# Inputs

*Table 1: Inputs*

| Key | Description | Value | Units |
|---|---|---|---|
| loadSchedule | Schedule of loads | [object Object], [object Object], [object Object] | |
| nBuildings | Number of buildings | 1 | buildings |
| tPeak | Peak network flow temperature | 65 | °C |
| hHighPoint | System height | 30 | m |
| supplyCWS | CWS Supply | boosted in plantroom | |
| tPriRtnDHW | DHW network return temperature | 19 | °C |
| profileDHW | DHW load profile | EST | |
| typeEmitter | Central heating emitter | underfloor | |
| connectionCH | Central heating connection | indirect | |
| tXPeak | External temperature at peak load | -5 | °C |
| tPriRtnCH | Central heating network return temperature | 35 | °C |
| divCH | Central heating diversity | 70 | % |
| baseTemp | Base temperature | 16 | |
| degDaysAvg | Central heating degree-days | 1749.5, 1884.5, 2023.9, 2167.9, 2316.2, 2467.9, 2623.5, 2782.4, 2944.3, 3108.6, 3275.4, 3444.9, 3615.7 | °days |
| degDays | Central heating degree-days at base temperature | 1850 | °days |
| goBoilers | Boilers | true | |
| goASHP | Air Source Heat Pumps | true | |
| goHN | External Heat Network Supply | true | |
| goWSHP | Water Source Heat Pumps | false | |
| goReclaim | Cooling Source Heat Pumps | false | |
| goCHP | Combined Heat & Power | false | |
| goSolar | Solar Thermal | false | |
| boilerFuel | Boiler fuel type | gas | |
| boilerEmissions | Boiler Emissions | 0.216 | kgCO2/kWh |
| listBSizes | Available boiler outputs | 30, 50, 75, 100, 250, 500, 750, 1000 | kW |
| selectBoilers | Boiler selection | 4 x 250 | n x kW |
| tariffHP | Electrical Tariff | flat | |
| elecEmissions | Electrical Supply Emissions | 0.233 | kgCO2/kWh |
| substationType | Substation Type | twin | |
| fridgeASHP | ASHP refrigerant | R744 | |
| listASHPSizes | Available heat pump outputs | 40 | kW |
| selectASHP | ASHP selection | 1 x 40 | n x kW |
| vBuffer | Buffer volume | 2000 | litres |

*Table 1: Inputs (continued)*

| | | | |
|---|---|---|---|
| networkTempValve | Network temperature control valve | false | |
| pipeSizes | Schedule of pipes sizes | [object Object], [object Object], [object Object], [object Object], [object Object], [object Object], [object Object], [object Object], [object Object], [object Object], [object Object], [object Object] | |
| maxVelocity | Flow pipe sizing maximum velocity | 1.5 | m/s |
| minVelocity | Return pipe sizing minimum velocity | 0.5 | m/s |
| allowPipeDiff | Allow different flow and return pipe sizing | true | |
| goSave | Save design | false | |

