ATLANTIS PRESS
Atlantis Highlights in Engineering, volume 4
13th International Renewable Energy Storage Conference (IRES 2019)

Heat pump and thermal storage sizing with time-of-use electricity pricing

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***Abstract*—Heat pump and thermal storage sizing studies require modelling to ensure capital and operational costs are minimised. Modelling should consider added flexibility, e.g. grid services, sector coupling benefits, e.g. utilising excess wind production, and access to electricity markets, e.g. time-of-use tariffs. This paper presents a two-step methodology for sizing heat pump and thermal storage systems with a time-of-use electricity tariff. The first step is a modelling method for decentralised energy systems, with the broader aim of assisting planning-level design, and consists of resource assessment, demand assessment, electrical components, thermal components, storage components, and control strategies. The second step is a parametric analysis of heat pump and thermal storage size combinations. This is then applied to a sizing study for an existing residential district heating network including a time-of-use electricity tariff. The performance metrics: % of heat pump thermal output at low-cost period, % of heat demand met by heat pump, electricity import cost, and capital cost, were plotted and tabulated to compare sizing combinations. Graphs explore the operation of the heat production units and the thermal storage. Future development involving use of model predictive control and grid services, and alternative applications including operational planning and feasibility studies, are then discussed.**

Keywords*—*heat pump, thermal storage, community energy, energy modelling, smart energy systems, DSM

I. INTRODUCTION

Decentralised energy systems consist of energy production units and demand side management (DSM) enabling technologies co-located with demands [1]. For example, community energy systems in the UK may contain locally owned wind turbines which provide electricity to local customers, and heat generation units utilising local resource (e.g. biomass, local renewable generation) serving district heating networks. The implementation of these has been motivated by reducing imported energy costs, increasing self-reliance, reducing carbon footprints, and providing revenue streams via government subsidies and exported electricity. The development of such systems in the UK marks a shift from the historical means of delivering electricity from centralised fossil fuel power production plants and providing heating from gas via distribution infrastructure. Another emerging concept for the future is the smart energy system [2] which is decentralised, digitalised, and decarbonised. Additionally, the different energy sectors, namely power, heating, and transport, can be coupled to enable synergistic benefits [3].

Heat pumps are a mature technology which can contribute to this future by coupling the power and heat sectors. An example of sector coupling via heat pumps is the utilisation of excess wind power production. In remote communities there are often grid constraints which limit the potential for exporting from stochastic renewable generation and curtailment of wind may become prevalent in a future highly renewable-dependent national grid as production of wind power may not coincide with demands. Heat pumps provide an additional electrical demand which can utilise excess wind production if the demand and production coincides. A greater proportion can be used if this demand can be controlled flexibly.

Thermal storage can provide this flexibility to the heat pump demand. These can be cost-effective particularly when comparing hot water tanks and battery storage. Benefits of thermal storage in conjunction with heat pumps have previously [4] been identified: (i) enabling grid services such as frequency response and demand side response, (ii) shifting electricity consumption to low pricing with economy 7 (day/night) and time-of-use electricity markets, (iii) increasing local generation self-consumption, (iv) plant optimisation (reducing generating size and increasing usage), and (v) enhancing service and resilience.

Suitable controls are important to ensure that the benefits of heat pump and thermal storage systems are realised. Control methods have been categorised in literature [5] with four main classifications emerging: classical, hard, soft, and combination control methods. Studies have previously compared control strategies and have identified the advantages associated with the use of predictive controls [6]. Additionally, Model Predictive Control (MPC) has been highlighted as being a particularly useful class of predictive control [7] at improving economic and technical performance metrics (e.g. reduced imported electricity costs and increased thermal comfort). The methodology presented in this paper uses a fixed-order control strategy, including MPC will be a future development.

Different electricity tariffs can be accessed at various scales of demand. Historically domestic users in the UK have been limited to flat rate tariffs and day/night tariffs (economy 7). Due to the widespread adoption of smart meters which monitor demand usage in half-hourly timesteps, time-of-use tariffs can be accessed where prices vary on smaller timescales. The use of thermal storage can shift heat pump electrical consumption to cheaper periods with variable electricity tariffs.

Sizing heat pumps and thermal storage components correctly is a vital component in the design of decentralised energy systems. Classical sizing methods rely on estimating peak demands for a design day (i.e. coldest day) and sizing the primary unit to match this peak [8]. For hybrid systems typically the heat pump is sized to match base load and the auxiliary units are oversized to provide back-up and peaking capability. When including thermal storage another approach is to size the primary unit such that continuous output on the design day matches the demand for the design day, with the thermal storage sized to meet peaks. This approach may enable the thermal storage benefits of plant optimisation and enhancing service and resilience but do not enable the other benefits: grid services, shifting electricity consumption, and increasing local generation self-consumption.

The aim of this paper is (i) to present a method for sizing district-level heat pumps and thermal storage and (ii) to by applying the method to an existing residential district heating network to size a heat pump and thermal storage system with a time-of-use electricity tariff.

This paper first describes a methodology capable of performing sizing studies of heat pumps and thermal storage, within a decentralised energy system. It consists of two steps: 1) a modelling method for decentralised energy systems including heat pumps and thermal storage, and 2) a sizing method using parametric analysis. A description of the first step, the modelling method, is given in Section 2, and the second step, the sizing method, in Section 3. The sizing methodology is then applied to a case study, described in Section 4, to size the heat pump and thermal storage. Section 5 presents the operation graphs and results using performance metrics which allow quantification of the benefits. These results are discussed, and conclusions are outlined regarding future extensions and applications of the methodology in Section 6.

II. Modelling Methodology

The methodology for modelling decentralised energy systems has been developed in the Python language, with inputs via an Excel spreadsheet. The timestep is hourly and simulations are performed over a year. The methods used are described under the following sections: resource assessment, demand assessment, electrical components, thermal components, storage components, and control strategies. An overview of the modelled technologies and energy flows is provided in Figure 1. This work furthers gaps in planning-level modelling tools previously identified [9].

In brief, the modelling methodology consists of the following workflow. The resource assessment method is used to feed weather conditions and local ambient resource temperatures into the wind turbine, PV, hot water tank and heat pump models as well as the district heating demand predictor. The demand assessment method is used to develop the district heating demand profile and the local electrical demand. The renewable production is then subtracted from the electrical demand to produce an electrical deficit/surplus profile. The district heating demand profile, electrical deficit/surplus profile, auxiliary electrical production models, thermal production models, storage models, and electricity tariff are all fed into the fixed-order controller which determines the use of supply and storage ensuring electrical and thermal demands are met, self-consumption of local renewable generation is maximised, and storage is charged during low-cost import periods. Further details are in [10].

A. *Resource assessment: Weather resources and heat pump source temperatures*

Resource assessment methods are used for extracting weather data and inputting heat pump source temperatures. The MEERA reanalysis hourly dataset including direct and diffuse solar radiation, windspeed, air temperature, etc. can be accessed via the website renewables.ninja. This can be compared against local weather station data for the available time periods and calibrated.

