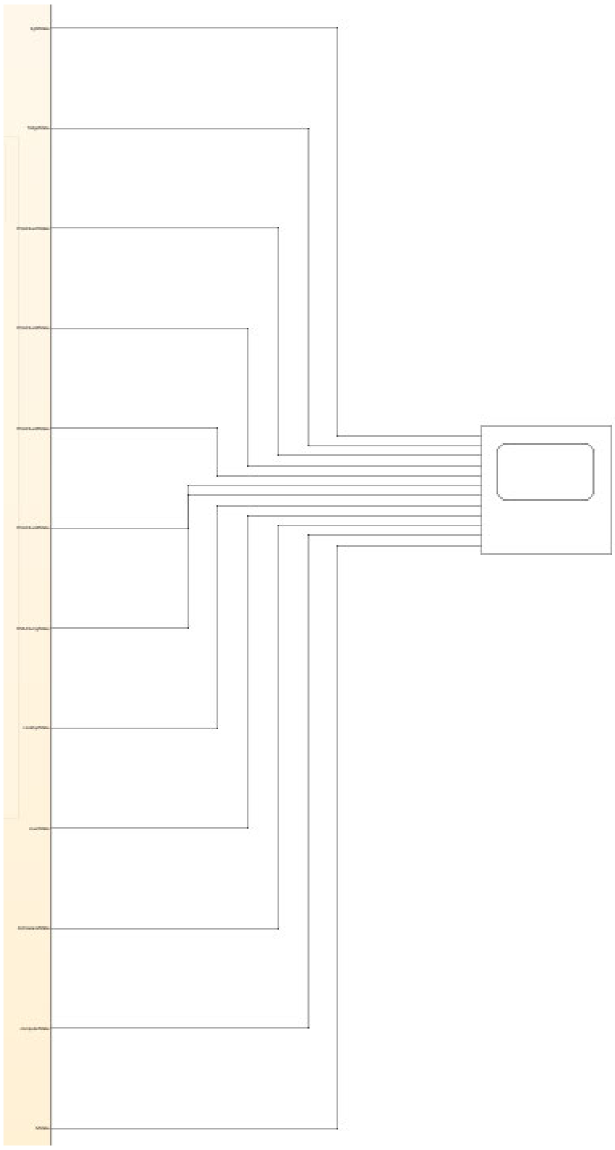


Figure 53. Uncontrollable appliance status scope

The bottom scope is used to display total power consumption for the premises, as well as the state of charge of the battery as both a percentage state of charge and in kilowatt-hours (kWh). The power consumption was displayed in this scope to help determine if the battery was working as expected. The battery will be discussed further in section 3.4.4.

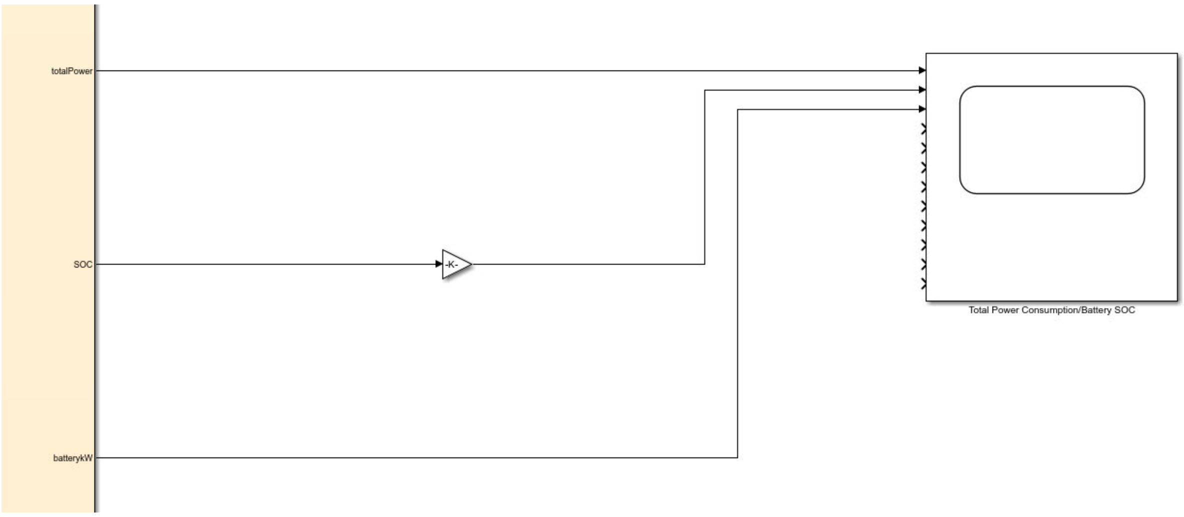


Figure 54. Power consumption and battery state of charge (SOC)

The floating scope displays the total power consumption, battery SOC and output of the solar system. This scope is used both as a visual aid for debugging to ensure that all components of the system are functioning as expected, as well as to assist in analysis of the performance of the system as a whole.

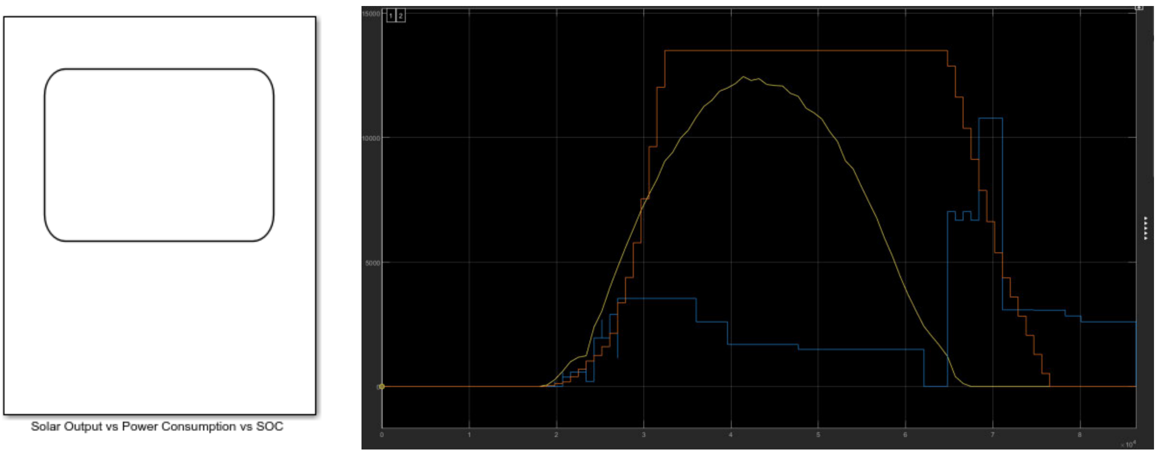


Figure 55. Solar generation, battery SOC and appliance consumption

With reference to Figure 55, yield from the solar system is shown in yellow, battery SOC in orange and total appliance power consumption in blue. This particular period is shown over a full summer day with a typical uncontrolled appliance operating profile, and controllable appliances being operated autonomously by the master controller.

Contained within the embedded statechart is the parent state MasterController, which encloses 18 child states – one for each appliance and one for the battery energy storage system.

Figure 56. Master controller topography

Magnification at the top of the master controller shows the entry conditions to the state and the first child state for the dishwasher. As the parent state, the MasterController has a solid border, while the child state borders are dashed. This provides a visual representation for orthogonal execution within Stateflow and is enabled by setting decomposition in the parent state to parallel (AND). Upon entry into the parent state, all states with dashed borders will be executed in parallel. Similarly, the child state dishwasherParent has its decomposition set to exclusive (OR), so that its own children execute sequentially.

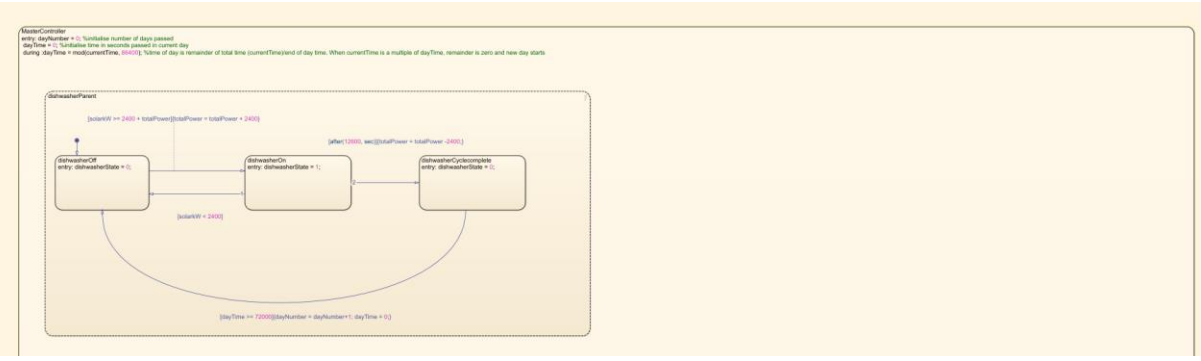


Figure 57. Master controller state

Upon entry into the MasterController state, two variables to track time within the child states are initialised:

- *dayNumber* – is used to track the number of days passed during the current simulation cycle and is initialised at zero.
- *dayTime* – is used to determine the time of the current day and is initialised at zero.

At each step during simulation, *dayTime* is calculated by using the modulo function to calculate the value of the modulus of the output of the clock input variable *currentTime* and the integer 86400 – the number of seconds within a day. When *currentTime* is equal to a multiple of 86400, the modulus is zero, resulting in values of *dayTime* that wrap around in daily cycles.

3.4.2 Solar Yield Input

The aforementioned Anstead Fronius Installation as logged from PVOutput.org serves as the basis for the solar yields to the model, with yields recorded in excel spreadsheets for each season. Figure 58 below shows the arrangement for the summer yield assigned to the input variable *solarkW*.

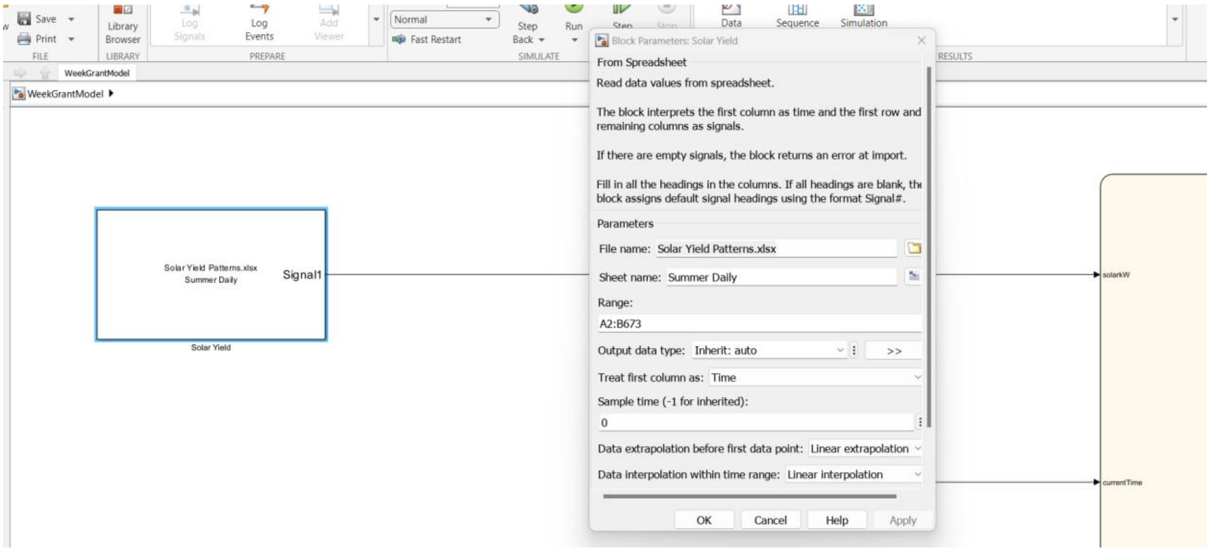


Figure 58. Solar yield variable input

Range has been selected to provide input data over a period of a week, in increments of 15 minutes (900 seconds). The time increment has been selected to provide further granularity, as it was found that the original hourly increment limited flexibility in appliance control. Weekly modelling of each season has been selected as the preferred balance between speed of simulation (based on the available computer processing power) and range of data analysis. Figure 59 below displays the first 8.5 hours of yield data for the summer season.

	A	B	C
1	Seconds	Output	Hour
2	0	0	0:00
3	900	0	0:15
4	1800	0	0:30
5	2700	0	0:45
6	3600	0	1:00
7	4500	0	1:15
8	5400	0	1:30
9	6300	0	1:45
10	7200	0	2:00
11	8100	0	2:15
12	9000	0	2:30
13	9900	0	2:45
14	10800	0	3:00
15	11700	0	3:15
16	12600	0	3:30
17	13500	0	3:45
18	14400	0	4:00
19	15300	0	4:15
20	16200	0	4:30
21	17100	0	4:45
22	18000	0	5:00
23	18900	212	5:15
24	19800	582	5:30
25	20700	911	5:45
26	21600	728	6:00
27	22500	838	6:15
28	23400	2345	6:30
29	24300	3088	6:45
30	25200	3945	7:00
31	26100	4782	7:15
32	27000	5492	7:30
33	27900	6354	7:45
34	28800	7064	8:00
35	29700	7798	8:15
36	30600	8402	8:30

Figure 59. Solar yield spreadsheet - summer

Simulink treats the first column A as time and remaining columns as signal data. The range has been selected to read column B as the signal data, with the hour in column C shown for reference only. Within the spreadsheet *Solar Yield Patterns*, each season is set up on a separate sheet. Modelling of each season is then enabled by changing the block parameter *sheet name* in Simulink.

3.4.3 Load States

As mentioned in section 3.3.3, loads are broadly categorized into controllable and uncontrollable groups, and then further divided into uninterruptable and interruptible loads. The following section describes how these loads are modelled within the Simulink environment.

3.4.3.1 Uncontrollable Loads

The manual switching of each uncontrollable load is simulated by a spreadsheet, with 0 representing the appliance as being de-energised and a 1 representing the appliance as being in use. Figure 60 below displays the first 8.5 hours of usage data for the lighting loads in a 4-person household in winter. The appliance usage spreadsheets that the uncontrolled appliance input spreadsheets are derived from can be found in Appendix D.

	A	B	C
1	Seconds	Lighting	Hour
2	0	0	0:00
3	900	0	0:15
4	1800	0	0:30
5	2700	0	0:45
6	3600	0	1:00
7	4500	0	1:15
8	5400	0	1:30
9	6300	0	1:45
10	7200	0	2:00
11	8100	0	2:15
12	9000	0	2:30
13	9900	0	2:45
14	10800	0	3:00
15	11700	0	3:15
16	12600	0	3:30
17	13500	0	3:45
18	14400	0	4:00
19	15300	0	4:15
20	16200	0	4:30
21	17100	0	4:45
22	18000	0	5:00
23	18900	0	5:15
24	19800	0	5:30
25	20700	0	5:45
26	21600	1	6:00
27	22500	1	6:15
28	23400	1	6:30
29	24300	1	6:45
30	25200	1	7:00
31	26100	1	7:15
32	27000	1	7:30
33	27900	1	7:45
34	28800	1	8:00
35	29700	1	8:15
36	30600	1	8:30

Figure 60. Lighting – 4-person household in winter

Similarly to the solar yield data, each uncontrollable load spreadsheet is assigned to an input variable, shown in italics as follows:

- Lighting assigned to *lightSwitch.*
- Bedroom HVAC unit 1 assigned to *HVACbed1Switch.*
- Bedroom HVAC unit 2 assigned to *HVACbed2Switch.*
- Bedroom HVAC unit 3 assigned to *HVACbed3Switch* (4-person only)
- Bedroom HVAC unit 4 assigned to *HVACbed4Switch* (4-person only)

- Living room HVAC unit assigned to *HVACliving Switch.*
- Oven assigned to *ovenSwitch.*
- Cooktop assigned to *cooktopSwitch.*
- Microwave assigned to assigned to *microwaveSwitch.*
- Television assigned to *tvSwitch.*
- Computer assigned to *computerSwitch.*
- Refrigerator/freezer assigned to *fridgeSwitch.*

Figure 61 below shows the arrangement for the lighting, fridge and HVAC1/2 usage profiles assigned to their respective inputs. Note that data interpolation for usage profiles is set to a zero-order hold as the input is assumed to hold the last input value for the sample period.

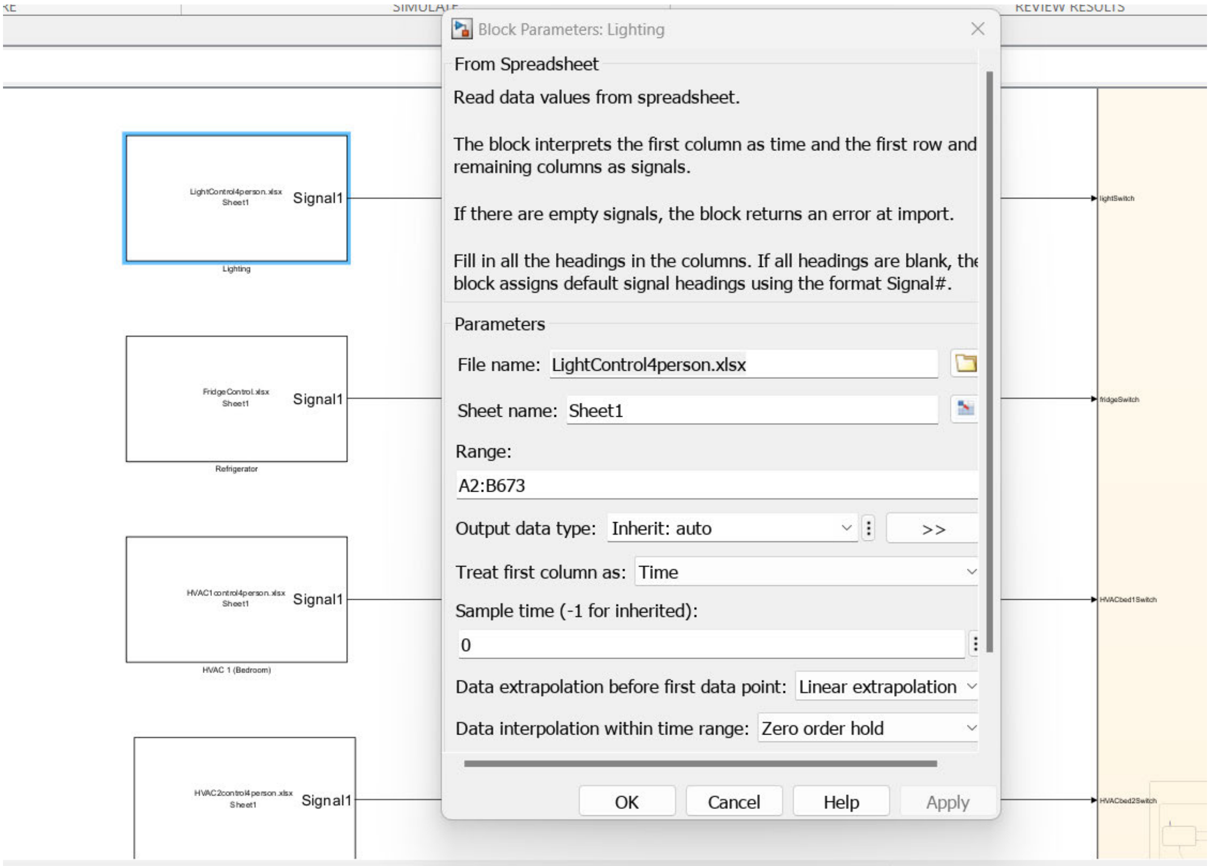


Figure 61. Uncontrollable loads input arrangement.

Delving into the statechart, each uncontrollable load is represented as a parallel parent, with child states in each representing if that appliance is on or off.

Figure 62. Uncontrollable load parent states

Taking lighting as an example, upon entry into the parent state *lightParent*, the child *lightOff* is entered as the default state. The entry to this default state sets the variable *lightState* to 0. When the spreadsheet input variable *lightSwitch* is equal to 1, the transition condition to the *lightOn* state is fulfilled. Upon entry to this state, the *lightState* output variable is now set to 1.

A transition action is also executed when transitioning between the on and off states. In order to track the current power consumption of all appliances, the variable *totalPower* is incremented and decremented by the appliance wattage as they cycle on and off.

Maximising the uncontrollable appliance status scope, the output variables for each appliance are displayed for graphical analysis. This is shown in Figure 63 below.

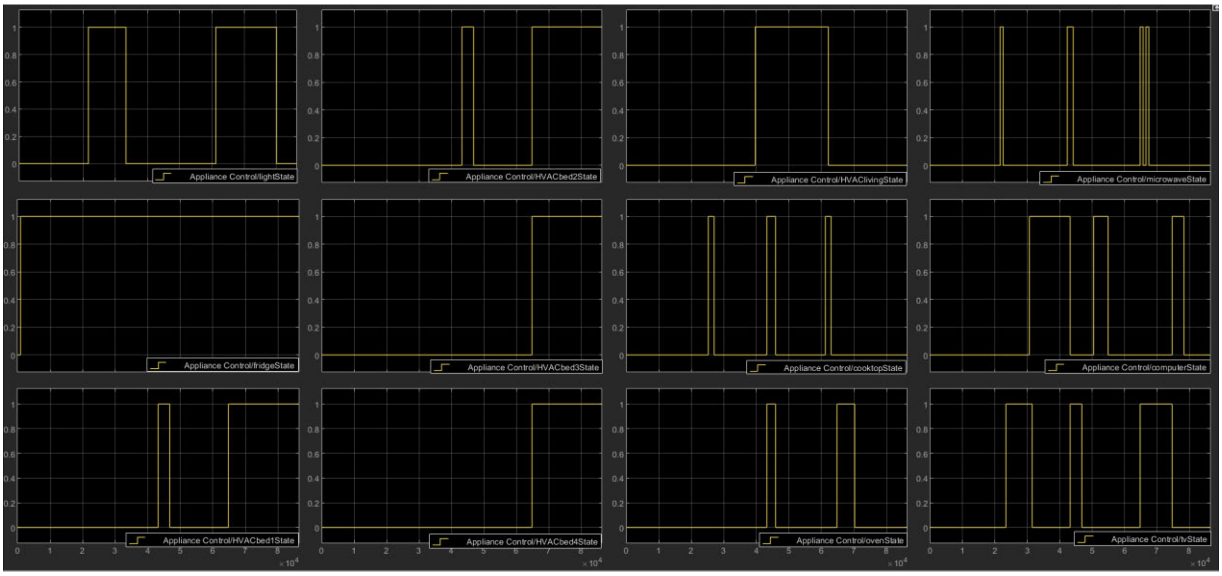


Figure 63. Uncontrollable appliance status scope display

3.4.3.2 Controllable Loads – Uninterruptable

The uninterruptable controllable loads consist of three parallel child states within the *MasterController* parent – *dishwasherParent*, *washingmachineParent* and *dryerParent*.

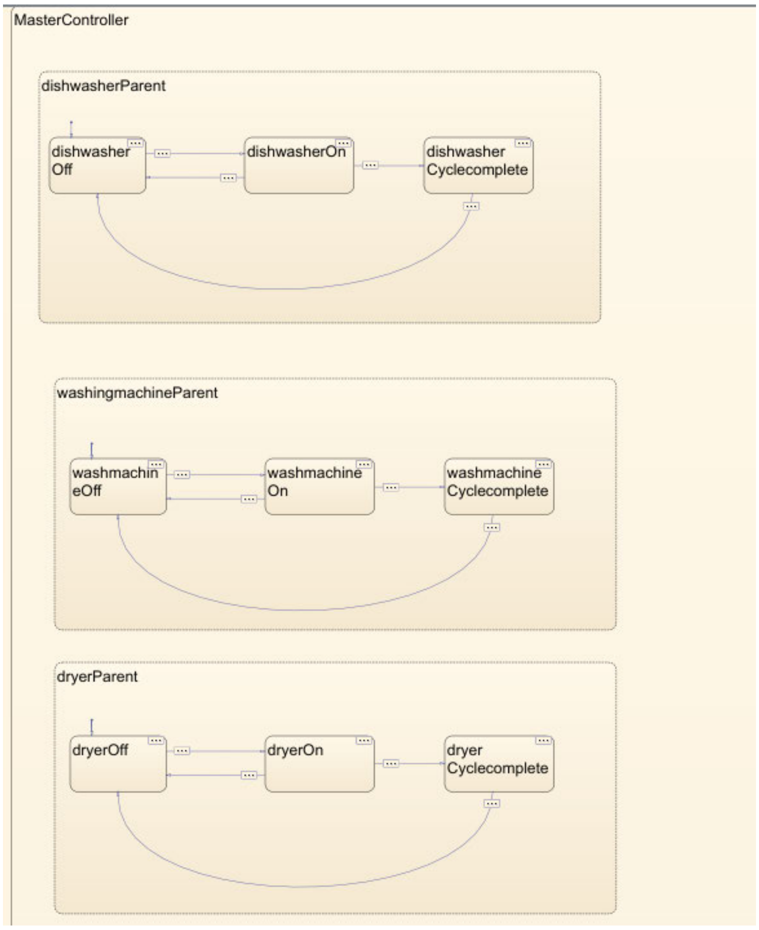


Figure 64. Uninterruptable load parent states

The parent for each uninterruptable load contains three exclusive states that determine when the appliance is off, on or if it has completed its cycle for that 24-hour period.

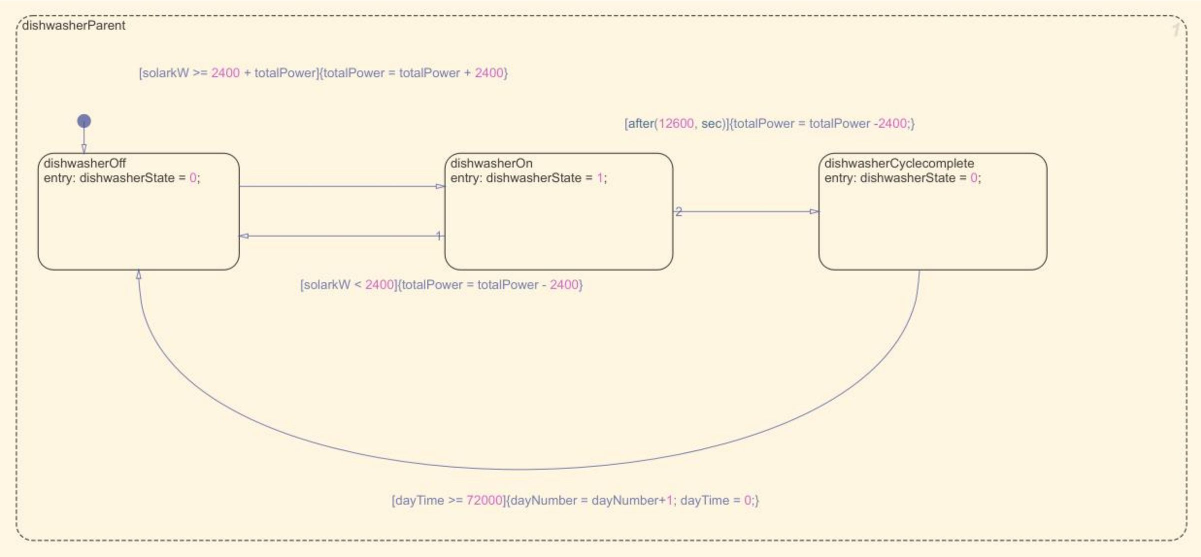


Figure 65. Dishwasher parent state showing child states and transition conditions and actions.

With reference to the dishwasher, upon entry into the parent state *dishwasherParent*, the default child state is *dishwasherOff*. The entry to this default state sets the variable *dishwasherState* to 0. Unlike the manual appliances whose transition condition to the on state is determined via a spreadsheet input, the transition condition to *dishwasherOn* is fulfilled when the available power from the inverter system is greater than or equal to the sum of the demand of the appliance and the current aggregate power consumption of all appliances. Entry to the on state then sets the appliance state variable *dishwasherState* to 1. For the dishwasher, the transition condition is shown as.

Equation 10

$$solarkW \geq 2400\ W + \sum Energised\ appliance\ demand$$

Conversely, transition from the on to off state is only triggered if the output of the solar system falls below the minimum demand of the appliance. For uninterruptible appliances, once transition to the on state is achieved, they will not abandon their cycle in response to the energisation of other appliances.

Transition between *dishwasherOn* to the final state *dishwasherCyclecomplete* is fulfilled after the appliance has completed its wash cycle. For a practical installation, this would be a signal from the appliance itself to denote the cycle has finished. For prototyping of the control algorithm, this can be simulated using the *after* function to count the cycle time documented in the appliance manufacturer data. For the dishwasher, this is equal to 3.5 hours – represented as 12600 seconds for simulation.

The cycle completion state is held until variable *dayTime* indicates the current day is over. Initially set at 86400 seconds (00:00), this has been set at 72000 seconds (20:00) to provide the time required for

Simulink to reset each appliance to the default state before the beginning of the subsequent day. Upon transition, *dayTime* is set back to zero and the variable *dayNumber* is incremented to denote the day has passed.

As per the manual appliances, the aggregate power consumption variable *totalPower* is incremented and decremented by the value of the appliance demand when transitioning between states.

3.4.3.3 Controllable Loads – Interruptible

The interruptible controllable loads consist of two parallel child states within the *MasterController* parent – *hwsParent* and *poolParent*, for the hot water system and pool pump respectively.

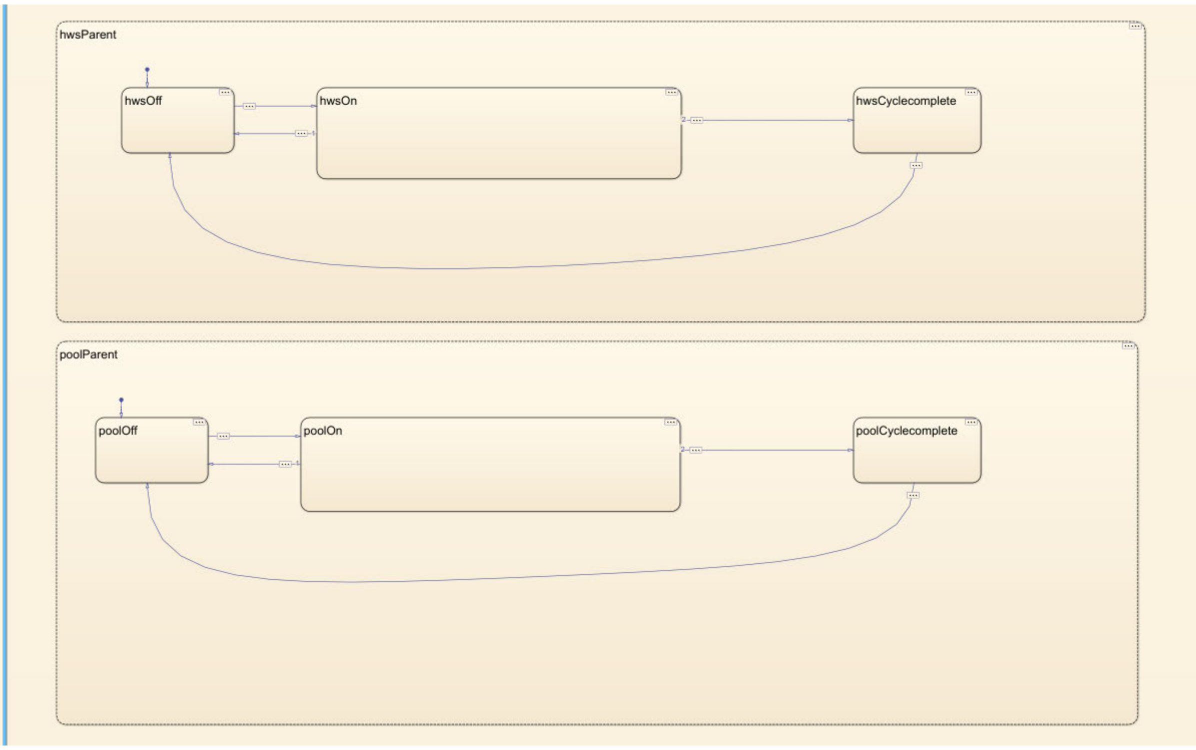


Figure 66. Interruptible load parent states

In a similar manner to the uninterruptable loads, the interruptible load parents each contain three exclusive child states that determine when the appliance is off, on or if it has completed its cycle.

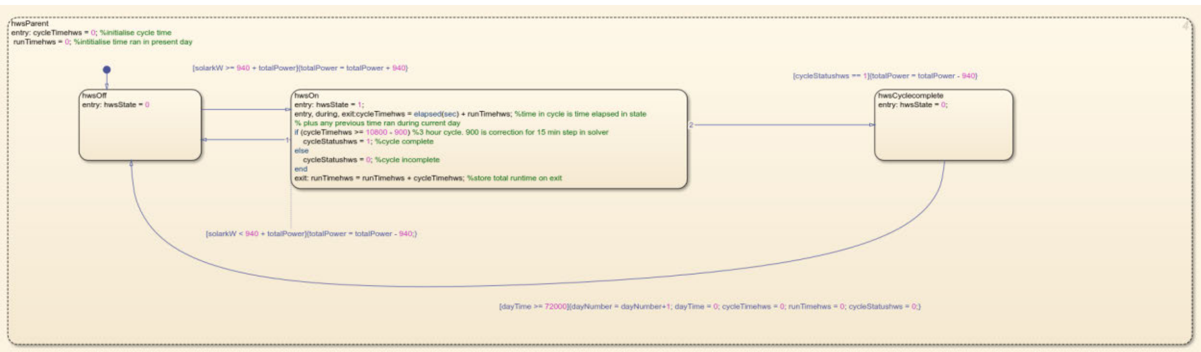


Figure 67. Hot water system parent state showing child states and transition conditions and actions.

Entry into the parent state initialises two variables that are used to keep track of the time the appliance has spent in its operating cycle during that specific day. This is crucial to track, as the hot water system and pool pump can be interrupted during their cycle in the on state when higher priority appliances cause *totalPower* to exceed *solarkW*. These cycle tracking variables are shown in Figure 67 for the hot water system as:

- *cycleTimehws* – used to track how long the appliance has currently been in the on state.
- *runTimehws* – used to store the total time the appliance has been energised, upon exit from the on state.

Further exploring the hot water system as an example, and as per previous appliances, *the* default child state when entering the parent is *hwsOff*, with an entry condition setting *hwsState* to 0. The transition condition to *hwsOn*, and the associated incrementation of *totalPower* is identical in execution to the uninterruptible loads.

Upon entry into *hwsOn*, the *hwsState* variable is set to 1 and *cycleTimehws* begins tracking time in cycle using the elapsed function and summing this with *runTimehws*. A conditional if statement is then used to check if the cycle is complete, shown below in Figure 68 for further clarity.

```
if (cycleTimehws >= 10800 - 900) %3 hour cycle. 900 is correction for 15 min step in solver
   cycleStatushws = 1; %cycle complete
else
   cycleStatushws = 0; %cycle incomplete
end
```

Figure 68. Hot water system conditional statement to determine cycle status.

For the hot water system, a 3-hour cycle (10800 seconds) is specified, with 900 seconds subtracted to correct simulation timing for the falling signal edge. When the value *cycleTimehws* is equal to or greater than the cycle time, the variable *cycleStatushws* is set to 1. This fulfils the condition required to transition to the *hwsCyclecomplete* state, setting *hwsState* to 0, indicating the cycle has been completed for that day.

If at any point during the appliance cycle in the *hwsOn*, the power output of the solar inverter solarkW falls below the aggregate appliance demand *totalPower*, the hot water system will transition back to the *hwsOff* state. In order to return to the same point in the cycle when re-entering, the exit condition of *hwsOn* increments the total run time variable *runTimehws* by the value of *cycleTimehws*.

As per the uninterruptable appliances, the cycle completion state is held until variable *dayTime* exceeds 72000 seconds. Upon transition, the following variables are updated as a transition action.

- *dayTime* is set back to zero.
- *dayNumber* is incremented by 1.

- *cycleTimehws* is reset to zero.
- *runTimehws* is reset to zero.
- *cyclestatuhws* is reset to zero.

3.4.4 Battery State

As mentioned, the Tesla Powerwall 3 has been selected as the reference BESS, with capacity and output assigned to the input variables *battCapacity* and *battOutput* respectively.

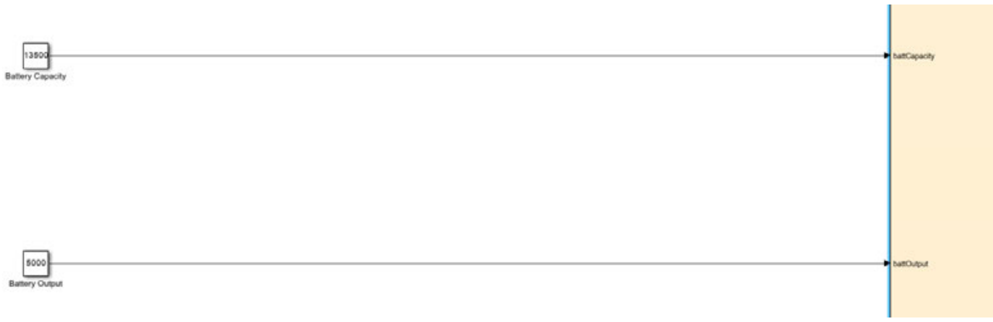


Figure 69. Battery system input variables

The *batteryParent* state is a parallel parent state with three exclusive child states - *batteryStandby*, *batteryCharge* and *batteryDischarge*.

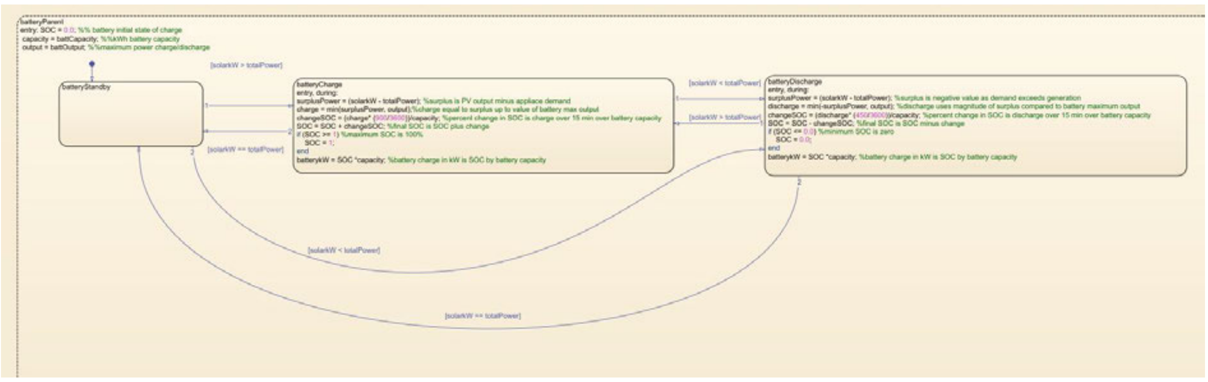


Figure 70. Battery parent state showing child states and transition conditions and actions.

Entry into *batteryParent* initialises the state of charge variable *SOC* at zero, denoting the battery as fully discharged. The input variables *battCapacity* and *battOutput* are then assigned to the variable's *capacity* and *output* respectively. The default child state *batteryStandby* is entered into, where the transition conditions to and from the *batteryCharge* and *batteryDisharge* state are defined.

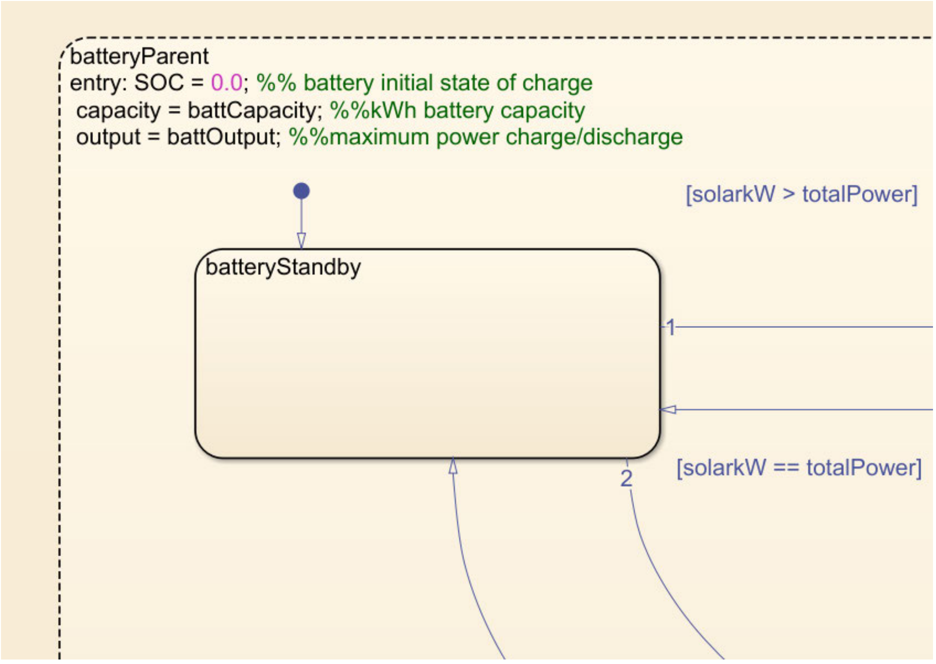


Figure 71. *batteryStandby* child state and *batteryParent* entry conditions

When the output of the solar inverter *solarkW* exceeds the aggregate power demand of the appliances, the excess power can be utilized to charge the BESS rather than export to the grid in order to maximise self-consumption through later discharge. When this condition is detected in either the *batteryStandby* or *batteryDischarge* states, the transition to the *batteryCharge* state is triggered. Upon entry and when within the *batteryCharge* state, the following variables are defined and updated for each simulation step.

- *surplusPower* is determined as the difference in power between the output of the solar inverter and the aggregate demand of the appliances.
- *charge* is then defined for the input power of the BESS. The maximum charging power is set at 5kW as specified in the data sheet, with the minimum power being the inverter output power that remains after supplying the appliances. The actual charging power is then determined as the minimum value between these two variables.
- *changeSOC* is defined as the percentage of the change of the state of charge of the battery. This is traditionally found as the ratio of the current charge over the maximum charge (capacity). Given the charge in kW and capacity in kWh, this is scaled within the model by half of the step size over 3600 seconds.

SOC is then incremented at each simulation step by the value of *changeSOC*. A conditional if statement is used to cap the maximum state of charge at 100% of the battery. Finally, the battery charge in kilowatts is found by the product of SOC and the battery capacity.

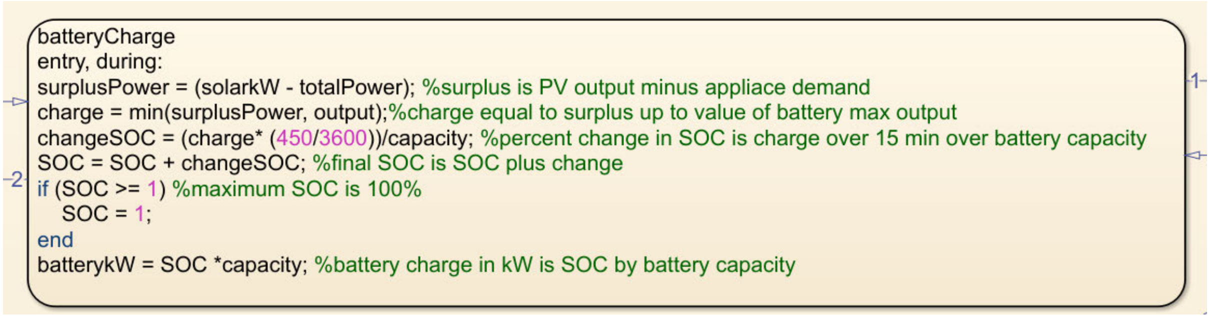


Figure 72. *batteryCharge* child state

When the aggregate power demand of the appliances exceeds the output of the solar inverter *solarkW*, the BESS is discharged to overcome the deficit in output and limit power drawn from the grid. When this condition is detected in either the *batteryStandby* or *batteryCharge* states, the transition to the *batteryDischarge* state is triggered. Upon entry and when within the *batteryDischarge* state, the following variables are defined and updated for each simulation step.

- *surplusPower* is determined as per the charge state, to find the difference in output between the inverter and appliance demand.
- *discharge* is found similarly to *charge*, however the negative of *surplusPower* is used to represent the deficit. This results in a maximum discharge equal to power deficit, up to a maximum of 5kW.
- *changeSOC* is defined as per the charge state, except using *discharge* instead of *charge* over the battery capacity.

SOC is again by the value of *changeSOC*, with conditional if statement capping minimum capacity at 0%.

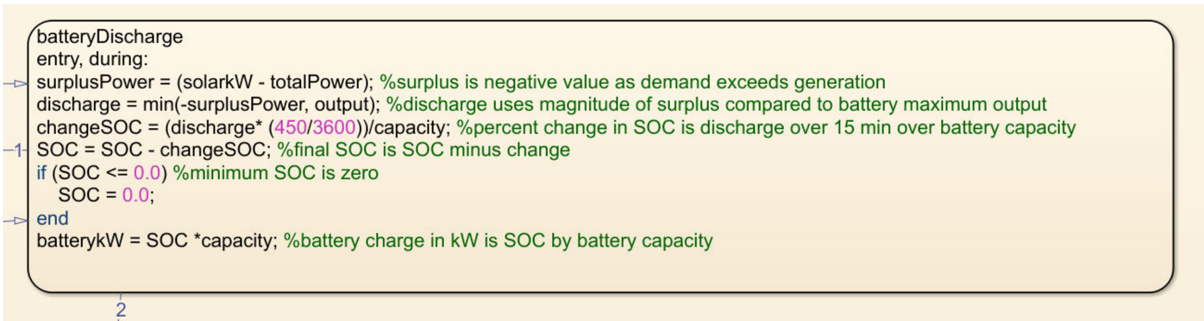


Figure 73. *batteryDischarge* child state

Maximising the Total Power Consumption/Battery SOC status scope, the output variables for *totalPower*, *SOC* and *batterykW* are displayed for graphical analysis. This is shown in Figure 74 below.

