University of Exeter

Buildings Decarbonisation

Decarbonisation Masterplan

REP/01

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Executive Summary

This Decarbonisation Masterplan provides a carbon reduction road map and implementation plan to allow the University of Exeter to meet published carbon reduction targets across buildings on Streatham and St. Lukes' campuses.

This decarbonisation master plan is a high-level overview that seeks to establish general principles that the University can follow to move towards reaching their carbon targets. Buildings have not been assessed individually, instead 'typical' buildings were considered to provide estimated energy and carbon impacts. A similar approach was taken to developing the costing rates for interventions. These were then applied across the campus buildings in a 'pro-rata' form'. The feasibility of carrying out the interventions or upgrades to individual buildings was not assessed under this plan, it is recommended that more building specific studies are part of the next steps in moving this plan towards implementation across the campuses.

It is anticipated that this plan will be the first phase in the University's transition, with future projects undertaken to further develop, design and implement changes to the estate. We understand that additional phases of work have already begun, including: the development of a heat decarbonisation plan for buildings with imminent scheduled heating plant replacements; and a heat decarbonisation plan for the FX-plus operated buildings on Penryn campus by WSP due for completion in March 2022. The review and approach to scope 3 carbon emissions is also understood to be a focus for the University in subsequent phases.

This decarbonisation masterplan follows the University's White Paper targets to reduce Scope 1 & 2 (excluding transport) carbon dioxide emission.

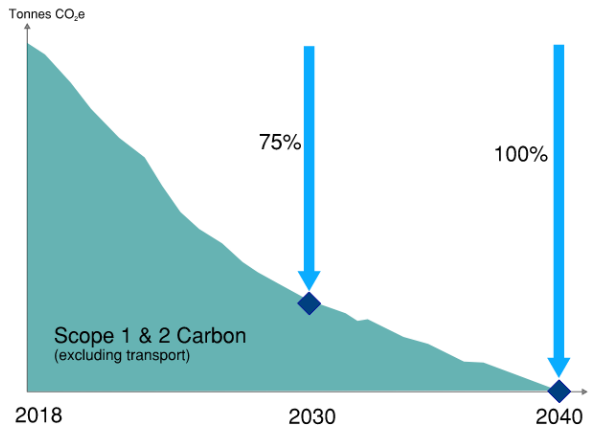


Figure 1: Carbon targets of this masterplan (based on the University's White Paper targets)

Energy and fuel consumption data for the academic year 2018/2019, site visits and anecdotal information were all used to establish a baseline. The principle of reducing building energy demand to reduce carbon was used to develop a shortlist of interventions that could be applied to buildings. The interventions to be tested were agreed with the University. Figure 2 summaries the intervention types that were tested. Table 1 details how interventions were applied to different building types across the estate.

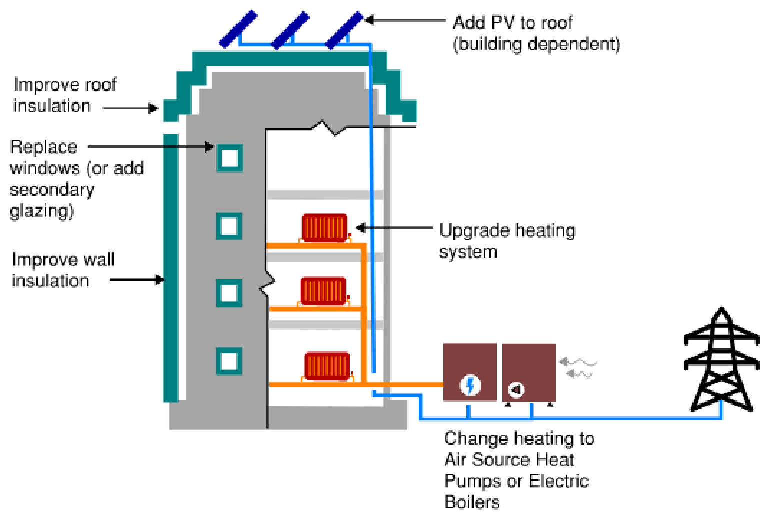


Figure 2: General building intervention illustration

	Listed Buildings	Buildings built Pre-1985	Buildings built 1985 - 2000	Building built Post-2000
Upgrade roof		✓		
Upgrade walls		✓		
Replace windows		✓	✓	
Add secondary glazing	✓			
Change heating to electric boilers	✓			
Change heating to ASHP		✓	✓	✓
Upgrade heating system controls	✓	✓	✓	
Add PVs to roof		✓	✓	✓

Table 1: Intervention summary per building group

In collaboration with the University, the agreed interventions were combined into five different scenarios that were modelled to test the possible outcomes shown in Figure 3.

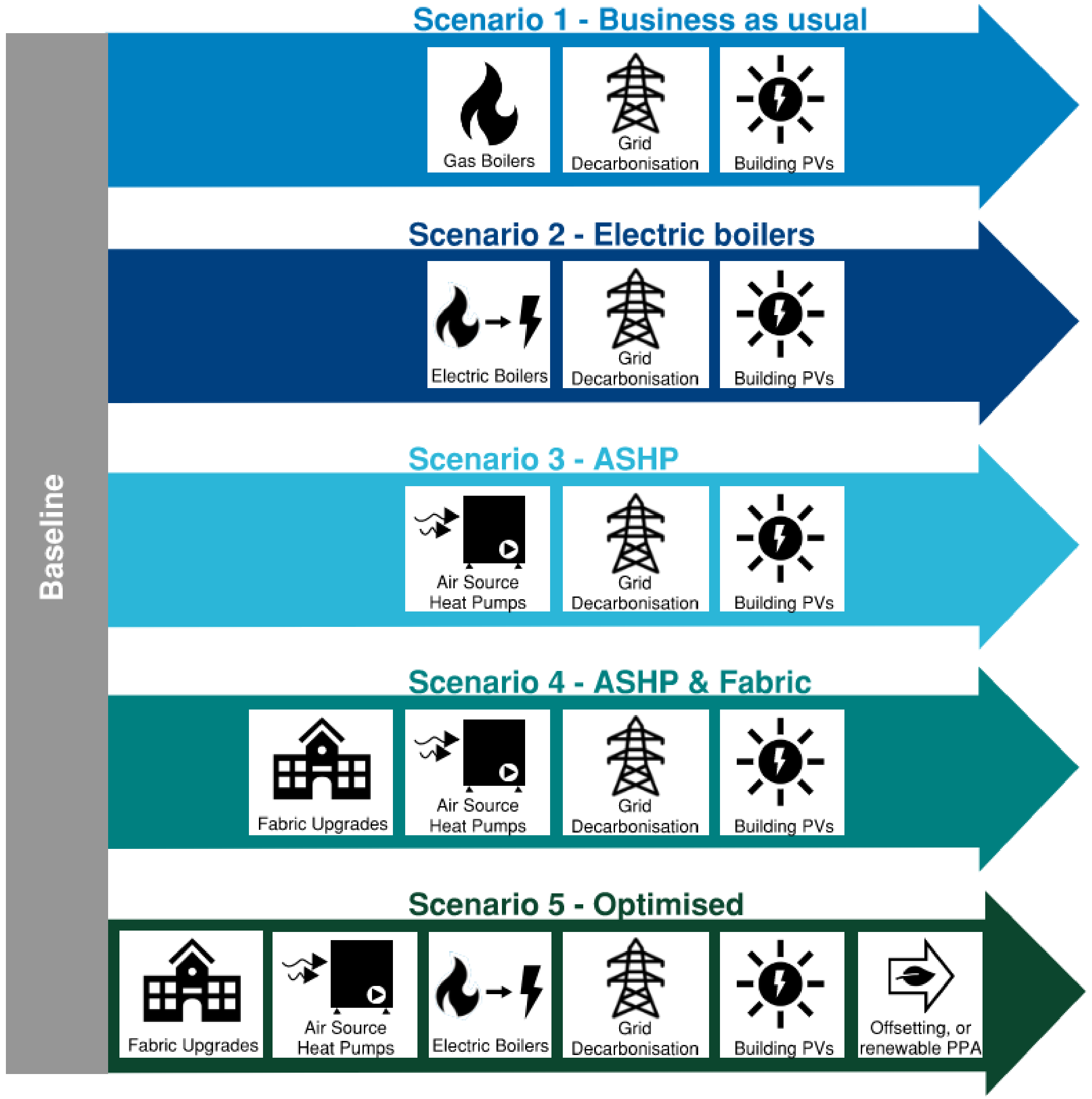


Figure 3: Modelled scenarios

Calculation spreadsheets and visualisation dashboards have been developed and will be shared with the University to allow the plans to be updated as projects are developed. This will enable progress against targets to be remodelled to keep progress on track.

Scenario five represents a route to meet the University's net-zero by 2040 target. Even with this scenario, which includes significant interventions at a building level, if the electricity national grid has not reached net-zero by 2040 the University will need to commit to one or more of the following: large scale off-site PV generation, larger contribution from Renewable Power Purchase Agreement and implementation of the emerging Environmental net gain strategy. However, if the UK Government's recently published commitment to generate all electricity from low carbon sources by 2035 is achieved then the above would not be necessary. Grid projections can be updated by the University (in the spreadsheet included with this report) as predictions are revised in the years ahead.

To offer the best opportunity to meet the targets and distribute projects throughout the years it is advised that the University begins developing projects in line with this plan as soon as possible. The later projects are begun, the more projects it will be necessary to run concurrently to keep on schedule (leading to greater logistical challenges and higher financial investment needed in later years). The estimated total cost of works for the recommended scenario (Scenario 5) for UoE owned buildings and electrical infrastructure is in the order of **£231.5m** spread over 19 years (inclusive of design fees, VAT and Inflation).

This cost cover on campus buildings owned by the University. This excludes buildings where the University lease space and those owned/operated by others. This totals 117 buildings. The cost plan is front loaded to meet the University's target of a 75% reduction by 2030. An implementation plan has been provided for scenario five as part of this document.

Buildings owned and operated by UPP, INTO and leased buildings are included within the decarbonisation plan and are counted within the Universities baseline. The cost of works to these buildings are considered separately however the implications on the University infrastructure have been included.

	GIA (m2)	Total building spend (inc VAT)	Construction (inc VAT)	Design fees (inc VAT)
UPP total	67,173	£10,060,000	£8,384,000	£1,676,000
INTO building	16,110	£1,557,000	£1,298,000	£259,000
Leasehold total	6,970	£645,000	£538,000	£107,000
Freehold	217,071	£166,785,000	£138,996,000	£27,789,000
Ground based PV & elec infrastructure		£26,242,000	£21,869,000	£4,373,000
Total	307,324	£205,289,000	£171,085,000	£34,204,000
UoE total exc. 3rd parties & leasehold		**£231,466,069** (£193,027,000 + Inflation)		

Table 2 - Estimated cost of works for decarbonisation plan

	GIA (m2)	Total building spend (inc VAT & OB*)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)
Streatham	191,569	£153,320,000	£127,772,000	£25,548,000
St Luke's	25,502	£20,792,000	£17,330,000	£3,462,000
Ground based PV		£18,915,000	£15,763,000	£3,152,000
UoE Total	217,071	**£231,466,069** (£193,027,000 + Inflation)		

Table 3 – Estimated cost of works for UoE buildings by Campus

*OB = Optimism Bias. See section 8.3 for description.

Guidance to support future project planning has been included to assist the University with developing projects to deliver the road map, including a low carbon decision tree update, boiler replacement and guidance on consultant input.

Recommended next steps:

To build on the work set out in this plan and enhance progression to meet the University's carbon targets we suggest the following steps are taken next:

- Produce reports addressing Carbon Scope 3 and Scope 1&2 transport emissions.
- Add other off campus estate buildings that were not included into the plan
- Carry out building specific studies to look at:
  - Ventilation (heat recovery and mixed mode) opportunities
  - Smart metering and BMS opportunities
  - Heat decarbonisation opportunities for transitioning away from gas and oil boilers
  - Opportunities to improve building fabric
  - Reviewing the electrical infrastructure for each building (to build on the site wide work in this plan)
- Review long term changes resulting from COVID-19 that could need to be factored into the plan (such as additional ventilation with associated heating load increases)
- Engage with operators of buildings not operated by the University and seek agreement with the decarbonisation masterplan principles and implementation plan
- Continue to define what Environment Net Gain means to the University, including ambitions and methodology for measurement (to enable before and after situations to be compared).
- Develop detailed plan for next 5 years
- Review resource requirements for the UoE project delivery team to implement the decarbonisation masterplan
- Review funding opportunities for transition
- Review the research and corroboration opportunities with Exeter Academic community. Identify opportunities for engagement between Academics and main contractors – in particular the assessment of embodied carbon in construction.

Next steps currently being progressed:

- Planning, investigating, and producing a heat decarbonisation plan for several buildings that have been granted funding from SALIX Low Carbon Skills Fund. Work will be concluded by end of March 2022.

1 Introduction

Arup have been appointed by the University of Exeter to produce a Decarbonisation Masterplan to enable the University to meet their declared ambitious carbon reduction targets across the estate.

The aims of the decarbonisation masterplan are to:

- Study the existing buildings, building services and site wide infrastructure.
- Identify opportunities based on the captured building data against the carbon/renewables agenda, wider masterplan and latest University business plan.
- Present a Carbon Reduction Roadmap Report and costed Delivery Programme
- Set the benchmark for innovative and integrated energy polices to enhance environmental performance and meet climate emergency and carbon reduction commitments
- Identify opportunities to:
    a. Improve the environmental performance of the retained estate
    b. Enhance the fabric to improve operational costs through better thermal performance
    c. Consider the suitability of incorporating an environmental measurement method e.g., Passive House EnerPHit
    d. Enable the transition from fossil fuel heating to renewable sources
    e. Upgrade the HV and LV network required to transition to renewable heating sources
    f. Meet the UoE Sustainable Design Guide Principles

1.1 Level of detail

This decarbonisation master plan is a high-level overview that seeks to establish general principles that the University can follow to move towards reaching their carbon targets. Buildings have not been assessed individually, instead ‘typical’ buildings were considered to provide estimated energy and carbon impacts, a similar approach was taken to developing the costing rates for interventions, these were then applied across the campus buildings in a ‘pro-rata’d’ form’.

The feasibility of carrying out the interventions or upgrades to individual buildings was not assessed under this plan, it is recommended that more detailed studies are untaken for buildings to review:

- further opportunities to reduce energy and carbon
- feasibility specific to the building
- risks and logistical challenges
- additional detail to build up data and calculation carried out in this plan

The costing data used through this report is early stage and high level informed by prorated rates. For consistency throughout the report VAT is included in all costing data. Inflation is included for where specifically noted. Refer to Appendix C3 for inflation calculation.

Constant gas and electricity prices have been used for calculating running costs. It is recommended that more detailed costing is undertaken as the plan is translated into live projects.

1.2 Buildings included

The masterplan includes many buildings from the University’s Exeter based estate portfolio, with the total included in this masterplan equalling 174. This includes 19 buildings from St Luke’s (on and off campus) and 155 from Streatham (on and off campus). Properties from Truro and Penryn are not included within this masterplan. In the future the University could add additional buildings to the plan to gain a broader overview of their estate’s position in respect to carbon emissions. These totals include 47 UPP operated buildings, 6 INTO buildings and 4 buildings where UoE lease space.

Refer to appendix G for comprehensive building list.

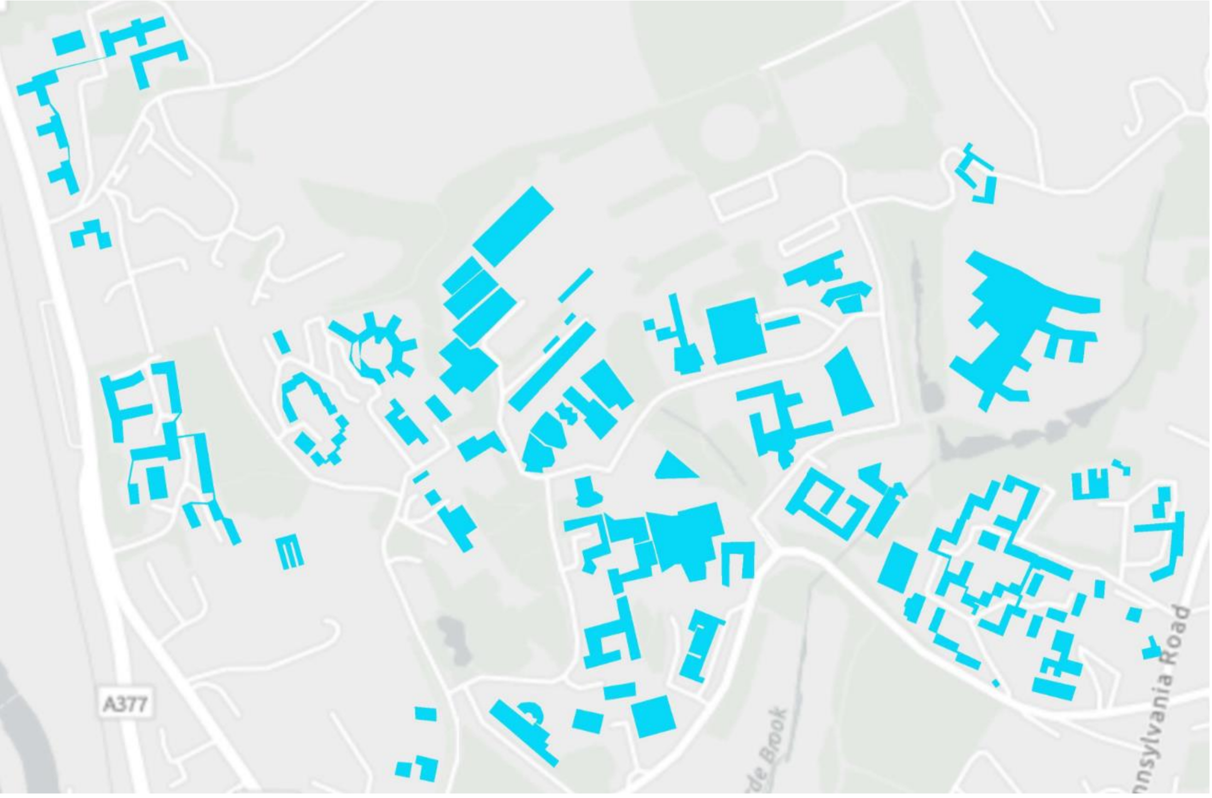


Figure 4: Buildings included in plan - Streatham Campus

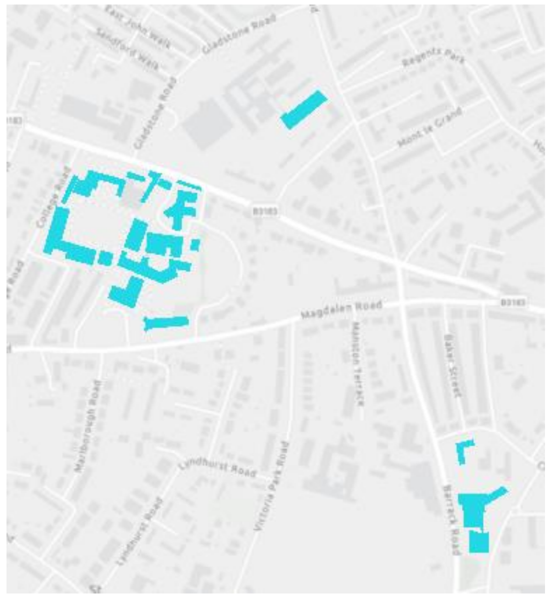


Figure 5: Buildings included in plan - St. Luke's Campus

1.3 Related projects

There are several current projects seeking to establishing the future needs of the University and investigating how the estate can be transformed to meet these. The decarbonisation master plan has interfaced with these where relevant to incorporate the future ambitions of the University.

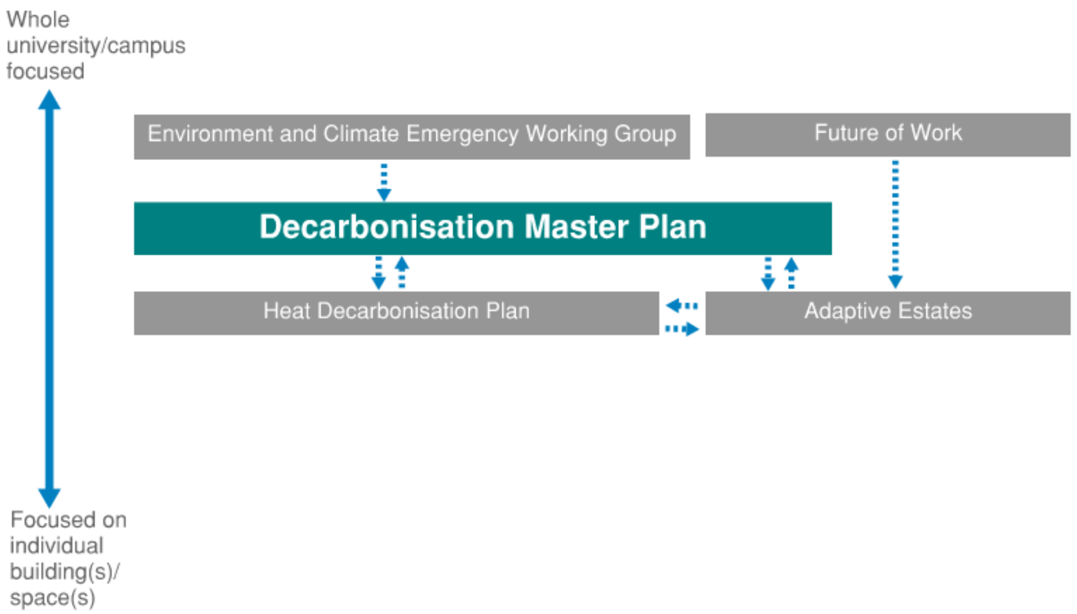


Figure 6: Project interfacing diagram

Environment and Climate Emergency Policy Statement and developing strategy

The University declared an Environment & Climate Emergency on 20th May 2019 and a working group was set up to develop a set of recommendations about what declaring a climate emergency should mean to the University.

The decarbonisation masterplan has reviewed the targets set out by the Environment and Climate Emergency (E&CE) Working Group White Paper and used these to determine carbon reduction targets in the plan.

Adaptive Estates

This project is reviewing the utilisation of several buildings and investigating possibilities of freeing up of space through the creation of agile working environments. The study will form holistic proposals for future improvements, including energy and carbon optimisation, to include a tie-in with planned replacement/refurb works. Anticipated outcomes from the project were not available at the time of writing this plan.

Knowledge gained from site visits and estate team interaction has been used to inform the decarbonisation masterplan where relevant. A difference between the projects is that the decarbonisation master plan looks across a wider number of buildings, focused on high-level ambitions across the estate. Whereas the Adaptive Estates is a feasibility study level focused on a smaller list of specific buildings.

Future of Work

This is project is examining how the University staff will work in the future. Although we are aware of the project it has not influence the production of this masterplan due to conclusion not being available at the time of writing.

Heat Decarbonisation Plan

The project that will review options for transitioning away from gas or oil heating systems for buildings scheduled for imminent boiler replacements, with funding granted by the government scheme SALIX. This project will look more individually at buildings and it is hoped to develop the relevant principles included in the Decarbonisation Masterplan further to inform the creation of tangible projects.

Sustainability Design Guide

The University has commissioned the production of an updated Sustainability Design Guide, by others. This sets out the principles to be followed and includes checklists for projects to ensure they are complying. We have reviewed the draft document, commented, and aligned the approach of the decarbonisation master plan with the guidance when appropriate.

1.4 Methodology and Data Gathering

We have sought to deliver a personalised plan and provide tools that can enable the University to update the plan in the future. We have also developed visualisations to present the outcomes from the calculations in an accessible way.

To build the plan we needed to understand the current baseline. To do this we visited the campuses, engaged with multiple members of the Estate team and the Environment & Climate Emergency team, alongside reviewing data held by the University. Often information was not available in a single source so early elements of the work were focused on collating and understanding the coverage of the information available.

1.5 Deliverables

To enable the decarbonisation masterplan to be a live document that can be updated as the University's plans, and projects evolve we have included deliverables in several forms to facilitate this. The deliverables list is included below:

- Decarbonisation Masterplan (this document):

  This document summaries the objectives, options considered, and the methodology used. It includes a roadmap and delivery plan for meeting the University's targets including a high-level project timeline and cost plan to meet the E&CE targets. Supplementary guidance and workings are included within Appendices.

- Calculation spreadsheet(s):

  Excel based spreadsheets that enable different interventions from the list to be applied to different buildings. It is possible to adjust the year that interventions are applied and then outputs such as energy and carbon are recalculated. Other data such as the carbon factor of the grid can also be adjusted to see how this influences the results. These spreadsheets can be edited by University to test different scenarios or routes to meet carbon commitments.

- Visualisations

  Microsoft Power BI software has been used to present key outputs from the spreadsheets in a form that is generally more intuitive than complex spreadsheets. It includes graphs, alongside maps of the campus and timelines of how the campus situation is projected to change under the modelled scenarios.

2 Approach to carbon reduction

2.1 Key terms

Several terms used in this report when discussing carbon reduction have been defined below:

Carbon - has been used for simplicity throughout this report when referring to carbon dioxide emissions.

Embodied Carbon - is the carbon footprint of a material. It considers the associated emissions throughout the supply chain.

Net zero - refers to the balance between the amount of greenhouse gas produced and the amount removed from the atmosphere

Operational Energy & Carbon - energy consumption and associated carbon emissions of an occupied/in use building e.g. heating, cooling, ICT equipment, refrigeration equipment, lighting, etc. The energy calculations within this report are based on metered data, which included regulated and unregulated energy.

Scope 1 - (Direct emissions) Carbon emission from activities controlled by the University. E.g. emissions from combustion in owned boilers, furnaces, vehicles

Scope 2 - (Energy indirect): Emissions associated with the University's consumption of purchased electricity, heat, steam and cooling, which occur at sources the University does not own or control.

Scope 3 - (Other indirect): Emissions which occur at sources which the University does not own or control and which are not classed as scope 2 emissions. E.g., business travel not owned or controlled, waste disposal, or purchased materials or fuels.

Whole life carbon - carbon attributed to the item from production, construction, to in use and end-of-life. This can be a 'cradle to grave' approach and includes embodied and operational carbon.

2.2 University published targets

The University has declared a climate emergency and embraced this challenge as part of its mission to challenge the usual way of thinking. Taking a lead in this is a vision for the University and is set out as such in the 2030 strategy.

Figure 7: ©University of Exeter, Strategy 2030

Clear targets for carbon reduction have been set and widely published to cement the University's commitment. The overall ambition is to reach net zero by 2050 with intermediate targets included along the way.

The following roadmap image from the University's Environment & Climate Emergency team illustrates the principles.

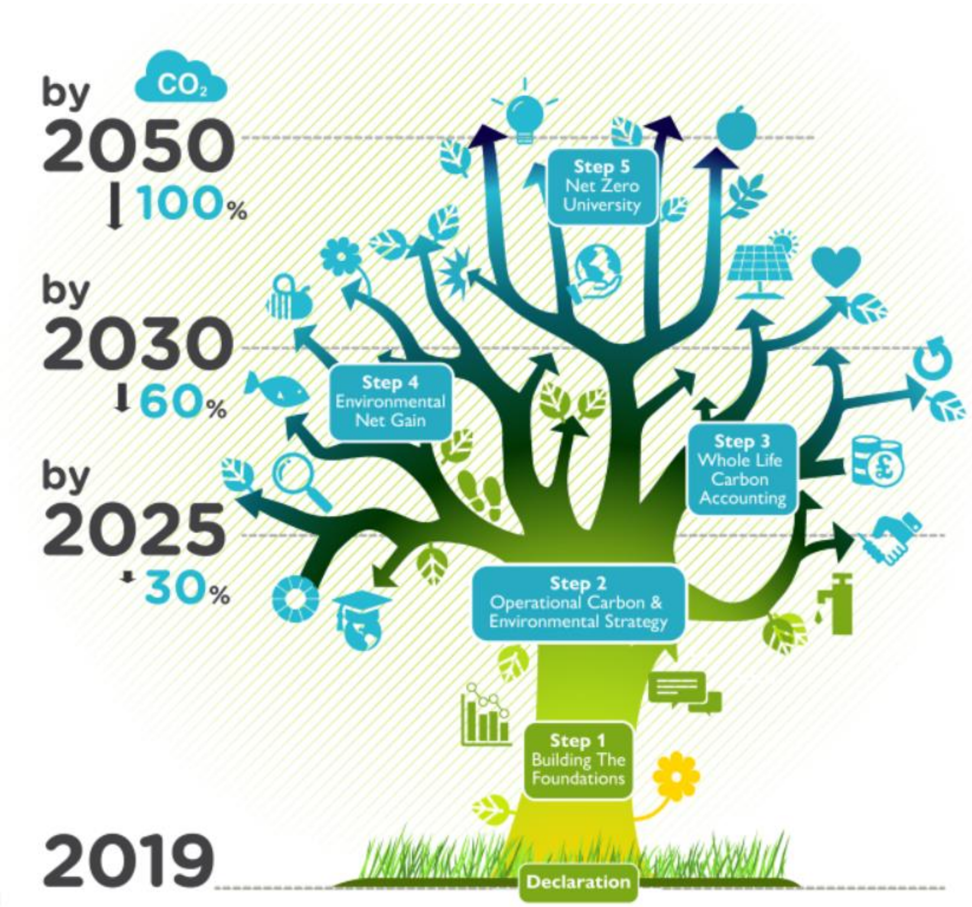


Figure 8: Carbon and Environmental Roadmap - University of Exeter ©

The Environment and Climate Emergency Working Group White Paper challenges the University to move faster in reducing carbon in some areas. This sets the targets for Scope 1&2 emission to be reduced 75% by 2030 and 100% by 2040; with all emissions, including Scope 3, reduced 100% by 2050.

This decarbonisation masterplan focuses on developing a road map for carbon reductions to meet Scope 1 & 2 targets (excluding transport) as set out in the white paper.

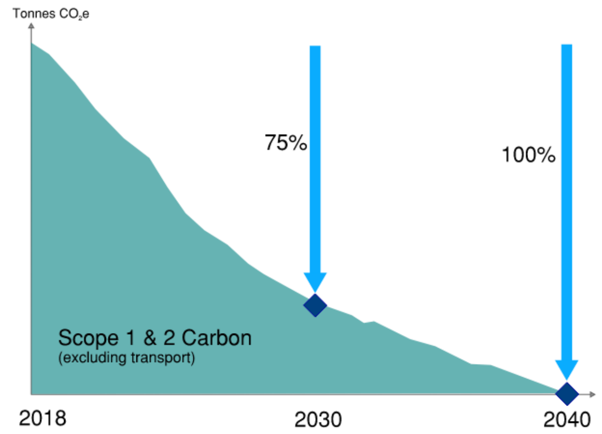


Figure 9: Visualisation of plan targets (based on University White Paper)

2.3 Decision tree

As part the University's approach to sustainable development, the University's Environment & Climate Emergency team have developed a Low Carbon decision tree. This guides the reader through the process of selecting projects that could be developed to enhance the University's carbon roadmap progress. It challenges the reader to ensure there is enough information available to inform a decision or offers routes to gather the missing data.

We have followed the principles of this decision tree in the development of this plan. We have also reviewed the process and made suggestions as to how this could be revised to form a key component of future project planning, refer to Section 10.1

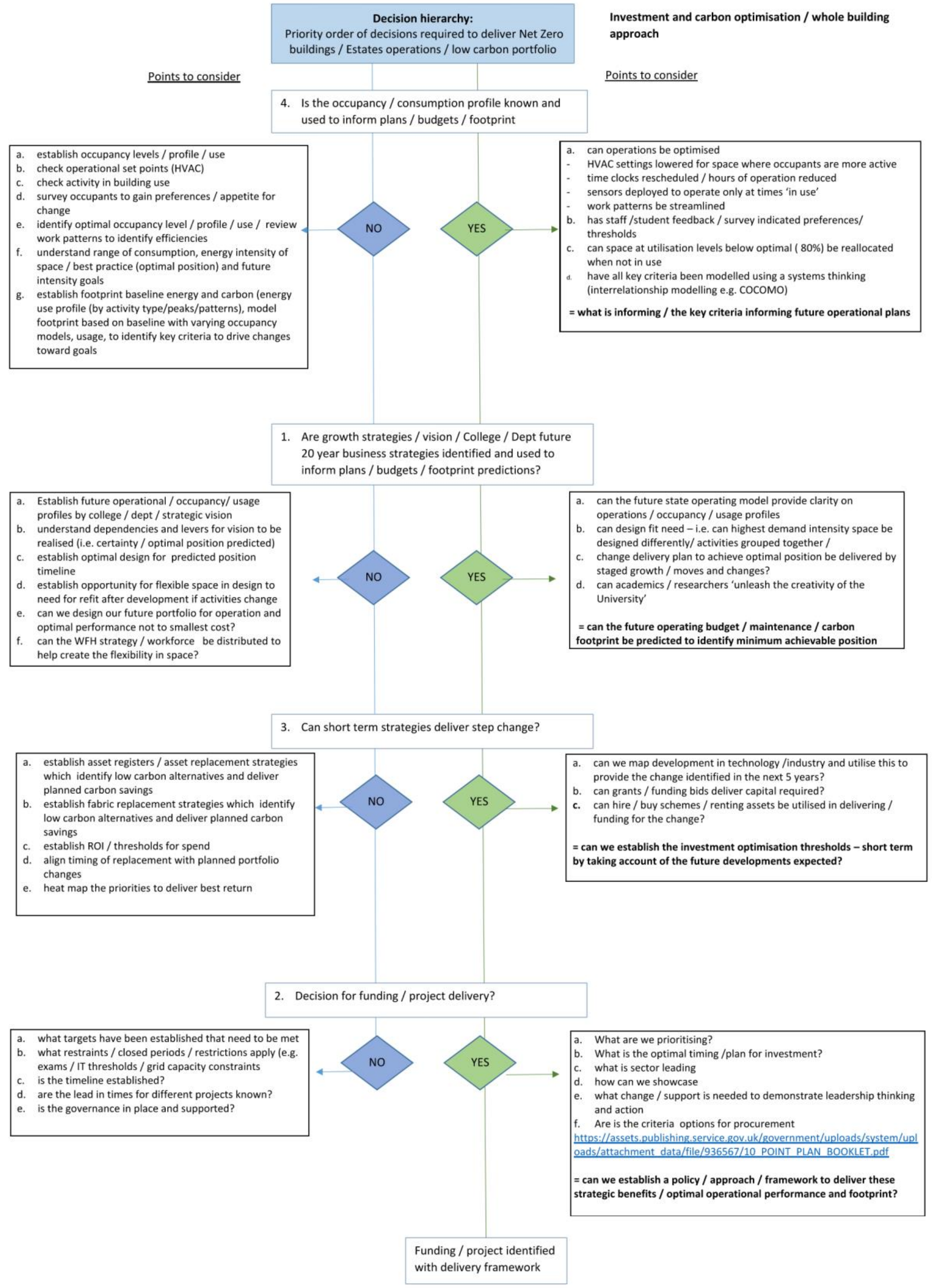


Figure 10: University of Exeter Decision Tree

2.4 Principles of carbon reduction

The UK Green Building Council (UKGBC) published "Net Zero Carbon Buildings: A Framework Definition" which defines the principle that achieving net zero is about reducing demand (both for energy and materials), with offsetting the last resort for residual emissions.

In the diagram below we summarise a typical recommended sequential approach to arriving at a net zero destination.

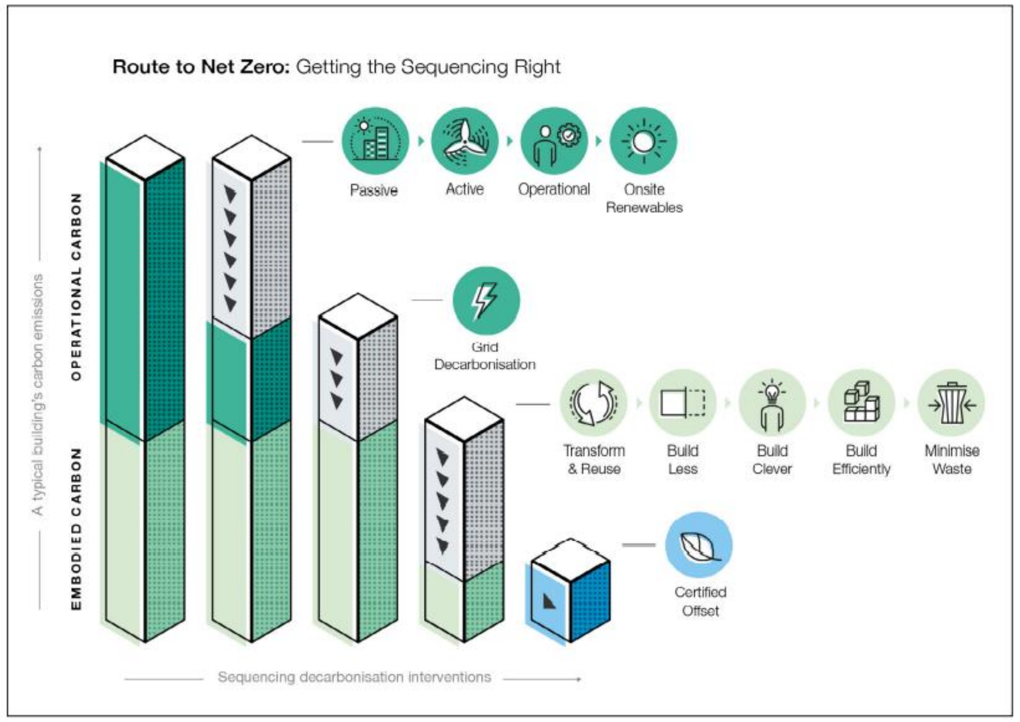


Figure 11: Net zero carbon approach

Embodied carbon can be minimised by thinking carefully about the spaces that will be needed and prioritising reuse of existing structures, whenever possible. Followed by employing lean design principles to minimise the embodied impacts of what must be built.