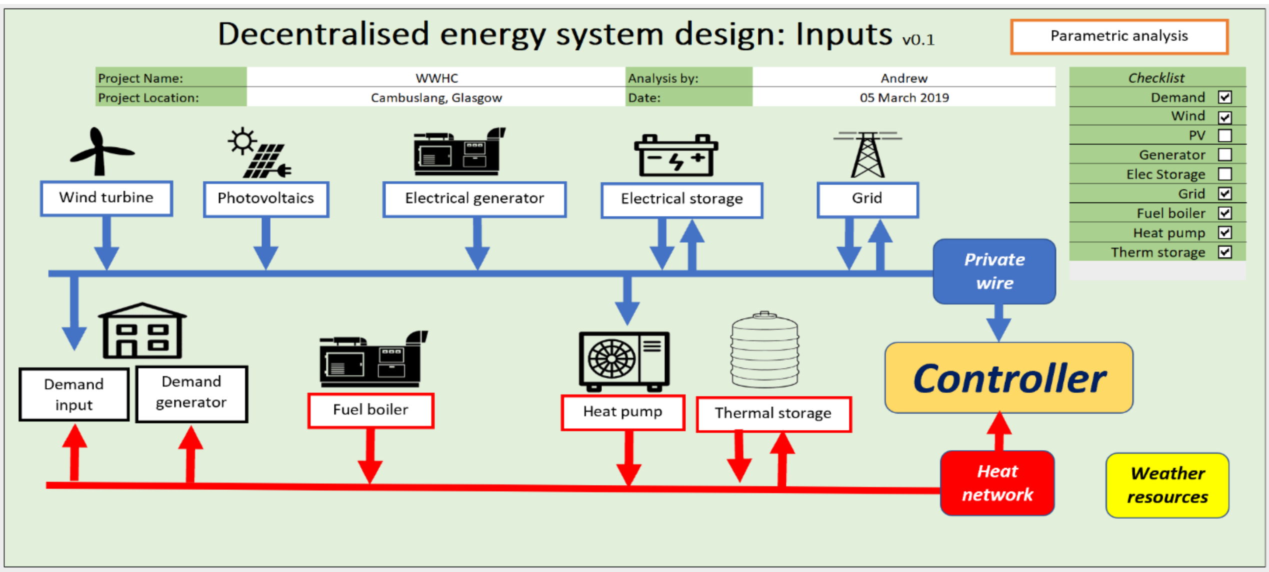

Figure 1: Modelling components and energy flows

B. Demand assessment: District heating and electrical demand profiles

Demand assessment methods are used for developing electrical and district heating demand profiles. Monitored data can be used to produce demand profiles, but these are not always readily available, or the system may still be at the design stage. Electrical demand profiles on an hourly timestep are generated using HOMER Pro software. This software contains a module which generates a profile based upon building types: residential, commercial, industrial or community. District heating demand profiles are generated in hourly timesteps using a method which uses regression analysis of pre-simulated housing standard profiles, scaling based on floor area, and applying diversity using a normalised smoothing method. This method is applicable to residential areas. Both methods use simple inputs available at the planning-level design stage.

C. Electrical components: Wind turbines, PV, auxiliary electrical generator, and grid

The electrical production technologies modelled are wind turbine and photovoltaics (PV) as primary units, and an electrical generator as an auxiliary unit. It is assumed that these can directly meet the local electrical demand via a (virtual-) private wire network. An optional grid connection provides limitless import and export. Renewable electricity production technologies are modelled to analyse how they match with the electrical demand, in addition to investigating sector coupling by utilising local, zero marginal cost electricity production in heat pumps.

Windpowerlib is a Python library which contains functions and classes for calculating the power output from wind turbines and PV is modelled using the PVLIB Python library which consists of a module and an optional inverter, and the power output is dependent on location inputs. The outputs are power produced for both the wind turbine and PV in hourly timesteps.

Costs can be assigned to electricity imported and exported from the grid. Flat rate tariffs are the simplest use fixed, static prices for both imports and exports. Two-tier tariffs have separate import and export prices depending on the time of day, e.g. economy 7 in the UK is a commonly used tariff with separate prices for day and night. Time-of-use tariffs have prices which are variable in half-hourly timesteps and have historically been accessed through the wholesale market (which can be accessed via a virtual power plant (VPP) platform, or with a smart meter). Historical APX half-hourly electricity spot market can be used as representative of a time of use pricing market.

Currently, several grid services contracts and markets are available to energy assets in exceedance of a minimum power requirement. Modelling requirements are the notice period, minimum/maximum duration, contracted periods, power requirement, and income. Current UK grid services include (i) Balancing mechanism: half-hourly market available for procuring services to balance the grid, (ii) Capacity market: contracted supply for grid stress events or balancing services, and continuous commitment with 4-hour notice period, (iii) Fast frequency response (FFR): used to stabilise the frequency of the grid with 30 second or sub-10 second notice periods, (iv) Short term operating reserve (STOR): generating or demand reduction capacity with requirements: maximum notice of 2 hours (less than 20 minutes preferred), minimum 3MW of response, and minimum committed duration of 2 hours. These services are described here to inform future development of the methodology but does not form a part of the methodology applied to the case study later.

D. Thermal components: Heat pump and auxiliary fuel boiler and electric heater

The thermal production technologies modelled are large-scale heat pumps as primary units, and fuel boilers or electric heaters as auxiliary units. These are used to provide space heating and hot water for use in a heat network.

The heat pump model is applicable for large-scale with capacity > 100kW. Air source heat pumps (ASHP) require additional consideration with respect to the defrost cycles which effect performance in temperature and humidity regions where freezing conditions are possible. Water source heat pumps (WSHP) are assumed to have a constant flow or limitless supply of ambient water, meaning that there is no degradation of the source temperature.

The approach is based on multiple variable linear regression analysis using measured COP and duty (maximum thermal output) at a range of standard test conditions. Ambient temperature and flow temperature are used as the two independent variables and part load effects on COP for variable speed heat pumps are neglected. Predictions for the COP are made in each of the timesteps using the underlying analysis and the flow and ambient temperatures.

E. Storage components: Battery storage and hot water tanks

Storage models for battery storage and hot water tanks are employed to investigate DSM strategies. Battery storage was chosen as it is currently the most commonly used form of electrical storage and has many potential applications. A simple battery model is used which captures the essential technical parameters: capacity, initial state, max charging/discharging, efficiency charging/discharging, min/max state of charge, and self-discharge.

Hot water tanks provide a cost-effective form of short to mid-term (from minutes to days) thermal storage, particularly when used at scale for district heating, and in comparison, to battery storage. They are modelled as a water filled cylinder which is vertically orientated with an outside shell of insulation. The tank is configured using a 4-port connection and the use of 5 temperature sensors, in accordance with CIBSE guidance for district heating design. A multi-node model was chosen to represent stratification.

F. Control strategies: Fixed order control

The fixed order control uses a pre-defined set of rules to order of the dispatch of supply and determine the usage of storage. This control is used to represent a classical controller which use fixed setpoints for components (e.g. thermal storage temperature setpoint) to provide on/off and PID output responses. Flow diagrams detailing the logic for when there is an electrical deficit or electrical surplus are shown in Figure 2. Electrical surplus is where local renewable generation is higher than electrical demand, and electrical deficit is where local renewable generation is lower than electrical demand.