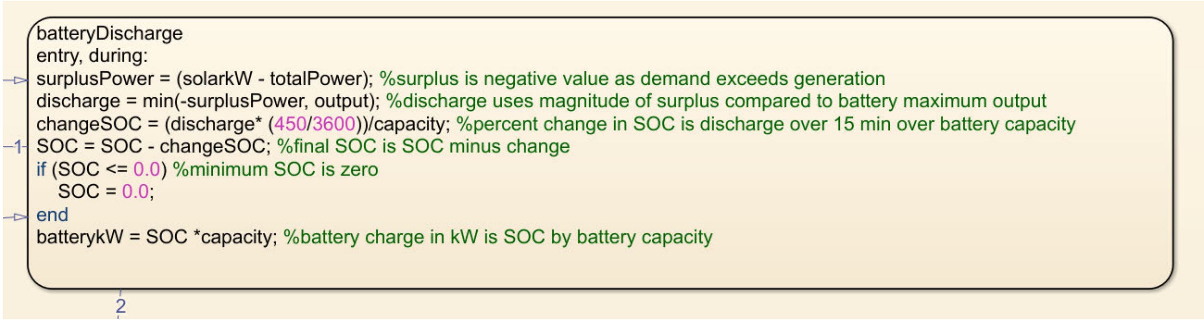


Figure 74. Total Power Consumption/Battery SOC status scope display

4 RESULTS AND ANAYLSIS

Chapters 4 and 5 focus on the analysis of the outputs of the prototype algorithm, to determine the effectiveness of the implemented control strategy with respect to an installation with no controller present. The measure of effectiveness is to be determined according to the following criteria.

- The change in the magnitude of self-consumption achieved with the controller present, when compared to a standalone system with a controller.
- The economic impact of the change in self-consumption, when compared against the typical tariff pricing structure for grid connected residential installations, as documented in the literature review.

To determine the effectiveness of the controller under different load conditions, analysis covers the following scenarios, for both the aforementioned 2 and 4 person households, and for instances with and without a BESS present.

- Daily typical loading for each season, based upon the load profiles developed through the literature review and subsequent methodology. Input spreadsheets for each season can be found in Appendix D.
- Daily heavy loading for each season, representing an increased usage of manual appliances. Generally, these profiles are based upon the typical load profiles, but include:
  - Cooktop output increased from three plates (4.1kW) to four plates (6.5kW)
  - Additional morning oven usage between the period of 8:30am to 10:00am
  - Additional television usage from 6:00am to 8:00am and 11:00am to 1:00pm.

  Input spreadsheets for each season of heavy loading can be found in Appendix D.

For both loading scenarios, daily results will subsequently be extrapolated during discussion to predict the impacts of the controller over weekly, seasonal and annual periods. Chapter 4 focuses on the raw output data and preliminary analysis of each scenario, while chapter 5 discusses the subsequent total effectiveness of the project.

4.1 Method of Analysis

The following signals of interest have been marked for logging in the Simulink model and then output for analysis using the data inspector.

- *solarkW* – labelled in data inspector as Inverter Output, highlighting the change in power output (kW) over the selected time interval.
- *totalPower* – labelled in data inspector as Appliance Demand, highlighting the change in aggregate power demand (kW) of all appliances over the selected time interval.

- *SOC* – labelled in data inspector as Battery SOC, highlighting the change the state of charge of the battery energy storage system over the selected time interval.

For each loading scenario, the logged signals from the data inspector are output as both a graph for visual inspection of trends, and an Excel spreadsheet containing the change in values over time. Figure 75 below shows the first 54 entries for the output spreadsheet of the 2-person typical load in summer for a standalone system with a controller.

	A	B	C
1	time	Appliance Demand	Inverter Output
2	0	0	0
3	900	2008.33	0
4	900	2008.33	0
5	1800	2008.33	0
6	1800	2008.33	0
7	2700	2008.33	0
8	2700	2008.33	0
9	3600	2008.33	0
10	3600	1068.33	0
11	4500	1068.33	0
12	4500	1068.33	0
13	5400	1068.33	0
14	5400	1068.33	0
15	6300	1068.33	0
16	6300	1068.33	0
17	7200	1068.33	0
18	7200	1068.33	0
19	8100	1068.33	0
20	8100	1068.33	0
21	9000	1068.33	0
22	9000	1068.33	0
23	9900	1068.33	0
24	9900	1068.33	0
25	10800	1068.33	0
26	10800	1068.33	0
27	11700	1068.33	0
28	11700	1068.33	0
29	12600	1068.33	0
30	12600	1068.33	0
31	13500	1068.33	0
32	13500	1068.33	0
33	14400	1068.33	0
34	14400	1068.33	0
35	15300	1068.33	0
36	15300	1068.33	0
37	16200	1068.33	0
38	16200	1068.33	0
39	17100	1068.33	0
40	17100	1068.33	0
41	18000	1068.33	0
42	18000	1068.33	0
43	18900	1068.33	58
44	18900	1068.33	58
45	19800	1068.33	274
46	19800	1068.33	274
47	20700	1068.33	611
48	20700	1068.33	611
49	21600	1068.33	995
50	21600	1618.33	995
51	22500	1618.33	1175
52	22500	1268.33	1175
53	23400	1268.33	1231
54	23400	1268.33	1231

Figure 75. Data inspector output spreadsheet for 2-person solar yield and uncontrolled appliance demand - summer

As both appliance demand and inverter output curves are values of power in kilowatt, integrating these curves with respect to time provides the energy used over that period, commonly known as the work done. Unit conversion can then be undertaken to determine the appliance consumption and solar inverter supply in kilowatt-hours. The relationship of the respective integrals between these two sets of curves then provides a method of determining the effectiveness of the system, by measuring the amount of produced solar energy that is either exported to the grid or utilised in self-consumption. The calculations required to determine this have been undertaken in the data inspector output spreadsheets, with the first 18 entries shown below in Figure 76.

	A	B	C	D	E	F	G	H	I	J	K
1	time	Appliance Demand	Inverter Output	Solar Export Raw	Solar Export to Grid	Energy Offset Solar	Appliance Integral	Inverter Integral	Raw Export Integral	Grid Export Integral	Solar Offset Integral
2	0	0	0	0	0	0	0	0	0	0	0
3	900	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
4	900	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
5	1800	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
6	1800	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
7	2700	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
8	2700	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
9	3600	2008.33	0	-2008.33	0	0	899065.8653	0	-899065.8653	0	0
10	3600	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
11	4500	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
12	4500	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
13	5400	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
14	5400	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
15	6300	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
16	6300	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
17	7200	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0
18	7200	1068.33	0	-1068.33	0	0	478257.5751	0	-478257.5751	0	0

Figure 76. Calculations for 2-person solar yield and uncontrolled appliance demand - summer

Solar export raw is used to determine the direction of energy flow with respect the grid for each entry. A negative value represents a portion of energy that is drawn from the grid, while a positive value represents energy that is exported to the grid. This is determined for each entry in accordance with Equation 11.

Equation 11

$$Solar\ Export\ Raw_n = Inverter\ Output_n - Appliance\ Demand_n$$

For each entry, solar export to grid is found using a logical statement, shown in Equation 12 below.

Equation 12

$$\begin{aligned}
&If\ (Solar\ Export\ Raw_n < 0)\\
&Solar\ Export\ to\ Grid_n = 0\\
&Else\\
&Solar\ Export\ to\ Grid_n = \ Solar\ Export\ Raw_n
\end{aligned}$$

For each entry, energy offset solar is determined using Equation 13. This represents the amount of energy the solar is offsetting from the grid for that period of appliance demand.

Equation 13

$$\begin{aligned}
&If\ (Inverter\ Output_n > Appliance\ Demand_n)\\
&Energy\ Offset\ Solar_n = \ Appliance\ Demand_n\\
&Else\\
&Energy\ Offset\ Solar_n = \ Inverter\ Output_n
\end{aligned}$$

To find the integral for the appliance demand, the area underneath the curve needs to be calculated. The energy or work associated with the appliance demand, inverter output, solar export and energy offset over a full day can now all be found by taking the definite integral from zero to 86400 seconds.

Equation 14

$$W = \int_0^{86400} P\, dt$$

As the output from data inspector consists of discrete entries, the integral is approximated via summation as shown in Equation 15.

Equation 15

$$W = \sum_0^{Total\, n} P_n$$

The measured time period of 86400 seconds is discretised into sequential steps *n* by the data inspector. This value is used to determine the area of each entry, which are then summed to find the work done. Equation 16 and Equation 17 below provides an example of this when assessing the integral for the appliance demand.

Equation 16

$$Appliance\ Demand\ Area_n = Appliance\ Demand_n * \left(\frac{86400}{Total\ n}\right)$$

Equation 17

$$W_{Appliance\ Demand} = \sum_0^{Total\, n} P_{Appliance\ Demand\ Area_n}$$

The process is repeated for the inverter output, grid export and solar offset data sets to obtain the work done for each.

In addition to the work integrals, the impact of the BESS is assessed in accordance with the change in SOC values over each day. The contribution for each charge and discharge cycle of the BESS is shown in Equation 18 below.

Equation 18

$$BESS = \Delta SOC * capacity$$

Given a battery capacity of 13.5kWh, a change of the battery SOC of 100% would be equal to 13.5kWh of energy.

4.2 Standalone System without Controller

The outputs for the Simulink modelling for a system with no controller or battery energy storage system incorporated are shown in the following sections. These outputs form a baseline on which to compare against the controlled system outputs.

4.2.1 2 Person Household

4.2.1.1 2 Person Summer Typical Load

Figure 77 below shows the uncontrolled daily profile for a typical summer load profile for a 2-person household.

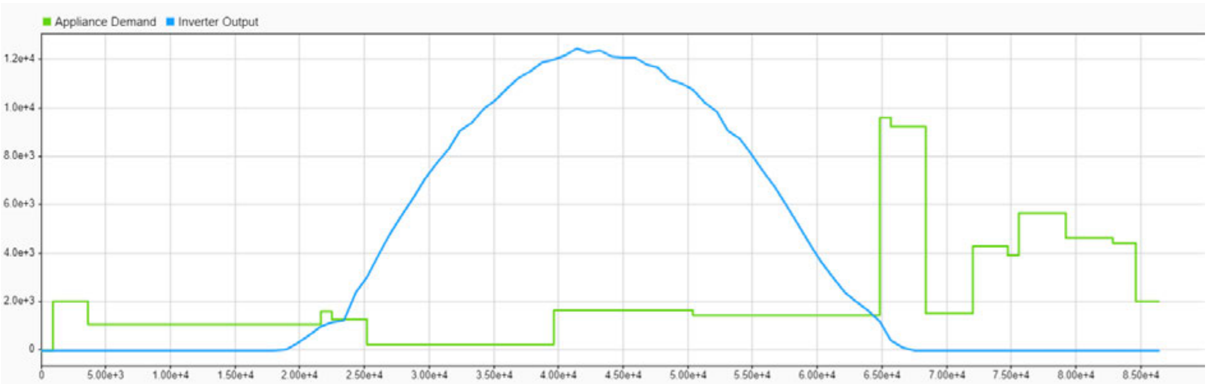


Figure 77. 2-person solar yield and uncontrolled appliance demand - summer

Table 6 below shows the results for the integration of output data from Simulink.

Table 6. Integration results of power curves – 2-person summer uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
175526014.01	341887933.68	293627624.46	48260309.22	Sum of Areas
48757.23	94968.87	81563.23	13405.64	Wh
48.76	94.97	81.56	13.41	kWh

4.2.1.2 2 Person Autumn Typical Load

Figure 78 below shows the uncontrolled daily profile for a typical autumn load profile for a 2-person household.

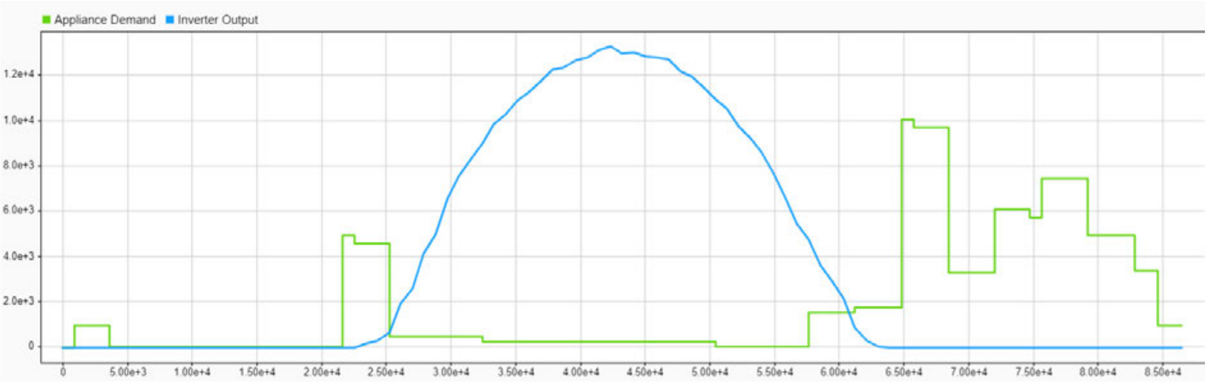


Figure 78. 2-person solar yield and uncontrolled appliance demand - autumn

Table **7** below shows the results for the integration of output data from Simulink.

Table 7. Integration results of power curves – 2-person autumn uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
161866755.98	322246035.23	307308652.60	14937382.63	Sum of Areas
44962.99	89512.79	85363.51	4149.27	Wh
44.96	89.51	85.36	4.15	kWh

4.2.1.3 2 Person Winter Typical Load

Figure 79 below shows the uncontrolled daily profile for a typical winter load profile for a 2-person household.

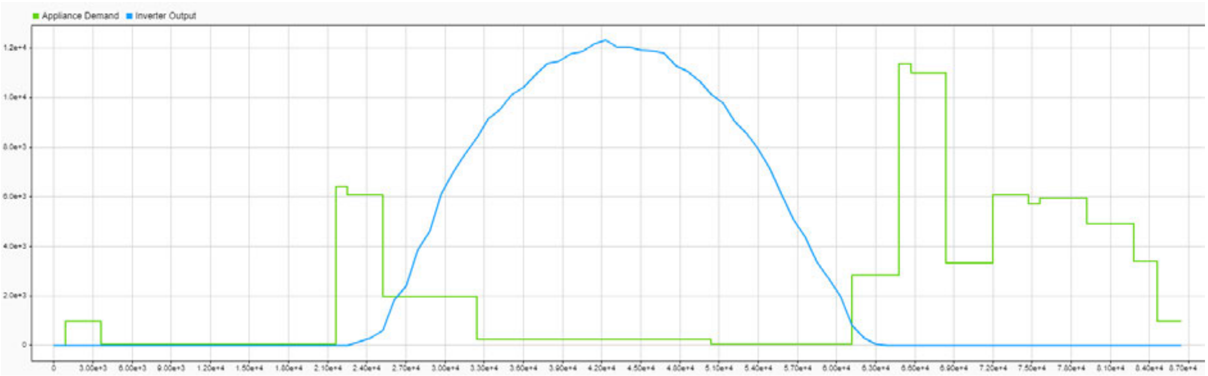


Figure 79. 2-person solar yield and uncontrolled appliance demand - winter

Table 8 below shows the results for the integration of output data from Simulink.

Table 8. Integration results of power curves – 2-person winter uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
175676430.59	299301239.38	279596931.48	19704307.90	Sum of Areas
48799.01	83139.23	77665.81	5473.42	Wh
48.80	83.14	77.67	5.47	kWh

4.2.1.4 2 Person Spring Typical Load

Figure 80 below shows the uncontrolled daily profile for a typical spring load profile for a 2-person household.

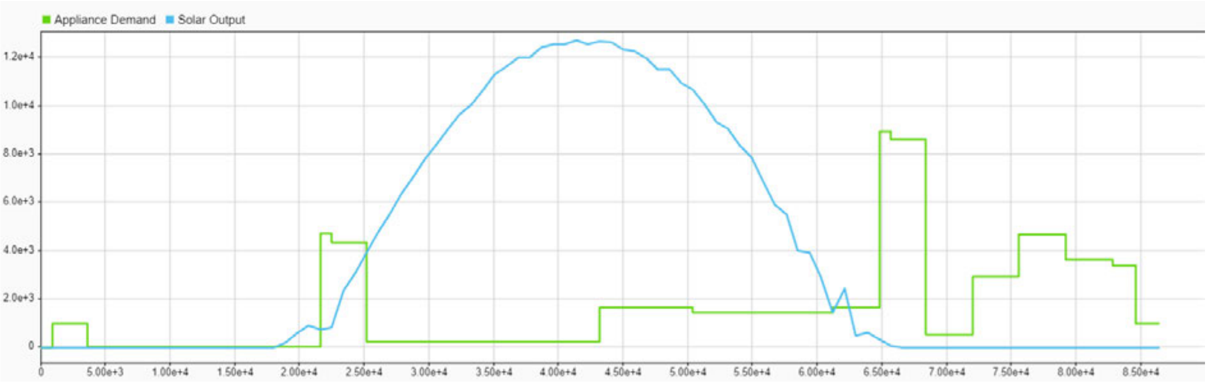


Figure 80. 2-person solar yield and uncontrolled appliance demand - spring

Table 9 below shows the results for the integration of output data from Simulink.

Table 9. Integration results of power curves – 2-person spring uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
138916588.10	346905401.04	303873558.72	43031842.32	Sum of Areas
38587.94	96362.61	84409.32	11953.29	Wh
38.59	96.36	84.41	11.95	kWh

4.2.1.5 2 Person Summer Heavy Load

Figure 81 below shows the uncontrolled daily profile for a typical summer load profile for a 2-person household.

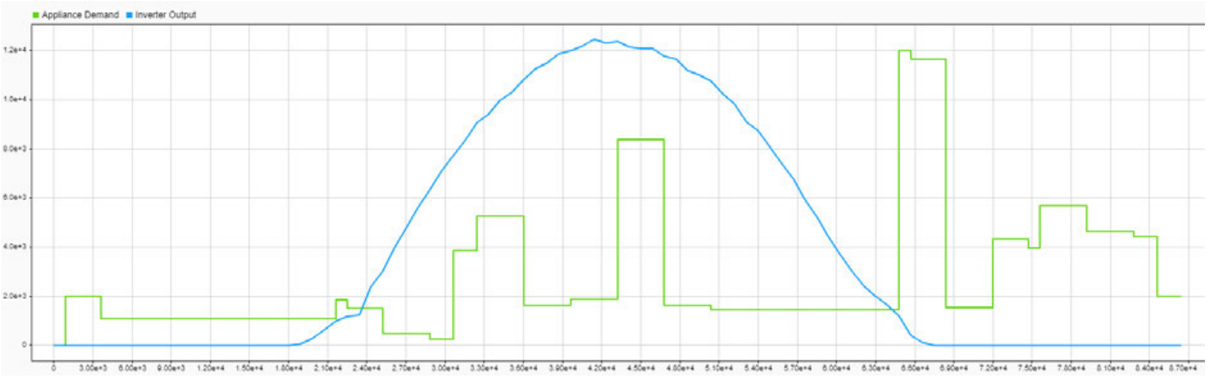


Figure 81. 2-person solar yield and uncontrolled heavy appliance demand - summer

Table 10 below shows the results for the integration of output data from Simulink.

Table 10. Integration results of heavy power curves – 2-person summer uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
240205143.54	341887933.68	238092121.87	103795811.81	Sum of Areas
66723.65	94968.87	66136.70	28832.17	Wh
66.72	94.97	66.14	28.83	kWh

4.2.1.6 2 Person Autumn Heavy Load

Figure 82 below shows the uncontrolled daily profile for a typical autumn load profile for a 2-person household.

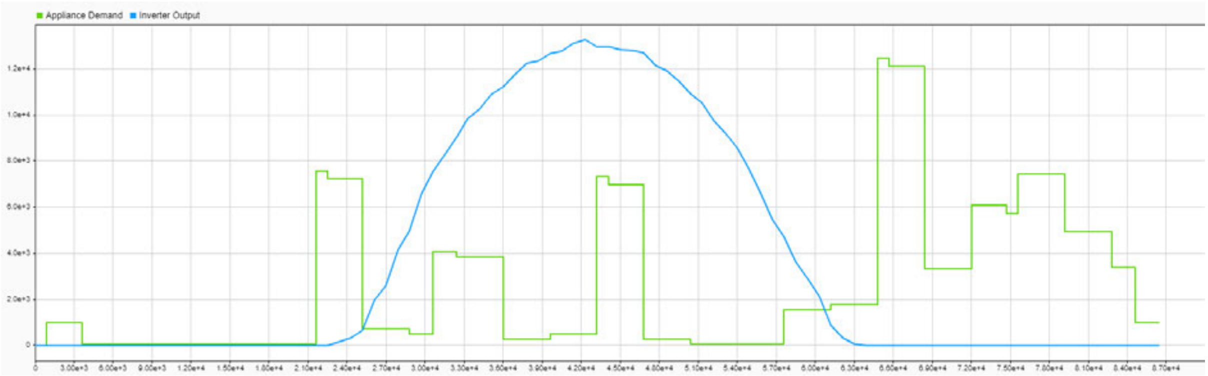


Figure 82. 2-person solar yield and uncontrolled heavy appliance demand - autumn

Table 11 below shows the results for the integration of output data from Simulink.

Table 11. Integration results of heavy power curves – 2-person autumn uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
225498341.47	322246035.23	261780924.68	60465110.55	Sum of Areas
62638.43	89512.79	72716.92	16795.86	Wh
62.64	89.51	72.72	16.80	kWh

4.2.1.7 2 Person Winter Heavy Load

Figure 83 below shows the uncontrolled daily profile for a heavy winter load profile for a 2-person household.

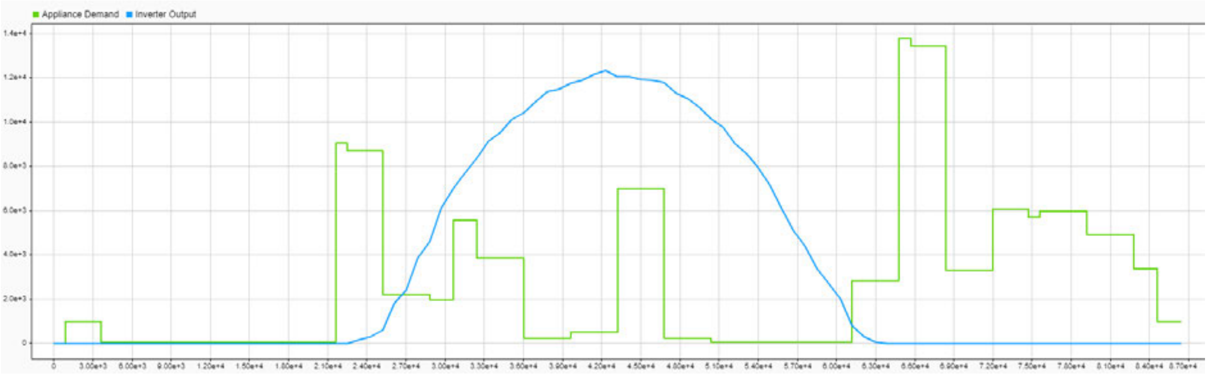


Figure 83. 2-person solar yield and uncontrolled heavy appliance demand - winter

Table 12 below shows the results for the integration of output data from Simulink.

Table 12. Integration results of heavy power curves – 2 people heavy uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
238994648.21	299301239.38	234675646.51	64625592.87	Sum of Areas
66387.40	83139.23	65187.68	17951.55	Wh
66.39	83.14	65.19	17.95	kWh

4.2.1.8 2 Person Spring Heavy Load

Figure 84 below shows the uncontrolled daily profile for a typical summer load profile for a 2-person household.

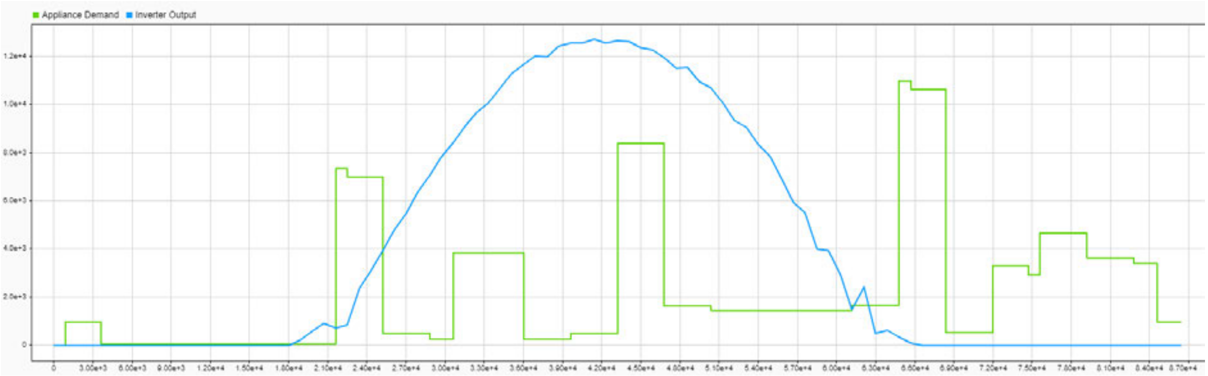


Figure 84. 2-person solar yield and uncontrolled heavy appliance demand - spring

Table 13 below shows the results for the integration of output data from Simulink.

Table 13. Integration results of heavy power curves – 2-person spring uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
201899054.42	346905401.04	258623237.47	88282163.56	Sum of Areas
56083.07	96362.61	71839.79	24522.82	Wh
56.08	96.36	71.84	24.52	kWh

4.2.2 4 Person Households

4.2.2.1 4 Person Summer Typical Load

Figure 85 below shows the uncontrolled daily profile for a typical summer load profile for a 2-person household.

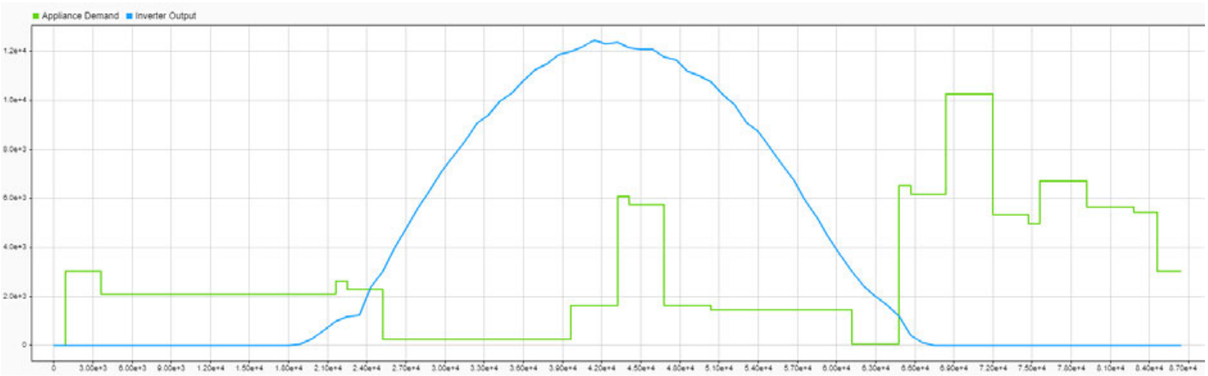


Figure 85. 4-person solar yield and uncontrolled appliance demand - summer

Table 14 below shows the results for the integration of output data from Simulink.

Table 14. Integration results of power curves – 4-person summer uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
245926345.62	341887933.68	282137619.73	59750313.95	Sum of Areas
68312.87	94968.87	78371.56	16597.31	Wh
68.31	94.97	78.37	16.60	kWh

4.2.2.2 4 Person Autumn Typical Load

Figure 86 below shows the uncontrolled daily profile for a typical autumn load profile for a 4-person household.

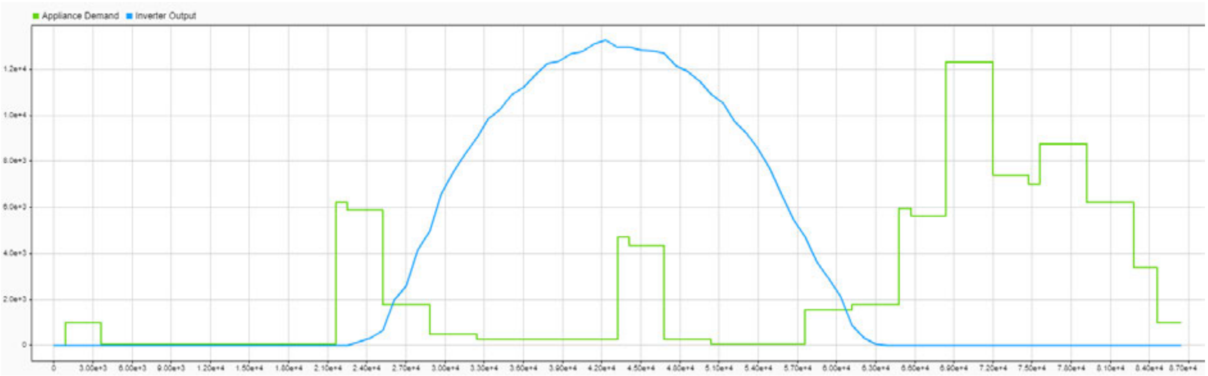


Figure 86. 4-person solar yield and uncontrolled appliance demand - autumn

Table 15 below shows the results for the integration of output data from Simulink.

Table 15. Integration results of power curves – 4-person autumn uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
217691004.68	322246035.23	288164261.47	34081773.76	Sum of Areas
60469.72	89512.79	80045.63	9467.16	Wh
60.47	89.51	80.05	9.47	kWh

4.2.2.3 4 Person Winter Typical Load

Figure 87 below shows the uncontrolled daily profile for a typical winter load profile for a 4-person household.

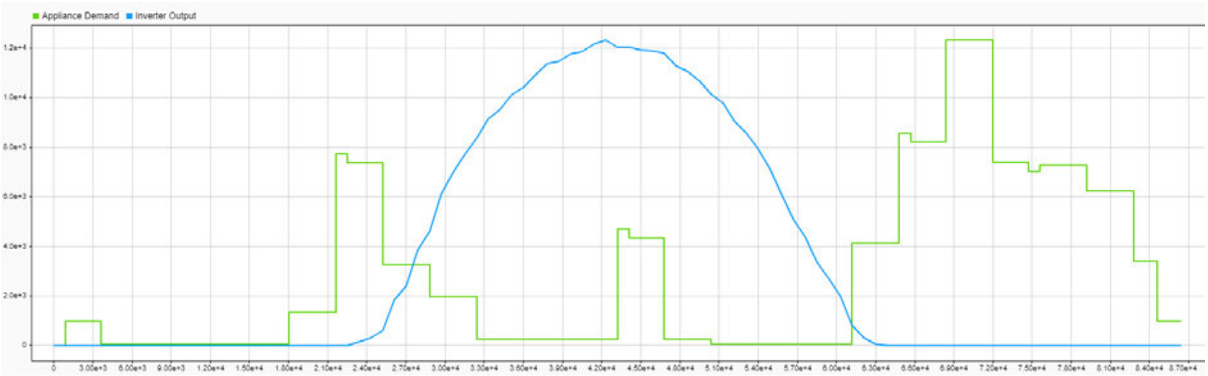


Figure 87. 4-person solar yield and uncontrolled appliance demand - winter

Table 16 below shows the results for the integration of output data from Simulink.

Table 16. Integration results of power curves – 4-person winter uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
245467933.18	299301239.38	262464957.51	36836281.87	Sum of Areas
68185.54	83139.23	72906.93	10232.30	Wh
68.19	83.14	72.91	10.23	kWh

4.2.2.4 4 Person Spring Typical Load

Figure 88 below shows the uncontrolled daily profile for a typical winter load profile for a 4-person household.

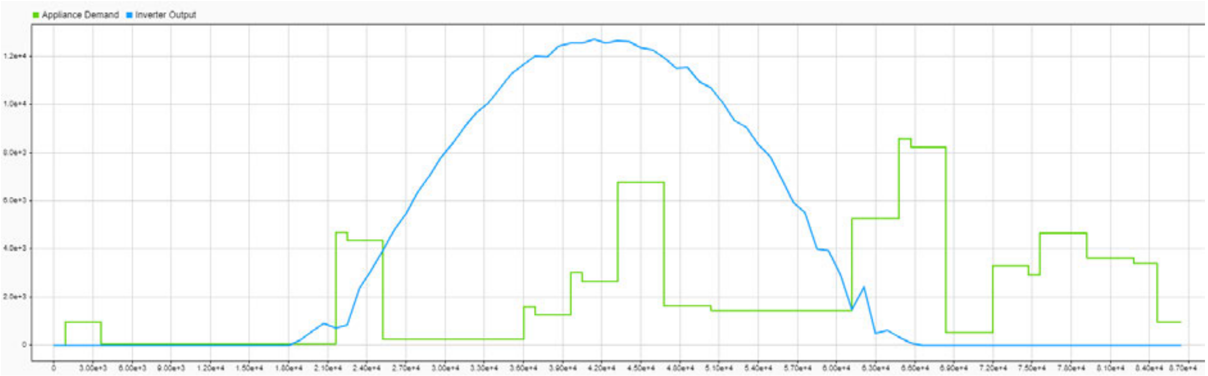


Figure 88. 4-person solar yield and uncontrolled appliance demand – spring

Table 17 below shows the results for the integration of output data from Simulink.

Table 17. Integration results of power curves – 4-person spring uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
182720940.44	346905401.04	271941667.65	74963733.39	Sum of Areas
50755.82	96362.61	75539.35	20823.26	Wh
50.76	96.36	75.54	20.82	kWh

4.2.2.5 4 Person Summer Heavy Load

Figure 89 below shows the uncontrolled daily profile for a heavy summer load profile for a 2-person household.

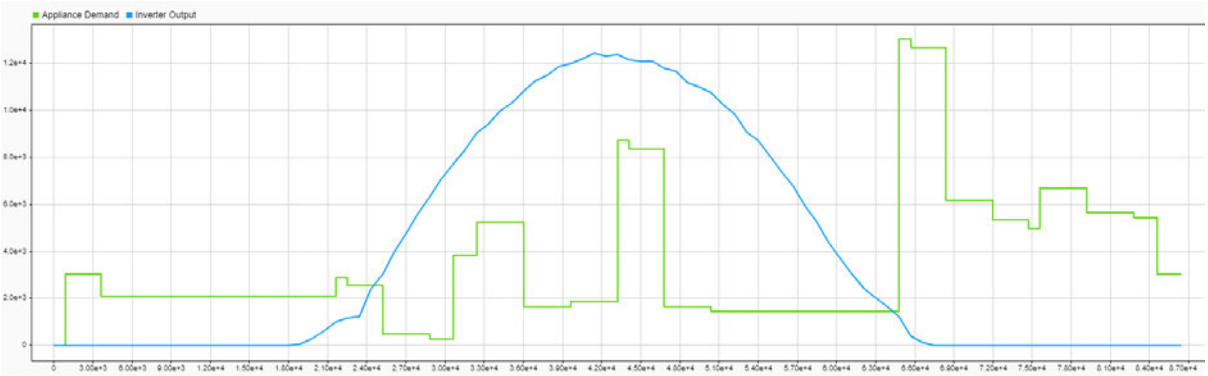


Figure 89. 4-person solar yield and uncontrolled heavy appliance demand - summer

Table 18 below shows the results for the integration of output data from Simulink.

Table 18. Integration results of heavy power curves – 4-person summer uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
300900024.37	341887933.68	236539008.00	105348925.68	Sum of Areas
83583.34	94968.87	65705.28	29263.59	Wh
83.58	94.97	65.71	29.26	kWh

4.2.2.6 4 Person Autumn Heavy Load

Figure 90 below shows the uncontrolled daily profile for a heavy autumn load profile for a 2-person household.

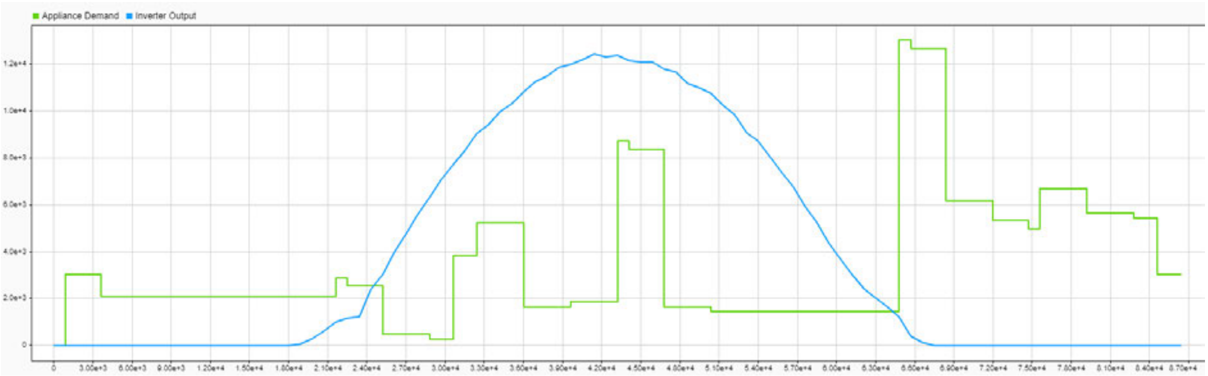


Figure 90. 4-person solar yield and uncontrolled heavy appliance demand - autumn

Table 19 below shows the results for the integration of output data from Simulink.

Table 19. Integration results of heavy power curves – 4-person autumn uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
266325698.98	322246035.23	257771006.67	64475028.56	Sum of Areas
73979.36	89512.79	71603.06	17909.73	Wh
73.98	89.51	71.60	17.91	kWh

4.2.2.7 4 Person Winter Heavy Load

Figure 91 below shows the uncontrolled daily profile for a heavy autumn load profile for a 2-person household.

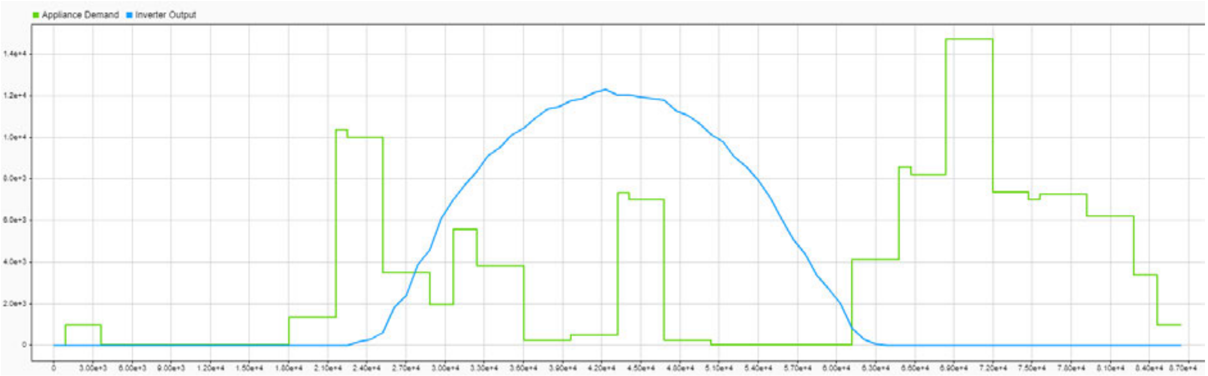


Figure 91. 4-person solar yield and uncontrolled heavy appliance demand - winter

Table 20 below shows the results for the integration of output data from Simulink.

Table 20. Integration results of heavy power curves – 4-person winter uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
294102627.48	299301239.38	232446553.37	66854686.01	Sum of Areas
81695.17	83139.23	64568.49	18570.75	Wh
81.70	83.14	64.57	18.57	kWh

4.2.2.8 4 Person Spring Heavy Load

Figure 92 below shows the uncontrolled daily profile for a heavy spring load profile for a 2-person household.

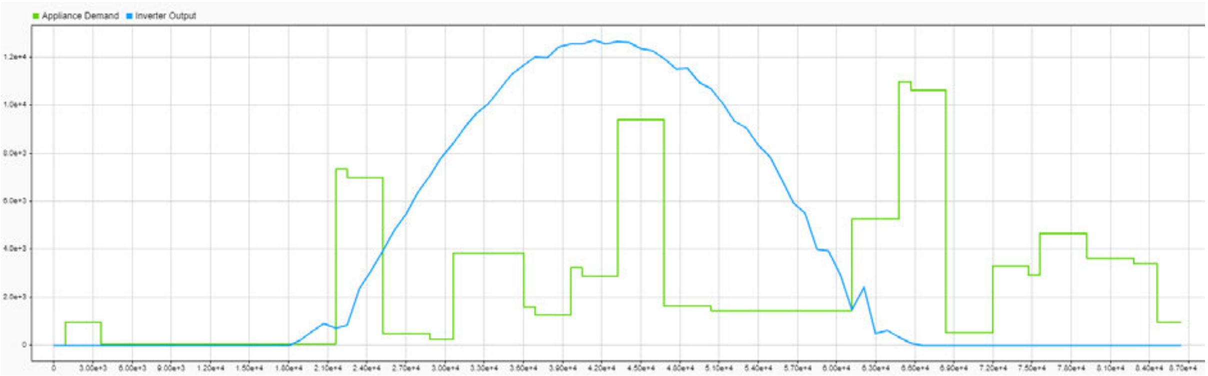


Figure 92. 4-person solar yield and uncontrolled heavy appliance demand - spring

Table 21 below shows the results for the integration of output data from Simulink.

Table 21. Integration results of heavy power curves – 4-person spring uncontrolled

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
231355634.74	346905401.04	241374869.72	105530531.32	Sum of Areas
64265.45	96362.61	67048.57	29314.04	Wh
64.27	96.36	67.05	29.31	kWh

4.3 Standalone and Hybrid System with Controller

The outputs for the Simulink modelling for a standalone system incorporating the controller and a hybrid system incorporating the controller and BESS are shown in the following sections.

4.3.1 2 Person Households

4.3.1.1 2 Person Summer Typical Load

Figure 93 below shows the daily profile for a typical summer load profile for a 2-person household.

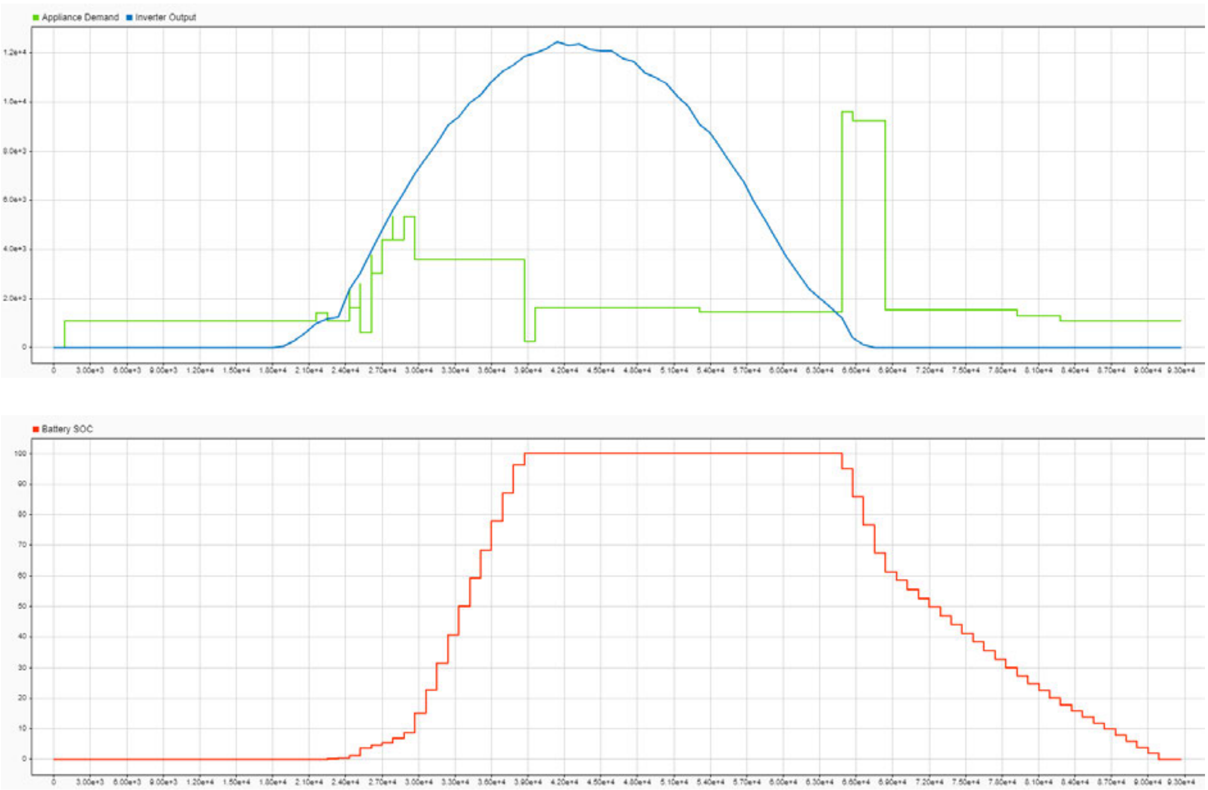


Figure 93. 2-person solar yield, appliance demand and battery SOC - summer

N.B. Day shown for 92700 as battery SOC reaches 0% at 91800.

Table 22 below shows the results for the integration of output data from Simulink.

Table 22. Integration results of power curves – 2-person summer

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
176206469.97	341887933.68	245235570.90	96652362.78	Sum of Areas
48946.24	94968.87	68120.99	26847.88	Wh
48.95	94.97	68.12	26.85	kWh

4.3.1.2 2 Person Autumn Typical Load

Figure 94 below shows the daily profile for a typical summer load profile for a 2-person household.