As the estate already has many existing buildings, a major focus of this plan is reducing operational carbon emissions. Typically, the approach is to start with strong passive design and to minimise the need for active systems. Efficient systems are then combined with operational tools to allow users and operators to choose how they will maintain net zero performance. Renewables and grid decarbonisation can then be included.

These general principles will be used as a guideline to develop a customised plan for the University's estate.

2.5 Sustainability Design Guide

The University has produced a Sustainability Design Strategy in collaboration with Industry and it's Academics to address the E&CE. We reviewed the draft document, commented, and aligned the approach of the decarbonisation master plan with the guidance when appropriate. The document contains sections outlining the approach to future projects undertaken by the University including new builds, refurbishment, and minor works. Checklists are provided to ensure projects comply.

It is understood that future works commissioned, including those following on from this decarbonisation masterplan, would need to follow the Sustainability Guide methodology and standards.

3 Current campus

Before looking at methods of reducing carbon, we have worked to establish a baseline for the University to produce a personalised plan.

For the purposes of the decarbonisation plan, buildings have been divided into typical groups based on construction age and principal use (such as academic, residential). This allows representative testing of scenarios for buildings where more information is accessible, normalising the results and then applying across the wider groups. Sample buildings were visited for the project alongside reviewing findings from the Adaptive Estates project visits.

3.1 Heritage and Conservation Areas

The campuses include a spectrum of building ages, sizes, and uses; with the oldest in this study constructed in 1820 and the most recent in 2021. There are several buildings that are recognised by Historic England as either Grade I or II listed. Several others are recognised as Locally Listed. The St. Luke's Campus is located within the St Leonards Conservation area. Changes to these buildings would need careful consideration and consultation with Historic England and/or local planners as appropriate.

3.2 Condition

The sites were visited to enable us to form a general impression of the condition, alongside gathering anecdotal feedback from the Estates team. The plant rooms and plant that were seen on the visits generally appeared to be in good condition with the plant rooms tidy and generally free from storage items. Insulation was observed on exposed pipework/ductwork and mostly appeared damage free; jackets for valves were generally in place. From a high-level visual overview, no ongoing major leaks or extensive external corrosion were observed on the walkarounds. We have obtained dates of install for heating plant items and we have reviewed the University's Long Term Maintenance plan (which covers the next five years) to understand when plant replacements are scheduled.

Figure 12: Example plant room (Laver Building)

Generally the external fabric observed from ground level appeared to be in reasonable condition, but it was noted that were several buildings retain single glazed windows, some of which appeared a little tired. The construction age and external visuals have been used to build up expected thermal performance typical for the age.

Figure 13: Example of buildings with single glazing (Queens & Amory)

A limited selection of internal spaces were visited and it was noted that some had older style fluorescent lighting, in the limited spaces visited these appeared to be operational on at the time.

The estates team have a system for logging maintenance work (PlanOn) and a Long-Term Maintenance plan for scheduling major projects.

3.3 Mechanical systems

Many of the buildings have heating systems reliant on gas boilers or occasionally oil boilers. A range of ventilation and cooling strategies are used (such as: natural ventilation, mechanical ventilation, air cooled chillers, refrigerant systems). The strategies appear to be individual to the building rather than a common approach across the campuses. Currently heating and cooling is primarily provided by plant located in each building, rather than in central locations or energy centres (the benefits and draw backs of district heating and energy centre arrangements are discussed in Section 4.1). Domestic hot water is generally either generated from the gas boiler systems or via standalone gas fired cylinders, a few of the sample buildings had electric point of use domestic hot water.

3.4 Electrical site wide networks

The University's buildings located off campus and at St. Luke's have dedicated Low Voltage (LV) supplies directly from Distribution Network Operator (DNO) owned and operated electrical substations. The DNO is Western Power Distribution (WPD).

The University owns and operates an existing private 11kV network on the Streatham campus which consists of three High Voltage (HV) rings distributing power to twenty-nine HV/LV substations. These then distribute electricity to most of the buildings on Streatham campus.

The current load demand for the Streatham Campus is circa 6 MVA with an agreed maximum capacity from WPD of up to 9MVA. There are ongoing projects with WPD to upgrade the Streatham capacity supply capacity to 12MVA, likely to be completed in 2023. This will require WPD to upgrade the two main 33/11kv transformers, cabling, and main switchgear.

It is anticipated that the incoming supplies and electrical infrastructure may require upgrading to accommodate the transition away from gas and oil heating to electric heating such as air source heat pumps.

A Substation-by-substation breakdown has been prepared to provide a summary and review the impact on the electrical infrastructure based on projected load increases due to the interventions applied. The has been tabulated to compare the current demand loads against the estimated increased load and can be found in Appendix B, which includes a substation-by-substation and building-by-building analysis. Further detail, including a Loop Analysis Summary, can also be found in this appendix.

3.4.1 Methodology

Streatham Campus:

Substation thresholds have been set at ninety percent of the transformer rating to avoid overloading.

This is summarised in the table below:

Transformer Size (kVA)	Substation Threshold (kVA)	Substation Maximum Available Loading (kVA)
500	450	500
800	720	800
1000	900	1000
1250	1125	1250
1500	1350	1500

Table 4: Substation loading methodology summary

Using this premise, the substation loadings are set out in detail in Appendix B.

The following buildings are supplied directly by the WPD at low voltage and have been scheduled separately:

- Estates Services Centre
- Garden Hill House
- Higher Hooper Cottage
- Higher Hooper Farm
- Knightley
- Redcot
- Streatham Lodge

Further investigation is required to stablish the impact on the incoming service infrastructure and the capacity available from WPD.

St. Luke's Campus

The buildings located at St. Luke's are supplied directly at Low Voltage by 2no. WPD owned HV/LV substations and has been tabled separately.

Off Campus Buildings

The buildings located off campus are supplied directly at Low Voltage by the DNO and has been tabled separately.

3.4.2 Assumptions

The following figures extracted from BSRIA Rules of thumb guideline document, have been used to estimate the current electrical maximum load demand of each building:

Building type / primary use	**Electrical Load W/m2 (net internal area)**	**Comments**
Academic	55	
Laboratories	90	
Administration / Offices	87	This figure is based on Air-conditioned spaces
Residences	28	
General	87	
IT/Data Centres	1500	
Social – Multipurpose	200	
Sports – Swimming pool/wellbeing	50	
Social – Catering	225	This figure is based on gas cooking Equipment
Library	50	
Hall - Auditorium	130	
Chapel	50	
Social – Sports (Indoor)	50	
Social – Sports (Outdoor)	10	External lighting only.
Storage	17	

Table 5: BSRIA Rules of Thumb - Electrical load

The following assumptions have been made:

- A 0.74 factor has been assumed and applied to factor in the diversity on the 11kV loops demand estimate calculations.
- It is understood that the maximum 11kV loop/ring circuit capacity is 4MW
- The current agreed capacity at Streatham Campus with the DNO is 9MVA with a plan to an increase of up to maximum of 12MVA.
- Approximate PV installation contribution has been taken into account.
- 30no. Electrical vehicle charging points have been included in Car Park B with a 0.5 simultaneous usage factor and @ 7kW per point.
- It is assumed that the HV/LV DNO substation that supply St. Luke’s Campus buildings are 1MVA transformers.

3.5 Energy data

To measure progress against the carbon reduction targets it is important to first establish a baseline to measure improvement. To mitigate any changes to building energy consumption that has occurred over the recent period due operational changes caused by COVID-19, the academic year of August 2018 to July 2019 was selected as the baseline.

Energy consumption data for gas and electricity was extracted from ‘monitoring points’ set up for each building from the University’s Team Sigma account. Oil usage was included from a spreadsheet provided by the University. This includes both regulated and unregulated energy.

The extent of sub-metering that was available on the system was limited. Electrical sub-metering to split cooling, lighting and small power was not available on this platform. Some buildings have heating sub-meters but of the those that were viewed it was found that these did not always match the total consumption. For the purposes of this plan sub-metering data has not been used due to lack of consistency and accuracy across the buildings, instead estimates of energy use were made with the use of our in-house tool EPOC.

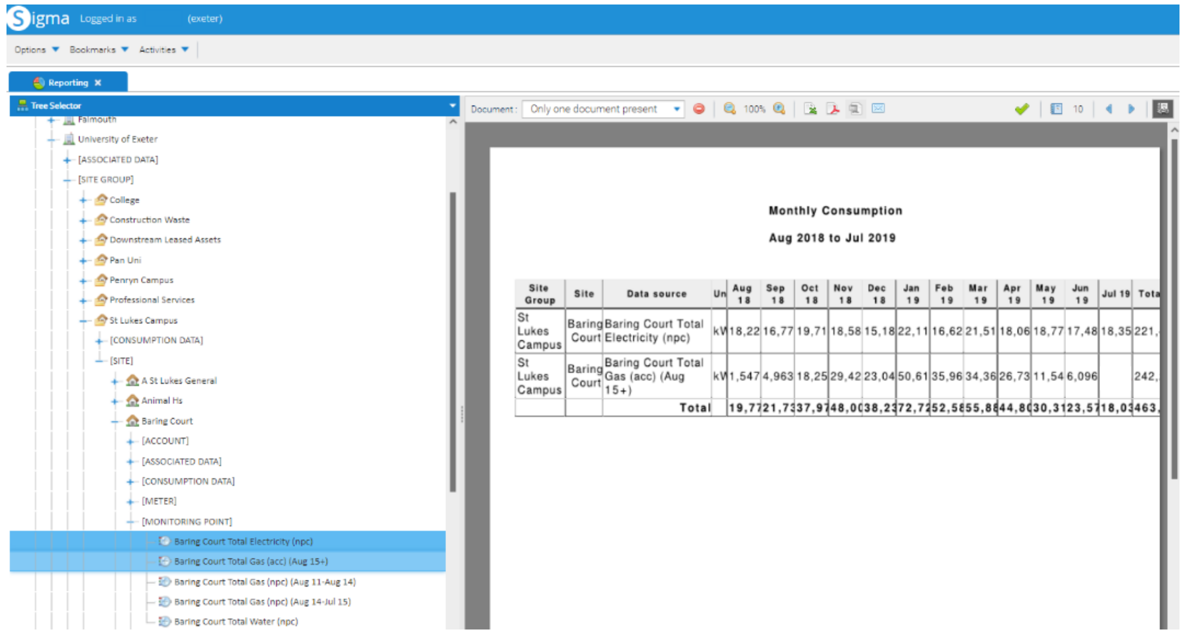


Figure 14: University’s Team Sigma Monitoring Point consumption example

4 Plant, energy, and distribution options

4.1 Site wide heat networks

Instead of generating heat locally in each building, an alternative approach is to have a heat network producing heat centrally and distributing heat via an underground piped network to each building.

The benefit of a heat network is that building one central energy centre can be cheaper than replacing the heating plant in each building. Heat networks can deliver heat in a more efficient manner by capturing thermal energy or waste heat, and therefore leading to lower carbon emissions. However, the associated capital costs of a heat network such as distribution, heat exchangers in each building may offset heating plant savings. The pumping losses of a heat network are also higher than electricity distribution, so the operational cost may be higher.

There are significant logistical issues to consider when developing a heat network. The routing of heat network pipes will determine the order in which buildings can be added to the heat network, which may not align with when their heating plant needs replacing. Similarly, to serve all buildings, the heat network may need to operate at the heating temperatures of the worst performing building or include local plant to boost the temperatures for some buildings. This will impact the efficiency of the system.

A building-by-building approach allows buildings to be upgraded to new heat generating plant when it is appropriate. It also allows each system to operate at the most efficient flow and return temperatures.

Another consideration is the density of heat demand. The pumping losses of heat networks can be offset by high concentrations of demand in small areas. Whilst the University has a good concentration of student residences in some areas, the overall campus is spread out which would increase the initial capital cost of running pipework and the operational cost of pumping losses.

The variety of buildings on site represents a benefit for sizing central heating plant compared to decentralised. A heat network allows a diversity to be applied to the main heating source. The peak load of the heat network will be lower than the sum of the building peaks, as those peaks are not simultaneous. For the academic buildings, the peak will occur at the start of the day when buildings are first heated up. For the residential buildings the peak is likely to occur at night.

The use of Combined Heat and Power plant, which have historically been used in heat networks by burning gas to produce heat and electricity, is no longer advised due to the reduction in carbon intensity of the grid and does not represent a long-term solution where reduction of operational carbon is a target.

Heat networks are most appropriate when there is a local source of waste heat. For example, energy from waste facilities, industrial processes or data centres. With the exception of the Laver data centre, there are no substantial sources of heat on either the St Luke's or Streatham campuses and as such we do not recommend developing a heat network.

4.2 Site wide renewables

4.2.1 Photovoltaics (PV)

PVs generate electrical power from sunlight though the use of semiconducting materials. These can be arranged in small arrays on building roofs, in carparks or larger scale arrays sometimes referred to as “solar farms”. They produce renewable electricity and once installed can reduce the amount of electricity that needs to be purchased from the national grid.

Figure 15: PV in car park on the University’s Streatham campus

Generating electricity locally from PVs, on a building roof or wall, has the advantage of minimising distribution loses. Solar panels are regarded as a renewable energy generation source so having these visible on a building can reinforce the idea that the institution is acting on reducing operational carbon.

However, access to roofs can be difficult meaning that installation and maintenance need to be carefully considered. There is also the downside that without battery storage, the generated electricity does not match the demand of the building so is not optimised to its full potential.

The advantage of having larger arrays is that infrastructure upgrades and ongoing maintenance are localised to one location. Having a larger site can allow PVs to be optimally orientated towards the sun and located to avoid overshading from nearby buildings or trees, they can then deliver higher yields than less optimal arrangements. Generated electricity can be delivered to a large of number of buildings, increasing the likelihood that peak generation can be consumed by the buildings on the network.

There are limited areas on the Streatham and St. Luke’s campuses where PV could be installed remotely from buildings without reducing the green space (and potentially the biodiversity) of the campus. PV has already been installed above Carpark B on the Streatham Campus and it may be possible to install a similar arrangement in other carparks, such as

Carpark D. This would need to be assessed for feasibility including overshading, existing slopes, yield, and ability to connect into campus electrical network.

There could be opportunity to install PV on land off campus if this does not compromise the existing site and biodiversity. The University has identified an area near to Duryard House where a ground mounted solar PV array could be located. This is expected to have a peak capacity of 750 kW with an annual output of 226,226 kWh. This has been incorporated into the decarbonisation plan with an anticipated construction year of 2023.

The campus PV document produced for the University by 'zlc energy' (*Exeter Uni PV Strategy Feb21 Prioritised Phased.xlsx)* indicates that the current peak capacity of the existing PV on Streatham campus is 840 kW. With the addition of 750 kW from the Duryard PV this equates to 1.6 MW of PV capacity. The University have indicated that there is a current electrical baseload of 2.5MW on Streatham campus, so it is anticipated that all generated electricity can be consumed on site without the need for additional energy storage.

The future 750kW PV installation at Duryard however will exceed the baseline electrical load demand of either of the substations in the vicinity (Substations 30 Kay house & Substation 340 Duryard East) and therefore will not be feasible to directly feed into those buildings.

The installation of this PV will also very likely exceed the current base electrical total load demand to HV ring/loop no.2 which feeds the Residential buildings at North and West of Streatham (Duryard, Birks, Moberly Hall & Kay house), therefore will be necessary to connect to other parts of the high voltage infrastructure within the site. This could require an additional Electrical substation and HV infrastructure upgrades comprising a LV to HV step up transformer and connection to nearest existing private 11kV circuit.

When options for new PV arrays, civil and infrastructure associated works shall be taken into consideration.

There could be future opportunities to engage with or partner off-campus installations of PVs.

Introducing PVs onto building roofs locally is considered an option for further consideration and is discussed later in the document. The option to use a power purchase agreement (PPA) utilising renewable energy generated offsite is also discussed later in this document.

4.2.2 Solar thermal

Solar thermal systems have collectors which reliant on being exposed to direct sunlight. The sunlight hits the solar collector and warms heat transfer fluid passing through it. A pump circulates the transfer fluid from the solar collector through a coil in a water tank to warm the water. Back-up heat sources are usually needed in the UK to boosts the tank water to the desired temperature before it is distributed for use as domestic water e.g., for hand washing, showers.

It is not usually efficient to provide all a building’s hot water load from solar thermal and with the proportion normally less than fifty percent, meaning that a secondary heat source is required. Due to heat losses at different stages of the heat transfer, the solar system efficiency is around thirty percent. Systems need to be designed carefully to avoid stagnation and the system becoming too warm. If antifreeze in the system is superheated repeatedly it can become corrosive and damage the system.

The benefits are that a percentage of the water has been heated by sunlight rather than gas, oil or electricity. Solar thermal is most efficient when it is installed on south facing locations with collectors on an angle. This is the same optimal location as PVs. Where there is limited space on a site, then due to the relatively low efficiency of solar thermal and the additional maintenance and water storage requirements, PV installations can the more suitable use of sunny space rather than solar thermal. However, if electricity demand on a building is low but hot water demand is more dominant it could be worth reviewing the feasibility of solar thermal.

4.2.3 Wind

Wind turbines generate electricity from the wind driving blades which in turn drives a turbine that generates electricity. There are two types of wind turbine: mast mounted and building mounted. Building mounted are smaller and the generated output would be limited and unlikely to significantly contribute towards the University’s energy use. Some building mounted turbines can be inefficient and consume for energy than they save.

Wind turbines on masts are highly visible and can be contentious depending on their location. Planning permission is required, and the percentage of accepted application is estimated at below fifty percent. Noise, the visual impact, and wildlife impact can be causes for concern for local communities. There are examples where higher education have installed wind turbines in the UK, Keele University has two installed as part of an energy generation zone.

The potential generation from a turbine is dependent on the site and would require detailed assessment. For the purposes of the decarbonisation master plan, onsite wind turbines have not been proposed on the main campuses due to the urban environment and anticipated planning and construction challenges. If the University has areas of land that are away from built up areas that have high wind speeds, then these could be considered for wind turbine installation. The logistics of connecting the turbine to the University’s electrical network would require consideration.

Instead of installing wind turbines, purchase of electricity from off-site windfarms as part of PPA could be considered and this is discussed later in this document.

4.2.4 Battery storage

The variability of renewable electricity production and the inherent demand peaks across the grid have created an incentive to store energy to create electricity when it is needed most. This can be used to absorb supply side excess, and offset demand side peaks. These are most beneficial when there is a substantial difference between when electricity is produced and when there is demand. For example, if a power plant cannot be shut down overnight, it’s energy can be stored for daytime use.

There are a number of ways to store energy: electrochemical batteries, thermal energy stores, compressed air and hydro storage. These can be utilised to balance energy surpluses and deficits across hours, days and even seasons. Typically, electrochemical batteries are used for hourly-daily peak lopping.

Short term battery storage allows energy that is generated during the day to be utilised at night without purchasing additional electricity from the grid. However, this is dependant on producing more electricity during the day than is consumed. Battery storage can also reduce energy costs by purchasing energy when it is cheap (typically at night) and using it during peak hours when the price increases. This requires a variable rate tariff to allow the purchase of cheaper electricity during times of low demand or excess supply.

Building and campus scale battery storage is a developing technology which could offer a number of benefits but there are a number of factors to balance to understand whether an installation would be beneficial.

Cost – As these are developing technologies, they are currently expensive to install and maintain.

Campus electricity demand – The half hourly electricity demand and generation across the campus would need to be analysed to understand any periods of surplus to model the charging and depletion of any battery storage.

Feed-in-tariff / Smart export guarantee – The current financial benefit of electricity generation would need to be understood to offset against any reduction in peak demand.

Purchase tariffs – Variable rate tariffs would need to be analysed using campus wide demand data to understand the implications on cost.

Efficiency – Lithium Ion batteries have a charge/discharge efficiency of 80-90%, which must be considered when assessing their viability.

With the current quantity of PV production on campus, a significant electricity excess is not expected as there is substantial demand in the academic buildings through the day. As the quantity of PV owned by the University increases, the need to store and release electricity to match demand will similarly increase.

4.3 Ground source heat pumps

Ground source heat pumps (GSHP) collect heat from the ground by a series of buried pipes with fluid running through the pipes that attracts the heat energy from the ground and transfers it to the heat pump which increases the temperature before circulating it through the building's heating system. Ground source heat pumps are theoretically more efficient and economical to operate compared to air source heat pumps and can be used in more extreme conditions. They can also be used in reverse to provide cooling. The GSHP array must be sized and positioned to avoid thermal depletion of the soil. For a horizontal array, the soil can be replenished by heat from the sun, with deeper arrays often being replenished by ground water movement. Alternating between seasonal heating and cooling can also help to replenish the soil.

Ground Source Heat Pumps have three ways to harvest heat energy: from a body of water via an open loop system, from the ground via either horizontal collectors, or from vertical collectors. As there are limited bodies of water on the University campuses the horizontal and vertical collector types would be the more feasible options to consider.

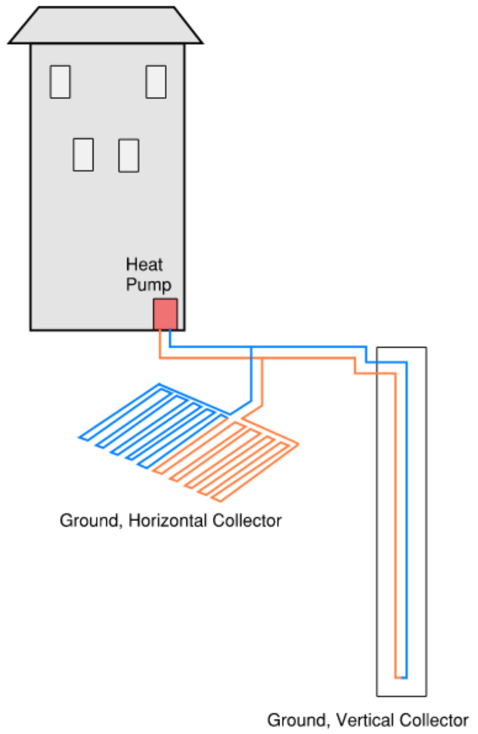


Figure 16: Ground source heat pump concept visualisation

4.3.1 Desktop study guidance

The outputs from ground source heat pumps are dependent on several factors influenced by the local situation. It is therefore advisable to undertake desktop studies on feasibility before progressing with a project.

Items to include are:

Studies of the local geology and ground thermal properties

It is understood that the bed rock is mud/sandstone around Streatham and Breccia around St. Luke's but this may vary across the site so the study should confirm the mix. Differing rock types have differing thermal properties which influences potential outputs from GSHP.

Ground temperatures

This is influenced by depth and generally the deeper the borehole the less variation is seen across the seasons. Ground temperature influences the temperatures of the water-loop used in the GSHP.

Borehole depth required for vertical arrays

Assess the maximum possible borehole depth using standard construction methods and knowledge of the local geology.

Spacing

There are minimal spacing required for boreholes and trenches for horizontal collectors. Having of boreholes or trenches in different arrangements or densities can influence output so it is important to include in any studies.

Full load run hours over the year

The run hours of the GSHP have a significant impact on the amount of energy that can be drawn from the ground. The longer the GSHP is operational (in either heating or cooling mode) the lower the amount of heat that can be extracted per length of collector. Therefore the collector must increase in size or the boreholes be spaced further apart.

Heat load needed

Understanding the scale of heat output required will be necessary to size any potential GHSP installations.

Array size

Using the factors listed above the potential array size can be estimated. This can be assessed against available space in the vicinity to identify options for positioning.

Limitations

Understanding whether there is enough space for a collector array to be installed (and maintained) on the site is a key consideration.

An overview of whether this is likely to be feasible with existing buried services would be recommended once potential sites have been identified.

4.3.2 Example ground source study

Using general guidance documentation and previous proposals submitted to the University for a ground source heat pump option, we have estimated the approximate space required for an example building to install GSHP as its heating source. This is a high-level study and a more detailed desktop study would be recommended to provide more detailed analysis and recommendations. We have based the example on replacing the installed boiler capacity at Amory (approximately 900kW following fabric improvements) with GSHPs and used the following parameters:

- Ground temperature: 11 °C
- Ground conductivity: 2.3 W/m/K (based on sandstone geology for Streatham)
- Vertical collector (bore hole) max power per unit length: 47 W/m
- Bore hole depth: 150m
- Spacing between bore holes 6m
- Horizontal collector max power per unit length: 107 W/m
- Spacing between trenches 3m

To provide the whole heating system for Amory from a GSHP would require a large amount of external space, approximately 4,600 m^2 for a borehole option and 25,200m^2 for a horizontal pipe arrangement based on square arrays. Therefore, medium to large buildings on the campus are anticipated to require significant external space for a GSHP, meaning this is unlikely to be a feasible option. A GSHP could be more feasible for smaller well insulated buildings on the campus.

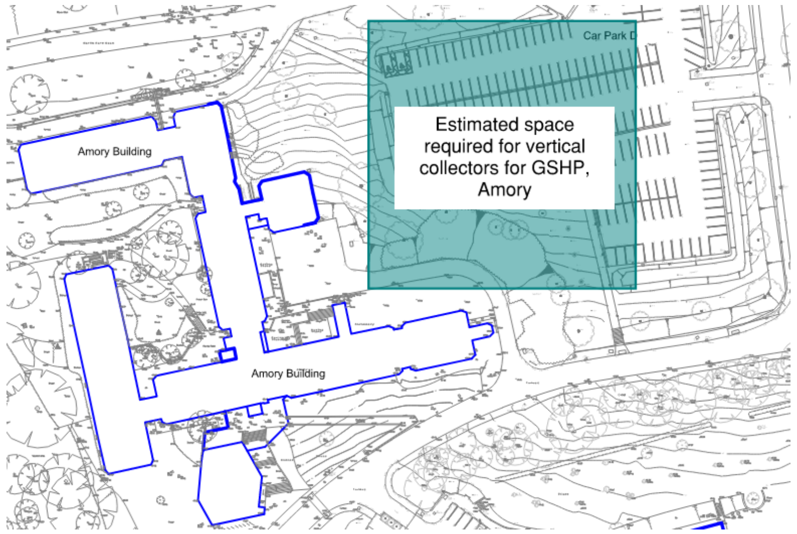


Figure 17: Estimated area needed for GSHP boreholes for Amory building

Figure 18: Estimated area needed for GSHP horizontal pipework for Amory building

Cost estimates for a GSHP for Amory are in the order of £2,250,000 for a horizontal piping installation and £3,375,000 for a vertical boreholes (based on https://www.gshp.org.uk/pdf/DECC_Heat_Pumps_in_District_Heating.pdf). Spons Mechanical and Electrical Service Price Book 2020 puts the cost at between £585,000 and £1,620,000. Additional cost such as inflation and particular influences of the site or project working and not included within these figures. Obtaining specific costing advice prior to advancing a GSHP installation project is recommended.

Medium to large buildings on the campus are anticipated to require significant external space for a GSHP, meaning this is unlikely to be a feasible option. A GSHP could be more feasible for smaller well insulated buildings on the campus. It could be possible to consider using other land owned by the University for remote from the main campus, however, the limitation here is the storage and transportation of the heat to buildings for use. Sites that are remote from heat demand are less likely to be feasible due to the difficulty connecting the heat source to the demand.

Based on the cost and space required the decarbonisation plan scenarios have focused on interventions with opportunities for ASHP which are less space intensive.

In February 2020 The University received a proposal for a campus-wide GSHP feasibility study from Black mountain titled "Tackling the Climate Emergency - Quantifying the opportunities for cost and carbon reduction using Geo-Exchange ground coupled heat pump technology" which could offer further insight into the practicalities and costs of increasing the quantity of GSHPs on the University campus.

4.4 Fuel cells

Fuel cells generate electricity by combining hydrogen with oxygen in an electrolyte between an anode and a cathode in the presence of a catalyst. The migration of protons and electrons that follows causes a transfer of charge that appears as a voltage across the electrodes. The by-product of the reaction between the hydrogen and oxygen is heat and a little water. Fuel cells are arranged in a stack with an inverter outputting ac at a user voltage. There are no moving parts in the fuel cell stack and no noise generated although pumps and fans are required to pressurise the fuel and circulate the coolant. The oxygen is derived from the air.

Fuel cells have several limitations to consider, the stack life is shortened by frequent start/stop cycles, so systems using fuel cells need careful design. There are high initial and ongoing cost, and they are sensitive to pollutants and can be damaged by small amounts.

Fuel cells operate at relatively high efficiency compared with internal combustion engine. However, the hydrogen gas obtained from the major gas suppliers is at present often derived from fossil fuel sources and requires significant energy to produce (which can be from fossil fuel derived electricity), therefore fuel cells cannot be considered to be a zero carbon power source although they are carbon free at the point of use. Zero carbon hydrogen can be generated by electrolysis of water using wind, wave, PV but this only makes economic sense if the electricity from the renewable sources cannot be directly used at the point and time of generation or cannot be exported to the grid.

If the methods of hydrogen production transform to become lower carbon with greater availability of both hydrogen and fuel cells, then the technology cells could become a more viable option in the future. However, at the present we have not included fuel cells as part of this masterplan due to the limitations highlighted.

4.5 Gas

Many of the buildings onsite currently use natural gas for heating systems and the production of domestic hot water.

There is ongoing research as to how hydrogen could play a part in reducing the carbon factor of the gas grid. Producing hydrogen itself currently requires significant energy consumption. Boiler manufacturers are developing technology to allow future boilers to convert from natural gas to hydrogen.

Current research indicates that twenty percent hydrogen could be introduced into the gas grid in the future. This percentage is unlikely to make a significant reduction is fossil fuel usage and therefore not provide the contribution required to meet the University's ambitious carbon targets. As the transition to hydrogen is still at a research stage and any decarbonisation of the gas grid is uncertain, the decarbonisation plan has focused on other measures to meet the University's targets. This approach could be reviewed in future years as more information emerges about hydrogen within gas networks. The carbon associated with using grid gas has been taken as a constant for the purposes of developing this plan.

4.6 Biomass and biofuel

4.6.1 Biomass

Biomass is often thought of as the raw material for producing alternative fuels or a solid fuel material itself. Examples of biomass include virgin wood (logs, chips, etc), energy crops (such as perennial grasses), agricultural residues (eg. corn cobs, barley straw or industrial residue/waste wood. Of these the virgin wood has the highest energy content but can be the most expensive and places demand on the limited natural resources available.

Biomass can be burnt in boilers or Combined Heat and Power (CHP) plant to produce heat, with CHPs also able to produce electricity. Burning biomass produces carbon dioxide emissions but this can be in balance with the carbon the plant absorbed during its lifetime. However, processing and transportation of biomass can mean that the associated carbon is higher if biomass cannot be sourced locally. Increasing demand for biomass worldwide can result in habitat loss or competition for land with food crops. Utilising biomass for commercial heating can require large volumes of fuel to be stored and regular deliveries to maintain supplies. Biomass boilers and CHPs require a steady heat demand to operate efficiently.

Due to the limitations highlighted above, biomass boilers are now generally not found to offer good low carbon heating solutions in the UK compared to alternative technologies.

4.6.2 Biofuel

Biofuel is produced from biomass and can be liquid or gas. It can be produced from renewable sources that can be replaced such as plants. The associated carbon and emissions vary, with some offering little benefit compared to fossil fuels and others having significant reductions. The two most common types are bioethanol and biodiesel. Currently a biofuel alternative to the domestic heating fuel oil, kerosene, is not available.

Bioethanol is produced from fermentation, often from carbohydrates in crops. It can be used as a fuel for vehicles or as an additive to in petrol to reduce vehicle emissions. Pure bioethanol cannot be used without modifying the engines if these have been using fossil fuels previously.

Biodiesel is produced from oils or fats. It can be used as fuel for vehicles, but it is often used as a diesel additive to reduce particulates, carbon monoxide, and hydrocarbons. It can be mixed with standard diesel to reduce emissions. In the UK B7 is the most commonly available blend with seven percent biodiesel mixed with standard diesel. One hundred percent biodiesel cannot currently be used in lower temperatures setting as engines are unable to start at below 15 degrees Celsius.

Hydrotreated Vegetable Oil (HVO) is a renewable diesel, sometimes referred to as green diesel, produced in the process of hydrogenation. This uses hydrogen as the catalyst, compared with methanol used for regular biodiesel production. Due to its production process, the key advantages of HVO over regular biodiesel and fossil diesel are:

- higher oxidation stability means much longer shelf life
- higher cetane number with higher calorific value.
- suitable for cold climate regions
- about 10% lower NOx emissions.
- reduced greenhouse emissions
- requires no engine modifications

These advantageous physical properties coupled with increasing global requirements of reducing greenhouse gas emissions have led to increased use of HVO.

As with biomass, there are downsides to biofuels as these can be produced on land or from crops that otherwise could have been used for food production. Sustainable sources of biofuel need consideration to ensure that local habitats are not damaged to grow biofuel crops and water consumption does not lead to droughts elsewhere in vicinity. Biofuel can be a higher cost per litre with a lower energy yield. However, biofuel research and development is continuing so improvements may be seen in the years ahead. Biofuels, if selected carefully, can offer the opportunity to reduce carbon emissions by mixing or replacing fossil fuels.

4.6.3 Oil and diesel

Several buildings on the estate currently rely on the use of gas oil or red diesel, generally this forms a back-up, such as in Geoffrey Pope where it is needed to comply with Home Office requirements. The downsides to continuing to use this fuel source are that it produces carbon dioxide and nitrogen oxides emissions.

Where diesel is used as a back-up fuel source, replacing this with alternatives will need some consideration. It is unlikely that in the short term a switch to relying on electricity only will be feasible as this may not provide the necessary resilience.

An option could be to retain some existing gas installations but use these as a back-up heating source while lower carbon electric generated heating is used as the primary heating, with the oil systems decommissioned. Where gas is not already available an alternative could be to consider changing to biofuel diesels.

This decarbonisation masterplan has focused on the transition of primary heating sources from fossil fuels to lower carbon alternatives because, over the campus as a whole, this is a greater influence than oil. Studies should be undertaken to review the equipment on the site currently reliant on diesel and the feasibility of transitioning to biofuels if suitable. In the longer-term it would be preferrable to phase out plant that relies on diesel/gas oil and replace with lower carbon alternatives as the technologies become available.

4.7 Comparable estates

A number of Universities across the country have invested in renewable technology to power their campuses. Below are a sample of Universities that have or are planning to install technology that exceeds the typical ‘building level’ renewables.

Most notably, Keele University are developing a Wind, Solar and battery storage energy park to provide 50% of the University’s electricity consumption. This comprises of 5.5 MW ground mounted solar PV, 1.7 MW wind and 1 MW (2MWh) battery storage. This is located at the edge of the University Campus which is in a rural location.

Ulster University has an 800 kW wind turbine located on it’s Coleraine campus in a rural setting.

The University of Lancaster is proposing a 16.5 MW solar PV farm on farmland near the university campus adjacent to the M6. It has an existing wind turbine in this area producing 15% of the University’s electricity.

Cambridge University are investigating the development of a 22 MW solar PV farm on university land.

The University should consider conducting feasibility studies across it’s Streatham and Penryn campuses to identify whether similar wind and PV projects would be feasible in addition to the Duryard PV already planned. The proximity of residential buildings to the campus may pose planning issues for large scale wind turbines.

Alternatively, the University may wish to engage with external funders and operators to identify opportunities for renewable energy production off site.

5 Factors informing the plan

5.1 Future campus developments

A number of buildings included within the decarbonisation plan are: not currently built and are in the design phase, under construction or do not have metering data available yet. For these buildings, predictions about their operational energy consumption have been made. These are described in the table below.

Building Number	Year of opening	Building name	Description
BG191	2021	South West Institute of Technology	TM46 energy benchmarks used for predicted consumption. VRF heated and cooled.
BG192	2021	Creative Quadrant	Considered as an extension to Streatham court (BG073) with TM46 energy benchmarks used for predicted consumption.
BG193	2022	Centre for Resilience in Environment, Water and Waste	Estimated annual energy consumption and PV yield taken from CREWW operational energy report

Table 6: Buildings without energy consumption data that are included in plan

5.2 Maintenance and controls

5.2.1 Maintenance

The University has a long-term maintenance plan for the next five years and this has been reviewed for opportunities to align fabric upgrades or heating replacement with these scheduled works. The age of other boiler plant has also been reviewed to anticipate when these may be due for replacement to look for other opportunities to change to alternative heating technologies.

As part of the future project planning guidance in Section 10, a boiler replacement decision tree, (included in Appendix A) has been produced detailing a process for determining which heating plant is suitable for buildings and when ASHPs can be included as part of the solution.