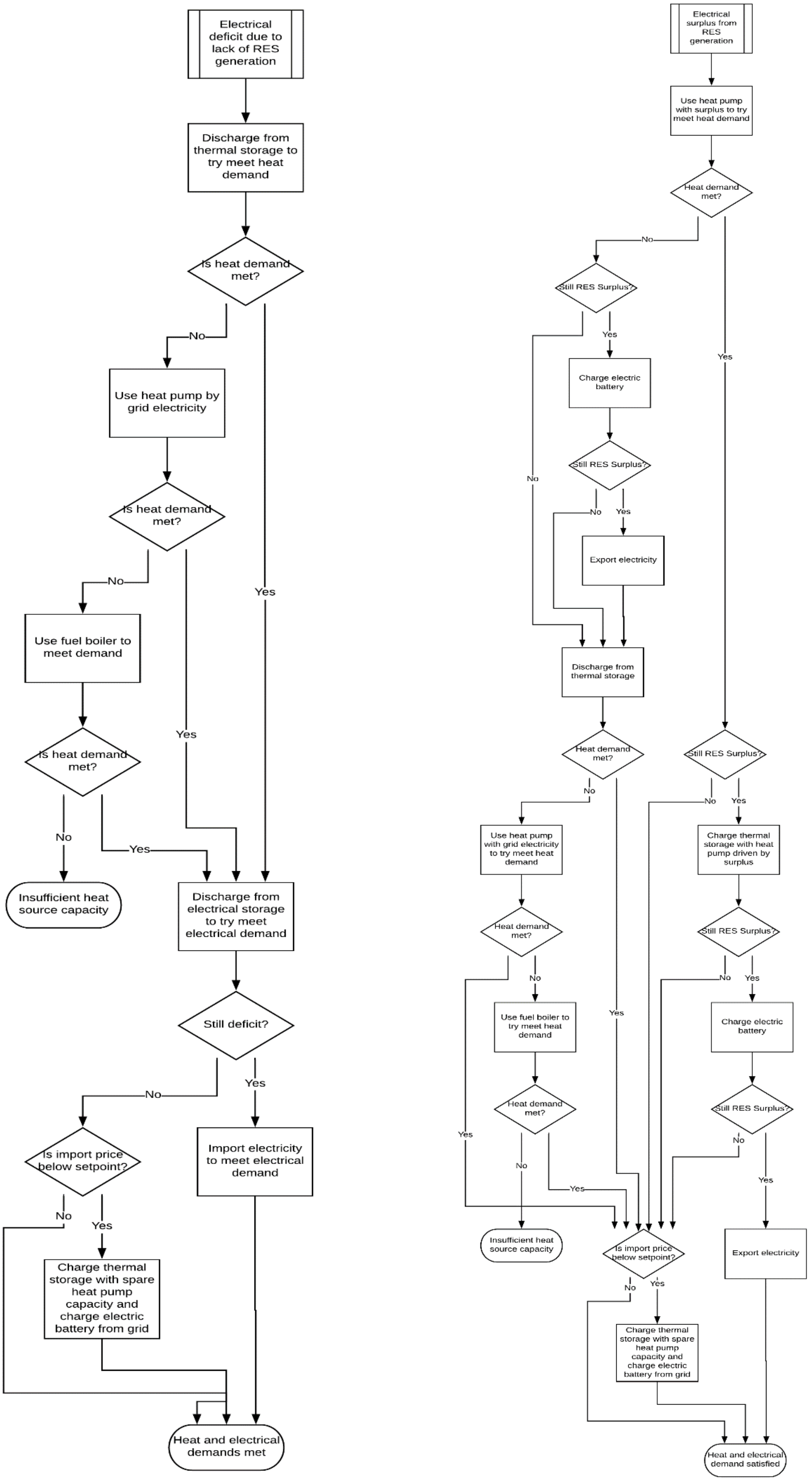

Figure 2: Fixed order controller flow diagrams for (i) left for electrical deficit, and (ii) right for electrical surplus

III. Sizing step

The sizing step consists of parametric analysis of the thermal storage and heat pump sizes. This automates the task of running multiple simulations while varying the volume of the hot water tank or the maximum thermal output of the heat pump. The range of values to include in this task is user input.

Performance metrics were chosen to compare the sizing results: % of heat pump thermal output at low-cost period, % of heat demand met by heat pump, electricity import cost, and capital cost of the heat pump and thermal storage. The low-cost period is when local renewable electricity or imports below the setpoint supply the heat pump. Capital costs have been sourced from the Danish Energy Agency [11] for large-scale heat pumps at £590/kW and for large-scale hot water tanks at £270/m^3.

IV. Residential district heating scheme

The developed sizing methodology was applied to a case study of an existing residential district heating system. The aim was to identify suitable size combinations of heat pump and thermal storage operating with a time-of-use electricity tariff. Graphical results are presented for the heat production units meeting demand, the electrical usage of the heat pump, electricity production, and the charging/discharging of the thermal storage. Numerical results of the performance metrics are tabulated and plotted in 3D graphs to compare between the different sized heat pump and thermal storage combinations.

A. Existing residential district heating scheme

West Whitlawburn Housing Co-operative (WWHC) is a fully mutual, tenant owned and controlled Housing Co-operative with charitable status, located in the south of Glasgow in Cambuslang, South Lanarkshire. It is an area of multiple deprivations and it was an aim to provide affordable, sustainable, and community energy to the households. They own and manage 644 properties: 432 multi-storey flats, 112 low-rise tenement flats, and 100 houses. Previously heat was supplied via electric storage and panels heaters in the individual dwellings. Due to the build construction types of the multi-storey and low-rise tenement flats gas heating could not be installed. These properties have had fabric upgrades including building, windows, and roofs. The largest investment was the addition of substantial external cladding to the multi-storey flats.

To tackle the rising problem of fuel poverty in the community alternatives to the inefficient electric heaters were sought. Therefore, a biomass district heating system was installed with a centralised energy centre supplying domestic heat and hot water to 544 of the dwelling dwellings via a district heating network. To improve performance of the biomass boiler thermal storage was included. A 740kW Viessman Pyrotec biomass boiler operates as the primary heat source and is connected in parallel to a 50 m^3 hot water tank. 3x 1.2 MW gas boilers were included to contribute to large peaks in demand during winter and provide back up in the event of a breakdown or maintenance of the biomass boiler.

There is concern around sustainability and air pollution issues related to the burning of wood for domestic heating [12]. Additionally, biomass may have a pivotal role to play in the wider energy system in decarbonising difficult sectors such as high-temperature industry and heavy transportation

Figure 3: West Whitlawburn view from above

[13]. From this holistic view of the wider energy system it is worthwhile exploring design options incorporating heat pumps as the primary heat source in residential district heating schemes such as WWHC.

B. Proposed heat pump and thermal storage system

As an alternative to the current design at WWHC it is proposed that an air-source heat pump and thermal storage system plus back-up electric heat with a connection to wind power generation and participating in a time-of-use electricity tariff can offer a low-carbon and low-cost provision of heat.

The following unit specifications were modelled using the above methodology, including graphs of preliminary results:

1) Resource assessment

Weather data – MEERA reanalysis hourly dataset for 2017 for wind speed (10m). Air temperature was collected using local sensors for 2017 for air temperature.

2) Demand assessment

Heating demand – existing hourly monitored data for the year 2017. Figure 4 displays the year profile and Figure 5 displays an example summer and winter day.

Electrical demand – generic community electrical demand profile synthesised in HOMER Pro. Figure 6 displays the year profile and Figure 7 displays an example summer and winter day.

3) Electrical components

Wind turbine – 2x 225kW Vestas V29 wind turbines. Figure 8 displays a bar chart of figures for monthly output, including the year output, and Figure 9 displays example summer and winter weeks.

Grid connection –Time-of-use tariff of half-hourly import prices from the APX electricity market for 2017 and an import set price of £30/MWh. Figure 10 displays an example week including the import setpoint.

4) Thermal components

Heat pump – Star Refrigeration Air Source Heat Pump (ASHP) Neatpump with variable speed compressor and 70/60 water temperature in/out (DH network 60/40 flow/return temperatures), and air ambient source. The regression curves are displayed in Figure 11, heat pump duty vs. ambient temperature, and figure 12, COP vs. ambient temperature.

Backup heat – electric heater with 100% efficiency.

5) Storage components

Thermal storage – generic hot water tank with specifications given in Table 1.