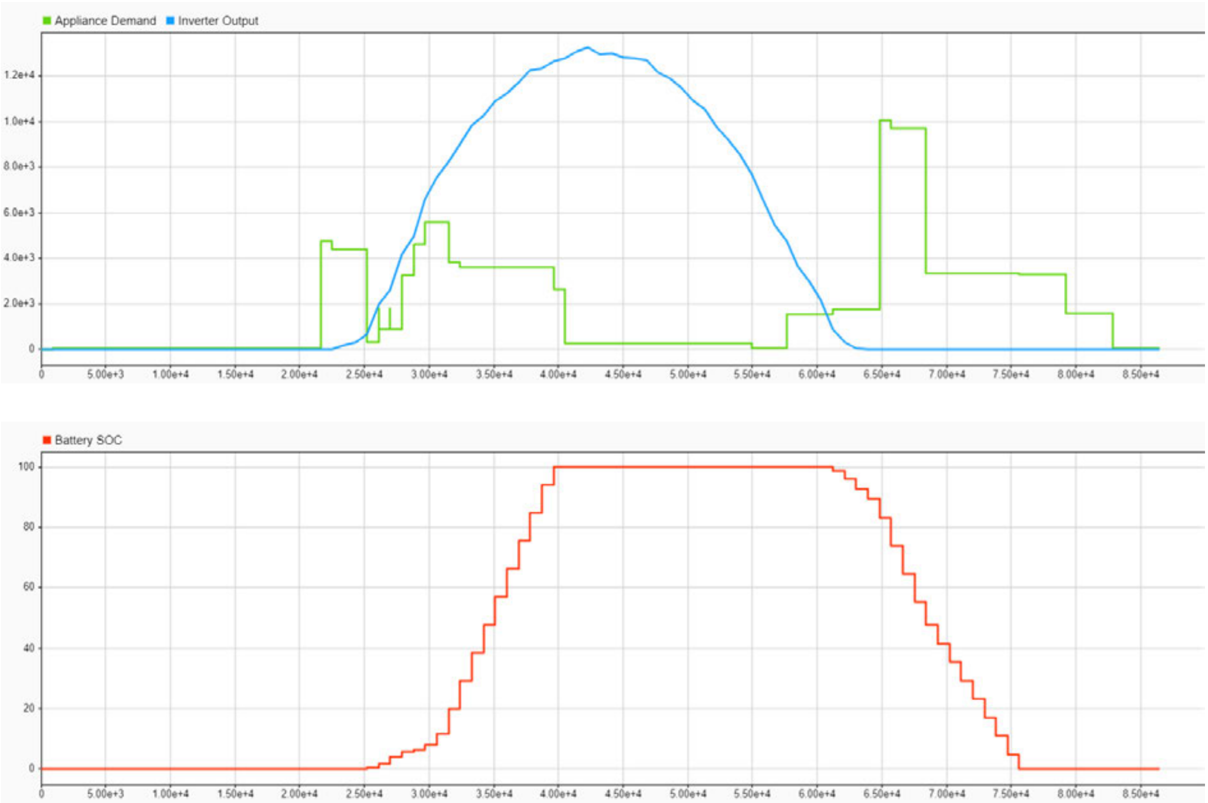


Figure 94. 2-person solar yield, appliance demand and battery SOC – autumn

Table 23 below shows the results for the integration of output data from Simulink.

Table 23. Integration results of power curves – 2-person autumn

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
161795129.04	322246035.23	259206683.69	63039351.54	Sum of Areas
44943.09	89512.79	72001.86	17510.93	Wh
44.94	89.51	72.00	17.51	kWh

4.3.1.3 2 Person Winter Typical Load

Figure 95 below shows the daily profile for a typical summer load profile for a 2-person household.

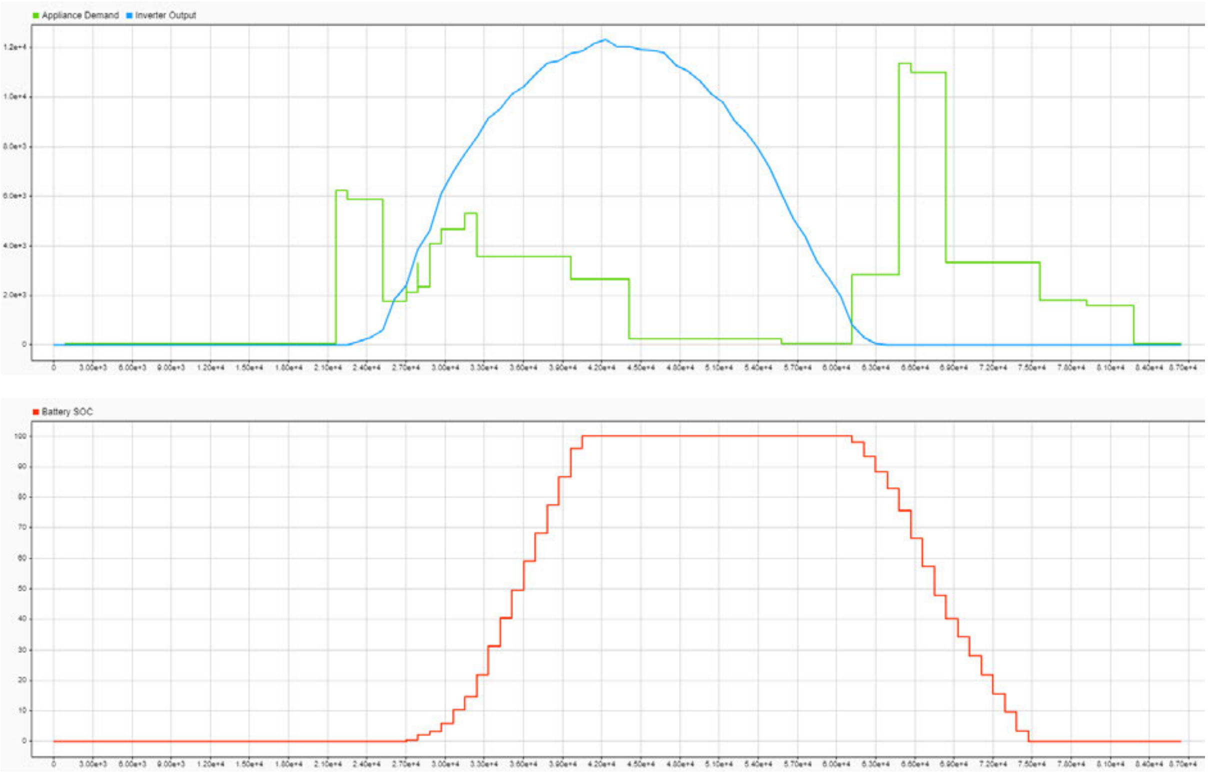


Figure 95. 2-person solar yield, appliance demand and battery SOC – winter

Table 24 below shows the results for the integration of output data from Simulink.

Table 24. Integration results of power curves – 2-person winter

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
175183995.36	299301239.38	231687164.52	67614074.86	Sum of Areas
48662.22	83139.23	64357.55	18781.69	Wh
48.66	83.14	64.36	18.78	kWh

4.3.1.4 2 Person Spring Typical Load

Figure 96 below shows the daily profile for a typical spring load profile for a 2-person household.

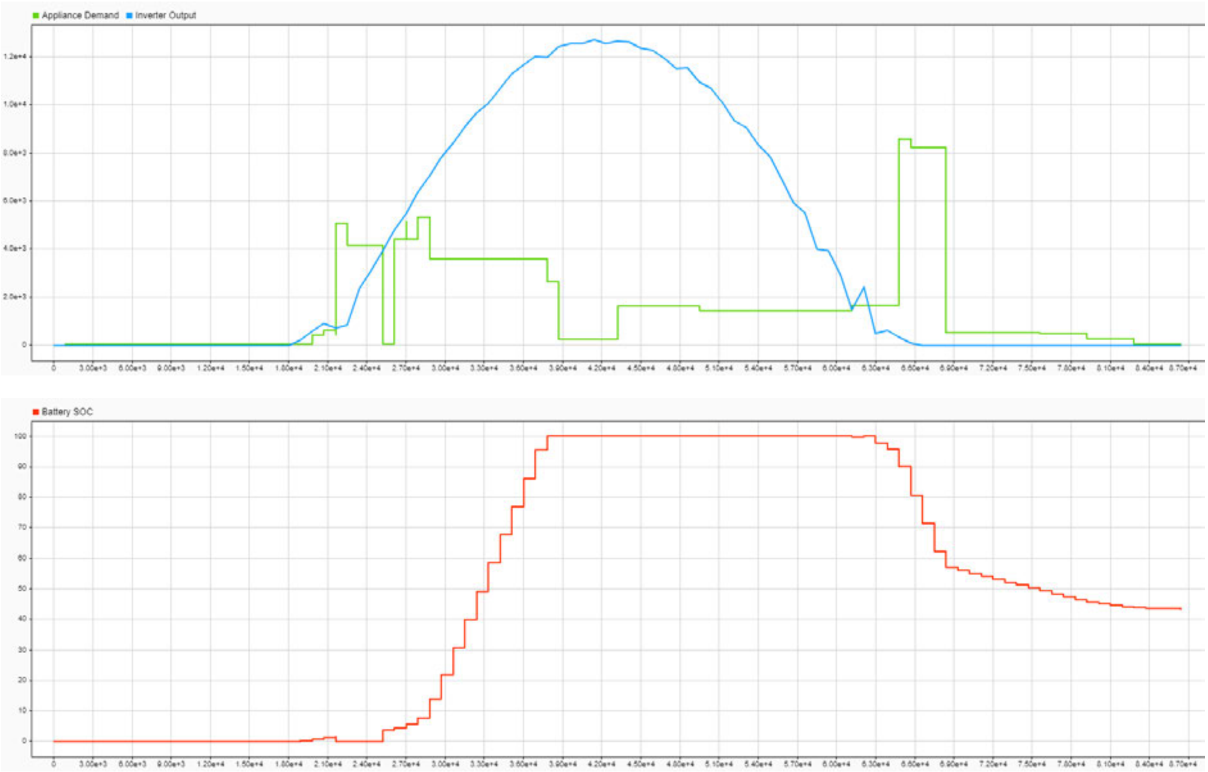


Figure 96. 2-person solar yield, appliance demand and battery SOC – Spring

Table 25 below shows the results for the integration of output data from Simulink.

Table 25. Integration results of power curves – 2-person spring

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
137282598.47	346905401.04	257255610.53	89649790.51	Sum of Areas
38134.06	96362.61	71459.89	24902.72	Wh
38.13	96.36	71.46	24.90	kWh

For the spring profile, the BESS does not fully discharge over a single day. To gain a clearer understanding of the system behaviour, it is important to analyse the system over consecutive days.

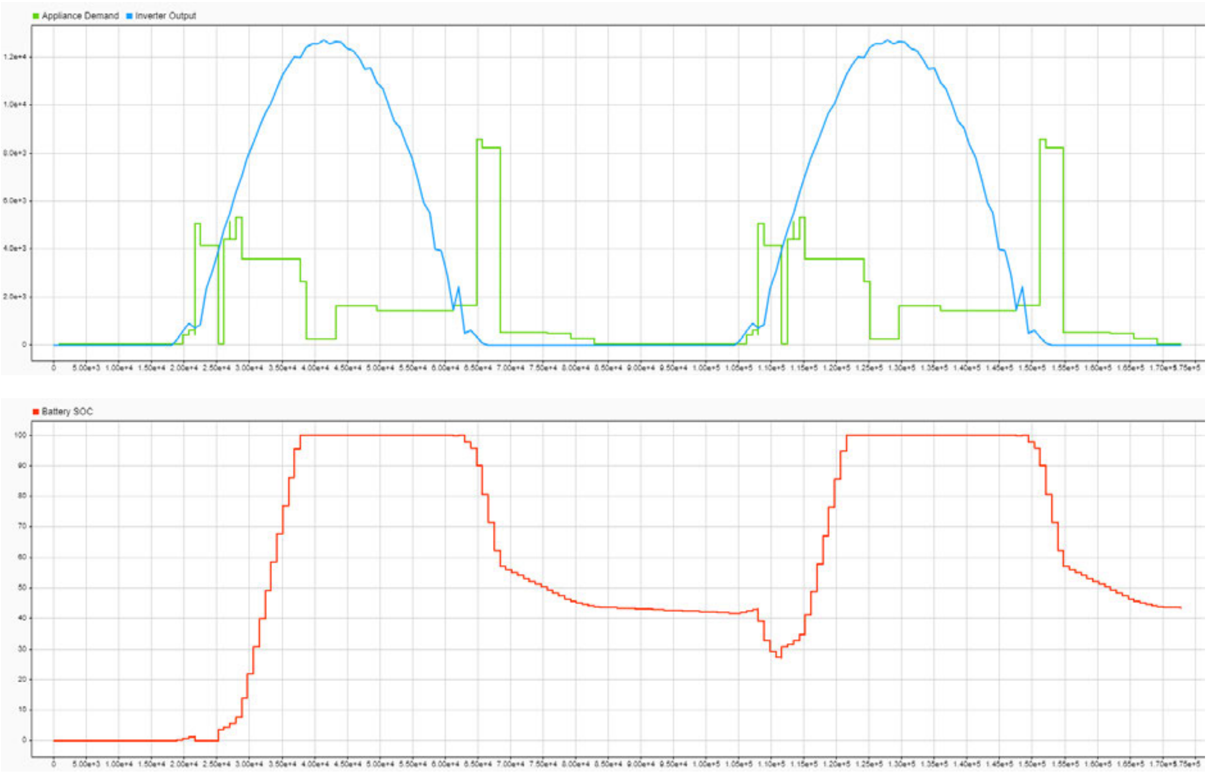


Figure 97. 2-person solar yield, appliance demand and battery SOC – Spring (Consecutive days)

Table 26. Integration results of power curves – 2-person spring on day 2

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
136917612.00	348712200.00	259675483.50	89036716.50	Sum of Areas
38032.67	96864.50	72132.08	24732.42	Wh
38.03	96.86	72.13	24.73	kWh

From Figure **97**, SOC is observed at 86400 on day 1 to be 43.49%. SOC between 86400 to 104400 (early morning day 2) discharges from 43.49% to 41.71% to run refrigerator. The amount of power discharged at each period is determined as the product of the battery capacity and the difference in SOC before and after discharging.

Equation 19

$$Evening\ Discharge: (1 - 0.4349) * 13.5kWh = 7628.85\ Wh$$

$$Morning\ Discharge: (0.4349 - 0.4171) * 13.5kWh = 240.3\ Wh$$

$$Total\ Discharge: 7869.15\ Wh$$

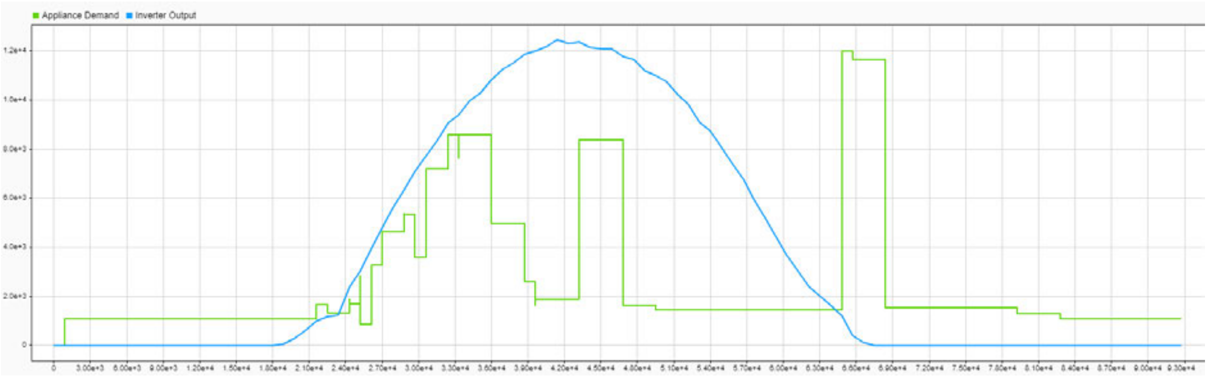
Upon sun rise, the BESS charges back up to 100%. Afternoon to evening discharge then again reduces SOC to 43.49% at 172800 (86400 on day 2).

Equation 20

$$Morning\ Charge: (1 - 0.4171) * 13.5kWh = 7869.15\ Wh$$

4.3.1.5 2 Person Summer Heavy Load

Figure 98 below shows the daily profile for a heavy summer load profile for a 2-person household.



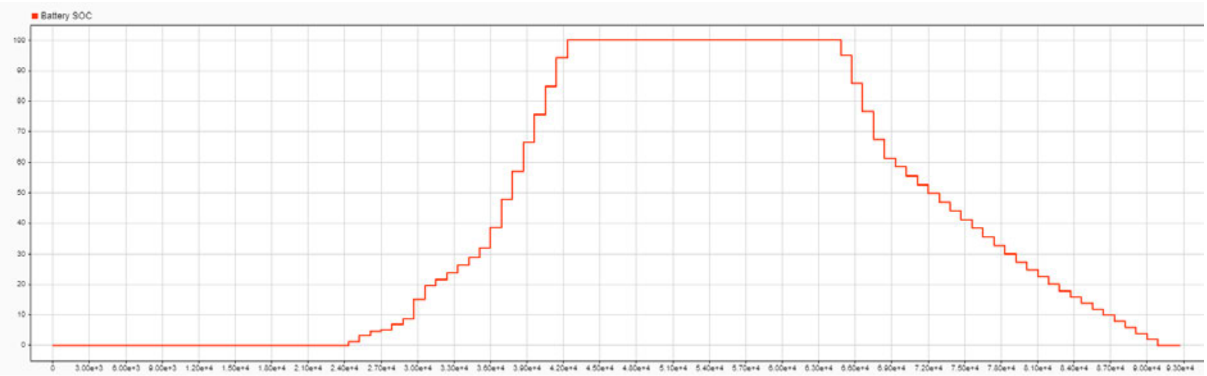


Figure 98. 2-person solar yield, heavy appliance demand and battery SOC - summer

N.B. Day shown for 92700 as battery SOC reaches 0% at 91800.

Table 27 below shows the results for the integration of output data from Simulink.

Table 27. Integration results of heavy power curves – 2-person summer

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
238727837.84	341887933.68	191664432.75	150223500.93	Sum of Areas
66313.29	94968.87	53240.12	41728.75	Wh
66.31	94.97	53.24	41.73	kWh

4.3.1.6 2 Person Autumn Heavy Load

Figure 99 below shows the daily profile for a heavy summer load profile for a 2-person household.

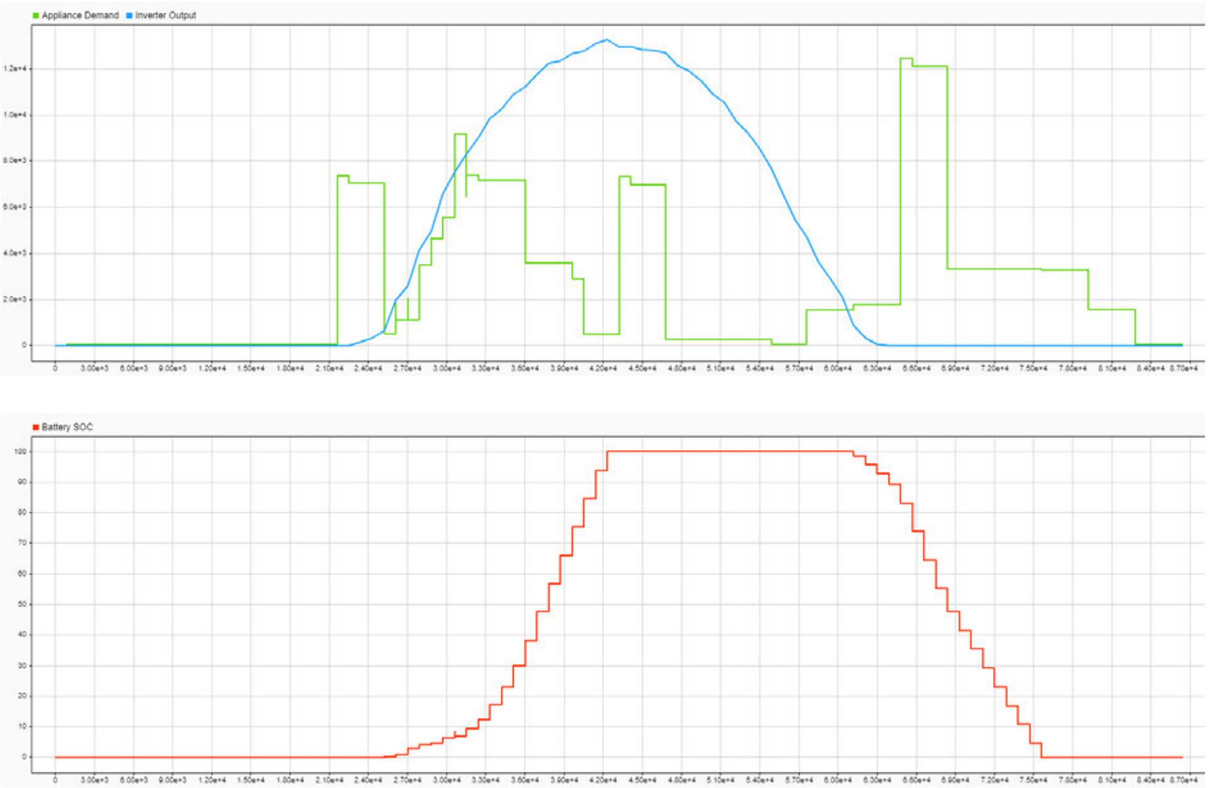


Figure 99. 2-person solar yield, appliance demand and battery SOC – autumn

N.B. Battery reaches 100% SOC on charge later than typical.

Table 28 below shows the results for the integration of output data from Simulink.

Table 28. Integration results of heavy power curves – 2-person autumn

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
224916372.56	322246035.23	214880945.41	107365089.82	Sum of Areas
62476.77	89512.79	59689.15	29823.64	Wh
62.48	89.51	59.69	29.82	kWh

4.3.1.7 2 Person Winter Heavy Load

Figure 100 below shows the daily profile for a heavy winter load profile for a 2-person household.

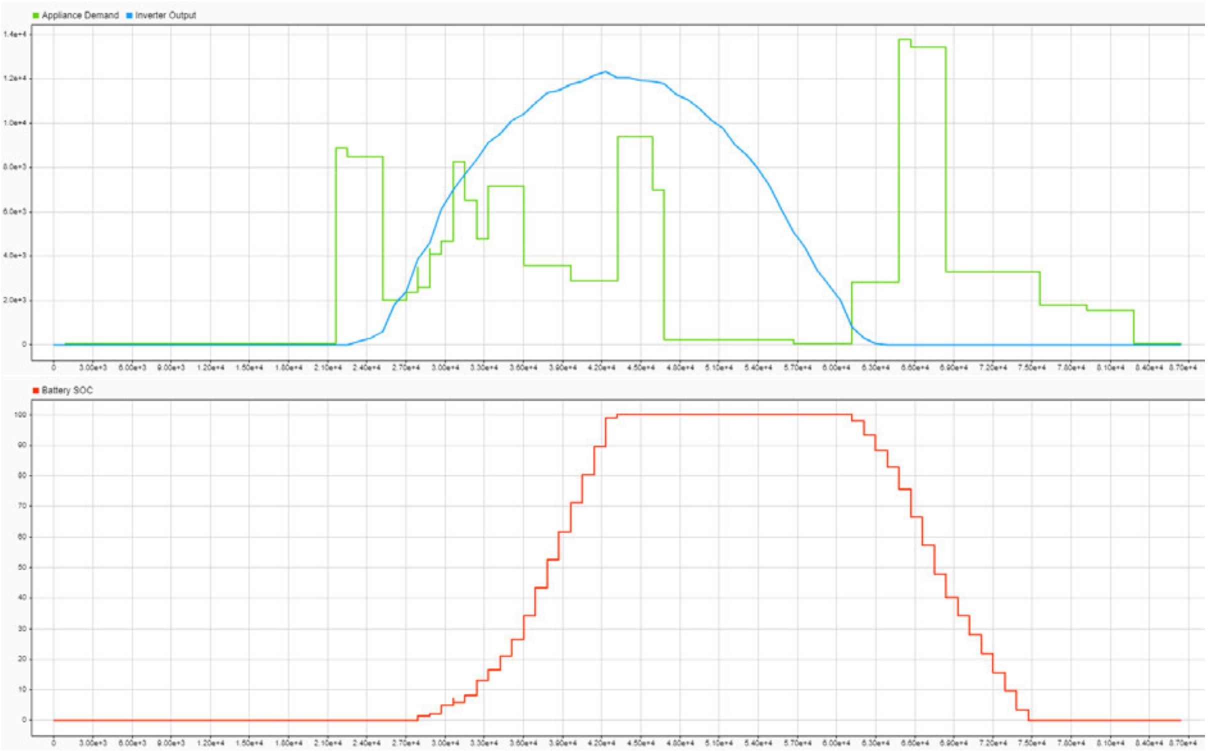


Figure 100. 2-person solar yield, heavy appliance demand and battery SOC – winter

Table 29 below shows the results for the integration of output data from Simulink.

Table 29. Integration results of heavy power curves – 2-person winter

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
237427808.83	299301239.38	188360917.55	110940321.82	Sum of Areas
65952.17	83139.23	52322.48	30816.76	Wh
65.95	83.14	52.32	30.82	kWh

4.3.1.8 2 Person Spring Heavy Load

Figure 101 below shows the daily profile for a typical summer load profile for a 2-person household.

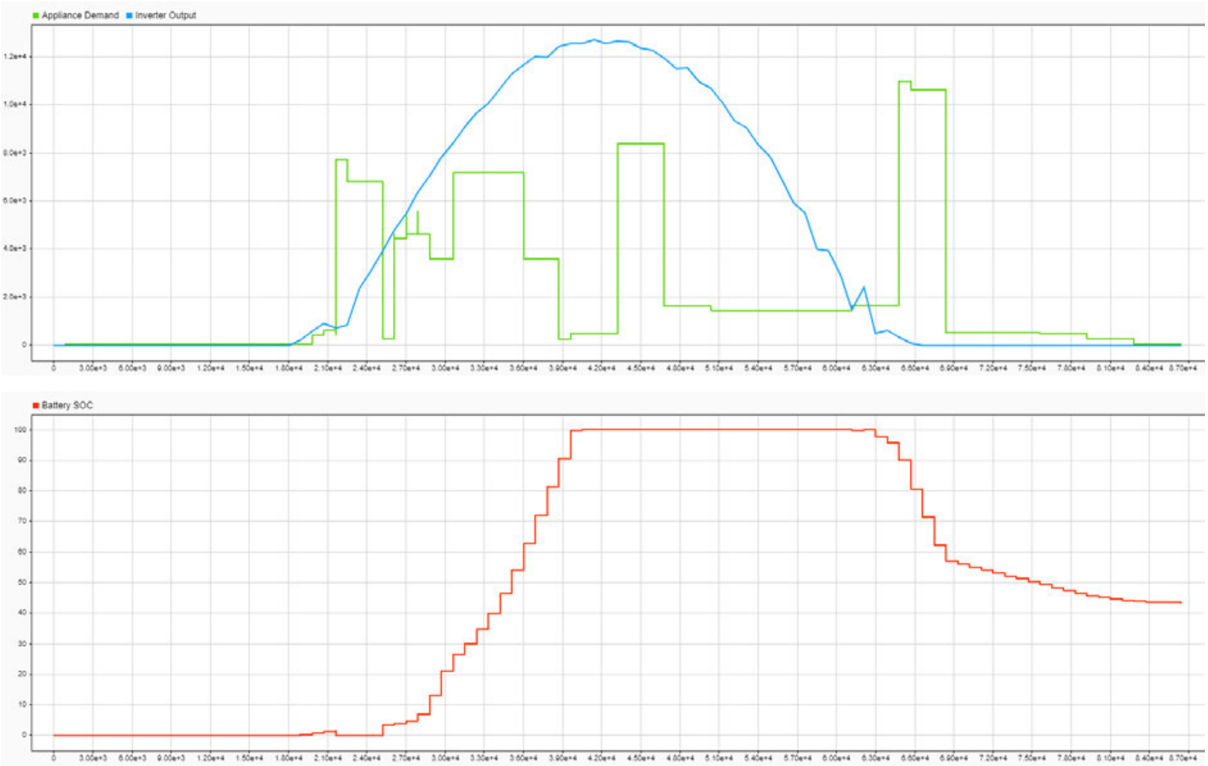


Figure 101. 2-person solar yield, heavy appliance demand and battery SOC – Spring

Table 30 below shows the results for the integration of output data from Simulink.

Table 30. Integration results of heavy power curves – 2-person spring

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
201111158.05	346905401.04	211494947.32	135410453.72	Sum of Areas
55864.21	96362.61	58748.60	37614.01	Wh
55.86	96.36	58.75	37.61	kWh

For the spring profile, the BESS does not fully discharge over a single day. To gain a clearer understanding of the system behaviour, it is important to analyse the system over consecutive days.

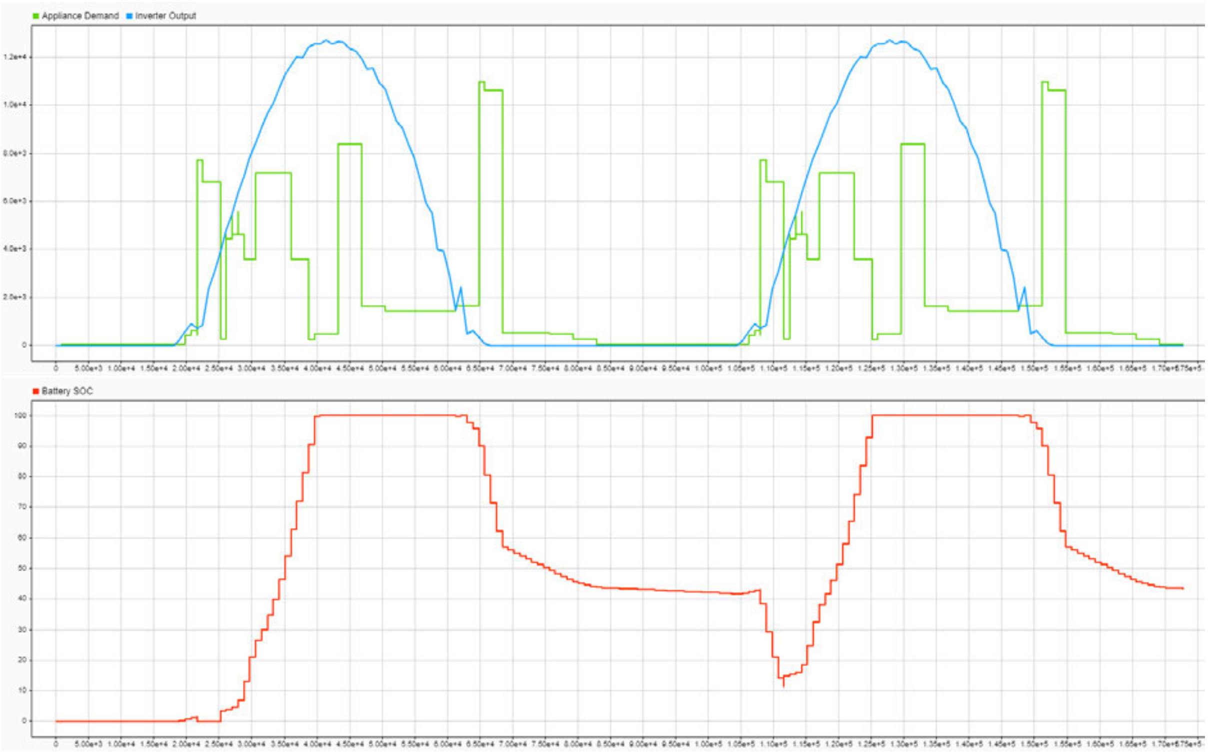


Figure 102. 2-person solar yield, appliance demand and battery SOC – Spring (Consecutive days)

Table 31. Integration results of power curves – 2-person spring on day 2

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
201078612.00	348712200.00	213676483.50	135035716.50	Sum of Areas
55855.17	96864.50	59354.58	37509.92	Wh
55.86	96.86	59.35	37.51	kWh

From Figure 102, SOC is observed at 86400 on day 1 to be 43.49%. SOC between 86400 to 104400 (early morning day 2) discharges from 43.49% to 11.49% to run refrigerator.

Equation 21

$$Evening\ Discharge: (1 - 0.4349) * 13.5kWh = 7628.85\ Wh$$

$$Morning\ Discharge: (0.4349 - 0.1149) * 13.5kWh = 4320\ Wh$$

$$Total\ Discharge: 11.95\ kWh$$

Upon sun rise, the BESS charges back up to 100%. Afternoon to evening discharge then again reduces SOC to 43.49% at 172800 (86400 on day 2).

Equation 22

$$Morning\ Charge: (1 - 0.1149) * 13.5kWh = 11.95\ kWh$$

4.3.2 4 Person Households

4.3.2.1 4 Person Summer Typical Load

Figure 103 below shows the daily profile for a typical summer load profile for a 4-person household.

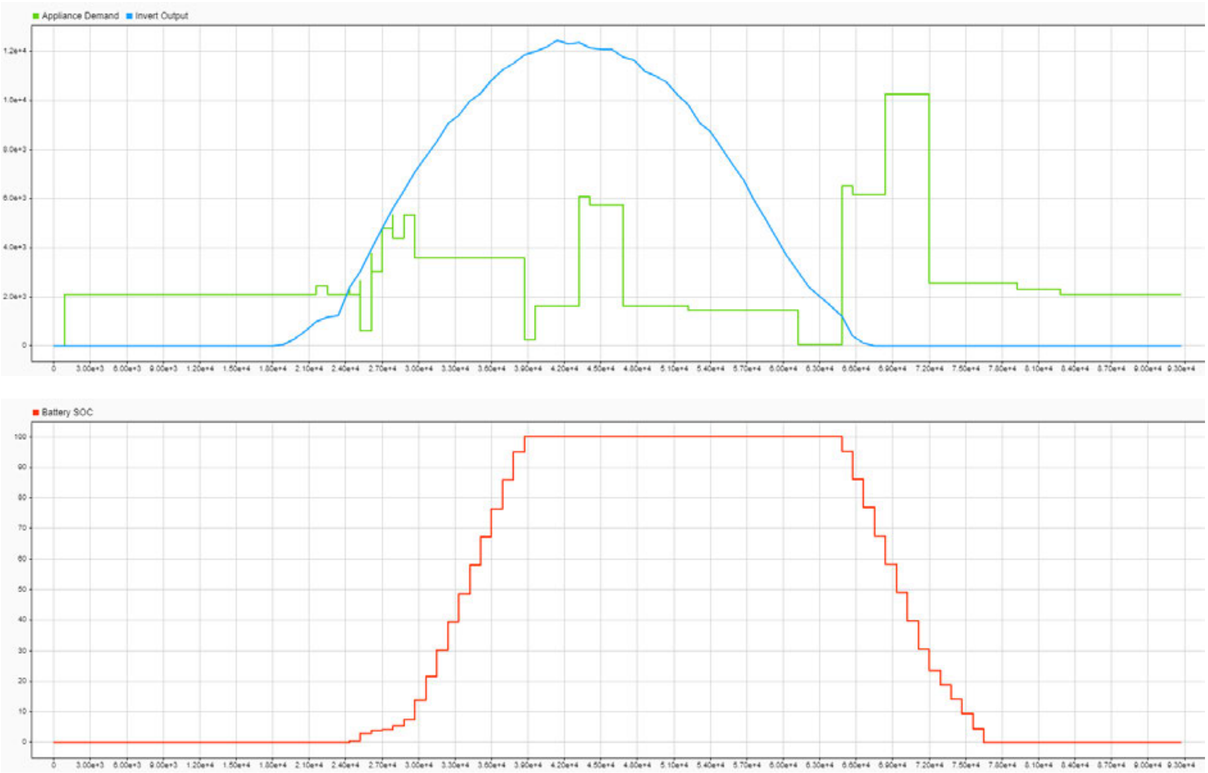


Figure 103. 4-person solar yield, appliance demand and battery SOC – Summer

Table 32 below shows the results for the integration of output data from Simulink.

Table 32. Integration results of power curves – 4-person summer

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
245496583.96	341887933.68	234662386.57	107225547.11	Sum of Areas
68193.50	94968.87	65184.00	29784.87	Wh
68.19	94.97	65.18	29.78	kWh

4.3.2.2 4 Person Autumn Typical Load

Figure 104 below shows the daily profile for a typical autumn load profile for a 4-person household.

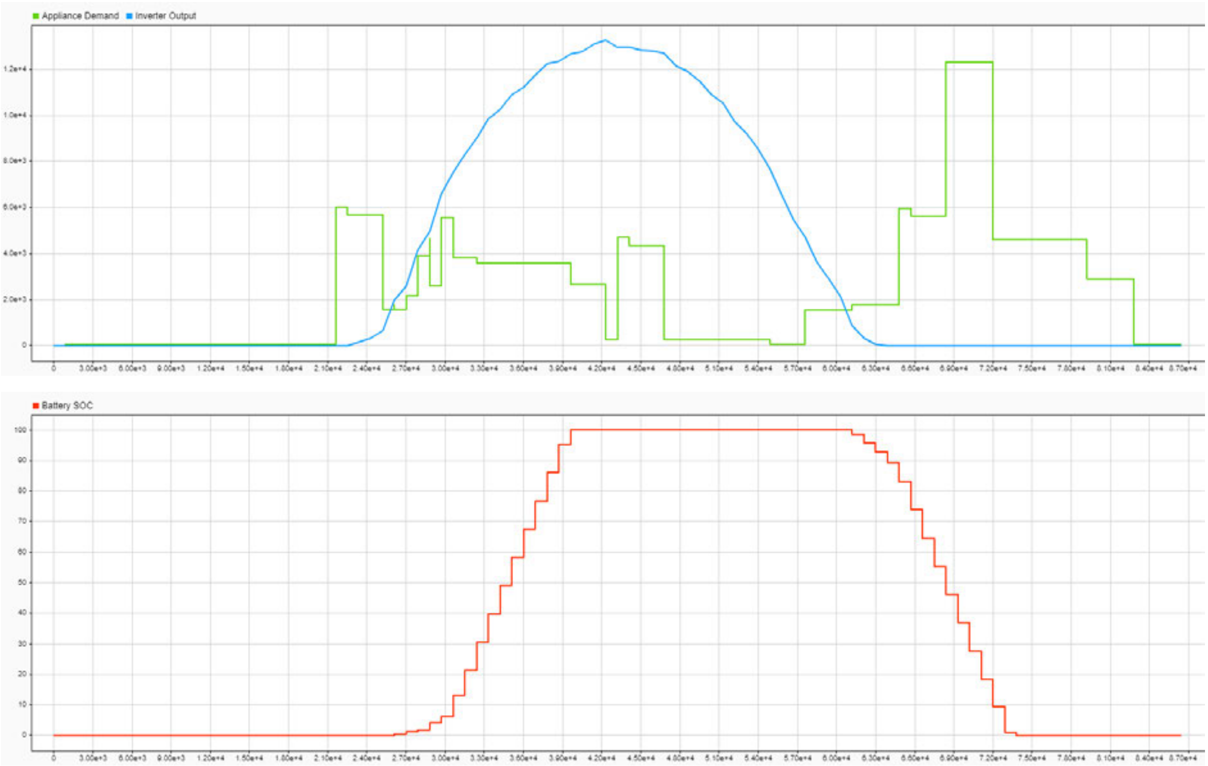


Figure 104. 4-person solar yield, appliance demand and battery SOC – Autumn

Table 33 below shows the results for the integration of output data from Simulink.

Table 33. Integration results of power curves – 4-person autumn

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
217109035.77	322246035.23	240483100.85	81762934.38	Sum of Areas
60308.07	89512.79	66800.86	22711.93	Wh
60.31	89.51	66.80	22.71	kWh

4.3.2.3 4 Person Winter Typical Load

Figure 105 below shows the daily profile for a typical autumn load profile for a 4-person household.

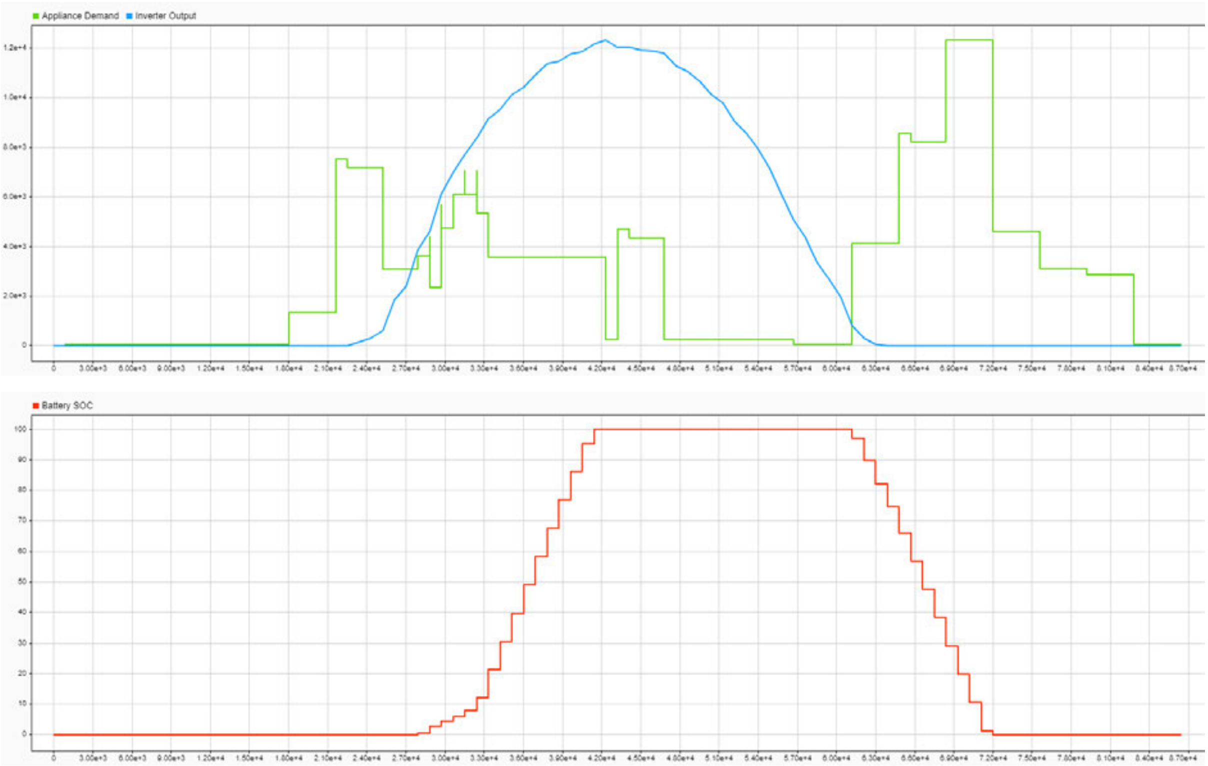


Figure 105. 4-person solar yield, appliance demand and battery SOC – Winter

Table 34 below shows the results for the integration of output data from Simulink.

Table 34. Integration results of power curves – 4-person winter

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
245727580.85	299301239.38	213584045.60	85717193.78	Sum of Areas
68257.66	83139.23	59328.90	23810.33	Wh
68.26	83.14	59.33	23.81	kWh

4.3.2.4 4 Person Spring Typical Load

Figure 106 below shows the daily profile for a typical spring load profile for a 4-person household.

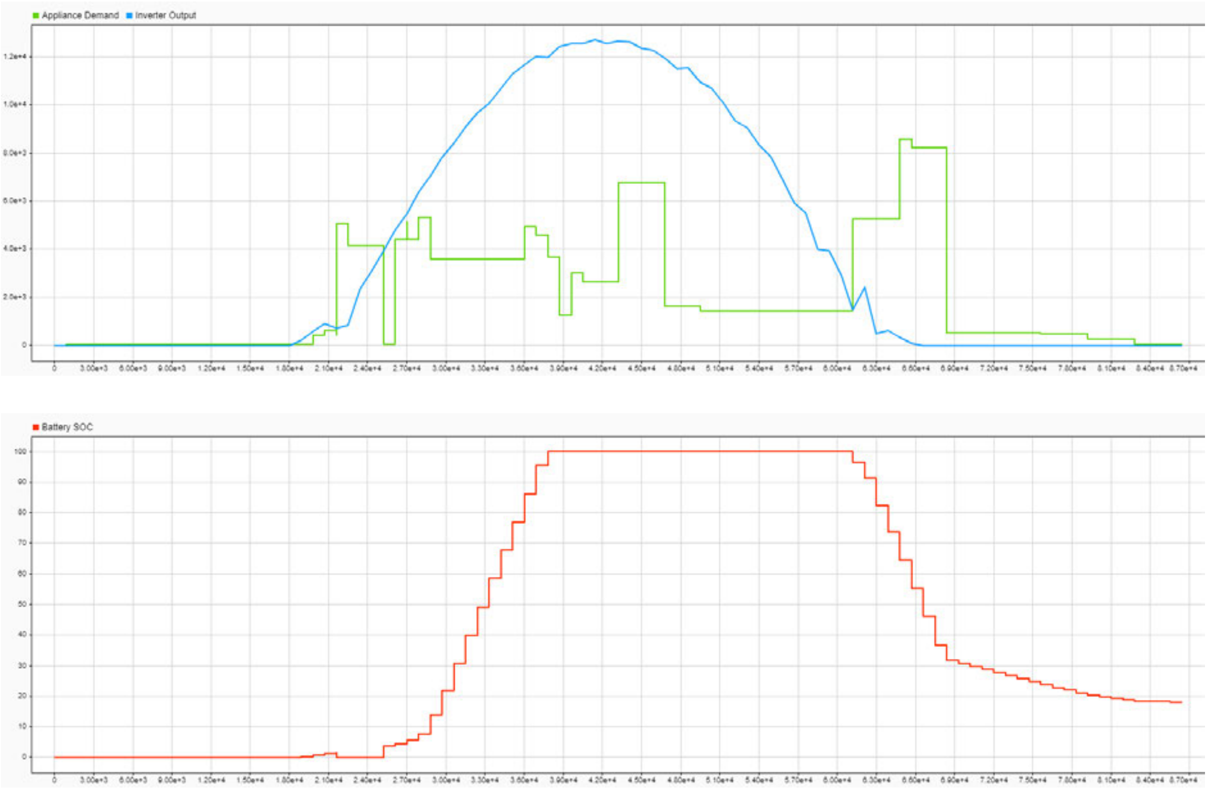


Figure 106. 4-person solar yield, appliance demand and battery SOC – Spring

Table 35 below shows the results for the integration of output data from Simulink.