Maintenance can play a role in the journey to reduce carbon alongside operation. Currently maintenance at the University is generally based on planned schedules and reactive calls, which is the common approach in the buildings industry. An alternative is to move to a more active condition driven approach where components are monitored and replaced when outside the acceptable range. When optimised this can provide earlier warning of key component failures and decrease waste if parts are replaced as needed rather than according to timed schedules.

5.2.2 Smart FM and analytics

New more agile ways of working, the broader digital revolution, a desire to make more effective use of space, and carbon and energy reduction targets, are all contributing to a demand to re-evaluate the conventional approach to how buildings are used, operated and maintained. The demand to improve the performance of buildings and close the 'performance gap' is also slowly increasing.

To meet these ambitions, strategic adoption and integration of new technologies and ways of working are key components. Operation and maintenance driven by data and analytics has been shown to have a substantial impact on performance.

Moving to a more data driven approach offers the opportunity to:

- Target investment where it will be most beneficial
- Optimise the use of staff and contractor expertise
- Aim to minimise reactive maintenance and user feedback callouts
- Reduce waste (where parts are replaced when still within acceptable limits)
- Achieve greater levels of optimisation. If data is reviewed and included in feedback loops or learning algorithms this can reduce energy and create a better user experience.
- Greater visibility of the current situation and assets

Potential drawbacks:

- Investment and additional training required
- Devices, data, and software may not effectively work together
- Data access and ownership may not be properly considered or managed
- Commercial agreements may not deliver what was promised or do not interface well with other elements

To avoid some of the highlighted risks, a suggested framework for a transitional road map is shown below:

1. Define desired outcomes including user experience, business case, energy savings
2. Create common data environment to join up data
3. Create validation layer to ensure data is reliable
4. Use condition-based data to provide context for decisions
5. Transition to active condition-based maintenance approach
6. Look for automation opportunities
7. Create interfaces to allow users to communicate with buildings and manage experiences

The impact of moving to a data driven FM system has not been modelled as part of the decarbonisation masterplan as the impacts will vary significantly depending on what scale this is invested in and adopted. However, it is highlighted as a point for consideration in planning for the future of the estate, Section 11.3 and the University should develop a strategy for enabling a more data driven approach utilising the framework above.

5.2.3 Setpoints and performance criteria

Operational energy and carbon use in buildings can be reduced in cases where the buildings services are over delivering against the true needs of a building or space. For example, when ventilation systems have been designed and commissioned to supply air for a greater number of people than use the space, or when air change rate to a technical space are higher than needed for operational or safety criteria. Reducing air flow can save fan energy and reduces heating demand (if the supplied air is heated).

Many building services have setpoints as part of their control systems, for example room temperatures that turn on cooling systems and turn off heating systems. Setpoints are normally adjustable either on the BMS or sometimes locally in the room or at plant local controllers. Operational energy and carbon can be reduced by adjusting setpoints if this is carefully considered and commissioned, however this needs to be balanced with user requirements and experience. For example, increasing the temperature that rooms rise to before cooling equipment turns on reduces cooling energy consumption over the year, but this needs to be balanced with user comfort. Gradual changes in setpoints can be more successful than sudden adjustments and allows an optimum to be found.

When a space has opposing systems (such as heating and cooling) having a dead band between the system setpoints is import as this prevents the systems cycling on and off and competing. We understand that having a dead band is generally part of the University's control philosophy, but it is worth including this as part of a review into building services performance.

It also important to consider the setpoints and control strategy against outside air temperature and how the building or zone performs over a day or several days. Reviewing trends can be beneficial to analyse opportunities for change.

Reviewing the time periods that plant is set to operate and whether it can be turned down or turned off to suit usage patterns can also lead to energy savings if this was not previously optimised.

The first steps, as per the University's decision tree, are to understand what is known and then to find out information about the space and buildings current needs. Next is to challenge these where appropriate to see if there is another way of approaching the criteria. Ideally all the above would form part of an energy performance audit of a building.

Setpoints and performance criteria adjustments benefits have not been modelled in the scenarios of this plan as any benefit will be unique to each building or system. However, it is recommended to include this as part energy performance auditing of buildings, starting with the highest consumers, as energy savings could be achieved, and the investment needed may be relatively small.

5.3 Thermal modelling and Hydraulic study

The Amory building was selected to be used as case study both for how analyse changes to the building and the resulting changes to energy and carbon. Impacts of improving the fabric and changing the heating system were modelled. The existing building is heated by gas boilers operating at 82/71°C.

A dynamic 3D thermal model has been created in IES to assess the heating requirements of the existing building throughout a typical year. This modelling aligned with the real-world gas consumption of the building. Then peak and annual heating requirements were assessed once agreed theoretical improvements to the building fabric had been added. One option assessed was improving the walls, roof and windows to PassivHaus Enerphit standard. The second was improving only the windows to Enerphit standard. This was to provide insight into the proportional improvements associated with upgrading the different fabric elements.

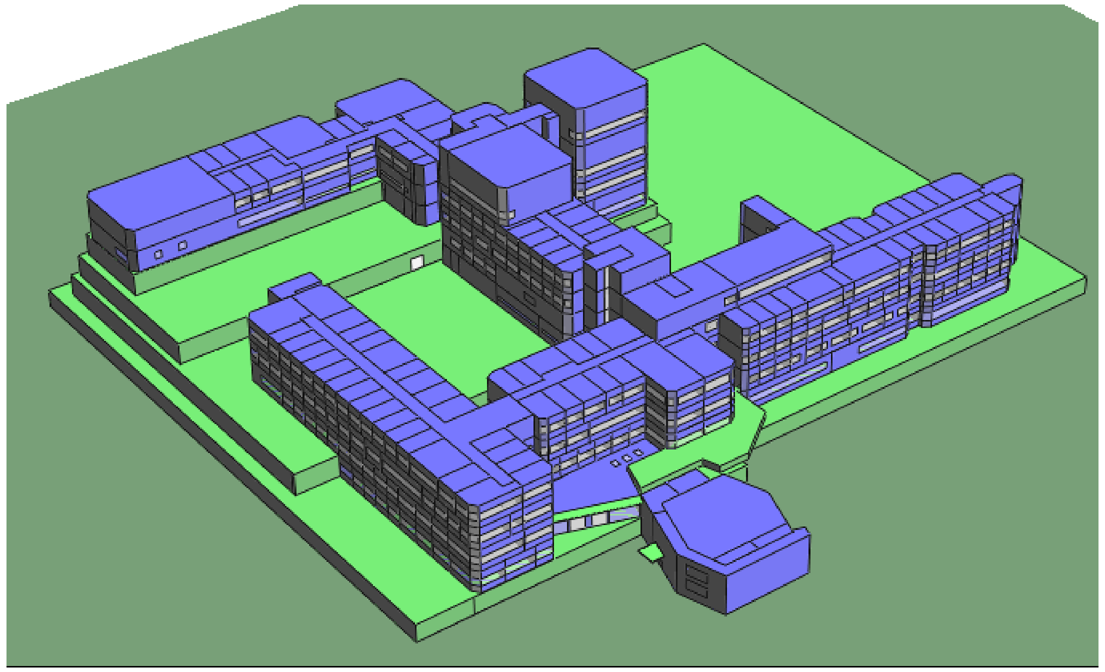


Figure 19: The Amory thermal model

The existing building was surveyed to assess the installed boiler plant, distribution routes and heat emitters throughout the building. This enabled us to compare the room heating requirement to the capacity of the existing emitters (such as radiators). This process demonstrated that in the majority of instances, the radiators were oversized for their current application, and could still provide sufficient heat if the system was operated at lower water temperatures.

In conjunction with software consultants Hysopt, the feasibility of switching to lower temperature air source heat pumps was assessed. This study determined that without amending the fabric, an ASHP would need to operate at 60°C to meet the space heating demands of the building. By improving the fabric, the flow temperature of the ASHP could be reduced to 50°C resulting in substantial efficiency improvements. This would require additional changes to air handling unit coils to ensure they could operate at a lower flow temperature.

This analysis has informed the wider study as it has given confidence to the concept of replacing existing high temperature gas boilers with lower temperature heat pumps, supporting the decarbonisation of the campus.

It has also demonstrated the impact of improving the building fabric, as it increased the efficiency of the heat pumps (as they were able to operate at lower temperatures) and allowed smaller capacity heat pumps to be selected due to the reduced space heating load.

5.4 National Grid

5.4.1 Grid Projections

As discussed in Section 4.4, the carbon factor associated with natural gas from the grid has been taken as constant within this plan.

The electrical national grid is in the process of transitioning away from using fossil fuels for electricity generation. With the increased availability of renewables such as wind and solar, alongside nuclear energy it is predicted that the carbon factor associated with consuming grid electricity will continue to decrease in the years ahead.

The Department for Business, Energy and Industry Strategy (BEIS) publishes grid carbon factors, with the most recent in its 'Updated Energy and Emissions Projections 2019'. This includes projections of the grid carbon factor (gCO_2e/kWhr) up till 2040. This shows a steady decline down but not reaching zero by 2040.

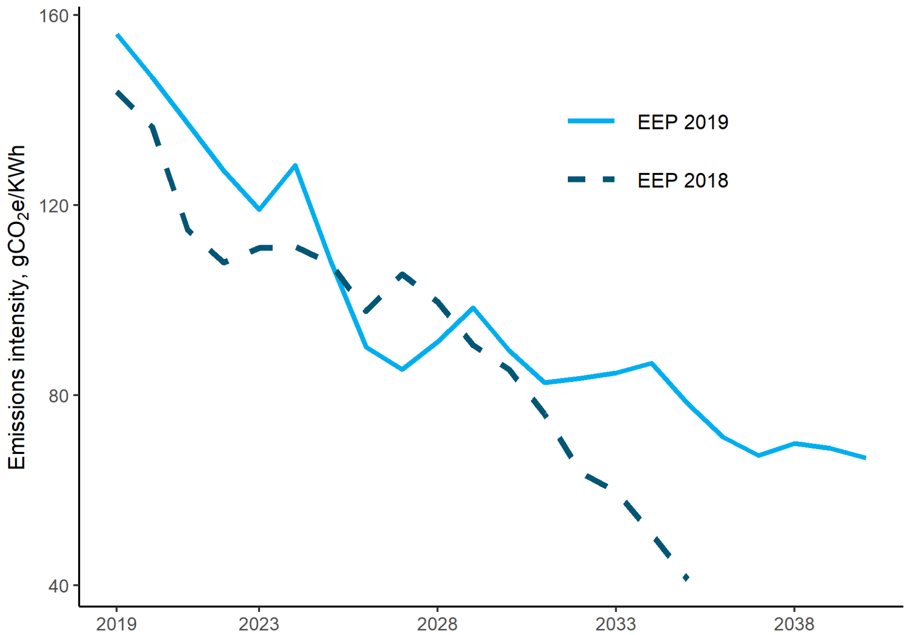


Figure 20: Emission intensity © BEIS, 2019 Updated Energy & Emissions Projections

The National Grid ESO has published Future Energy Scenarios 2021. This includes four scenarios: Steady Progression, System Transformation, Consumer Transformation, and Leading the Way. The slowest grid decarbonisation occurs in the 'Steady progression' scenario, with some sectors not predicted to reach net zero carbon by 2050. Both 'Transformation' scenarios rely on either changing the way energy is used or generated/supplied to be net zero by 2050. 'Leading the Way' relies on high consumer engagement, world leading technology and investment to offer the fast route to net zero carbon.

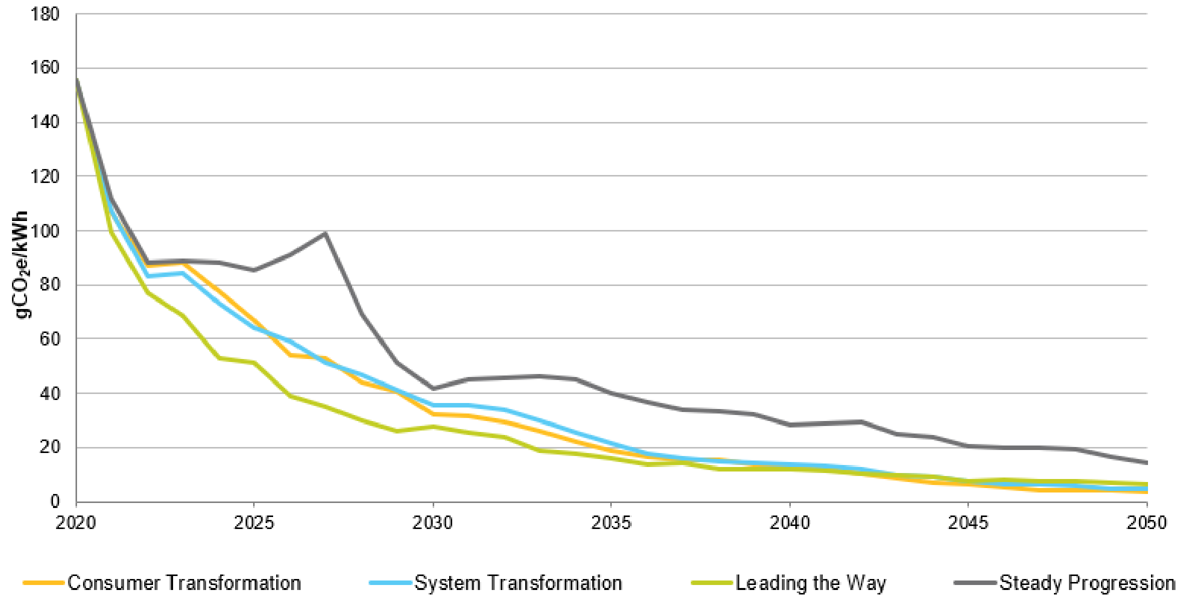


Figure 21: Power sector carbon © National Grid ESO, Future Energy Scenarios July 2021

Based on more conservative projection, 'Steady Progression', it is anticipated that the grid may not have reached net zero by 2040, with it projected to have not reached net-zero by 2050. If this is the path that the grid follows, the University may need to be purchase low carbon electricity, add additional renewable generation, or consider implementing carbon offsetting to meet its targets.

At the time of writing, the UK government had recently published its 'Net Zero Strategy: Build Back Greener' document which committed to producing all electricity from low carbon sources by 2035 subject to supply security. If this is implemented, then this could simplify the approach needed to meet the University's targets.

For this masterplan we have used the National Grid Future Energy Scenarios 2021 Steady Progression in the calculations, to produce a more conservative estimate. The projection used can be altered by the University in the future using the spreadsheets shared as part of the project.

5.4.2 Power Purchase Agreements (PPA)

Renewable energy generated offsite could be purchased by the University via a PPA. This could enable the University to purchase low (or zero) carbon electricity at a greater proportion than would be available generally from the national grid mix. Currently the University has agreed a PPA for ten years which includes 20% of the electricity generated by renewables. When this PPA agree is due for renewal an agreement which includes a larger percentage of renewable generation could be considered. If the University has transitioned to all electric by this point in time, procuring a 100% renewable PPA could offer the potential to bridge the gap to achieving the plan targets (net-zero for Scope 1&2).

5.5 Environmental net gain and carbon offsetting

5.5.1 Environmental net gain

The concept of Environmental Net Gain is about leaving the environment in a better state than initially encountered. Typically, it encourages estates to consider biodiversity and to deliver increases in habitat and ecological features over and above those being lost or degraded and to help to restore broader ecological networks. Achieving net gains in biodiversity for wider benefits of society requires focusing on avoiding the loss of biodiversity and ensuring stakeholders are involved. The gains should be valuable both locally and regionally, with benefits for the environment, society, and economy.

The draft University Sustainability Design Guide includes a project hierarchy for approaching environmental and biodiversity impacts, starting with avoidance, followed by mitigation and finally compensation.

Setting out the aims, priorities and how Environmental Net Gain will be measured will be important to it being widely followed and used in projects. We recommend this is include as part of the strategy that is being developed.

Reviewing the existing environment and biodiversity of the estate was not included in the scope of this project. In order to measure Environmental Net Gain a clear understanding of the current situation is recommended, including habitat type and relationships with the local area. Developing this understanding would be advised prior to starting any projects.

We have highlighted possible opportunities or impacts on environmental net gain where these relate to the decarbonisation plan or the suggested inventions. All would need further investigation and reviewing against a site wide vision for the environment and biodiversity.

- Air quality – is there opportunity to reduced emissions from boilers, vehicles onsite, diesel generators?
- Biodiversity – consider sites of any new plant such as ASHP to avoid impacting biodiversity. Can natural screening be used to reduce noise from external plant at ground level (without compromising air flow or security)
- Green walls and roofs - Could it be feasible or suitable to add green walls/roof component as part of future recladding / insulation works.
- Solar shading - Is it possibility to use natural shading to reduce solar gain into buildings?
- Wildlife habitat – Is it feasible to provide additional habitats or artificial ones such as bird boxes, bee/bug hotels as part of works?
- External lighting – can light pollution and energy use be reduced without impacting safety or security of the campus?
- Climate change – how can the environment be protected or enhanced to avoid expected impact from climate change and weather patterns?
- Circular economy – can items in good working order be used elsewhere on the campus, such as relocated existing working boilers in buildings that will take longer to transition away from gas rather than buying new ones. Can items be repurposed or recycled rather than disposed of?
- Procurement – are contractors and manufacturers aligned with University’s principles with regards to net-zero carbon and the Sustainability Design Guide and are they able to account for associate carbon from their works? Are supply chain and procurement chains considering circular economy principles?

The list is not exhaustive, and it is recommended that the University undertake a separate study for a holistic review of environment net gain opportunities or risks to the estate.

5.5.2 Carbon Offsetting

Definitions of offsetting vary but it can be described as certifiable and transferrable units of emission reduction or removal that can be purchased by an entity to balance their emission outputs and meet their emission targets (e.g., carbon neutral, net zero carbon). In practice, offsets aim to balance the ‘damage’ caused by carbon emissions in one location with ‘repair’ elsewhere.

Offsetting is often viewed as the final option to account for residual emissions that are unavoidable, labour-intensive, or financially inhibitive to mitigate.

Most offsets currently available achieve emission reductions rather than genuine carbon removal. Instead, investing in offsets that offer long-term carbon storage to reduce the risk of reversal would be preferential.

Offsetting can offer a way to meet carbon reduction targets. However, there can be downsides to offsetting with negative perceptions and damage to credibility. Offsetting can be viewed by some as ‘buying your way out’. To mitigate this, offsetting should be used as a transitional action and a last resort after other measures have been investigated and invested in. Relying on offsetting also carries the risk of being vulnerable to market price changes and the limited availability of offsetting activities.

5.5.3 Approach

The University is committed to developing a strategy for managing residual carbon emissions through Natural Offset methods that actively contribute to Environmental Net Gain. Building the Foundations, the first step on the Environment and Climate 5-Step Journey, has been started by the University to develop a better understanding of the natural capital of the estate through iTree surveys and Natural England’s Biodiversity Metric assessments.

With the help of research projects currently underway, a Natural Offset strategy will be developed by 2023 that will determine a hierarchy of suitable methods of offset for the University to invest in. This will likely feature channels such as afforestation, restoration of peatlands and seagrass plantation, alongside technological solutions for offset such as investment in wind farms and sequestration projects.

Largescale projects will be expected to contribute to the funding of Natural Offset through an internal fund, where Technical Evaluation of the projects will determine the residual carbon associated and therefore the payment required. The funding from this will contribute to the investment of assets for Natural Offset and Environmental Net Gain.

Management of residual carbon is expected to commence from 2025 as part of a phased implementation. 15% of the residual carbon will be offset through Natural Offset and Environmental Net Gain projects. The proportion of residual carbon will then be increased year on year such that Net Zero status can be achieved before 2050.

6 Interventions

Based on the information gathered and discussions with the University, a series of measures that could reduce the operational carbon of buildings on the estate have been established. These are referred to as ‘Interventions’. The interventions are discussed in detail below. In subsequent sections combinations of interventions have been grouped into ‘Scenarios’ to test their impact on carbon reduction while balancing the associated costs involved. The decarbonisation plan looks at what combinations could enable the University’s targets to be achieved.

It is noted there are several student residences on the campus that are operated by third parties. We have developed the plan on the basis that the student residences will follow the same interventions as the other buildings on campus, but it should be noted that this will be dependent on the building operator agreeing with the approach.

These interventions align with the University’s sustainable design guide, including the target of improving the fabric of refurbishment projects to the Enerphit standard, introducing low and zero carbon technologies and improving the operation of existing systems to minimise energy demand.

6.1 Ventilation systems

6.1.1 Heat recovery

Mechanical ventilation systems supply air into spaces and usually include heating coils to warm outside air up to a setpoint to avoid occupant discomfort, (alternatively the space heating system needs to be designed to include the heat load of the incoming air). Air is normally extracted from spaces to balance the pressure and remove contaminants. When this extract is released straight to atmosphere then the opportunity to use some of this room temperature air to partially heat the incoming air is lost. It is good practice to install a form of heat recovery in mechanical ventilation systems, these are often thermal wheels or plate heat exchanges.

In new builds heat recovery can be designed in from an early stage, however, refurbishments or retrofitting can be more challenging. This is due to the supply and extract normally needing to be within the same unit which is then larger than supply/extract only systems. Installing run around coils can overcome this but these are less efficient and the pumping energy within the system needs to be balanced against the heat recovery energy savings.

In systems that have extract air that is “dirty” or contaminated there can be concern about transferring these back into the incoming supply air. Thermal wheels normally include purge sections, while plate exchangers avoid the two air streams coming into contact and have low leakage rates, so a solution is generally possible for most generally uses. Hazardous areas would need additional consideration. Where it is unavoidable to maintain separate extracts, such as fume cupboards, the rate of extract should be carefully designed. The possibility to use a system with heat recovery when the specialist system is not in use (to allow partial heat recovery) should be considered.

It is recommended to review existing ventilation design and consider introducing heat recovery. To minimise capital cost this could be when the existing plant reaches the end of its life or when refurbishment is planned.

The addition of heat recovery has not been modelled as part of the scenarios as it will be highly dependent on feasibility on individual systems and over relying on this could leave the University at risk of not meeting its targets. It is recommended to assess opportunities for ventilation improvements as part of ongoing maintenance and space utilisation planning. We understand that this is aligned with the current approach of the University’s Estates Team.

6.1.2 Mixed mode

Several office spaces at the University rely on outside air being provided via natural ventilation through manual opening windows. The advantages of this are that is gives the user a degree of control over their environment and no fan energy is used. In mid seasons and, depending on conditions, summer the outside air can provide cooling to the spaces. However, the downsides are that in cooler months draughts can be experienced and the heating system needs to provide extra heating to compensate for the cold incoming air. Noise from external environments can be an issue.

Mixed mode is a hybrid system that can operate as a mechanical ventilation system or natural ventilation depending on which optimal. If the system relies on users manually opening windows it is important that they understand when they should do this and when to rely on the mechanical system, having automated windows or openings can remove this complication. If designed well mixed mode can save heating energy in the winter months, while minimising fan energy usage at other times. The range, scale, and complexity of systems available varies greatly so careful selection of the best solution is needed.

Changing systems to mixed mode ventilation has not been modelled as part of the scenarios as it will be dependent on feasibility on individual systems as to where the benefit can be implemented. Relying on this change could leave the University at risk of not meeting its targets as the feasibility is very building and space dependant. It is recommended to assess opportunities for mixed mode as part of ongoing maintenance and space utilisation planning, alongside other system reviews.

6.2 Smart metering and BMS analysis

Understanding where and how energy is being consumed in a building allows trends and potential improvement areas to be identified. A way to do this is to install metering and sub-metering that can be logged an interrogated. Having this information available on the BMS can provide visibility and allow for comparisons across the estate. As discussed in Section 5.2.2 developing a holistic and integrated vision and strategy for future FM processes allows the right technology to be installed to ensure different aspects can integrated as these are installed.

Installing additional metering or ability to carry out more analyse on the BMS does not automatically deliver energy and carbon savings. Unless this is a fully automated facility it relies on the estate team reviewing the data, identifying areas for improvement, and then working with stakeholders to achieve these. Having simple dashboards available for stakeholders to view can encourage them to engage and make changes to behaviour. Energy savings of ten to twenty percent can be achieved through smart metering and optimising plant.

Smart metering has not been modelled within the scenarios of this masterplan as savings will very subjective and vary from building to building and is not something that can be planned in a high-level implementation plan. However, it is recommended to include this as part of a future planning of the estate management. Guidance and standards are currently defined for the BMS system, but this is separate from other systems such as maintenance (PlanOn), room booking systems and some sub-metering. Redefining a long-term vision will allow elements to be added and integrated in a phased approach.

6.3 Fabric upgrades

Improving the external fabric performance on buildings and the air tightness reduces the heating demand, saving operational energy and carbon. Having better insulated buildings can also widen the range of heating technologies that are feasible due to the lower intensity of heating needed.

Improving the shading on a building can reduce the cooling demand and improve user comfort by limiting the solar gain experienced. This needs to be balanced with the beneficial effect that heating from the sun can provide in the winter months. Windows and glass design can also impact the solar gain experienced in a space, which needs to be balanced with the benefits of natural daylight. Benefits to carbon reduction of altering solar shading or glazing tinting have not been modelled as part of the scenarios in this plan. Specific studies to review optimisation of the solar impact on a building would be beneficial to highlight opportunities and it is recommended this is included as part of any fabric upgrade design works.

The fabric upgrades considered in this plan have been simplified into three types depending on the building age and whether they have listed status. Before any fabric upgrades are carried out specific feasibility studies would be recommended for each building.

To target investment at buildings with the worst thermal performance, enhancements to buildings built after 2000 has not been included. This is based on the higher standards of thermal performance that were introduced under building regulations from this period.

6.3.1 Listed buildings

This category of buildings includes Grade I and II listed properties alongside locally listed buildings. The facades are sensitive with limited or no cavities. Considering this, insulating the walls has not been proposed. Improving the roof insulation could be considered on a case-by-case basis but has not been included within the master plan. Whether this is feasible will be subject to individual building construction and condition.

Improving the windows is an area that is proposed under the master plan. This has been based on the provision that secondary glazing can be added to improve the thermal performance. In instances it may be possible to replace the windows entirely, but this would require detailed review and discussions on the aesthetic implications.

6.3.2 Buildings constructed pre-1985

Following the principles of the University's Sustainability Guide, it is proposed to consider upgrade the external fabric to the Passive House retrofit standard, EnerPHit. For buildings of this age it is proposed to upgrade the walls and roof and replace the windows with triple glazing (to meet EnerPHit standard). It has been assumed that these upgrades also lead to an improvement in the building's air tightness and so this has been included in the calculations.

6.3.3 Buildings constructed between 1985 and 2000

Based on enhancements of building regulations around this period it would typically be expected that the roof and walls would have been constructed to a reasonable level of thermal performance, although lower than current best practice. It has been proposed to upgrade the windows to a standard equivalent to EnerPhit u-value standards with the air tightness also assumed to have improved as a result of the works.

6.3.4 Summary

Building category	**Fabric Upgrades**
Listed buildings	Secondary glazing added
Non-listed buildings pre-1985	Walls and roof upgraded. Windows replaced
Non-listed buildings 1985-2000	Windows replaced
Non-listed buildings post 2000	No upgrades

Table 7: Fabric interventions summary

For buildings located in Exeter the Enerphit standard equates to:

Fabric type	**U-value (W/m^2K)**
Exterior insulation (e.g. walls and roof)	0.3
Vertical windows	1.05

Table 8: Enerphit U-values for Exeter location

6.4 Air source heat pumps

Air Source Heat Pumps (ASHP) use the refrigeration cycle to extract heat from the external air. This can be transferred to internal spaces either via refrigerant and room emitters or via low temperature hot water (LTHW) system and emitters. For this plan air to water heat pumps have been proposed as many buildings already have LTHW systems to provide heating.

ASHP are powered by electricity and able to produce between two to three times the kilowatts output of heat for each kilowatt of electricity they consume. They are produced by a range of manufacturers which offer a range in efficiency and the temperatures of water they can produce. Replacing gas boilers with ASHP requires modification to the primary plant alongside the change of heating source.

Two types of ASHP have been proposed for the master plan: High temperature ASHP which produce water at higher temperatures but are lower efficiency, and lower temperature ASHP. Lower temperature ASHP have been considered for buildings that have good fabric performance (or proposed to have upgrades) due to the lower heating load. Higher temperature ASHP are considered for other non-listed buildings. Listed buildings had heating systems changed to electric boilers due to anticipated poor thermal performance of the fabric. In practice there may be individual listed buildings that are suitable for use with ASHP and is recommended that all buildings are assessed on a case-by-case basis in additional studies following on from this master plan.

Type	SCOP	Example model reference
Low temperature ASHP - 50°C	3.53	Daikin EWYT650B-XLA2
High temperature ASHP - 65°C	2.15	Daikin EWYT215B-XLA1 Air – water heat pump & EWWH150J-SS Water-water heat pump in cascade arrangement

Table 9: ASHP efficiencies based on example products

6.5 Electric boilers

Electric boilers are similar to gas boilers but required no flue and do not produce emissions. They produce slightly less than one kilowatt of heat for each kilowatt of electricity they consume. They are able to produce higher temperature LTHW than ASHPs and are therefore suitable for buildings where the fabric cannot be improved. Electrical consumption is high compared to heat pumps as their overall efficiency is typically 99%. It is unlikely that existing buildings will have been designed with sufficient spare capacity to support electric boiler heating. It is anticipated that changing to electric boilers would require upgrades to the building's (and potentially sitewide) electrical infrastructure.

6.6 Heating system upgrades

Many heating systems within the estate operate on a constant volume system, where the quantity of water pumped around the circuit (and the pumping energy) is not modulated down as the heat demand decreases. Heating systems now are generally designed to be variable volume, allowing less pumping energy to be used.

This intervention is based on replacing and upgrading elements of the heating system to enable conversion to a 2-port (variable volume) system. It is anticipated that pipework and emitters such as radiators would be upgraded or replaced as part of the works. Replacing pipework and emitters can also allow the system to be designed to operate at lower temperatures and reduce heat output (if suitable for the building and system type).

As part of heating system upgrades the controls and setpoints should be reviewed and modified to enable the system to operate most efficiently. (The opportunity to review this on other systems is recommended but not modelled within the scenarios in this plan).

The efficiency saving of improving the heating system within the Amory building has been calculated to be 7% of the heating energy. This is in line with experience on other projects and forms the basis for the energy saving where the heating system is proposed to be upgraded on other buildings.

6.7 Lighting upgrades

Replacing lighting with LEDs can save energy and reduce carbon. Changing to lighting controls that include daylight dimming and presence/absence detection can also save energy if designed correctly as it minimises the time that artificial lighting is in use and removes the onus from the users to ensure lights are switched off.

The decarbonisation plan considers upgrading older lighting systems based on the buildings targeted by the University. Estimates of the efficiency benefits and cost were taken from historic lighting quotes provided by the University's contractor Intoheat. The proportion of electricity used for lighting is based upon good practice and past project experience.

General proportion of electrical consumption for lighting within an academic building	8 %
Reduction in lighting power consumption with efficiency and controls upgrades	40 %
Total energy saving from lighting upgrades as a proportion of building total electricity consumption	**3 %**

Table 10: Lighting improvements

6.8 PVs

The University has completed a number of studies to identify potential for PV on the campus building roofs and within the surrounding area. One area under consideration for a ground-based system is the Duryard array, with 250kW and 750kW arrays under consideration. For the purpose of this plan, we have included the 750kW peak array and the predicted annual yield within the options. Other off-site PV opportunities are discussed within the implementation plan, Section 9. There could be opportunities for smaller arrays above carparks on the sites.

Adding PV onto individual buildings is a common way to reduce the electricity consumed from the grid. The University previously commissioned ZLC energy to assess the feasibility of adding PV to roofs of buildings on Streatham and St. Luke's campuses. This information has been used to inform costs, potential yields and priority for installing PVs. The priority for PV installation is based on speed of payback. After reviewing the ZLC information the buildings identified as priority 1, 2, 3 & 4 have had PV additions included within this plan. Installations across the buildings have been phased to limit the number of concurrent projects.

Campus	Building name	Modelled year of PV installation	Cost (£)	Yearly estimated yield (kWh)
Streatham On Campus	Amory Building	2030	£333,000	289,496
Streatham On Campus	Cornwall House	2025	£163,800	116,549
Streatham On Campus	Forum	2031	£108,000	90,000
Streatham On Campus	Great Hall	2036	£146,000	112,500
Streatham On Campus	Harrison Building	2027	£486,000	340,200
Streatham On Campus	Kay Building (Labs)	2031	£38,000	25,500
Streatham On Campus	Laver Building	2029	£207,000	149,829
Streatham On Campus	Lopes Hall	2031	£61,000	39,100
Streatham On Campus	Newman Building	2028	£77,000	55,000
Streatham On Campus	Northcote House	2033	£125,000	85,000
Streatham On Campus	Old Library	2030	£84,000	60,000
Streatham On Campus	Physics Building	2030	£185,000	147,200
Streatham On Campus	Queen's Building	2024	£254,000	198,720
Streatham On Campus	Sports Hall	2030	£185,000	160,000
Streatham On Campus	Streatham Court New	2032	£179,000	121,125
St Luke's On Campus	Baring Court	2031	£141,000	98,806
St Luke's On Campus	College House	2031	£104,000	66,267
St Luke's On Campus	Exeter Medical School Building	2026	£102,000	73,951
St Luke's On Campus	Richards Building	2026	£167,000	130,050
St Luke's On Campus	St Luke's Sports Centre	2030	£127,000	96,968
Streatham On Campus	Holland Hall - All blocks	2028	£596,000	421,515
Streatham On Campus	Pennsylvania Court - All blocks	2024	£212,000	183,600
Streatham On Campus	Lafrowda - All blocks	2027	£405,000	349,988
Total			**£3,737,000**	**3,469,000**

Table 11: PV installations to buildings informed assessment undertaken by University contractor ZLC

The University also has the option of developing a large scale PV array off site to directly offset it’s electricity consumption. This option is included within scenario 5 to show a route to net zero for the University should the national grid not be decarbonised by 2040 as current predictions indicate.

6.9 Costing

The cost of each intervention has been assessed to allow the University to understand the scale of investment required to meet their carbon targets.

These costs represent early stage estimates and will need to be refined on a building by building basis as projects develop. As more experience is gained on each project the future cost estimates should be refined.

These costs do not allow for inflation and exclude asbestos works. They are inclusive of VAT. Refer to the costing information provided by RLB within Appendix F for further information on exclusions and the specific basis of these costings.

Costing of electrical infrastructure works has been done by Arup and is based on past project experience and high level industry guidance.

6.9.1 Assumptions

1. Base date is Q3 2021.

2. Costs (Capex and Life Cycle) are based on notional works, and have not been tailored for each building/site.

3. Life cycle cost is replacement/maintenance costs over a 40 year period.

4. All costs are REAL. (Not inflated and based in Q3 2021). Noting that an overall value for inflation is however included for the total cost profile of Scenario 5, as shown within the appendix C3.

5. Day 1 efficiency is maintained throughout the 40 years.

6. Minimum area for globally applied rates assumed to be 1,000m².

7. Minimum scale of project assumed to be £2m (construction capex cost).

8. We have assumed existing service risers and services distribution routes are adequately sized and do not requirement enlargement / alternative distribution routes to be created in the building fabric.

9. Costs associated with the removal of asbestos have been excluded as we do not have details of the extent of intervention required for each building and the level of asbestos removal

necessary. We understand that this principal has been agreed as the basis of costing with the University.

Exclusions

1. Costs associated with the removal of asbestos have been excluded as we do not have details of the extent of intervention required for each building and the level of asbestos removal necessary. We understand that this principal has been agreed as the basis of costing with the University

2. No allowance for fire precautions upgrades as a consequence of proposed works or as additional scope while refurbishment is undertaken.

3. No allowance for DDA or other access improvements as part of scope or as additional scope while refurbishment is undertaken.

4. No allowance for layout changes or construction of new plant rooms as a consequence of upgrade works.

5. No allowance for consequential upgrade required by Building Regulations.

6. No allowance for temporary accommodation or decant of spaces. This will be a project specific cost dependent on scale and nature of accommodation being decanted.

7. No allowance within the RLB rates applied include for services infrastructure upgrades or increase in capacity of supplies to buildings to suit new M&E systems. Noting however that these costs are picked up separately as part of the electrical system works by Arup

8. No allowance has been included for backlog maintenance items or works to upgrade the structure or fabric of the building beyond the specific intervention identified.

9. No allowance for FF&E, IT/AV or specialist departmental equipment.

Adjustment factors have been applied at the building level of:

20% for a Complex building (this has been taken as a building with a GIA >500m^2)

45% for a Listed building (If building is complex and listed, then max is 65%)

6.9.2 Costing information

The tables below list the estimated costs for each intervention. The RLB solution numbers relate to those listed in Appendix F which give further descriptions of the basis of cost for each intervention.