# Calculations

*Table 2: Calculations*

| key | Description | Value | Units |
|---|---|---|---|
| pPP | Average people per property | 3 | people |
| density | Average people per building (density) | 60 | people |
| kwDHWEst | Typical HIU rating for DHW | 45 | kW |
| peepDS439 | People per standard DS439 property | 2.3 | people |
| eqPropDS439 | Equivalent number of DS439 properties | 26.086 | properties |
| kwDS439 | Peak DHW Load | 145 | kW |
| vPPEST | Volume DHW used per property per day | 40 | litres |
| vPHEST | Volume DHW used per person per day | 28 | litres |
| tRiseEST | Average temperature Rise on DHW | 35 | °C |
| vDHWEST | Volume drawn per day for DHW (tap) | 2480 | litres |
| kwhDHWEST | Energy used per day for DHW | 101.266 | kWh |
| vPDHW | Volume used per day for DHW (primary) | 1886.956 | litres |
| vBuffer9 | Buffer Storage for DHW (based on 9%) | 169.826 | litres |
| kwCH | Peak diversified (steady state) central heating load | 56 | kW |
| kwhCH | Energy used per day for CH | 1344 | kWh |
| vPCH | Volume used on peak load day for CH (primary) | 38400 | litres |
| kwhP24 | Peak energy used per day | 1445.266 | kWh |
| vP24 | Peak volume used per day (primary) | 40286.956 | litres |
| kwPeak | Peak load | 201 | kW |
| kwP24 | Average 24h peak load | 60.219 | kW |
| m3hDHWPeak | Primary flow rate at peak DHW load | 2.701 | m3/h |
| m3hCHPeak | Primary flow rate at peak central heating load | 1.599 | m3/h |
| m3hPeak | Primary flow rate at peak load | 4.3 | m3/h |
| tPriRtnPeak | Primary return temperature at peak load | 24.933 | °C |
| tVWART24 | Weighted primary return temperature on peak load day | 34.25 | °C |
| bufferkWh | Buffer storage peak energy content | 93.489 | kWh |
| boilerQty | Boiler quantity | 4 | boilers |
| boilerkW | Boiler unit power | 250 | kW |
| boilerkWPeak | Boiler peak power (n) | 1000 | kW |
| boilerkWxN1 | Boiler power (n-1) | 750 | kW |
| ASHPQty | ASHP quantity | 1 | ASHPs |
| ASHPkW | ASHP unit power | 40 | kW |
| ASHPkWPeak | ASHP peak power (n) | 40 | kW |
| ASHPkWxN1 | ASHP power (n-1) | 0 | kW |
| kWInPeak | Peak power available from all sources | 1040 | kW |
| kWxN1 | Peak power available from (n-1) sources | 790 | kW |
| sparekW | Excess power availiable (n) | 979.781 | kW |
| oversizing | Oversizing (n) | 1627.029 | % |

*Table 2: Calculations (continued)*

| | | | |
|---|---|---|---|
| ovsersizingN1 | Oversizing (n-1) | 1211.878 | % |
| dDaysCalc | Calculated degree days per year | 1749.5 | °days |
| dDaysPeak | Peak load day degree days | 21 | °days |
| eqDaysPeak | Annual days of full load heating | 83.309 | days |
| kwhCH365 | Annual energy for central heating | 28224 | kWh |
| kwhDHW365 | Annual energy for domestic hot water | 36962 | kWh |
| kwhUsed365 | Annual energy utilised | 65186 | kWh |
| kwhDistLoss365 | Annual distribution heat losses (est at 20%) | 13037 | kWh |
| kwh365 | Annual energy required | 78223 | kWh |
| borePeak | Pipe bore at peak load and velocity | 31.841 | mm |
| dnMain | Nominal main line pipe size (max velocity) | DN32 | |
| boreMain | Nominal main line pipe bore | 33 | mm |
| velocityPeak | Velocity at peak load using nominal size | 1.396 | m/s |
| borePeakMax | Maximum pipe bore at peak load and minimum velocity | 55.15 | mm |
| dnMainMax | Maximum main line pipe size (min velocity) | DN50 | |
| fillPressure | System cold fill pressure (ground floor) | 3.5 | bar |
| fillPressureB | System cold fill pressure (basement) | 3.8 | bar |

# DHW Loads

The following table shows DHW figures and buffer utilisation.