Table 35. Integration results of power curves – 4-person winter

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
181422702.09	346905401.04	225323719.46	121581681.58	Sum of Areas
50395.20	96362.61	62589.92	33772.69	Wh
50.40	96.36	62.59	33.77	kWh

Analysis of consecutive days shows that the battery SOC discharges to 1.71% by 111600 seconds and recharges to 100% from 111600-124200 seconds.

4.3.2.5 4 Person Summer Heavy Load

Figure 107 below shows the daily profile for a heavy summer load profile for a 4-person household.

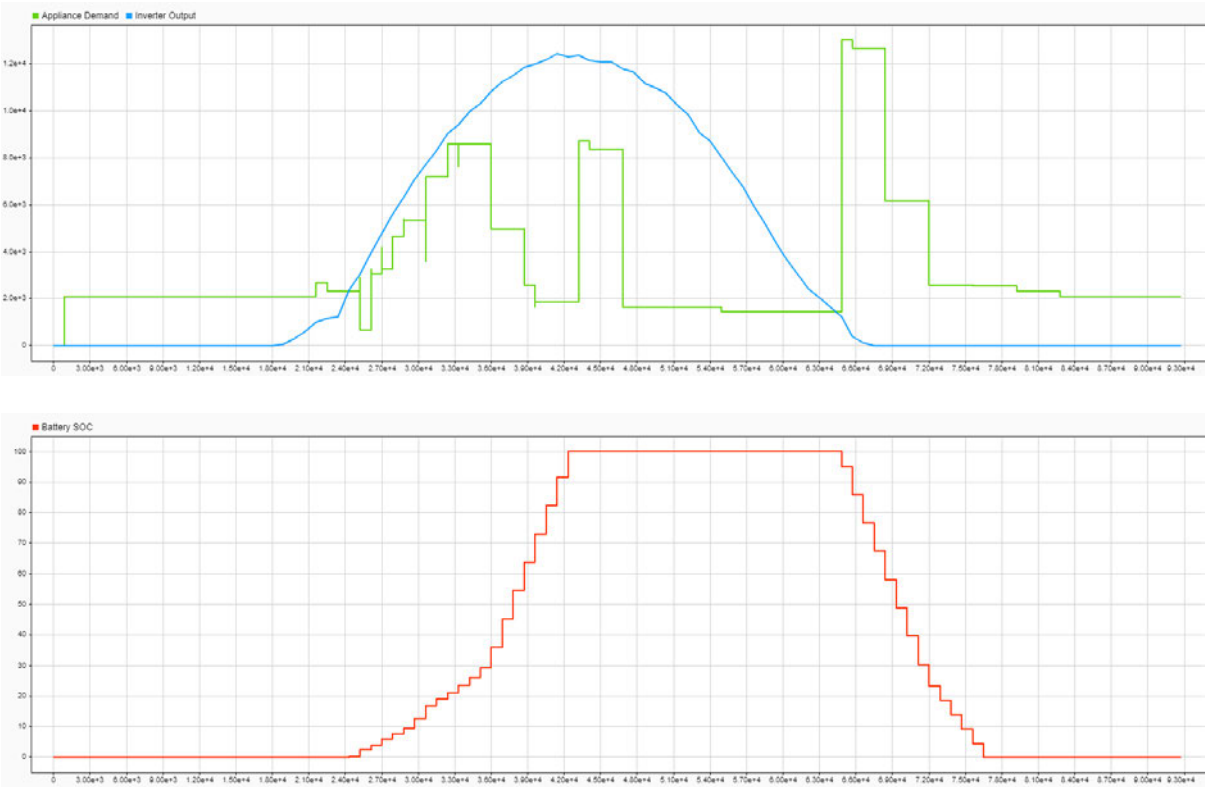


Figure 107. 4-person solar yield, heavy appliance demand and battery SOC - summer

Table 36 below shows the results for the integration of output data from Simulink.

Table 36. Integration results of heavy power curves – 4-person summer

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
300407589.14	341887933.68	188996329.12	152891604.56	Sum of Areas
83446.55	94968.87	52498.98	42469.89	Wh
83.45	94.97	52.50	42.47	kWh

4.3.2.6 4 Person Autumn Heavy Load

Figure 108 below shows the daily profile for a heavy autumn load profile for a 4-person household.

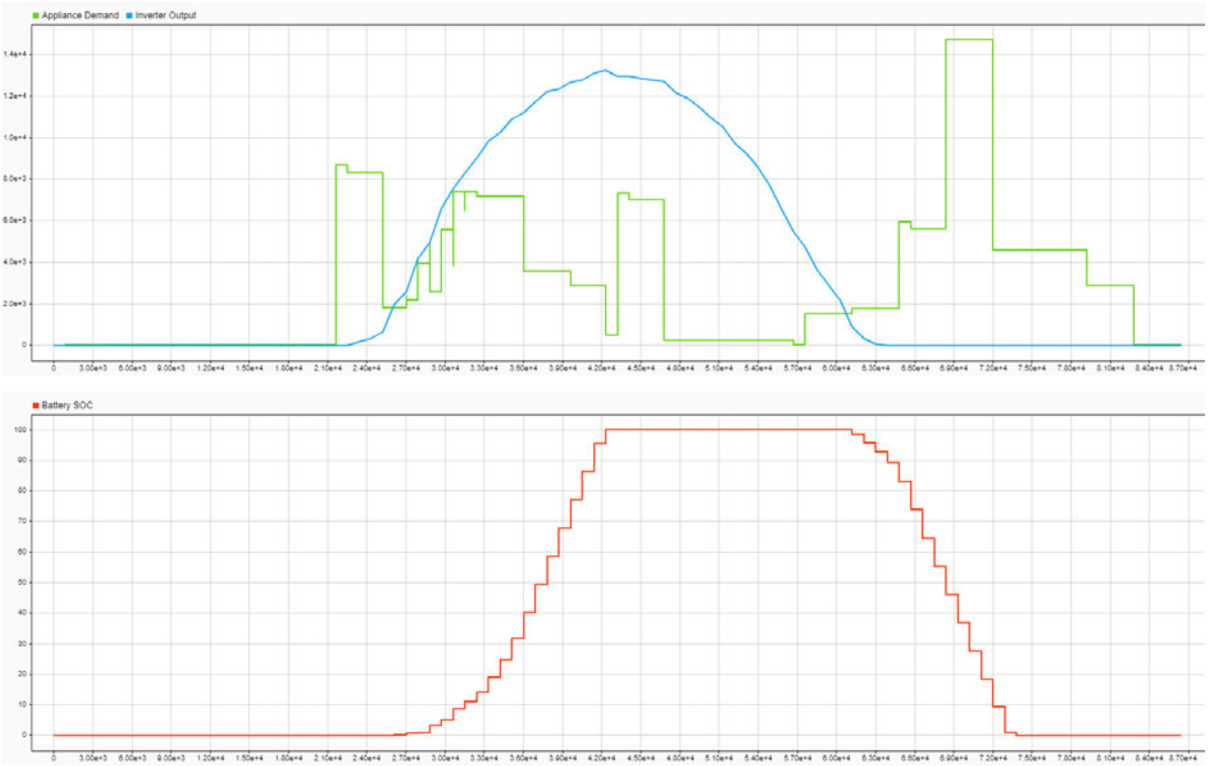


Figure 108. 4-person solar yield, heavy appliance demand and battery SOC – Autumn

Table 37 below shows the results for the integration of output data from Simulink.

Table 37. Integration results of heavy power curves – 4-person autumn

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
265412455.46	322246035.23	210357256.29	111888778.94	Sum of Areas
73725.68	89512.79	58432.57	31080.22	Wh
73.73	89.51	58.43	31.08	kWh

4.3.2.7 4 Person Winter Heavy Load

Figure 109 below shows the daily profile for a heavy winter load profile for a 4-person household.

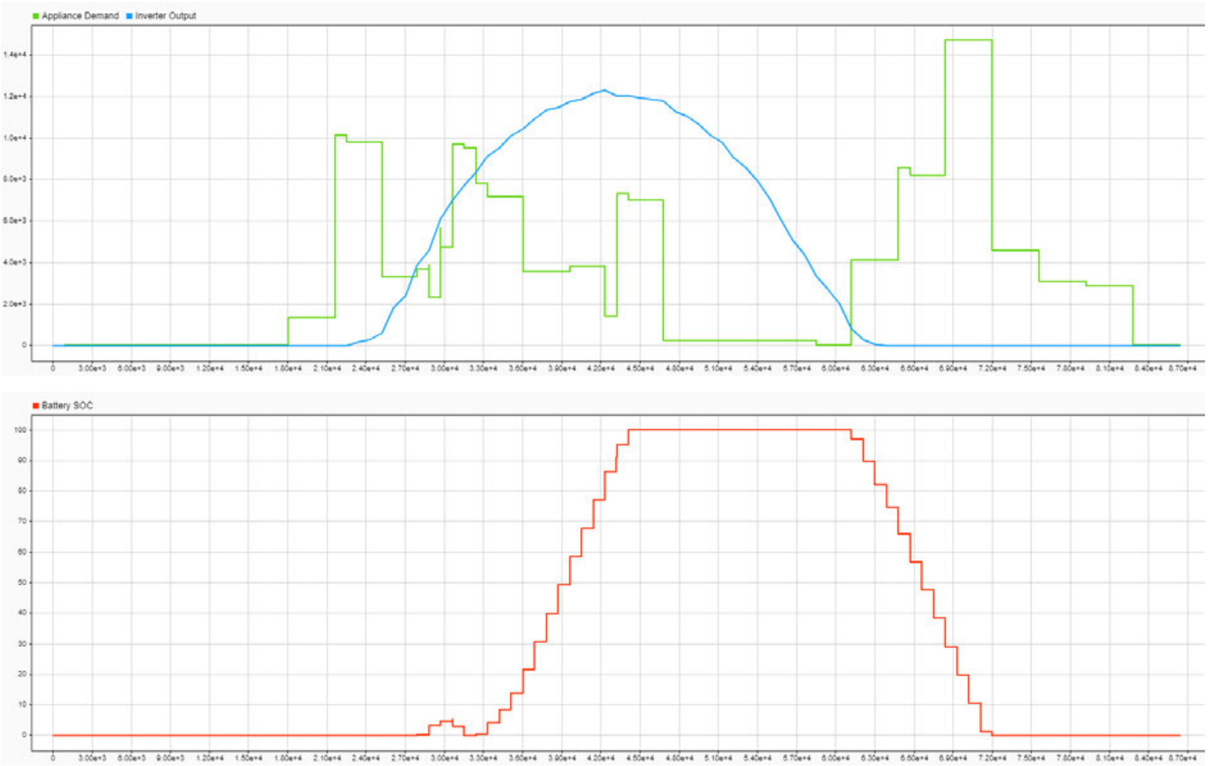


Figure 109. 4-person solar yield, heavy appliance demand and battery SOC – Winter

Table 38 below shows the results for the integration of output data from Simulink.

Table 38. Integration results of heavy power curves – 4-person winter

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
293520658.57	299301239.38	187781030.30	111520209.08	Sum of Areas
81533.52	83139.23	52161.40	30977.84	Wh
81.53	83.14	52.16	30.98	kWh

4.3.2.8 4 Person Spring Heavy Load

Figure 110 below shows the daily profile for a heavy spring load profile for a 4-person household.

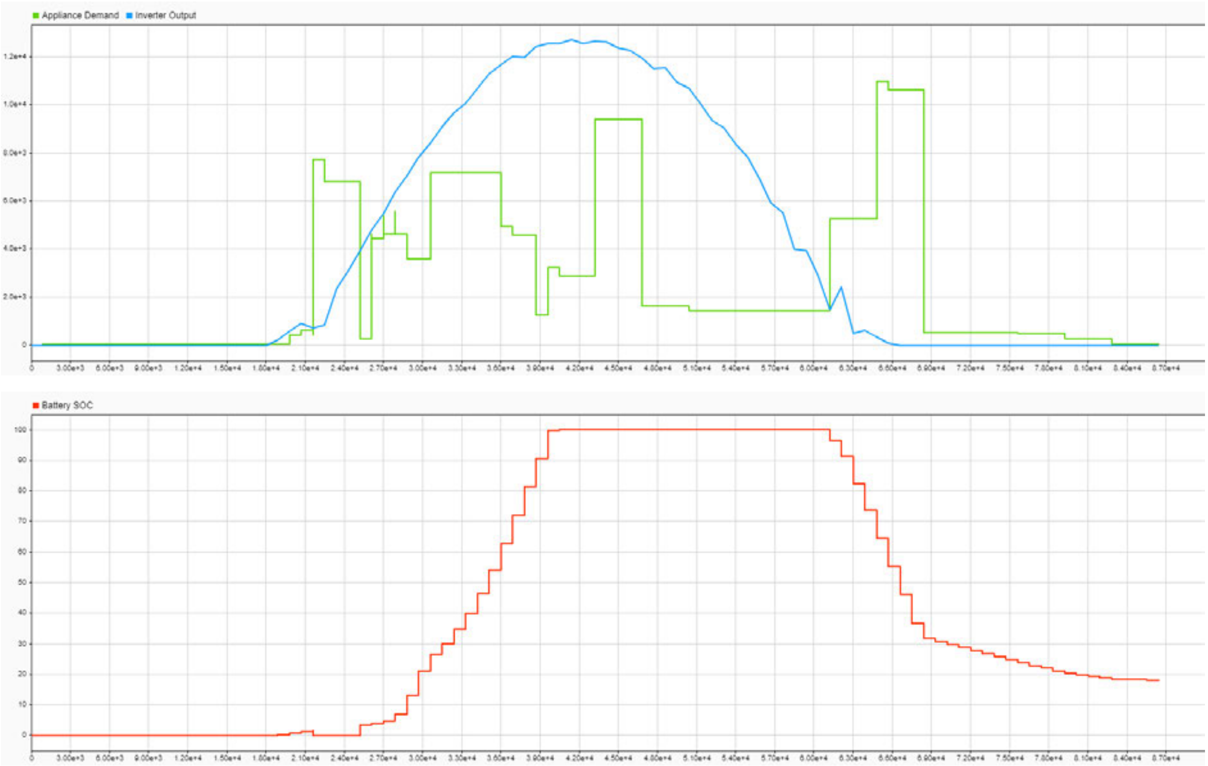


Figure 110. 4-person spring yield, heavy appliance demand and battery SOC - spring

Table 39 below shows the results for the integration of output data from Simulink.

Table 39. Integration results of heavy power curves – 4-person spring

Appliance Integral	Inverter Integral	Grid Export Integral	Solar Offset Integral	
230567738.36	346905401.04	194246579.56	152658821.47	Sum of Areas
64046.59	96362.61	53957.38	42405.23	Wh
64.05	96.36	53.96	42.41	kWh

Analysis of consecutive days shows that the battery SOC discharges to zero by 109800 seconds.

5 DISCUSSION

With reference to the preliminary analysis undertaken in chapter 4, this chapter discusses the effectiveness of the project in meeting its stated aims. As previously mentioned, the measure of effectiveness is determined according to the following criteria for each scenario.

- The change in the magnitude of self-consumption achieved with the controller present, when compared to a standalone system with a controller.
- The economic impact of the change in self-consumption, when compared against the typical tariff pricing structure for grid connected residential installations, as documented in the literature review.

5.1 Effectiveness of Controller

Table 40 below highlights the effective change in self-consumption and solar offset in the 2-person household for all seasons.

Table 40. 2-person household daily results consolidated

Season	Summer		Autumn		Winter		Spring	
Integral	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset
Uncontrolled Typical (kWh)	81.56	13.41	85.36	4.15	77.67	5.47	84.41	11.95
Controlled Typical (kWh)	68.12	26.85	72.00	17.51	64.36	18.78	72.13	24.73
Typical Change (%)	-16.48	100.22	-15.65	321.93	-17.14	243.33	-14.55	106.95
Uncontrolled Heavy (kWh)	66.14	28.83	72.72	16.80	65.19	17.95	71.84	24.52
Controlled Heavy (kWh)	53.24	41.73	59.69	29.82	52.32	30.82	59.35	37.51
Heavy Change (%)	-19.50	44.75	-17.92	77.50	-19.74	71.69	-17.39	52.98

In a typical 2-person household, the controller reduces grid export between 14.55% to 17.14%. The algorithm successfully shifts controllable loads to times where solar generation exceeds appliance demand, resulting in an increase in the power offset by the system of 100.22% to 321.93% when compared to an installation with no control. For the typical system, the seasonal solar offset:

- Increases by 1209.6 kWh in summer.
- Increases by 1229.12 kWh in autumn.
- Increases by 1224.52 kWh in winter.
- Increases by 1162.98 kWh in spring.

This provides an annual increase in self-consumption of 4826.22kWh.

For a 2-person household with a heavy usage profile, grid export is reduced between 17.93% and 19.74%, will power offset increases between 44.75% to 77.5%. The solar offset for each season

- Increases by 1161 kWh in summer.
- Increases by 1197.84 kWh in autumn.
- Increases by 1184.04 kWh in winter.
- Increases by 1182.09 kWh in spring.

For an increase in annual self-consumption of 4724.97 kWh.

The controller in a 4-person household also reduces grid export and increases the rate of self-consumption through improved power offset. Table 41 shows the resultant change for all seasons.

Table 41. 4-person household daily results consolidated

Season	Summer		Autumn		Winter		Spring	
Integral	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset
Uncontrolled Typical (kW)	78.37	16.60	80.05	9.47	72.91	10.23	75.54	20.82
Controlled Typical (kW)	65.18	29.78	66.80	22.71	59.33	23.81	62.59	33.77
Typical Change (%)	-16.83	79.39	- 16.55	139.81	-18.63	132.75	-17.14	62.19
Uncontrolled Heavy (kW)	65.71	29.26	71.60	17.91	64.57	18.57	67.05	29.31
Controlled Heavy (kW)	52.50	42.47	58.43	31.08	52.16	30.98	53.96	42.41
Heavy Change (%)	-20.1	45.15	-18.39	73.53	-19.22	66.83	-19.52	44.69

In a typical 4-person household, the controller reduces grid export between 16.55% to 18.63% and improves self-consumption by 62.19% to 139.18%. For this profile, the seasonal solar offset.

- Increases by 1186.2 kWh in summer.
- Increases by 1218.08 kWh in autumn.
- Increases by 1249.36 kWh in winter.
- Increases by 1178.45 kWh in spring.

This provides an annual increase in self-consumption of 4832.09 kWh.

For a 4-person household with a heavy usage profile, grid export is reduced between 18.39% and 20.1%, while self-consumption increases between 45.15% to 73.53%. The solar offset for each season

- Increases by 1188.9 kWh in summer.
- Increases by 1211.64 kWh in autumn.
- Increases by 1141.72 kWh in winter.

- Increases by 1192.1 kWh in spring.

This provides an annual increase in self-consumption of 4734.36 kWh.

While the control algorithm is less effective at increasing self-consumption within the 4-person household when compared to the 2-person household, it still successfully shifts all controllable loads to peak solar generation hours. The reduction in overall effectiveness can be attributed to the lower contribution of controlled appliances in the total demand profile of larger households. While the controllable loads still only require a single cycle per day for the 4 person households, the usage of uncontrollable appliances increases in frequency and duration. The same conclusion can be drawn when comparing the apparent reduced effectiveness of the controller for heavy load profiles to its performance for typical profiles. Both of these observations are made evident in the similar magnitudes of seasonal and annual offset values between the different occupancy types or for different load profiles of the same occupancy type.

Effectiveness of Battery Energy Storage System

Graphical analysis of the battery state of charge, shown for each scenario in the figures in section 4.3, reveals the following.

- Battery reaches 100% SOC during all seasons, charging when the output of the solar system inverter exceeds the aggregate demand of all appliances.
- For summer, autumn and winter, the BESS fully discharges in the afternoon and early evening, providing an increase in daily self-consumption equal to the battery capacity (13.5 kWh).
- For the 2-person household, in spring the battery lasts overnight for both typical and heavy load profiles. For the typical load profile, this provides additional daily self-consumption of approximately 7869.15 kWh, while heavy load profile self-consumption increases by approximately 7628.85 kWh.
- For the typical 4-person household, in spring the battery lasts overnight, providing additional daily self-consumption of approximately 13269.15 kWh. For the heavy load profile in spring, the 4 person BESS fully discharges overnight, reach 0% SOC by 6:30am the following morning.
- On heavy load profiles Battery reaches 100% SOC on charge later than typical load profiles, however it still reaches full charge before aggregate demand exceeds inverter output.

Table 42 below shows the increased rate in self-consumption and decreased export to the grid for a 2-person household with a controller and BESS.

Table 42. 2-person household results consolidated with BESS

Season	Summer		Autumn		Winter		Spring	
Integral	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset
Uncontrolled Typical (kW)	81.56	13.41	85.36	4.15	77.67	5.47	84.41	11.95
Controlled Typical (kW)	54.62	40.35	58.50	31.01	50.86	32.28	64.26	32.60
Typical Change (%)	-33.03	200.89	-31.47	647.23	-34.52	490.13	-23.87	172.80
Uncontrolled Heavy (kW)	66.14	28.83	72.72	16.80	65.19	17.95	71.84	24.52
Controlled Heavy (kW)	39.74	55.23	46.19	43.32	38.82	44.32	47.40	49.46
Heavy Change (%)	-39.92	91.57	-36.48	157.86	-40.45	146.91	-34.02	101.71

With reference to Table 40, it can be seen that the inclusion of the BESS impacts grid export and solar offset more significantly than a system with a controller without any storage. The inclusion of a BESS has resulted in further improvements to the seasonal solar offset. Seasonal offset with respect to an uncontrolled typical system is as follows.

- Increases by 2424.6 kWh in summer.
- Increases by 2471.12 kWh in autumn.
- Increases by 2466.52 kWh in winter.
- Increases by 1879.15 kWh in spring.

This provides an annual increase in self-consumption of 9241.39 kWh.

Likewise, a BESS installed on a heavy load profile yields the following seasonal power offset values.

- Increases by 2376 kWh in summer.
- Increases by 2439.84 kWh in autumn.
- Increases by 2426.04 kWh in winter.
- Increases by 2269.54 kWh in spring.

This provides an annual increase in self-consumption of 9511.42 kWh.

The impact of the inclusion of a BESS in the 4-person household can be seen in Table 43 below.

Table 43. 4-person household results consolidated with BESS

Season	Summer		Autumn		Winter		Spring	
Integral	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset	Grid Export	Solar Offset
Uncontrolled Typical (kW)	78.37	16.6	80.05	9.47	72.91	10.23	75.54	20.82
Controlled Typical (kW)	51.68	43.28	53.3	36.21	45.83	37.31	49.321	47.04
Typical Change (%)	-34.06	160.72	-33.42	282.37	-37.14	264.71	-34.71	125.93
Uncontrolled Heavy (kW)	65.71	29.26	71.6	17.91	64.57	18.57	67.05	29.31
Controlled Heavy (kW)	39.00	55.97	44.93	44.58	38.66	44.48	40.46	55.91
Heavy Change (%)	-40.65	91.29	-37.25	148.91	-40.13	139.53	-39.66	90.75

As per the 2 person household, comparison of the results with Table 41 demonstrates further reduction in export and improvements in self-consumption with the inclusion of the BESS. Seasonal offset with respect to an uncontrolled typical system:

- Increases by 2401.2 kWh in summer.
- Increases by 2460.08 kWh in autumn.
- Increases by 2491.36 kWh in winter.
- Increases by 2385.93 kWh in spring.

This provides an annual increase in self-consumption of 9738.57 kWh.

A heavy load profile with the inclusion of a BESS shows similar seasonal and annual self-consumption increases.

- Increases by 2403.9 kWh in summer.
- Increases by 2453.64 kWh in autumn.
- Increases by 2383.72 kWh in winter.
- Increases by 2420.6 kWh in spring.

This provides an annual increase in self-consumption of 9660.86 kWh.

As observed in an installation without a BESS, due to the controlled loads comprising a smaller percentage of the aggregate appliance demand, the percentage effectiveness of the algorithm in the 4-person household is less than the 2-person household. The controller still successfully shifts operating times of controllable loads to peak generation periods, while also prioritising charging of the BESS when aggregate demand is less than the output of the inverter. The charging cycle of the battery results in a further reduction in grid export, as the surplus power is dedicated to the battery when SOC is less than 100%. During discharge, the battery makes a significant improvement on the magnitude of self-consumption in all load profiles, across all seasons.

5.2 Techno Economic Analysis

With the technical impacts of the controller established, preliminary economic analysis is performed to baseline anticipated cost savings to potential consumers. To undertake economic analysis of the entire system, the upfront cost of generation, storage and controller is required. The following limitations have been implemented to achieve this.

- Economic analysis is undertaken on the impacts for the typical yields and usage patterns developed within the project methodology only, with reference to the Origin Energy tariff pricing structure identified within the literature review (Table **1**).
- Due to difficulties in determining upfront BESS and PV system costs, without sourcing multiple quotes across different system sizes, the economic analysis will assume a 'rule of thumb" of $1000/kW for each.
- The HEMS currently only consists of a control algorithm. The future pricing of the microcontroller required to physically implement the system is unknown. A price of 10% of the overall system cost is assumed.
- The protocol and associated appliance integrated hardware for the HEMS to communicate with household devices is outside the scope of the project. It is assumed that all appliances within the household already have the means to accept instruction from the HEMS.
- The life cycle of the entire installation is taken as the warranty period of the BESS and inverter at 10 years.
- Discount rate has been assumed at 4% as per Tushar et al.

5.2.1 Metrics for Analysis

The analysis consists of determining the net present value (NPV), payback period (PB) and levelized cost of energy (LCOE) for both the 2 person and 4 person households with the following installation configuration.

- Solar system alone with no controller
- Solar system alone with controller
- Solar system with controller and BESS

Each configuration is assessed against a household with no embedded generation, supplied via the grid only. The Origin Solar Boost plan is used as the tariff structure for all installations.

Table 44. Origin Energy Electricity Plan – Origin Solar Boost

Charge		Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

The net present value is a measure of the present value of benefits weighed against the present value of costs of the installation over its service life (Tushar et al. 2023). Equation **23** below shows how the NPV is calculated as a function of the annual system costs and applied discount rate (4%), summed over the system lifetime (Aurora Solar 2024). For the purposes of a solar installation, the system cost or annual cash flow is the difference in annual cost between an installation with no solar installed and the system configuration under assessment.

Equation 23

$$NPV = \sum_{i=0}^{N} \frac{Annual\ Cash\ Flow_i}{(1+d)^i}$$

Following determination of the net present value, the payback period is determined as the ratio between the annual cash and the initial installation cost (Kagan 2024). This is a metric for how long the system takes to recover the outlay for the initial installation.

Equation 24

$$PB = Cost\ of\ \frac{Investment}{Annual\ Cash\ Flow}$$

The levelized cost of energy provides a method to directly compare the per kilowatt hour generating costs of different imbedded generation systems. This is determined as the ratio between the NPV of the total cost (including initial investment) of the system over its operating life and the NPV of the energy generated by the same system (CFI 2024). As the project is concerned with offsetting appliance demand as much as possible, the energy generation used to determine the LCOE is equal to the level of self-consumption in each configuration. Calculation of the LCOE is undertaken with Equation 25 below.

Equation 25

$$LCOE = \frac{\sum_{i=0}^{N} \frac{Annual\ Cash\ Flow_i}{(1+d)^i}}{\sum_{i=0}^{N} \frac{Annual\ Energy_i}{(1+d)^i}}$$

5.2.2 Analysis of 2 Person Household

To find the baseline cost per day, the typical daily total energy consumption is broken down between primary (general usage), secondary (controlled usage) and feed-in tariffs. Table 45 and Table 46 shows the daily usage and cost breakdown respectively, for a household with no solar installed. Note that daily supply charges for the primary and secondary tariff have been applied.

Table 45. 2-person household daily usage (usage) breakdown – No solar

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	48.76	0.00	2.82	45.94
Autumn	44.96	0.00	2.82	42.14
Winter	48.80	0.00	2.82	45.98
Spring	38.59	0.00	2.82	35.77

Table 46. 2-person household daily cost (cents) breakdown – No solar

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	59.53	1560.12	0.00	0.00	1761.57
Autumn	59.53	1431.07	0.00	0.00	1632.52
Winter	59.53	1561.48	0.00	0.00	1762.93
Spring	59.53	1214.75	0.00	0.00	1416.20

Table 47 and Table 48 show the daily usage and cost for a household with solar and no controller installed. Note that daily supply charges for the primary, secondary and feed-in tariff have been applied.

Table 47. 2-person household daily usage (usage) breakdown – Uncontrolled

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	35.35	81.56	2.82	32.53
Autumn	40.81	85.36	2.82	37.99
Winter	43.33	77.67	2.82	40.51
Spring	26.64	84.41	2.82	23.82

Table 48. 2-person household daily cost (cents) breakdown – Uncontrolled

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	59.53	1104.72	140.00	270.24	905.50
Autumn	59.53	1290.14	140.00	285.44	1075.72
Winter	59.53	1375.72	140.00	254.68	1192.06
Spring	59.53	808.93	140.00	281.64	598.31

Table 49 and Table 50 show the daily usage and cost for a household with both solar and controller installed. Note that daily supply charges for the primary and feed-in tariff have been applied. As the controller shifts the hot water system usage to daylight hours, the need for a secondary tariff is eliminated.

Table 49. 2-person household daily usage (usage) breakdown – Controlled

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	22.10	68.12	0.00	22.10
Autumn	27.44	72.00	0.00	27.44
Winter	29.88	64.36	0.00	29.88
Spring	13.30	72.13	0.00	13.30

Table 50. 2-person household daily cost (cents) breakdown – Controlled

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	0.00	750.52	140.00	216.48	541.64
Autumn	0.00	931.86	140.00	232.00	707.46
Winter	0.00	1014.72	140.00	201.44	820.88
Spring	0.00	451.67	140.00	232.52	226.75

Table 51 and Table 52 show the daily usage and cost for a household with solar, controller and a BESS installed. Note that daily supply charges for the primary and feed-in tariff have been applied. As per the previous configuration, the secondary tariff is not required.

Table 51. 2-person household daily usage (usage) breakdown – Controlled with BESS

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	8.60	54.62	0.00	8.60
Autumn	13.94	58.50	0.00	13.94
Winter	16.38	50.86	0.00	16.38
Spring	5.43	64.26	0.00	5.43

Table 52. 2-person household daily cost (cents) breakdown – Controlled with BESS

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	0.00	292.06	140.00	162.48	137.18
Autumn	0.00	473.40	140.00	178.00	303.00
Winter	0.00	556.26	140.00	147.44	416.42
Spring	0.00	184.43	140.00	201.04	-9.01

The cost per season and resultant annual cost for each configuration is consolidated from the above tables below in Table 53. It can be seen that with each subsequent addition to the generation configuration, and increasing levels of self-consumption, the cost is reduced. Of particular note, the addition of the controller and BESS in spring increases self-consumption to a degree that nil energy is drawn from the grid and the feed-in tariff results in a net profit for the season under typical usage.

Table 53. 2-person household seasonal and annual cost (cents)

Season	Days per Season	Cost			
		No Solar	Uncontrolled	Controlled	Controlled w/ BESS
Summer	90.00	158541.53	81494.91	48747.24	12345.84
Autumn	92.00	150192.26	98966.30	65086.54	27876.22
Winter	92.00	162189.65	109669.50	75521.40	38311.08
Spring	91.00	128874.15	54445.97	20634.07	-820.07
Annual		599797.59	344576.68	209989.25	77713.07

The net present value is calculated based upon the costing determined in Table 54, adjusted as a dollar value for ease of reading. The variables to be used in Equation 23 to calculate the NPV for each configuration are as follows.

Table 54. 2-person household NPV variables

Discount rate	0.04
PV Cost ($)	15000
BESS Cost ($)	15000
Controller Cost PV ($)	1500
Controller cost BESS ($)	3000

Table 55 below shows the calculated initial cost, annual cost, NPV and payback period for each configuration in a 2-person household. Detailed calculations for NPV, PB and LCOE are shown for reference in the Appendix E spreadsheets.

Table 55. 2-person household net present value

	Uncontrolled	Controlled	Controlled w/ BESS
Initial Cost ($)	15000	16500	33000
Annual Cost ($)	2552.21	3898.08	5220.85
NPV ($)	5700.70	15116.95	9345.73
Payback Period (years)	5.88	4.23	6.32

Taking the NPV of total costs for each configuration, the LCOE is calculated using Equation 25. This is compared against the primary tariff cost for an installation with no solar installed.

Table 56. 2-person household levelized cost of energy

Configuration	LCOE ($/kWh)	LCOE (c/kWh)
No Solar	1.3803	138.03
Uncontrolled	0.3447	34.47
Controlled	0.1849	18.49
Controlled with BESS	0.2511	25.11

The payback period for all three configurations is well within the system warranty period, with the standalone controlled system having the shortest period at 4.2 years and the controlled system with a BESS the longest at 6.3 years. The net present value for each configuration is positive, indicating that all configurations would be sound investments. While the standalone controlled system had the highest NPV, in line with what would be predicted by the literature review, the controlled BESS edged out the uncontrolled solar system as the second most attractive option. This stands in contrast to the findings of Tushar et al in the literature review, where the inclusion of a BESS negatively impacted the economic viability of residential solar generation. The levelized cost of energy also predicted a similar ranking of the configurations to the NPV, with the controlled system the most financially attractive and the controlled BESS overtaking the uncontrolled installation. All three configurations were significantly more cost effective per kilowatt hour than a household with no solar installed, with reductions in the order of 75 to 86.6%.

5.2.3 Analysis of 4 Person Household

The process for the economic analysis of the 4-person household is identical to that undertaken in the previous section. Table 57 to Table 64 show the daily usage and cost breakdowns for each configuration in a 4-person household.

Table 57. 4-person household daily usage (usage) breakdown – No solar

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	68.31	0.00	2.82	65.49
Autumn	60.47	0.00	2.82	57.65
Winter	68.19	0.00	2.82	65.37
Spring	50.76	0.00	2.82	47.94

Table 58. 4-person household daily cost (cents) breakdown – No solar

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	59.53	2224.04	0.00	0.00	2425.49
Autumn	59.53	1957.79	0.00	0.00	2159.24
Winter	59.53	2219.97	0.00	0.00	2421.42
Spring	59.53	1628.04	0.00	0.00	1829.49

Table 59. 4-person household daily usage (usage) breakdown – Uncontrolled

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	51.71	78.37	2.82	48.89
Autumn	51.00	80.05	2.82	48.18
Winter	57.96	72.91	2.82	55.14
Spring	29.94	75.54	2.82	27.12

Table 60. 4-person household daily cost (cents) breakdown – Uncontrolled

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	59.53	1660.30	140.00	257.48	1473.84
Autumn	59.53	1636.19	140.00	264.20	1443.01
Winter	59.53	1872.55	140.00	235.64	1707.93
Spring	59.53	921.00	140.00	246.16	745.86

Table 61. 4-person household daily usage (usage) breakdown – Controlled

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	38.41	65.18	0.00	38.41
Autumn	37.60	66.80	0.00	37.60
Winter	44.45	59.33	0.00	44.45
Spring	16.63	62.59	0.00	16.63

Table 62. 4-person household daily cost (cents) breakdown – Controlled

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	0.00	1304.40	140.00	204.72	1107.28
Autumn	0.00	1276.90	140.00	211.20	1073.30
Winter	0.00	1509.52	140.00	181.32	1335.80
Spring	0.00	564.75	140.00	194.36	377.99

Table 63. 4-person household daily usage (usage) breakdown – Controlled with BESS

Season	Total Consumption	Feed-in	Secondary	Primary
Summer	24.91	51.68	0.00	24.91
Autumn	24.10	53.30	0.00	24.10
Winter	30.95	45.83	0.00	30.95
Spring	3.36	49.32	0.00	3.36

Table 64. 4-person household daily cost (cents) breakdown – Controlled with BESS

Season	Secondary	Primary	Feed-in first 14kWh	Feed-in default	Cost per day
Summer	0.00	845.94	140.00	150.72	702.82
Autumn	0.00	818.44	140.00	157.20	668.84
Winter	0.00	1051.06	140.00	127.32	931.34
Spring	0.00	114.14	140.00	141.28	-19.54

As per the 2-person household Table 65 and

Table **66** shows the calculated initial cost, annual cost, NPV, payback period and LCOE for each configuration in a 4 person household. Detailed calculations are shown for reference in the Appendix E spreadsheets.

Table 65. 4-person household net present value

	Uncontrolled	Controlled	Controlled w/ BESS
Initial Cost ($)	15000	16500	33000
Annual Cost ($)	3157.93	4505.09	5975.07
NPV ($)	10613.61	20040.28	15463.15
Payback Period (years)	4.75	3.66	5.52

Table 66. 4-person household levelized cost of energy

Configuration	LCOE ($/kWh)	LCOE (c/kWh)
No Solar	1.3803	138.03
Uncontrolled	0.2402	24.02
Controlled	0.1628	16.28
Controlled with BESS	0.2227	22.27

As observed in the 2-person household, the payback period for each configuration is significantly less than the 10-year warranty period of the equipment. For the 4-person household, the payback period is lessened to an even greater degree, due to the increased energy consumption of the higher density occupancy coupled with identical initial investment. The payback period ranges from 3.66 years for the controlled configuration to 5.52 years for the BESS configuration. The net present value is similarly positively impacted by the greater appliance demand, as each configuration benefits from an increased NPV of approximately 33-75% over the 2-person household, indicating an even greater economic investment for this occupancy type. Levelized cost of energy confirms the trend, where the increased self-consumption drops the per kilowatt hour cost between 82.6-88.2% when compared to the general tariff offered by Origin Energy.

6 CONCLUSION

The projects aim was to reduce reliance on the grid and maximise economic benefit for a household with solar generation, through the design and implementation of an optimal energy management and control algorithm. The algorithm was to serve as the foundational basis for future integration into a wider home energy management system, controlling appliance usage to align solar generation and demand as close as reasonably practicable. This aim has been achieved, with the implementation of a statechart that successfully automates the operation of controllable appliances in response to changing solar yields. Throughout the subsequent technical and economic analysis, it has been demonstrated that households that implement the algorithm as part of their wider energy management system experience an increase in self-consumption, reduction in grid draw and reduction in electricity costs. In meeting this aim, the two research questions in section 1.2 have been answered.

- Can a control algorithm be developed to automate appliance usage within a household, to minimise the time difference between generation and demand profiles?
- What is the feasibility of incorporating battery storage to further bridge the gap between generation and demand?

The algorithm minimised the temporal difference between generation and demand through automation of the appliances in both 2 and 4 person households, for all seasons and for differing magnitudes and patterns of consumption. The economic feasibility for the integration of a battery energy storage system was shown to increase with the implementation of the algorithm, as the improvements in self-consumption provide favourable conditions to reduce the payback period.

In addition to answering the problem questions, the outcome objectives detailed in section 1.3 have also been met.

Table 67. Project Outcome Objectives

Outcome	Objective	Result
1	Identification of typical power requirements and usage patterns of appliances for 2 person and 4 person households.	Success
2	Recommendation of solar system and BESS capacity to maximise self-consumption of energy generated for 2 and 4 person households, based on demand and generation patterns.	Success
3	Development and simulation of an algorithm to automate appliance usage as much as practicable, to align usage with demand profiles, for the future implementation in a wider HEMS for a standalone solar system.	Success

4	Development and simulation of an algorithm to automate appliance usage as much as practicable, to align usage with demand profiles, for the future implementation in a wider HEMS for a hybrid solar system with integrated BESS.	Success
5	Provision of a techno-economic analysis to determine feasibility of both standalone and BESS integrated installations.	Success

With the success of the project, work can now begin on refining the algorithm, improving its accuracy and resolution, and preparing for its integration into hardware for prototype testing. As part of future works, the following details could be considered.

- Separate consumption (kWh) and demand (kW) tracking will allow for more accurate modelling of energy profiles.
- Introduce further appliance diversity and smaller windows of operation to increase model resolution and response times. And
- Integrate internal appliance characteristics into the model such as duty cycle on refrigeration, PID controllers on ovens and coffee machines, variable speed drives on pool pumps. This will further increase the model accuracy as it responds to more realistic appliance logic.
- Introduce variable weather conditions, including measures to address and overcome rapid cycling during periods of intermittent cloud cover.
- Experiment with a wider variety of appliance usage patterns, PV system sizes and BESS output and capacities. This could provide insight into the optimisation of the individual system components to maximise the economic benefit.
- Begin development of prototype hardware to test the algorithm in response to real PV system outputs and appliance demands.

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8 APPENDIX A: SPECIFICATION

Sample Specification and Work Plan 07/02/2024

Title: Optimising Power Usage Control for Residential Appliances for a Home with Solar Generation

Name : Brad Grant

Student ID : [redacted]

Supervisor: Professor Paul Wen

Introduction and Background:

Leading the world with solar uptake (energy.gov.au 2023), residential photovoltaic systems have become an ubiquitous addition to the Australian energy landscape. With over 3.4 million rooftop installations, consumers are becoming increasingly energy conscious, however reductions to feed-in tariffs and lower subsidies mean that homeowners are not reaping the same financial benefits as they once were (Ludlow 2023).

Technological advancement in equipment, such as panel or inverter efficiencies, can help to maximize generation, however optimization of energy usage to take advantage of peak solar yields is becoming increasingly important to offset regulatory changes, reduce grid reliance and ultimately save on household expenditure in a time where cost of living is rising.

While solar still remains an economically sounds investment, with a typical return on investment of 3 to 5 years (energy.gov.au 2023), the primary issue still remains that generation can only be achieved when the sun is shining. These “full sun” hours do not align with the typical demand profiles of everyday Australians, with most of the population outside of the home working during the most potent irradiance periods of the day. While battery storage may be a potential solution to merge the gap between generation and demand time periods, the economic viability of this for the residential market is still poorly understood. Given these conditions, implementation of a home energy management system (HEMS) looks to be the logical solution.

Objectives and Aims:

The overarching aim of the project is to reduce reliance on the grid and maximise economic benefit for the homeowner as much as is practicable. The means to achieve this is proposed to be through the development and implementation of a HEMS, to monitor and control appliance usage with respect to energy generation from a local solar generation installation. Such as system would serve to minimise the time difference between solar generation and appliance demand as much as possible. Following this, the feasibility of incorporating battery storage to further bridge this time gap and optimise usage outside of sun hours should be considered.

The objectives that are required to be undertaken in order to achieve the stated aims, as well as the expected outcomes are as follows.

Specific Objectives:

- Research the existing literature to determine the current level of knowledge around residential HEMS, the techno-economic feasibility of battery energy storage systems (BESS), energy usage profiles for typical Australian homes and the configuration and performance of a typical residential solar system.
- Identify a clear knowledge gap in the existing literature to justify the proposed research project.
- Develop a clear methodology to develop and test the HEMS, analyse both its performance and the implementation of a BESS, and draw a sound conclusion.
- Develop a schedule and risk assessment to assist in the justification and delivery of the project.

Expected Outcomes:

- Identification of typical power requirements and usage patterns of appliances for 2 person and 4 person households.
- Recommendation of solar system capacities to maximise self-consumption of energy generated for 2 and 4 person households, based on demand and generation patterns.
- Development and simulation of an algorithm to automate appliance usage as much as practicable, to align usage with demand profiles, for the future implementation in a wider HEMS.
- If time permits, refinement and simulation of algorithm for a hybrid installation that includes a BESS.
- Provision of a techno-economic analysis to determine feasibility of both standard and hybrid installations.

Work Plan

Timeline: You can use table to format and you can include the following information

- **Month 1: Project Initiation and Proposal**
    - Refine research proposal developed during ENG4110 and submit to Paul Wen for confirmation of project scope.
    - Install and familiarise with MATLAB, Simulink and Homer.
- **Months 2-3: Literature Review and Research Design**
    - Review, update and expand upon preliminary literature review undertaken as part of proposal. Primary focus on:
        1. Individual appliance usage patterns and power requirements
        2. Solar generation data for typical capacities in the Brisbane region.
        3. Ideal solar system sizes for 2 and 4 person households
    - Review and finalise methodology developed as part of proposal.
    - Begin draft of dissertation including skeleton of documentation, literature review and methodology.
- **Months 4-5: Preliminary Algorithm Development**

        - Develop daily, weekly, monthly, seasonal and annual usage patterns for a 2 person and a 4 person household.
        - Develop daily, weekly, monthly, seasonal and annual solar generation patterns for systems on 2 and 4 person households.
        - Begin preliminary algorithm design for state machine. Develop possible states and map I/O triggers for state changes.
        - Continue draft.
    - **Months 6-7: Detailed Algorithm Development and Simulation**
        - Implement state machine in Simulink. Review and optimize.
        - Simulate and analyse performance of control algorithm.
        - Include state for BESS if time permits.
        - Continue draft.
    - **Months 8-9: Analysis and Finalization of Draft**
        - Undertake techno-economic analysis as well as analysis of project outcomes.
        - Finalise draft report.
    - **Month 10: Final Report and Presentation**
        - Undertake final edit of report, make any key changes and submit.
        - Develop presentation for residential school, outlining research development and outcomes.