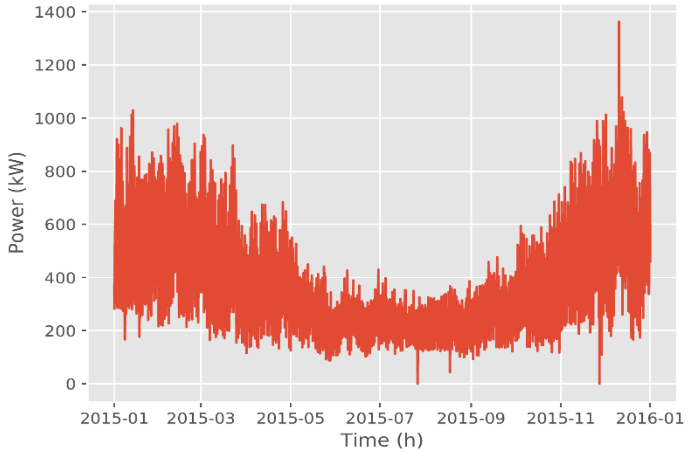

Figure 4: Heat demand profile over year

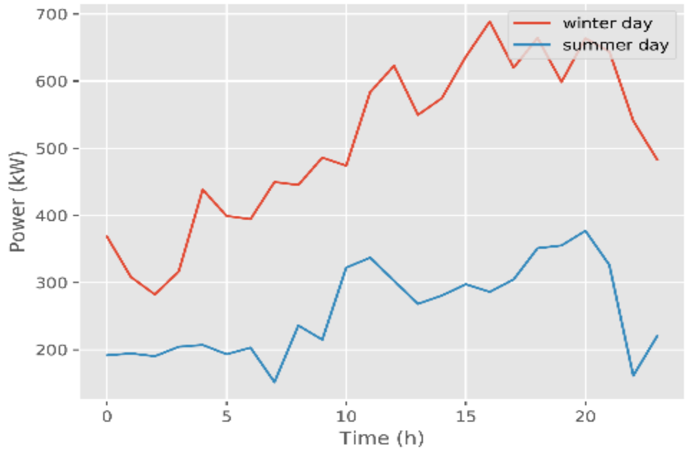

Figure 5: Heat demand profile for example winter and summer days

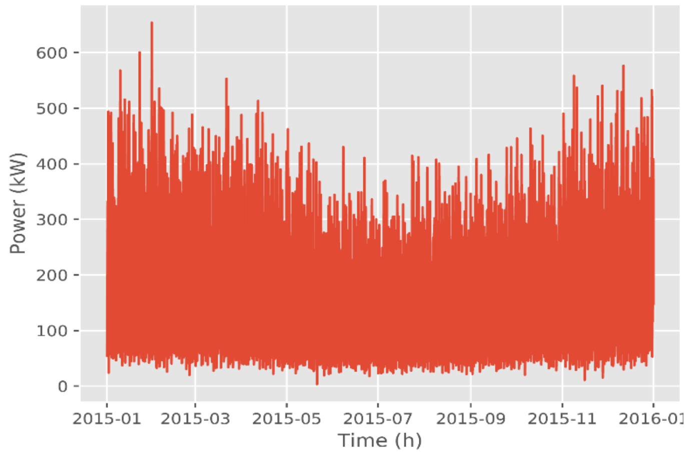

Figure 6: Electrical demand profile over year

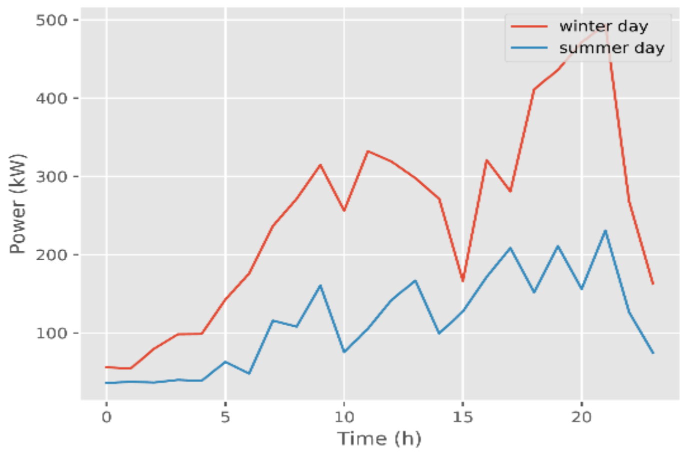

Figure 7: Electrical demand profile for example winter and summer days

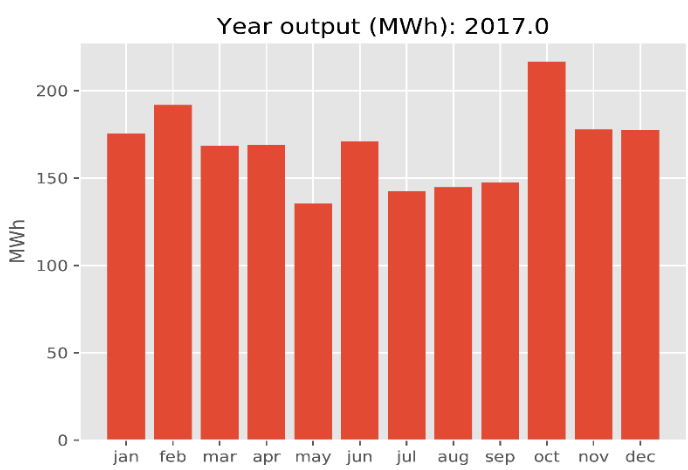

Figure 8: Wind power output for each month and output for year

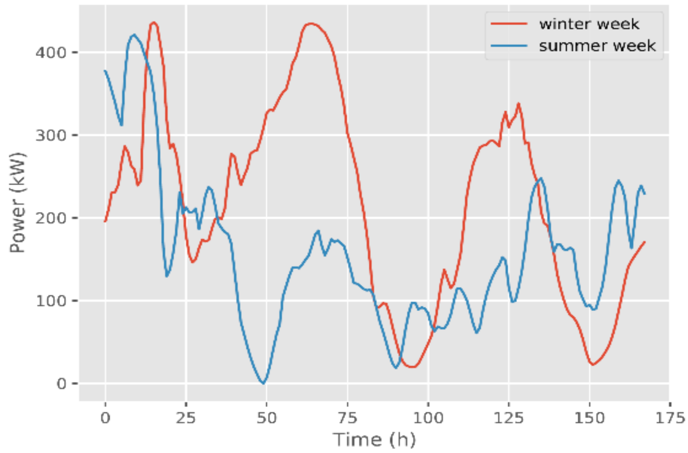

Figure 9: Wind power output for example winter and summer weeks

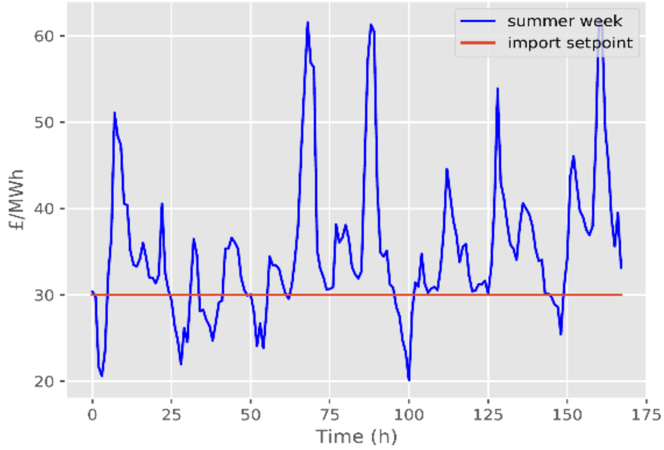

Figure 10: Time-of-use electricity tariff for a summer week including import setpoint