*Table 3: Buffer Load Analysis*

| Hour | DHW % | DHW kWh | Buffer kWh |
|---|---|---|---|
| 0:00 | 1.8 | 1.82 | 93.48 |
| 1:00 | 1.2 | 1.21 | 93.48 |
| 2:00 | 1 | 1.01 | 93.48 |
| 3:00 | 0.8 | 0.81 | 93.48 |
| 4:00 | 1.3 | 1.31 | 93.48 |
| 5:00 | 1.7 | 1.72 | 93.48 |
| 6:00 | 4.5 | 4.55 | 93.48 |
| 7:00 | 8.7 | 8.81 | 93.48 |
| 8:00 | 7.6 | 7.69 | 93.48 |
| 9:00 | 6.1 | 6.17 | 93.48 |
| 10:00 | 5.4 | 5.46 | 93.48 |
| 11:00 | 4.8 | 4.86 | 93.48 |
| 12:00 | 4.2 | 4.25 | 93.48 |
| 13:00 | 3.6 | 3.64 | 93.48 |
| 14:00 | 3.1 | 3.13 | 93.48 |
| 15:00 | 3.2 | 3.24 | 93.48 |
| 16:00 | 3.7 | 3.74 | 93.48 |
| 17:00 | 5.3 | 5.36 | 93.48 |
| 18:00 | 7.7 | 7.79 | 93.48 |
| 19:00 | 7.3 | 7.39 | 93.48 |
| 20:00 | 6.1 | 6.17 | 93.48 |
| 21:00 | 4.9 | 4.96 | 93.48 |
| 22:00 | 3.7 | 3.74 | 93.48 |
| 23:00 | 2.4 | 2.43 | 93.48 |

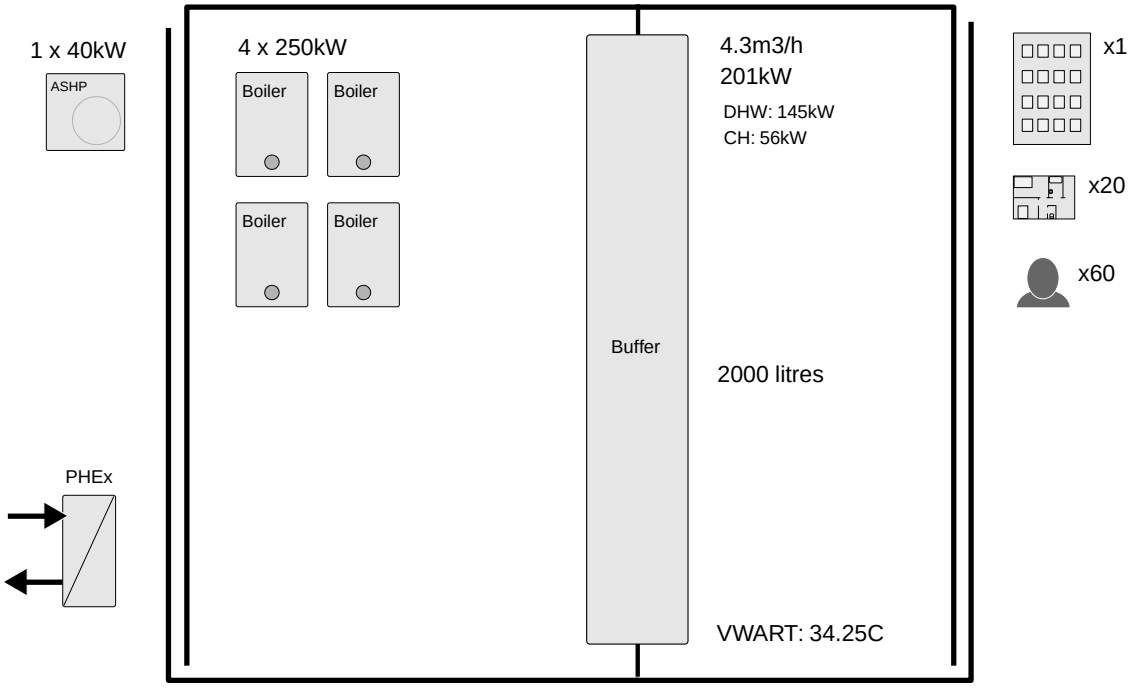
# Historical Modelling

The following table shows energy use and generation for 2020 weather data.