Intervention	**Capex cost £/m^2**	**Lifecycle cost (over 40 years) £/m^2**	**RLB solution Nr**
Glazing	£1,114	£2,230	2
Roof	£171	£210	8
Wall insulation	£257	£626	5
Secondary glazing	£464	£1,302	3
Heating zones and controls upgrades	£39	£174	22
Making good	£99	N/A	Global add on #2
Roof PV	£643	£776	10

Table 12: Intervention costing

Heat source	**Size (kW)**	**Capex Cost**	**Lifecycle cost**	**RLB solution Nr**
Electric boilers	50	£12,098	£36,157	17
	100	£20,756	£50,010	18
	200	£27,854	£61,366	19
	500	£40,775	£93,240	20
	1000	£78,190	£181,104	21
ASHP	50	£31,199	£115,677	11
	100	£90,063	£303,183	12
	200	£152,782	£499,068	13
	500	£338,940	£1,094,926	14
	1000	£594,707	£1,892,650	15

Table 13: Heat source costing

Costing for lighting upgrades has been taken from estimates provided to the University by Intoheat.

The following factors have been applied to the costings:

Description	**Rate**	**RLB global add on ref**
Design fees	20% of construction cost	4
Optimism bias due to high level feasibility model	39%	5
VAT	20%	6

Table 14 - Global add-ons to unit rates

7 Tested Scenarios

Following consultation with the University, five scenarios have been selected to test the impact on the estate of applying various combination of interventions. It is anticipated that some of the scenarios may not enable the University's ambitious carbon reduction targets to be achieved, but these are included to demonstrate which approaches could be less feasible or those that potentially would need to rely on a greater degree of carbon offsetting.

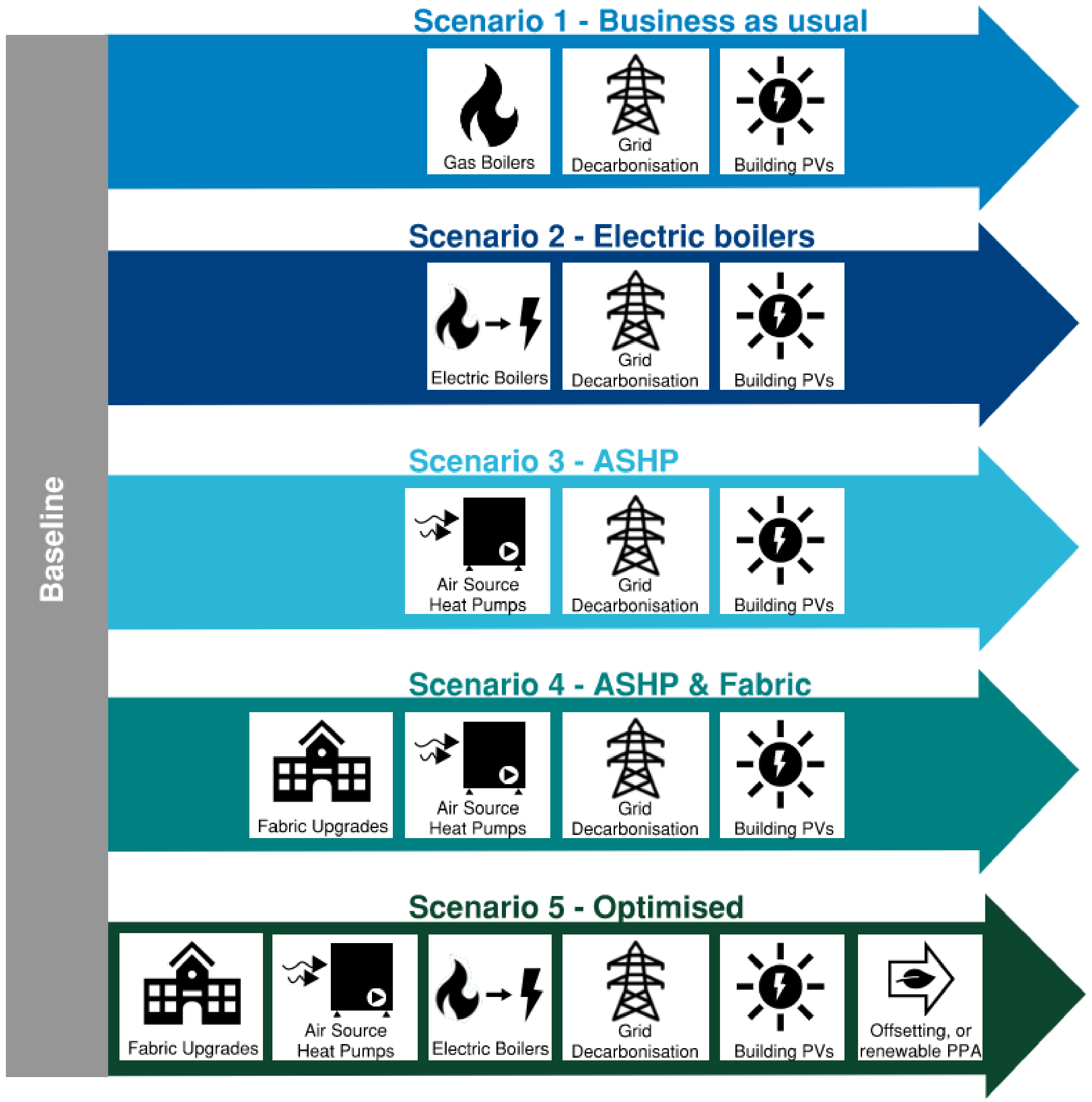
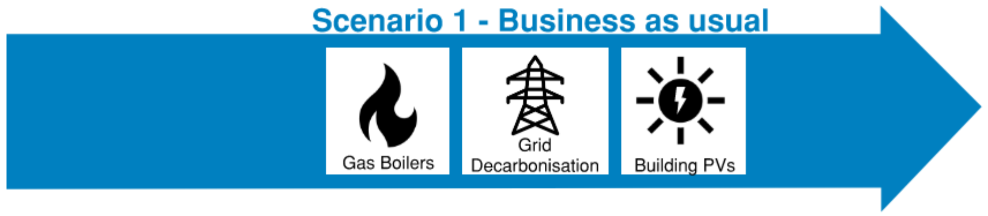


Figure 22: Modelled scenarios

7.1 Scenario 1 - Business as usual

This scenario is based on the University making limited interventions to reduce operational energy. It includes predicted reduction in the carbon factor of electricity supplied from the national grid alongside installing PVs onto the roofs of suitable buildings.

Included in the scenario:



- Heating plant replaced with new gas boilers (at end of life)
- Decarbonisation of grid electricity (FES 2021 Steady Progression)
- PV added to priority buildings in phased approach (building list as per Section 6.8)

Predicted advantages:

- Plant replacement and maintenance budgets remain in line with previous years
- Limited disruption to estate

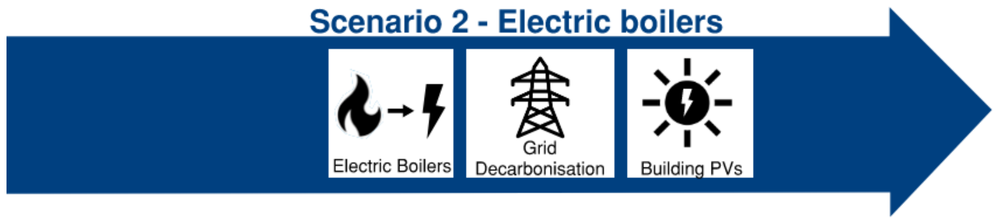
Predicted disadvantages:

- No energy reduction realised
- Targets for reduction are not met and cause reputational damage
- Opportunities for including staggered interventions are missed

7.2 Scenario 2 - Electric boilers

This scenario is based on the University decarbonising their heating system by replacing gas or oil boilers with electric boilers.

Included in the scenario:



- Main heating plant replaced with new electric boilers (at end of life)
- Decarbonisation of grid electricity
- PV added to priority buildings in phased approach (building list as per Section 6.8)
- Heating control upgrades to buildings built prior to 2000

Predicted advantages:

- Limited disruption to buildings while boilers are replaced (as heating systems upstream from plant room unaffected)
- Electric boilers alone are relatively low capital cost
- Operational carbon reduced
- No combustion emissions from heating, such as NOx

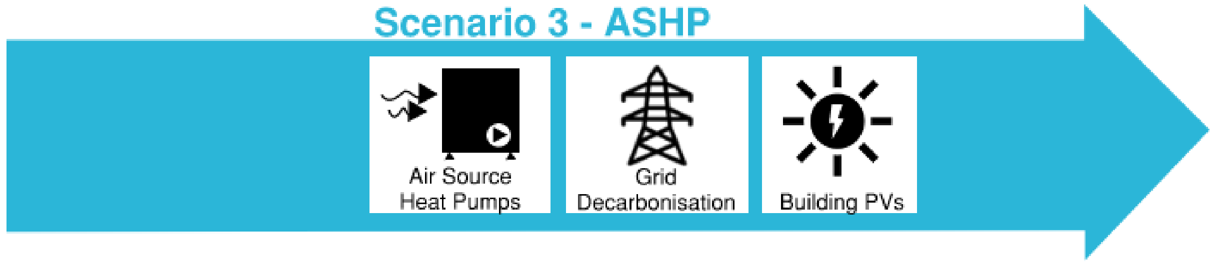
Predicted disadvantages:

- No energy reduction realised
- Bills for heating to increase significantly
- Electrical demand to increase significantly, triggering the need for major upgrades both on campus and for utility company

7.3 Scenario 3 – ASHPs (no fabric upgrades)

In this scenario, gas/oil boilers are replaced with ASHP for most buildings with electric boilers in listed buildings (as the fabric and heating system is anticipated to be unlikely to be able to operate at temperatures suitable for ASHP). The ASHP are modelled as being less efficient than Scenario 4 as they will likely need to operate at higher temperatures.

Included in the scenario:



- Main heating plant replaced with ASHP in most building, electric boilers in listed buildings
- Decarbonisation of grid electricity
- PV added to priority buildings in phased approach (building list as per Section 6.8)
- Heating control upgrades to buildings built prior to 2000

Predicted advantages:

- Operational carbon reduced
- No combustion emissions from heating, such as NOx

Predicted disadvantages:

- Bills for heating to increase more significantly than scenario 3
- Electrical demand to increase more significantly than scenario 3
- Space for ASHP is needed externally with possible planning or noise limitations
- Extent of plant replacement needed for ASHP is greater than electric boiler upgrade
-

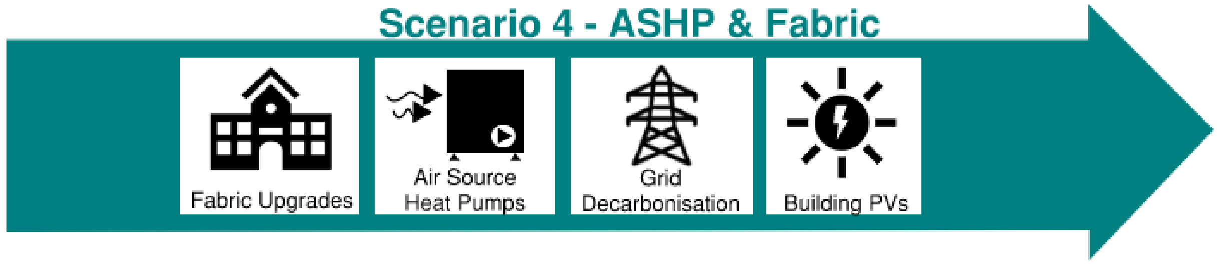
7.4 Scenario 4 - Fabric upgrades with ASHPs

This scenario is based on the University reducing the heating demand of buildings by improving the external envelope.

The heating system will be decarbonised by replacing gas/oil boilers with ASHP for most buildings. The ASHP are predicted to be able to operate lower temperatures than boilers due to the enhanced thermal performance of the building. The lower the water temperature, the more efficiently ASHP are generally able to operate.

Listed buildings have been assumed to have gas boilers replaced with electric boiler due to the difficulties of enhancing the fabric and anticipated constrained plant rooms. (Further feasibility studies would be recommended to assess if listed buildings could be suitable for heating via ASHP in place of electric boilers.)

Included in the scenario:



- Building fabric upgraded (as per Section 6.3.4)
- Main heating plant replaced with ASHP in most building with electric boilers in listed buildings
- Decarbonisation of grid electricity
- PV added to priority buildings in phased approach (building list as per Section 6.8)
- Heating control upgrades to buildings built prior to 2000

Predicted advantages:

- Operational energy and carbon reduced
- Buildings should retain heat better and could improve user comfort
- No combustion emissions from heating, such as NOx
- Fabric upgrades allows ASHP to work more efficient (at lower temperatures)

Predicted disadvantages:

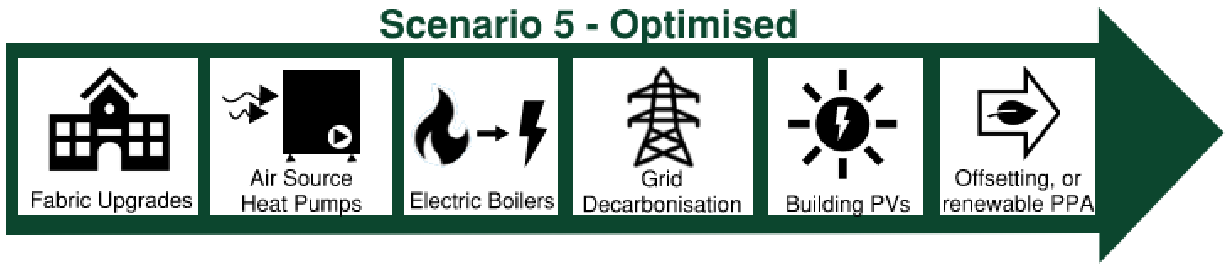
- Bills for heating to increase
- Electrical demand to increase

- Space for ASHP is needed externally with possible planning or noise limitations
- Disruption to buildings while fabric is upgraded
- High capital cost for fabric upgrades
- Extent of plant replacement needed for ASHP is greater than electric boiler upgrade

7.5 Scenario 5 – Optimised scenario

The aim of this scenario is to present an economically optimised route to achieving the carbon reduction targets. The ambition is to maximise the use of interventions that offer the best return on investment in terms of carbon reduction. Ideally the spend profile will be reasonably evenly distributed across the years taking into account the University’s budget structure where this is feasible.

Included in the scenario:



- Fabric upgrades (as per Section 6.3.4)
- Main heating plant replaced with ASHPs or electric boilers
- Decarbonisation of grid electricity
- PV added to priority buildings in phased approach (building list as per Section 6.8)
- 20% renewables PPA extended to 2040
- Large scale PV offsets remaining carbon consumption 2035-2040.
- Heating control upgrades to buildings built prior to 2000

Predicted advantages:

- Operational energy and carbon reduced
- Upgraded buildings should retain heat better and could improve user comfort
- No combustion emissions from heating, such as NOx
- Fabric upgrades allows ASHP to work more efficient (at lower temperatures)

Predicted disadvantages:

- Bills for heating to increase
- Electrical demand to increase
- Space for ASHP is needed externally with possible planning or noise limitations
- Disruption to buildings while fabric is upgraded
- High capital cost for fabric upgrades

8 Scenario outcomes

8.1 Calculation overview

A key priority in the development of this decarbonisation master plan was that the accompanying calculation tool would enable the University to adjust the timings of applying interventions to buildings to enable the plan to be a live document. The excel based tool, delivered alongside this report, offers this functionality. We have supplied versions spreadsheet to the University to enable future editing of the plan.

In summary the tool enables:

- Interventions from the list to be ticked off or on for buildings included in the plan
- Dates to be adjusted for when interventions from the list are applied
- Output such as energy, carbon, electrical and cost information to be updated based on the combination of inputs used

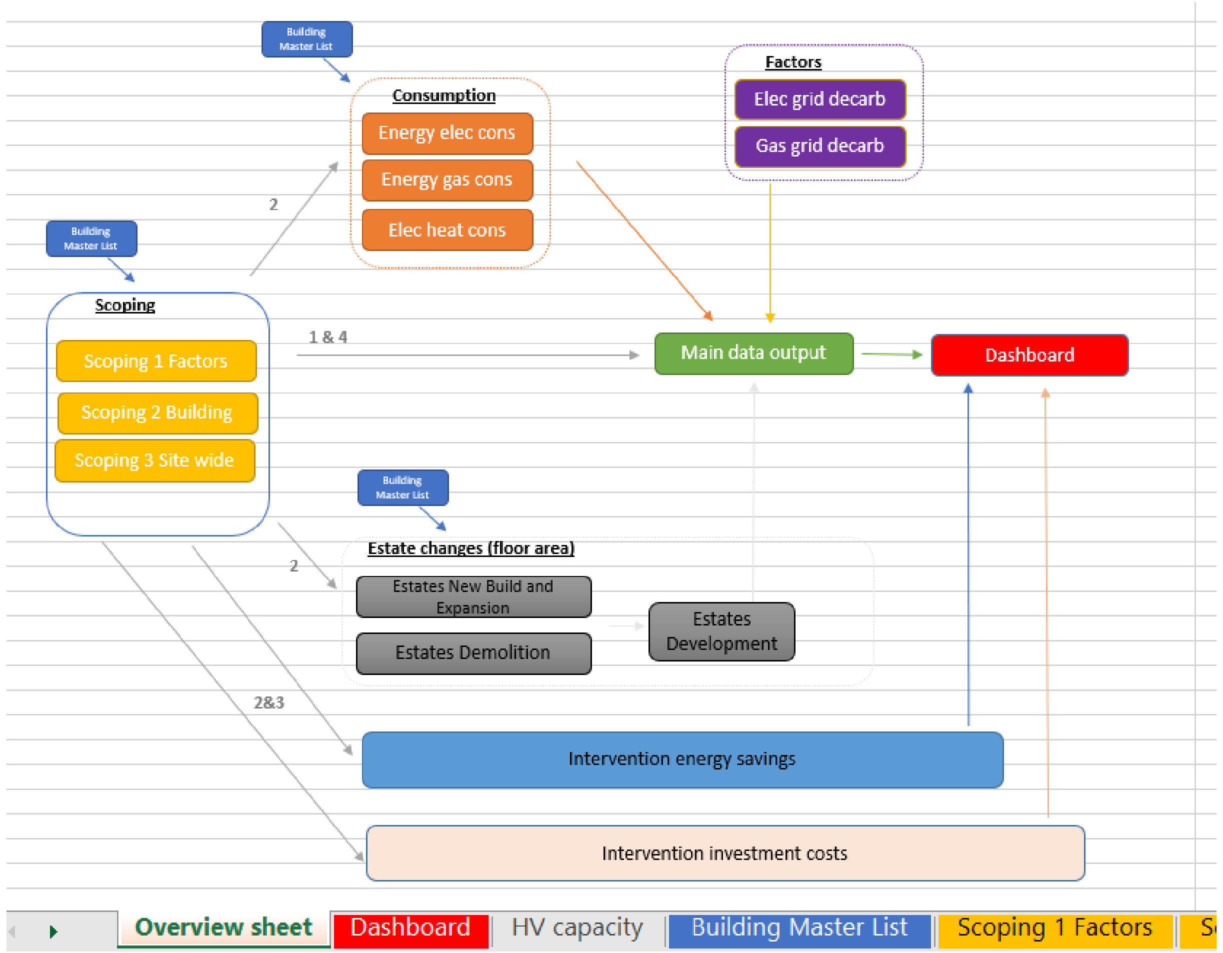


Figure 23: Overview of calculation model

Alongside the excel based calculation tool we have presented a visualisation tool using Microsoft PowerBI which enables the data to be viewed in a more accessible way, with trends and differences easy to view for the differing scenarios. Outputs from this visualisation are included within the report. Access to the PowerBI dashboard will be provided to the University to enable long term use of the tool.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Heating system	Gas boilers	Electric boilers	ASHPs (Listed buildings have electric boilers)	ASHPs (Listed buildings have electric boilers)	ASHPs (Listed buildings have electric boilers)
Heating control upgrades	No	Yes (buildings pre-2000)	Yes (buildings pre-2000)	Yes (buildings pre-2000)	Yes (buildings pre-2000)
Fabric upgrades	No	No	No	Yes as per Section 6.3	Yes
PV	Buildings as per Section 6.8 & Duryard	Buildings as per Section 6.8 & Duryard	Buildings as per Section 6.8 & Duryard	Buildings as per Section 6.8 & Duryard	Buildings as per Section 6.8 & Duryard. Large scale PV array to offset electricity consumption in 2035
PPA renewable percentage	20% up to 2029	20% up to 2029	20% up to 2029	20% up to 2029	20% up to 2040

Table 15: Modelled scenario summary

8.2 Energy and Carbon

The graph below illustrates the energy consumption for each scenario over time.

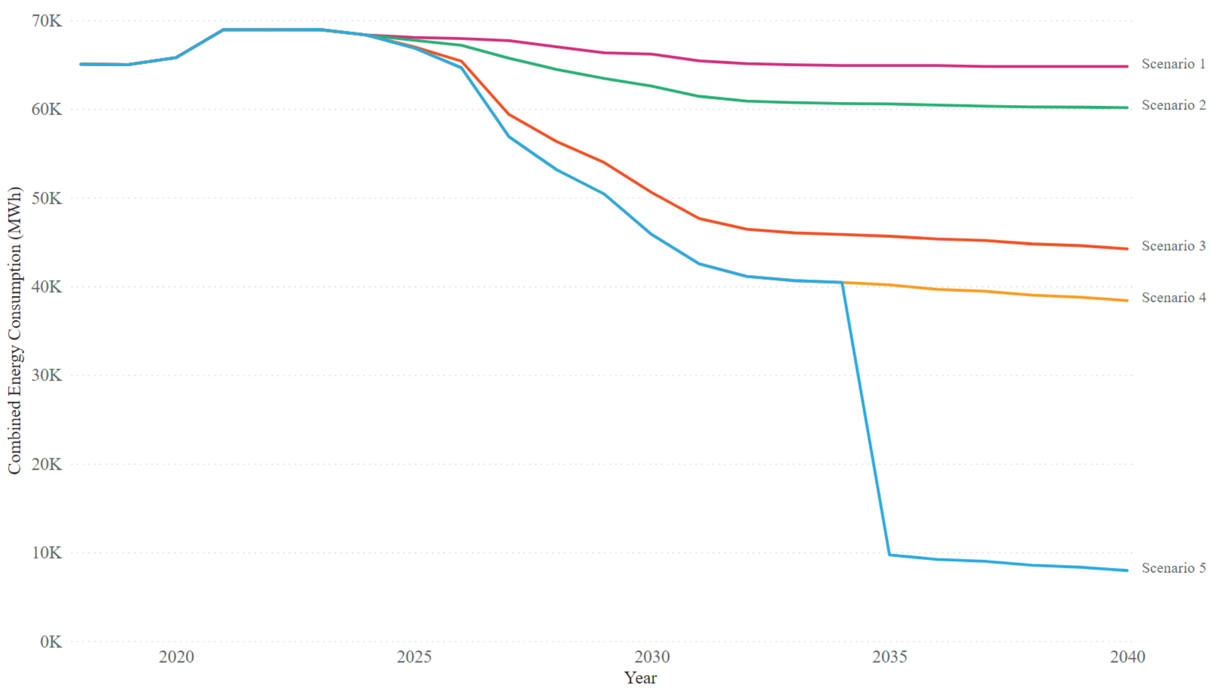


Figure 24: Scenario comparison – Total annual energy consumption

Scenario 1 has a slight reduction due to the introduction of PV on rooftops across the campus. Similarly, scenario 2 reduces energy use slightly, due to the PV and the improved efficiency of the electric boilers compared to the existing gas and oil boilers.

Scenario 3 offers further energy reductions as the ASHPs are far more efficient than gas boilers.

Scenario 4 has the lowest overall energy consumption of the initial 4 scenarios as the heat pumps are operating at lower temperatures due to the improved fabric performance of the buildings.

Scenario 5 shows the impact of a large scale PV farm intended to meet the annual electricity consumption of the University installed in 2035 to meet the Universities net zero target. This could also be met by the purchase of 100% renewable energy via PPA.

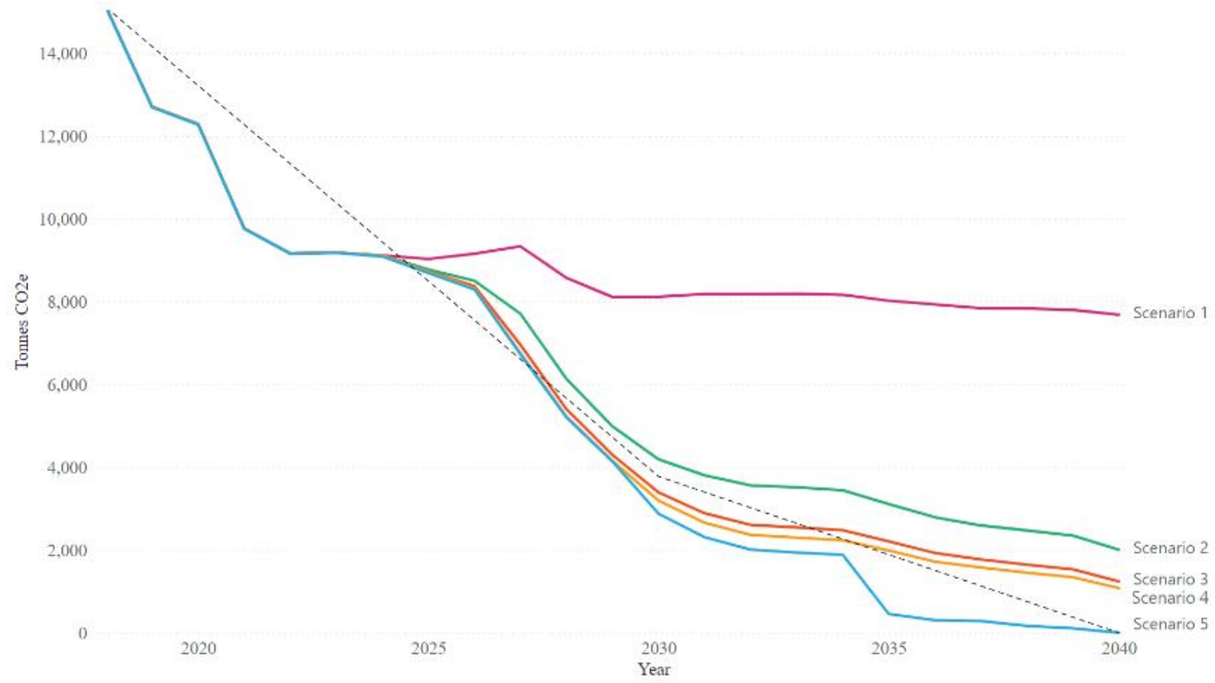


Figure 25: Scenario comparison – Total yearly carbon emissions (Scope 1&2 excluding transport)

Figure 25 illustrates the carbon emissions for each scenario over time compared to the University target line.

Scenario 1 will benefit from the decarbonisation of the grid until ~2025, however as gas consumption will remain high so will carbon consumption.

Scenario 2 follows the universities carbon targets until ~2030. As the electric boilers have higher energy usage than ASHP emissions and no fabric improvements are made, emissions remain higher even as the grid decarbonises.

Scenarios 3 and 4 have similar carbon trajectories and meet the University’s targets until ~2034.

Scenario 5 meets the Universities target by utilising energy produced by a large-scale PV farm. This could also be achieved by purchasing 100% renewable energy. Scenario 5 also has lower carbon emissions from 2029-2035 by maintaining the existing 20% renewables PPA.

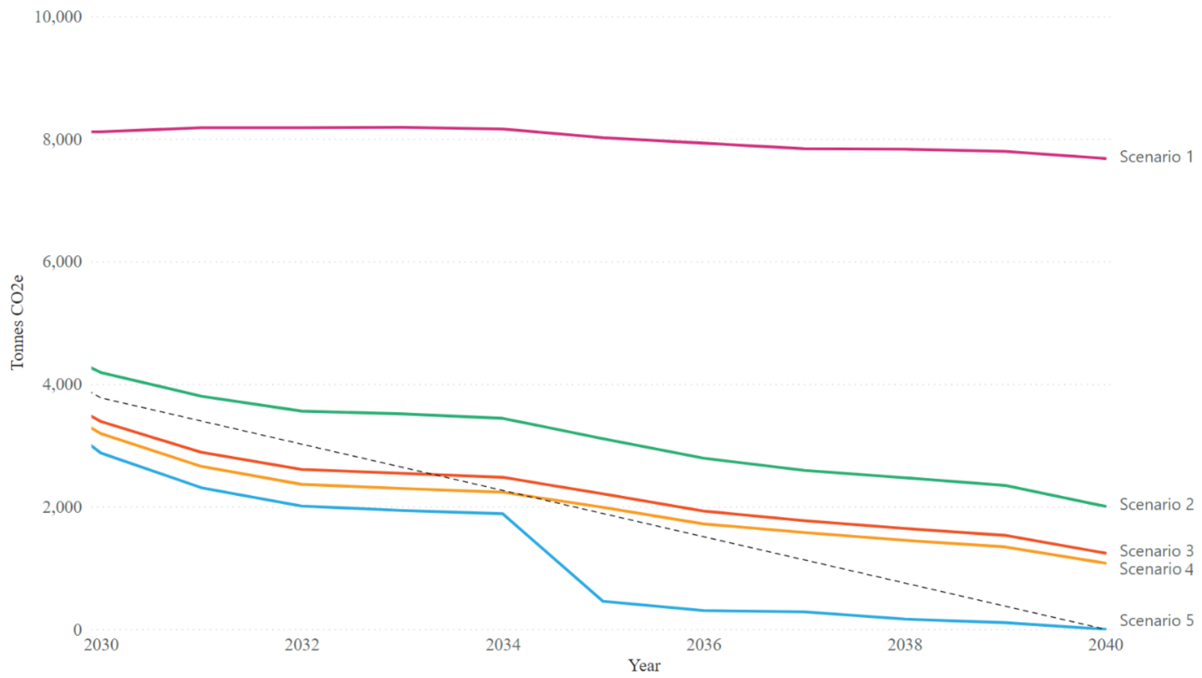


Figure 26: Scenario comparison - 2030-2040 Carbon emissions

Figure 26 shows the carbon emissions from 2030 to 2040. This illustrates the difference between Scenario 2 (Electric boilers), and the reduced emissions of scenarios 3,4 and 5 with ASHPs.

Currently scenarios 2,3 and 4 are not predicted to reach the University's target of reducing carbon emissions by 100% by 2040.

Part of the limitation is that the electrical grid is not consistently predicted to reach net zero by 2040 in conservative modelled projections. Given the United Kingdom's commitment to reaching net-zero as the projections are remodelled it may be that the grid decarbonises at a faster rate than included in this plan. For example, one of the more ambitious National Grid projections such as 'Leading the way' could emerge as the closest to reality. If the grid does reach net-zero by 2040 then the UoE's target could be achieved without introducing large scale solar PV or using PPAs provided gas and oil have been replaced with electricity based heating sources across the University's buildings.

Alternatively, as the plan evolves if the grid is still not predicted to reach net-zero by 2040 the UoE could commit to purchasing electricity generated from 100% renewable sources instead via a Power Purchase Agreement. The availability and choice of renewable PPAs is likely to increase as nuclear and renewables continue to contribute more significantly to power generation across the UK.

Reducing the energy consumption further such as replacing end-of life items with more efficient installations and heat recovery (as the University does currently) when appropriate can also contribute to additional energy and carbon savings not modelled as part of this plan. Monitoring and targeting high consuming buildings/departments alongside engagement can also assist with further reducing energy and carbon usage.

8.3 Capital and energy costs

The graph below illustrates the spend profile for scenario 5 over time for University owned buildings.

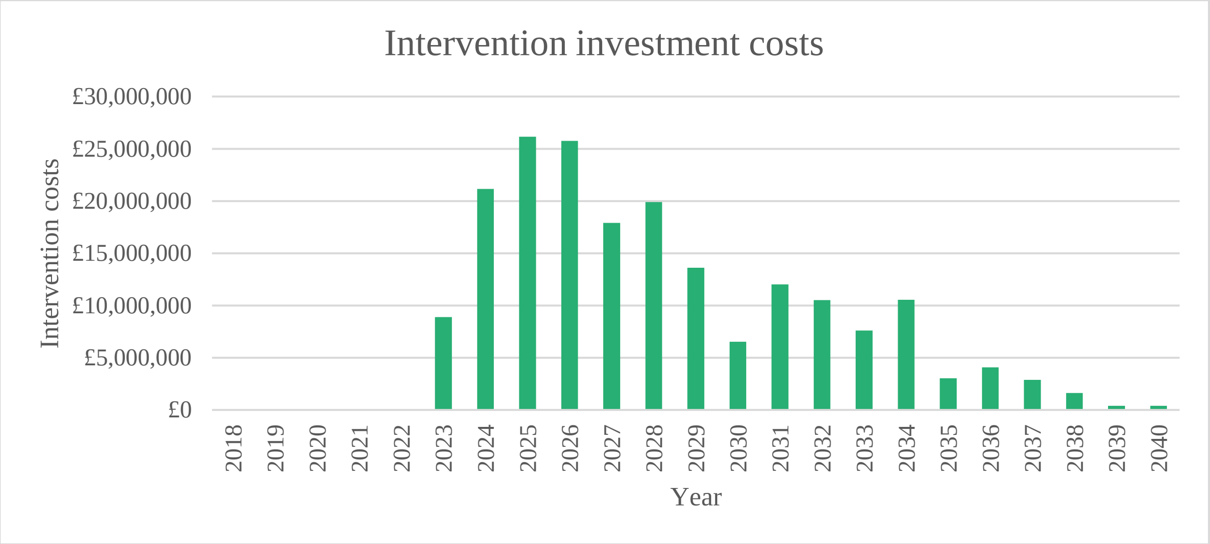


Figure 27: Scenario 5 annual investment

The total investment cost required for each scenario is listed below. These costs are based on rates provided by RLB combined with Arup estimates for building façade areas, heat plant sizes and building floor areas from University data. These costs represent UoE owned buildings only.

Scenario	Estimated total investment cost (non-inflated)
1	£14,000,000
2	£35,000,000
3	£61,000,000
4	£175,000,000
5	£193,000,000

Table 16: Scenario investment costs

This highlights the impact of fabric interventions on the overall investment cost. Scenarios 4 and 5 both include improvements to building fabric.

The breakdown of costs for scenario 5 is shown below.

Total Cost	VAT	Optimism Bias*	Design	Construction
£231,466,069 (£193,027,000 + Inflation)	£32,171,000	£45,132,000	£19,287,000	£96,437,000

Table 17 - Expenditure for Scenario 5

*RLB have included an addition for 'Optimism Bias' , which is applied to the overall cash flow for the anticipated works. The principle of applying Optimism Bias to very early stage estimates is set out in the HM Treasury Green Book guidance for appraising projects and programmes of work and is designed to redress the demonstrated, systematic tendency for project appraisers to be overly optimistic in initial estimates. The guidance recommends the application of Optimism Bias of between 2% and 51% on capital expenditure for buildings, depending on the specific project type. Using criteria set out in the Green Book and based on the range of buildings, nature of the work and anticipated duration of the decarbonisation programme, we have identified an Optimism Bias of 39%. This allowance can be reduced as the programme of work is developed and project specific factors associated with scope, complexity, site characteristics, stakeholder input and statutory compliance are defined and resolved

Included within these figures are the values below for upgrading the campus electrical infrastructure and building panel boards. These electrical costing estimates have been calculated by Arup.

Description	Cost including VAT
Streatham Site Wide infrastructure upgrades and building's incoming supplies upgrades	£6,050,000
Streatham buildings estimate upgrades to internal main electrical distribution equipment.	£825,000
St Luke's upgraded incoming supply connections	£462,000

Table 18 - Electrical infrastructure costs

Refer to section 8.7 for description of the anticipated works.

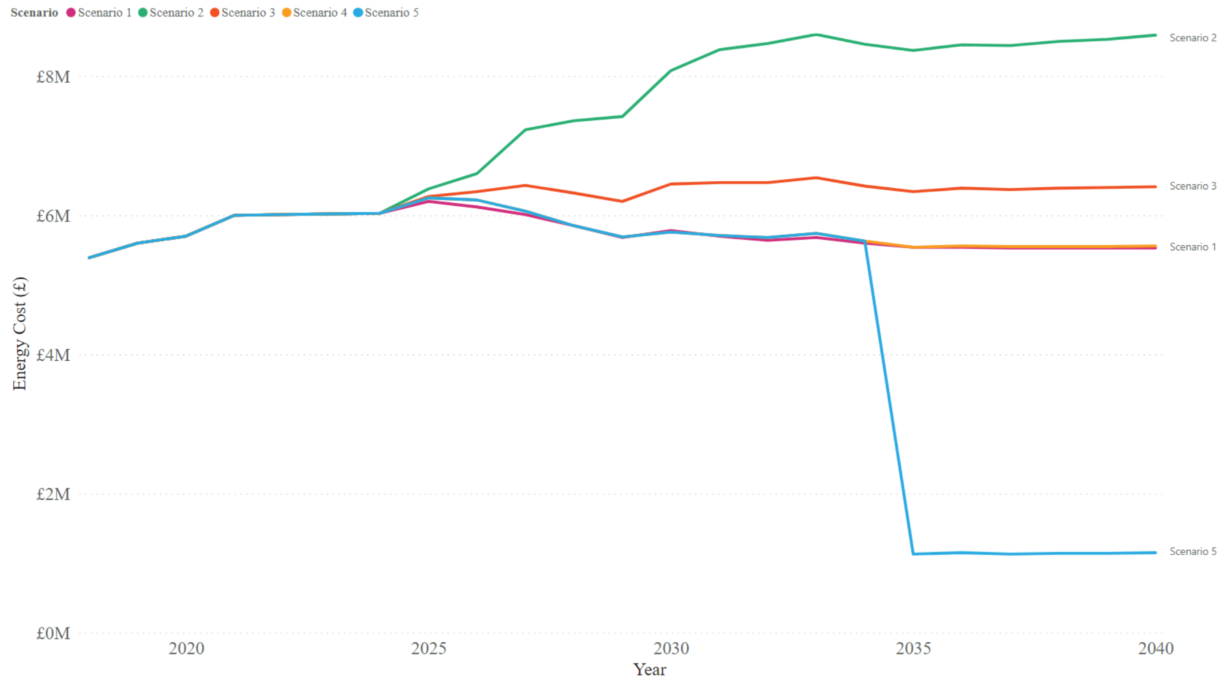


Figure 28: Scenario comparison - Annual energy costs

The graph above illustrates the impact of using electric boilers (Scenario 2) compared to ASHPs (Scenarios 3 & 4). Annual energy costs are expected to be £2-3M more each year in this scenario. These values are based on energy costs of 16p/kWh for electricity, and 4p/kWh for gas.