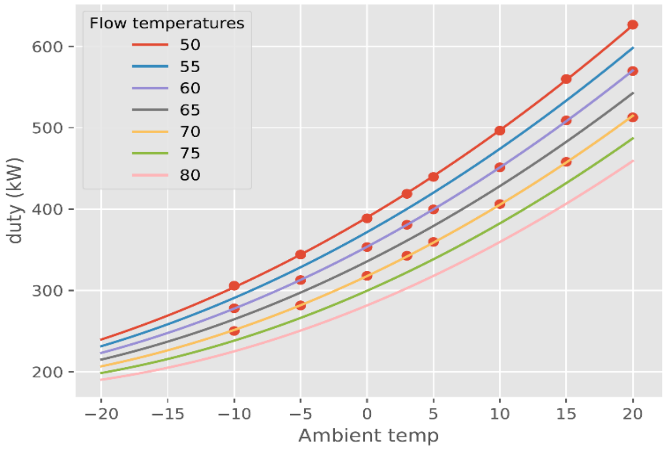

Figure 11: Regression analysis for heat pump duty vs. ambient temperature

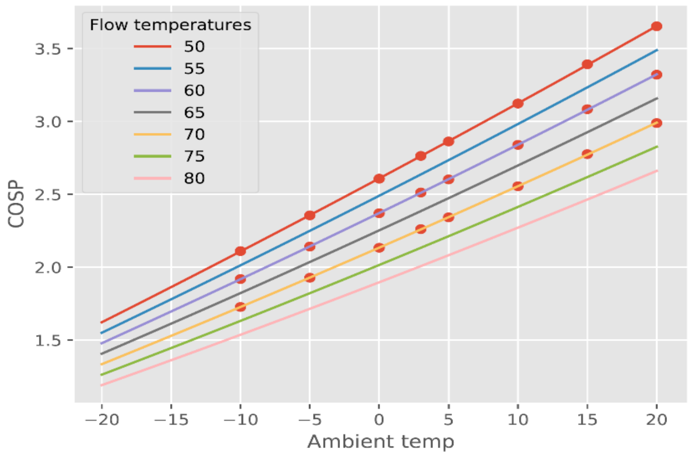

Figure 12: Regression analysis for COSP vs. ambient temperature

C. Validation

Before exploring the main sizing results an example using the same proposed system but with a day/night tariff is simulated to validate the modelling steps and in particular the logic of the fixed order controller. This logic can be difficult to ascertain when using the time-of-use tariff which varies

Table 1: Thermal storage inputs

Capacity (L)	10000
Insulation	Polyurethane
Location	Inside
Number of nodes	5
Height - l (m)	5
Total width - do (m)	2
Insulation thickness - δ (m)	0.25
Tank opening (#)	5
diameter (mm)	35
Uninsulated connections (#)	0
diameter (mm)	35
Insulated connections (#)	2
diameter (mm)	50.8

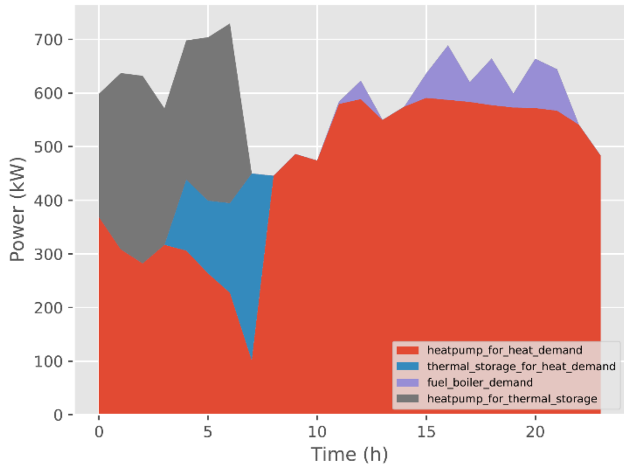

Figure 13: Stacked heat pump output and thermal storage discharge for one day in winter

hourly. The tariff has off-peak prices (£50/MWh) from 00:00 to 07:00 and peak prices (£100/MWh) the rest of the day.

Figure 13 shows the stacked heat pump output and thermal storage discharge for one day in winter. For the off-peak hours from 00:00 to 07:00 the heat pump meets demand and charges the thermal storage, while the thermal storage discharges when there is insufficient RES to supply heat pump. After 07:00 the thermal storage discharges to replace heat pump output, the heat pump modulates to meet demand when the thermal storage is empty, and the back-up electric heater meets the peak in demand when the heat pump reaches maximum output and can't meet demand.

This allows the heat pump to operate more in low-cost periods, but this operation is not optimised to minimise operation costs. If the controller could predict ahead that there would be a need for the back-up heater then it could discharge the thermal storage later. Additionally, the thermal storage could discharge after the off-peak period to maximise the heat pump operation there. This highlights the need for predictive control and the complicated nature of a rule-based fixed order controller.

V. Operation and Sizing Results

Different size combinations of heat pump and thermal storage capacities were analysed for the proposed WWHC system. Graphs show typical weeks of the operation of heat production units, the heat pump electrical usage, electricity

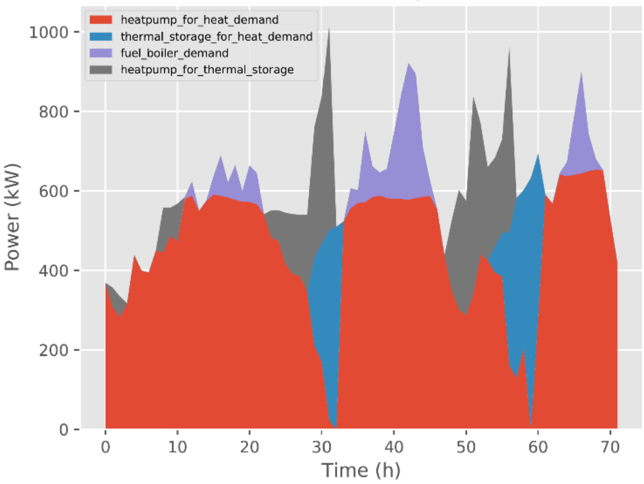

Figure 14: Stacked heat production to meet heat demand for example 3 days in winter

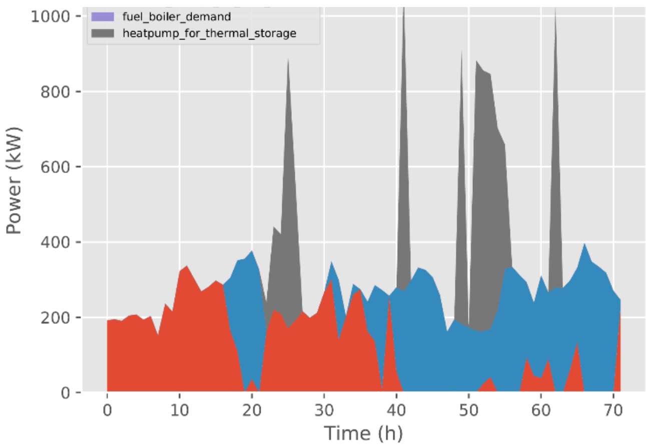

Figure 15: Stacked heat production to meet heat demand for example 3 days in summer

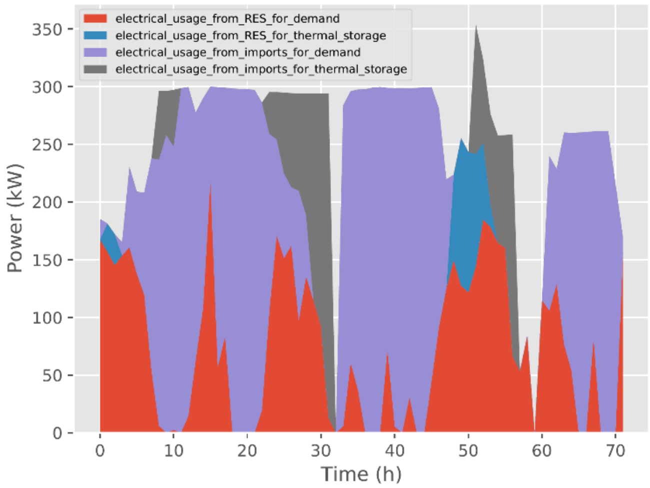

Figure 16: Stacked heat pump electricity usage for example 3 days in winter

production, and the thermal storage node temperatures. 3-D plots are then presented of the different size combinations of heat pump and thermal storage along with the performance metrics. The following graphical results analysis are based upon the size combination of an 600kW ASHP and 150m^3 hot water tank.