Resources Required:

- **Equipment:**
    - Laptop
    - Stationery and exercise book
- **Software:**
    - Microsoft Office – Word for development of the dissertation and Excel for data analysis, table and graph development.
    - MATLAB with Simulink and Stateflow for calculations, development of algorithm and simulation.
    - Homer to assist with techno-economic analysis and preliminary simulation of typical solar systems.
    - Endnote for management of references
- **Access:**
    - Internet access for literature review – USQ standards online, Google Scholar and Science Direct

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energy.gov.au 2023, *Solar PV and batteries*, Department of Climate Change, Energy, the Environment and Water, viewed Feburary 6, <https://www.energy.gov.au/households/solar-pv-and-batteries>.

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9 APPENDIX B: GANTT CHART

The following Gantt chart has been modified from the previous chart developed as part of ENG4110 in Semester 2 2023, to assist in completion of the project.

TRIMESTER WEEKS	TRIMESTER 1														STUDY BREAK	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TASK					Planning Document						Literature Review					
Confirm final project scope with supervisor Professor Paul Wen.																
Complete and submit planning document.																
Undertake literature review.																
Analyse power requirements and individual usage patterns of appliances.																
Development of daily, weekly, monthly, seasonal and annual usage patterns for each household.																
Gather load generation data for typical solar system capacities. Analyse capacities and determine ideal sizes for usage patterns.																
Preliminary algorithm design - develop possible states, develop input spreadsheets.																
Preliminary algorithm design - finalise preliminary design and submit methodology.																
Detailed algorithm design - implement state machine in Simulink.																
Detailed algorithm design - review and optimize state machine, update methodology.																
Simulate and analyse performance of control algorithm.																
Prepare and present research at Professional Practice 2 conference																
Prepare and complete Reflection																
Prepare and submit preliminary dissertation draft																
Review, update and submit final dissertation																

TRIMESTER WEEKS	TRIMESTER 2														STUDY BREAK	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TASK		Methodology														
Confirm final project scope with supervisor Professor Paul Wen.																
Complete and submit planning document.																
Undertake literature review.																
Analyse power requirements and individual usage patterns of appliances.																
Development of daily, weekly, monthly, seasonal and annual usage patterns for each household.																
Gather load generation data for typical solar system capacities. Analyse capacities and determine ideal sizes for usage patterns.																
Preliminary algorithm design - develop possible states, develop input spreadsheets.																
Preliminary algorithm design - finalise preliminary design and submit methodology.																
Detailed algorithm design - implement state machine in Simulink.																
Detailed algorithm design - review and optimize state machine, update methodology.																
Simulate and analyse performance of control algorithm.																
Prepare and present research at Professional Practice 2 conference																
Prepare and complete Reflection																
Prepare and submit preliminary dissertation draft																
Review, update and submit final dissertation																

TRIMESTER WEEKS	TRIMESTER 3													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TASK		Draft					Presentation	Reflection			Thesis			
Confirm final project scope with supervisor Professor Paul Wen.														
Complete and submit planning document.														
Undertake literature review.														
Analyse power requirements and individual usage patterns of appliances.														
Development of daily, weekly, monthly, seasonal and annual usage patterns for each household.														
Gather load generation data for typical solar system capacities. Analyse capacities and determine ideal sizes for usage patterns.														
Preliminary algorithm design - develop possible states, develop input spreadsheets.														
Preliminary algorithm design - finalise preliminary design and submit methodology.														
Detailed algorithm design - implement state machine in Simulink.														
Detailed algorithm design - review and optimize state machine, update methodology.														
Simulate and analyse performance of control algorithm.														
Prepare and present research at Professional Practice 2 conference														
Prepare and complete Reflection														
Prepare and submit preliminary dissertation draft														
Review, update and submit final dissertation														

10 APPENDIX C: RISK MANAGEMENT PLAN

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

		Current Rating	Residual Rating
Name	**Optimising Power Usage Control for Residential Appliances for a Home with Solar Generation**	Medium	Low
Location	**Off Campus: Sunshine Coast**		

Business Unit	Last Review Date	Risk Owner
USQ Council	7/09/2024	Brad Grant

Risk Assessment Team	Risk Approver
Brad Grant	Paul Wen

Additional Notes

Describe task / use

Computer based tasks associated with research, development and delivery of final year dissertation (ENP4111). Includes literature review, data analysis and algorithm development.

University of Southern Queensland

Reports identifying people are confidential documents.
Statistical information shall only be used for internal reporting purposes.

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Page 1 of 10

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Risk Factors

Risk Factor	Ergonomics and Manual Handling

Description

Prolonged sitting at desk with poor posture. Musculoskeletal injury to the back and neck including strains and sprains. Possible chronic injury such as disc or nerve impingement.

- Does the activity involve manual tasks: -- No
- Does the work involve:
- Other (please specify in the above text box) -- Yes
- Does the work involve sustaining static postures for long periods of time e.g. sitting or standing? -- Yes
- Are there egonomic hazards related to:
- Furniture e.g. desks, chairs? -- Yes
- Work station or work area design? -- Yes

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Medium	Low		
Existing Controls	**Proposed Controls**		
	Description	Responsibility	Target Date
• 4 - Engineering: Use chair with back rest and ergonomic support. Ensure chair is at correct height with feet flat on the ground. Maintain upright posture with shoulders back and back straight.	Take regular breaks to walk and stretch. Stay hydrated. Elevate screen to prevent looking down and rounding shoulders.		4/11/2024

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Risk Factor	Ergonomics and Manual Handling

Description	
Keyboard and mouse tasks. Repetitive strain injury - strains and sprains to the wrists and hands	• Does the activity involve manual tasks: -- Yes • Does the work involve: • Repetitive movements? -- Yes • Other (please specify in the above text box) -- Yes • Does the work involve sustaining static postures for long periods of time e.g. sitting or standing? -- No • Are there egonomic hazards related to: • Work station or work area design? -- Yes

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Medium	Low		
Existing Controls	**Proposed Controls**		
• 4 - Engineering: Maintain relaxed posture. Use appropriately sized mouse.	Description	Responsibility	Target Date
	Take regular breaks to stretch arms and hands. Stay hydrated. Used mousepad with wrist support.		4/11/2024

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Risk Factor	Ergonomics and Manual Handling

Description

Screen based tasks. Visual strain, headache and fatigue

- Does the activity involve manual tasks: -- Yes
- Does the work involve:
- Other (please specify in the above text box) -- Yes
- Does the work involve sustaining static postures for long periods of time e.g. sitting or standing? -- No
- Are there egonomic hazards related to:
- Work station or work area design? -- Yes

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Low	Very Low		
Existing Controls	**Proposed Controls**		
• 4 - Engineering: Ensure screen contrast and brightness are set to limit squinting, strain on eyes. Undertake tasks in well lit environment.	Description	Responsibility	Target Date
	Take regular breaks and stay hydrated		4/11/2024

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Risk Factor	Personal and Behavioural

Description	
Time and academic pressure. Fatigue, stress and anxiety. Irritability and strain on interpersonal relationships.	• Is there the potential for hazards created by: • Other (please specify in the above text box) -- Yes • Could workers or students be affected by fatigue? • Other? (please specify in the above text box) -- Yes • Could workers or students be affected by experiencing or witnessing traumatic events? -- No

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Low	Very Low		
Existing Controls	**Proposed Controls**		
• 5 - Administration: Develop and follow planning documentation.	Description	Responsibility	Target Date
	Include breaks as part of planning documentation. Prioritise spending time with family and friends when not studying.		4/11/2024

UniSC

Risk Assessment [Ref Number: 5690] - Live

Date Printed: Monday, 7 October 2024

Appendix

Risk Matrix Level	
Very Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Medium	Task can proceed upon approval of the risk assessment by a Category 4 or higher delegate
High	Task can only proceed in extraordinary circumstances provided there is authorisation by the Vice Chancellor
Extreme	Task must not proceed. Appropriate and prompt action must be taken to reduce the risk to as low as reasonable practicable

11 APPENDIX D: SIMULINK MODEL

Refer for the following resources utilised in development of the model.

- Typical Appliance Usage Pattern Spreadsheets
- Heavy Appliance Usage Pattern Spreadsheets
- Desired Optimised Appliance Usage Patterns
- Solar Yield Spreadsheets
- Controller Model (Simulink and Stateflow View)
- No Controller Model (Simulink and Stateflow View)

Appliance input spreadsheets for the model are developed from each column of the typical/heavy appliance usage pattern spreadsheet. Extract column of desired appliance for the season required and replace consumption (kWh) entry with integer 1 (to denote appliance on). Replace blank entries in column with integer 0 (to denote appliance off).

Typical Appliance Usage 2 Person Summer

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235	0.1275	0.1275						0.0120825							0.5020825
0:15	0.235	0.1275	0.1275						0.0120825							0.5020825
0:30	0.235	0.1275	0.1275						0.0120825							0.5020825
0:45	0.235	0.1275	0.1275						0.0120825							0.5020825
1:00		0.1275	0.1275						0.0120825							0.2670825
1:15		0.1275	0.1275						0.0120825							0.2670825
1:30		0.1275	0.1275						0.0120825							0.2670825
1:45		0.1275	0.1275						0.0120825							0.2670825
2:00		0.1275	0.1275						0.0120825							0.2670825
2:15		0.1275	0.1275						0.0120825							0.2670825
2:30		0.1275	0.1275						0.0120825							0.2670825
2:45		0.1275	0.1275						0.0120825							0.2670825
3:00		0.1275	0.1275						0.0120825							0.2670825
3:15		0.1275	0.1275						0.0120825							0.2670825
3:30		0.1275	0.1275						0.0120825							0.2670825
3:45		0.1275	0.1275						0.0120825							0.2670825
4:00		0.1275	0.1275						0.0120825							0.2670825
4:15		0.1275	0.1275						0.0120825							0.2670825
4:30		0.1275	0.1275						0.0120825							0.2670825
4:45		0.1275	0.1275						0.0120825							0.2670825
5:00		0.1275	0.1275						0.0120825							0.2670825
5:15		0.1275	0.1275						0.0120825							0.2670825
5:30		0.1275	0.1275						0.0120825							0.2670825
5:45		0.1275	0.1275						0.0120825							0.2670825
6:00		0.1275	0.1275				0.35		0.0120825						0.0482	0.6652825
6:15		0.1275	0.1275						0.0120825						0.0482	0.3152825
6:30		0.1275	0.1275						0.0120825						0.0482	0.3152825
6:45		0.1275	0.1275						0.0120825						0.0482	0.3152825
7:00									0.0120825						0.0482	0.0602825
7:15									0.0120825						0.0482	0.0602825
7:30									0.0120825						0.0482	0.0602825
7:45									0.0120825						0.0482	0.0602825
8:00									0.0120825						0.0482	0.0602825
8:15									0.0120825						0.0482	0.0602825
8:30									0.0120825						0.0482	0.0602825
8:45									0.0120825						0.0482	0.0602825
9:00									0.0120825						0.0482	0.0602825
9:15									0.0120825						0.0482	0.0602825
9:30									0.0120825						0.0482	0.0602825
9:45									0.0120825						0.0482	0.0602825
10:00									0.0120825						0.0482	0.0602825
10:15									0.0120825						0.0482	0.0602825
10:30									0.0120825						0.0482	0.0602825
10:45									0.0120825						0.0482	0.0602825
11:00				0.3475					0.0120825						0.0482	0.4077825
11:15				0.3475					0.0120825						0.0482	0.4077825
11:30				0.3475					0.0120825						0.0482	0.4077825
11:45				0.3475					0.0120825						0.0482	0.4077825
12:00				0.3475					0.0120825						0.0482	0.4077825
12:15				0.3475					0.0120825						0.0482	0.4077825
12:30				0.3475					0.0120825						0.0482	0.4077825
12:45				0.3475					0.0120825						0.0482	0.4077825
13:00				0.3475					0.0120825						0.0482	0.4077825
13:15				0.3475					0.0120825						0.0482	0.4077825
13:30				0.3475					0.0120825						0.0482	0.4077825
13:45				0.3475					0.0120825						0.0482	0.4077825
14:00				0.3475					0.0120825							0.3595825
14:15				0.3475					0.0120825							0.3595825
14:30				0.3475					0.0120825							0.3595825
14:45				0.3475					0.0120825							0.3595825
15:00				0.3475					0.0120825							0.3595825
15:15				0.3475					0.0120825							0.3595825
15:30				0.3475					0.0120825							0.3595825
15:45				0.3475					0.0120825							0.3595825
16:00				0.3475					0.0120825							0.3595825
16:15				0.3475					0.0120825							0.3595825
16:30				0.3475					0.0120825							0.3595825
16:45				0.3475					0.0120825							0.3595825
17:00				0.3475					0.0120825							0.3595825
17:15				0.3475					0.0120825							0.3595825
17:30				0.3475					0.0120825							0.3595825
17:45				0.3475					0.0120825							0.3595825
18:00		0.1275	0.1275		0.0585	0.9	0.35	1.025	0.0120825					0.06125		2.6618325
18:15		0.1275	0.1275		0.0585	0.9		1.025	0.0120825					0.06125		2.3118325
18:30		0.1275	0.1275		0.0585	0.9		1.025	0.0120825					0.06125		2.3118325
18:45		0.1275	0.1275		0.0585	0.9		1.025	0.0120825					0.06125		2.3118325
19:00		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:15		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:30		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:45		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
20:00		0.1275	0.1275		0.0585				0.0120825	0.6	0.09375			0.06125		1.0805825
20:15		0.1275	0.1275		0.0585				0.0120825	0.6	0.09375			0.06125		1.0805825
20:30		0.1275	0.1275		0.0585				0.0120825	0.6	0.09375			0.06125		1.0805825
20:45		0.1275	0.1275		0.0585				0.0120825	0.6				0.06125		0.9868325
21:00		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
21:15		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
21:30		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
21:45		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
22:00	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
22:15	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
22:30	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
22:45	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
23:00	0.235	0.1275	0.1275						0.0120825	0.6						1.1020825
23:15	0.235	0.1275	0.1275						0.0120825	0.6						1.1020825
23:30	0.235	0.1275	0.1275						0.0120825							0.5020825
23:45	0.235	0.1275	0.1275						0.0120825							0.5020825
Total Energy Usage																49.47857

Typical Appliance Usage 2 Person Spring

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235								0.0120825							0.2470825
0:15	0.235								0.0120825							0.2470825
0:30	0.235								0.0120825							0.2470825
0:45	0.235								0.0120825							0.2470825
1:00									0.0120825							0.0120825
1:15									0.0120825							0.0120825
1:30									0.0120825							0.0120825
1:45									0.0120825							0.0120825
2:00									0.0120825							0.0120825
2:15									0.0120825							0.0120825
2:30									0.0120825							0.0120825
2:45									0.0120825							0.0120825
3:00									0.0120825							0.0120825
3:15									0.0120825							0.0120825
3:30									0.0120825							0.0120825
3:45									0.0120825							0.0120825
4:00									0.0120825							0.0120825
4:15									0.0120825							0.0120825
4:30									0.0120825							0.0120825
4:45									0.0120825							0.0120825
5:00									0.0120825							0.0120825
5:15									0.0120825							0.0120825
5:30									0.0120825							0.0120825
5:45									0.0120825							0.0120825
6:00							0.35	1.025	0.0120825						0.0482	1.4352825
6:15								1.025	0.0120825						0.0482	1.0852825
6:30								1.025	0.0120825						0.0482	1.0852825
6:45								1.025	0.0120825						0.0482	1.0852825
7:00									0.0120825						0.0482	0.0602825
7:15									0.0120825						0.0482	0.0602825
7:30									0.0120825						0.0482	0.0602825
7:45									0.0120825						0.0482	0.0602825
8:00									0.0120825						0.0482	0.0602825
8:15									0.0120825						0.0482	0.0602825
8:30									0.0120825						0.0482	0.0602825
8:45									0.0120825						0.0482	0.0602825
9:00									0.0120825						0.0482	0.0602825
9:15									0.0120825						0.0482	0.0602825
9:30									0.0120825						0.0482	0.0602825
9:45									0.0120825						0.0482	0.0602825
10:00									0.0120825						0.0482	0.0602825
10:15									0.0120825						0.0482	0.0602825
10:30									0.0120825						0.0482	0.0602825
10:45									0.0120825						0.0482	0.0602825
11:00									0.0120825						0.0482	0.0602825
11:15									0.0120825						0.0482	0.0602825
11:30									0.0120825						0.0482	0.0602825
11:45									0.0120825						0.0482	0.0602825
12:00				0.3475					0.0120825						0.0482	0.4077825
12:15				0.3475					0.0120825						0.0482	0.4077825
12:30				0.3475					0.0120825						0.0482	0.4077825
12:45				0.3475					0.0120825						0.0482	0.4077825
13:00				0.3475					0.0120825						0.0482	0.4077825
13:15				0.3475					0.0120825						0.0482	0.4077825
13:30				0.3475					0.0120825						0.0482	0.4077825
13:45				0.3475					0.0120825						0.0482	0.4077825
14:00				0.3475					0.0120825							0.3595825
14:15				0.3475					0.0120825							0.3595825
14:30				0.3475					0.0120825							0.3595825
14:45				0.3475					0.0120825							0.3595825
15:00				0.3475					0.0120825							0.3595825
15:15				0.3475					0.0120825							0.3595825
15:30				0.3475					0.0120825							0.3595825
15:45				0.3475					0.0120825							0.3595825
16:00				0.3475					0.0120825							0.3595825
16:15				0.3475					0.0120825							0.3595825
16:30				0.3475					0.0120825							0.3595825
16:45				0.3475					0.0120825							0.3595825
17:00				0.3475	0.0585				0.0120825							0.4180825
17:15				0.3475	0.0585				0.0120825							0.4180825
17:30				0.3475	0.0585				0.0120825							0.4180825
17:45				0.3475	0.0585				0.0120825							0.4180825
18:00					0.0585	0.9	0.35	1.025	0.0120825					0.06125		2.4068325
18:15					0.0585	0.9		1.025	0.0120825					0.06125		2.0568325
18:30					0.0585	0.9		1.025	0.0120825					0.06125		2.0568325
18:45					0.0585	0.9		1.025	0.0120825					0.06125		2.0568325
19:00					0.0585				0.0120825					0.06125		0.1318325
19:15					0.0585				0.0120825					0.06125		0.1318325
19:30					0.0585				0.0120825					0.06125		0.1318325
19:45					0.0585				0.0120825					0.06125		0.1318325
20:00					0.0585				0.0120825	0.6	0.09375			0.06125		0.8255825
20:15					0.0585				0.0120825	0.6	0.09375			0.06125		0.8255825
20:30					0.0585				0.0120825	0.6	0.09375			0.06125		0.8255825
20:45					0.0585				0.0120825	0.6				0.06125		0.7318325
21:00					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
21:15					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
21:30					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
21:45					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
22:00	0.235				0.0585				0.0120825	0.6						0.9055825
22:15	0.235				0.0585				0.0120825	0.6						0.9055825
22:30	0.235				0.0585				0.0120825	0.6						0.9055825
22:45	0.235				0.0585				0.0120825	0.6						0.9055825
23:00	0.235								0.0120825	0.6						0.8470825
23:15	0.235								0.0120825	0.6						0.8470825
23:30	0.235								0.0120825							0.2470825
23:45	0.235								0.0120825							0.2470825
Total Energy Usage																37.821323

Typical Appliance Usage 2 Person Autumn

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235								0.0120825							0.2470825
0:15	0.235								0.0120825							0.2470825
0:30	0.235								0.0120825							0.2470825
0:45	0.235								0.0120825							0.2470825
1:00									0.0120825							0.0120825
1:15									0.0120825							0.0120825
1:30									0.0120825							0.0120825
1:45									0.0120825							0.0120825
2:00									0.0120825							0.0120825
2:15									0.0120825							0.0120825
2:30									0.0120825							0.0120825
2:45									0.0120825							0.0120825
3:00									0.0120825							0.0120825
3:15									0.0120825							0.0120825
3:30									0.0120825							0.0120825
3:45									0.0120825							0.0120825
4:00									0.0120825							0.0120825
4:15									0.0120825							0.0120825
4:30									0.0120825							0.0120825
4:45									0.0120825							0.0120825
5:00									0.0120825							0.0120825
5:15									0.0120825							0.0120825
5:30									0.0120825							0.0120825
5:45									0.0120825							0.0120825
6:00							0.35	1.025	0.0120825						0.0482	1.4352825
6:15					0.0585			1.025	0.0120825						0.0482	1.1437825
6:30					0.0585			1.025	0.0120825						0.0482	1.1437825
6:45					0.0585			1.025	0.0120825						0.0482	1.1437825
7:00					0.0585				0.0120825						0.0482	0.1187825
7:15					0.0585				0.0120825						0.0482	0.1187825
7:30					0.0585				0.0120825						0.0482	0.1187825
7:45					0.0585				0.0120825						0.0482	0.1187825
8:00					0.0585				0.0120825						0.0482	0.1187825
8:15					0.0585				0.0120825						0.0482	0.1187825
8:30					0.0585				0.0120825						0.0482	0.1187825
8:45					0.0585				0.0120825						0.0482	0.1187825
9:00									0.0120825						0.0482	0.0602825
9:15									0.0120825						0.0482	0.0602825
9:30									0.0120825						0.0482	0.0602825
9:45									0.0120825						0.0482	0.0602825
10:00									0.0120825						0.0482	0.0602825
10:15									0.0120825						0.0482	0.0602825
10:30									0.0120825						0.0482	0.0602825
10:45									0.0120825						0.0482	0.0602825
11:00									0.0120825						0.0482	0.0602825
11:15									0.0120825						0.0482	0.0602825
11:30									0.0120825						0.0482	0.0602825
11:45									0.0120825						0.0482	0.0602825
12:00									0.0120825						0.0482	0.0602825
12:15									0.0120825						0.0482	0.0602825
12:30									0.0120825						0.0482	0.0602825
12:45									0.0120825						0.0482	0.0602825
13:00									0.0120825						0.0482	0.0602825
13:15									0.0120825						0.0482	0.0602825
13:30									0.0120825						0.0482	0.0602825
13:45									0.0120825						0.0482	0.0602825
14:00									0.0120825							0.0120825
14:15									0.0120825							0.0120825
14:30									0.0120825							0.0120825
14:45									0.0120825							0.0120825
15:00									0.0120825							0.0120825
15:15									0.0120825							0.0120825
15:30									0.0120825							0.0120825
15:45									0.0120825							0.0120825
16:00				0.3725					0.0120825							0.3845825
16:15				0.3725					0.0120825							0.3845825
16:30				0.3725					0.0120825							0.3845825
16:45				0.3725					0.0120825							0.3845825
17:00				0.3725	0.0585				0.0120825							0.4430825
17:15				0.3725	0.0585				0.0120825							0.4430825
17:30				0.3725	0.0585				0.0120825							0.4430825
17:45				0.3725	0.0585				0.0120825							0.4430825
18:00				0.3725	0.0585	0.9	0.35	1.025	0.0120825					0.06125		2.7793325
18:15				0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.4293325
18:30				0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.4293325
18:45				0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.4293325
19:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
20:00		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5230825
20:15		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5230825
20:30		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5230825
20:45		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6				0.06125		1.4293325
21:00		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4905825
21:15		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4905825
21:30		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4905825
21:45		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4905825
22:00	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
22:15	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
22:30	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
22:45	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
23:00	0.235								0.0120825	0.6						0.8470825
23:15	0.235								0.0120825	0.6						0.8470825
23:30	0.235								0.0120825							0.2470825
23:45	0.235								0.0120825							0.2470825
Total Energy Usage																42.774823

Typical Appliance Usage 2 Person Winter

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235								0.0120825							0.2471
0:15	0.235								0.0120825							0.2471
0:30	0.235								0.0120825							0.2471
0:45	0.235								0.0120825							0.2471
1:00									0.0120825							0.0121
1:15									0.0120825							0.0121
1:30									0.0120825							0.0121
1:45									0.0120825							0.0121
2:00									0.0120825							0.0121
2:15									0.0120825							0.0121
2:30									0.0120825							0.0121
2:45									0.0120825							0.0121
3:00									0.0120825							0.0121
3:15									0.0120825							0.0121
3:30									0.0120825							0.0121
3:45									0.0120825							0.0121
4:00									0.0120825							0.0121
4:15									0.0120825							0.0121
4:30									0.0120825							0.0121
4:45									0.0120825							0.0121
5:00									0.0120825							0.0121
5:15									0.0120825							0.0121
5:30									0.0120825							0.0121
5:45									0.0120825							0.0121
6:00				0.3725	0.0585		0.35	1.025	0.0120825						0.0482	1.8663
6:15				0.3725	0.0585			1.025	0.0120825						0.0482	1.5163
6:30				0.3725	0.0585			1.025	0.0120825						0.0482	1.5163
6:45				0.3725	0.0585			1.025	0.0120825						0.0482	1.5163
7:00				0.3725	0.0585				0.0120825						0.0482	0.4913
7:15				0.3725	0.0585				0.0120825						0.0482	0.4913
7:30				0.3725	0.0585				0.0120825						0.0482	0.4913
7:45				0.3725	0.0585				0.0120825						0.0482	0.4913
8:00				0.3725	0.0585				0.0120825						0.0482	0.4913
8:15				0.3725	0.0585				0.0120825						0.0482	0.4913
8:30				0.3725	0.0585				0.0120825						0.0482	0.4913
8:45				0.3725	0.0585				0.0120825						0.0482	0.4913
9:00									0.0120825						0.0482	0.0603
9:15									0.0120825						0.0482	0.0603
9:30									0.0120825						0.0482	0.0603
9:45									0.0120825						0.0482	0.0603
10:00									0.0120825						0.0482	0.0603
10:15									0.0120825						0.0482	0.0603
10:30									0.0120825						0.0482	0.0603
10:45									0.0120825						0.0482	0.0603
11:00									0.0120825						0.0482	0.0603
11:15									0.0120825						0.0482	0.0603
11:30									0.0120825						0.0482	0.0603
11:45									0.0120825						0.0482	0.0603
12:00									0.0120825						0.0482	0.0603
12:15									0.0120825						0.0482	0.0603
12:30									0.0120825						0.0482	0.0603
12:45									0.0120825						0.0482	0.0603
13:00									0.0120825						0.0482	0.0603
13:15									0.0120825						0.0482	0.0603
13:30									0.0120825						0.0482	0.0603
13:45									0.0120825						0.0482	0.0603
14:00									0.0120825							0.0121
14:15									0.0120825							0.0121
14:30									0.0120825							0.0121
14:45									0.0120825							0.0121
15:00									0.0120825							0.0121
15:15									0.0120825							0.0121
15:30									0.0120825							0.0121
15:45									0.0120825							0.0121
16:00									0.0120825							0.0121
16:15									0.0120825							0.0121
16:30									0.0120825							0.0121
16:45									0.0120825							0.0121
17:00		0.1625	0.1625	0.3725					0.0120825							0.7096
17:15		0.1625	0.1625	0.3725					0.0120825							0.7096
17:30		0.1625	0.1625	0.3725					0.0120825							0.7096
17:45		0.1625	0.1625	0.3725					0.0120825							0.7096
18:00		0.1625	0.1625	0.3725	0.0585	0.9	0.35	1.025	0.0120825					0.06125		3.1043
18:15		0.1625	0.1625	0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.7543
18:30		0.1625	0.1625	0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.7543
18:45		0.1625	0.1625	0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.7543
19:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
20:00		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5231
20:15		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5231
20:30		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5231
20:45		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6				0.06125		1.4293
21:00		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
21:15		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
21:30		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
21:45		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
22:00	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
22:15	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
22:30	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
22:45	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
23:00	0.235								0.0120825	0.6						0.8471
23:15	0.235								0.0120825	0.6						0.8471
23:30	0.235								0.0120825							0.2471
23:45	0.235								0.0120825							0.2471
Total Energy Usage																48.1793

Typical Appliance 4 Person Summer

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825							0.7570825
0:15	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825							0.7570825
0:30	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825							0.7570825
0:45	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825							0.7570825
1:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
6:00		0.1275	0.1275	0.1275	0.1275				0.35		0.0120825						0.0482	0.9202825
6:15		0.1275	0.1275	0.1275	0.1275						0.0120825						0.0482	0.5702825
6:30		0.1275	0.1275	0.1275	0.1275						0.0120825						0.0482	0.5702825
6:45		0.1275	0.1275	0.1275	0.1275						0.0120825						0.0482	0.5702825
7:00											0.0120825						0.0482	0.0602825
7:15											0.0120825						0.0482	0.0602825
7:30											0.0120825						0.0482	0.0602825
7:45											0.0120825						0.0482	0.0602825
8:00											0.0120825						0.0482	0.0602825
8:15											0.0120825						0.0482	0.0602825
8:30											0.0120825						0.0482	0.0602825
8:45											0.0120825						0.0482	0.0602825
9:00											0.0120825						0.0482	0.0602825
9:15											0.0120825						0.0482	0.0602825
9:30											0.0120825						0.0482	0.0602825
9:45											0.0120825						0.0482	0.0602825
10:00											0.0120825						0.0482	0.0602825
10:15											0.0120825						0.0482	0.0602825
10:30											0.0120825						0.0482	0.0602825
10:45											0.0120825						0.0482	0.0602825
11:00						0.3475					0.0120825						0.0482	0.4077825
11:15						0.3475					0.0120825						0.0482	0.4077825
11:30						0.3475					0.0120825						0.0482	0.4077825
11:45						0.3475					0.0120825						0.0482	0.4077825
12:00						0.3475			0.35	1.025	0.0120825						0.0482	1.7827825
12:15						0.3475				1.025	0.0120825						0.0482	1.4327825
12:30						0.3475				1.025	0.0120825						0.0482	1.4327825
12:45						0.3475				1.025	0.0120825						0.0482	1.4327825
13:00						0.3475					0.0120825						0.0482	0.4077825
13:15						0.3475					0.0120825						0.0482	0.4077825
13:30						0.3475					0.0120825						0.0482	0.4077825
13:45						0.3475					0.0120825						0.0482	0.4077825
14:00						0.3475					0.0120825							0.3595825
14:15						0.3475					0.0120825							0.3595825
14:30						0.3475					0.0120825							0.3595825
14:45						0.3475					0.0120825							0.3595825
15:00						0.3475					0.0120825							0.3595825
15:15						0.3475					0.0120825							0.3595825
15:30						0.3475					0.0120825							0.3595825
15:45						0.3475					0.0120825							0.3595825
16:00						0.3475					0.0120825							0.3595825
16:15						0.3475					0.0120825							0.3595825
16:30						0.3475					0.0120825							0.3595825
16:45						0.3475					0.0120825							0.3595825
17:00						0.3475					0.0120825							0.3595825
17:15						0.3475					0.0120825							0.3595825
17:30						0.3475					0.0120825							0.3595825
17:45						0.3475					0.0120825							0.3595825
18:00		0.1275	0.1275	0.1275	0.1275		0.0675	0.9	0.35		0.0120825					0.06125		1.9008325
18:15		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
18:30		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
18:45		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
19:00		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
19:15		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
19:30		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
19:45		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
20:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6	0.09375			0.06125		1.3445825
20:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6	0.09375			0.06125		1.3445825
20:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6	0.09375			0.06125		1.3445825
20:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6				0.06125		1.2508325
21:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
21:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
21:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
21:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
22:00	0.235	0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.8620825
22:15	0.235	0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.8620825
22:30	0.235	0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.8620825
22:45	0.235	0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.8620825
23:00	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825	0.6						1.3570825
23:15	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825	0.6						1.3570825
23:30	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825							0.7570825
23:45	0.235	0.1275	0.1275	0.1275	0.1275						0.0120825							0.7570825
Total Energy Usage																		72.71857

Typical Appliance 4 Person Spring

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235										0.0120825							0.2470825
0:15	0.235										0.0120825							0.2470825
0:30	0.235										0.0120825							0.2470825
0:45	0.235										0.0120825							0.2470825
1:00											0.0120825							0.0120825
1:15											0.0120825							0.0120825
1:30											0.0120825							0.0120825
1:45											0.0120825							0.0120825
2:00											0.0120825							0.0120825
2:15											0.0120825							0.0120825
2:30											0.0120825							0.0120825
2:45											0.0120825							0.0120825
3:00											0.0120825							0.0120825
3:15											0.0120825							0.0120825
3:30											0.0120825							0.0120825
3:45											0.0120825							0.0120825
4:00											0.0120825							0.0120825
4:15											0.0120825							0.0120825
4:30											0.0120825							0.0120825
4:45											0.0120825							0.0120825
5:00											0.0120825							0.0120825
5:15											0.0120825							0.0120825
5:30											0.0120825							0.0120825
5:45											0.0120825							0.0120825
6:00									0.35	1.025	0.0120825						0.0482	1.4352825
6:15										1.025	0.0120825						0.0482	1.0852825
6:30										1.025	0.0120825						0.0482	1.0852825
6:45										1.025	0.0120825						0.0482	1.0852825
7:00											0.0120825						0.0482	0.0602825
7:15											0.0120825						0.0482	0.0602825
7:30											0.0120825						0.0482	0.0602825
7:45											0.0120825						0.0482	0.0602825
8:00											0.0120825						0.0482	0.0602825
8:15											0.0120825						0.0482	0.0602825
8:30											0.0120825						0.0482	0.0602825
8:45											0.0120825						0.0482	0.0602825
9:00											0.0120825						0.0482	0.0602825
9:15											0.0120825						0.0482	0.0602825
9:30											0.0120825						0.0482	0.0602825
9:45											0.0120825						0.0482	0.0602825
10:00				0.1275	0.1275				0.35	1.025	0.0120825						0.0482	1.6902825
10:15				0.1275	0.1275					1.025	0.0120825						0.0482	1.3402825
10:30				0.1275	0.1275					1.025	0.0120825						0.0482	1.3402825
10:45				0.1275	0.1275					1.025	0.0120825						0.0482	1.3402825
11:00				0.1275	0.1275	0.3475			0.35		0.0120825						0.0482	1.0127825
11:15				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
11:30				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
11:45				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
12:00				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
12:15				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
12:30				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
12:45				0.1275	0.1275	0.3475					0.0120825						0.0482	0.6627825
13:00						0.3475					0.0120825						0.0482	0.4077825
13:15						0.3475					0.0120825						0.0482	0.4077825
13:30						0.3475					0.0120825						0.0482	0.4077825
13:45						0.3475					0.0120825						0.0482	0.4077825
14:00						0.3475					0.0120825							0.3595825
14:15						0.3475					0.0120825							0.3595825
14:30						0.3475					0.0120825							0.3595825
14:45						0.3475					0.0120825							0.3595825
15:00						0.3475					0.0120825							0.3595825
15:15						0.3475					0.0120825							0.3595825
15:30						0.3475					0.0120825							0.3595825
15:45						0.3475					0.0120825							0.3595825
16:00						0.3475					0.0120825							0.3595825
16:15						0.3475					0.0120825							0.3595825
16:30						0.3475					0.0120825							0.3595825
16:45						0.3475					0.0120825							0.3595825
17:00						0.3475	0.0675	0.9			0.0120825							1.3270825
17:15						0.3475	0.0675	0.9			0.0120825							1.3270825
17:30						0.3475	0.0675	0.9			0.0120825							1.3270825
17:45						0.3475	0.0675	0.9			0.0120825							1.3270825
18:00							0.0675	0.9	0.35	1.025	0.0120825					0.06125		2.4158325
18:15							0.0675	0.9		1.025	0.0120825					0.06125		2.0658325
18:30							0.0675	0.9		1.025	0.0120825					0.06125		2.0658325
18:45							0.0675	0.9		1.025	0.0120825					0.06125		2.0658325
19:00							0.0675				0.0120825					0.06125		0.1408325
19:15							0.0675				0.0120825					0.06125		0.1408325
19:30							0.0675				0.0120825					0.06125		0.1408325
19:45							0.0675				0.0120825					0.06125		0.1408325
20:00							0.0675				0.0120825	0.6	0.09375			0.06125		0.8345825
20:15							0.0675				0.0120825	0.6	0.09375			0.06125		0.8345825
20:30							0.0675				0.0120825	0.6	0.09375			0.06125		0.8345825
20:45							0.0675				0.0120825	0.6				0.06125		0.7408325
21:00							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
21:15							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
21:30							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
21:45							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
22:00	0.235						0.0675				0.0120825	0.6						0.9145825
22:15	0.235						0.0675				0.0120825	0.6						0.9145825
22:30	0.235						0.0675				0.0120825	0.6						0.9145825
22:45	0.235						0.0675				0.0120825	0.6						0.9145825
23:00	0.235										0.0120825	0.6						0.8470825
23:15	0.235										0.0120825	0.6						0.8470825
23:30	0.235										0.0120825							0.2470825
23:45	0.235										0.0120825							0.2470825
Total Energy Usage																		52.22857

Typical Appliance 4 Person Autumn

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235										0.0120825							0.2470825
0:15	0.235										0.0120825							0.2470825
0:30	0.235										0.0120825							0.2470825
0:45	0.235										0.0120825							0.2470825
1:00											0.0120825							0.0120825
1:15											0.0120825							0.0120825
1:30											0.0120825							0.0120825
1:45											0.0120825							0.0120825
2:00											0.0120825							0.0120825
2:15											0.0120825							0.0120825
2:30											0.0120825							0.0120825
2:45											0.0120825							0.0120825
3:00											0.0120825							0.0120825
3:15											0.0120825							0.0120825
3:30											0.0120825							0.0120825
3:45											0.0120825							0.0120825
4:00											0.0120825							0.0120825
4:15											0.0120825							0.0120825
4:30											0.0120825							0.0120825
4:45											0.0120825							0.0120825
5:00											0.0120825							0.0120825
5:15											0.0120825							0.0120825
5:30											0.0120825							0.0120825
5:45											0.0120825							0.0120825
6:00				0.1625	0.1625		0.0675		0.35	1.025	0.0120825						0.0482	1.8277825
6:15				0.1625	0.1625		0.0675			1.025	0.0120825						0.0482	1.4777825
6:30				0.1625	0.1625		0.0675			1.025	0.0120825						0.0482	1.4777825
6:45				0.1625	0.1625		0.0675			1.025	0.0120825						0.0482	1.4777825
7:00				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
7:15				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
7:30				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
7:45				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
8:00							0.0675				0.0120825						0.0482	0.1277825
8:15							0.0675				0.0120825						0.0482	0.1277825
8:30							0.0675				0.0120825						0.0482	0.1277825
8:45							0.0675				0.0120825						0.0482	0.1277825
9:00											0.0120825						0.0482	0.0602825
9:15											0.0120825						0.0482	0.0602825
9:30											0.0120825						0.0482	0.0602825
9:45											0.0120825						0.0482	0.0602825
10:00											0.0120825						0.0482	0.0602825
10:15											0.0120825						0.0482	0.0602825
10:30											0.0120825						0.0482	0.0602825
10:45											0.0120825						0.0482	0.0602825
11:00											0.0120825						0.0482	0.0602825
11:15											0.0120825						0.0482	0.0602825
11:30											0.0120825						0.0482	0.0602825
11:45											0.0120825						0.0482	0.0602825
12:00									0.35	1.025	0.0120825						0.0482	1.4352825
12:15										1.025	0.0120825						0.0482	1.0852825
12:30										1.025	0.0120825						0.0482	1.0852825
12:45										1.025	0.0120825						0.0482	1.0852825
13:00											0.0120825						0.0482	0.0602825
13:15											0.0120825						0.0482	0.0602825
13:30											0.0120825						0.0482	0.0602825
13:45											0.0120825						0.0482	0.0602825
14:00											0.0120825							0.0120825
14:15											0.0120825							0.0120825
14:30											0.0120825							0.0120825
14:45											0.0120825							0.0120825
15:00											0.0120825							0.0120825
15:15											0.0120825							0.0120825
15:30											0.0120825							0.0120825
15:45											0.0120825							0.0120825
16:00						0.3725					0.0120825							0.3845825
16:15						0.3725					0.0120825							0.3845825
16:30						0.3725					0.0120825							0.3845825
16:45						0.3725					0.0120825							0.3845825
17:00						0.3725	0.0675				0.0120825							0.4520825
17:15						0.3725	0.0675				0.0120825							0.4520825
17:30						0.3725	0.0675				0.0120825							0.4520825
17:45						0.3725	0.0675				0.0120825							0.4520825
18:00						0.3725	0.0675	0.9	0.35		0.0120825					0.06125		1.7633325
18:15						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
18:30						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
18:45						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
19:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
19:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
19:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
19:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
20:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8570825
20:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8570825
20:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8570825
20:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6				0.06125		1.7633325
21:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
21:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
21:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
21:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
22:00	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5645825
22:15	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5645825
22:30	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5645825
22:45	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5645825
23:00	0.235										0.0120825	0.6						0.8470825
23:15	0.235										0.0120825	0.6						0.8470825
23:30	0.235										0.0120825							0.2470825
23:45	0.235										0.0120825							0.2470825
Total Energy Usage																		61.83857

Typical Appliance 4 Person Winter

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235										0.0120825							0.2471
0:15	0.235										0.0120825							0.2471
0:30	0.235										0.0120825							0.2471
0:45	0.235										0.0120825							0.2471
1:00											0.0120825							0.0121
1:15											0.0120825							0.0121
1:30											0.0120825							0.0121
1:45											0.0120825							0.0121
2:00											0.0120825							0.0121
2:15											0.0120825							0.0121
2:30											0.0120825							0.0121
2:45											0.0120825							0.0121
3:00											0.0120825							0.0121
3:15											0.0120825							0.0121
3:30											0.0120825							0.0121
3:45											0.0120825							0.0121
4:00											0.0120825							0.0121
4:15											0.0120825							0.0121
4:30											0.0120825							0.0121
4:45											0.0120825							0.0121
5:00				0.1625	0.1625						0.0120825							0.3371
5:15				0.1625	0.1625						0.0120825							0.3371
5:30				0.1625	0.1625						0.0120825							0.3371
5:45				0.1625	0.1625						0.0120825							0.3371
6:00				0.1625	0.1625	0.3725	0.0675		0.35	1.025	0.0120825						0.0482	2.2003
6:15				0.1625	0.1625	0.3725	0.0675			1.025	0.0120825						0.0482	1.8503
6:30				0.1625	0.1625	0.3725	0.0675			1.025	0.0120825						0.0482	1.8503
6:45				0.1625	0.1625	0.3725	0.0675			1.025	0.0120825						0.0482	1.8503
7:00				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
7:15				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
7:30				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
7:45				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
8:00						0.3725	0.0675				0.0120825						0.0482	0.5003
8:15						0.3725	0.0675				0.0120825						0.0482	0.5003
8:30						0.3725	0.0675				0.0120825						0.0482	0.5003
8:45						0.3725	0.0675				0.0120825						0.0482	0.5003
9:00											0.0120825						0.0482	0.0603
9:15											0.0120825						0.0482	0.0603
9:30											0.0120825						0.0482	0.0603
9:45											0.0120825						0.0482	0.0603
10:00											0.0120825						0.0482	0.0603
10:15											0.0120825						0.0482	0.0603
10:30											0.0120825						0.0482	0.0603
10:45											0.0120825						0.0482	0.0603
11:00											0.0120825						0.0482	0.0603
11:15											0.0120825						0.0482	0.0603
11:30											0.0120825						0.0482	0.0603
11:45											0.0120825						0.0482	0.0603
12:00									0.35	1.025	0.0120825						0.0482	1.4353
12:15										1.025	0.0120825						0.0482	1.0853
12:30										1.025	0.0120825						0.0482	1.0853
12:45										1.025	0.0120825						0.0482	1.0853
13:00											0.0120825						0.0482	0.0603
13:15											0.0120825						0.0482	0.0603
13:30											0.0120825						0.0482	0.0603
13:45											0.0120825						0.0482	0.0603
14:00											0.0120825							0.0121
14:15											0.0120825							0.0121
14:30											0.0120825							0.0121
14:45											0.0120825							0.0121
15:00											0.0120825							0.0121
15:15											0.0120825							0.0121
15:30											0.0120825							0.0121
15:45											0.0120825							0.0121
16:00											0.0120825							0.0121
16:15											0.0120825							0.0121
16:30											0.0120825							0.0121
16:45											0.0120825							0.0121
17:00		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:15		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:30		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:45		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
18:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9	0.35		0.0120825					0.06125		2.4133
18:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
18:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
18:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
19:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
19:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
19:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
19:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
20:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8571
20:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8571
20:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8571
20:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6				0.06125		1.7633
21:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
21:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
21:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
21:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
22:00	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5646
22:15	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5646
22:30	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5646
22:45	0.235	0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.5646
23:00	0.235										0.0120825							0.2471
23:15	0.235										0.0120825							0.2471
23:30	0.235										0.0120825							0.2471
23:45	0.235										0.0120825							0.2471
Total Energy Usage																		68.3586