The impact of fabric improvements can also be seen by comparing scenario 3 (ASHP only) to scenario 4 (ASHP + fabric upgrades). Scenario 4's annual energy bill is expected to be around £1m less per year than scenario 3 from 2030 onwards. Over the 22 years looked at in this study, this difference equates to £10m.

The energy cost in scenario 5 drops off in 2035 as this is when a large scale PV farm is assumed to come online to generate the equivalent electricity to power the campus as the building heating is moved to electrical sources. The anticipated cost of this is in the region of £19m (excluding land purchase of 360,000m^2).

Consistent energy prices matching current prices have been assumed for this calculation as long term energy prices are difficult to predict. Recent increases in energy costs (Sep/Oct 21) have not been reflected in this analysis, however this highlights the necessity to minimise energy consumption where possible to reduce exposure to price fluctuations.

The spend profile for scenario 5 taking account of Net Present Value is included within Appendix C3.

	Boiler replacement ASHP	Boiler replacement Electric boiler	Lighting	Fabric improvements	Heating systems controls upgrades	Building PV
Total spend	£32,293,141	£978,089	£1,972,883	£123,039,307	£16,279,678	£4,485,187
Annual kWh saved	17,842,590	324,748	4,042,116	4,042,116	484,039	3,468,988
kWh/£	0.55	0.33	2.05	0.03	0.03	0.77

Table 19 - Cost benefit of interventions

The table above illustrates the kWh energy saved for every pound spent on an intervention. This highlights that the ASHP and lighting are the most cost-effective interventions, with fabric improvements and heating systems controls upgrades offering the least benefit per pound spent. However these can offer wider improvements such as increased occupant comfort and alignment with the Universities sustainable design guide.

The table below separates the costs within the masterplan by the building owner. Refer to Appendix G for the list of buildings included in this plan with building owners indicated.

	GIA (m2)	Total building spend (inc VAT)	Construction (inc VAT)	Design fees (inc VAT)
UPP total	67,173	£10,060,000	£8,384,000	£1,676,000
INTO building	16,110	£1,557,000	£1,298,000	£259,000
Leasehold total	6,970	£645,000	£538,000	£107,000
Freehold	217,071	£166,785,000	£138,996,000	£27,789,000
Ground based PV & elec infrastructure		£26,242,000	£21,869,000	£4,373,000
Total	307,324	£205,289,000	£171,085,000	£34,204,000
UoE total exc. 3rd parties & leasehold		**£231,466,069** (£193,027,000 + Inflation)		

Table 20 - Costs separated by building owner

	GIA (m2)	Total building spend (inc VAT & OB)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)
Streatham	191,569	£153,320,000	£127,772,000	£25,548,000
St Luke's	25,502	£20,792,000	£17,330,000	£3,462,000
Ground based PV		£18,915,000	£15,763,000	£3,152,000
UoE Total	217,071	**£231,466,069** (£193,027,000 + Inflation)		

Table 21 – Costs for UoE buildings by campus

8.4 UPP operated buildings

The on campus buildings operated by UPP included within the decarbonisation plan are listed within the table below:

Building
Chagford
Christow
Lydford
Widecombe
Spreytonway UPP
Rowe House - All blocks
Lafrowda - All blocks
UPP East Park - All blocks
Moberly UPP
UPP Duryard - All blocks
UPP Birks - All blocks

Table 22: UPP operated buildings

These buildings are included within the overall carbon targets of the University, but are not directly controlled by the University. As such, it is important for the University to liaise with UPP to align their goals. The UPP website references the UK target of net zero by 2050, but does not identify other objectives.

In the base year of 2018, the UPP operated buildings produced 1,800 tonnes $CO2_e$, of which 700 tonnes was produced by electricity demand, and 1,100 tonnes by burning gas.
This consumption is dominated by the Lafrowda residences which produce 75% of UPPs emissions.
UPP's emissions represent approximately 10% of the scope 1&2 emissions of the buildings included within this study.

To align with the University's targets, overall emissions need to reduce from 1,800 tonnes in 2018 to 450 tonnes by 2030, and 0 tonnes by 2040.

To achieve this, UPP should focus on moving away from gas heating to heat pumps across their residences. Student halls of residence often contain oversized domestic hot water systems which can be wasteful. Prior to any changes, real world data should be collected to understand the peak and general hot water demand in each residence so systems can be sized appropriately.
Fabric improvements should be made where possible to minimise heating requirements.

For the purposes of the Decarbonisation masterplan, the buildings have followed the same scenario as the University buildings, with fabric upgrades for all pre-2000 buildings and gas boilers replaced with heat pumps.

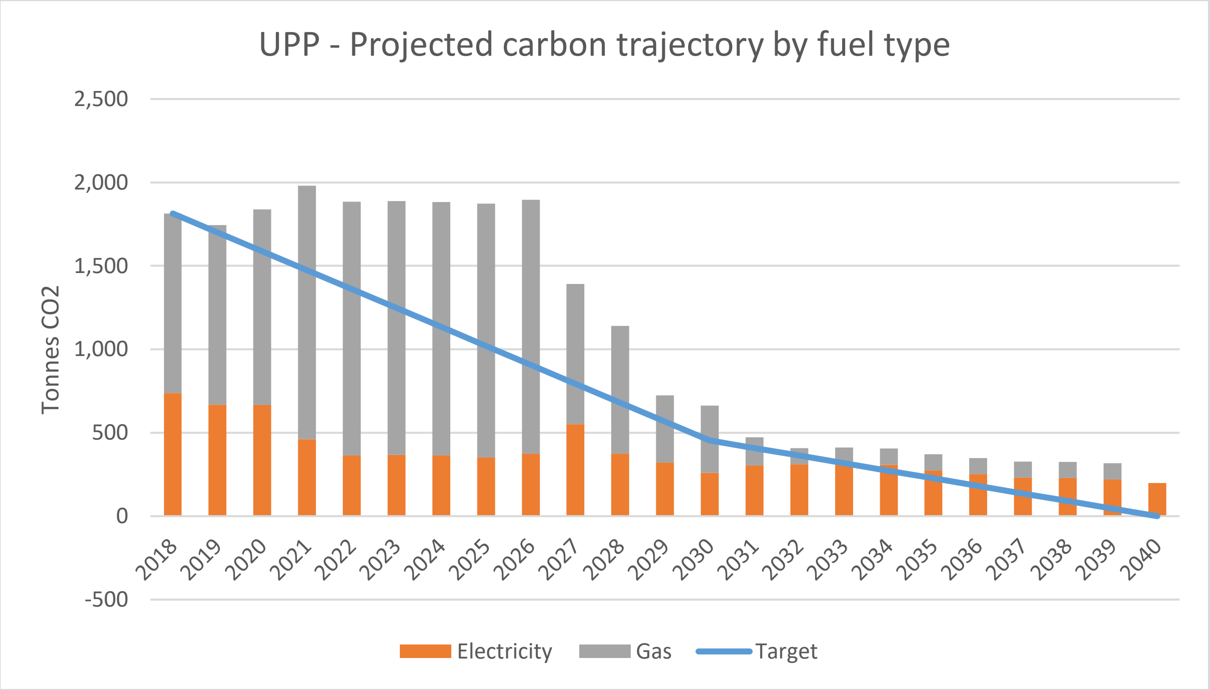


Figure 29 - UPP carbon consumption in Scenario 5

In the image above, Lafrowda's gas boilers are replaced with heat pumps in 2026. To remain on trajectory to align with the Universities goals of a 75% reduction by 2030, Lafrowda should transition away from gas by this date.
It is anticipated that in 2040 the UPP buildings will be consuming 7,000 MWh electricity annually. If the grid has not decarbonised by this date, then this electricity would need to be purchased via a renewable PPA or produced via renewables owned either by the University or UPP. This electrical consumption has been incorporated into the size of the solar PV farm required for the University to meet their net zero target in 2040.

8.5 INTO buildings

The INTO non-residential building and INTO Duryard blocks A-E are included within the decarbonisation plan, but costed separately from the UoE buildings.

The university will need to engage with INTO to ensure their decarbonisation goals align with the Universities.

8.6 Leased buildings

Building
Research, Innovation, Learning & Development Centre
Clinical Skills Resource Centre, RD & E, Heavitree
Engineering Research Centre
Mireille Gillings Neuroimaging Centre

Table 23 – List of leased buildings included within the decarbonisation plan

The buildings above are included within the decarbonisation masterplan. For RILD and CSRD, the carbon consumption is based on the proportion of floor area leased by UoE.

UoE should engage with the relevant stakeholders to ensure metering allows energy consumption to be apportioned for carbon accounting and to align decarbonisation goals.

8.7 Electrical networks

The Streatham and St Luke's electrical network has been analysed using information provided by the University including utilities drawings, HV schematics, substation schematics and partial information about which substation each building is connected to. We have collated this information to develop a picture of the University's network, it's current loading and the implications of increasing electrical demand by moving to electricity-based heating sources.

An analysis has been conducted to identify the potential areas of concern, this is based on the optimised scenario, Scenario 5.

8.7.1 Summary of Impacts

The University network has been analysed at the building, substation and overall level to identify areas which may need upgrading. For further details of expected electrical load demand and increase, refer to Appendix B.

Streatham Campus:

The following buildings have been identified as requiring further detailed analysis to determine whether the existing main incoming low voltage supply characteristics and main electrical distribution switchgear equipment are suitable. As part of any changes to ASHP or Electric boilers the following buildings will need to have their electrical infrastructure reviewed against the forecasted loads.

Building	Source of Supply	Proposed year for heating upgrade
Amory Building	S/S 80 Harrison Building	2029
Clydesdale Rise – Block A	S/S 120 Mardon Hill	2037
Cornwall house	S/S 100 Cornwall House	2024
Devonshire house	S/S 60 Northcote House	2027
Forum	S/S 70 Stocker Road	2030
Great Hall	S/S 60 Northcote House	2035
Hatherly Building	S/S 130 Hatherly Laboratories (Externally located within GRP enclosure)	2025
Hope Hall	S/S 110 Hope Hall	2025
Lafrowda – All blocks	S/S 240 Lafrowda House	2026
Laver Building	S/S 50 Laver Building	2028
Lopes Hall	S/S 110 Hope Hall	2035
Mardon Hall	S/S 120 Mardon Hill	2030
Newman Building	S/S 140 Physics Building	2027
Northcote House	SS/60 Northcote House	2032
Nash Grove – All blocks	S/S 120 Mardon Hill	2026
Northcote Theatre	SS/60 Northcote House	2028
Old Library	S/S 130 Hatherly Laboratories (Externally located within GRP enclosure)	2029
Physics Building	S/S 140 Physics Building	2029
Queen's Building	S/S 60 Northcote House	2027
Reed Hall	S/S 180 Reed Mews	2031
Roborough	S/S 190 Washington Singer	2029
Russell Seal fitness centre	S/S 250 Sports Park	2032
Streatham Farm	S/S 70 Stocker Road	2028
Washington Singer	S/S 190 Washington Singer	2026
Estate Services	Directly by WPD at Low Voltage	2027
Garden Hill house	Directly by WPD at Low Voltage	2025
Higher Hoopern Farm	Directly by WPD at Low Voltage	2036

Building	Source of Supply	Proposed year for heating upgrade
Knightley	Directly by WPD at Low Voltage	2037
Redcot	Directly by WPD at Low Voltage	2034
Streatham lodge	Directly by WPD at Low Voltage	2038

Table 24: Buildings requiring infrastructure reviews

Garden Hill House, Higher Hoopern Cottage, Higher Hoopern Farm, Redcot and Streatham Lodge, which are supplied directly at Low Voltage by the DNO, could have an estimated electrical load increase of over 100% in scenario 5.

These buildings are supplied directly at Low Voltage from DNO (WPD) Substations and further investigation will be required to establish the impact on the incoming service infrastructure. Enquiries with the electricity supplier will be undertaken within the next steps to determine whether there is sufficient available capacity within their substations.

At substation level (Private HV network), the following 11/0.4 kV substations at the Streatham Campus have been identified as requiring upgrades and/or likely to exceed 90% threshold capacity following upgrades to the heating system:

Substation		Location	Potential upgrade year
S/S 60	Northcote House	Northcote House Basement	2023
S/S70	Stocker Road	(Streatham Farm) Located External within Yard	2028
S/S80	Harrison Building	Harrison Building	2024
S/S 110	Hope Hall	Located Externally within GRP Enclosure	2022
S/S 130	Hatherly Laboratories	Located Externally within GRP Enclosure	2022
S/S 190	Washington Singer	Externally located	2026

Table 25: Substations identified as likely to require upgrades

For further details of expect electrical load demand and increase, refer to Appendix B.

The following table shows the estimated increased electrical loads on Streatham Campus.

		Supplying Substations:	Comments	Current Load Demand Estimate diversified (kW)	Future Load Demand Estimate diversified (kW)
Streatham Campus HV Network	Loop 1	S/S 250, S/S 90, S/S260, S/S 270, S/S 240, S/S 110, S/S 100, S/S 210, S/S 70, S/S 60, S/S 130, S/S 190, S/S 180	Serving South and East Residential blocks Mainly	4,027	**5,971**
	Loop 2	S/S 160, S/S 170, S/S 20, S/S 30, S/S 340, S/S 350, S/S 230, S/S 220	Serving North West Residential Blocks: Birks, Duryard, Kay house, Moberly Hall	955	1,442
	Loop 3	S/S 120, S/S 150, S/S 80, S/S 50, S/S 200, S/S 40, S/S 140	Serving Academic, Administration and Social Buildings Mainly	2,203	3,125
TOTAL				**7,184 kW**	**10,538 kW**

Table 26: Estimated Streatham electrical loading

This represents an overall site load increase percentage of approximately 47% over the period up to 2040 in scenario 5.

The following MV Loops from the Private HV network will likely exceed their total available loop capacity of 4 MW.:

- Loop s/1

St. Luke's Campus

South Cloisters, Haighton Library, Holnicot Wing, North Cloisters and St. Luke's Sports Centre buildings could have an estimated electrical load increase of over 50% in scenario 5.

All buildings are supplied directly at Low Voltage from DNO (WPD) Substations and further investigation is required to establish the impact on the incoming service infrastructure. Enquiries with the electricity supplier will be undertaken within next steps to determine whether there is sufficient available capacity within their substations.

St. Luke's Off Campus

The 3no. buildings located off St. Luke's campus are likely to have an estimated load percentage increase of over 25% in scenario 5.

Further investigation is required to establish the impact on the incoming service infrastructure. Enquiries with the electricity supplier will be undertaken within next steps to determine whether there is sufficient available capacity within their substations.

8.7.2 Recommended sitewide upgrades

Streatham Campus:

- Remove Substation S/S 60 Northcote House from existing HV circuit (loop 1)
- Built additional HV/LV substation in the vicinity and to share loads with S/S 60
- Additional 11kV circuit to serve S/S 60 and new proposed substation.
- Replace existing transformer at Substation S/S 110 Hope Hall for 1000kVA rated 11/0.4 Transformer
- Replace existing transformer at Substation S/S 130 Hatherly Laboratories for 1000kVA rated 11/0.4 Transformer
- Replace existing transformer at Substation S/S 190 Washington Singer for 1000kVA rated 11/0.4 Transformer

8.7.3 Recommended next steps

To build on the work in this master plan and assist with developing projects forward we recommend the following are undertaken:

- Obtain a measured current load peak demand figures for each building to improve the accuracy over the estimates utilised here.
- Further investigate load profiles of the buildings where substations have been highlighted in this report with a potential overloading issue. This shall include a detailed load profile of existing and future loads on each building and across all buildings connected to same supply substations.
- Further assess the impact and necessary upgrades on site wide high voltage infrastructure at Streatham Campus.
- Further engagement with the electricity supplier at St. Luke’s and off Campus buildings to determine the available capacity within their HV/LV substations.
- Establish the impact on the incoming service infrastructure and the electrical infrastructure within each building to accommodate the future loads.

8.8 Recommended scenario

Following a fabric first approach, we recommend improving the fabric of buildings where possible and replacing existing gas and oil boilers with low temperature ASHPs. Improving the fabric of buildings will reduce overall energy consumption as well as improving the thermal comfort of occupants. It has an additional benefit of reducing the peak heating demand, which will reduce the external plant space required for ASHPs.

Where fabric improvements are not feasible, high temperature ASHPs or electric boilers should replace the existing gas and oil boilers. These are less efficient and have higher energy costs than low temperature ASHPs but as the grid decarbonises will offer substantial carbon savings over the existing heating plant. In older buildings it will be essential that the fabric is upgraded to allow ASHPs to be used. A pragmatic approach to fabric upgrades should be taken to maximise insulation gains whilst minimising cost. For example, Enerphit standard insulation is unlikely to be possible with cavity wall insulation, but cavity wall insulation will be substantially cheaper and quicker than overcladding with additional insulation.

PV represents a very good value proposition for reducing carbon when compared to the other interventions and should be installed on building roofs where possible as described in ZLC’s work.

Based on the quotes that have been provided to the University, lighting is a particularly cost effective method of reducing electricity consumption so old fittings should be replaced as part of the University’s ongoing maintenance works.

A number of buildings not operated by the University are included within the decarbonisation plan. For the purposes of determining a route to net zero carbon and allow the University to understand the implications on their electrical network we have included and costed for upgrades to these buildings. As these buildings are included within the University’s carbon targets, it is essential that collaboration takes place to align the goals of the building operators with the University’s targets and understand when works will take place.

Without taking into account any further decarbonisation of the grid from 2021, implementing Scenario 5 would reduce the University’s carbon consumption from 15,100 tonnes in 2018 to 7,100 in 2040 representing a reduction of 53%.

We recommend that the University aims to increase the proportion of electricity purchased that is produced by renewables. The current 20% agreement is due to end in 2029, and this should be extended and increased if possible. The cost of doing so should be assessed against the cost of increasing the renewable energy generated by the university.

Using the figures provided by ZLC, a PV array to produce the electricity required in Scenario 5 in 2040 would cost in the region of £18m (current price & excluding land purchase) and require an area of ~**89 acres** to generate approximately 30,000 MWh yield.

The cost of PV is constantly reducing, which means that developing a new installation could be cost effective, but also means that the cost of renewable PPAs should also reduce which would not require an upfront investment cost.

9 Implementation plan

Based on the best overall scenario outcomes we have developed an implementation plan to demonstrate how the scenario could be phased and developed through to construction and operation. This is based on general timescales for project types and maybe subject to variation based on specific building or department needs. For the development of the plan we have endeavoured to keep the number of concurrent projects at a roughly consistent level if possible. We have based the plan on projects experiencing no delays due to planning or legal objections. We have not reviewed displacement or interdependencies of buildings or departments as part of the plan, and it is recommended this is reviewed as the decarbonisation plan is further developed into projects by the University.

We have aimed to maintain a consistent spend profile through to 2030 to align with the University's front loaded carbon targets, with a reduced spend from 2030-2040.

In the initial 5 years (commencing 2023) we have aimed to align with the University's boiler replacement plan, with boiler due for replacement in 2021 moved to 2022. Following these initial buildings, the order of interventions can be dictated by reducing carbon emissions as aggressively as possible within the budget constraints of the University. Buildings operating with oil boilers (Geoffrey Pope, Harrison and Streatham Farm) have been prioritised as these are less efficient than gas.

The full intervention schedule including individual costs can be found in Appendix C. This lists the interventions for each building to be actioned each year. For the purposes of the calculations, the key interventions affecting the building heating systems have been assumed to take place in the same year. It is likely that these will be affected by other campus works, limitations on the disruption to students and staff, so precise scheduling has not been attempted.

The programme highlights the number of simultaneous projects that need to occur for the University to meet their carbon targets.

Projects are dated by the year from which the carbon savings are taken, which is when projects need to complete. Refer to the project timelines within Appendix C2 which illustrates estimated project durations based on a construction spend of £1,000,000 per quarter, and a design spend of £400,000 per quarter. These durations are intended to illustrate that there will be substantial time periods between projects starting and when the energy and carbon savings are realised. Further work with contractors and the University would be required to identify accurate project timeframes taking into consideration planning, scheduling, occupant decant and other University construction and maintenance. Note that the table below illustrates projects that are due to be completed within the first 5 years and excludes projects that will commence during this period but not complete. The total cost of the interventions below is less than the planned spend over this period for this reason.

This plan illustrates that the University must commence works on their largest energy consumers as a priority and identify funding streams to allow this to take place.

Year	Building/ Department Name	Applied Interventions	Intervention cost (£) inc design fee. Non Inflated.
2024	Baring Court	Lighting	£136,537
2024	Building:One	Lighting	£250,175
2024	Byrne House	Boiler Replacement - Electric Boiler	£39,955
2024	Byrne House	Fabric Improvements	£296,561
2024	Byrne House	Heating Systems Controls Upgrade	£76,209
2024	Cornwall House	Boiler Replacement - ASHP	£814,107
2024	Cornwall House	Heating Systems Controls Upgrade	£225,329
2024	Cornwall House	Lighting	£119,293
2024	Knightley	Lighting	£68,221
2024	Lafrowda House	Lighting	£57,845
2024	Laver Building	Lighting	£207,066
2024	North Cloisters	Boiler Replacement - Electric Boiler	£134,665
2024	North Cloisters	Fabric Improvements	£524,898
2024	North Cloisters	Heating Systems Controls Upgrade	£470,436
2024	Pennsylvania Court - All blocks	Boiler Replacement - ASHP	£366,970
2024	Pennsylvania Court - All blocks	Heating Systems Controls Upgrade	£371,515
2024	Pennsylvania Court - All blocks	PVs	£212,330
2024	Physics Building	Lighting	£394,369
2024	Streatham Court New	Boiler Replacement - ASHP	£814,107
2024	Streatham Court New	Heating Systems Controls Upgrade	£371,941
2025	Birks Grange	Boiler Replacement - ASHP	£678,422
2025	Cornwall House	PVs	£162,848
2025	Exeter Medical School Building	Boiler Replacement - ASHP	£366,970
2025	Garden Hill House	Boiler Replacement - ASHP	£74,938
2025	Garden Hill House	Fabric Improvements	£1,170,106
2025	Garden Hill House	Heating Systems Controls Upgrade	£49,835
2025	Hatherly Building	Boiler Replacement - Electric Boiler	£134,665
2025	Hatherly Building	Fabric Improvements	£1,533,102
2025	Hatherly Building	Heating Systems Controls Upgrade	£481,386
2025	Henry Wellcome Building for Biocatalysis	Lighting	£68,557

2025	Hope Hall	Boiler Replacement - ASHP	£366,970
2025	Hope Hall	Fabric Improvements	£2,678,665
2025	Hope Hall	Heating Systems Controls Upgrade	£198,504
2025	Kay Building (Labs)	Lighting	£21,368
2025	Ransom Pickard - All blocks	Boiler Replacement - ASHP	£216,324
2025	Ransom Pickard - All blocks	Fabric Improvements	£1,683,426
2025	Ransom Pickard - All blocks	Heating Systems Controls Upgrade	£149,411
2025	Richards Building	Boiler Replacement - ASHP	£216,324
2025	Richards Building	Fabric Improvements	£777,688
2025	Richards Building	Heating Systems Controls Upgrade	£177,762
2026	Amory Building	Lighting	£468,672
2026	Exeter Medical School Building	PVs	£102,324
2026	Geoffrey Pope	Boiler Replacement - ASHP	£814,107
2026	Geoffrey Pope	Fabric Improvements	£5,472,353
2026	Geoffrey Pope	Heating Systems Controls Upgrade	£645,298
2026	Harrison Building	Boiler Replacement - ASHP	£1,428,439
2026	Harrison Building	Fabric Improvements	£3,868,130
2026	Harrison Building	Heating Systems Controls Upgrade	£840,087
2026	Living Systems Institute	Boiler Replacement - ASHP	£814,107
2026	Mary Harris Memorial Chapel	Lighting	£2,767
2026	Nash Grove - All blocks	Boiler Replacement - ASHP	£216,324
2026	Nash Grove - All blocks	Fabric Improvements	£1,504,801
2026	Nash Grove - All blocks	Heating Systems Controls Upgrade	£190,441
2026	Richards Building	PVs	£167,176
2026	Washington Singer	Boiler Replacement - Electric Boiler	£134,665
2026	Washington Singer	Fabric Improvements	£1,518,266
2026	Washington Singer	Heating Systems Controls Upgrade	£621,794
2027	Devonshire House	Boiler Replacement - ASHP	£814,107
2027	Devonshire House	Fabric Improvements	£4,924,502
2027	Devonshire House	Heating Systems Controls Upgrade	£432,655
2027	Estate Services Centre	Boiler Replacement - ASHP	£216,324
2027	Estate Services Centre	Fabric Improvements	£1,138,944
2027	Estate Services Centre	Heating Systems Controls Upgrade	£80,072
2027	Harrison Building	PVs	£485,908
2027	Holland Hall - All blocks	Boiler Replacement - ASHP	£814,107
2027	Holland Hall - All blocks	Heating Systems Controls Upgrade	£1,021,993
2027	Newman Building	Boiler Replacement - ASHP	£366,970
2027	Newman Building	Fabric Improvements	£1,541,446
2027	Newman Building	Heating Systems Controls Upgrade	£173,023
2027	Newman Building	Lighting	£104,599
2027	Queen's Building	Boiler Replacement - ASHP	£814,107
2027	Queen's Building	Fabric Improvements	£9,108,005
2027	Queen's Building	Heating Systems Controls Upgrade	£684,976
2028	Holland Hall - All blocks	PVs	£595,582
2028	Laver Building	Boiler Replacement - ASHP	£814,107
2028	Laver Building	Fabric Improvements	£10,314,996
2028	Laver Building	Heating Systems Controls Upgrade	£431,262
2028	Newman Building	PVs	£77,062
2028	Northcott Theatre	Boiler Replacement - ASHP	£366,970
2028	Northcott Theatre	Fabric Improvements	£1,192,418
2028	Northcott Theatre	Heating Systems Controls Upgrade	£167,639
2028	Queen's Building	PVs	£253,931
2028	Ransom Pickard - All blocks	Lighting	£73,412
2028	Streatham Farm	Boiler Replacement - Electric Boiler	£91,992
2028	Streatham Farm	Fabric Improvements	£1,114,160
2028	Streatham Farm	Heating Systems Controls Upgrade	£216,460
		Total	**£74,000,000**

Table 27: Interventions for UoE buildings with scheduled boiler replacements

The table above highlights the works to improve buildings which are due for boiler replacements. Due to their imminent boiler replacement it is essential to consider the work required to improve these buildings immediately. If the buildings have like for like gas or oil boiler replacements, these operational carbon emissions are likely to be locked in for the lifetime of the boilers. It is unlikely that functioning boiler plant with a remaining lifespan would or should be replaced unless they can be utilised elsewhere within the University's buildings. Boilers coming to the end of their lifespan and in need of replacement should form the focus of the University's plans – this is why the buildings above form the core of the start of the decarbonisation plan.

The addition of PV to the buildings above has been scheduled to follow any fabric upgrades to aid access and ensure PVs don't need to be removed to install roof insulation.

Buildings that were due for boiler replacement in 2021 (Byrne House, Garden hill house, North Cloisters, Queen's building and Richards building) have been scheduled for later years to allow an in depth assessment of potential boiler replacement works.

The estimated total cost of works for the recommended scenario (Scenario 5) is in the order of **£231.5m** (£193m + Inflation) spread over 19 years. This is front loaded to meet the University's target of a 75% reduction by 2030.

The spend profile required for the first 5 years is illustrated below.

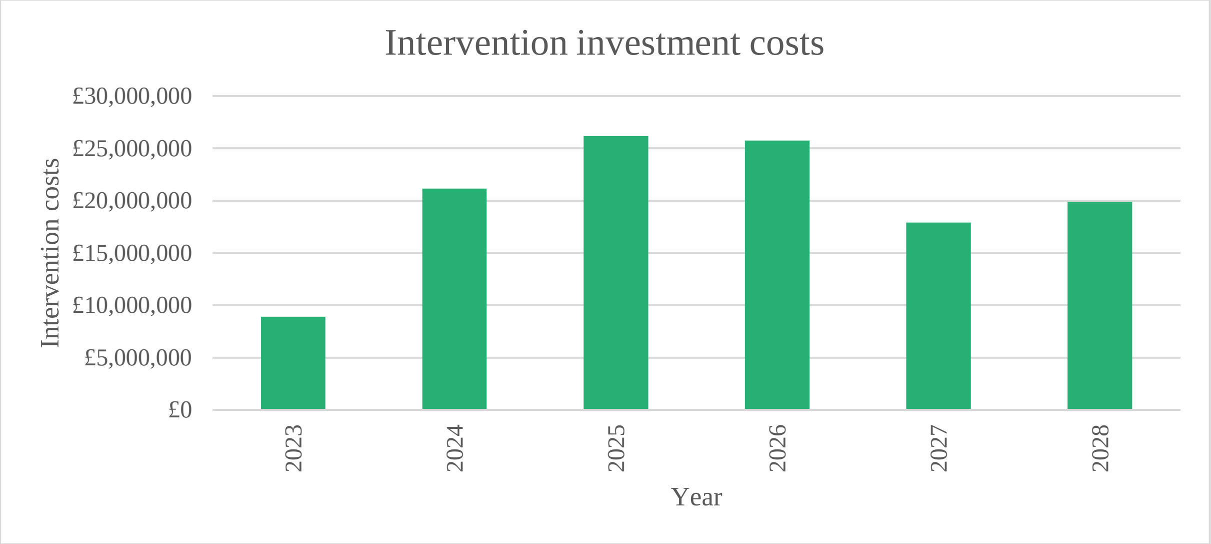


Figure 30: Investment required for the first 5 years

10 Future Project Planning Guidance

The ambitious targets the University have set mean it will be necessary to undertake many projects and improvements over the coming year to meet the targets. This is demonstrated in the implementation plan. To help the University prioritise opportunities and develop common process we have developed suggested workflows and provided guidance on when external collaborators may be required.

10.1 Sustainability Decision tree

We have reviewed the current revision of the decision tree and produced an update which is included in Appendix A. A key difference is the inclusion of the decarbonisation masterplan plan and University's carbon targets in the decision-making process.

The main themes of the updated decision tree are summarised below:

- Are targets known? Is rate of progress against these known?
- Is enough known about the building's current situation and how it fits into future plans?
- How can required information be gathered?
- How can the University challenge expectations and lead in this space?
- Is the project realistic with a pathway for further development?

10.2 Heating replacement decision tree

The implementation plan includes changing the heating source for several buildings from gas boilers to ASHPs. It is noted that ASHP are not a like-for-like replacement and may not always be suitable for all buildings. To help the University with the decision of what to replace gas boilers with when these are scheduled for replacement a decision workflow has been produced. A simplified version is included below with a more in-depth technical version is included in Appendix A2 alongside a worked example.

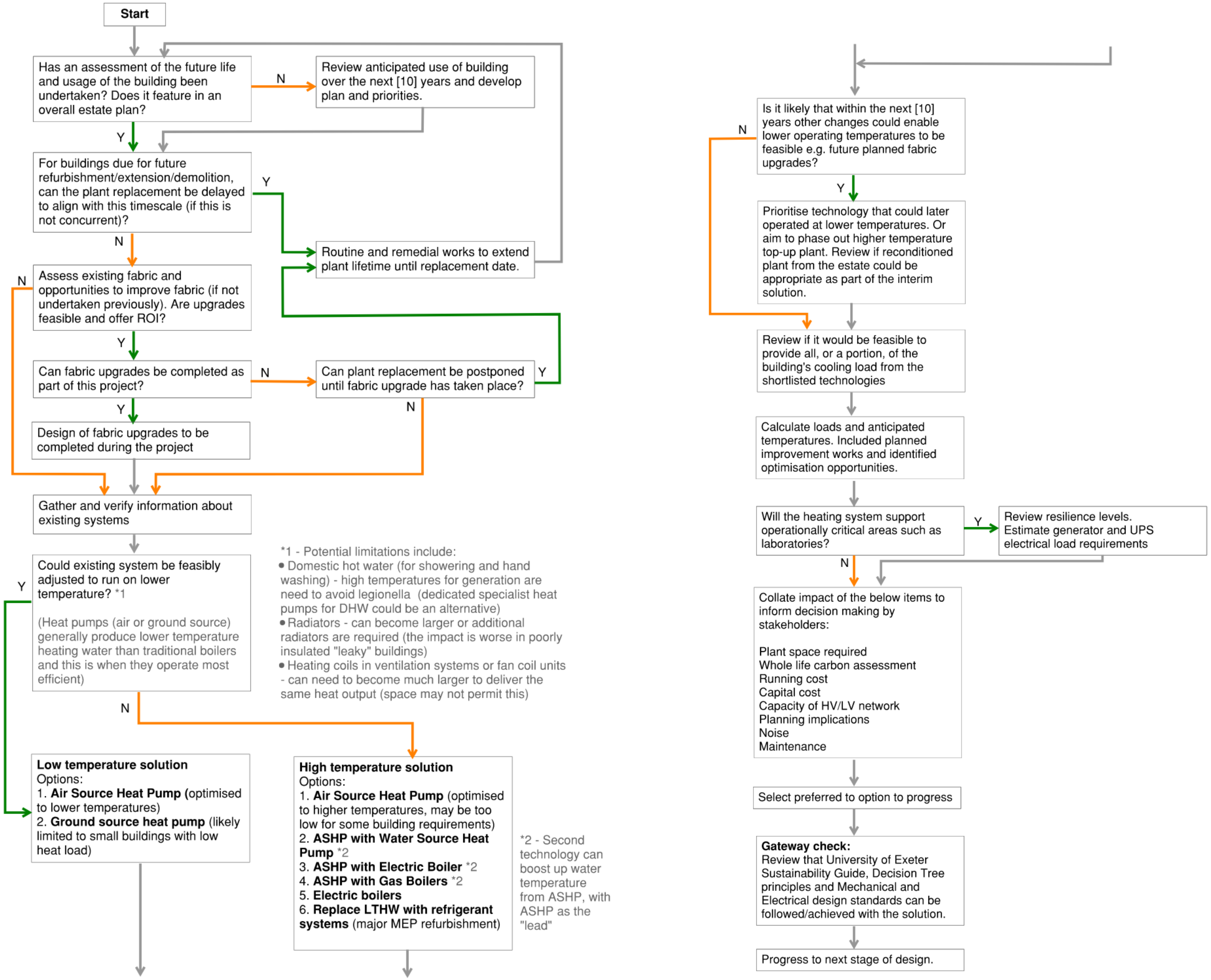


Figure 31: Boiler replacement decision tree

10.3 'Typical' Project – Design Stages

To help give context to how the University may plan these decarbonisation projects this section provides an outline of the typical stages of works that should be factored into programmes and budgets.

Each building will have its own unique characteristics which will inform the details of the project and inform the durations of each stage, however, following the framework of the RIBA plan of works will provide a recognised structure. Figure 32 below shows each design stage, and the tasks that would be expected to be considered as part of decarbonisation type projects that would include fabric improvements and the introduction of ASHPs.