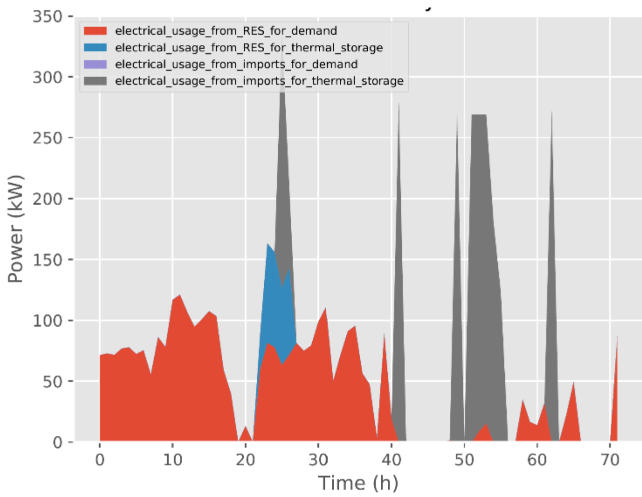

Figure 17: Stacked heat pump electricity usage for example 3 days in summer

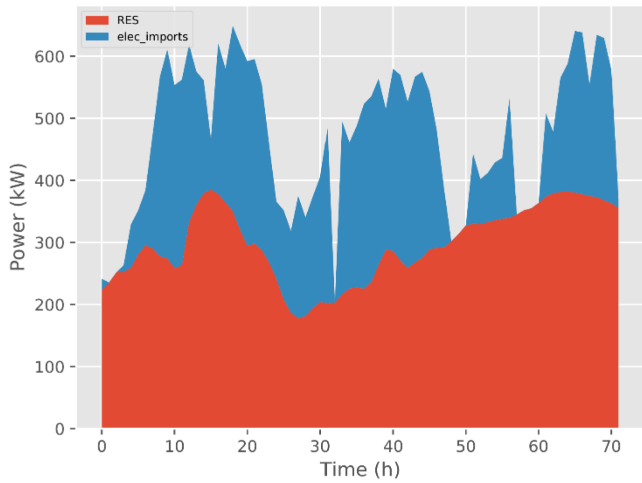

Figure 18: Stacked electricity production for example 3 days in winter

Figures 14 and 15 are stacked graphs for 3-day periods in winter and summer of the heat production units, from bottom: (i) heat pump thermal output to heat demand, (ii) heat pump thermal output to thermal storage, (iii) thermal storage output to heat demand, and (iv) electric heater thermal output.

In the example period, in the winter due to higher demand the electric heater meets some of the demand, whereas in the summer in the example they are not required. This is reflected in a high import of electricity for use by the heat pump. The heat pump will meet demand using renewable generation when there is local wind production, and it will store heat when there is excess renewable electricity. This allows the storage to meet demand during low wind production.

Figures 16 and 17 are stacked graphs for example 3-day periods in winter and summer of the electrical usage of the heat pump, from bottom: (i) local wind generation used by heat pump, (ii) thermal storage charged by heat pump using local wind generation, (iii) grid imports for heat pump to meet demand, and (iv) grid imports to charge thermal storage with import price below setpoint.

In the winter there are sizeable periods where imports are required to cover the heat demand. In the summer it can be seen the heat pump is required to run less and a large spike in

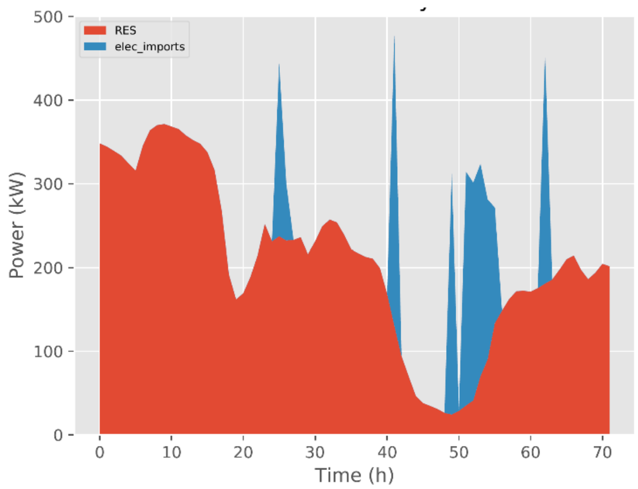

Figure 19: Stacked electricity production for example 3 days in summer

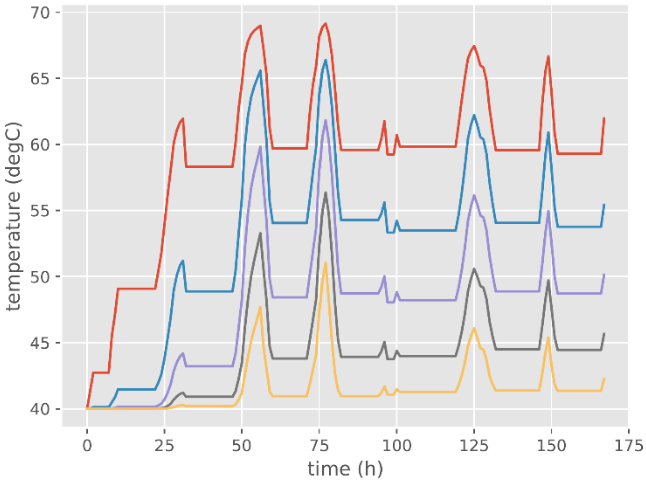

Figure 20: Hot water tank node temperatures for example 3 days in winter

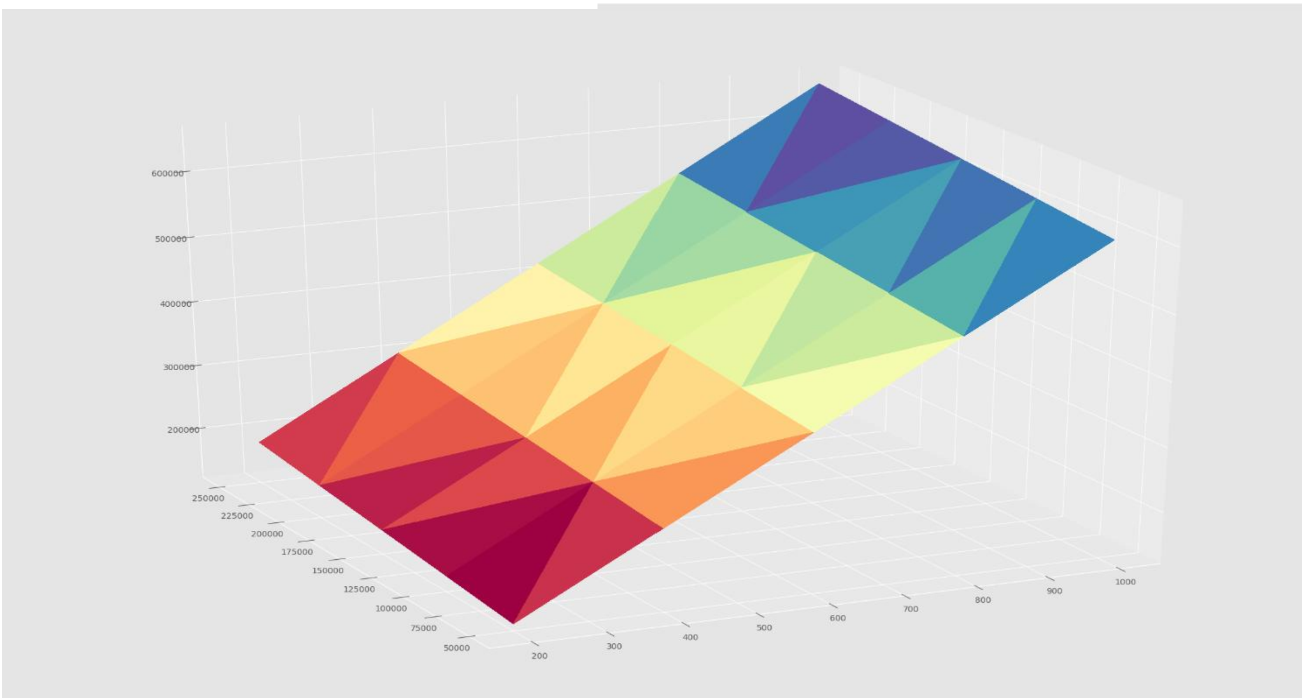

Figure 21: Plot of capital cost of heat pump and thermal storage vs. heat pump sizes vs thermal storage sizes

local wind production can be fill the thermal storage to meet the heat demand later.