Appliance Heavy 2 Person Summer

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235	0.1275	0.1275						0.0120825							0.5020825
0:15	0.235	0.1275	0.1275						0.0120825							0.5020825
0:30	0.235	0.1275	0.1275						0.0120825							0.5020825
0:45	0.235	0.1275	0.1275						0.0120825							0.5020825
1:00		0.1275	0.1275						0.0120825							0.2670825
1:15		0.1275	0.1275						0.0120825							0.2670825
1:30		0.1275	0.1275						0.0120825							0.2670825
1:45		0.1275	0.1275						0.0120825							0.2670825
2:00		0.1275	0.1275						0.0120825							0.2670825
2:15		0.1275	0.1275						0.0120825							0.2670825
2:30		0.1275	0.1275						0.0120825							0.2670825
2:45		0.1275	0.1275						0.0120825							0.2670825
3:00		0.1275	0.1275						0.0120825							0.2670825
3:15		0.1275	0.1275						0.0120825							0.2670825
3:30		0.1275	0.1275						0.0120825							0.2670825
3:45		0.1275	0.1275						0.0120825							0.2670825
4:00		0.1275	0.1275						0.0120825							0.2670825
4:15		0.1275	0.1275						0.0120825							0.2670825
4:30		0.1275	0.1275						0.0120825							0.2670825
4:45		0.1275	0.1275						0.0120825							0.2670825
5:00		0.1275	0.1275						0.0120825							0.2670825
5:15		0.1275	0.1275						0.0120825							0.2670825
5:30		0.1275	0.1275						0.0120825							0.2670825
5:45		0.1275	0.1275						0.0120825							0.2670825
6:00		0.1275	0.1275				0.35		0.0120825					0.06125	0.0482	0.7265325
6:15		0.1275	0.1275						0.0120825					0.06125	0.0482	0.3765325
6:30		0.1275	0.1275						0.0120825					0.06125	0.0482	0.3765325
6:45		0.1275	0.1275						0.0120825					0.06125	0.0482	0.3765325
7:00									0.0120825					0.06125	0.0482	0.1215325
7:15									0.0120825					0.06125	0.0482	0.1215325
7:30									0.0120825					0.06125	0.0482	0.1215325
7:45									0.0120825					0.06125	0.0482	0.1215325
8:00									0.0120825						0.0482	0.0602825
8:15									0.0120825						0.0482	0.0602825
8:30						0.9			0.0120825						0.0482	0.9602825
8:45						0.9			0.0120825						0.0482	0.9602825
9:00				0.3475		0.9			0.0120825						0.0482	1.3077825
9:15				0.3475		0.9			0.0120825						0.0482	1.3077825
9:30				0.3475		0.9			0.0120825						0.0482	1.3077825
9:45				0.3475		0.9			0.0120825						0.0482	1.3077825
10:00				0.3475					0.0120825						0.0482	0.4077825
10:15				0.3475					0.0120825						0.0482	0.4077825
10:30				0.3475					0.0120825						0.0482	0.4077825
10:45				0.3475					0.0120825						0.0482	0.4077825
11:00				0.3475					0.0120825					0.06125	0.0482	0.4690325
11:15				0.3475					0.0120825					0.06125	0.0482	0.4690325
11:30				0.3475					0.0120825					0.06125	0.0482	0.4690325
11:45				0.3475					0.0120825					0.06125	0.0482	0.4690325
12:00				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
12:15				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
12:30				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
12:45				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
13:00				0.3475					0.0120825						0.0482	0.4077825
13:15				0.3475					0.0120825						0.0482	0.4077825
13:30				0.3475					0.0120825						0.0482	0.4077825
13:45				0.3475					0.0120825						0.0482	0.4077825
14:00				0.3475					0.0120825							0.3595825
14:15				0.3475					0.0120825							0.3595825
14:30				0.3475					0.0120825							0.3595825
14:45				0.3475					0.0120825							0.3595825
15:00				0.3475					0.0120825							0.3595825
15:15				0.3475					0.0120825							0.3595825
15:30				0.3475					0.0120825							0.3595825
15:45				0.3475					0.0120825							0.3595825
16:00				0.3475					0.0120825							0.3595825
16:15				0.3475					0.0120825							0.3595825
16:30				0.3475					0.0120825							0.3595825
16:45				0.3475					0.0120825							0.3595825
17:00				0.3475					0.0120825							0.3595825
17:15				0.3475					0.0120825							0.3595825
17:30				0.3475					0.0120825							0.3595825
17:45				0.3475					0.0120825							0.3595825
18:00		0.1275	0.1275		0.0585	0.9	0.35	1.625	0.0120825					0.06125		3.2618325
18:15		0.1275	0.1275		0.0585	0.9		1.625	0.0120825					0.06125		2.9118325
18:30		0.1275	0.1275		0.0585	0.9		1.625	0.0120825					0.06125		2.9118325
18:45		0.1275	0.1275		0.0585	0.9		1.625	0.0120825					0.06125		2.9118325
19:00		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:15		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:30		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:45		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
20:00		0.1275	0.1275		0.0585				0.0120825	0.6	0.09375			0.06125		1.0805825
20:15		0.1275	0.1275		0.0585				0.0120825	0.6	0.09375			0.06125		1.0805825
20:30		0.1275	0.1275		0.0585				0.0120825	0.6	0.09375			0.06125		1.0805825
20:45		0.1275	0.1275		0.0585				0.0120825	0.6				0.06125		0.9868325
21:00		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
21:15		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
21:30		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
21:45		0.1275	0.1275		0.0585				0.0120825	0.6		0.4375	0.0575			1.4205825
22:00	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
22:15	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
22:30	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
22:45	0.235	0.1275	0.1275		0.0585				0.0120825	0.6						1.1605825
23:00	0.235	0.1275	0.1275						0.0120825	0.6						1.1020825
23:15	0.235	0.1275	0.1275						0.0120825	0.6						1.1020825
23:30	0.235	0.1275	0.1275						0.0120825							0.5020825
23:45	0.235	0.1275	0.1275						0.0120825							0.5020825
Total Energy Usage																67.53857

Appliance Heavy 2 Person Spring

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235								0.0120825							0.2470825
0:15	0.235								0.0120825							0.2470825
0:30	0.235								0.0120825							0.2470825
0:45	0.235								0.0120825							0.2470825
1:00									0.0120825							0.0120825
1:15									0.0120825							0.0120825
1:30									0.0120825							0.0120825
1:45									0.0120825							0.0120825
2:00									0.0120825							0.0120825
2:15									0.0120825							0.0120825
2:30									0.0120825							0.0120825
2:45									0.0120825							0.0120825
3:00									0.0120825							0.0120825
3:15									0.0120825							0.0120825
3:30									0.0120825							0.0120825
3:45									0.0120825							0.0120825
4:00									0.0120825							0.0120825
4:15									0.0120825							0.0120825
4:30									0.0120825							0.0120825
4:45									0.0120825							0.0120825
5:00									0.0120825							0.0120825
5:15									0.0120825							0.0120825
5:30									0.0120825							0.0120825
5:45									0.0120825							0.0120825
6:00							0.35	1.625	0.0120825					0.06125	0.0482	2.0965325
6:15								1.625	0.0120825					0.06125	0.0482	1.7465325
6:30								1.625	0.0120825					0.06125	0.0482	1.7465325
6:45								1.625	0.0120825					0.06125	0.0482	1.7465325
7:00									0.0120825					0.06125	0.0482	0.1215325
7:15									0.0120825					0.06125	0.0482	0.1215325
7:30									0.0120825					0.06125	0.0482	0.1215325
7:45									0.0120825					0.06125	0.0482	0.1215325
8:00									0.0120825						0.0482	0.0602825
8:15									0.0120825						0.0482	0.0602825
8:30						0.9			0.0120825						0.0482	0.9602825
8:45						0.9			0.0120825						0.0482	0.9602825
9:00						0.9			0.0120825						0.0482	0.9602825
9:15						0.9			0.0120825						0.0482	0.9602825
9:30						0.9			0.0120825						0.0482	0.9602825
9:45						0.9			0.0120825						0.0482	0.9602825
10:00									0.0120825						0.0482	0.0602825
10:15									0.0120825						0.0482	0.0602825
10:30									0.0120825						0.0482	0.0602825
10:45									0.0120825						0.0482	0.0602825
11:00									0.0120825					0.06125	0.0482	0.1215325
11:15									0.0120825					0.06125	0.0482	0.1215325
11:30									0.0120825					0.06125	0.0482	0.1215325
11:45									0.0120825					0.06125	0.0482	0.1215325
12:00				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
12:15				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
12:30				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
12:45				0.3475				1.625	0.0120825					0.06125	0.0482	2.0940325
13:00				0.3475					0.0120825						0.0482	0.4077825
13:15				0.3475					0.0120825						0.0482	0.4077825
13:30				0.3475					0.0120825						0.0482	0.4077825
13:45				0.3475					0.0120825						0.0482	0.4077825
14:00				0.3475					0.0120825							0.3595825
14:15				0.3475					0.0120825							0.3595825
14:30				0.3475					0.0120825							0.3595825
14:45				0.3475					0.0120825							0.3595825
15:00				0.3475					0.0120825							0.3595825
15:15				0.3475					0.0120825							0.3595825
15:30				0.3475					0.0120825							0.3595825
15:45				0.3475					0.0120825							0.3595825
16:00				0.3475					0.0120825							0.3595825
16:15				0.3475					0.0120825							0.3595825
16:30				0.3475					0.0120825							0.3595825
16:45				0.3475					0.0120825							0.3595825
17:00				0.3475	0.0585				0.0120825							0.4180825
17:15				0.3475	0.0585				0.0120825							0.4180825
17:30				0.3475	0.0585				0.0120825							0.4180825
17:45				0.3475	0.0585				0.0120825							0.4180825
18:00					0.0585	0.9	0.35	1.625	0.0120825					0.06125		3.0068325
18:15					0.0585	0.9		1.625	0.0120825					0.06125		2.6568325
18:30					0.0585	0.9		1.625	0.0120825					0.06125		2.6568325
18:45					0.0585	0.9		1.625	0.0120825					0.06125		2.6568325
19:00					0.0585				0.0120825					0.06125		0.1318325
19:15					0.0585				0.0120825					0.06125		0.1318325
19:30					0.0585				0.0120825					0.06125		0.1318325
19:45					0.0585				0.0120825					0.06125		0.1318325
20:00					0.0585				0.0120825	0.6	0.09375			0.06125		0.8255825
20:15					0.0585				0.0120825	0.6	0.09375			0.06125		0.8255825
20:30					0.0585				0.0120825	0.6	0.09375			0.06125		0.8255825
20:45					0.0585				0.0120825	0.6				0.06125		0.7318325
21:00					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
21:15					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
21:30					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
21:45					0.0585				0.0120825	0.6		0.4375	0.0575			1.1655825
22:00	0.235				0.0585				0.0120825	0.6						0.9055825
22:15	0.235				0.0585				0.0120825	0.6						0.9055825
22:30	0.235				0.0585				0.0120825	0.6						0.9055825
22:45	0.235				0.0585				0.0120825	0.6						0.9055825
23:00	0.235								0.0120825	0.6						0.8470825
23:15	0.235								0.0120825	0.6						0.8470825
23:30	0.235								0.0120825							0.2470825
23:45	0.235								0.0120825							0.2470825
Total Energy Usage																55.5013225

Appliance Heavy 2 Person Autumn

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235								0.0120825							0.2470825
0:15	0.235								0.0120825							0.2470825
0:30	0.235								0.0120825							0.2470825
0:45	0.235								0.0120825							0.2470825
1:00									0.0120825							0.0120825
1:15									0.0120825							0.0120825
1:30									0.0120825							0.0120825
1:45									0.0120825							0.0120825
2:00									0.0120825							0.0120825
2:15									0.0120825							0.0120825
2:30									0.0120825							0.0120825
2:45									0.0120825							0.0120825
3:00									0.0120825							0.0120825
3:15									0.0120825							0.0120825
3:30									0.0120825							0.0120825
3:45									0.0120825							0.0120825
4:00									0.0120825							0.0120825
4:15									0.0120825							0.0120825
4:30									0.0120825							0.0120825
4:45									0.0120825							0.0120825
5:00									0.0120825							0.0120825
5:15									0.0120825							0.0120825
5:30									0.0120825							0.0120825
5:45									0.0120825							0.0120825
6:00							0.35	1.625	0.0120825					0.06125	0.0482	2.0965325
6:15					0.0585			1.625	0.0120825					0.06125	0.0482	1.8050325
6:30					0.0585			1.625	0.0120825					0.06125	0.0482	1.8050325
6:45					0.0585			1.625	0.0120825					0.06125	0.0482	1.8050325
7:00					0.0585				0.0120825					0.06125	0.0482	0.1800325
7:15					0.0585				0.0120825					0.06125	0.0482	0.1800325
7:30					0.0585				0.0120825					0.06125	0.0482	0.1800325
7:45					0.0585				0.0120825					0.06125	0.0482	0.1800325
8:00					0.0585				0.0120825						0.0482	0.1187825
8:15					0.0585				0.0120825						0.0482	0.1187825
8:30					0.0585	0.9			0.0120825						0.0482	1.0187825
8:45					0.0585	0.9			0.0120825						0.0482	1.0187825
9:00						0.9			0.0120825						0.0482	0.9602825
9:15						0.9			0.0120825						0.0482	0.9602825
9:30						0.9			0.0120825						0.0482	0.9602825
9:45						0.9			0.0120825						0.0482	0.9602825
10:00									0.0120825						0.0482	0.0602825
10:15									0.0120825						0.0482	0.0602825
10:30									0.0120825						0.0482	0.0602825
10:45									0.0120825						0.0482	0.0602825
11:00									0.0120825					0.06125	0.0482	0.1215325
11:15									0.0120825					0.06125	0.0482	0.1215325
11:30									0.0120825					0.06125	0.0482	0.1215325
11:45									0.0120825					0.06125	0.0482	0.1215325
12:00								1.625	0.0120825					0.06125	0.0482	1.7465325
12:15								1.625	0.0120825					0.06125	0.0482	1.7465325
12:30								1.625	0.0120825					0.06125	0.0482	1.7465325
12:45								1.625	0.0120825					0.06125	0.0482	1.7465325
13:00									0.0120825						0.0482	0.0602825
13:15									0.0120825						0.0482	0.0602825
13:30									0.0120825						0.0482	0.0602825
13:45									0.0120825						0.0482	0.0602825
14:00									0.0120825							0.0120825
14:15									0.0120825							0.0120825
14:30									0.0120825							0.0120825
14:45									0.0120825							0.0120825
15:00									0.0120825							0.0120825
15:15									0.0120825							0.0120825
15:30									0.0120825							0.0120825
15:45									0.0120825							0.0120825
16:00				0.3725					0.0120825							0.3845825
16:15				0.3725					0.0120825							0.3845825
16:30				0.3725					0.0120825							0.3845825
16:45				0.3725					0.0120825							0.3845825
17:00				0.3725	0.0585				0.0120825							0.4430825
17:15				0.3725	0.0585				0.0120825							0.4430825
17:30				0.3725	0.0585				0.0120825							0.4430825
17:45				0.3725	0.0585				0.0120825							0.4430825
18:00				0.3725	0.0585	0.9	0.35	1.625	0.0120825					0.06125		3.3793325
18:15				0.3725	0.0585	0.9		1.625	0.0120825					0.06125		3.0293325
18:30				0.3725	0.0585	0.9		1.625	0.0120825					0.06125		3.0293325
18:45				0.3725	0.0585	0.9		1.625	0.0120825					0.06125		3.0293325
19:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
20:00		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5230825
20:15		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5230825
20:30		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5230825
20:45		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6				0.06125		1.4293325
21:00		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6		0.4375	0.0575			1.8630825
21:15		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6		0.4375	0.0575			1.8630825
21:30		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6		0.4375	0.0575			1.8630825
21:45		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6		0.4375	0.0575			1.8630825
22:00	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
22:15	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
22:30	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
22:45	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2305825
23:00	0.235								0.0120825	0.6						0.8470825
23:15	0.235								0.0120825	0.6						0.8470825
23:30	0.235								0.0120825							0.2470825
23:45	0.235								0.0120825							0.2470825
Total Energy Usage																61.9448225

Appliance Heavy 2 Person Winter

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00	0.235								0.0120825							0.2471
0:15	0.235								0.0120825							0.2471
0:30	0.235								0.0120825							0.2471
0:45	0.235								0.0120825							0.2471
1:00									0.0120825							0.0121
1:15									0.0120825							0.0121
1:30									0.0120825							0.0121
1:45									0.0120825							0.0121
2:00									0.0120825							0.0121
2:15									0.0120825							0.0121
2:30									0.0120825							0.0121
2:45									0.0120825							0.0121
3:00									0.0120825							0.0121
3:15									0.0120825							0.0121
3:30									0.0120825							0.0121
3:45									0.0120825							0.0121
4:00									0.0120825							0.0121
4:15									0.0120825							0.0121
4:30									0.0120825							0.0121
4:45									0.0120825							0.0121
5:00									0.0120825							0.0121
5:15									0.0120825							0.0121
5:30									0.0120825							0.0121
5:45									0.0120825							0.0121
6:00				0.3725	0.0585		0.35	1.625	0.0120825					0.06125	0.0482	2.5275
6:15				0.3725	0.0585			1.625	0.0120825					0.06125	0.0482	2.1775
6:30				0.3725	0.0585			1.625	0.0120825					0.06125	0.0482	2.1775
6:45				0.3725	0.0585			1.625	0.0120825					0.06125	0.0482	2.1775
7:00				0.3725	0.0585				0.0120825					0.06125	0.0482	0.5525
7:15				0.3725	0.0585				0.0120825					0.06125	0.0482	0.5525
7:30				0.3725	0.0585				0.0120825					0.06125	0.0482	0.5525
7:45				0.3725	0.0585				0.0120825					0.06125	0.0482	0.5525
8:00				0.3725	0.0585				0.0120825						0.0482	0.4913
8:15				0.3725	0.0585				0.0120825						0.0482	0.4913
8:30				0.3725	0.0585	0.9			0.0120825						0.0482	1.3913
8:45				0.3725	0.0585	0.9			0.0120825						0.0482	1.3913
9:00						0.9			0.0120825						0.0482	0.9603
9:15						0.9			0.0120825						0.0482	0.9603
9:30						0.9			0.0120825						0.0482	0.9603
9:45						0.9			0.0120825						0.0482	0.9603
10:00									0.0120825						0.0482	0.0603
10:15									0.0120825						0.0482	0.0603
10:30									0.0120825						0.0482	0.0603
10:45									0.0120825						0.0482	0.0603
11:00									0.0120825					0.06125	0.0482	0.1215
11:15									0.0120825					0.06125	0.0482	0.1215
11:30									0.0120825					0.06125	0.0482	0.1215
11:45									0.0120825					0.06125	0.0482	0.1215
12:00								1.625	0.0120825					0.06125	0.0482	1.7465
12:15								1.625	0.0120825					0.06125	0.0482	1.7465
12:30								1.625	0.0120825					0.06125	0.0482	1.7465
12:45								1.625	0.0120825					0.06125	0.0482	1.7465
13:00									0.0120825						0.0482	0.0603
13:15									0.0120825						0.0482	0.0603
13:30									0.0120825						0.0482	0.0603
13:45									0.0120825						0.0482	0.0603
14:00									0.0120825							0.0121
14:15									0.0120825							0.0121
14:30									0.0120825							0.0121
14:45									0.0120825							0.0121
15:00									0.0120825							0.0121
15:15									0.0120825							0.0121
15:30									0.0120825							0.0121
15:45									0.0120825							0.0121
16:00									0.0120825							0.0121
16:15									0.0120825							0.0121
16:30									0.0120825							0.0121
16:45									0.0120825							0.0121
17:00		0.1625	0.1625	0.3725					0.0120825							0.7096
17:15		0.1625	0.1625	0.3725					0.0120825							0.7096
17:30		0.1625	0.1625	0.3725					0.0120825							0.7096
17:45		0.1625	0.1625	0.3725					0.0120825							0.7096
18:00		0.1625	0.1625	0.3725	0.0585	0.9	0.35	1.625	0.0120825					0.06125		3.7043
18:15		0.1625	0.1625	0.3725	0.0585	0.9		1.625	0.0120825					0.06125		3.3543
18:30		0.1625	0.1625	0.3725	0.0585	0.9		1.625	0.0120825					0.06125		3.3543
18:45		0.1625	0.1625	0.3725	0.0585	0.9		1.625	0.0120825					0.06125		3.3543
19:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
20:00		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5231
20:15		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5231
20:30		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6	0.09375			0.06125		1.5231
20:45		0.1625	0.1625	0.3725	0.0585				0.0120825	0.6				0.06125		1.4293
21:00		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
21:15		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
21:30		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
21:45		0.1625	0.1625		0.0585				0.0120825	0.6		0.4375	0.0575			1.4906
22:00	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
22:15	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
22:30	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
22:45	0.235	0.1625	0.1625		0.0585				0.0120825	0.6						1.2306
23:00	0.235								0.0120825	0.6						0.8471
23:15	0.235								0.0120825	0.6						0.8471
23:30	0.235								0.0120825							0.2471
23:45	0.235								0.0120825							0.2471
Total Energy Usage																65.8593

Appliance Heavy 4 Person Summer

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
0:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
0:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
0:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
6:00		0.1275	0.1275	0.1275	0.1275				0.35		0.0120825					0.06125	0.0482	0.9815325
6:15		0.1275	0.1275	0.1275	0.1275						0.0120825					0.06125	0.0482	0.6315325
6:30		0.1275	0.1275	0.1275	0.1275						0.0120825					0.06125	0.0482	0.6315325
6:45		0.1275	0.1275	0.1275	0.1275						0.0120825					0.06125	0.0482	0.6315325
7:00											0.0120825					0.06125	0.0482	0.1215325
7:15											0.0120825					0.06125	0.0482	0.1215325
7:30											0.0120825					0.06125	0.0482	0.1215325
7:45											0.0120825					0.06125	0.0482	0.1215325
8:00											0.0120825						0.0482	0.0602825
8:15											0.0120825						0.0482	0.0602825
8:30								0.9			0.0120825						0.0482	0.9602825
8:45								0.9			0.0120825						0.0482	0.9602825
9:00						0.3475		0.9			0.0120825						0.0482	1.3077825
9:15						0.3475		0.9			0.0120825						0.0482	1.3077825
9:30						0.3475		0.9			0.0120825						0.0482	1.3077825
9:45						0.3475		0.9			0.0120825						0.0482	1.3077825
10:00	0.235					0.3475					0.0120825						0.0482	0.6427825
10:15	0.235					0.3475					0.0120825						0.0482	0.6427825
10:30	0.235					0.3475					0.0120825						0.0482	0.6427825
10:45	0.235					0.3475					0.0120825						0.0482	0.6427825
11:00	0.235					0.3475					0.0120825					0.06125	0.0482	0.7040325
11:15	0.235					0.3475					0.0120825					0.06125	0.0482	0.7040325
11:30	0.235					0.3475					0.0120825					0.06125	0.0482	0.7040325
11:45	0.235					0.3475					0.0120825					0.06125	0.0482	0.7040325
12:00	0.235					0.3475			0.35	1.625	0.0120825					0.06125	0.0482	2.6790325
12:15	0.235					0.3475				1.625	0.0120825					0.06125	0.0482	2.3290325
12:30	0.235					0.3475				1.625	0.0120825					0.06125	0.0482	2.3290325
12:45	0.235					0.3475				1.625	0.0120825					0.06125	0.0482	2.3290325
13:00						0.3475					0.0120825						0.0482	0.4077825
13:15						0.3475					0.0120825						0.0482	0.4077825
13:30						0.3475					0.0120825						0.0482	0.4077825
13:45						0.3475					0.0120825						0.0482	0.4077825
14:00						0.3475					0.0120825							0.3595825
14:15						0.3475					0.0120825							0.3595825
14:30						0.3475					0.0120825							0.3595825
14:45						0.3475					0.0120825							0.3595825
15:00						0.3475					0.0120825							0.3595825
15:15						0.3475					0.0120825							0.3595825
15:30						0.3475					0.0120825							0.3595825
15:45						0.3475					0.0120825							0.3595825
16:00						0.3475					0.0120825							0.3595825
16:15						0.3475					0.0120825							0.3595825
16:30						0.3475					0.0120825							0.3595825
16:45						0.3475					0.0120825							0.3595825
17:00						0.3475					0.0120825							0.3595825
17:15						0.3475					0.0120825							0.3595825
17:30						0.3475					0.0120825							0.3595825
17:45						0.3475					0.0120825							0.3595825
18:00		0.1275	0.1275	0.1275	0.1275		0.0675	0.9	0.35	1.625	0.0120825					0.06125		3.5258325
18:15		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.625	0.0120825					0.06125		3.1758325
18:30		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.625	0.0120825					0.06125		3.1758325
18:45		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.625	0.0120825					0.06125		3.1758325
19:00		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
19:15		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
19:30		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
19:45		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
20:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6	0.09375			0.06125		1.3445825
20:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6	0.09375			0.06125		1.3445825
20:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6	0.09375			0.06125		1.3445825
20:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6				0.06125		1.2508325
21:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
21:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
21:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
21:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375	0.0575			1.6845825
22:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.6270825
22:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.6270825
22:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.6270825
22:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825	0.6		0.4375				1.6270825
23:00		0.1275	0.1275	0.1275	0.1275						0.0120825	0.6						1.1220825
23:15		0.1275	0.1275	0.1275	0.1275						0.0120825	0.6						1.1220825
23:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
23:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
Total Energy Usage																		86.67857

Appliance Heavy 4 Person Spring

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00											0.0120825							0.0120825
0:15											0.0120825							0.0120825
0:30											0.0120825							0.0120825
0:45											0.0120825							0.0120825
1:00											0.0120825							0.0120825
1:15											0.0120825							0.0120825
1:30											0.0120825							0.0120825
1:45											0.0120825							0.0120825
2:00											0.0120825							0.0120825
2:15											0.0120825							0.0120825
2:30											0.0120825							0.0120825
2:45											0.0120825							0.0120825
3:00											0.0120825							0.0120825
3:15											0.0120825							0.0120825
3:30											0.0120825							0.0120825
3:45											0.0120825							0.0120825
4:00											0.0120825							0.0120825
4:15											0.0120825							0.0120825
4:30											0.0120825							0.0120825
4:45											0.0120825							0.0120825
5:00											0.0120825							0.0120825
5:15											0.0120825							0.0120825
5:30											0.0120825							0.0120825
5:45											0.0120825							0.0120825
6:00									0.35	1.625	0.0120825					0.06125	0.0482	2.0965325
6:15										1.625	0.0120825					0.06125	0.0482	1.7465325
6:30										1.625	0.0120825					0.06125	0.0482	1.7465325
6:45										1.625	0.0120825					0.06125	0.0482	1.7465325
7:00											0.0120825					0.06125	0.0482	0.1215325
7:15											0.0120825					0.06125	0.0482	0.1215325
7:30											0.0120825					0.06125	0.0482	0.1215325
7:45											0.0120825					0.06125	0.0482	0.1215325
8:00											0.0120825						0.0482	0.0602825
8:15											0.0120825						0.0482	0.0602825
8:30								0.9			0.0120825						0.0482	0.9602825
8:45								0.9			0.0120825						0.0482	0.9602825
9:00								0.9			0.0120825						0.0482	0.9602825
9:15								0.9			0.0120825						0.0482	0.9602825
9:30								0.9			0.0120825						0.0482	0.9602825
9:45								0.9			0.0120825						0.0482	0.9602825
10:00	0.235			0.1275	0.1275				0.35	1.625	0.0120825						0.0482	2.5252825
10:15	0.235			0.1275	0.1275					1.625	0.0120825						0.0482	2.1752825
10:30	0.235			0.1275	0.1275					1.625	0.0120825						0.0482	2.1752825
10:45	0.235			0.1275	0.1275					1.625	0.0120825						0.0482	2.1752825
11:00	0.235			0.1275	0.1275	0.3475			0.35		0.0120825					0.06125	0.0482	1.3090325
11:15	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
11:30	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
11:45	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
12:00	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
12:15	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
12:30	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
12:45	0.235			0.1275	0.1275	0.3475					0.0120825					0.06125	0.0482	0.9590325
13:00						0.3475					0.0120825						0.0482	0.4077825
13:15						0.3475					0.0120825						0.0482	0.4077825
13:30						0.3475					0.0120825						0.0482	0.4077825
13:45						0.3475					0.0120825						0.0482	0.4077825
14:00						0.3475					0.0120825							0.3595825
14:15						0.3475					0.0120825							0.3595825
14:30						0.3475					0.0120825							0.3595825
14:45						0.3475					0.0120825							0.3595825
15:00						0.3475					0.0120825							0.3595825
15:15						0.3475					0.0120825							0.3595825
15:30						0.3475					0.0120825							0.3595825
15:45						0.3475					0.0120825							0.3595825
16:00						0.3475					0.0120825							0.3595825
16:15						0.3475					0.0120825							0.3595825
16:30						0.3475					0.0120825							0.3595825
16:45						0.3475					0.0120825							0.3595825
17:00						0.3475	0.0675	0.9			0.0120825							1.3270825
17:15						0.3475	0.0675	0.9			0.0120825							1.3270825
17:30						0.3475	0.0675	0.9			0.0120825							1.3270825
17:45						0.3475	0.0675	0.9			0.0120825							1.3270825
18:00							0.0675	0.9	0.35	1.625	0.0120825					0.06125		3.0158325
18:15							0.0675	0.9		1.625	0.0120825					0.06125		2.6658325
18:30							0.0675	0.9		1.625	0.0120825					0.06125		2.6658325
18:45							0.0675	0.9		1.625	0.0120825					0.06125		2.6658325
19:00							0.0675				0.0120825					0.06125		0.1408325
19:15							0.0675				0.0120825					0.06125		0.1408325
19:30							0.0675				0.0120825					0.06125		0.1408325
19:45							0.0675				0.0120825					0.06125		0.1408325
20:00							0.0675				0.0120825	0.6	0.09375			0.06125		0.8345825
20:15							0.0675				0.0120825	0.6	0.09375			0.06125		0.8345825
20:30							0.0675				0.0120825	0.6	0.09375			0.06125		0.8345825
20:45							0.0675				0.0120825	0.6				0.06125		0.7408325
21:00							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
21:15							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
21:30							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
21:45							0.0675				0.0120825	0.6		0.4375	0.0575			1.1745825
22:00							0.0675				0.0120825	0.6						0.6795825
22:15							0.0675				0.0120825	0.6						0.6795825
22:30							0.0675				0.0120825	0.6						0.6795825
22:45							0.0675				0.0120825	0.6						0.6795825
23:00											0.0120825	0.6						0.6120825
23:15											0.0120825	0.6						0.6120825
23:30											0.0120825							0.0120825
23:45											0.0120825							0.0120825
Total Energy Usage																		65.80857

Appliance Heavy 4 Person Autumn

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00											0.0120825							0.0120825
0:15											0.0120825							0.0120825
0:30											0.0120825							0.0120825
0:45											0.0120825							0.0120825
1:00											0.0120825							0.0120825
1:15											0.0120825							0.0120825
1:30											0.0120825							0.0120825
1:45											0.0120825							0.0120825
2:00											0.0120825							0.0120825
2:15											0.0120825							0.0120825
2:30											0.0120825							0.0120825
2:45											0.0120825							0.0120825
3:00											0.0120825							0.0120825
3:15											0.0120825							0.0120825
3:30											0.0120825							0.0120825
3:45											0.0120825							0.0120825
4:00											0.0120825							0.0120825
4:15											0.0120825							0.0120825
4:30											0.0120825							0.0120825
4:45											0.0120825							0.0120825
5:00											0.0120825							0.0120825
5:15											0.0120825							0.0120825
5:30											0.0120825							0.0120825
5:45											0.0120825							0.0120825
6:00				0.1625	0.1625		0.0675		0.35	1.625	0.0120825					0.06125	0.0482	2.4890325
6:15				0.1625	0.1625		0.0675			1.625	0.0120825					0.06125	0.0482	2.1390325
6:30				0.1625	0.1625		0.0675			1.625	0.0120825					0.06125	0.0482	2.1390325
6:45				0.1625	0.1625		0.0675			1.625	0.0120825					0.06125	0.0482	2.1390325
7:00				0.1625	0.1625		0.0675				0.0120825					0.06125	0.0482	0.5140325
7:15				0.1625	0.1625		0.0675				0.0120825					0.06125	0.0482	0.5140325
7:30				0.1625	0.1625		0.0675				0.0120825					0.06125	0.0482	0.5140325
7:45				0.1625	0.1625		0.0675				0.0120825					0.06125	0.0482	0.5140325
8:00							0.0675				0.0120825						0.0482	0.1277825
8:15							0.0675				0.0120825						0.0482	0.1277825
8:30							0.0675	0.9			0.0120825						0.0482	1.0277825
8:45							0.0675	0.9			0.0120825						0.0482	1.0277825
9:00								0.9			0.0120825						0.0482	0.9602825
9:15								0.9			0.0120825						0.0482	0.9602825
9:30								0.9			0.0120825						0.0482	0.9602825
9:45								0.9			0.0120825						0.0482	0.9602825
10:00	0.235										0.0120825						0.0482	0.2952825
10:15	0.235										0.0120825						0.0482	0.2952825
10:30	0.235										0.0120825						0.0482	0.2952825
10:45	0.235										0.0120825						0.0482	0.2952825
11:00	0.235										0.0120825					0.06125	0.0482	0.3565325
11:15	0.235										0.0120825					0.06125	0.0482	0.3565325
11:30	0.235										0.0120825					0.06125	0.0482	0.3565325
11:45	0.235										0.0120825					0.06125	0.0482	0.3565325
12:00	0.235								0.35	1.625	0.0120825					0.06125	0.0482	2.3315325
12:15	0.235									1.625	0.0120825					0.06125	0.0482	1.9815325
12:30	0.235									1.625	0.0120825					0.06125	0.0482	1.9815325
12:45	0.235									1.625	0.0120825					0.06125	0.0482	1.9815325
13:00											0.0120825						0.0482	0.0602825
13:15											0.0120825						0.0482	0.0602825
13:30											0.0120825						0.0482	0.0602825
13:45											0.0120825						0.0482	0.0602825
14:00											0.0120825							0.0120825
14:15											0.0120825							0.0120825
14:30											0.0120825							0.0120825
14:45											0.0120825							0.0120825
15:00											0.0120825							0.0120825
15:15											0.0120825							0.0120825
15:30											0.0120825							0.0120825
15:45											0.0120825							0.0120825
16:00						0.3725					0.0120825							0.3845825
16:15						0.3725					0.0120825							0.3845825
16:30						0.3725					0.0120825							0.3845825
16:45						0.3725					0.0120825							0.3845825
17:00						0.3725	0.0675				0.0120825							0.4520825
17:15						0.3725	0.0675				0.0120825							0.4520825
17:30						0.3725	0.0675				0.0120825							0.4520825
17:45						0.3725	0.0675				0.0120825							0.4520825
18:00						0.3725	0.0675	0.9	0.35		0.0120825					0.06125		1.7633325
18:15						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
18:30						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
18:45						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
19:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883325
19:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883325
19:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883325
19:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883325
20:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8570825
20:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8570825
20:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8570825
20:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6				0.06125		1.7633325
21:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
21:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
21:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
21:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6		0.4375	0.0575			2.1970825
22:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3295825
22:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3295825
22:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3295825
22:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3295825
23:00											0.0120825	0.6						0.6120825
23:15											0.0120825	0.6						0.6120825
23:30											0.0120825							0.0120825
23:45											0.0120825							0.0120825
Total Energy Usage																		75.41857

Appliance Heavy 4 Person Winter

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00											0.0120825							0.0121
0:15											0.0120825							0.0121
0:30											0.0120825							0.0121
0:45											0.0120825							0.0121
1:00											0.0120825							0.0121
1:15											0.0120825							0.0121
1:30											0.0120825							0.0121
1:45											0.0120825							0.0121
2:00											0.0120825							0.0121
2:15											0.0120825							0.0121
2:30											0.0120825							0.0121
2:45											0.0120825							0.0121
3:00											0.0120825							0.0121
3:15											0.0120825							0.0121
3:30											0.0120825							0.0121
3:45											0.0120825							0.0121
4:00											0.0120825							0.0121
4:15											0.0120825							0.0121
4:30											0.0120825							0.0121
4:45											0.0120825							0.0121
5:00				0.1625	0.1625						0.0120825							0.3371
5:15				0.1625	0.1625						0.0120825							0.3371
5:30				0.1625	0.1625						0.0120825							0.3371
5:45				0.1625	0.1625						0.0120825							0.3371
6:00				0.1625	0.1625	0.3725	0.0675		0.35	1.625	0.0120825					0.06125	0.0482	2.8615
6:15				0.1625	0.1625	0.3725	0.0675			1.625	0.0120825					0.06125	0.0482	2.5115
6:30				0.1625	0.1625	0.3725	0.0675			1.625	0.0120825					0.06125	0.0482	2.5115
6:45				0.1625	0.1625	0.3725	0.0675			1.625	0.0120825					0.06125	0.0482	2.5115
7:00				0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125	0.0482	0.8865
7:15				0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125	0.0482	0.8865
7:30				0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125	0.0482	0.8865
7:45				0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125	0.0482	0.8865
8:00						0.3725	0.0675				0.0120825						0.0482	0.5003
8:15						0.3725	0.0675				0.0120825						0.0482	0.5003
8:30						0.3725	0.0675	0.9			0.0120825						0.0482	1.4003
8:45						0.3725	0.0675	0.9			0.0120825						0.0482	1.4003
9:00								0.9			0.0120825						0.0482	0.9603
9:15								0.9			0.0120825						0.0482	0.9603
9:30								0.9			0.0120825						0.0482	0.9603
9:45								0.9			0.0120825						0.0482	0.9603
10:00	0.235										0.0120825						0.0482	0.2953
10:15	0.235										0.0120825						0.0482	0.2953
10:30	0.235										0.0120825						0.0482	0.2953
10:45	0.235										0.0120825						0.0482	0.2953
11:00	0.235										0.0120825					0.06125	0.0482	0.3565
11:15	0.235										0.0120825					0.06125	0.0482	0.3565
11:30	0.235										0.0120825					0.06125	0.0482	0.3565
11:45	0.235										0.0120825					0.06125	0.0482	0.3565
12:00	0.235								0.35	1.625	0.0120825					0.06125	0.0482	2.3315
12:15	0.235									1.625	0.0120825					0.06125	0.0482	1.9815
12:30	0.235									1.625	0.0120825					0.06125	0.0482	1.9815
12:45	0.235									1.625	0.0120825					0.06125	0.0482	1.9815
13:00											0.0120825						0.0482	0.0603
13:15											0.0120825						0.0482	0.0603
13:30											0.0120825						0.0482	0.0603
13:45											0.0120825						0.0482	0.0603
14:00											0.0120825							0.0121
14:15											0.0120825							0.0121
14:30											0.0120825							0.0121
14:45											0.0120825							0.0121
15:00											0.0120825							0.0121
15:15											0.0120825							0.0121
15:30											0.0120825							0.0121
15:45											0.0120825							0.0121
16:00											0.0120825							0.0121
16:15											0.0120825							0.0121
16:30											0.0120825							0.0121
16:45											0.0120825							0.0121
17:00		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:15		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:30		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:45		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
18:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9	0.35		0.0120825					0.06125		2.4133
18:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
18:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
18:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
19:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883
19:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883
19:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883
19:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.625	0.0120825					0.06125		3.6883
20:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8571
20:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8571
20:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6	0.09375			0.06125		1.8571
20:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825	0.6				0.06125		1.7633
21:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
21:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
21:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
21:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6		0.4375	0.0575			1.8246
22:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3296
22:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3296
22:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3296
22:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825	0.6						1.3296
23:00											0.0120825							0.0121
23:15											0.0120825							0.0121
23:30											0.0120825							0.0121
23:45											0.0120825							0.0121
Total Energy Usage																		81.9386

Optimised Appliance 2 Person Summer

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00		0.1275	0.1275						0.0120825							0.2670825
0:15		0.1275	0.1275						0.0120825							0.2670825
0:30		0.1275	0.1275						0.0120825							0.2670825
0:45		0.1275	0.1275						0.0120825							0.2670825
1:00		0.1275	0.1275						0.0120825							0.2670825
1:15		0.1275	0.1275						0.0120825							0.2670825
1:30		0.1275	0.1275						0.0120825							0.2670825
1:45		0.1275	0.1275						0.0120825							0.2670825
2:00		0.1275	0.1275						0.0120825							0.2670825
2:15		0.1275	0.1275						0.0120825							0.2670825
2:30		0.1275	0.1275						0.0120825							0.2670825
2:45		0.1275	0.1275						0.0120825							0.2670825
3:00		0.1275	0.1275						0.0120825							0.2670825
3:15		0.1275	0.1275						0.0120825							0.2670825
3:30		0.1275	0.1275						0.0120825							0.2670825
3:45		0.1275	0.1275						0.0120825							0.2670825
4:00		0.1275	0.1275						0.0120825							0.2670825
4:15		0.1275	0.1275						0.0120825							0.2670825
4:30		0.1275	0.1275						0.0120825							0.2670825
4:45		0.1275	0.1275						0.0120825							0.2670825
5:00		0.1275	0.1275						0.0120825							0.2670825
5:15		0.1275	0.1275						0.0120825							0.2670825
5:30		0.1275	0.1275						0.0120825							0.2670825
5:45		0.1275	0.1275						0.0120825							0.2670825
6:00		0.1275	0.1275				0.35		0.0120825							0.6170825
6:15		0.1275	0.1275						0.0120825							0.2670825
6:30		0.1275	0.1275						0.0120825							0.2670825
6:45		0.1275	0.1275						0.0120825							0.2670825
7:00									0.0120825						0.0482	0.0602825
7:15									0.0120825						0.0482	0.0602825
7:30									0.0120825						0.0482	0.0602825
7:45									0.0120825						0.0482	0.0602825
8:00									0.0120825						0.0482	0.0602825
8:15									0.0120825						0.0482	0.0602825
8:30									0.0120825						0.0482	0.0602825
8:45									0.0120825						0.0482	0.0602825
9:00									0.0120825						0.0482	0.0602825
9:15									0.0120825						0.0482	0.0602825
9:30									0.0120825						0.0482	0.0602825
9:45									0.0120825						0.0482	0.0602825
10:00	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:15	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:30	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:45	0.235								0.0120825	0.6					0.0482	0.8952825
11:00	0.235			0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
11:15	0.235			0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
11:30	0.235			0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
11:45	0.235			0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
12:00	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
12:15	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
12:30	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
12:45	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
13:00				0.3475					0.0120825	0.6					0.0482	1.0077825
13:15				0.3475					0.0120825	0.6					0.0482	1.0077825
13:30				0.3475					0.0120825						0.0482	0.4077825
13:45				0.3475					0.0120825						0.0482	0.4077825
14:00				0.3475					0.0120825						0.0482	0.4077825
14:15				0.3475					0.0120825						0.0482	0.4077825
14:30				0.3475					0.0120825						0.0482	0.4077825
14:45				0.3475					0.0120825						0.0482	0.4077825
15:00				0.3475					0.0120825							0.3595825
15:15				0.3475					0.0120825							0.3595825
15:30				0.3475					0.0120825							0.3595825
15:45				0.3475					0.0120825							0.3595825
16:00				0.3475					0.0120825							0.3595825
16:15				0.3475					0.0120825							0.3595825
16:30				0.3475					0.0120825							0.3595825
16:45				0.3475					0.0120825							0.3595825
17:00				0.3475					0.0120825							0.3595825
17:15				0.3475					0.0120825							0.3595825
17:30				0.3475					0.0120825							0.3595825
17:45				0.3475					0.0120825							0.3595825
18:00		0.1275	0.1275		0.0585	0.9	0.35	1.025	0.0120825					0.06125		2.6618325
18:15		0.1275	0.1275		0.0585	0.9		1.025	0.0120825					0.06125		2.3118325
18:30		0.1275	0.1275		0.0585	0.9		1.025	0.0120825					0.06125		2.3118325
18:45		0.1275	0.1275		0.0585	0.9		1.025	0.0120825					0.06125		2.3118325
19:00		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:15		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:30		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
19:45		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
20:00		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
20:15		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
20:30		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
20:45		0.1275	0.1275		0.0585				0.0120825					0.06125		0.3868325
21:00		0.1275	0.1275		0.0585				0.0120825				0.0575			0.3830825
21:15		0.1275	0.1275		0.0585				0.0120825				0.0575			0.3830825
21:30		0.1275	0.1275		0.0585				0.0120825				0.0575			0.3830825
21:45		0.1275	0.1275		0.0585				0.0120825				0.0575			0.3830825
22:00		0.1275	0.1275		0.0585				0.0120825							0.3255825
22:15		0.1275	0.1275		0.0585				0.0120825							0.3255825
22:30		0.1275	0.1275		0.0585				0.0120825							0.3255825
22:45		0.1275	0.1275		0.0585				0.0120825							0.3255825
23:00		0.1275	0.1275						0.0120825							0.2670825
23:15		0.1275	0.1275						0.0120825							0.2670825
23:30		0.1275	0.1275						0.0120825							0.2670825
23:45		0.1275	0.1275						0.0120825							0.2670825
Total Energy Usage																49.47857