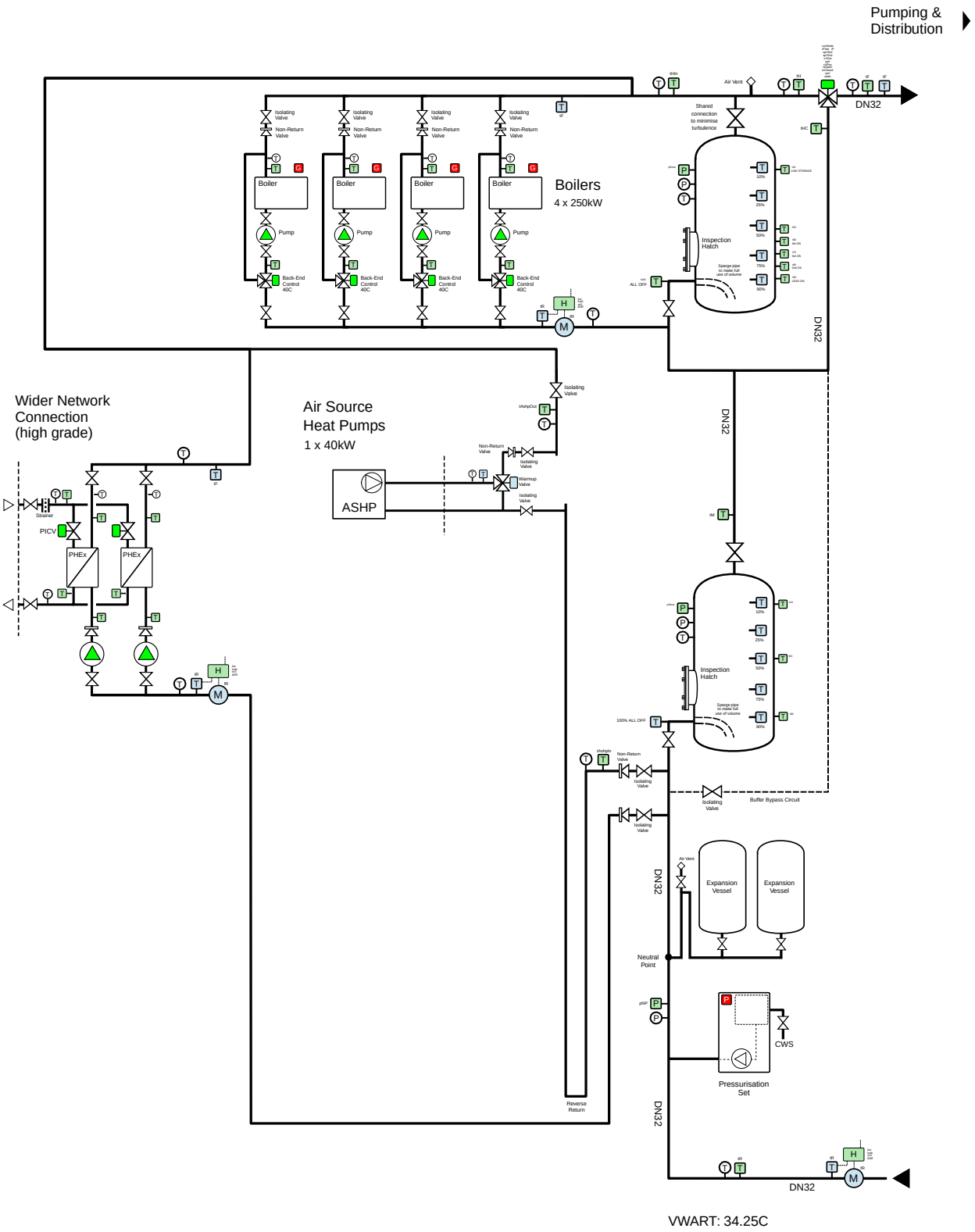
*Table 4: 2020 Load Analysis*

| Calculation | Value | Units |
|---|---|---|
| Base temperature used | 16 | °C |
| Degree days for 2020 | 1641 | °days |
| Energy used in 2020 | 142030 | kWh |
| Energy used for DHW in 2020 | 36962 | kW |
| Energy used for central heating in 2020 | 105068 | kWh |
| Energy supplied via Gas Boilers in 2020 | 54 | kWh |
| Percentage via Gas Boilers in 2020 | 0 | % |
| Assumed boiler efficiency | 90 | % |
| Energy input via Gas Boilers in 2020 | 60 | kWh |
| Emissions factor for gas | 0.216 | Kg CO2 / kWh |
| Carbon emissions for gas used in 2020 | 12.9 | Kg CO2 |
| Energy supplied via Heat Pumps in 2020 | 141976 | kWh |
| Percentage via Heat Pumps in 2020 | 99.9 | % |
| Assumed COP for heat pumps | 3 | |
| Electrical input to Heat Pumps in 2020 | 47325.3 | kWh |
| Emissions factor for electricity | 0.233 | Kg CO2 / kWh |
| Carbon emissions for electricity used in 2020 | 11026.7 | Kg CO2 |
| Total Carbon emissions in 2020 | 11039.6 | Kg CO2 |

# Topology


1 x 40kW
ASHP
4 x 250kW
Boiler
Boiler
Boiler
Boiler
4.3m3/h
201kW
DHW: 145kW
CH: 56kW
Buffer
2000 litres
VWART: 34.25C
PHEx
x1
x20
x60

# Plantroom Schematic



# Control Points

The following table shows control points for the plantroom supply stage.