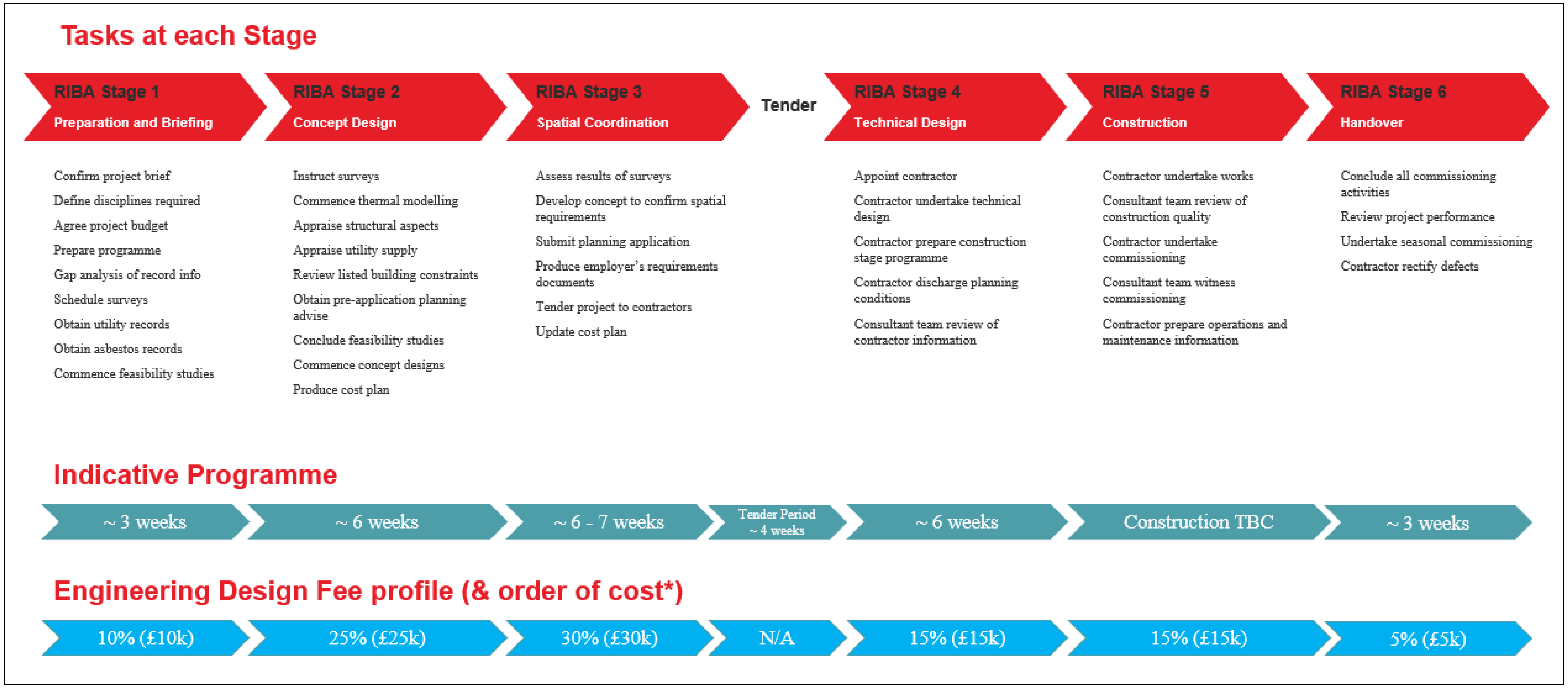


Figure 32 - 'Typical' Project - Tasks, Programme & Fees

(* Indicative MEP design fees based upon experience to date at the Amory building, where the replacement of gas boilers with ASHP's would take place alongside building fabric upgrades)

The number of different design disciplines involved in a project will vary. For example, the need for a structural engineer will be influenced by whether new equipment is being installed on an existing structure; and the requirement for an architect will vary depending on the type of building fabric interventions involved. A fundamental part of the early project inception stage will be to establish which design specialists are required.

11 Conclusions and recommendations

11.1 Conclusions

To meet the ambitious carbon targets of the University will need to make changes to their estate. We have presented an optimised scenario and implementation to provide a route for carbon reduction. Even with this scenario, which includes significant interventions, the University will possibly need to commit to purchasing 100% renewable electricity if the electricity national grid has not reached net-zero by 2040 or developing large scale electricity generation. Excluding the decarbonisation of the grid, PPAs and a large scale PV farm, the overall carbon reduction of Scenario 5 would be 45%.

To offer the best opportunity to meet the targets and distribute projects throughout the years it is advised that the University begins developing projects in line with this plan as soon as possible. The later projects are begun the more projects it will be necessary to run concurrently to keep on schedule (leading to greater logistical challenges and higher financial investment needed in later years).

The estimated total cost of works for the recommended scenario (Scenario 5) is in the order of **£231.5m** (£193m + Inflation) spread over 19 years. This is front loaded to meet the University's target of a 75% reduction by 2030.

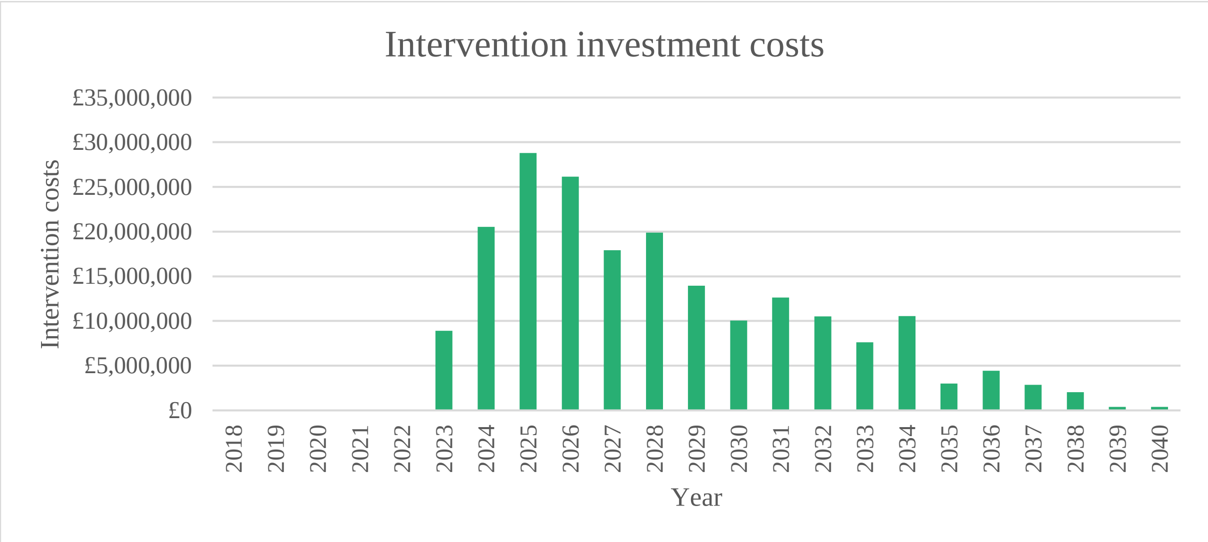


Figure 33 - Spend profile for scenario 5

Alongside the construction and design costs, the University will also require substantial internal resources to manage the number of ongoing projects. The implementation plan and annual projected spend should be compared to the University's normal annual profile to assess the scale of increased resource required. Guidance for typical project timescales has also been included within this report, the University is advised to review these and consider if any additional lead time is needed for project creation approval (due to governance procedures).

This plan has been developed based on building types having common interventions applied. A summary of the optimised scenario interventions is included in the Table 28.

	Listed Buildings	Buildings built Pre-1985	Buildings built 1985 - 2000	Building built Post-2000
Upgrade roof		✓		
Upgrade walls		✓		
Replace windows		✓	✓	
Add secondary glazing	✓			
Change heating to electric boilers	✓			
Change heating to ASHP		✓	✓	✓
Upgrade heating system controls	✓	✓	✓	
Add PVs to roof		✓	✓	✓

Table 28: Summary of interventions applied to building types in the optimised scenario

11.2 Recommendations

11.2.1 Estate database

During the development of the plan, it emerged that data and information held about the estate and its assets are not stored in common or easily accessed locations, and at times it was found that the information was out of date. Having up to date and accessible information is key to making informed decisions. Developing a database that captures which buildings have already been upgraded with energy savings measures would allow faster identification of remaining opportunities. The database could contain heating and hot water generation summary e.g. gas boilers or ASHP, alongside ages of main plant, any fabric upgrades and a summary of the lighting installations. There is knowledge within the estate team about these items, but collating (and keeping the information up to date) in a central location would allow for holistic campus wide assessments and would be a valuable tool in apply this decarbonisation masterplan and future planning for the estate. Knowledgeable stakeholders would still need to be consulted but this approach could reduce the time needed and allow for faster identification of opportunities.

Alongside this information, comprehensive record drawings should be developed to enable the estates team to assess issues more quickly and improve the accuracy of refurbishment design works. Similarly, the University should maintain a database of BIM models for each building which would enable faster refurbishments/remedial works with reduced design risk.

These improvements would have a significant impact on the speed of delivery of works for the decarbonisation masterplan by substantially reducing the 'data gathering' phase of design. Accurate and easily accessible record information would also reduce the margin of risk carried throughout each project.

11.2.2 Communication/engagement

Given the ambitious targets for carbon reduction many stakeholders including staff and students will need to be part of the transformation. As part of an engagement strategy the use of dashboards in accessible location can play a part in encouraging stakeholders to make changes. Showing energy/carbon use against benchmarks and targets can encourage departments to look for changes they can make if buildings are performing less well. Some visualisations have been included as part of the decarbonisation masterplan and these could be the starting point for further development of how the plan can be communicated with stakeholders.

It can also be beneficial for teams or departments to feel they have an active role in contributing to the goals. Having carbon or Environment & Climate 'champions' for each building or department can encourage changes to be made on a more local level to reduce energy use and carbon. If this is implemented across the whole campus this could produce savings to contribute towards the University's targets with limited investment needed when the savings are driven principally by behavioural changes.

11.2.3 Estates project team

The scale of works needed to meet the University's targets will require a substantial client team to manage projects. The University should consider the size of their existing team against the work that is currently being undertaken to assess the investment that may be required in the future. The role that the client-side team will play should also be identified to ensure upskilling can take place prior to projects commencing. For example, the University's involvement may be more of a project management rather than technical role.

11.3 Next Steps

Although the scope of this decarbonisation plan is broad and sets a roadmap to follow it does not cover all buildings on the estate or all types of carbon emissions. The plan is a high-level holistic overview based on building types so does not focus on individual building requirements or irregularities.

To build on the work set out in this plan and enhance progression to meet the University's carbon targets we suggest the following steps are taken next. These are outside the scope of this project but are suggestions to move the University forward on their decarbonisation journey:

- Add in Carbon Scope 3 and Scope 1&2 transport emissions to the plan.
- Add off campus UoE buildings where appropriate that are not included in the plan
- Carry out building specific studies to look at:
  - Ventilation (heat recovery and mixed mode) opportunities
  - Smart metering and BMS opportunities
  - Heat decarbonisation opportunities for transitioning away from gas and oil boilers
  - Opportunities to improve building fabric
  - Reviewing the electrical infrastructure for each building (to build on the site wide work in this plan)
  - Building occupant guidance to ensure efficient operation of room level systems.
- Carry out a detailed assessment of the works required for the University's electrical infrastructure to allow the estates team to pre-empt increases in electrical demand across their campuses.
- Review long term changes resulting from COVID-19 that could need to be factored into the plan (such as additional ventilation with associated heating load increases)
- Engage with operators of buildings not operated by the University and seek agreement with the decarbonisation masterplan principles and implementation plan
- Continue to define what Environment Net Gain means to the University, including ambitions and methodology for measurement (to enable before and after situations to be compared).
- Develop detailed plan for next 5 years
- Review funding opportunities for transition
- Review the research and corroboration opportunities with Exeter Academic community

Next steps currently being progressed:

The University is already taking further steps to progress its carbon reduction ambitions, with the following second phase of projects underway:

- Planning, investigating, and producing a heat decarbonisation plan for several buildings that have been granted funding from SALIX Low Carbon Skills Fund. Work will be concluded by end of March 2022. This includes buildings on the Streatham campus (Arup). Buildings at Penryn are also having a heating decarbonisation plan developed (by others).

11.3.1 Outline action plan

Below is a suggested timeframe for undertaking the recommendations and next steps of this plan. More detailed project ordering and completion date can be found in the implementation schedule and project timelines in appendices C1 and C2. The below are suggestions and should be reviewed by the University to ensure compliance with governance and timeframes.

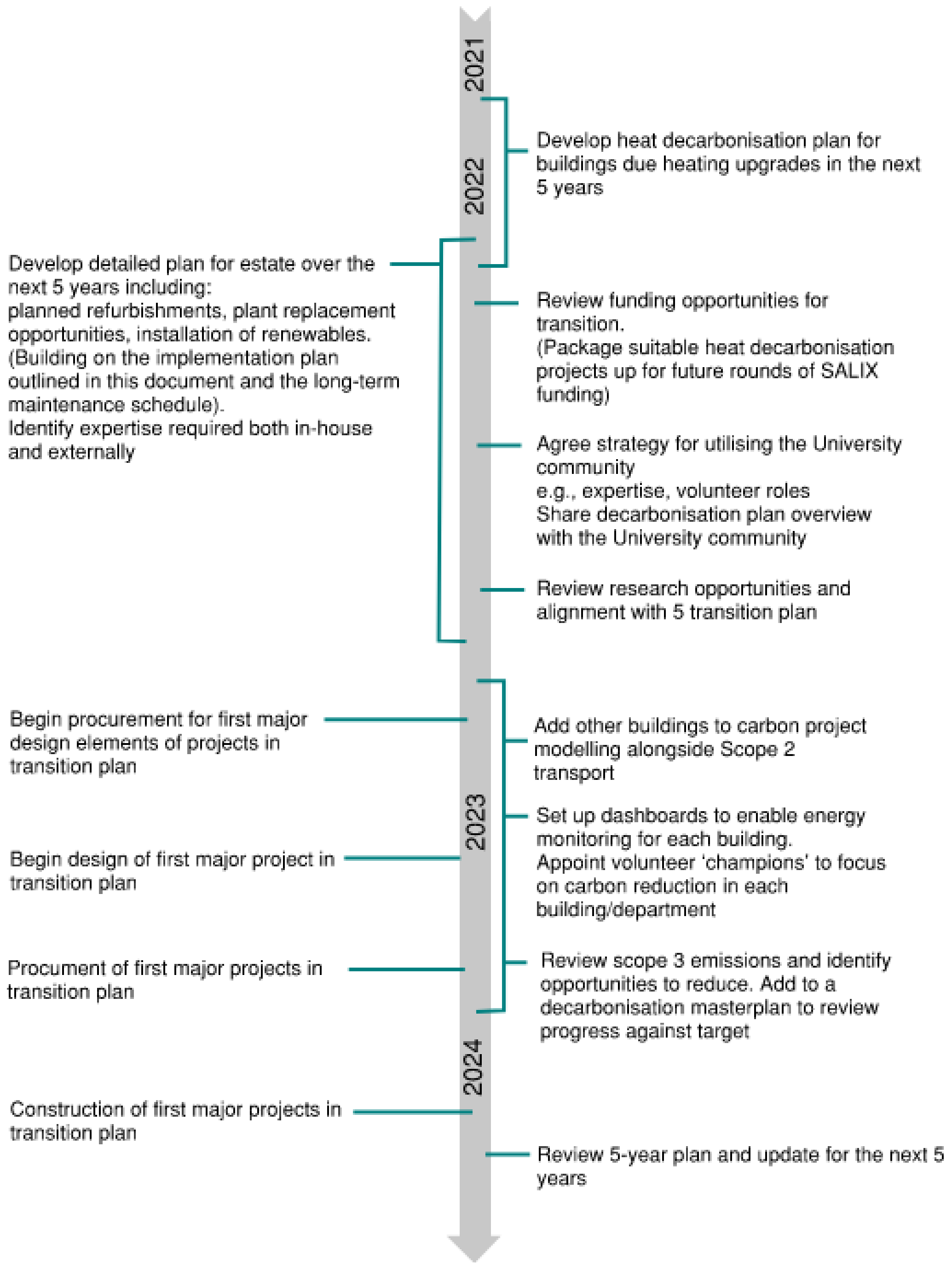


Figure 34:Suggested next steps action plan

	Suggested action	**Date**
1	Develop heat decarbonisation plan for buildings due heating upgrades in the next 5 years	2021 / 2022
2	Develop detailed plan for estate over the next 5 years including planned refurbishments, plant replacement opportunities, installation of renewables. (Building on the implementation plan outlined in this document and the long-term maintenance schedule). Identify expertise required both in-house and externally	2022
3	Review funding opportunities for transition. Package suitable heat decarbonisation projects up for future rounds of SALIX funding	2022
4	Agree strategy for utilising the University community e.g., expertise, volunteer roles Share decarbonisation plan overview with the University community	2022
5	Review research opportunities and alignment with 5 year transition plan	2022
6	Begin procurement for designing first projects identified within 5 year plan. Set dates for procuring future projects.	2022
7	Add other buildings to carbon project modelling alongside Scope 2 transport	2022 / 2023
8	Set up dashboards to enable energy monitoring for each building. Appoint volunteer 'champions' to focus on carbon reduction in each building/department	2022 / 2023
9	Review scope 3 emissions and identify opportunities to reduce. Add to a decarbonisation masterplan to review progress against target	2022 / 2023
10	Begin design of first major projects in transition plan	2023
11	Construction of first major projects in transition plan	2024
12	Review 5-year plan and update for the next 5 years	2023 / 2024

Appendix A

Decision Trees

A1 Updated Project Investment Decision Tree

Decision hierarchy:
Priority order of decisions required to deliver Net Zero buildings / Estates operations / low carbon portfolio

Investment and carbon optimisation / whole building approach

Points to consider (N) | Points to consider (Y)

1. Are the ambitions and priorities of the University for low carbon portfolio/net zero buildings clearly defined?
   Is documentation/guidance available and current?

N

a. Review existing documentation and identify any gaps/contradictions
b. Determine if any specialist advise is needed
c. Define/update terminology and measurement strategy
d. Review timelines: are these realistic/ambitious enough, can these be informed by previous progress/achievements?
e. Update documentation, ideally building on previous work to keep momentum and engagement

Y

a. Is documentation accessible, is it easy to find the current version and has this been promoted to the University community
b. Is more support structure/training of personnel needed to encourage adoption and regular use/engagement?
c. Can departments be better engaged to prioritise/assess /generalate future projects/research in line with guidance

= Aim to engage the whole University community in common goals with knowledge bank to draw from

2. Is the existing building/estate's progress against carbon ambitions known?

N

a. Review building(s) last calculated carbon baseline and whether this was included in estate plan
b. Calculate latest carbon data for building(s)
c. Add into overall estate carbon calculation
d. Check new position against aims and whether planned trajectory is still achievable without additional interventions/investment

Y

a. If a building's progress is behind target, is there opportunity to improve this with investment/intervention project/or further engagement with stakeholders
b. If a building is ahead of target, is continuing to invest beneficial for the overall campus or are there other opportunities that could feasibly deliver greater overall benefit
c. Where significant progress/milestone have been achieved has this promoted/celebrated internally and externally

= Target investment that will benefit the whole institution and zero carbon ambitions the most

3. Is the existing occupancy/ usage / consumption profile known and short-term needs understood?

N

a. Establish occupancy levels / profile / use
b. Check operational set points (HVAC)
c. Check activity in building use
d. Survey occupants to gain preferences / appetite for change
e. Identify optimal occupancy level / profile / use / review work patterns to identify efficiencies
f. Establish footprint baseline energy and carbon (energy use profile (by activity type/peaks/patterns), model footprint based on baseline with varying occupancy models, usage, to identify key criteria to drive changes toward goals
g. Understand range of consumption, energy intensity of space / best practice (optimal position) and future intensity goals. Compare with similar buildings/space types.
h. Review/establish upcoming refurbishment/scheduled maintenance plans
i. Identify personnel who will be champions for identifying/promoting carbon reduction for building/department

Y

a. Can operations be optimised
- HVAC settings lowered for space where occupants are more active
- Align HVAC provision with current occupancy/technical requirements rather than historic sizing
- Time clocks rescheduled / hours of operation reduced
- Sensors deployed to operate only at times 'in use'
- Work patterns be streamlined
b. Has staff /student feedback / survey indicated preferences/ thresholds
c. Can space at utilisation levels below optimal (80%) be reallocated when not in use
d. Can spaces with similar usage patterns / technical requirements (e.g. 24 hour operation be grouped in clutters/shared between departments)
e. Have all key criteria been modelled using a systems thinking (interrelationship modelling e.g. COCOMO)
f. Are power consuming FF&E items in communal spaces needed/well used (e.g., vending machines, display screens)

= What is informing / the key criteria informing future operational plans

4. Are growth strategies / vision / College / Dept future 20 year business strategies identified and used to inform plans / budgets / footprint

N

a. Establish future operational / occupancy/ usage profiles by college / dept / strategic vision
b. Understand dependencies and levers for vision to be realised (i.e. certainty / optimal position predicted)
c. Establish optimal design for predicted position timeline
d. Establish opportunity for flexible space in design to need for refit after development if activities change
e. Can we design our future portfolio for operation and optimal performance not to smallest cost?
f. Can the WFH strategy / workforce be distributed to help create the flexibility in space?

Y

a. Can the future state operating model provide clarity on operations / occupancy / usage profiles
b. Can design fit need – i.e. can highest demand intensity space be designed differently/ activities grouped together /
c. Change delivery plan to achieve optimal position be delivered by staged growth / moves and changes?
d. Are there projects/interventions that need to happen in the short term to facilitate future plans
e. Can academics / researchers 'unleash the creativity of the University'

= Can the future operating budget / maintenance / carbon footprint be predicted to identify minimum achievable position and facilitate future proofing

5. Have opportunities to reduce carbon within the building(s) been identified/planned?

N

a. Establish asset registers / asset replacement strategies which identify low carbon alternatives and deliver planned carbon savings
b. Establish fabric replacement strategies which identify low carbon alternatives and deliver planned carbon savings
c. Establish ROI / thresholds for spend
d. Align timing of replacement with planned portfolio changes
e. Heat map the priorities to deliver best return

Y

a. Can we map development in technology /industry and utilise this to provide the change identified in the next 5 years?
b. Can grants / funding bids deliver capital required?
c. Can hire / buy schemes / renting assets be utilised in delivering / funding for the change?

= Can we establish the investment optimisation thresholds – short term by taking account of the future developments expected?

6. Has the projects positive contribution to Sustainability goals been established, alongside provisional funding, programme considerations

N

a. Assess projects likely impact on Sustainability Goals
b. Establish targets that need to be met and means of measurement/assessment
c. Determine restraints / closed periods / restrictions that could apply (e.g. exams / IT thresholds / grid capacity constraints)
d. Establish the governance
e. Identify key stakeholders and their availability
f. Determine likely contractors/consultants input required
g. Review funding/grant opportunities
h. Establish the timeline
i. Determine likely lead in times for project
j. Establish any benefit/risks of running concurrently with similar projects

Y

a. What are we prioritising and how will this be measured/demonstrated throughout project?
b. What is the optimal timing /plan for investment?
c. Can it be sector leading
d. How can we showcase
e. What change / support is needed to demonstrate leadership thinking and action
f. Are the criteria and options for procurement

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf

= Can we establish a policy / approach / framework to deliver these strategic benefits / optimal operational performance and footprint?

Funding / project identified with delivery framework

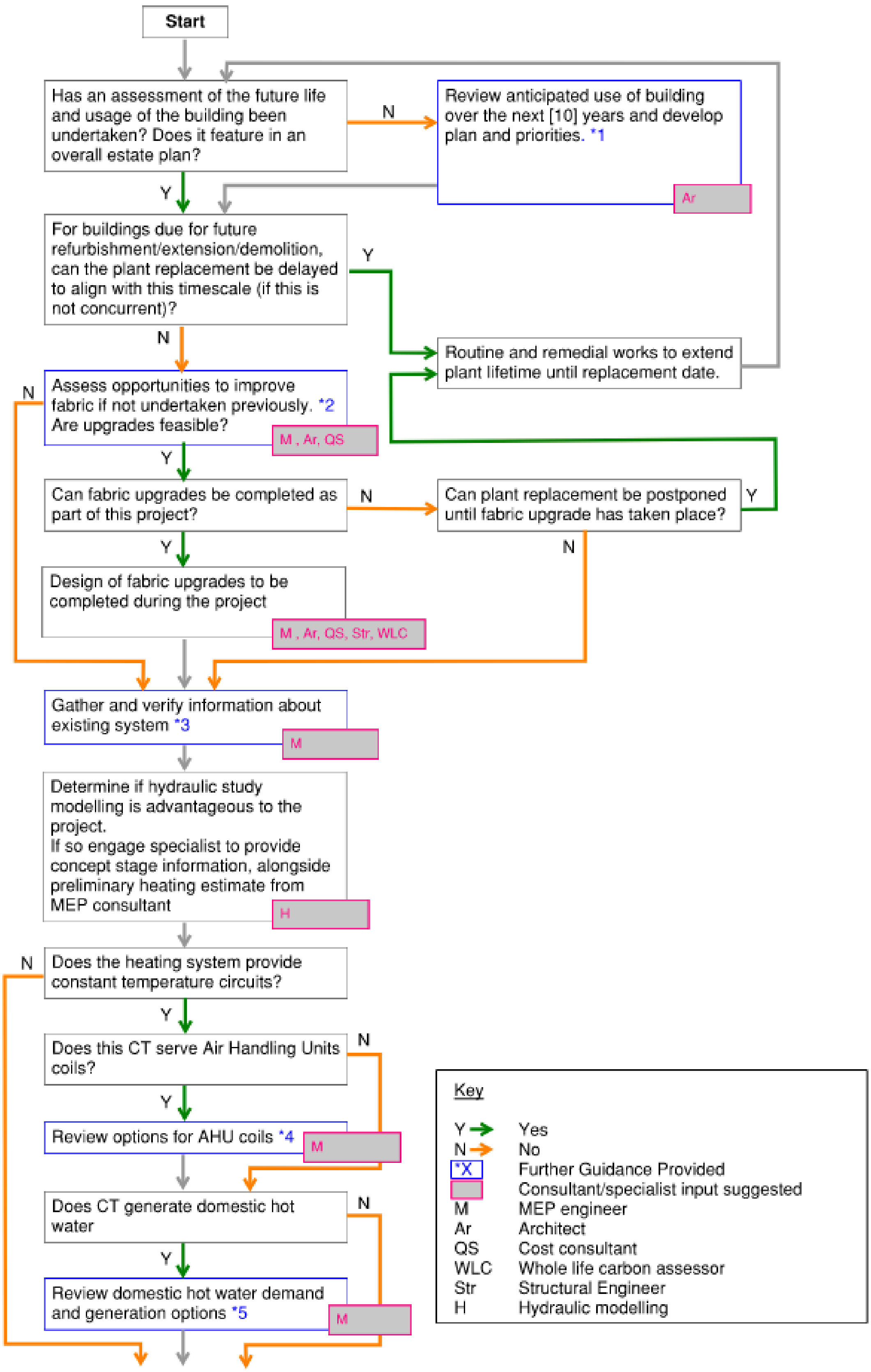
A2 Boiler Replacement Decision Tree

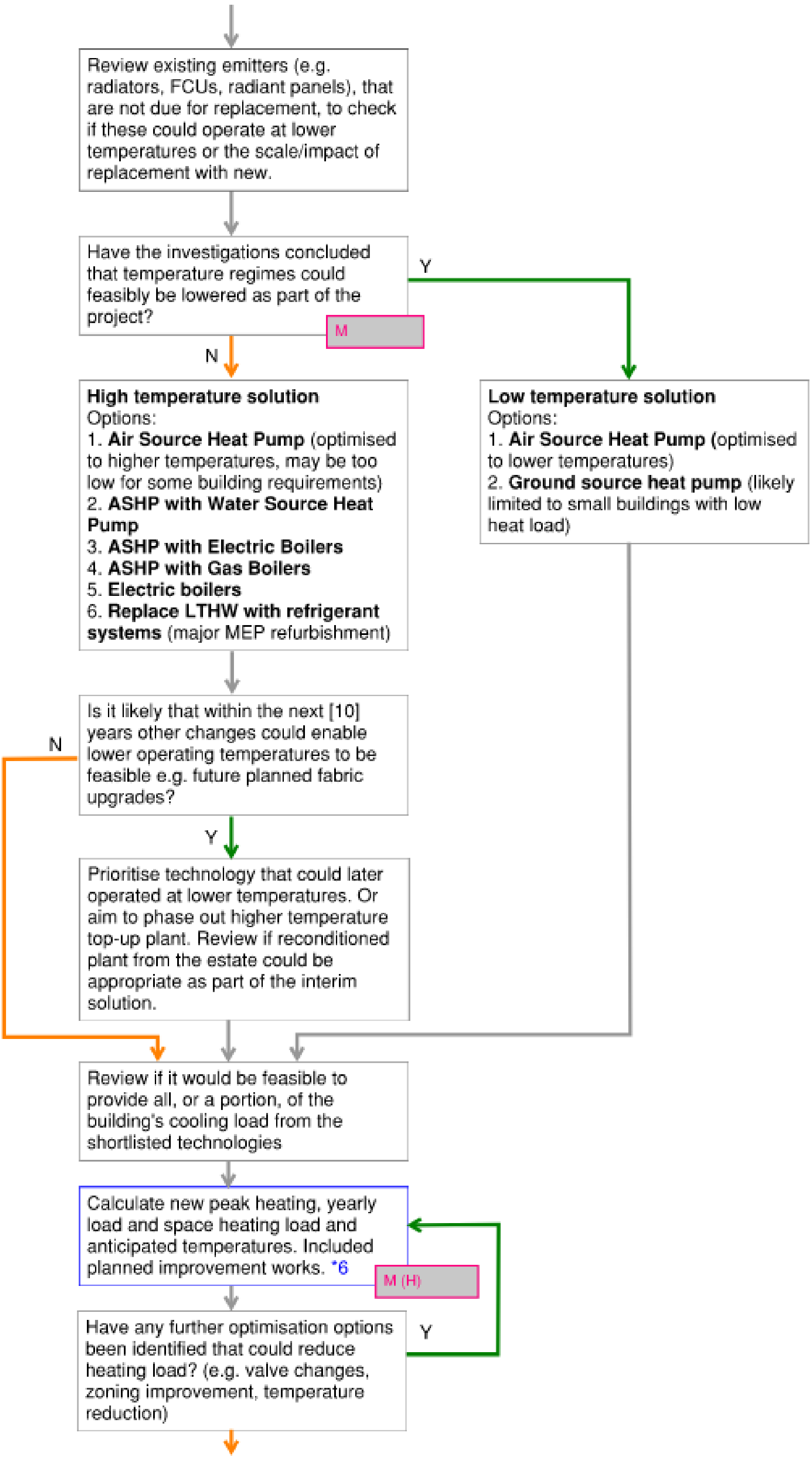
University of Exeter

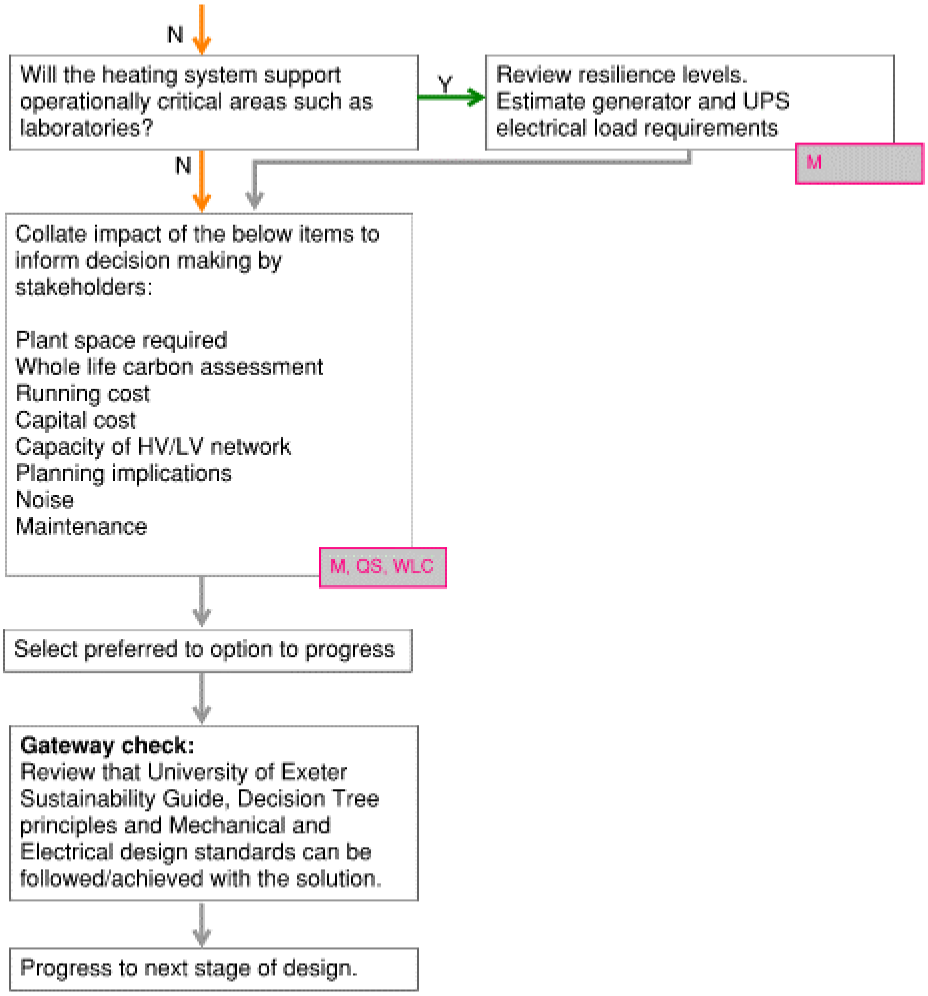
Decarbonisation Masterplan

Boiler Replacement Decision Tree

1 Boiler Replacement Decision Tree




Review existing emitters (e.g. radiators, FCUs, radiant panels), that are not due for replacement, to check if these could operate at lower temperatures or the scale/impact of replacement with new.
Have the investigations concluded that temperature regimes could feasibly be lowered as part of the project?
M
Y
N
High temperature solution
Options:
1. Air Source Heat Pump (optimised to higher temperatures, may be too low for some building requirements)
2. ASHP with Water Source Heat Pump
3. ASHP with Electric Boilers
4. ASHP with Gas Boilers
5. Electric boilers
6. Replace LTHW with refrigerant systems (major MEP refurbishment)
Low temperature solution
Options:
1. Air Source Heat Pump (optimised to lower temperatures)
2. Ground source heat pump (likely limited to small buildings with low heat load)
Is it likely that within the next [10] years other changes could enable lower operating temperatures to be feasible e.g. future planned fabric upgrades?
N
Y
Prioritise technology that could later operated at lower temperatures. Or aim to phase out higher temperature top-up plant. Review if reconditioned plant from the estate could be appropriate as part of the interim solution.
Review if it would be feasible to provide all, or a portion, of the building's cooling load from the shortlisted technologies
Calculate new peak heating, yearly load and space heating load and anticipated temperatures. Included planned improvement works. *6
M (H)
Have any further optimisation options been identified that could reduce heating load? (e.g. valve changes, zoning improvement, temperature reduction)
Y


N
Will the heating system support operationally critical areas such as laboratories?
Y
Review resilience levels. Estimate generator and UPS electrical load requirements
M
N
Collate impact of the below items to inform decision making by stakeholders:
Plant space required
Whole life carbon assessment
Running cost
Capital cost
Capacity of HV/LV network
Planning implications
Noise
Maintenance
M, QS, WLC
Select preferred to option to progress
Gateway check:
Review that University of Exeter Sustainability Guide, Decision Tree principles and Mechanical and Electrical design standards can be followed/achieved with the solution.
Progress to next stage of design.

1.1 Additional Guidance

***1 - Reviewing anticipated building use and optimisation**

Review anticipated use of building over the next [10] years and develop plan and priorities.

Compare building department and space type against business plan(s) and future growth

Review how well utilised and occupied the current building is. E.g. Review any occupancy survey results or commission study to monitor utilisation. Review attendance records and timetabling data.
Review research/academic/operation needs and priorities

Gather and verify data on the condition of building and any remedial works required,including items such as fire, accessibility, asbestos.

***2 - Reviewing fabric upgrades**

Determine the age of existing building and whether any extensions or fabric upgrades have taken place since construction.

Carry out thermal imaging survey in winter months while the heating is operation to identify where heat loss is occurring from the building external.

Review building existing fabric condition

Record installations on the roofs

For Listed buildings
Review Listing type and constraints that are applicable.
Review construction types and estimate u-values
Undertake an assessment to establish if draught proofing would be feasible and estimate the expected energy benefits.
Undertake assessment to establish if secondary glazing (in place of draught proofing) would be feasible and estimate the expected energy benefits
Assess if insulation can be added to the loft
Refer to Historic England guidance for additional information

For buildings without listed status
Review construction types and review/estimate the u-values
Carry out study to determine if building can be upgraded to meet EnerPHit standard. Improvements to consider include:
- Replacing windows with triple glazing
- Replacing roof with additional insulation
- Insulating walls via external cladding or with internal insulation (noted the latter is more disruptive for occupied buildings)
- Replacing external doors

Ideally all buildings would be upgrade to EnerPHit standard and each should be reviewed individually. However to target investment a rough frame is proposed below to prioritise improvements based on the construction date:

Before 1985:	upgrade/replace roof, walls and windows
1985 -2000:	replace windows
After 2000:	targeted interventions to areas with high leakage or poor fabric condition

*3 Data gathering

Gather and review heating system performance information, engaging with Estates team to collect anecdotal feedback and PlanOn records
If issues are not limited to components being replaced then review opportunities to address/mitigate under this project.

Gather and verify data on existing peak heating load and base load alongside yearly gas usage, and any heat metering

Gather and verify record information on existing system including secondary circuits, distribution and emitters. (Includes layout, schematics, duties of coils, emitter sizes, control valve types and sizes, etc.) Identify gaps in information.

Commission/undertake survey to fill identified gaps

*4 AHU coil options

Gather and verify information about existing AHUs including duty, age, heat recovery, dimensions, heating coil, frost coil and overall spatial dimensions.