Optimised Appliance 2 Person Spring

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00									0.0120825							0.0120825
0:15									0.0120825							0.0120825
0:30									0.0120825							0.0120825
0:45									0.0120825							0.0120825
1:00									0.0120825							0.0120825
1:15									0.0120825							0.0120825
1:30									0.0120825							0.0120825
1:45									0.0120825							0.0120825
2:00									0.0120825							0.0120825
2:15									0.0120825							0.0120825
2:30									0.0120825							0.0120825
2:45									0.0120825							0.0120825
3:00									0.0120825							0.0120825
3:15									0.0120825							0.0120825
3:30									0.0120825							0.0120825
3:45									0.0120825							0.0120825
4:00									0.0120825							0.0120825
4:15									0.0120825							0.0120825
4:30									0.0120825							0.0120825
4:45									0.0120825							0.0120825
5:00									0.0120825							0.0120825
5:15									0.0120825							0.0120825
5:30									0.0120825							0.0120825
5:45									0.0120825							0.0120825
6:00							0.35	1.025	0.0120825							1.3870825
6:15								1.025	0.0120825							1.0370825
6:30								1.025	0.0120825							1.0370825
6:45								1.025	0.0120825							1.0370825
7:00									0.0120825						0.0482	0.0602825
7:15									0.0120825						0.0482	0.0602825
7:30									0.0120825						0.0482	0.0602825
7:45									0.0120825						0.0482	0.0602825
8:00									0.0120825						0.0482	0.0602825
8:15									0.0120825						0.0482	0.0602825
8:30									0.0120825						0.0482	0.0602825
8:45									0.0120825						0.0482	0.0602825
9:00									0.0120825						0.0482	0.0602825
9:15									0.0120825						0.0482	0.0602825
9:30									0.0120825						0.0482	0.0602825
9:45									0.0120825						0.0482	0.0602825
10:00	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:15	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:30	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:45	0.235								0.0120825	0.6					0.0482	0.8952825
11:00	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
11:15	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
11:30	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
11:45	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
12:00	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
12:15	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
12:30	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
12:45	0.235			0.3475					0.0120825	0.6					0.0482	1.2427825
13:00				0.3475					0.0120825	0.6					0.0482	1.0077825
13:15				0.3475					0.0120825	0.6					0.0482	1.0077825
13:30				0.3475					0.0120825						0.0482	0.4077825
13:45				0.3475					0.0120825						0.0482	0.4077825
14:00				0.3475					0.0120825						0.0482	0.4077825
14:15				0.3475					0.0120825						0.0482	0.4077825
14:30				0.3475					0.0120825						0.0482	0.4077825
14:45				0.3475					0.0120825						0.0482	0.4077825
15:00				0.3475					0.0120825							0.3595825
15:15				0.3475					0.0120825							0.3595825
15:30				0.3475					0.0120825							0.3595825
15:45				0.3475					0.0120825							0.3595825
16:00				0.3475					0.0120825							0.3595825
16:15				0.3475					0.0120825							0.3595825
16:30				0.3475					0.0120825							0.3595825
16:45				0.3475					0.0120825							0.3595825
17:00				0.3475	0.0585				0.0120825							0.4180825
17:15				0.3475	0.0585				0.0120825							0.4180825
17:30				0.3475	0.0585				0.0120825							0.4180825
17:45				0.3475	0.0585				0.0120825							0.4180825
18:00					0.0585	0.9	0.35	1.025	0.0120825					0.06125		2.4068325
18:15					0.0585	0.9		1.025	0.0120825					0.06125		2.0568325
18:30					0.0585	0.9		1.025	0.0120825					0.06125		2.0568325
18:45					0.0585	0.9		1.025	0.0120825					0.06125		2.0568325
19:00					0.0585				0.0120825					0.06125		0.1318325
19:15					0.0585				0.0120825					0.06125		0.1318325
19:30					0.0585				0.0120825					0.06125		0.1318325
19:45					0.0585				0.0120825					0.06125		0.1318325
20:00					0.0585				0.0120825					0.06125		0.1318325
20:15					0.0585				0.0120825					0.06125		0.1318325
20:30					0.0585				0.0120825					0.06125		0.1318325
20:45					0.0585				0.0120825					0.06125		0.1318325
21:00					0.0585				0.0120825				0.0575			0.1280825
21:15					0.0585				0.0120825				0.0575			0.1280825
21:30					0.0585				0.0120825				0.0575			0.1280825
21:45					0.0585				0.0120825				0.0575			0.1280825
22:00					0.0585				0.0120825							0.0705825
22:15					0.0585				0.0120825							0.0705825
22:30					0.0585				0.0120825							0.0705825
22:45					0.0585				0.0120825							0.0705825
23:00									0.0120825							0.0120825
23:15									0.0120825							0.0120825
23:30									0.0120825							0.0120825
23:45									0.0120825							0.0120825
Total Energy Usage																39.16257

Optimised Appliance 2 Person Autumn

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00									0.0120825							0.0120825
0:15									0.0120825							0.0120825
0:30									0.0120825							0.0120825
0:45									0.0120825							0.0120825
1:00									0.0120825							0.0120825
1:15									0.0120825							0.0120825
1:30									0.0120825							0.0120825
1:45									0.0120825							0.0120825
2:00									0.0120825							0.0120825
2:15									0.0120825							0.0120825
2:30									0.0120825							0.0120825
2:45									0.0120825							0.0120825
3:00									0.0120825							0.0120825
3:15									0.0120825							0.0120825
3:30									0.0120825							0.0120825
3:45									0.0120825							0.0120825
4:00									0.0120825							0.0120825
4:15									0.0120825							0.0120825
4:30									0.0120825							0.0120825
4:45									0.0120825							0.0120825
5:00									0.0120825							0.0120825
5:15									0.0120825							0.0120825
5:30									0.0120825							0.0120825
5:45									0.0120825							0.0120825
6:00							0.35	1.025	0.0120825							1.3870825
6:15					0.0585			1.025	0.0120825							1.0955825
6:30					0.0585			1.025	0.0120825							1.0955825
6:45					0.0585			1.025	0.0120825							1.0955825
7:00					0.0585				0.0120825						0.0482	0.1187825
7:15					0.0585				0.0120825						0.0482	0.1187825
7:30					0.0585				0.0120825						0.0482	0.1187825
7:45					0.0585				0.0120825						0.0482	0.1187825
8:00					0.0585				0.0120825						0.0482	0.1187825
8:15					0.0585				0.0120825						0.0482	0.1187825
8:30					0.0585				0.0120825						0.0482	0.1187825
8:45					0.0585				0.0120825						0.0482	0.1187825
9:00									0.0120825						0.0482	0.0602825
9:15									0.0120825						0.0482	0.0602825
9:30									0.0120825						0.0482	0.0602825
9:45									0.0120825						0.0482	0.0602825
10:00	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:15	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:30	0.235								0.0120825	0.6	0.09375				0.0482	0.9890325
10:45	0.235								0.0120825	0.6					0.0482	0.8952825
11:00	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
11:15	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
11:30	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
11:45	0.235								0.0120825	0.6		0.4375			0.0482	1.3327825
12:00	0.235								0.0120825	0.6					0.0482	0.8952825
12:15	0.235								0.0120825	0.6					0.0482	0.8952825
12:30	0.235								0.0120825	0.6					0.0482	0.8952825
12:45	0.235								0.0120825	0.6					0.0482	0.8952825
13:00									0.0120825	0.6					0.0482	0.6602825
13:15									0.0120825	0.6					0.0482	0.6602825
13:30									0.0120825						0.0482	0.0602825
13:45									0.0120825						0.0482	0.0602825
14:00									0.0120825						0.0482	0.0602825
14:15									0.0120825						0.0482	0.0602825
14:30									0.0120825						0.0482	0.0602825
14:45									0.0120825						0.0482	0.0602825
15:00									0.0120825							0.0120825
15:15									0.0120825							0.0120825
15:30									0.0120825							0.0120825
15:45									0.0120825							0.0120825
16:00				0.3725					0.0120825							0.3845825
16:15				0.3725					0.0120825							0.3845825
16:30				0.3725					0.0120825							0.3845825
16:45				0.3725					0.0120825							0.3845825
17:00				0.3725	0.0585				0.0120825							0.4430825
17:15				0.3725	0.0585				0.0120825							0.4430825
17:30				0.3725	0.0585				0.0120825							0.4430825
17:45				0.3725	0.0585				0.0120825							0.4430825
18:00				0.3725	0.0585	0.9	0.35	1.025	0.0120825					0.06125		2.7793325
18:15				0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.4293325
18:30				0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.4293325
18:45				0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.4293325
19:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
19:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
20:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
20:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
20:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
20:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293325
21:00		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4530825
21:15		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4530825
21:30		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4530825
21:45		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4530825
22:00		0.1625	0.1625		0.0585				0.0120825							0.3955825
22:15		0.1625	0.1625		0.0585				0.0120825							0.3955825
22:30		0.1625	0.1625		0.0585				0.0120825							0.3955825
22:45		0.1625	0.1625		0.0585				0.0120825							0.3955825
23:00									0.0120825							0.0120825
23:15									0.0120825							0.0120825
23:30									0.0120825							0.0120825
23:45									0.0120825							0.0120825
Total Energy Usage																44.11607

Optimised Appliance 2 Person Winter

	Consumption															
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00									0.0120825							0.0121
0:15									0.0120825							0.0121
0:30									0.0120825							0.0121
0:45									0.0120825							0.0121
1:00									0.0120825							0.0121
1:15									0.0120825							0.0121
1:30									0.0120825							0.0121
1:45									0.0120825							0.0121
2:00									0.0120825							0.0121
2:15									0.0120825							0.0121
2:30									0.0120825							0.0121
2:45									0.0120825							0.0121
3:00									0.0120825							0.0121
3:15									0.0120825							0.0121
3:30									0.0120825							0.0121
3:45									0.0120825							0.0121
4:00									0.0120825							0.0121
4:15									0.0120825							0.0121
4:30									0.0120825							0.0121
4:45									0.0120825							0.0121
5:00									0.0120825							0.0121
5:15									0.0120825							0.0121
5:30									0.0120825							0.0121
5:45									0.0120825							0.0121
6:00				0.3725	0.0585		0.35	1.025	0.0120825							1.8181
6:15				0.3725	0.0585			1.025	0.0120825							1.4681
6:30				0.3725	0.0585			1.025	0.0120825							1.4681
6:45				0.3725	0.0585			1.025	0.0120825							1.4681
7:00				0.3725	0.0585				0.0120825						0.0482	0.4913
7:15				0.3725	0.0585				0.0120825						0.0482	0.4913
7:30				0.3725	0.0585				0.0120825						0.0482	0.4913
7:45				0.3725	0.0585				0.0120825						0.0482	0.4913
8:00				0.3725	0.0585				0.0120825						0.0482	0.4913
8:15				0.3725	0.0585				0.0120825						0.0482	0.4913
8:30				0.3725	0.0585				0.0120825						0.0482	0.4913
8:45				0.3725	0.0585				0.0120825						0.0482	0.4913
9:00									0.0120825						0.0482	0.0603
9:15									0.0120825						0.0482	0.0603
9:30									0.0120825						0.0482	0.0603
9:45									0.0120825						0.0482	0.0603
10:00	0.235								0.0120825	0.6	0.09375				0.0482	0.9890
10:15	0.235								0.0120825	0.6	0.09375				0.0482	0.9890
10:30	0.235								0.0120825	0.6	0.09375				0.0482	0.9890
10:45	0.235								0.0120825	0.6					0.0482	0.8953
11:00	0.235								0.0120825	0.6		0.4375			0.0482	1.3328
11:15	0.235								0.0120825	0.6		0.4375			0.0482	1.3328
11:30	0.235								0.0120825	0.6		0.4375			0.0482	1.3328
11:45	0.235								0.0120825	0.6		0.4375			0.0482	1.3328
12:00	0.235								0.0120825	0.6					0.0482	0.8953
12:15	0.235								0.0120825	0.6					0.0482	0.8953
12:30	0.235								0.0120825	0.6					0.0482	0.8953
12:45	0.235								0.0120825	0.6					0.0482	0.8953
13:00									0.0120825	0.6					0.0482	0.6603
13:15									0.0120825	0.6					0.0482	0.6603
13:30									0.0120825						0.0482	0.0603
13:45									0.0120825						0.0482	0.0603
14:00									0.0120825						0.0482	0.0603
14:15									0.0120825						0.0482	0.0603
14:30									0.0120825						0.0482	0.0603
14:45									0.0120825						0.0482	0.0603
15:00									0.0120825							0.0121
15:15									0.0120825							0.0121
15:30									0.0120825							0.0121
15:45									0.0120825							0.0121
16:00									0.0120825							0.0121
16:15									0.0120825							0.0121
16:30									0.0120825							0.0121
16:45									0.0120825							0.0121
17:00		0.1625	0.1625	0.3725					0.0120825							0.7096
17:15		0.1625	0.1625	0.3725					0.0120825							0.7096
17:30		0.1625	0.1625	0.3725					0.0120825							0.7096
17:45		0.1625	0.1625	0.3725					0.0120825							0.7096
18:00		0.1625	0.1625	0.3725	0.0585	0.9	0.35	1.025	0.0120825					0.06125		3.1043
18:15		0.1625	0.1625	0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.7543
18:30		0.1625	0.1625	0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.7543
18:45		0.1625	0.1625	0.3725	0.0585	0.9		1.025	0.0120825					0.06125		2.7543
19:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
19:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
20:00		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
20:15		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
20:30		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
20:45		0.1625	0.1625	0.3725	0.0585				0.0120825					0.06125		0.8293
21:00		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4531
21:15		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4531
21:30		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4531
21:45		0.1625	0.1625		0.0585				0.0120825				0.0575			0.4531
22:00		0.1625	0.1625		0.0585				0.0120825							0.3956
22:15		0.1625	0.1625		0.0585				0.0120825							0.3956
22:30		0.1625	0.1625		0.0585				0.0120825							0.3956
22:45		0.1625	0.1625		0.0585				0.0120825							0.3956
23:00									0.0120825							0.0121
23:15									0.0120825							0.0121
23:30									0.0120825							0.0121
23:45									0.0120825							0.0121
Total Energy Usage																49.5206

Optimised Appliance 4 Person Summer

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
0:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
0:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
0:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
1:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
2:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
3:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
4:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
5:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
6:00		0.1275	0.1275	0.1275	0.1275				0.35		0.0120825							0.8720825
6:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
6:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
6:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
7:00											0.0120825						0.0482	0.0602825
7:15											0.0120825						0.0482	0.0602825
7:30											0.0120825						0.0482	0.0602825
7:45											0.0120825						0.0482	0.0602825
8:00											0.0120825						0.0482	0.0602825
8:15											0.0120825						0.0482	0.0602825
8:30											0.0120825						0.0482	0.0602825
8:45											0.0120825						0.0482	0.0602825
9:00											0.0120825						0.0482	0.0602825
9:15											0.0120825						0.0482	0.0602825
9:30											0.0120825						0.0482	0.0602825
9:45											0.0120825						0.0482	0.0602825
10:00	0.235										0.0120825	0.6	0.09375				0.0482	0.9890325
10:15	0.235										0.0120825	0.6	0.09375				0.0482	0.9890325
10:30	0.235										0.0120825	0.6	0.09375				0.0482	0.9890325
10:45	0.235										0.0120825	0.6					0.0482	0.8952825
11:00	0.235					0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
11:15	0.235					0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
11:30	0.235					0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
11:45	0.235					0.3475					0.0120825	0.6		0.4375			0.0482	1.6802825
12:00	0.235					0.3475			0.35	1.025	0.0120825	0.6					0.0482	2.6177825
12:15	0.235					0.3475				1.025	0.0120825	0.6					0.0482	2.2677825
12:30	0.235					0.3475				1.025	0.0120825	0.6					0.0482	2.2677825
12:45	0.235					0.3475				1.025	0.0120825	0.6					0.0482	2.2677825
13:00						0.3475					0.0120825	0.6					0.0482	1.0077825
13:15						0.3475					0.0120825	0.6					0.0482	1.0077825
13:30						0.3475					0.0120825						0.0482	0.4077825
13:45						0.3475					0.0120825						0.0482	0.4077825
14:00						0.3475					0.0120825						0.0482	0.4077825
14:15						0.3475					0.0120825						0.0482	0.4077825
14:30						0.3475					0.0120825						0.0482	0.4077825
14:45						0.3475					0.0120825						0.0482	0.4077825
15:00						0.3475					0.0120825							0.3595825
15:15						0.3475					0.0120825							0.3595825
15:30						0.3475					0.0120825							0.3595825
15:45						0.3475					0.0120825							0.3595825
16:00						0.3475					0.0120825							0.3595825
16:15						0.3475					0.0120825							0.3595825
16:30						0.3475					0.0120825							0.3595825
16:45						0.3475					0.0120825							0.3595825
17:00						0.3475					0.0120825							0.3595825
17:15						0.3475					0.0120825							0.3595825
17:30						0.3475					0.0120825							0.3595825
17:45						0.3475					0.0120825							0.3595825
18:00		0.1275	0.1275	0.1275	0.1275		0.0675	0.9	0.35		0.0120825					0.06125		1.9008325
18:15		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
18:30		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
18:45		0.1275	0.1275	0.1275	0.1275		0.0675	0.9			0.0120825					0.06125		1.5508325
19:00		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
19:15		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
19:30		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
19:45		0.1275	0.1275	0.1275	0.1275		0.0675	0.9		1.025	0.0120825					0.06125		2.5758325
20:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825					0.06125		0.6508325
20:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825					0.06125		0.6508325
20:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825					0.06125		0.6508325
20:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825					0.06125		0.6508325
21:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825				0.0575			0.6470825
21:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825				0.0575			0.6470825
21:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825				0.0575			0.6470825
21:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825				0.0575			0.6470825
22:00		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825							0.5895825
22:15		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825							0.5895825
22:30		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825							0.5895825
22:45		0.1275	0.1275	0.1275	0.1275		0.0675				0.0120825							0.5895825
23:00		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
23:15		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
23:30		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
23:45		0.1275	0.1275	0.1275	0.1275						0.0120825							0.5220825
Total Energy Usage																		70.96857

Optimised Appliance 4 Person Spring

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00											0.0120825							0.0120825
0:15											0.0120825							0.0120825
0:30											0.0120825							0.0120825
0:45											0.0120825							0.0120825
1:00											0.0120825							0.0120825
1:15											0.0120825							0.0120825
1:30											0.0120825							0.0120825
1:45											0.0120825							0.0120825
2:00											0.0120825							0.0120825
2:15											0.0120825							0.0120825
2:30											0.0120825							0.0120825
2:45											0.0120825							0.0120825
3:00											0.0120825							0.0120825
3:15											0.0120825							0.0120825
3:30											0.0120825							0.0120825
3:45											0.0120825							0.0120825
4:00											0.0120825							0.0120825
4:15											0.0120825							0.0120825
4:30											0.0120825							0.0120825
4:45											0.0120825							0.0120825
5:00											0.0120825							0.0120825
5:15											0.0120825							0.0120825
5:30											0.0120825							0.0120825
5:45											0.0120825							0.0120825
6:00									0.35	1.025	0.0120825							1.3870825
6:15										1.025	0.0120825							1.0370825
6:30										1.025	0.0120825							1.0370825
6:45										1.025	0.0120825							1.0370825
7:00											0.0120825						0.0482	0.0602825
7:15											0.0120825						0.0482	0.0602825
7:30											0.0120825						0.0482	0.0602825
7:45											0.0120825						0.0482	0.0602825
8:00											0.0120825						0.0482	0.0602825
8:15											0.0120825						0.0482	0.0602825
8:30											0.0120825						0.0482	0.0602825
8:45											0.0120825						0.0482	0.0602825
9:00											0.0120825						0.0482	0.0602825
9:15											0.0120825						0.0482	0.0602825
9:30											0.0120825						0.0482	0.0602825
9:45											0.0120825						0.0482	0.0602825
10:00	0.235			0.1275	0.1275				0.35	1.025	0.0120825	0.6	0.09375				0.0482	2.6190325
10:15	0.235			0.1275	0.1275					1.025	0.0120825	0.6	0.09375				0.0482	2.2690325
10:30	0.235			0.1275	0.1275					1.025	0.0120825	0.6	0.09375				0.0482	2.2690325
10:45	0.235			0.1275	0.1275					1.025	0.0120825	0.6					0.0482	2.1752825
11:00	0.235			0.1275	0.1275	0.3475			0.35		0.0120825	0.6		0.4375			0.0482	2.2852825
11:15	0.235			0.1275	0.1275	0.3475					0.0120825	0.6		0.4375			0.0482	1.9352825
11:30	0.235			0.1275	0.1275	0.3475					0.0120825	0.6		0.4375			0.0482	1.9352825
11:45	0.235			0.1275	0.1275	0.3475					0.0120825	0.6		0.4375			0.0482	1.9352825
12:00	0.235			0.1275	0.1275	0.3475					0.0120825	0.6					0.0482	1.4977825
12:15	0.235			0.1275	0.1275	0.3475					0.0120825	0.6					0.0482	1.4977825
12:30	0.235			0.1275	0.1275	0.3475					0.0120825	0.6					0.0482	1.4977825
12:45	0.235			0.1275	0.1275	0.3475					0.0120825	0.6					0.0482	1.4977825
13:00						0.3475					0.0120825	0.6					0.0482	1.0077825
13:15						0.3475					0.0120825	0.6					0.0482	1.0077825
13:30						0.3475					0.0120825						0.0482	0.4077825
13:45						0.3475					0.0120825						0.0482	0.4077825
14:00						0.3475					0.0120825						0.0482	0.4077825
14:15						0.3475					0.0120825						0.0482	0.4077825
14:30						0.3475					0.0120825						0.0482	0.4077825
14:45						0.3475					0.0120825						0.0482	0.4077825
15:00						0.3475					0.0120825							0.3595825
15:15						0.3475					0.0120825							0.3595825
15:30						0.3475					0.0120825							0.3595825
15:45						0.3475					0.0120825							0.3595825
16:00						0.3475					0.0120825							0.3595825
16:15						0.3475					0.0120825							0.3595825
16:30						0.3475					0.0120825							0.3595825
16:45						0.3475					0.0120825							0.3595825
17:00						0.3475	0.0675	0.9			0.0120825							1.3270825
17:15						0.3475	0.0675	0.9			0.0120825							1.3270825
17:30						0.3475	0.0675	0.9			0.0120825							1.3270825
17:45						0.3475	0.0675	0.9			0.0120825							1.3270825
18:00							0.0675	0.9	0.35	1.025	0.0120825					0.06125		2.4158325
18:15							0.0675	0.9		1.025	0.0120825					0.06125		2.0658325
18:30							0.0675	0.9		1.025	0.0120825					0.06125		2.0658325
18:45							0.0675	0.9		1.025	0.0120825					0.06125		2.0658325
19:00							0.0675				0.0120825					0.06125		0.1408325
19:15							0.0675				0.0120825					0.06125		0.1408325
19:30							0.0675				0.0120825					0.06125		0.1408325
19:45							0.0675				0.0120825					0.06125		0.1408325
20:00							0.0675				0.0120825					0.06125		0.1408325
20:15							0.0675				0.0120825					0.06125		0.1408325
20:30							0.0675				0.0120825					0.06125		0.1408325
20:45							0.0675				0.0120825					0.06125		0.1408325
21:00							0.0675				0.0120825				0.0575			0.1370825
21:15							0.0675				0.0120825				0.0575			0.1370825
21:30							0.0675				0.0120825				0.0575			0.1370825
21:45							0.0675				0.0120825				0.0575			0.1370825
22:00							0.0675				0.0120825							0.0795825
22:15							0.0675				0.0120825							0.0795825
22:30							0.0675				0.0120825							0.0795825
22:45							0.0675				0.0120825							0.0795825
23:00											0.0120825							0.0120825
23:15											0.0120825							0.0120825
23:30											0.0120825							0.0120825
23:45											0.0120825							0.0120825
Total Energy Usage																		52.22857

Optimised Appliance 4 Person Autumn

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00											0.0120825							0.0120825
0:15											0.0120825							0.0120825
0:30											0.0120825							0.0120825
0:45											0.0120825							0.0120825
1:00											0.0120825							0.0120825
1:15											0.0120825							0.0120825
1:30											0.0120825							0.0120825
1:45											0.0120825							0.0120825
2:00											0.0120825							0.0120825
2:15											0.0120825							0.0120825
2:30											0.0120825							0.0120825
2:45											0.0120825							0.0120825
3:00											0.0120825							0.0120825
3:15											0.0120825							0.0120825
3:30											0.0120825							0.0120825
3:45											0.0120825							0.0120825
4:00											0.0120825							0.0120825
4:15											0.0120825							0.0120825
4:30											0.0120825							0.0120825
4:45											0.0120825							0.0120825
5:00											0.0120825							0.0120825
5:15											0.0120825							0.0120825
5:30											0.0120825							0.0120825
5:45											0.0120825							0.0120825
6:00				0.1625	0.1625		0.0675		0.35	1.025	0.0120825							1.7795825
6:15				0.1625	0.1625		0.0675			1.025	0.0120825							1.4295825
6:30				0.1625	0.1625		0.0675			1.025	0.0120825							1.4295825
6:45				0.1625	0.1625		0.0675			1.025	0.0120825							1.4295825
7:00				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
7:15				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
7:30				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
7:45				0.1625	0.1625		0.0675				0.0120825						0.0482	0.4527825
8:00							0.0675				0.0120825						0.0482	0.1277825
8:15							0.0675				0.0120825						0.0482	0.1277825
8:30							0.0675				0.0120825						0.0482	0.1277825
8:45							0.0675				0.0120825						0.0482	0.1277825
9:00											0.0120825						0.0482	0.0602825
9:15											0.0120825						0.0482	0.0602825
9:30											0.0120825						0.0482	0.0602825
9:45											0.0120825						0.0482	0.0602825
10:00	0.235										0.0120825	0.6	0.09375				0.0482	0.9890325
10:15	0.235										0.0120825	0.6	0.09375				0.0482	0.9890325
10:30	0.235										0.0120825	0.6	0.09375				0.0482	0.9890325
10:45	0.235										0.0120825	0.6					0.0482	0.8952825
11:00	0.235										0.0120825	0.6		0.4375			0.0482	1.3327825
11:15	0.235										0.0120825	0.6		0.4375			0.0482	1.3327825
11:30	0.235										0.0120825	0.6		0.4375			0.0482	1.3327825
11:45	0.235										0.0120825	0.6		0.4375			0.0482	1.3327825
12:00	0.235								0.35	1.025	0.0120825	0.6					0.0482	2.2702825
12:15	0.235									1.025	0.0120825	0.6					0.0482	1.9202825
12:30	0.235									1.025	0.0120825	0.6					0.0482	1.9202825
12:45	0.235									1.025	0.0120825	0.6					0.0482	1.9202825
13:00											0.0120825	0.6					0.0482	0.6602825
13:15											0.0120825	0.6					0.0482	0.6602825
13:30											0.0120825						0.0482	0.0602825
13:45											0.0120825						0.0482	0.0602825
14:00											0.0120825						0.0482	0.0602825
14:15											0.0120825						0.0482	0.0602825
14:30											0.0120825						0.0482	0.0602825
14:45											0.0120825						0.0482	0.0602825
15:00											0.0120825							0.0120825
15:15											0.0120825							0.0120825
15:30											0.0120825							0.0120825
15:45											0.0120825							0.0120825
16:00						0.3725					0.0120825							0.3845825
16:15						0.3725					0.0120825							0.3845825
16:30						0.3725					0.0120825							0.3845825
16:45						0.3725					0.0120825							0.3845825
17:00						0.3725	0.0675				0.0120825							0.4520825
17:15						0.3725	0.0675				0.0120825							0.4520825
17:30						0.3725	0.0675				0.0120825							0.4520825
17:45						0.3725	0.0675				0.0120825							0.4520825
18:00						0.3725	0.0675	0.9	0.35		0.0120825					0.06125		1.7633325
18:15						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
18:30						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
18:45						0.3725	0.0675	0.9			0.0120825					0.06125		1.4133325
19:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
19:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
19:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
19:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883325
20:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633325
20:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633325
20:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633325
20:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633325
21:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825				0.0575			1.1595825
21:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825				0.0575			1.1595825
21:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825				0.0575			1.1595825
21:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825				0.0575			1.1595825
22:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7295825
22:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7295825
22:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7295825
22:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7295825
23:00											0.0120825							0.0120825
23:15											0.0120825							0.0120825
23:30											0.0120825							0.0120825
23:45											0.0120825							0.0120825
Total Energy Usage																		61.83857

Optimised Appliance 4 Person Winter

	Consumption																	
Hour	HWS	HVAC (Bedroom 1)	HVAC (Bedroom 2)	HVAC (Bedroom 3)	HVAC (Bedroom 4)	HVAC (Living)	Downlight (LED)	Oven	Microwave	Cooktop	Refrigerator	Dishwasher	Washing Machine	Clothes Dryer	Computer	Television	Pool Pump	Total
0:00											0.0120825							0.0121
0:15											0.0120825							0.0121
0:30											0.0120825							0.0121
0:45											0.0120825							0.0121
1:00											0.0120825							0.0121
1:15											0.0120825							0.0121
1:30											0.0120825							0.0121
1:45											0.0120825							0.0121
2:00											0.0120825							0.0121
2:15											0.0120825							0.0121
2:30											0.0120825							0.0121
2:45											0.0120825							0.0121
3:00											0.0120825							0.0121
3:15											0.0120825							0.0121
3:30											0.0120825							0.0121
3:45											0.0120825							0.0121
4:00											0.0120825							0.0121
4:15											0.0120825							0.0121
4:30											0.0120825							0.0121
4:45											0.0120825							0.0121
5:00				0.1625	0.1625						0.0120825							0.3371
5:15				0.1625	0.1625						0.0120825							0.3371
5:30				0.1625	0.1625						0.0120825							0.3371
5:45				0.1625	0.1625						0.0120825							0.3371
6:00				0.1625	0.1625	0.3725	0.0675		0.35	1.025	0.0120825							2.1521
6:15				0.1625	0.1625	0.3725	0.0675			1.025	0.0120825							1.8021
6:30				0.1625	0.1625	0.3725	0.0675			1.025	0.0120825							1.8021
6:45				0.1625	0.1625	0.3725	0.0675			1.025	0.0120825							1.8021
7:00				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
7:15				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
7:30				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
7:45				0.1625	0.1625	0.3725	0.0675				0.0120825						0.0482	0.8253
8:00						0.3725	0.0675				0.0120825						0.0482	0.5003
8:15						0.3725	0.0675				0.0120825						0.0482	0.5003
8:30						0.3725	0.0675				0.0120825						0.0482	0.5003
8:45						0.3725	0.0675				0.0120825						0.0482	0.5003
9:00											0.0120825						0.0482	0.0603
9:15											0.0120825						0.0482	0.0603
9:30											0.0120825						0.0482	0.0603
9:45											0.0120825						0.0482	0.0603
10:00	0.235										0.0120825	0.6	0.09375				0.0482	0.9890
10:15	0.235										0.0120825	0.6	0.09375				0.0482	0.9890
10:30	0.235										0.0120825	0.6	0.09375				0.0482	0.9890
10:45	0.235										0.0120825	0.6					0.0482	0.8953
11:00	0.235										0.0120825	0.6		0.4375			0.0482	1.3328
11:15	0.235										0.0120825	0.6		0.4375			0.0482	1.3328
11:30	0.235										0.0120825	0.6		0.4375			0.0482	1.3328
11:45	0.235										0.0120825	0.6		0.4375			0.0482	1.3328
12:00	0.235								0.35	1.025	0.0120825	0.6					0.0482	2.2703
12:15	0.235									1.025	0.0120825	0.6					0.0482	1.9203
12:30	0.235									1.025	0.0120825	0.6					0.0482	1.9203
12:45	0.235									1.025	0.0120825	0.6					0.0482	1.9203
13:00											0.0120825	0.6					0.0482	0.6603
13:15											0.0120825	0.6					0.0482	0.6603
13:30											0.0120825						0.0482	0.0603
13:45											0.0120825						0.0482	0.0603
14:00											0.0120825						0.0482	0.0603
14:15											0.0120825						0.0482	0.0603
14:30											0.0120825						0.0482	0.0603
14:45											0.0120825						0.0482	0.0603
15:00											0.0120825							0.0121
15:15											0.0120825							0.0121
15:30											0.0120825							0.0121
15:45											0.0120825							0.0121
16:00											0.0120825							0.0121
16:15											0.0120825							0.0121
16:30											0.0120825							0.0121
16:45											0.0120825							0.0121
17:00		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:15		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:30		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
17:45		0.1625	0.1625	0.1625	0.1625	0.3725					0.0120825							1.0346
18:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9	0.35		0.0120825					0.06125		2.4133
18:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
18:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
18:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9			0.0120825					0.06125		2.0633
19:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
19:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
19:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
19:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675	0.9		1.025	0.0120825					0.06125		3.0883
20:00		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633
20:15		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633
20:30		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633
20:45		0.1625	0.1625	0.1625	0.1625	0.3725	0.0675				0.0120825					0.06125		1.1633
21:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825				0.0575			0.7871
21:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825				0.0575			0.7871
21:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825				0.0575			0.7871
21:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825				0.0575			0.7871
22:00		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7296
22:15		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7296
22:30		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7296
22:45		0.1625	0.1625	0.1625	0.1625		0.0675				0.0120825							0.7296
23:00											0.0120825							0.0121
23:15											0.0120825							0.0121
23:30											0.0120825							0.0121
23:45											0.0120825							0.0121
Total Energy Usage																		69.5586

Solar Yield Patterns

Summer

Seconds	Output	Hour
0	0	0:00
900	0	0:15
1800	0	0:30
2700	0	0:45
3600	0	1:00
4500	0	1:15
5400	0	1:30
6300	0	1:45
7200	0	2:00
8100	0	2:15
9000	0	2:30
9900	0	2:45
10800	0	3:00
11700	0	3:15
12600	0	3:30
13500	0	3:45
14400	0	4:00
15300	0	4:15
16200	0	4:30
17100	0	4:45
18000	0	5:00
18900	58	5:15
19800	274	5:30
20700	611	5:45
21600	995	6:00
22500	1175	6:15
23400	1231	6:30
24300	2388	6:45
25200	3033	7:00
26100	3967	7:15
27000	4783	7:30
27900	5583	7:45
28800	6324	8:00
29700	7083	8:15
30600	7721	8:30
31500	8315	8:45
32400	9052	9:00
33300	9405	9:15
34200	9973	9:30
35100	10301	9:45
36000	10816	10:00
36900	11257	10:15
37800	11498	10:30
38700	11872	10:45
39600	11997	11:00
40500	12170	11:15
41400	12453	11:30
42300	12296	11:45
43200	12368	12:00
44100	12133	12:15
45000	12094	12:30
45900	12075	12:45
46800	11781	13:00
47700	11657	13:15
48600	11180	13:30
49500	10998	13:45
50400	10748	14:00
51300	10240	14:15
52200	9838	14:30
53100	9072	14:45
54000	8738	15:00
54900	8054	15:15
55800	7407	15:30
56700	6761	15:45
57600	5945	16:00
58500	5228	16:15
59400	4403	16:30
60300	3674	16:45
61200	3034	17:00
62100	2413	17:15
63000	2017	17:30
63900	1637	17:45
64800	1212	18:00
65700	397	18:15
66600	118	18:30
67500	1	18:45
68400	0	19:00
69300	0	19:15
70200	0	19:30
71100	0	19:45
72000	0	20:00
72900	0	20:15
73800	0	20:30
74700	0	20:45
75600	0	21:00
76500	0	21:15
77400	0	21:30
78300	0	21:45
79200	0	22:00
80100	0	22:15
81000	0	22:30
81900	0	22:45
82800	0	23:00
83700	0	23:15
84600	0	23:30
85500	0	23:45
86400	0	0:00

Spring

Seconds	Output	Hour
0	0	0:00
900	0	0:15
1800	0	0:30
2700	0	0:45
3600	0	1:00
4500	0	1:15
5400	0	1:30
6300	0	1:45
7200	0	2:00
8100	0	2:15
9000	0	2:30
9900	0	2:45
10800	0	3:00
11700	0	3:15
12600	0	3:30
13500	0	3:45
14400	0	4:00
15300	0	4:15
16200	0	4:30
17100	0	4:45
18000	0	5:00
18900	212	5:15
19800	582	5:30
20700	911	5:45
21600	728	6:00
22500	838	6:15
23400	2345	6:30
24300	3088	6:45
25200	3945	7:00
26100	4782	7:15
27000	5492	7:30
27900	6354	7:45
28800	7064	8:00
29700	7798	8:15
30600	8402	8:30
31500	9074	8:45
32400	9659	9:00
33300	10059	9:15
34200	10694	9:30
35100	11290	9:45
36000	11645	10:00
36900	12017	10:15
37800	11984	10:30
38700	12416	10:45
39600	12541	11:00
40500	12546	11:15
41400	12694	11:30
42300	12526	11:45
43200	12645	12:00
44100	12619	12:15
45000	12339	12:30
45900	12266	12:45
46800	11954	13:00
47700	11493	13:15
48600	11521	13:30
49500	10935	13:45
50400	10692	14:00
51300	10048	14:15
52200	9312	14:30
53100	9051	14:45
54000	8357	15:00
54900	7853	15:15
55800	6929	15:30
56700	5919	15:45
57600	5513	16:00
58500	4008	16:15
59400	3931	16:30
60300	2937	16:45
61200	1466	17:00
62100	2437	17:15
63000	493	17:30
63900	621	17:45
64800	342	18:00
65700	91	18:15
66600	0	18:30
67500	0	18:45
68400	0	19:00
69300	0	19:15
70200	0	19:30
71100	0	19:45
72000	0	20:00
72900	0	20:15
73800	0	20:30
74700	0	20:45
75600	0	21:00
76500	0	21:15
77400	0	21:30
78300	0	21:45
79200	0	22:00
80100	0	22:15
81000	0	22:30
81900	0	22:45
82800	0	23:00
83700	0	23:15
84600	0	23:30
85500	0	23:45
86400	0	0:00

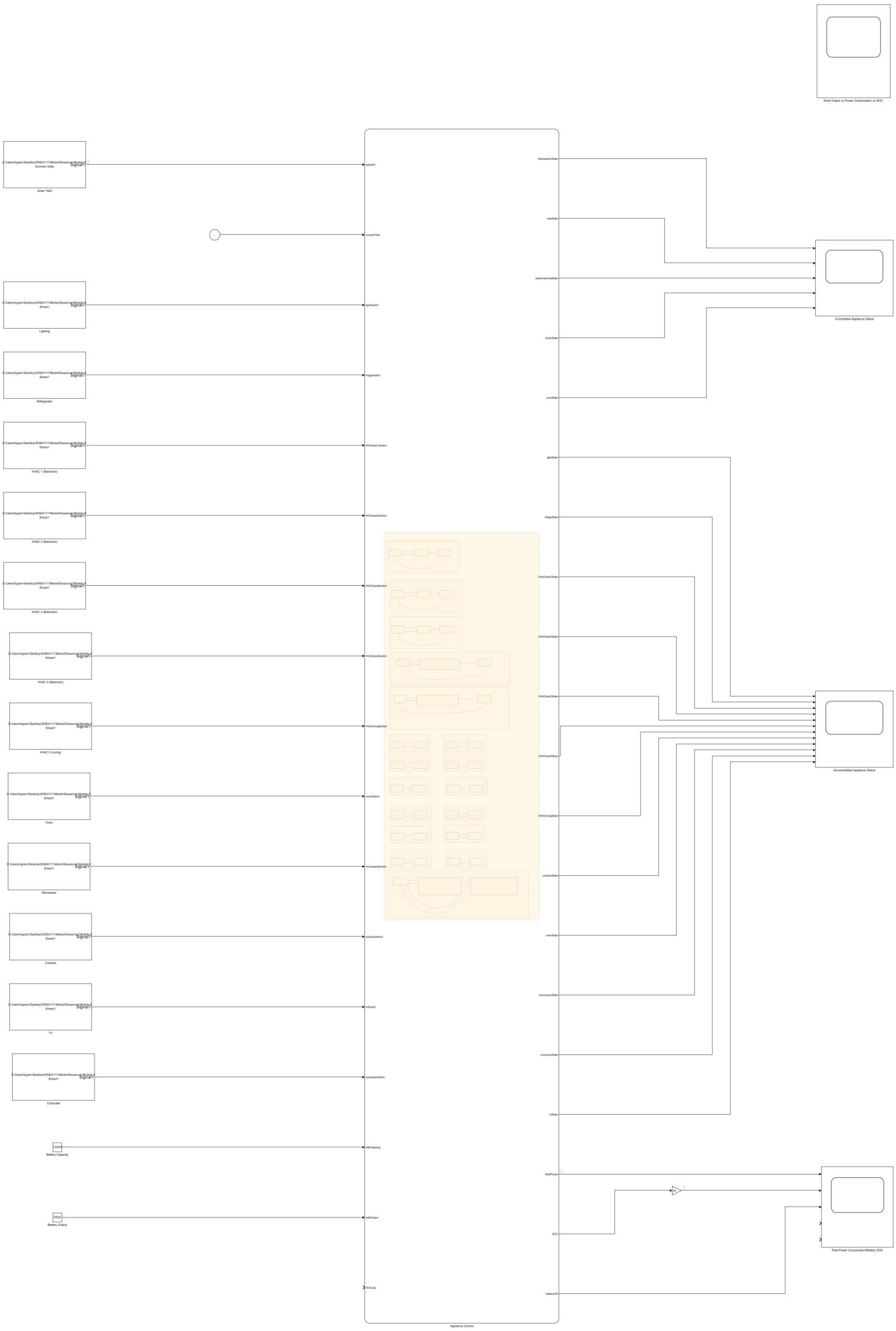
Autumn

Seconds	Output	Hour
0	0	0:00
900	0	0:15
1800	0	0:30
2700	0	0:45
3600	0	1:00
4500	0	1:15
5400	0	1:30
6300	0	1:45
7200	0	2:00
8100	0	2:15
9000	0	2:30
9900	0	2:45
10800	0	3:00
11700	0	3:15
12600	0	3:30
13500	0	3:45
14400	0	4:00
15300	0	4:15
16200	0	4:30
17100	0	4:45
18000	0	5:00
18900	0	5:15
19800	0	5:30
20700	0	5:45
21600	0	6:00
22500	0	6:15
23400	176	6:30
24300	320	6:45
25200	647	7:00
26100	1956	7:15
27000	2592	7:30
27900	4155	7:45
28800	4965	8:00
29700	6577	8:15
30600	7547	8:30
31500	8279	8:45
32400	9004	9:00
33300	9829	9:15
34200	10273	9:30
35100	10890	9:45
36000	11230	10:00
36900	11743	10:15
37800	12237	10:30
38700	12356	10:45
39600	12667	11:00
40500	12787	11:15
41400	13104	11:30
42300	13264	11:45
43200	12972	12:00
44100	12985	12:15
45000	12842	12:30
45900	12800	12:45
46800	12709	13:00
47700	12163	13:15
48600	11922	13:30
49500	11477	13:45
50400	10942	14:00
51300	10526	14:15
52200	9742	14:30
53100	9225	14:45
54000	8572	15:00
54900	7677	15:15
55800	6573	15:30
56700	5464	15:45
57600	4744	16:00
58500	3633	16:15
59400	2931	16:30
60300	2151	16:45
61200	892	17:00
62100	318	17:15
63000	58	17:30
63900	0	17:45
64800	0	18:00
65700	0	18:15
66600	0	18:30
67500	0	18:45
68400	0	19:00
69300	0	19:15
70200	0	19:30
71100	0	19:45
72000	0	20:00
72900	0	20:15
73800	0	20:30
74700	0	20:45
75600	0	21:00
76500	0	21:15
77400	0	21:30
78300	0	21:45
79200	0	22:00
80100	0	22:15
81000	0	22:30
81900	0	22:45
82800	0	23:00
83700	0	23:15
84600	0	23:30
85500	0	23:45
86400	0	0:00

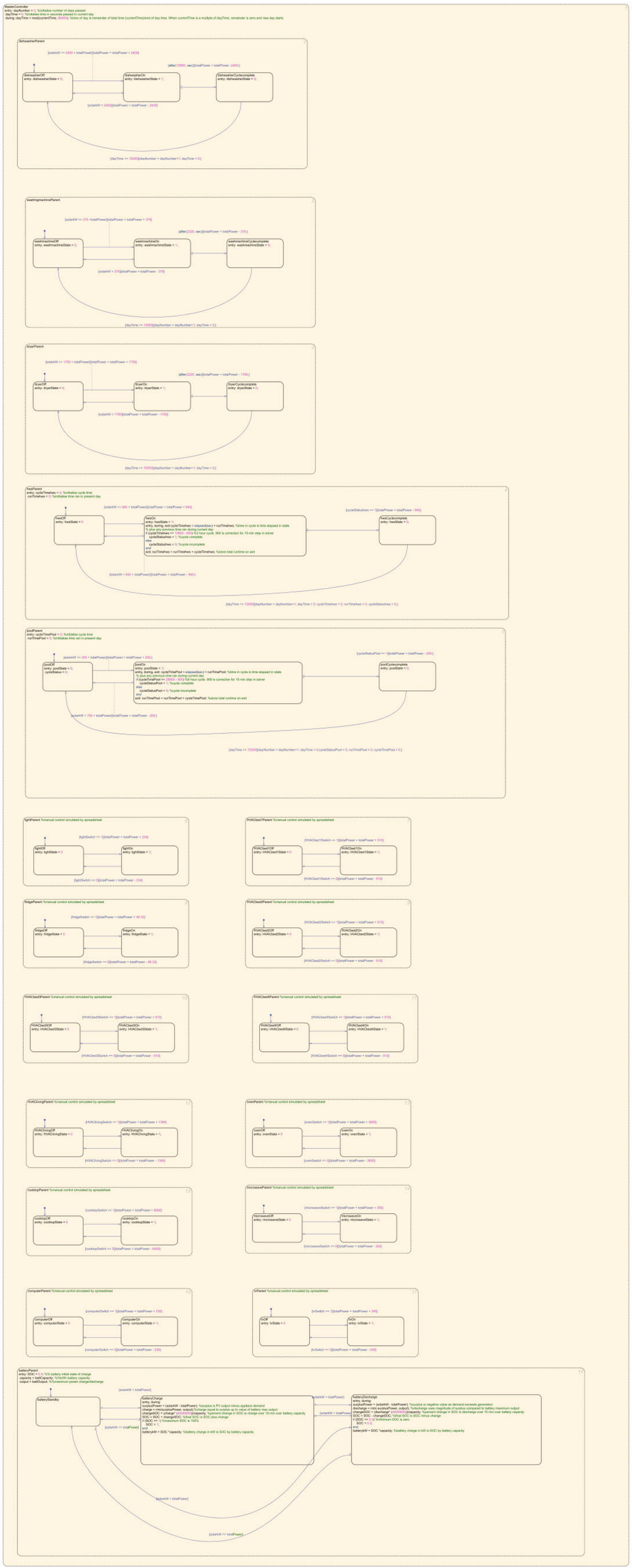
Winter

Seconds	Output	Hour
0	0	0:00
900	0	0:15
1800	0	0:30
2700	0	0:45
3600	0	1:00
4500	0	1:15
5400	0	1:30
6300	0	1:45
7200	0	2:00
8100	0	2:15
9000	0	2:30
9900	0	2:45
10800	0	3:00
11700	0	3:15
12600	0	3:30
13500	0	3:45
14400	0	4:00
15300	0	4:15
16200	0	4:30
17100	0	4:45
18000	0	5:00
18900	0	5:15
19800	0	5:30
20700	0	5:45
21600	0	6:00
22500	0	6:15
23400	163	6:30
24300	297	6:45
25200	601	7:00
26100	1817	7:15
27000	2407	7:30
27900	3859	7:45
28800	4611	8:00
29700	6109	8:15
30600	7010	8:30
31500	7690	8:45
32400	8363	9:00
33300	9129	9:15
34200	9542	9:30
35100	10115	9:45
36000	10430	10:00
36900	10907	10:15
37800	11366	10:30
38700	11476	10:45
39600	11765	11:00
40500	11877	11:15
41400	12171	11:30
42300	12320	11:45
43200	12048	12:00
44100	12060	12:15
45000	11928	12:30
45900	11889	12:45
46800	11804	13:00
47700	11297	13:15
48600	11073	13:30
49500	10660	13:45
50400	10163	14:00
51300	9777	14:15
52200	9048	14:30
53100	8568	14:45
54000	7962	15:00
54900	7130	15:15
55800	6105	15:30
56700	5075	15:45
57600	4406	16:00
58500	3374	16:15
59400	2722	16:30
60300	1998	16:45
61200	828	17:00
62100	295	17:15
63000	54	17:30
63900	0	17:45
64800	0	18:00
65700	0	18:15
66600	0	18:30
67500	0	18:45
68400	0	19:00
69300	0	19:15
70200	0	19:30
71100	0	19:45
72000	0	20:00
72900	0	20:15
73800	0	20:30
74700	0	20:45
75600	0	21:00
76500	0	21:15
77400	0	21:30
78300	0	21:45
79200	0	22:00
80100	0	22:15
81000	0	22:30
81900	0	22:45
82800	0	23:00
83700	0	23:15
84600	0	23:30
85500	0	23:45
86400	0	0:00