Figures 18 and 19 displays stacked electricity generation of the local renewable generation and imports. There is a larger requirement for imports during the winter, even with a higher renewable generation during this season. This is due to the larger seasonal electricity demand and heat demand with the heat pump using more electricity.

Figure 20 shows the changing temperatures of the 5 nodes of the hot water tank as it is charged and discharged during an example winter day. Table 2 contains the numerical outputs based on the performance metrics which were chosen to provide a quantification of the benefits of different sizing combinations and comparison between the options. Graphs 21, 22, 23 and 24 are 3-D visualisations of the performance metrics to offer further insight into deciding on a size combination.

VI. Discussion and Conclusions

The sizing methodology has proved capable of producing a range of outputs regarding the performance of different size combinations for the WWHC case study. More detailed financial analysis, such as NPV calculations, will allow decisions to be made based upon the specific requirements of the planners, and the optimal sizing combination to be chosen.

There is value in utilising thermal storage to minimise the size of heat pump installed. A larger thermal storage can result in a higher % low-cost electric heat pump consumption. The thermal storage is charged by the heat pump using excess renewable generation and low-import cost such that in later periods where there is a lack of renewable generation or higher tariff cost the thermal storage can cover these periods. There can be a reduction in electricity import cost if the thermal storage displaces some of the back-up heating.

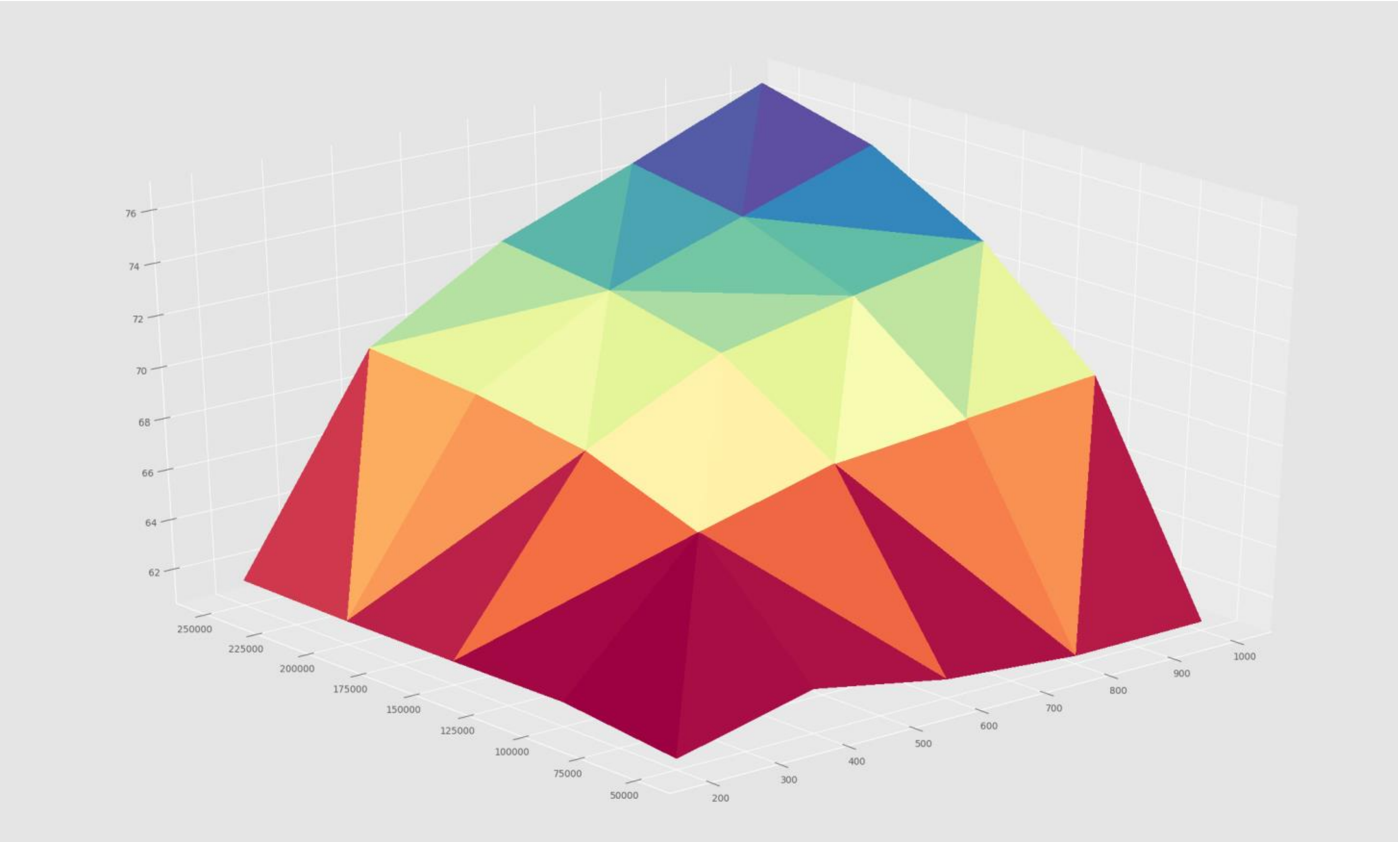

Figure 22: Plot of % low-cost electric heat pump consumption vs. heat pump sizes vs thermal storage sizes