*Table 5: Control Points - Supply*

| No. | Device | Group | Key | Type | Units | Description |
|---|---|---|---|---|---|---|
| 1 | supply | dat | tF | NTC 10k Input | degC | Network supply temperature |
| 2 | supply | dat | tR | NTC 10k Input | degC | Network return temperature |
| 3 | storeH | dat | t70 | NTC 10k Input | degC | High grade buffer temperature, 70% |
| 4 | storeH | dat | t90 | NTC 10k Input | degC | High grade buffer temperature, 90% |
| 5 | storeH | dat | t80 | NTC 10k Input | degC | High grade buffer temperature, 80% |
| 6 | storeH | dat | t10 | NTC 10k Input | degC | High grade buffer temperature, 10% |
| 7 | storeH | dat | pStore | 0-10v Input | bar | High grade buffer pressure |
| 8 | storeH | dat | t60 | NTC 10k Input | degC | High grade buffer temperature, 60% |
| 9 | storeH | dat | t50 | NTC 10k Input | degC | High grade buffer temperature, 50% |
| 10 | boilers | meter | tR | M-Bus | degC | Boiler group metered return temperature |
| 11 | boilers | meter | kw | M-Bus | kW | Boiler group metered power |
| 12 | boilers | meter | kwh | M-Bus | kW | Boiler group metered historic energy |
| 13 | boilers | meter | m3 | M-Bus | m3 | Boiler group metered historic volume |
| 14 | boilers | meter | tDiff | M-Bus | degC | Boiler group metered temperature difference |
| 15 | boilers | meter | fR | M-Bus | m3/h | Boiler group metered flow rate |
| 16 | boilers | meter | tF | M-Bus | degC | Boiler group metered flow temperature |
| 17 | supply | dat | tHIn | NTC 10k Input | degC | Hot input temperature to high grade storage |
| 18 | storeH | dat | t100 | NTC 10k Input | degC | High grade buffer temperature, 90% |
| 19 | supply | dat | tAshpIn | NTC 10k Input | degC | Temperature inlet to high grade heat pump array |
| 20 | supply | dat | tAshpOut | NTC 10k Input | degC | Temperature output from high grade heat pump array |
| 21 | storeL | dat | pStore | 0-10v Input | bar | Low grade buffer pressure |
| 22 | storeL | dat | t90 | NTC 10k Input | degC | Low grade buffer temperature, 90% |
| 23 | storeL | dat | t10 | NTC 10k Input | degC | Low grade buffer temperature, 10% |
| 24 | storeL | dat | t50 | NTC 10k Input | degC | Low grade buffer temperature, 50% |
| 25 | supplyTV | dat | xpV | % Open | % | Network tempering valve percentage open (hot) |
| 26 | supplyTV | dat | xpVSet | Setpoint % | % | Network tempering valve setpoint percent |
| 27 | supplyTV | ana | vVSet | 0-10v Output | V | Network tempering valve setpoint analogue |
| 28 | supplyTV | ana | vVPos | 0-10v Input | V | Network tempering valve analogue feedback |
| 29 | supplyTV | dat | isOpen | Volt-Free Input | | Network tempering valve end-switch fully open |
| 30 | supplyTV | dat | isClosed | Volt-Free Input | | Network tempering valve end-switch fully closed |
| 31 | supplyTV | cmd | xpVSet | Setpoint % | % | Network tempering valve setpoint percent (command) |
| 32 | supplyTV | alarm | xpV | Alarm | % | Network tempering valve position alarm |
| 33 | supplyTV | stat | state | State | | Network tempering valve operating state |
| 34 | supplyTV | settings | tFSet | Setpoint Temp | degC | Network tempering valve setpoint temperature |
| 35 | supplyTV | settings | runMode | Mode | | Network tempering valve run mode (auto, on, off) |
| 36 | supplyTV | alarm | tF | Alarm | | Network tempering valve temperature alarm |
| 37 | supply | dat | tH | NTC 10k Input | degC | Network tempering valve hot input temperature |
| 38 | supply | dat | tHC | NTC 10k Input | degC | Network tempering valve cold input temperature |
| 39 | supply | dat | tM | NTC 10k Input | degC | Temperature at lower grade storage output |

*Table 5: Control Points - Supply (continued)*

| | | | | | | |
|---|---|---|---|---|---|---|
| 40 | network | dat | pNP | 0-10V Input | bar | Neutral point static pressure |
| 41 | supply | meter | tF | M-Bus | degC | Network metered flow temperature |
| 42 | supply | meter | tR | M-Bus | degC | Network metered return temperature |
| 43 | supply | meter | fR | M-Bus | m3/h | Network metered flow rate |
| 44 | supply | meter | kw | M-Bus | kW | Network metered power |
| 45 | supply | meter | kwh | M-Bus | kW | Network metered historic energy |
| 46 | supply | meter | m3 | M-Bus | m3 | Network metered historic volume |
| 47 | supply | meter | tDiff | M-Bus | degC | Network metered temperature difference |
| 48 | subSt | meter | tR | M-Bus | degC | Substation metered return temperature |
| 49 | subSt | meter | kw | M-Bus | kW | Substation metered power |
| 50 | subSt | meter | kwh | M-Bus | kW | Substation metered historic energy |
| 51 | subSt | meter | m3 | M-Bus | m3 | Substation metered historic volume |
| 52 | subSt | meter | tDiff | M-Bus | degC | Substation metered temperature difference |
| 53 | subSt | meter | fR | M-Bus | m3/h | Substation metered flow rate |
| 54 | subSt | meter | tF | M-Bus | degC | Substation metered flow temperature |