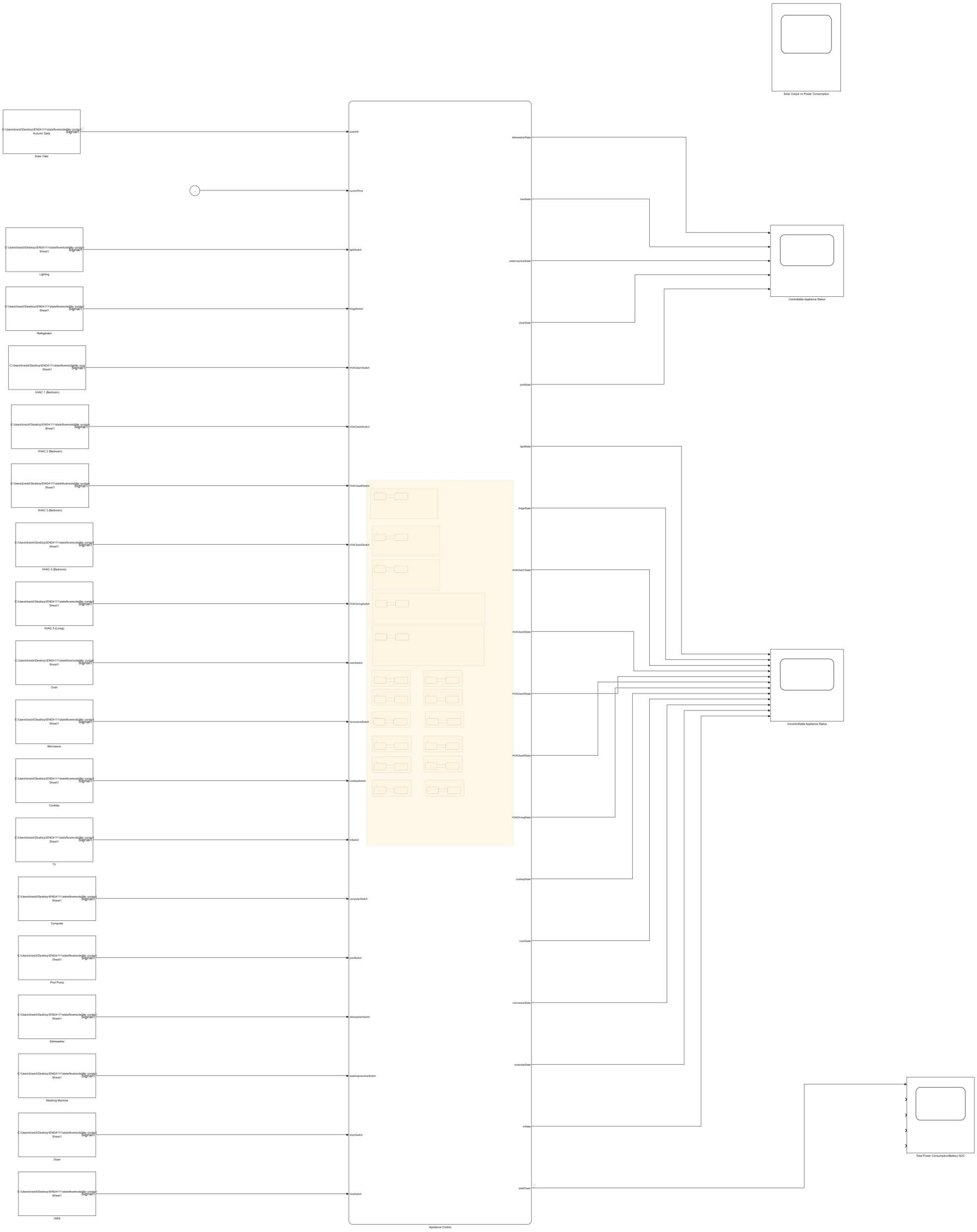
Controller Model (Simulink)



Controller Model (Stateflow)



No Controller Model (Simulink)



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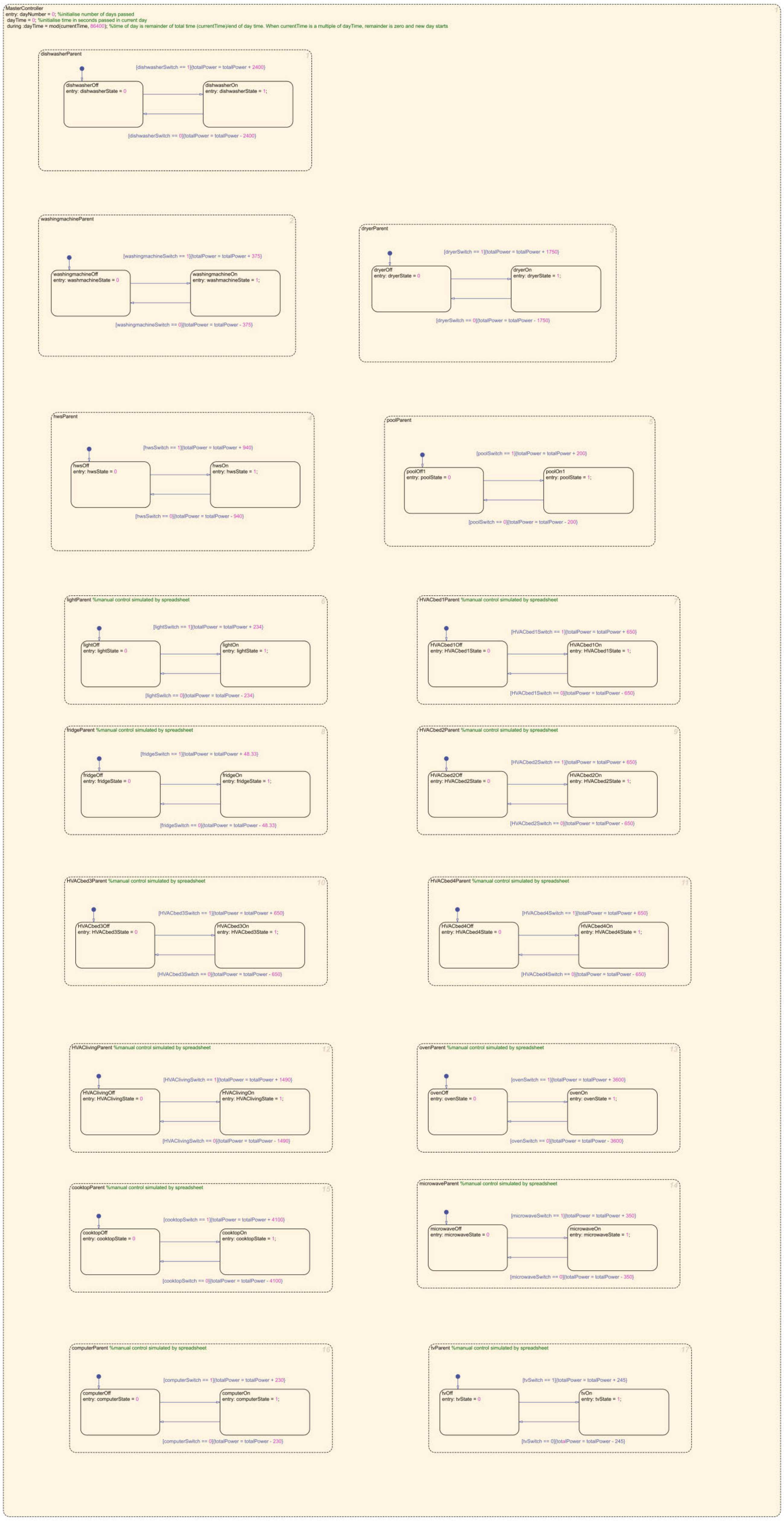

12 APPENDIX E: RESULTS AND TECHNO-ECONOMIC ANALYSIS

Refer zip file attachment for the following resources related to project results and techno-economic analysis.

- Results spreadsheet
- Economics with no BESS spreadsheet
- Economics with BESS spreadsheet

Note that results spreadsheet shown is for 2-person typical summer only to demonstrate methodology. Contact for additional 27 results spreadsheets.

2 Person Typical Summer Results

time	Appliance Demand	Battery SOC	Inverter Output	Solar Export Raw	Solar Export to Grid	Energy Offset Solar	Appliance Integral	Inverter Integral	Raw Export Integral	Grid Export Integral	Solar Offset Integral	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
900.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
900.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
1800.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
1800.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
2700.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
2700.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
3600.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
3600.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
4500.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
4500.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
5400.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
5400.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
6300.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
6300.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
7200.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
7200.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
8100.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
8100.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
9000.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
9000.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
9900.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
9900.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
10800.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
10800.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
11700.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
11700.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
12600.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
12600.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
13500.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
13500.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
14400.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
14400.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
15300.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
15300.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
16200.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
16200.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
17100.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
17100.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
18000.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
18000.00	1068.33	0.00	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
18900.00	1068.33	0.00	58.00	-1010.33	0.00	58.00	478257.58	25964.77	-452292.81	0.00	25964.77	
18900.00	1068.33	0.00	58.00	-1010.33	0.00	58.00	478257.58	25964.77	-452292.81	0.00	25964.77	

19800.00	1068.33	0.00	274.00	-794.33	0.00	274.00	478257.58	122661.14	-355596.44	0.00	122661.14	
19800.00	1068.33	0.00	274.00	-794.33	0.00	274.00	478257.58	122661.14	-355596.44	0.00	122661.14	
20700.00	1068.33	0.00	611.00	-457.33	0.00	611.00	478257.58	273525.39	-204732.19	0.00	273525.39	
20700.00	1068.33	0.00	611.00	-457.33	0.00	611.00	478257.58	273525.39	-204732.19	0.00	273525.39	
21600.00	1068.33	0.00	995.00	-73.33	0.00	995.00	478257.58	445430.05	-32827.52	0.00	445430.05	
21600.00	1418.33	0.00	995.00	-423.33	0.00	995.00	634941.51	445430.05	-189511.46	0.00	445430.05	
22500.00	1418.33	0.00	1175.00	-243.33	0.00	1175.00	634941.51	526010.36	-108931.15	0.00	526010.36	
22500.00	1068.33	0.10	1175.00	106.67	106.67	1068.33	478257.58	526010.36	47752.79	47752.79	478257.58	
23400.00	1068.33	0.25	1231.00	162.67	162.67	1068.33	478257.58	551079.79	72822.22	72822.22	478257.58	
23400.00	1068.33	0.40	1231.00	162.67	162.67	1068.33	478257.58	551079.79	72822.22	72822.22	478257.58	
24300.00	2383.33	0.40	2388.00	4.67	4.67	2383.33	1066941.51	1069032.12	2090.61	2090.61	1066941.51	
24300.00	1643.33	1.09	2388.00	744.67	744.67	1643.33	735666.90	1069032.12	333365.22	333365.22	735666.90	
25200.00	2583.33	1.51	3033.00	449.67	449.67	2583.33	1156475.19	1357778.24	201303.05	201303.05	1156475.19	
25200.00	623.33	3.74	3033.00	2409.67	2409.67	623.33	279045.14	1357778.24	1078733.10	1078733.10	279045.14	
26100.00	3763.33	3.93	3967.00	203.67	203.67	3763.33	1684723.90	1775900.52	91176.62	91176.62	1684723.90	
26100.00	3023.33	4.80	3967.00	943.67	943.67	3023.33	1353449.28	1775900.52	422451.23	422451.23	1353449.28	
27000.00	4398.33	5.16	4783.00	384.67	384.67	4398.33	1968993.33	2141197.93	172204.60	172204.60	1968993.33	
27000.00	4398.33	5.52	4783.00	384.67	384.67	4398.33	1968993.33	2141197.93	172204.60	172204.60	1968993.33	
27900.00	5338.33	5.74	5583.00	244.67	244.67	5338.33	2389801.62	2499332.64	109531.03	109531.03	2389801.62	
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28800.00	5338.33	7.75	6324.00	985.67	985.67	5338.33	2389801.62	2831054.92	441253.31	441253.31	2389801.62	
28800.00	5338.33	8.66	6324.00	985.67	985.67	5338.33	2389801.62	2831054.92	441253.31	441253.31	2389801.62	
29700.00	3588.33	11.90	7083.00	3494.67	3494.67	3588.33	1606381.93	3170835.23	1564453.31	1564453.31	1606381.93	
29700.00	3588.33	15.14	7083.00	3494.67	3494.67	3588.33	1606381.93	3170835.23	1564453.31	1564453.31	1606381.93	
30600.00	3588.33	18.96	7721.00	4132.67	4132.67	3588.33	1606381.93	3456447.67	1850065.74	1850065.74	1606381.93	
30600.00	3588.33	22.79	7721.00	4132.67	4132.67	3588.33	1606381.93	3456447.67	1850065.74	1850065.74	1606381.93	
31500.00	3588.33	27.17	8315.00	4726.67	4726.67	3588.33	1606381.93	3722362.69	2115980.77	2115980.77	1606381.93	
31500.00	3588.33	31.54	8315.00	4726.67	4726.67	3588.33	1606381.93	3722362.69	2115980.77	2115980.77	1606381.93	
32400.00	3588.33	36.17	9052.00	5463.67	5463.67	3588.33	1606381.93	4052294.30	2445912.37	2445912.37	1606381.93	
32400.00	3588.33	40.80	9052.00	5463.67	5463.67	3588.33	1606381.93	4052294.30	2445912.37	2445912.37	1606381.93	
33300.00	3588.33	45.43	9405.00	5816.67	5816.67	3588.33	1606381.93	4210321.24	2603939.32	2603939.32	1606381.93	
33300.00	3588.33	50.06	9405.00	5816.67	5816.67	3588.33	1606381.93	4210321.24	2603939.32	2603939.32	1606381.93	
34200.00	3588.33	54.69	9973.00	6384.67	6384.67	3588.33	1606381.93	4464596.89	2858214.96	2858214.96	1606381.93	
34200.00	3588.33	59.32	9973.00	6384.67	6384.67	3588.33	1606381.93	4464596.89	2858214.96	2858214.96	1606381.93	
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36000.00	3588.33	77.84	10816.00	7227.67	7227.67	3588.33	1606381.93	4841981.35	3235599.42	3235599.42	1606381.93	
36900.00	3588.33	82.47	11257.00	7668.67	7668.67	3588.33	1606381.93	5039403.11	3433021.18	3433021.18	1606381.93	
36900.00	3588.33	87.10	11257.00	7668.67	7668.67	3588.33	1606381.93	5039403.11	3433021.18	3433021.18	1606381.93	
37800.00	3588.33	91.73	11498.00	7909.67	7909.67	3588.33	1606381.93	5147291.19	3540909.26	3540909.26	1606381.93	
37800.00	3588.33	96.36	11498.00	7909.67	7909.67	3588.33	1606381.93	5147291.19	3540909.26	3540909.26	1606381.93	
38700.00	3588.33	100.00	11872.00	8283.67	8283.67	3588.33	1606381.93	5314719.17	3708337.24	3708337.24	1606381.93	
38700.00	248.33	100.00	11872.00	11623.67	11623.67	248.33	111169.49	5314719.17	5203549.68	5203549.68	111169.49	
39600.00	248.33	100.00	11997.00	11748.67	11748.67	248.33	111169.49	5370677.72	5259508.23	5259508.23	111169.49	
39600.00	1638.33	100.00	11997.00	10358.67	10358.67	1638.33	733428.56	5370677.72	4637249.16	4637249.16	733428.56	

40500.00	1638.33	100.00	12170.00	10531.67	10531.67	1638.33	733428.56	5448124.35	4714695.79	4714695.79	733428.56	
40500.00	1638.33	100.00	12170.00	10531.67	10531.67	1638.33	733428.56	5448124.35	4714695.79	4714695.79	733428.56	
41400.00	1638.33	100.00	12453.00	10814.67	10814.67	1638.33	733428.56	5574814.51	4841385.95	4841385.95	733428.56	
41400.00	1638.33	100.00	12453.00	10814.67	10814.67	1638.33	733428.56	5574814.51	4841385.95	4841385.95	733428.56	
42300.00	1638.33	100.00	12296.00	10657.67	10657.67	1638.33	733428.56	5504530.57	4771102.01	4771102.01	733428.56	
42300.00	1638.33	100.00	12296.00	10657.67	10657.67	1638.33	733428.56	5504530.57	4771102.01	4771102.01	733428.56	
43200.00	1638.33	100.00	12368.00	10729.67	10729.67	1638.33	733428.56	5536762.69	4803334.13	4803334.13	733428.56	
43200.00	1638.33	100.00	12368.00	10729.67	10729.67	1638.33	733428.56	5536762.69	4803334.13	4803334.13	733428.56	
44100.00	1638.33	100.00	12133.00	10494.67	10494.67	1638.33	733428.56	5431560.62	4698132.06	4698132.06	733428.56	
44100.00	1638.33	100.00	12133.00	10494.67	10494.67	1638.33	733428.56	5431560.62	4698132.06	4698132.06	733428.56	
45000.00	1638.33	100.00	12094.00	10455.67	10455.67	1638.33	733428.56	5414101.55	4680672.99	4680672.99	733428.56	
45000.00	1638.33	100.00	12094.00	10455.67	10455.67	1638.33	733428.56	5414101.55	4680672.99	4680672.99	733428.56	
45900.00	1638.33	100.00	12075.00	10436.67	10436.67	1638.33	733428.56	5405595.85	4672167.30	4672167.30	733428.56	
45900.00	1638.33	100.00	12075.00	10436.67	10436.67	1638.33	733428.56	5405595.85	4672167.30	4672167.30	733428.56	
46800.00	1638.33	100.00	11781.00	10142.67	10142.67	1638.33	733428.56	5273981.35	4540552.79	4540552.79	733428.56	
46800.00	1638.33	100.00	11781.00	10142.67	10142.67	1638.33	733428.56	5273981.35	4540552.79	4540552.79	733428.56	
47700.00	1638.33	100.00	11657.00	10018.67	10018.67	1638.33	733428.56	5218470.47	4485041.91	4485041.91	733428.56	
47700.00	1638.33	100.00	11657.00	10018.67	10018.67	1638.33	733428.56	5218470.47	4485041.91	4485041.91	733428.56	
48600.00	1638.33	100.00	11180.00	9541.67	9541.67	1638.33	733428.56	5004932.64	4271504.08	4271504.08	733428.56	
48600.00	1638.33	100.00	11180.00	9541.67	9541.67	1638.33	733428.56	5004932.64	4271504.08	4271504.08	733428.56	
49500.00	1638.33	100.00	10998.00	9359.67	9359.67	1638.33	733428.56	4923456.99	4190028.44	4190028.44	733428.56	
49500.00	1638.33	100.00	10998.00	9359.67	9359.67	1638.33	733428.56	4923456.99	4190028.44	4190028.44	733428.56	
50400.00	1638.33	100.00	10748.00	9109.67	9109.67	1638.33	733428.56	4811539.90	4078111.34	4078111.34	733428.56	
50400.00	1638.33	100.00	10748.00	9109.67	9109.67	1638.33	733428.56	4811539.90	4078111.34	4078111.34	733428.56	
51300.00	1638.33	100.00	10240.00	8601.67	8601.67	1638.33	733428.56	4584124.35	3850695.79	3850695.79	733428.56	
51300.00	1638.33	100.00	10240.00	8601.67	8601.67	1638.33	733428.56	4584124.35	3850695.79	3850695.79	733428.56	
52200.00	1638.33	100.00	9838.00	8199.67	8199.67	1638.33	733428.56	4404161.66	3670733.10	3670733.10	733428.56	
52200.00	1638.33	100.00	9838.00	8199.67	8199.67	1638.33	733428.56	4404161.66	3670733.10	3670733.10	733428.56	
53100.00	1638.33	100.00	9072.00	7433.67	7433.67	1638.33	733428.56	4061247.67	3327819.11	3327819.11	733428.56	
53100.00	1438.33	100.00	9072.00	7633.67	7633.67	1438.33	643894.88	4061247.67	3417352.79	3417352.79	643894.88	
54000.00	1438.33	100.00	8738.00	7299.67	7299.67	1438.33	643894.88	3911726.42	3267831.54	3267831.54	643894.88	
54000.00	1438.33	100.00	8738.00	7299.67	7299.67	1438.33	643894.88	3911726.42	3267831.54	3267831.54	643894.88	
54900.00	1438.33	100.00	8054.00	6615.67	6615.67	1438.33	643894.88	3605521.24	2961626.36	2961626.36	643894.88	
54900.00	1438.33	100.00	8054.00	6615.67	6615.67	1438.33	643894.88	3605521.24	2961626.36	2961626.36	643894.88	
55800.00	1438.33	100.00	7407.00	5968.67	5968.67	1438.33	643894.88	3315879.79	2671984.91	2671984.91	643894.88	
55800.00	1438.33	100.00	7407.00	5968.67	5968.67	1438.33	643894.88	3315879.79	2671984.91	2671984.91	643894.88	
56700.00	1438.33	100.00	6761.00	5322.67	5322.67	1438.33	643894.88	3026686.01	2382791.13	2382791.13	643894.88	
56700.00	1438.33	100.00	6761.00	5322.67	5322.67	1438.33	643894.88	3026686.01	2382791.13	2382791.13	643894.88	
57600.00	1438.33	100.00	5945.00	4506.67	4506.67	1438.33	643894.88	2661388.60	2017493.72	2017493.72	643894.88	
57600.00	1438.33	100.00	5945.00	4506.67	4506.67	1438.33	643894.88	2661388.60	2017493.72	2017493.72	643894.88	
58500.00	1438.33	100.00	5228.00	3789.67	3789.67	1438.33	643894.88	2340410.36	1696515.48	1696515.48	643894.88	
58500.00	1438.33	100.00	5228.00	3789.67	3789.67	1438.33	643894.88	2340410.36	1696515.48	1696515.48	643894.88	
59400.00	1438.33	100.00	4403.00	2964.67	2964.67	1438.33	643894.88	1971083.94	1327189.06	1327189.06	643894.88	
59400.00	1438.33	100.00	4403.00	2964.67	2964.67	1438.33	643894.88	1971083.94	1327189.06	1327189.06	643894.88	
60300.00	1438.33	100.00	3674.00	2235.67	2235.67	1438.33	643894.88	1644733.68	1000838.80	1000838.80	643894.88	
60300.00	1438.33	100.00	3674.00	2235.67	2235.67	1438.33	643894.88	1644733.68	1000838.80	1000838.80	643894.88	

61200.00	1438.33	100.00	3034.00	1595.67	1595.67	1438.33	643894.88	1358225.91	714331.03	714331.03	643894.88	
61200.00	1438.33	100.00	3034.00	1595.67	1595.67	1438.33	643894.88	1358225.91	714331.03	714331.03	643894.88	
62100.00	1438.33	100.00	2413.00	974.67	974.67	1438.33	643894.88	1080223.83	436328.95	436328.95	643894.88	
62100.00	1438.33	100.00	2413.00	974.67	974.67	1438.33	643894.88	1080223.83	436328.95	436328.95	643894.88	
63000.00	1438.33	100.00	2017.00	578.67	578.67	1438.33	643894.88	902947.15	259052.27	259052.27	643894.88	
63000.00	1438.33	100.00	2017.00	578.67	578.67	1438.33	643894.88	902947.15	259052.27	259052.27	643894.88	
63900.00	1438.33	100.00	1637.00	198.67	198.67	1438.33	643894.88	732833.16	88938.28	88938.28	643894.88	
63900.00	1438.33	100.00	1637.00	198.67	198.67	1438.33	643894.88	732833.16	88938.28	88938.28	643894.88	
64800.00	1438.33	99.79	1212.00	-226.33	0.00	1212.00	643894.88	542574.09	-101320.79	0.00	542574.09	
64800.00	9597.33	95.16	1212.00	-8385.33	0.00	1212.00	4296421.31	542574.09	-3753847.21	0.00	542574.09	
65700.00	9597.33	90.53	397.00	-9200.33	0.00	397.00	4296421.31	177724.35	-4118696.95	0.00	177724.35	
65700.00	9247.33	85.90	397.00	-8850.33	0.00	397.00	4139737.37	177724.35	-3962013.02	0.00	177724.35	
66600.00	9247.33	81.27	118.00	-9129.33	0.00	118.00	4139737.37	52824.87	-4086912.50	0.00	52824.87	
66600.00	9247.33	76.64	118.00	-9129.33	0.00	118.00	4139737.37	52824.87	-4086912.50	0.00	52824.87	
67500.00	9247.33	72.01	1.00	-9246.33	0.00	1.00	4139737.37	447.67	-4139289.70	0.00	447.67	
67500.00	9247.33	67.38	1.00	-9246.33	0.00	1.00	4139737.37	447.67	-4139289.70	0.00	447.67	
68400.00	9247.33	62.75	0.00	-9247.33	0.00	0.00	4139737.37	0.00	-4139737.37	0.00	0.00	
68400.00	1547.33	61.32	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
69300.00	1547.33	59.89	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
69300.00	1547.33	58.46	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
70200.00	1547.33	57.02	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
70200.00	1547.33	55.59	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
71100.00	1547.33	54.16	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
71100.00	1547.33	52.72	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
72000.00	1547.33	51.29	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
72000.00	1547.33	49.86	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
72900.00	1547.33	48.43	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
72900.00	1547.33	46.99	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
73800.00	1547.33	45.56	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
73800.00	1547.33	44.13	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
74700.00	1547.33	42.70	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
74700.00	1547.33	41.26	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
75600.00	1547.33	39.83	0.00	-1547.33	0.00	0.00	692690.74	0.00	-692690.74	0.00	0.00	
75600.00	1532.33	38.41	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
76500.00	1532.33	36.99	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
76500.00	1532.33	35.57	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
77400.00	1532.33	34.15	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
77400.00	1532.33	32.74	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
78300.00	1532.33	31.32	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
78300.00	1532.33	29.90	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
79200.00	1532.33	28.48	0.00	-1532.33	0.00	0.00	685975.71	0.00	-685975.71	0.00	0.00	
79200.00	1302.33	27.27	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
80100.00	1302.33	26.07	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
80100.00	1302.33	24.86	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
81000.00	1302.33	23.66	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
81000.00	1302.33	22.45	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	

81900.00	1302.33	21.24	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
81900.00	1302.33	20.04	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
82800.00	1302.33	18.83	0.00	-1302.33	0.00	0.00	583011.98	0.00	-583011.98	0.00	0.00	
82800.00	1068.33	17.84	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
83700.00	1068.33	16.85	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
83700.00	1068.33	15.86	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
84600.00	1068.33	14.88	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
84600.00	1068.33	13.89	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
85500.00	1068.33	12.90	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
85500.00	1068.33	11.91	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
86400.00	1068.33	10.92	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
86400.00	1068.33	9.93	0.00	-1068.33	0.00	0.00	478257.58	0.00	-478257.58	0.00	0.00	
87300.00	1068.33	8.94	0.00	-1068.33	0.00	0.00	Appliance Integral	Inverter Integral	Raw Export Integral	Grid Export Integral	Solar Offset Integral	
87300.00	1068.33	7.95	0.00	-1068.33	0.00	0.00	176206469.97	341887933.68	165681463.71	245235570.90	96652362.78	Sum of Areas
88200.00	1068.33	6.96	0.00	-1068.33	0.00	0.00	48946.24	94968.87	46022.63	68120.99	26847.88	Wh
88200.00	1068.33	5.97	0.00	-1068.33	0.00	0.00	48.95	94.97	46.02	68.12	26.85	kWh

Economics – 2 person No Solar

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	48.76	0.00	66.72	0.00	2.82	45.94	63.90
Autumn	92.00	44.96	0.00	62.64	0.00	2.82	42.14	59.82
Winter	92.00	48.80	0.00	66.39	0.00	2.82	45.98	63.57
Spring	91.00	38.59	0.00	56.08	0.00	2.82	35.77	53.26

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS									
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	59.53	1560.12	2170.04	0.00	0.00	140.00	-56.00	1761.57	2287.49
Autumn	59.53	1431.07	2031.49	0.00	0.00	140.00	-56.00	1632.52	2148.94
Winter	59.53	1561.48	2158.84	0.00	0.00	140.00	-56.00	1762.93	2276.29
Spring	59.53	1214.75	1808.71	0.00	0.00	140.00	-56.00	1416.20	1926.16

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	158541.53	205874.48
Autumn	92.00	150192.26	197702.24
Winter	92.00	162189.65	209418.44
Spring	91.00	128874.15	175280.54
Annual		599797.59	788275.70

Economics with no BESS – 2 person Uncontrolled

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	35.35	81.56	37.89	66.14	2.82	32.53	35.07
Autumn	92.00	40.81	85.36	45.84	72.72	2.82	37.99	43.02
Winter	92.00	43.33	77.67	48.44	65.19	2.82	40.51	45.62
Spring	91.00	26.64	84.41	31.56	71.84	2.82	23.82	28.74

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS										
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	59.53	1104.72	1190.98	140.00	270.24	140.00	208.56	905.50	1053.44
Autumn	59.53	1290.14	1460.96	140.00	285.44	140.00	234.88	1075.72	1297.10
Winter	59.53	1375.72	1549.26	140.00	254.68	140.00	204.76	1192.06	1415.52
Spring	59.53	808.93	976.01	140.00	281.64	140.00	231.36	598.31	815.67

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	81494.91	94809.37
Autumn	92.00	98966.30	119333.14
Winter	92.00	109669.50	130227.42
Spring	91.00	54445.97	74226.02
Annual		344576.68	418595.95

Economics with no BESS – 2 person Controlled

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	22.10	68.12	24.58	53.24	0.00	22.10	24.58
Autumn	92.00	27.44	72.00	32.66	59.69	0.00	27.44	32.66
Winter	92.00	29.88	64.36	35.13	52.32	0.00	29.88	35.13
Spring	91.00	13.30	72.13	18.35	59.35	0.00	13.30	18.35

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS									
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	0.00	750.52	834.74	140.00	216.48	140.00	156.96	541.64	685.38
Autumn	0.00	931.86	1109.13	140.00	232.00	140.00	182.76	707.46	933.97
Winter	0.00	1014.72	1193.01	140.00	201.44	140.00	153.28	820.88	1047.33
Spring	0.00	451.67	623.17	140.00	232.52	140.00	181.40	226.75	449.37

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	48747.24	61683.91
Autumn	92.00	65086.54	85925.57
Winter	92.00	75521.40	96354.80
Spring	91.00	20634.07	40892.31
Annual		209989.25	284856.59

Economics with no BESS – 2 person NPV

Annual Cost No Bess	$
Typical No Solar	5997.98
Typical Uncontrolled	3445.77
Typical Controlled	2099.89

Discount rate	0.04
PV Cost	15000
BESS Cost	15000
Controller Cost PV	1500
Controller cost BESS	3000

NPV Uncontrolled
N.B sum of (no solar-uncontrolled)i/(1+d)I over 10 years

Year	0	1	2	3	4	5	6	7	8	9	10
Initial Cost	15000										
Annual Cost		2552.21	2552.21	2552.21	2552.21	2552.21	2552.21	2552.21	2552.21	2552.21	2552.21
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value	15000	2454.047254	2359.660821	2268.904636	2181.639073	2097.729878	2017.047959	1939.469192	1864.874223	1793.148291	1724.181049
NPV Total	5700.702										

NPV Controlled
N.B sum of (no solar-uncontrolled)i/(1+d)I over 10 years

Year	0	1	2	3	4	5	6	7	8	9	10
Initial Cost	16500										
Annual Cost		3898.08	3898.08	3898.08	3898.08	3898.08	3898.08	3898.08	3898.08	3898.08	3898.08
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value	16500	3748.157156	3603.997265	3465.381986	3332.098063	3203.940445	3080.711967	2962.223045	2848.291389	2738.741721	2633.405501
NPV Total	15116.95										

Payback Period Uncontrolled	5.877261
Payback Period Controlled	4.232849

LCOE Uncontrolled (Self Consumption)	0.344743	$/kWh	34.47428518 c/kWh

N.B NPV total costs/NPV Energy over lifetime
NPV Energy Uncontrolled

Year	0	1	2	3	4	5	6	7	8	9	10
Energy Produced		12767.70	12767.70	12767.70	12767.70	12767.70	12767.70	12767.70	12767.70	12767.70	12767.70
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value		12276.63462	11804.45636	11350.43881	10913.88347	10494.11872	10090.49877	9702.402664	9329.23333	8970.416664	8625.400638
NPV Total	103557.5										

LCOE Controlled (Self Consumption)	0.184968	$/kWh	18.49676444 c/kWh

N.B NPV total costs/NPV Energy over lifetime
NPV Energy Uncontrolled

Year	0	1	2	3	4	5	6	7	8	9	10
Energy Produced		32072.55	32072.55	32072.55	32072.55	32072.55	32072.55	32072.55	32072.55	32072.55	32072.55
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value		30838.99038	29652.87537	28512.38016	27415.75016	26361.29823	25347.40214	24372.50206	23435.09813	22533.74821	21667.06558
NPV Total	260137.1										

Economics – 4 person No Solar

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	68.31	0.00	83.58	0.00	2.82	65.49	80.76
Autumn	92.00	60.47	0.00	73.98	0.00	2.82	57.65	71.16
Winter	92.00	68.19	0.00	81.70	0.00	2.82	65.37	78.88
Spring	91.00	50.76	0.00	64.27	0.00	2.82	47.94	61.45

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS									
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	59.53	2224.04	2742.61	0.00	0.00	0.00	0.00	2425.49	2944.06
Autumn	59.53	1957.79	2416.59	0.00	0.00	0.00	0.00	2159.24	2618.04
Winter	59.53	2219.97	2678.76	0.00	0.00	0.00	0.00	2421.42	2880.22
Spring	59.53	1628.04	2086.84	0.00	0.00	0.00	0.00	1829.49	2288.29

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	218294.15	264965.38
Autumn	92.00	198650.47	240860.03
Winter	92.00	222770.22	264979.78
Spring	91.00	166483.83	208234.59
Annual		806198.66	979039.78

Economics with no BESS – 4 person Uncontrolled

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	51.71	78.37	54.32	65.71	2.82	48.89	51.50
Autumn	92.00	51.00	80.05	56.07	71.60	2.82	48.18	53.25
Winter	92.00	57.96	72.91	63.13	64.57	2.82	55.14	60.31
Spring	91.00	29.94	75.54	34.96	67.05	2.82	27.12	32.14

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS									
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	59.53	1660.30	1748.94	140.00	257.48	140.00	206.84	1473.84	1613.12
Autumn	59.53	1636.19	1808.37	140.00	264.20	140.00	230.40	1443.01	1648.99
Winter	59.53	1872.55	2048.13	140.00	235.64	140.00	202.28	1707.93	1916.87
Spring	59.53	921.00	1091.47	140.00	246.16	140.00	212.20	745.86	950.29

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	132646.01	145180.82
Autumn	92.00	132757.20	151707.10
Winter	92.00	157129.98	176351.84
Spring	91.00	67872.84	86476.81
Annual		490406.03	559716.56

Economics with no BESS – 4 person Controlled

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	38.41	65.18	40.98	52.50	0.00	38.41	40.98
Autumn	92.00	37.60	66.80	42.65	58.43	0.00	37.60	42.65
Winter	92.00	44.45	59.33	50.55	52.16	0.00	44.45	50.55
Spring	91.00	16.63	62.59	21.64	53.96	0.00	16.63	21.64

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS									
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	0.00	1304.40	1391.68	140.00	204.72	140.00	154.00	1107.28	1245.28
Autumn	0.00	1276.90	1448.39	140.00	211.20	140.00	177.72	1073.30	1278.27
Winter	0.00	1509.52	1716.68	140.00	181.32	140.00	152.64	1335.80	1571.64
Spring	0.00	564.75	734.89	140.00	194.36	140.00	159.84	377.99	582.65

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	99655.52	112075.27
Autumn	92.00	98743.23	117601.21
Winter	92.00	122893.78	144590.70
Spring	91.00	34397.53	53021.55
Annual		355690.07	427288.73

Economics with no BESS – 4 person NPV

Annual Cost No Bess	$
Typical No Solar	8061.99
Typical Uncontrolled	4904.06
Typical Controlled	3556.90

Discount rate	0.04
PV Cost	15000
Bess Cost	15000
Controller Cost PV	1500
Controller cost BESS	3000

NPV Uncontrolled

N.B sum of (no solar-uncontrolled)i/(1+d)I over 10 years subtracted by initial cost

Year	0	1	2	3	4	5	6	7	8	9	10
Initial Cost	15000										
Annual Cost		3157.93	3157.93	3157.93	3157.93	3157.93	3157.93	3157.93	3157.93	3157.93	3157.93
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value	15000	3036.467588	2919.680374	2807.384975	2699.408629	2595.585221	2495.75502	2399.764442	2307.46581	2218.717125	2133.381851
NPV Total	10613.61										

NPV Controlled

N.B sum of (no solar-uncontrolled)i/(1+d)I over 10 years

Year	0	1	2	3	4	5	6	7	8	9	10
Initial Cost	16500										
Annual Cost		4505.09	4505.09	4505.09	4505.09	4505.09	4505.09	4505.09	4505.09	4505.09	4505.09
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value	16500	4331.813433	4165.205224	4005.005023	3850.966368	3702.852277	3560.434882	3423.495079	3291.822191	3165.213645	3043.474659
NPV Total	20040.28										

Payback Period Uncontrolled	4.749953
Payback Period Controlled	3.662527

LCOE Uncontrolled (Self Consumption)	0.240172	$/kWh	24.01716385	c/kWh

N.B NPV total costs/NPV Energy over lifetime

NPV Energy Uncontrolled

Year	0	1	2	3	4	5	6	7	8	9	10
Energy Produced		20848.80	20848.80	20848.80	20848.80	20848.80	20848.80	20848.80	20848.80	20848.80	20848.80
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value		20046.92308	19275.88757	18534.50728	17821.64162	17136.19386	16477.10948	15843.3745	15234.01395	14648.09033	14084.70224
NPV Total	169102.4										

LCOE Controlled (Self Consumption)	0.16277	$/kWh	16.27703056	c/kWh

N.B NPV total costs/NPV Energy over lifetime

NPV Energy Uncontrolled

Year	0	1	2	3	4	5	6	7	8	9	10
Energy Produced		40175.55	40175.55	40175.55	40175.55	40175.55	40175.55	40175.55	40175.55	40175.55	40175.55
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value		38630.33654	37144.55436	35715.91766	34342.22852	33021.37357	31751.32074	30530.1161	29355.88087	28226.80852	27141.16204
NPV Total	325859.7										

Economics with Bess – 2 person controlled

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

N.B with BESS, fully charges and discharges for summer, autumn and winter (minus 13.5kWh from daily consumption and feed in)
Spring typical discharges to low of 41.7% and recharges to 100%. 7.86915 W charge and discharge per day.
Spring heavy discharges to low of 11.49% and recharges to 100%. 11.949 W charge and discharge per day.

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	8.60	54.62	11.08	39.74	0.00	8.60	11.08
Autumn	92.00	13.94	58.50	19.16	46.19	0.00	13.94	19.16
Winter	92.00	16.38	50.86	21.63	38.82	0.00	16.38	21.63
Spring	91.00	5.43	64.26	6.40	47.40	0.00	5.43	6.40

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS										
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	0.00	292.06	376.28	140.00	162.48	140.00	102.96	137.18	280.92
Autumn	0.00	473.40	650.67	140.00	178.00	140.00	128.76	303.00	529.51
Winter	0.00	556.26	734.55	140.00	147.44	140.00	99.28	416.42	642.87
Spring	0.00	184.43	217.38	140.00	201.04	140.00	133.60	-9.01	91.37

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	12345.84	25282.51
Autumn	92.00	27876.22	48715.25
Winter	92.00	38311.08	59144.48
Spring	91.00	-820.07	8315.03
Annual		77713.07	141457.28

Economics with Bess – 2 person NPV

Annual Cost No Bess	$
Typical No Solar	5997.98
Typical Controlled	777.13

Discount rate	0.04
PV Cost	15000
Bess Cost	15000
Controller Cost PV	1500
Controller cost BESS	3000

NPV Controlled

N.B sum of (no solar-uncontrolled)i/(1+d)I over 10 years

Year	0	1	2	3	4	5	6	7	8	9	10
Initial Cost	33000										
Annual Cost		5220.85	5220.85	5220.85	5220.85	5220.85	5220.85	5220.85	5220.85	5220.85	5220.85
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value	33000	5020.043461	4826.964867	4641.312372	4462.800358	4291.15419	4126.109798	3967.413267	3814.820449	3668.096586	3527.015948
NPV Total	9345.731										

Payback Period	6.320816

LCOE (Self Consumpt	0.251066	$/kWh	25.10657786	c/kWh

N.B NPV total costs/NPV Energy over lifetime

NPV Energy

Year	0	1	2	3	4	5	6	7	8	9	10
Energy Produced		37000.05	37000.05	37000.05	37000.05	37000.05	37000.05	37000.05	37000.05	37000.05	37000.05
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value		35576.97115	34208.62611	32892.90972	31627.79781	30411.34405	29241.67697	28116.99708	27035.57412	25995.74435	24995.90802
NPV Total	300103.5										

Economics with Bess – 4 person controlled

	Type	Cents
Daily	Daily Supply	138.03
	Solar Meter Charge	9.57
	Daily Supply - Controlled	3.89
Per kWh	General Usage (Primary Tariff)	33.96
	Controlled Load Usage (Secondary Tariff)	21.11
	Feed-In (first 14kWh)	10
	Default Feed-In	4

N.B with BESS, fully charges and discharges for summer, autumn and winter in all modes and spring in heavy (minus 13.5kWh from daily consumption and feed in)

Spring heavy discharges to low of 1.71% and recharges to 100%. 13269.15W charge and discharge per day.

DAILY CONSUMPTION KWH								
Season	Days per Season	Typical kWh/day Consumption	Typical kWh/Day Feed-in	Heavy kWh/Day	Heavy kWh/Day Feed-in	Controlled Load/day	Typical General usage/day	Heavy General usage/day
Summer	90.00	24.91	51.68	27.48	39.00	0.00	24.91	27.48
Autumn	92.00	24.10	53.30	29.15	44.93	0.00	24.10	29.15
Winter	92.00	30.95	45.83	37.05	38.66	0.00	30.95	37.05
Spring	91.00	3.36	49.32	8.14	40.46	0.00	3.36	8.14

N.B Controlled load per day = HWS*3hrs

DAILY CONSUMPTION CENTS										
Season	Controlled Load/day	Typical General/day	Heavy General/day	Typical Feed-in/day first 14kWh	Typical Feed-in/day default	Heavy Feed-in/day first 14kWh	Heavy Feed-in/day default	Typical Cost per day	Heavy Cost per Day
Summer	0.00	845.94	933.22	140.00	150.72	140.00	100.00	702.82	840.82
Autumn	0.00	818.44	989.93	140.00	157.20	140.00	123.72	668.84	873.81
Winter	0.00	1051.06	1258.22	140.00	127.32	140.00	98.64	931.34	1167.18
Spring	0.00	114.14	276.43	140.00	141.28	140.00	105.84	-19.54	178.19

N.B Controlled load per day = HWS*3hrs*cost

Seasonal and Annual Cost			
Season	Days per Season	Typical Cost Per Season	Heavy Cost Per Season
Summer	90.00	63254.12	75673.87
Autumn	92.00	61532.91	80390.89
Winter	92.00	85683.46	107380.38
Spring	91.00	-1778.54	16215.69
Annual		208691.96	279660.83

Economics with Bess – 4 person NPV

Annual Cost No Bess	$
Typical No Solar	8061.99
Typical Controlled	2086.92

Discount rate	0.04
PV Cost	15000
Bess Cost	15000
Controller Cost PV	1500
Controller cost BESS	3000

NPV Controlled

N.B sum of (no solar-uncontrolled)i/(1+d)I over 10 years

Year	0	1	2	3	4	5	6	7	8	9	10
Initial Cost	33000										
Annual Cost		5975.07	5975.07	5975.07	5975.07	5975.07	5975.07	5975.07	5975.07	5975.07	5975.07
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value	33000	5745.256806	5524.285391	5311.812876	5107.51238	4911.069596	4722.182304	4540.559908	4365.922988	4198.002873	4036.541224
NPV Total	15463.15										

Payback Period	5.522951

LCOE	0.222683	$/kWh	22.26826842	c/kWh

N.B NPV total costs/NPV Energy over lifetime

NPV Energy

Year	0	1	2	3	4	5	6	7	8	9	10
Energy Produced		45103.05	45103.05	45103.05	45103.05	45103.05	45103.05	45103.05	45103.05	45103.05	45103.05
Discount Factor		1.04	1.0816	1.124864	1.16985856	1.216652902	1.265319018	1.315931779	1.36856905	1.423311812	1.480244285
Present Value		43368.31731	41700.3051	40096.44721	38554.27617	37071.41939	35645.59557	34274.61112	32956.35685	31688.80466	30470.00448
NPV Total	365826.1										