Commission/undertake survey to fill identified gaps

Review if AHUs are scheduled for replacement in the next [5] years. Where this is the case it is suggested that existing heating supply is maintained to the AHU but that future AHU requirements are considered.

Gather information about design criteria for the spaces served from the AHU, compare against benchmarks/good practice for space type.

If a frost coil is included review whether this is still required

Review opportunity to include heat recovery to AHUs where this is not included.

Review opportunity to operate AHU at lower air volume.

Review if the design criteria could be maintained by supplying the heating coils with lower temperature water. Where this is not the case consider if there is space to add (and maintain) additional heating coil rows to the AHU or heater battery in the ductwork

Review the scale and impact of any AHU replacements or modifications.

*5 Domestic hot water (DHW) generation

Gather and verify information about existing domestic hot water including duty, age, metering and overall spatial dimensions.

Commission/undertake survey to fill identified gaps

Compare against benchmarks/good practice for space/building type.

Review if DHW system is scheduled for replacement in the next [5] years and if this can be concurrent to the project. Where replacement is immanent but not concurrent, it is suggested that existing heating supply is maintained to the calorifier but that future DHW requirements are considered.

Gather information about design loading for the spaces served from the DHW, compare against benchmarks/good practice for space type.

Review peak load and storage requirements

Review if DHW load could be more efficiently served from local point of use

Consider options for separate ASHP system for DHW generation via plate heat exchanger with storage and immersion heater back-up

Alternatively retain as part of combined heating system

***6 Calculating heat load**

Collate all information about building fabric (including any upgrades) and heating system loads and schematic design.

Build a thermal model to determine the peak space heating load. Where upgrades have been proposed a before and after comparison should be produced.

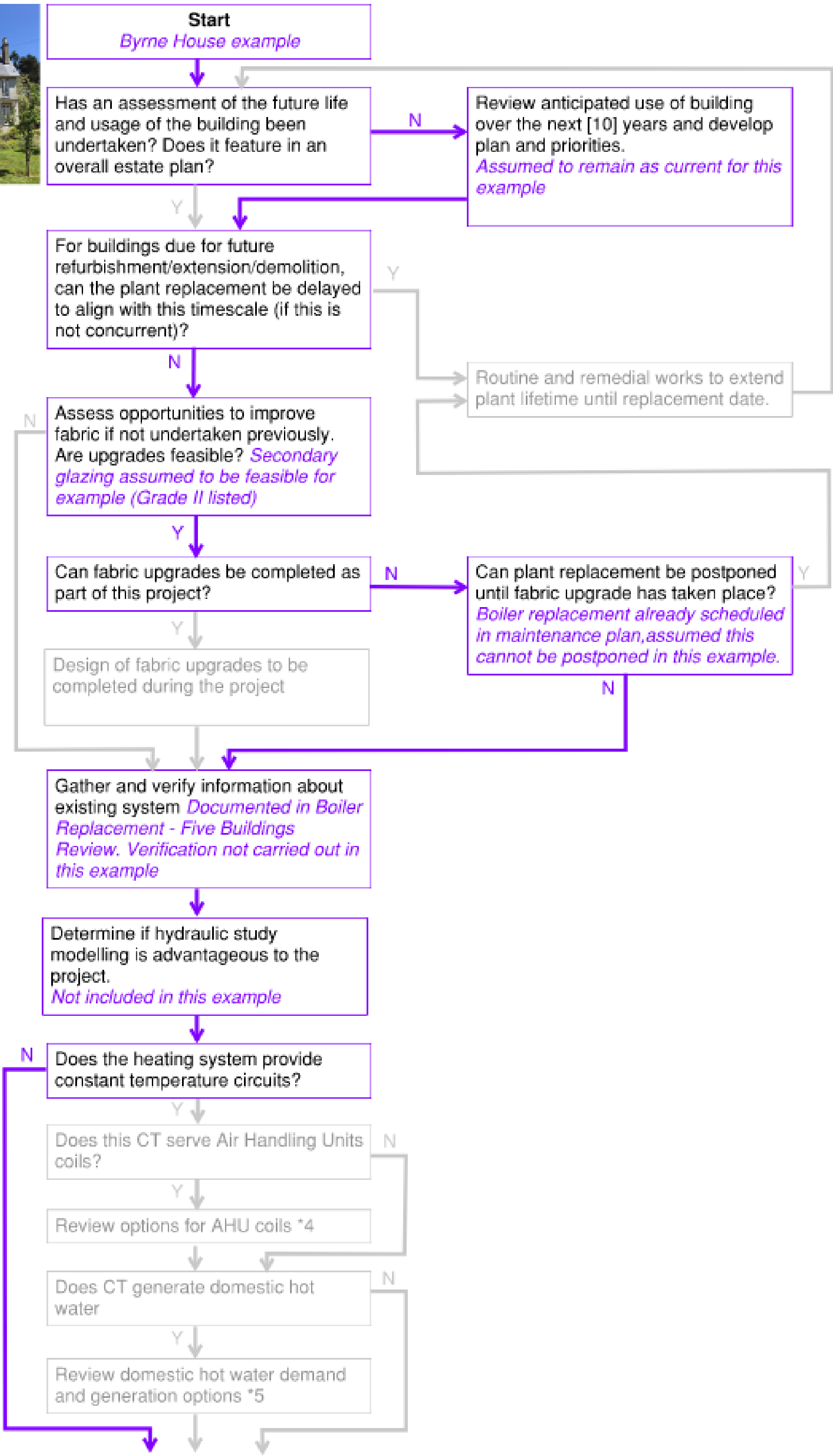
Determine the peak load for other elements of the heating system e.g. AHU coils.

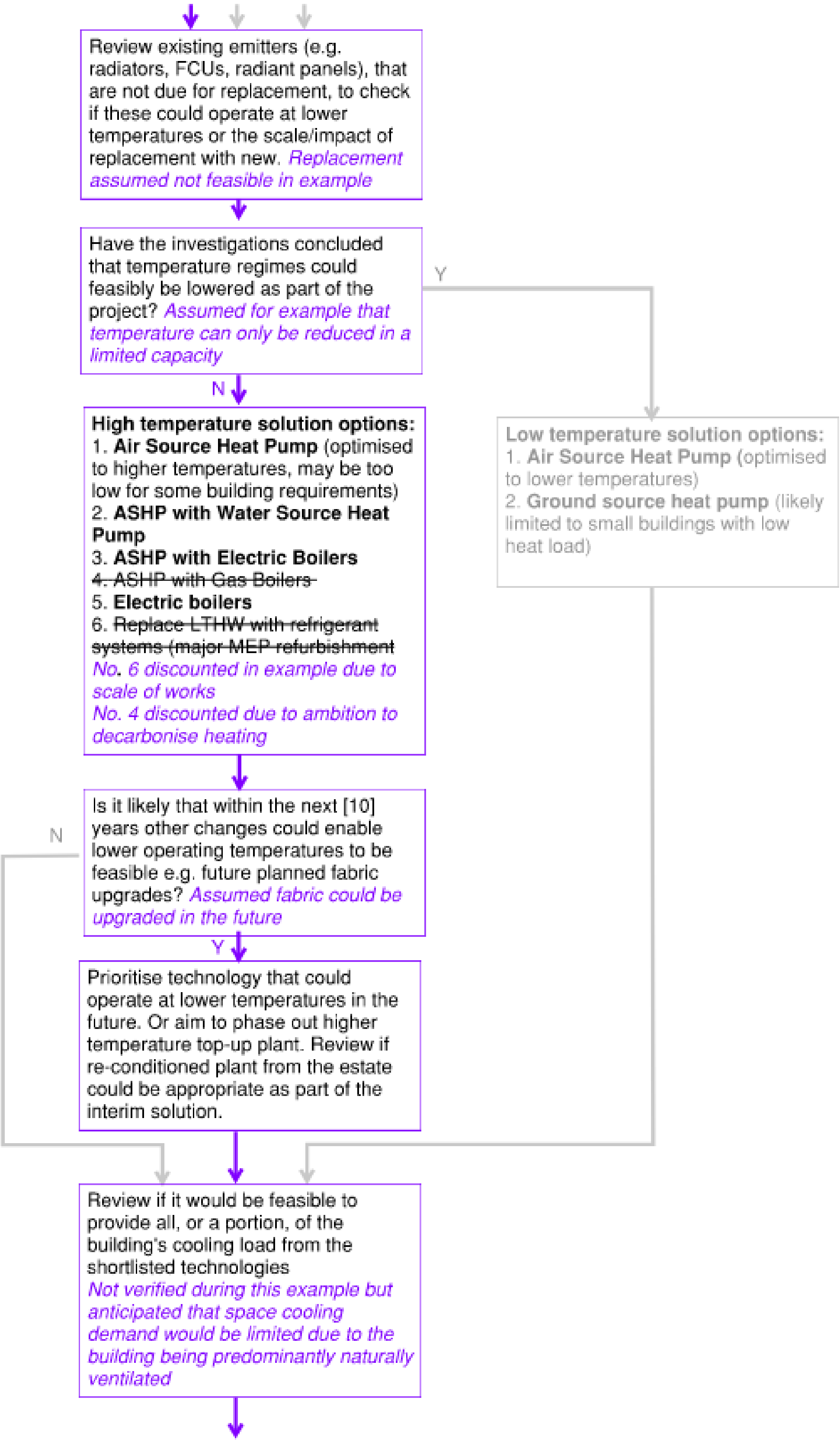
Consider building or further developing hydraulic model of the proposed system .

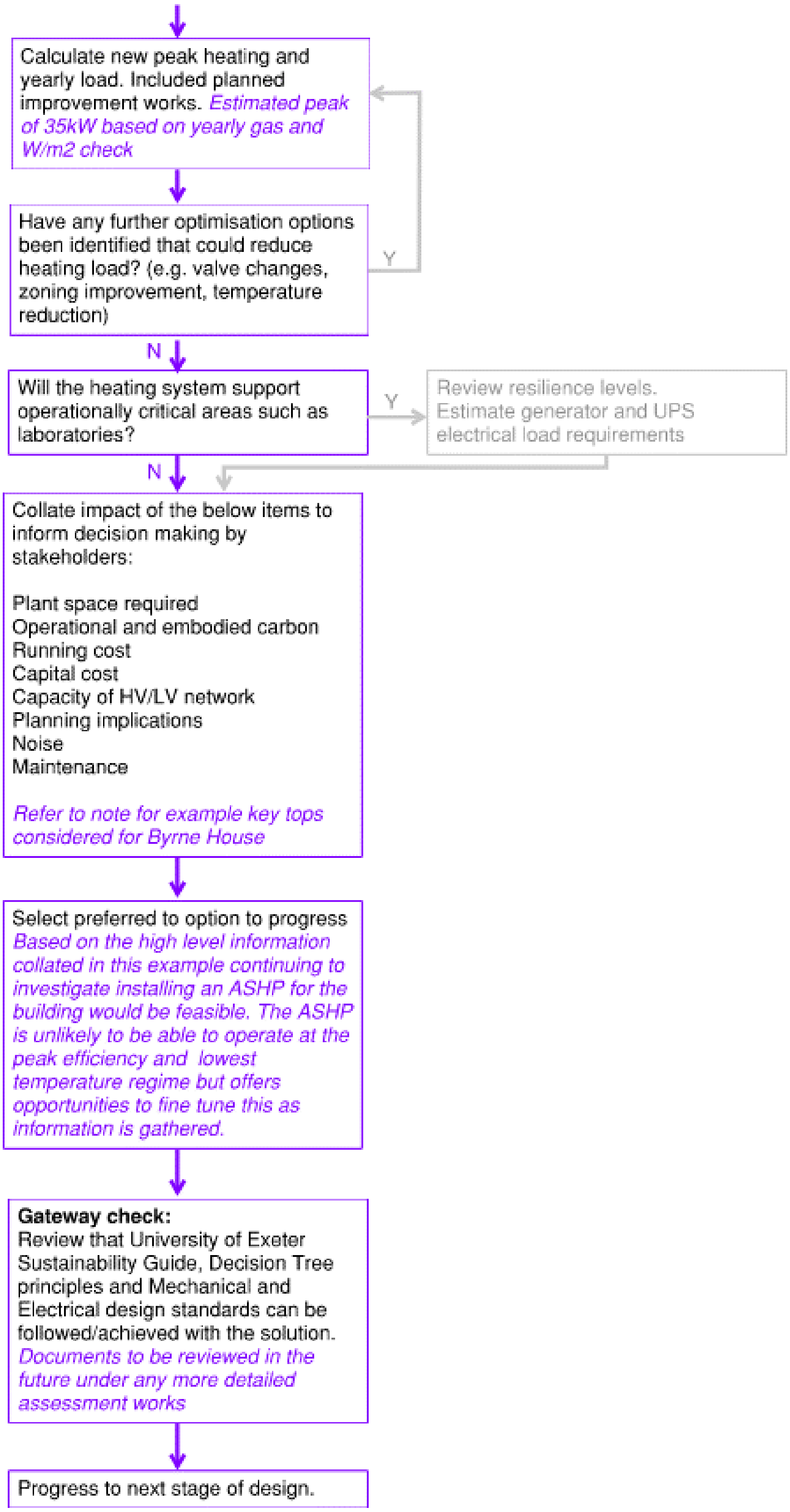
Carry out dynamic modelling to review heat load and energy consumption over a year.

Where hydraulic modelling has been included, look to optimise the temperature regime and valve control to minimise the energy use and fuel consumption.

1.2 Worked Example




Review existing emitters (e.g. radiators, FCUs, radiant panels), that are not due for replacement, to check if these could operate at lower temperatures or the scale/impact of replacement with new. *Replacement assumed not feasible in example*
Have the investigations concluded that temperature regimes could feasibly be lowered as part of the project? *Assumed for example that temperature can only be reduced in a limited capacity*
Y
N
High temperature solution options:
1. **Air Source Heat Pump** (optimised to higher temperatures, may be too low for some building requirements)
2. **ASHP with Water Source Heat Pump**
3. **ASHP with Electric Boilers**
~~4. ASHP with Gas Boilers~~
5. **Electric boilers**
6. ~~Replace LTHW with refrigerant systems (major MEP refurbishment~~
No. 6 discounted in example due to scale of works
No. 4 discounted due to ambition to decarbonise heating
Low temperature solution options:
1. **Air Source Heat Pump** (optimised to lower temperatures)
2. **Ground source heat pump** (likely limited to small buildings with low heat load)
Is it likely that within the next [10] years other changes could enable lower operating temperatures to be feasible e.g. future planned fabric upgrades? *Assumed fabric could be upgraded in the future*
N
Y
Prioritise technology that could operate at lower temperatures in the future. Or aim to phase out higher temperature top-up plant. Review if re-conditioned plant from the estate could be appropriate as part of the interim solution.
Review if it would be feasible to provide all, or a portion, of the building's cooling load from the shortlisted technologies
Not verified during this example but anticipated that space cooling demand would be limited due to the building being predominantly naturally ventilated


Calculate new peak heating and yearly load. Included planned improvement works. *Estimated peak of 35kW based on yearly gas and W/m2 check*
Have any further optimisation options been identified that could reduce heating load? (e.g. valve changes, zoning improvement, temperature reduction)
Y
N
Will the heating system support operationally critical areas such as laboratories?
Y
Review resilience levels. Estimate generator and UPS electrical load requirements
N
Collate impact of the below items to inform decision making by stakeholders:
Plant space required
Operational and embodied carbon
Running cost
Capital cost
Capacity of HV/LV network
Planning implications
Noise
Maintenance
Refer to note for example key tops considered for Byrne House
Select preferred to option to progress *Based on the high level information collated in this example continuing to investigate installing an ASHP for the building would be feasible. The ASHP is unlikely to be able to operate at the peak efficiency and lowest temperature regime but offers opportunities to fine tune this as information is gathered.*
Gateway check: Review that University of Exeter Sustainability Guide, Decision Tree principles and Mechanical and Electrical design standards can be followed/achieved with the solution. *Documents to be reviewed in the future under any more detailed assessment works*
Progress to next stage of design.

Appendix B

Electrical Infrastructure Overview

B1 Electrical Infrastructure Overview

The method of reporting sets the substation threshold at 90% of the transformer rating to avoid overloading.

A ‘green’ highlighted cell indicates the substation threshold is unlikely to be exceeded.

A ‘yellow’ highlighted cell indicates the substation threshold will likely be exceeding (i.e. 90%) or source of supply shall be investigated further.

A ‘red’ highlighted cell indicates the substation maximum availability will likely be exceeding (i.e. 100%).

University of Exeter - Carbon Management Plan Tool

A 'green' highlighted cell indicates the substation threshold is likely to not be exceeded.
A 'yellow' highlighted cell indicates the substation threshold (90%) may be exceeded and/or requires further investigation.
A 'red' highlighted cell indicates the substation maximum availability will likely be exceeded and requires further investigation.

St. Luke's Off Campus

Substation St. Luke's Off Campus — **Transformer Rating** 1000 KVA — *Typical WPD 1MVA HV/LV Susbtation

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Research, Innovation, Learning & Development Centre	0	2013	BG145	4045	Academic	55	222.5	ASHP	274.1	0.98	279.7	52.6	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
Clinical Skills Resource Centre, RD & E, Heavitree	0	1992	BG146	1462	Academic	55	80.4	ASHP	107.3	0.98	109.5	27.5	
Mireille Gillings Neuroimaging Centre	0	2020	BG176	384	Academic	55	21.1	ASHP	26.0	0.98	26.6	5.0	
					TOTALS		324.1		407.5		415.8		
					Substation Diversity factor	1.00					415.8		

Streatham Off Campus

Substation Streatham Off Campus — **Transformer Rating** 1000 KVA — *Typical WPD 1MVA HV/LV Susbtation

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Engineering Research Centre	0	2019	BG169	1078	Academic	55	59.3		59.3	0.98	60.5	0.0	
					TOTALS		59.3		59.3		60.5		
					Substation Diversity factor	1.00					60.5		

Streatham On Campus

Substation 40 — **Transformer Rating** 1500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Geoffrey Pope	0	1965	BG030	6889	Academic	55	378.9	ASHP	574.0	0.98	585.7	199.1	
					TOTALS		378.9		574.0		585.7		
					Substation Diversity factor	0.80					468.6		

Substation 50 — **Transformer Rating** 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Laver Building	0	1968	BG049	4604	Academic	55	253.2	ASHP	383.6	0.98	391.5	133.1	Existing Building Main Switchboard may not have capacity or need modification. To be investigated further.
Centre for Resilience in Environment, Water and Waste	0	2022	BG193	1486	Academic	55.0	81.7		81.7	1.0	83.4	0.0	
					TOTALS		334.9		465.4		474.9		
					Substation Diversity factor	0.80					379.9		

Substation 60 — **Transformer Rating** 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Devonshire House	0	1960	BG021	4619	Social - Catering	225	1039.2	ASHP	1170.0	0.98	1193.9	133.5	Existing Building Switchboard and incoming supply from may not have capacity, to be investigated further.
Great Hall	0	1964	BG031	3151	Hall - Auditorium	130	409.6	ASHP	498.9	0.98	509.1	91.1	Existing Switchboard may not have capacity, to be investigated further.
Northcote House	0	1960	BG058	4609	Admin/Office	87	401.0	ASHP	531.6	0.98	542.4	133.2	Existing Building Switchboard and incoming supply from may not have capacity, to be investigated further.
Northcott Theatre	0	1967	BG059	1790	Hall - Auditorium	130	232.6	ASHP	283.3	0.98	289.1	51.7	Existing Building Switchboard and incoming supply from may not have capacity, to be investigated further.
Queen's Building	0	1958	BG063	7312	Academic	55	402.2	ASHP	609.3	0.98	621.8	211.4	Existing Building Main Switchboard likely to not have capacity, to be investigated further.
					TOTALS		2484.7		3093.2		3156.3		
					Substation Diversity factor	0.69					2177.9		

Substation 70 — **Transformer Rating** 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Forum	0	2012	BG028	15093	Library	50	754.6	ASHP	947.0	0.98	966.4	196.3	Existing supply from Substation feeder pillar not sufficient. To be investigated further
Streatham Farm	Listed	1820	BG074	1681	Storage	17	28.6	EB	196.6	0.98	200.6	171.5	Existing Building Panelboard and incoming supply (250A) may not be sufficient, to be investigated further.
INTO Building	0	2011	BG158	2865	Academic	55	157.6	ASHP	194.1	0.98	198.1	37.3	
					TOTALS		940.8		1337.8		1365.1		
					Substation Diversity factor	0.69					941.9		

Substation 80 — **Transformer Rating** 2 x 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
													Existing Building Main Switchboard/Panelboard may not have capacity (rated at 800A) , to be investigated further.
Amory Building	0	1974	BG002	11027	Academic	55	606.5	ASHP	1031.4	0.98	1052.5	433.6	
Harrison Building	0	1968	BG032	8968	Academic	55	493.2	ASHP	747.3	0.98	762.6	259.2	
Innovation Centre	0	2001	BG039	1745	Admin/Office	87	151.8	ASHP	174.0	0.98	177.6	22.7	
Innovation Centre - Phase 2	0	2007	BG040	3648	Hall - Auditorium	130	474.3	ASHP	520.8	0.98	531.4	47.5	
Kay Building (Labs)	0	1975	BG042	222	Laboratory	90	19.9	ASHP	26.2	0.98	26.8	6.4	
Tensile Tennis Courts	0	2012	BG147	4312	Social - Sports Outdoor	10	43.1		43.1	0.98	44.0	0.0	
South West Institute of Technology	0	2021	BG191	417	Academic	55	22.9		22.9	0.98	23.4	0.0	
Cark Park B Electric Vehicle Charging (30no @7kw/point - 0.5 DF)							105.0		105.0	0.98	107.1		
Car Park B - 1580m2 PV installation @0.8 Factor,180W/m2							-227.5		-227.5	0.98	-232.2		
Innovation Centre Ph2 - 400m2 PV installation @0.8 Factor,180W/m2							-57.6		-57.6	0.98	-58.8		
					TOTALS		1631.7		2385.7		2434.4		
					Substation Diversity factor	0.69					1679.7		

Substation	90								Transformer Rating		1500 KVA		
Building/ Department Name	**Alternative Building Name/Notes**	**Building age**	**Building Number**	**Gross Internal Area [m2]**	**Building Type**	**Load Demand Estimate Benchmark (W/m2)**	**Current Load Demand Estimate (kW)**	**Intervention**	**Expected 'All Electric' Load Demand (kW)**	**PF**	**Expected Load Demand Estimate (kVA)**	**Load Demand Estimate Increase (kVA)**	**Notes**
Computer Building (Laver Data Centre)	0	1970	BG017	422	Data Centre	1500	633.0		633.0	0.98	645.9	0.0	
					TOTALS		633.0		633.0		645.9		
					Substation Diversity factor	0.80					516.7		

Substation	100								Transformer Rating		800 KVA		
Building/ Department Name	**Alternative Building Name/Notes**	**Building age**	**Building Number**	**Gross Internal Area [m2]**	**Building Type**	**Load Demand Estimate Benchmark (W/m2)**	**Current Load Demand Estimate (kW)**	**Intervention**	**Expected 'All Electric' Load Demand (kW)**	**PF**	**Expected Load Demand Estimate (kVA)**	**Load Demand Estimate Increase (kVA)**	**Notes**
Cornwall House	0	1971	BG018	2405	Social - Multipurpose	200	481.1	ASHP	549.2	0.98	560.4	69.5	Existing supply and Building Main Switchboard/Panelboard may not have capacity and current supply (400A) not sufficient, to be investigated further.
Cornwall House Pool	0	1972	BG019	123	Sports - Swimming/wellbeing	50	6.2		6.2	0.98	6.3	0.0	
Rowe House - All blocks	0	1990	BK035	3379	Residential	28	94.6	ASHP	156.8	0.98	160.0	63.5	
					TOTALS		581.9		712.2		726.7		
					Substation Diversity factor	0.69					501.5		

Substation	110								Transformer Rating		800 KVA		
Building/ Department Name	**Alternative Building Name/Notes**	**Building age**	**Building Number**	**Gross Internal Area [m2]**	**Building Type**	**Load Demand Estimate Benchmark (W/m2)**	**Current Load Demand Estimate (kW)**	**Intervention**	**Expected 'All Electric' Load Demand (kW)**	**PF**	**Expected Load Demand Estimate (kVA)**	**Load Demand Estimate Increase (kVA)**	**Notes**
Byrne House	Listed	1840	BG008	592	Academic	55	32.5	EB	91.7	0.98	93.6	60.4	
Chagford	0	1995	BG009	873	Residential	28	24.4		24.4	0.98	24.9	0.0	
Christow	0	1995	BG010	873	Residential	28	24.4		24.4	0.98	24.9	0.0	
Hope Hall	0	1872	BG038	2119	Residential	28	59.3	ASHP	119.4	0.98	121.8	61.3	Building Main Switchboard/Panel board may not have capacity. To be investigated further
Lazenby	0	1920	BG050	380	Residential	28	10.6	ASHP	21.4	0.98	21.8	11.0	
Lopes Cottage	0	1890	BG052	230	Residential	28	6.4	ASHP	13.0	0.98	13.2	6.6	
Lopes Hall	Listed	1866	BG053	2675	Residential	28	74.9	EB	342.4	0.98	349.4	273.0	Existing supply capacity and Building Main Switchboard/Panel board may not have capacity. To be investigated further
Lydford	0	1997	BG054	873	Residential	28	24.4	ASHP	40.5	0.98	41.3	16.4	
Widecombe	0	1992	BG084	873	Residential	28	24.4		24.4	0.98	24.9	0.0	
Owlets	0	2019	BG173	717	Admin/Office	87	62.4	ASHP	71.5	0.98	73.0	9.3	
Spreytonway UPP	0	2020	BG194	4235	Residential	28	118.6	ASHP	172.6	0.98	176.1	55.1	
Pennsylvania Court - All blocks	0	2005	BK027	3966	Residential	28	111.0	ASHP	161.6	0.98	164.9	51.6	
Ransom Pickard - All blocks	0	1967	BK033	1595	Residential	28.0	44.7	ASHP	89.8	1.0	91.7	46.1	
					TOTALS		618.3		1197.2		1221.7		
					Substation Diversity factor	0.69					843.0		

Substation	120								Transformer Rating		800 KVA		
Building/ Department Name	**Alternative Building Name/Notes**	**Building age**	**Building Number**	**Gross Internal Area [m2]**	**Building Type**	**Load Demand Estimate Benchmark (W/m2)**	**Current Load Demand Estimate (kW)**	**Intervention**	**Expected 'All Electric' Load Demand (kW)**	**PF**	**Expected Load Demand Estimate (kVA)**	**Load Demand Estimate Increase (kVA)**	**Notes**
Clydesdale Court - All blocks	0	1989	BG015	1500	Residential	28	42.0		42.0	0.98	42.9	0.0	
Clydesdale House	0	1989	BG016	463	Admin/Office	87	40.3	ASHP	48.8	0.98	49.8	8.7	
Mardon Hall	0	1933	BG055	3330	Residential	28	93.2	ASHP	187.6	0.98	191.4	96.3	Existing panel/switchboard may need re-configuration.
Clydesdale Rise - Block A	0	1990	BK001	2855	Residential	28	79.9	ASHP	132.5	0.98	135.2	53.6	Existing supply and Building Main Switchboard/Panel board may not have capacity. To be investigated further
Nash Grove - All blocks	0	1990	BK021	2033	Residential	28	56.9	ASHP	94.4	0.98	96.3	38.2	Existing Panel boards may need re-configuration. To be investigated further
					TOTALS		312.4		505.2		515.5		
					Substation Diversity factor	0.69					355.7		

Substation	130								Transformer Rating		800 KVA		
Building/ Department Name	**Alternative Building Name/Notes**	**Building age**	**Building Number**	**Gross Internal Area [m2]**	**Building Type**	**Load Demand Estimate Benchmark (W/m2)**	**Current Load Demand Estimate (kW)**	**Intervention**	**Expected 'All Electric' Load Demand (kW)**	**PF**	**Expected Load Demand Estimate (kVA)**	**Load Demand Estimate Increase (kVA)**	**Notes**
Hatherly Building	Listed	1952	BG033	3737	Laboratory	90	336.4	EB	710.1	0.98	724.6	381.4	Existing supply and Building Main Switchboard/Panel board may not have capacity. To be investigated further
Old Library	0	1965	BG060	5334	Library	50	266.7	ASHP	417.8	0.98	426.3	154.2	Existing supply and Building Main Switchboard/Panel board may not have capacity. To be investigated further
					TOTALS		603.1		1127.9		1150.9		
					Substation Diversity factor	0.69					794.1		

Substation	140								Transformer Rating		1000 KVA		
Building/ Department Name	**Alternative Building Name/Notes**	**Building age**	**Building Number**	**Gross Internal Area [m2]**	**Building Type**	**Load Demand Estimate Benchmark (W/m2)**	**Current Load Demand Estimate (kW)**	**Intervention**	**Expected 'All Electric' Load Demand (kW)**	**PF**	**Expected Load Demand Estimate (kVA)**	**Load Demand Estimate Increase (kVA)**	**Notes**
Henry Wellcome Building for Biocatalysis	0	2004	BG034	910	Academic	55	50.1	ASHP	61.7	0.98	62.9	11.8	
Institute of Arab and Islamic Studies	0	2003	BG041	1711	Admin/Office	87	148.9	ASHP	170.7	0.98	174.2	22.3	
Newman Building	0	1965	BG057	1847	Academic	55	101.6	ASHP	153.9	0.98	157.1	53.4	Existing supply (200A) likely not sufficient. To be investigated further.
Peter Chalk Centre	0	1998	BG061	1229	Residential	28	34.4	ASHP	57.0	0.98	58.2	23.1	
Physics Building	0	1966	BG062	6629	Academic	55	364.6	ASHP	552.4	0.98	563.6	191.6	Existing supply (800A) and Building Main Switchboard/Panel board may not have capacity. To be investigated further
Helium Liquefier Building	0	1964	BG154	134	Laboratory	90.0	12.1	ASHP	15.9	1.0	16.2	3.9	
					TOTALS		711.6		1011.6		1032.2		
					Substation Diversity factor	0.69					712.2		

Substation 150 — Transformer Rating 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Holland Hall - All blocks	0	2005	BK004	10910	Residential	28	305.5	ASHP	444.6	0.98	453.6	141.9	
					TOTALS		305.5		444.6		453.6		
					Substation Diversity factor	0.69					313.0		

Substation 180 — Transformer Rating 500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Family Centre	0	1990	BG027	285	Admin/Office	87	24.8	ASHP	30.0	0.98	30.7	5.4	
Reed Hall	Listed	1867	BG065	2065	Residential	28	57.8	EB	264.3	0.98	269.7	210.7	Existing supply and Building Main Switchboard/Panel board may not have capacity. To be investigated further
Reed Mews Wellbeing	0	1890	BG066	250	Admin/Office	87	21.7	EB	46.7	0.98	47.6	25.5	
Reed Mews Health Centre	0	1890	BG067	289	Admin/Office	87.0	25.1	ASHP	33.3	1.0	34.0	8.3	
					TOTALS		129.5		374.4		382.0		
					Substation Diversity factor	0.69					263.6		

Substation 190 — Transformer Rating 800 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Mary Harris Memorial Chapel	Listed	1958	BG056	407	Chapel	50	20.4		20.4	0.98	20.8	0.0	
Roborough	Listed	1940	BG068	1618	Academic	55	89.0	EB	250.8	0.98	255.9	165.1	Existing building panel/switchboard may need re-configuration. To be investigated further.
Washington Singer	Listed	1931	BG082	4827	Academic	55	265.5	EB	748.3	0.98	763.5	492.6	Existing supply and Building Main Switchboard/Panel board may not have capacity. To be investigated further
Sir Henry Wellcome Bdg for Mood Disorders Research	0	2012	BG083	707	Academic	55	38.9		38.9	0.98	39.7	0.0	
					TOTALS		413.7		1058.3		1079.9		
					Substation Diversity factor	0.69					745.1		

Substation 200 — Transformer Rating 1500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Living Systems Institute	0	2016	BG144	9145	Academic	55	503.0	ASHP	619.6	0.98	632.2	119.0	Existing Building Main Switchboard/Panel board may need re-configuration. To be investigated further
Life Support Systems Building	0	2013	BG157	248	Laboratory	90	22.3		22.3	0.98	22.8	0.0	
510m2 PV installation @0.8 Factor,180W/m2									-73.0	0.98	*-74.5*		
					TOTALS		525.3		568.9		580.5		
					Substation Diversity factor	0.69					400.6		

Substation 210 — Transformer Rating 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Building:One	0	2011	BG007	2955	Academic	55	162.5	ASHP	200.2	0.98	204.3	38.4	
Streatham Court New	0	1998	BG073	3971	Academic	55	218.4	ASHP	291.5	0.98	297.4	74.6	
Xfi Building	0	2004	BG085	1549	Academic	55	85.2	ASHP	105.0	0.98	107.1	20.2	
Creative Quadrant	0	2021	BG192	0	General	87.0	0.0		0.0	1.0	0.0	0.0	
					TOTALS		466.1		596.6		608.8		
					Substation Diversity factor	0.69					420.1		

Substation 240 — Transformer Rating 1000 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Lafrowda Cottage	0	1890	BG045	95	Residential	28	2.7	EB	12.2	0.98	12.4	9.7	
Lafrowda House	0	1890	BG046	582	Residential	28	16.3	ASHP	32.8	0.98	33.4	16.8	
Lafrowda - All blocks	0	2012	BK096	13222	Residential	28	370.2	ASHP	538.8	0.98	549.8	172.0	Existing separate supplies and Main block Switchboard/Panels board may not have capacity. To be investigated further
					TOTALS		389.2		583.7		595.6		
					Substation Diversity factor	0.69					411.0		

Substation 250 — Transformer Rating 800 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Biosciences Greenhouse	0	2009	BG003	370	Laboratory	90	33.3	ASHP	38.0	0.98	38.8	4.8	
Sir Christopher Ondaatje Devon Cricket Centre	0	2009	BG020	1201	Social - Sports Outdoor	10	12.0	ASHP	27.3	0.98	27.9	15.6	
Sports Hall	0	1967	BG069	5217	Social - Sports Indoor	50.0	260.9	ASHP	408.7	0.98	417.0	150.8	
Changing Pavilion	0	2013	BG149	347	General	87.0	30.2	ASHP	34.6	0.98	35.3	4.5	
Russell Seal Fitness Centre	0	2013	BG150	2135	Social - Sports Indoor	50.0	106.7	ASHP	134.0	0.98	136.7	27.8	Existing supply may not have sufficient capacity. To be investigated further
1762m2 PV installation @0.8 Factor,180W/m2							*-253.0*		*-253.0*	0.98	*-258.2*		
					TOTALS		190.1		389.6		397.5		
					Substation Diversity factor	0.69					274.3		

Substation 260 — Transformer Rating 1250 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
UPP East Park - All blocks	0	2020	BK120	10342	Residential	28	289.6	ASHP	421.4	0.98	430.0	134.5	
					TOTALS		289.6		421.4		430.0		
					Substation Diversity factor	0.80					344.0		

Substation 160 — Transformer Rating 500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Birks Central	0	1965	BG004	1594.94	Social - Catering	225.0	358.9	ASHP	404.0	0.98	412.3	46.1	Existing incoming supply (400 A) likely insufficient. To be upgraded to 630A supply.
					TOTALS		358.9		404.0		412.3		
					Substation Diversity factor	0.50					206.1		

Substation 170 — Transformer Rating 500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Birks Grange	0	2006	BG006	7100	Residential	28.0	198.8	ASHP	289.3	0.98	295.2	92.4	
					TOTALS		198.8		289.3		295.2		
					Substation Diversity factor	0.69					203.7		

Substation 20 — Transformer Rating 500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Moberly UPP	0	2020	BG195	6561	Residential	28.0	183.7	ASHP	267.3	0.98	272.8	85.3	Substation re-built. Network should be checked.
					TOTALS		183.7		267.3		272.8		
					Substation Diversity factor	0.69					188.2		

Substation 30 — Transformer Rating 500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Kay House	0	1965	BG043	1489.68	General	87.0	129.6	ASHP	171.8	0.98	175.3	43.1	
					TOTALS		129.6		171.8		175.3		
					Substation Diversity factor	0.69					121.0		

Substation 340 — Transformer Rating 800 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
UPP Duryard - All blocks	0	2012	BK103	4733	Residential	28	132.5	ASHP	192.9	0.98	196.8	61.6	
INTO Duryard - All blocks	0	0	BK115	4415	Residential	28	123.6	ASHP	248.7	0.98	253.8	127.6	
Duryard East (Block E)													
					TOTALS		256.1		441.6		450.6		
					Substation Diversity factor	0.69					310.9		

Substation 350 — **Transformer Rating** 800 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
INTO Duryard - All blocks	0	0	BK115	8809	Residential	28	246.7	ASHP	496.2	0.98	506.3	254.6	
Duryard West (Dart house, Bovey house, Creedy house, Avon house)													
					TOTALS		246.7		496.2		506.3		
					Substation Diversity factor	0.69					349.4		

Substation 230 — **Transformer Rating** 800 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
UPP Birks - All blocks	0	2011	BK105	14105	Residential	28	394.9	ASHP	574.7	0.98	586.5	183.5	
Birks north blocks (F, G, H, J, K)													
					TOTALS		394.9		574.7		586.5		
					Substation Diversity factor	0.69					404.7		

Substation 220 — **Transformer Rating** 500 KVA

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
UPP Birks - All blocks	0	2011	BK105	7104	Residential	28	198.9	ASHP	289.5	0.98	295.4	92.4	
Birks south (Blocks L, M, N, Q, P)													
					TOTALS		198.9		289.5		295.4		
					Substation Diversity factor	0.69					203.8		

Streatham On Campus - Supplied Directly from DNO at Low Voltage

Separate

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Clayden	0	1954	BG011	294	Academic	55	16.2	ASHP	24.5	0.98	25.0	8.5	
Estate Services Centre	0	1960	BG026	855	Admin/Office	87	74.4	ASHP	98.6	0.98	100.6	24.7	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
Garden Hill House	0	1920	BG029	532	Residential	28	14.9	ASHP	30.0	0.98	30.6	15.4	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
Higher Hoopern Cottage	0	1890	BG035	121	Residential	28	3.4	ASHP	6.8	0.98	7.0	3.5	
Higher Hoopern Farm	0	1850	BG036	657	Social - Sports Outdoor	10	6.6	ASHP	25.2	0.98	25.7	19.0	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
Knightley	0	1890	BG044	634	Academic	55	34.9	ASHP	52.8	0.98	53.9	18.3	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
Redcot	0	1920	BG064	495	Residential	28	13.9	ASHP	27.9	0.98	28.5	14.3	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
Streatham Lodge	Listed	1860	BG075	114	Residential	28	3.2	EB	14.6	0.98	14.9	11.6	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.