# Plantroom Components

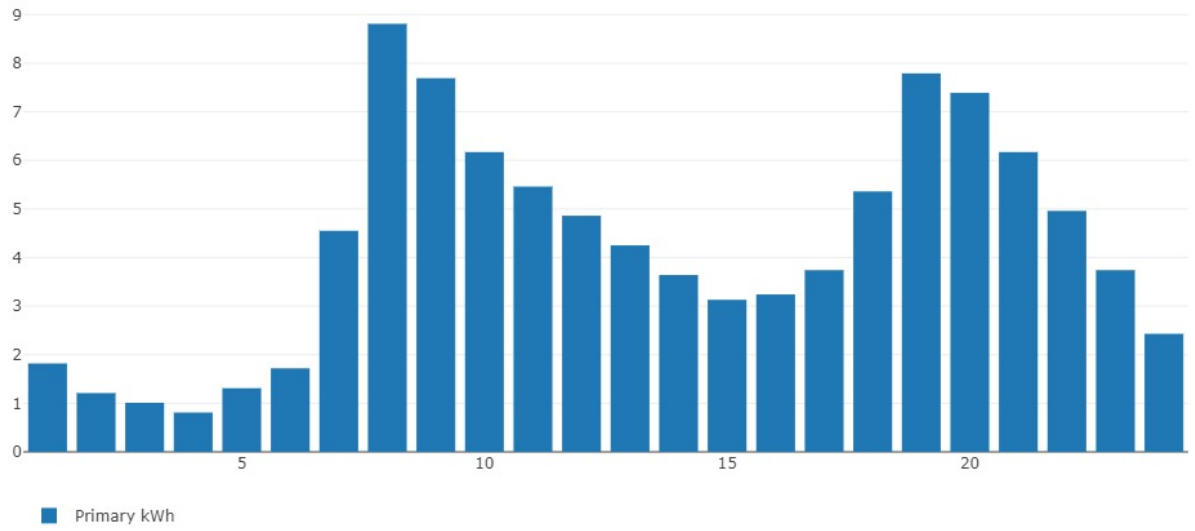
The following table shows components for the plantroom supply stage.

*Table 6: Components - Supply*

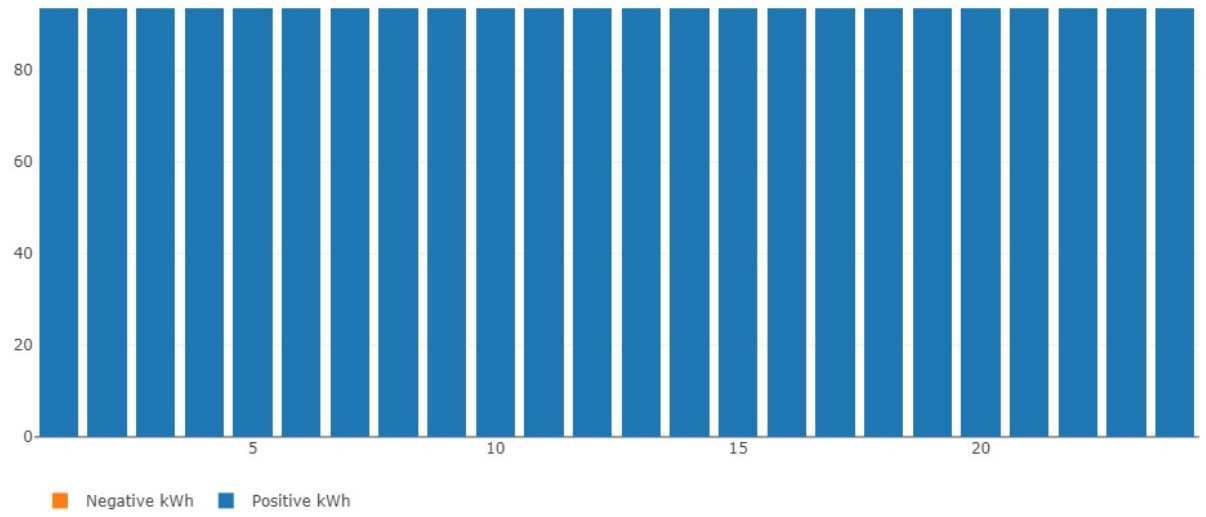
| Item | Part ID | Qty | Title | Description |
|---|---|---|---|---|
| 1 | NTC10KPIPE100MM | 17 | NTC Pipe Temperature Sensor | NTC10K Thermistor Sensor for insertion mounting into pipework. Complete with 100mm pocket and cable gland. |
| 2 | LOADV1 | 4 | Boiler Loading Valve | |
| 3 | BOILER250GAS | 4 | 250kW Boiler (gas) | |
| 4 | BUFFER2000H | 1 | Buffer Store, 2000 litres | 2000 litres, with DN32 flanged inlet/outlet connections. Sparge pipe fitted on cold inlet. See seperate schedule of boss positions. |
| 5 | NTC10KDEEP | 9 | NTC Storage Temperature Sensor | NTC10K Thermistor Sensor for insertion mounting into storage. Complete with 250mm pocket and cable gland. |
| 6 | ASHPTSDEEP | 11 | ASHP Storage Temperature Sensor | Heat pump temperature sensor for insertion mounting into storage. Complete with 250mm pocket and cable gland. |
| 7 | PS10 | 2 | Pressure sensor, 0-10 bar. | Pressure sensor, 0-10 bar, 0-10v. Complete with cable gland. |
| 8 | EXPVESS | 2 | Expansion Vessel.  litres | |
| 9 | PRESSSET1 | 1 | Pressurisation Set | |
| 10 | HM-DN32 | 1 | Heat Meter DN32 with M-Bus | |