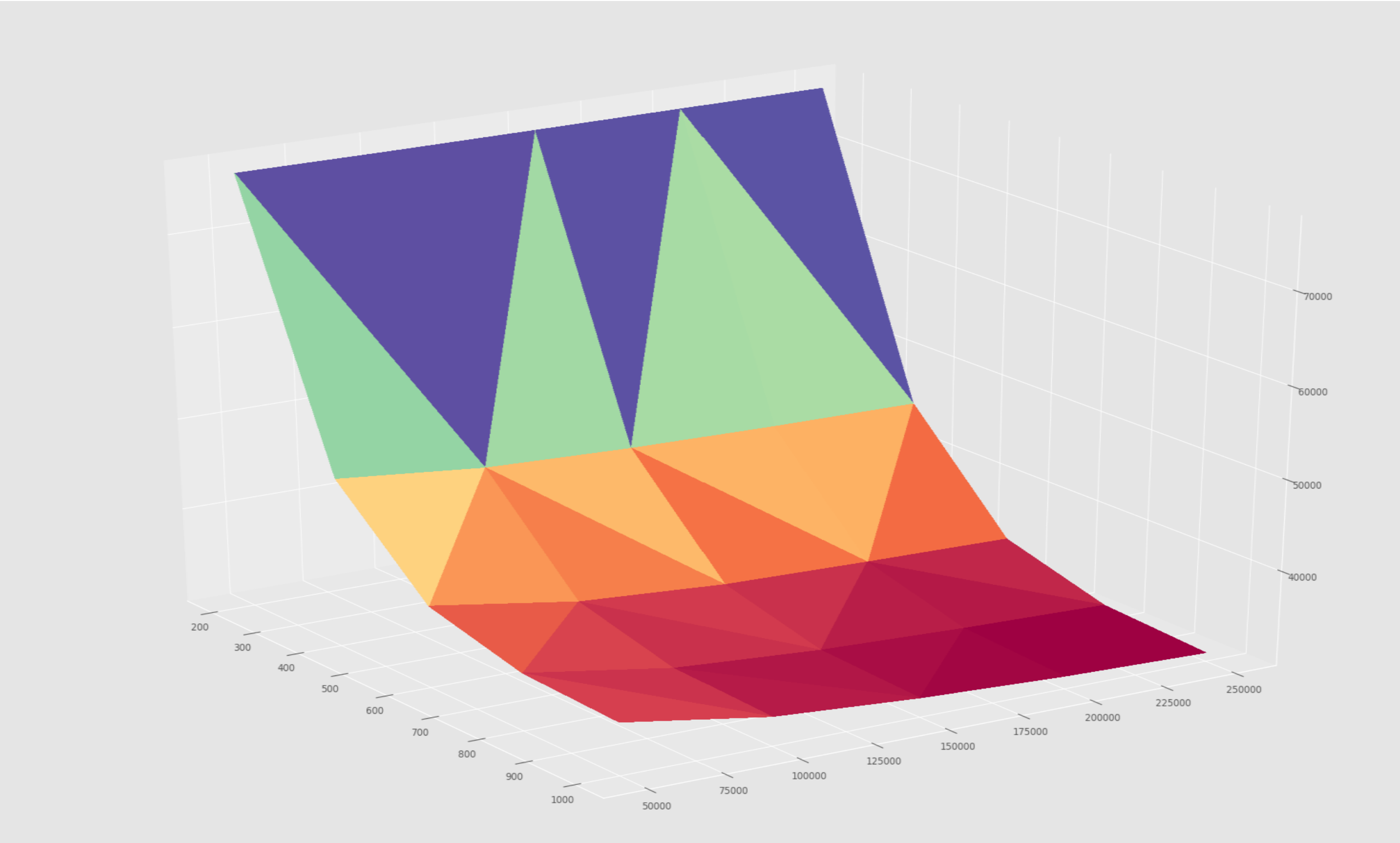

Figure 23: Plot of import costs vs. heat pump sizes vs thermal storage sizes

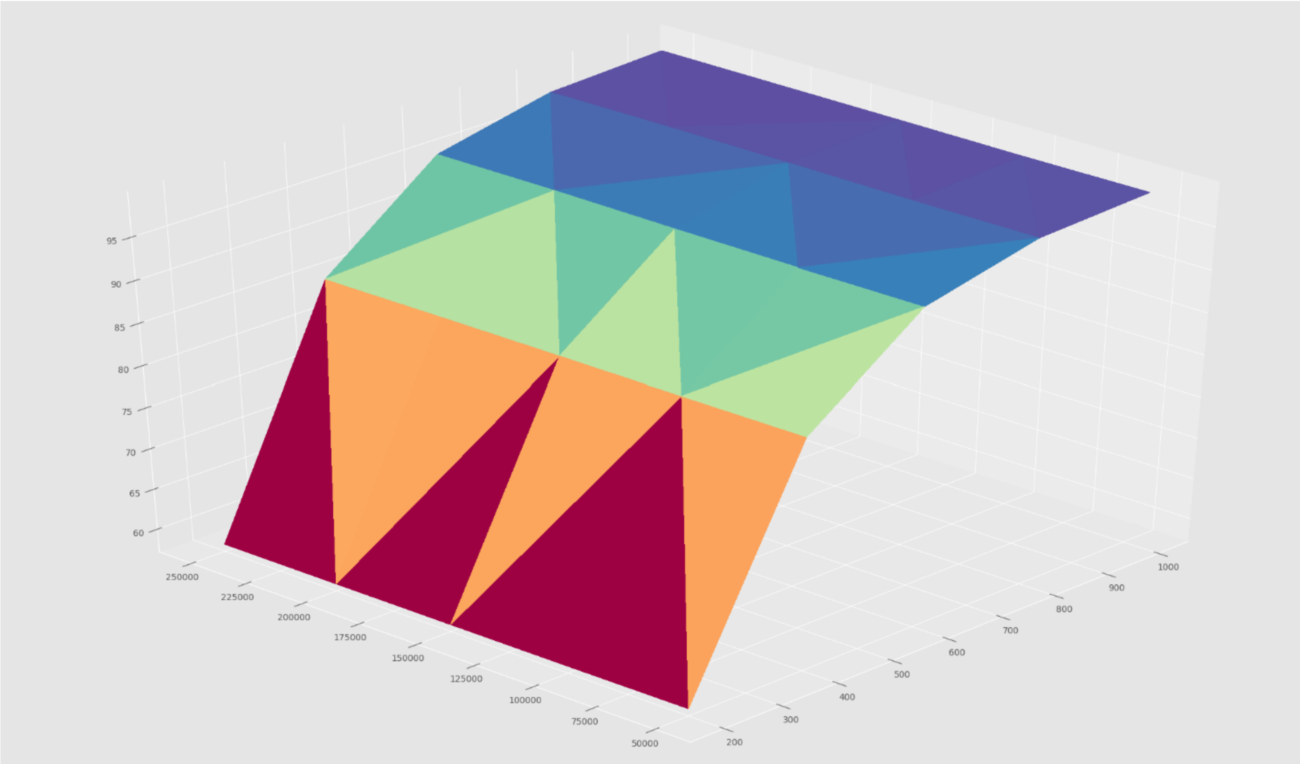

Figure 23: Plot of % of heat demand met by heat pump vs. heat pump sizes vs thermal storage sizes

With the use of a variable tariff, the fixed order controller can ensure that imports are made when costs are low such that the thermal storage can cover periods of higher import prices. However, the fixed order control strategy is limited in its ability to store at periods of low import cost and relies on a user input price setpoint. If the controller knows the prices of imports in a lookahead period, then it would be possible to reduce the periods of importing electricity at high prices.

A Model Predictive Controller (MPC) would further enable the benefits of a time-of-use tariff by implementing optimisation algorithms along with demand and weather forecasts to schedule operation such that import costs are reduced and local renewable generation usage is increased. This should result in greater value of the thermal storage. The MPC control strategy will be implemented into the modelling methodology as part of future development.

An emerging market for decentralised energy resources is grid services. Designing heat pump and thermal storage systems with access to the revenue of providing grid services included, allows for additional revenue, thus increasing the feasibility of implementing heat pump and thermal storage systems in future district heating networks. Inclusion of these markets is a future step in the development of the modelling methodology.

In conclusion, this paper has presented a method capable of sizing district-level heat pumps and thermal storage and applied this method to an existing residential district heating network to quantify performance metrics which can inform design decisions on selecting heat pump and thermal storage size combinations. Future improvements to this methodology include Model Predictive Control (MPC) and grid services. In addition, the modelling methodology can be utilised to perform feasibility studies and produce operational schedules.

Table 2: Performance indicators for each of the sizing combinations

Combo (HP+TS)	Low-cost HP (%)	HP demand (%)	Capex (£)	Opex (£)
200+50	61.0	58.5	£131,500	£76,859
200+100	61.6	58.5	£145,000	£76,778
200+150	61.5	58.5	£158,500	£76,772
200+200	61.5	58.5	£172,000	£76,792
200+250	61.6	58.5	£185,500	£76,810
400+50	62.4	85.9	£249,500	£48,106
400+100	66.9	86.1	£263,000	£46,547
400+150	68.5	86.2	£276,500	£45,957
400+200	69.3	86.2	£290,000	£45,670
400+250	69.6	86.2	£303,500	£45,531
600+50	61.4	96.1	£367,500	£38,562
600+100	68.4	96.3	£381,000	£36,045
600+150	71.0	96.3	£394,500	£34,993
600+200	72.1	96.3	£408,000	£34,607
600+250	72.7	96.4	£421,500	£34,316
800+50	60.9	99.2	£485,500	£35,865
800+100	68.7	99.3	£499,000	£33,323
800+150	72.1	99.3	£512,500	£32,256
800+200	73.8	99.3	£526,000	£31,656
800+250	74.6	99.3	£539,500	£31,249
1000+50	61.0	99.9	£603,500	£35,355
1000+100	69.2	99.9	£617,000	£32,794
1000+150	73.1	99.9	£630,500	£31,687
1000+200	75.5	99.9	£644,000	£30,963
1000+250	76.7	99.9	£657,500	£30,517

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