# DHW Loads

The following graph shown the energy used for domestic hot water, for each hour of the day. This is the standard profile for domestic properties from the EST.

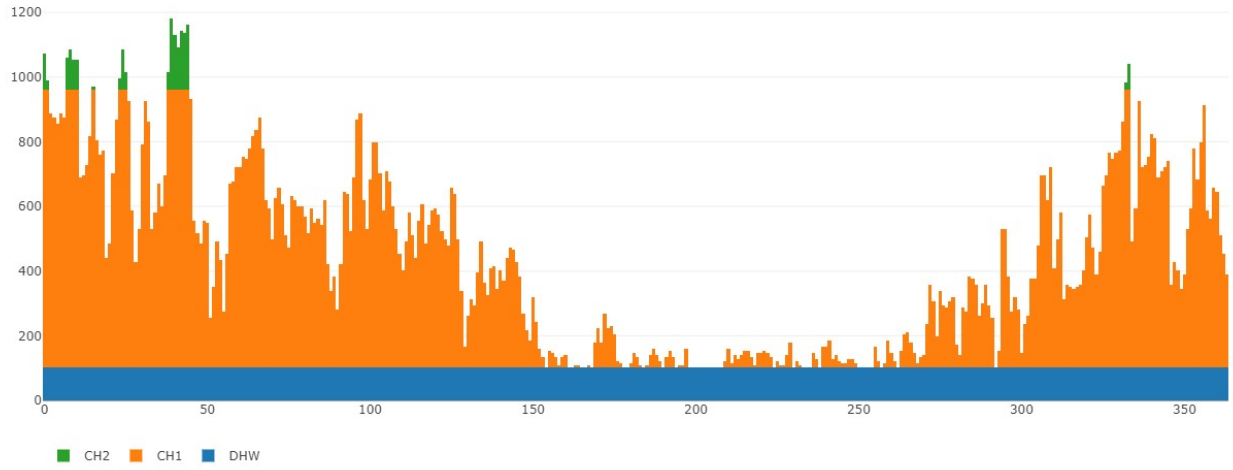



The following chart shows the energy stored in the buffer at the end of each hour, starting with an empty buffer. The storage must remain positive throughout the day.



# Historical Modelling

The following chart shows the estimated loads for 2020 using historical degree day data.




The following chart shows the estimated loads for 2021 using historical degree day data.