St. Luke's On Campus

Substation — **St. Luke's WPD Substation no.1** — **Transformer Rating** **1000** — *Typical WPD 1MVA HV/LV Susbtation

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
South Cloisters	0	1968	BG114	5442	Academic	55	299.3	ASHP	453.5	0.98	462.7	157.3	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
722 m2 PV installation @0.8 Factor,180W/m2							*-104.0*		*-104.0*	0.98	*-106.1*		
					TOTALS		195.3		349.5		356.6		
					Substation Diversity factor	0.80					**285.3**		

Substation — **St. Luke's WPD Substation no.2** — **Transformer Rating** **1000** — *Typical WPD 1MVA HV/LV Susbtation

Building/ Department Name	Alternative Building Name/Notes	Building age	Building Number	Gross Internal Area [m2]	Building Type	Load Demand Estimate Benchmark (W/m2)	Current Load Demand Estimate (kW)	Intervention	Expected 'All Electric' Load Demand (kW)	PF	Expected Load Demand Estimate (kVA)	Load Demand Estimate Increase (kVA)	Notes
Baring Court	0	1989	BG096	2896	Academic	55	159.3	ASHP	212.6	0.98	216.9	54.4	Buidings directly supplied at Low Voltage from the DNO. Further investigation required.
St Luke's Chapel	Listed	1863	BG097	196	Chapel	50	9.8		9.8	0.98	10.0	0.0	
Club Alley	0	1890	BG099	192	General	87	16.7	ASHP	22.2	0.98	22.6	5.6	
College House	0	1990	BG100	2277	Admin/Office	87	198.1		198.1	0.98	202.1	0.0	
Dance Studio	0	1940	BG101	118	Social - Multipurpose	200	23.6	ASHP	27.0	0.98	27.5	3.4	
Haighton Library	0	1950	BG103	2028	Library	50	101.4	ASHP	158.8	0.98	162.1	58.6	
Holnicote Annexe	0	1880	BG104	281	Admin/Office	87	24.4		24.4	0.98	24.9	0.0	
Holnicote Wing	Listed	1890	BG105	613	Admin/Office	87	53.3	EB	114.6	0.98	116.9	62.5	
North Cloisters	Listed	1890	BG108	3652	Academic	55	200.9	EB	566.1	0.98	577.7	372.7	
Exeter Medical School Building	0	2002	BG109	2780	Academic	55	152.9	ASHP	188.3	0.98	192.2	36.2	
Richards Building	0	1989	BG110	1898	Academic	55	104.4	ASHP	139.3	0.98	142.2	35.7	
Smeall Building	0	1990	BG112	764	Academic	55	42.0	ASHP	56.1	0.98	57.2	14.4	
St Luke's Sports Centre	0	1950	BG116	1955	Social - Sports Indoor	50	97.8	ASHP	153.1	0.98	156.3	56.5	
Staff House	0	1889	BG117	411	Admin/Office	87	35.8		35.8	0.98	36.5	0.0	
					TOTALS		1220.3		1906.2		1945.1		
					Substation Diversity factor	0.80					**1556.1**		

University of Exeter - Carbon Management Plan Tool

Streatham On Campus

Existing Distribution Description									Arup Re-Analysis of the Loads					
Loop No.	Substation Ref	Transformer kVA Rating	Available loop Capacity (kW)	Estimated Power Factor (Corrected)	Substation Diversity Factor	11kV Loop Diversity Factor	Current Load Demand Estimate undiversified (kW)	Current Load Demand Estimate diversified (kW)	Calculated Undiversified Load (kW)	Calculated diversified Load (kW)	Loop Load Diversified (kW)	Calculated diversified Load (kVA)	Percentage of Increase %	Availability
											F = ΣG x 0.74 Loop DF			
	250	800		0.98	0.69		190.1	131.2	389.6	268.8		274.3	105%	525.7
	90	1500		0.98	0.80		633.0	506.4	633.0	506.4		516.7	0%	983.3
	260	1250		0.98	0.80		289.6	231.7	421.4	337.1		344.0	46%	906.0
	270	*1250*		0.98				0.0		0.0			0%	1250.0
	240	1000		0.98	0.69		389.2	268.5	583.7	402.7		411.0	50%	589.0
	110	800		0.98	0.69		618.3	426.6	1197.2	826.1		843.0	94%	-43.0
s/1	100	800		0.98	0.69		581.9	401.5	712.2	491.4		501.5	22%	298.5
	210	1000		0.98	0.69		466.1	321.6	596.6	411.7		420.1	28%	579.9
	70	1000		0.98	0.69		940.8	649.1	1337.8	923.1		941.9	42%	58.1
	60	1000		0.98	0.69		2484.7	1714.4	3093.2	2134.3		2177.9	24%	-1177.9
	130	800		0.98	0.69		603.1	416.1	1127.9	778.3		794.1	87%	5.9
	190	800		0.98	0.69		413.7	285.5	1058.3	730.2		745.1	156%	54.9
	180	500		0.98	0.69		129.5	89.3	374.4	258.3		263.6	189%	236.4
Subtotal			**4000**			**0.74**		**4027 kW**		**8068 kW**	**5971 kW**			**-1971 kW**
	160	*500*		*0.98*	*0.5*		*358.9*	*179.4*	*404.0*	*202.0*		*206.1*	13%	*293.9*
	170	*500*		*0.98*	*0.69*		*198.8*	*137.2*	*289.3*	*199.6*		*203.7*	46%	*296.3*
	20	*500*		*0.98*	*0.69*		*183.7*	*126.8*	*267.3*	*184.5*		*188.2*	46%	*311.8*
	30	*500*		*0.98*	*0.69*		*129.6*	*89.4*	*171.8*	*118.5*		*121.0*	33%	*379.0*
	340	*800*		*0.98*	*0.69*		*256.1*	*176.7*	*441.6*	*304.7*		*310.9*	72%	*489.1*
	350	*800*		*0.98*	*0.69*		*246.7*	*170.2*	*496.2*	*342.4*		*349.4*	101%	*450.6*
	230	*800*		*0.98*	*0.69*		*394.9*	*272.5*	*574.7*	*396.6*		*404.7*	46%	*395.3*
	220	*500*		*0.98*	*0.69*		*198.9*	*137.2*	*289.5*	*199.7*		*203.8*	46%	*296.2*
Subtotal			***4000***			***0.74***		***954 kW***		***1948 kW***	**1442 kW**			**2558 kW**
	120	800		0.98	0.69		312.4	215.5	505.2	348.6		355.7	62%	444.3
	150	1000		0.98	0.69		305.5	210.8	444.6	306.7		313.0	46%	687.0
	80	2 x 1000		0.98	0.69		1631.7	1125.9	2385.7	1646.1		1679.7	46%	320.3
s/3	50	1000		0.98	0.80		334.9	268.0	465.4	372.3		379.9	39%	620.1
	200	1500		0.98	0.69		525.3	362.5	568.9	392.5		400.6	8%	1099.4
	40	1500		0.98	0.80		378.9	303.1	574.0	459.2		468.6	52%	1031.4
	140	1000		0.98	0.69		711.6	491.0	1011.6	698.0		712.2	42%	287.8
Subtotal			**4000**			**0.74**		**2203 kW**		**4224 kW**	**3125 kW**			**875 kW**
		Total =						**7184 kW**			**10538 kW**			

1) 0.74 DF has been applied on 11kV MV Loop demands estimate calculations.

2) This schedule has been based on the configuration of 11kV ring circuits under normal/standard operation as shown on HV network schematic, dwgL 656425-SCH004.

3) A maximum loop/ring circuit capacity of 4MW has taken into account to determine the loop overloading.

4) Current maximum load demand has been estimated using w/m2 typical values for each of the buildings.

Appendix C

Intervention schedule

C1 Intervention costing

Year	Building/ Department Name	Applied Interventions	Intervention cost (£) inc design fee. Non inflated.	Building owner
2024	Baring Court	Lighting	£136,537	UoE
2024	Building:One	Lighting	£250,175	UoE
2024	Byrne House	Boiler Replacement - Electric Boiler	£39,955	UoE
2024	Byrne House	Fabric Improvements	£296,561	UoE
2024	Byrne House	Heating Systems Controls Upgrade	£76,209	UoE
2024	Cornwall House	Boiler Replacement - ASHP	£814,107	UoE
2024	Cornwall House	Heating Systems Controls Upgrade	£225,329	UoE
2024	Cornwall House	Lighting	£119,293	UoE
2024	Knightley	Lighting	£68,221	UoE
2024	Lafrowda House	Lighting	£57,845	UoE
2024	Laver Building	Lighting	£207,066	UoE
2024	North Cloisters	Boiler Replacement - Electric Boiler	£134,665	UoE
2024	North Cloisters	Fabric Improvements	£524,898	UoE
2024	North Cloisters	Heating Systems Controls Upgrade	£470,436	UoE
2024	Pennsylvania Court - All blocks	Boiler Replacement - ASHP	£366,970	UoE
2024	Pennsylvania Court - All blocks	Heating Systems Controls Upgrade	£371,515	UoE
2024	Pennsylvania Court - All blocks	PVs	£212,330	UoE
2024	Physics Building	Lighting	£394,369	UoE
2024	Streatham Court New	Boiler Replacement - ASHP	£814,107	UoE
2024	Streatham Court New	Heating Systems Controls Upgrade	£371,941	UoE
2025	Birks Grange	Boiler Replacement - ASHP	£678,422	UoE
2025	Cornwall House	PVs	£162,848	UoE
2025	Exeter Medical School Building	Boiler Replacement - ASHP	£366,970	UoE
2025	Garden Hill House	Boiler Replacement - ASHP	£74,938	UoE
2025	Garden Hill House	Fabric Improvements	£1,170,106	UoE
2025	Garden Hill House	Heating Systems Controls Upgrade	£49,835	UoE
2025	Hatherly Building	Boiler Replacement - Electric Boiler	£134,665	UoE
2025	Hatherly Building	Fabric Improvements	£1,533,102	UoE
2025	Hatherly Building	Heating Systems Controls Upgrade	£481,386	UoE
2025	Henry Wellcome Building for Biocatalysis	Lighting	£68,557	UoE
2025	Hope Hall	Boiler Replacement - ASHP	£366,970	UoE
2025	Hope Hall	Fabric Improvements	£2,678,665	UoE
2025	Hope Hall	Heating Systems Controls Upgrade	£198,504	UoE
2025	Kay Building (Labs)	Lighting	£21,368	UoE
2025	Ransom Pickard - All blocks	Boiler Replacement - ASHP	£216,324	UoE
2025	Ransom Pickard - All blocks	Fabric Improvements	£1,683,426	UoE
2025	Ransom Pickard - All blocks	Heating Systems Controls Upgrade	£149,411	UoE

2025	Richards Building	Boiler Replacement - ASHP	£216,324	UoE
2025	Richards Building	Fabric Improvements	£777,688	UoE
2025	Richards Building	Heating Systems Controls Upgrade	£177,762	UoE
2026	Amory Building	Lighting	£468,672	UoE
2026	Exeter Medical School Building	PVs	£102,324	UoE
2026	Geoffrey Pope	Boiler Replacement - ASHP	£814,107	UoE
2026	Geoffrey Pope	Fabric Improvements	£5,472,353	UoE
2026	Geoffrey Pope	Heating Systems Controls Upgrade	£645,298	UoE
2026	Harrison Building	Boiler Replacement - ASHP	£1,428,439	UoE
2026	Harrison Building	Fabric Improvements	£3,868,130	UoE
2026	Harrison Building	Heating Systems Controls Upgrade	£840,087	UoE
2026	Lafrowda - All blocks	Boiler Replacement - ASHP	£1,428,439	UPP
2026	Lafrowda - All blocks	Heating Systems Controls Upgrade	£1,238,569	UPP
2026	Living Systems Institute	Boiler Replacement - ASHP	£814,107	UoE
2026	Mary Harris Memorial Chapel	Lighting	£2,767	UoE
2026	Moberly UPP	Boiler Replacement - ASHP	£678,422	UPP
2026	Nash Grove - All blocks	Boiler Replacement - ASHP	£216,324	UoE
2026	Nash Grove - All blocks	Fabric Improvements	£1,504,801	UoE
2026	Nash Grove - All blocks	Heating Systems Controls Upgrade	£190,441	UoE
2026	Richards Building	PVs	£167,176	UoE
2026	Washington Singer	Boiler Replacement - Electric Boiler	£134,665	UoE
2026	Washington Singer	Fabric Improvements	£1,518,266	UoE
2026	Washington Singer	Heating Systems Controls Upgrade	£621,794	UoE
2027	Devonshire House	Boiler Replacement - ASHP	£814,107	UoE
2027	Devonshire House	Fabric Improvements	£4,924,502	UoE
2027	Devonshire House	Heating Systems Controls Upgrade	£432,655	UoE
2027	Estate Services Centre	Boiler Replacement - ASHP	£216,324	UoE
2027	Estate Services Centre	Fabric Improvements	£1,138,944	UoE
2027	Estate Services Centre	Heating Systems Controls Upgrade	£80,072	UoE
2027	Harrison Building	PVs	£485,908	UoE
2027	Holland Hall - All blocks	Boiler Replacement - ASHP	£814,107	UoE
2027	Holland Hall - All blocks	Heating Systems Controls Upgrade	£1,021,993	UoE
2027	Lafrowda - All blocks	PVs	£404,704	UPP
2027	Newman Building	Boiler Replacement - ASHP	£366,970	UoE
2027	Newman Building	Fabric Improvements	£1,541,446	UoE
2027	Newman Building	Heating Systems Controls Upgrade	£173,023	UoE
2027	Newman Building	Lighting	£104,599	UoE
2027	Queen's Building	Boiler Replacement - ASHP	£814,107	UoE
2027	Queen's Building	Fabric Improvements	£9,108,005	UoE
2027	Queen's Building	Heating Systems Controls Upgrade	£684,976	UoE
2027	UPP Duryard - All blocks	Boiler Replacement - ASHP	£678,422	UPP
2028	Holland Hall - All blocks	PVs	£595,582	UoE
2028	Laver Building	Boiler Replacement - ASHP	£814,107	UoE
2028	Laver Building	Fabric Improvements	£10,314,996	UoE

2028	Laver Building	Heating Systems Controls Upgrade	£431,262	UoE
2028	Newman Building	PVs	£77,062	UoE
2028	Northcott Theatre	Boiler Replacement - ASHP	£366,970	UoE
2028	Northcott Theatre	Fabric Improvements	£1,192,418	UoE
2028	Northcott Theatre	Heating Systems Controls Upgrade	£167,639	UoE
2028	Queen's Building	PVs	£253,931	UoE
2028	Ransom Pickard - All blocks	Lighting	£73,412	UoE
2028	Streatham Farm	Boiler Replacement - Electric Boiler	£91,992	UoE
2028	Streatham Farm	Fabric Improvements	£1,114,160	UoE
2028	Streatham Farm	Heating Systems Controls Upgrade	£216,460	UoE
2028	UPP Birks - All blocks	Boiler Replacement - ASHP	£1,190,366	UPP
2029	Amory Building	Boiler Replacement - ASHP	£1,428,439	UoE
2029	Amory Building	Fabric Improvements	£13,521,643	UoE
2029	Amory Building	Heating Systems Controls Upgrade	£1,032,968	UoE
2029	INTO Duryard - All blocks	Boiler Replacement - ASHP	£1,190,366	INTO
2029	Laver Building	PVs	£207,100	UoE
2029	Old Library	Boiler Replacement - ASHP	£814,107	UoE
2029	Old Library	Fabric Improvements	£2,306,892	UoE
2029	Old Library	Heating Systems Controls Upgrade	£499,671	UoE
2029	Physics Building	Boiler Replacement - ASHP	£814,107	UoE
2029	Physics Building	Fabric Improvements	£11,764,127	UoE
2029	Physics Building	Heating Systems Controls Upgrade	£620,954	UoE
2029	Reed Mews Health Centre	Boiler Replacement - ASHP	£62,448	UoE
2029	Reed Mews Health Centre	Fabric Improvements	£257,675	UoE
2029	Reed Mews Health Centre	Heating Systems Controls Upgrade	£22,543	UoE
2029	Roborough	Boiler Replacement - Electric Boiler	£91,992	UoE
2029	Roborough	Fabric Improvements	£549,401	UoE
2029	Roborough	Heating Systems Controls Upgrade	£208,377	UoE
2029	Sports Hall	Boiler Replacement - ASHP	£814,107	UoE
2029	Sports Hall	Fabric Improvements	£3,060,950	UoE
2029	Sports Hall	Heating Systems Controls Upgrade	£488,736	UoE
2029	St Luke's Chapel	Fabric Improvements	£110,348	UoE
2029	St Luke's Sports Centre	Boiler Replacement - ASHP	£366,970	UoE
2029	St Luke's Sports Centre	Fabric Improvements	£2,003,307	UoE
2029	St Luke's Sports Centre	Heating Systems Controls Upgrade	£183,134	UoE
2030	Amory Building	PVs	£332,936	UoE
2030	Baring Court	Boiler Replacement - ASHP	£366,970	UoE
2030	Baring Court	Fabric Improvements	£1,427,059	UoE
2030	Baring Court	Heating Systems Controls Upgrade	£271,243	UoE
2030	Birks Central	Boiler Replacement - ASHP	£305,808	UoE
2030	Forum	Boiler Replacement - ASHP	£1,428,439	UoE
2030	Haighton Library	Boiler Replacement - ASHP	£366,970	UoE
2030	Haighton Library	Fabric Improvements	£1,844,835	UoE
2030	Haighton Library	Heating Systems Controls Upgrade	£189,948	UoE

2030	Kay Building (Labs)	Boiler Replacement - ASHP	£62,448	UoE
2030	Kay Building (Labs)	Fabric Improvements	£575,744	UoE
2030	Kay Building (Labs)	Heating Systems Controls Upgrade	£17,303	UoE
2030	Lafrowda Cottage	Boiler Replacement - Electric Boiler	£24,215	UoE
2030	Lafrowda Cottage	Fabric Improvements	£242,388	UoE
2030	Lafrowda Cottage	Heating Systems Controls Upgrade	£7,416	UoE
2030	Mardon Hall	Boiler Replacement - ASHP	£366,970	UoE
2030	Mardon Hall	Fabric Improvements	£4,041,074	UoE
2030	Mardon Hall	Heating Systems Controls Upgrade	£311,937	UoE
2030	Old Library	PVs	£84,067	UoE
2030	Physics Building	PVs	£185,108	UoE
2030	Sports Hall	PVs	£185,108	UoE
2030	St Luke's Sports Centre	PVs	£127,332	UoE
2030	UPP East Park - All blocks	Boiler Replacement - ASHP	£814,107	UPP
2031	Baring Court	PVs	£141,175	UoE
2031	Clinical Skills Resource Centre, RD & E, Heavitree	Boiler Replacement - ASHP	£216,324	Leasehold
2031	College House	PVs	£103,805	UoE
2031	Forum	PVs	£108,086	UoE
2031	Helium Liquefier Building	Boiler Replacement - ASHP	£62,448	UoE
2031	Helium Liquefier Building	Fabric Improvements	£206,690	UoE
2031	INTO Building	Boiler Replacement - ASHP	£366,970	INTO
2031	Kay Building (Labs)	PVs	£38,281	UoE
2031	Kay House	Boiler Replacement - ASHP	£305,808	UoE
2031	Lopes Hall	PVs	£60,683	UoE
2031	Lydford	Boiler Replacement - ASHP	£74,938	UPP
2031	Lydford	Fabric Improvements	£475,902	UPP
2031	Lydford	Heating Systems Controls Upgrade	£81,778	UPP
2031	Reed Hall	Boiler Replacement - Electric Boiler	£91,992	UoE
2031	Reed Hall	Fabric Improvements	£1,005,918	UoE
2031	Reed Hall	Heating Systems Controls Upgrade	£265,995	UoE
2031	Rowe House - All blocks	Boiler Replacement - ASHP	£366,970	UPP
2031	Rowe House - All blocks	Fabric Improvements	£1,944,269	UPP
2031	Rowe House - All blocks	Heating Systems Controls Upgrade	£316,527	UPP
2031	Xfi Building	Boiler Replacement - ASHP	£216,324	UoE
2032	Building:One	Boiler Replacement - ASHP	£366,970	UoE
2032	Clayden	Boiler Replacement - ASHP	£62,448	UoE
2032	Clayden	Fabric Improvements	£416,656	UoE
2032	Clayden	Heating Systems Controls Upgrade	£22,936	UoE
2032	College House	Fabric Improvements	£1,303,982	UoE
2032	Northcote House	Boiler Replacement - ASHP	£814,107	UoE
2032	Northcote House	Fabric Improvements	£4,903,777	UoE
2032	Northcote House	Heating Systems Controls Upgrade	£431,786	UoE
2032	Russell Seal Fitness Centre	Boiler Replacement - ASHP	£216,324	UoE
2032	Streatham Court New	PVs	£178,643	UoE

2033	Biosciences Greenhouse	Boiler Replacement - ASHP	£62,448	UoE
2033	Clydesdale Court - All blocks	Fabric Improvements	£922,836	UoE
2033	Holnicote Annexe	Fabric Improvements	£483,290	UoE
2033	Lopes Cottage	Boiler Replacement - ASHP	£62,448	UoE
2033	Lopes Cottage	Fabric Improvements	£439,045	UoE
2033	Lopes Cottage	Heating Systems Controls Upgrade	£17,954	UoE
2033	Northcote House	PVs	£124,634	UoE
2033	South Cloisters	Boiler Replacement - ASHP	£814,107	UoE
2033	South Cloisters	Fabric Improvements	£4,327,329	UoE
2033	South Cloisters	Heating Systems Controls Upgrade	£509,796	UoE
2034	Clydesdale House	Boiler Replacement - ASHP	£62,448	UoE
2034	Clydesdale House	Fabric Improvements	£301,763	UoE
2034	Clydesdale House	Heating Systems Controls Upgrade	£36,128	UoE
2034	Peter Chalk Centre	Boiler Replacement - ASHP	£216,324	UoE
2034	Peter Chalk Centre	Fabric Improvements	£254,627	UoE
2034	Peter Chalk Centre	Heating Systems Controls Upgrade	£115,118	UoE
2034	Redcot	Boiler Replacement - ASHP	£62,448	UoE
2034	Redcot	Fabric Improvements	£891,838	UoE
2034	Redcot	Heating Systems Controls Upgrade	£38,664	UoE
2034	Staff House	Fabric Improvements	£529,186	UoE
2035	Family Centre	Boiler Replacement - ASHP	£62,448	UoE
2035	Family Centre	Fabric Improvements	£124,851	UoE
2035	Family Centre	Heating Systems Controls Upgrade	£22,247	UoE
2035	Great Hall	Boiler Replacement - ASHP	£366,970	UoE
2035	Great Hall	Fabric Improvements	£3,508,918	UoE
2035	Great Hall	Heating Systems Controls Upgrade	£295,162	UoE
2035	Henry Wellcome Building for Biocatalysis	Boiler Replacement - ASHP	£74,938	UoE
2035	Holnicote Wing	Boiler Replacement - Electric Boiler	£39,955	UoE
2035	Holnicote Wing	Fabric Improvements	£345,247	UoE
2035	Lopes Hall	Boiler Replacement - Electric Boiler	£134,665	UoE
2035	Lopes Hall	Fabric Improvements	£1,298,944	UoE
2035	Lopes Hall	Heating Systems Controls Upgrade	£344,579	UoE
2035	Sir Christopher Ondaatje Devon Cricket Centre	Boiler Replacement - ASHP	£216,324	UoE
2036	Great Hall	PVs	£146,367	UoE
2036	Higher Hoopern Cottage	Boiler Replacement - ASHP	£62,448	UoE
2036	Higher Hoopern Cottage	Fabric Improvements	£418,301	UoE
2036	Higher Hoopern Cottage	Heating Systems Controls Upgrade	£9,474	UoE
2036	Higher Hoopern Farm	Boiler Replacement - ASHP	£74,938	UoE
2036	Higher Hoopern Farm	Fabric Improvements	£1,075,134	UoE
2036	Higher Hoopern Farm	Heating Systems Controls Upgrade	£61,542	UoE
2036	Mary Harris Memorial Chapel	Fabric Improvements	£258,217	UoE
2036	Smeall Building	Boiler Replacement - ASHP	£74,938	UoE
2036	Smeall Building	Fabric Improvements	£360,604	UoE
2036	Smeall Building	Heating Systems Controls Upgrade	£71,553	UoE

2037	Changing Pavilion	Boiler Replacement - ASHP	£62,448	UoE
2037	Clydesdale Rise - Block A	Boiler Replacement - ASHP	£366,970	UoE
2037	Clydesdale Rise - Block A	Fabric Improvements	£423,334	UoE
2037	Clydesdale Rise - Block A	Heating Systems Controls Upgrade	£267,443	UoE
2037	Innovation Centre	Boiler Replacement - ASHP	£216,324	UoE
2037	Institute of Arab and Islamic Studies	Boiler Replacement - ASHP	£216,324	UoE
2037	Knightley	Boiler Replacement - ASHP	£74,938	UoE
2037	Knightley	Fabric Improvements	£1,407,802	UoE
2037	Knightley	Heating Systems Controls Upgrade	£59,393	UoE
2037	Owlets	Boiler Replacement - ASHP	£74,938	UoE
2037	Reed Mews Wellbeing	Boiler Replacement - Electric Boiler	£24,215	UoE
2037	Reed Mews Wellbeing	Fabric Improvements	£448,313	UoE
2037	Reed Mews Wellbeing	Heating Systems Controls Upgrade	£19,489	UoE
2037	Research, Innovation, Learning & Development Centre	Boiler Replacement - ASHP	£366,970	Leasehold
2038	Club Alley	Boiler Replacement - ASHP	£62,448	UoE
2038	Club Alley	Fabric Improvements	£560,282	UoE
2038	Club Alley	Heating Systems Controls Upgrade	£15,020	UoE
2038	Dance Studio	Boiler Replacement - ASHP	£62,448	UoE
2038	Dance Studio	Fabric Improvements	£183,537	UoE
2038	Dance Studio	Heating Systems Controls Upgrade	£9,222	UoE
2038	Innovation Centre - Phase 2	Boiler Replacement - ASHP	£366,970	UoE
2038	Lazenby	Boiler Replacement - ASHP	£62,448	UoE
2038	Lazenby	Fabric Improvements	£1,027,865	UoE
2038	Lazenby	Heating Systems Controls Upgrade	£29,668	UoE
2038	Streatham Lodge	Boiler Replacement - Electric Boiler	£35,112	UoE
2038	Streatham Lodge	Fabric Improvements	£41,815	UoE
2038	Streatham Lodge	Heating Systems Controls Upgrade	£12,892	UoE
2039	Lafrowda House	Boiler Replacement - ASHP	£74,938	UoE
2039	Lafrowda House	Fabric Improvements	£1,081,126	UoE
2039	Lafrowda House	Heating Systems Controls Upgrade	£54,486	UoE
2039	Mireille Gillings Neuroimaging Centre	Boiler Replacement - ASHP	£62,448	Leasehold
2039	Spreytonway UPP	Boiler Replacement - ASHP	£366,970	UPP
Total (Note that this excludes Electrical infrastructure and large scale PV projects)			£174,500,000	

C2 Project timeline

University of Exeter - Carbon Management Plan Tool

UoE total cost £193,027,000

Project timeline — Max design spend per quarter £400,000

Design period

Quarterly/Annual totals are UoE buildings only

University of Exeter CMP 1.0 — Max construction spend per quarter £1,000,000

Construction period

Design fees 20%

Classification	Building/ Department Name	Alternative Building Name/Notes	Building category	Building age	Building Number	Building Owner
Streatham On Campus	Amory Building	0	Non Residential	1974	BG002	UoE
Streatham On Campus	Biosciences Greenhouse	0	Non Residential	2009	BG003	UoE
Streatham On Campus	Building:One	0	Non Residential	2011	BG007	UoE
Streatham On Campus	Byrne House	Listed	Non Residential	1840	BG008	UoE
Streatham On Campus	Chagford	0	Residential	1995	BG009	UPP
Streatham On Campus	Christow	0	Residential	1995	BG010	UPP
Streatham On Campus	Clayden	0	Non Residential	1954	BG011	UoE
Streatham On Campus	Clydesdale Court - All blocks	0	Residential	1989	BG015	UoE
Streatham On Campus	Clydesdale House	0	Non Residential	1989	BG016	UoE
Streatham On Campus	Computer Building (Laver Data Centre)	0	Non Residential	1970	BG017	UoE
Streatham On Campus	Cornwall House	0	Non Residential	1971	BG018	UoE
Streatham On Campus	Cornwall House Pool	0	Non Residential	1972	BG019	UoE
Streatham On Campus	Sir Christopher Ondaatje Devon Cricket Centre	0	Non Residential	2009	BG020	UoE
Streatham On Campus	Devonshire House	0	Non Residential	1960	BG021	UoE
Streatham On Campus	Estate Services Centre	0	Non Residential	1960	BG026	UoE
Streatham On Campus	Family Centre	0	Non Residential	1990	BG027	UoE
Streatham On Campus	Forum	0	Non Residential	2012	BG028	UoE
Streatham On Campus	Garden Hill House	0	Residential	1920	BG029	UoE
Streatham On Campus	Geoffrey Pope	0	Non Residential	1965	BG030	UoE
Streatham On Campus	Great Hall	0	Non Residential	1964	BG031	UoE
Streatham On Campus	Harrison Building	0	Non Residential	1968	BG032	UoE
Streatham On Campus	Hatherly Building	Listed	Non Residential	1952	BG033	UoE
Streatham On Campus	Henry Wellcome Building for Biocatalysis	0	Non Residential	2004	BG034	UoE
Streatham On Campus	Higher Hoopern Cottage	0	Residential	1890	BG035	UoE
Streatham On Campus	Higher Hoopern Farm	0	Non Residential	1850	BG036	UoE
Streatham On Campus	Hope Hall	0	Non Residential	1872	BG038	UoE
Streatham On Campus	Innovation Centre	0	Non Residential	2001	BG039	UoE
Streatham On Campus	Innovation Centre - Phase 2	0	Non Residential	2007	BG040	UoE
Streatham On Campus	Institute of Arab and Islamic Studies	0	Non Residential	2003	BG041	UoE
Streatham On Campus	Kay Building (Labs)	0	Non Residential	1975	BG042	UoE
Streatham On Campus	Knightley	0	Non Residential	1890	BG044	UoE
Streatham On Campus	Lafrowda Cottage	0	Residential	1890	BG045	UoE
Streatham On Campus	Lafrowda House	0	Non Residential	1890	BG046	UoE
Streatham On Campus	Laver Building	0	Non Residential	1968	BG049	UoE
Streatham On Campus	Lazenby	0	Non Residential	1920	BG050	UoE
Streatham On Campus	Lopes Cottage	0	Residential	1890	BG052	UoE
Streatham On Campus	Lopes Hall	Listed	Residential	1866	BG053	UoE
Streatham On Campus	Lydford	0	Residential	1997	BG054	UPP
Streatham On Campus	Mardon Hall	0	Residential	1933	BG055	UoE
Streatham On Campus	Mary Harris Memorial Chapel	Listed	Non Residential	1958	BG056	UoE
Streatham On Campus	Newman Building	0	Non Residential	1965	BG057	UoE
Streatham On Campus	Northcote House	0	Non Residential	1960	BG058	UoE
Streatham On Campus	Northcott Theatre	0	Non Residential	1967	BG059	UoE
Streatham On Campus	Old Library	0	Non Residential	1965	BG060	UoE
Streatham On Campus	Peter Chalk Centre	0	Non Residential	1998	BG061	UoE
Streatham On Campus	Physics Building	0	Non Residential	1966	BG062	UoE
Streatham On Campus	Queen's Building	0	Non Residential	1958	BG063	UoE
Streatham On Campus	Redcot	0	Residential	1920	BG064	UoE
Streatham On Campus	Reed Hall	Listed	Non Residential	1867	BG065	UoE
Streatham On Campus	Reed Mews Wellbeing	0	Non Residential	1890	BG066	UoE
Streatham On Campus	Reed Mews Health Centre	0	Non Residential	1890	BG067	UoE
Streatham On Campus	Roborough	Listed	Non Residential	1940	BG068	UoE
Streatham On Campus	Sports Hall	0	Non Residential	1967	BG069	UoE
Streatham On Campus	Streatham Court New	0	Non Residential	1998	BG073	UoE
Streatham On Campus	Streatham Farm	Listed	Non Residential	1820	BG074	UoE
Streatham On Campus	Streatham Lodge	Listed	Residential	1860	BG075	UoE
Streatham On Campus	Washington Singer	Listed	Non Residential	1931	BG082	UoE
Streatham On Campus	Sir Henry Wellcome Bdg for Mood Disorders Research	0	Non Residential	2012	BG083	UoE
Streatham On Campus	Widecombe	0	Residential	1992	BG084	UPP
Streatham On Campus	Xfi Building	0	Non Residential	2004	BG085	UoE
St Luke's On Campus	Baring Court	0	Non Residential	1989	BG096	UoE
St Luke's On Campus	St Luke's Chapel	Listed	Non Residential	1863	BG097	UoE
St Luke's On Campus	Club Alley	0	Non Residential	1890	BG099	UoE
St Luke's On Campus	College House	0	Non Residential	1990	BG100	UoE
St Luke's On Campus	Dance Studio	0	Non Residential	1940	BG101	UoE
St Luke's On Campus	Haighton Library	0	Non Residential	1950	BG103	UoE
St Luke's On Campus	Holnicote Annexe	0	Non Residential	1880	BG104	UoE
St Luke's On Campus	Holnicote Wing	Listed	Non Residential	1890	BG105	UoE
St Luke's On Campus	North Cloisters	Listed	Non Residential	1890	BG108	UoE
St Luke's On Campus	Exeter Medical School Building	0	Non Residential	2002	BG109	UoE
St Luke's On Campus	Richards Building	0	Non Residential	1989	BG110	UoE
St Luke's On Campus	Smeall Building	0	Non Residential	1990	BG112	UoE
St Luke's On Campus	South Cloisters	0	Non Residential	1968	BG114	UoE
St Luke's On Campus	St Luke's Sports Centre	0	Non Residential	1950	BG116	UoE
St Luke's On Campus	Staff House	0	Non Residential	1889	BG117	UoE
Streatham On Campus	Living Systems Institute	0	Non Residential	2016	BG144	UoE
St Luke's Off Campus	Research, Innovation, Learning & Development Centre	0	Non Residential	2013	BG145	Leasehold
St Luke's Off Campus	Clinical Skills Resource Centre, RD & E, Heavitree	0	Non Residential	1992	BG146	Leasehold
Streatham On Campus	Tensile Tennis Courts	0	Non Residential	2012	BG147	UoE
Streatham On Campus	Changing Pavilion	0	Non Residential	2013	BG149	UoE
Streatham On Campus	Russell Seal Fitness Centre	0	Non Residential	2013	BG150	UoE
Streatham On Campus	Helium Liquefier Building	0	Non Residential	1964	BG154	UoE
Streatham On Campus	Life Support Systems Building	0	Non Residential	2013	BG157	UoE
Streatham On Campus	INTO Building	0	Non Residential	2011	BG158	INTO
Streatham Off Campus	Engineering Research Centre	0	Non Residential	2019	BG169	Leasehold
Streatham On Campus	Owlets	0	Non Residential	2019	BG173	UoE
St Luke's Off Campus	Mireille Gillings Neuroimaging Centre	0	Non Residential	2020	BG176	Leasehold
Streatham On Campus	South West Institute of Technology	0	Non Residential	2021	BG191	UoE
Streatham On Campus	Creative Quadrant	0	Non Residential	2021	BG192	UoE
Streatham On Campus	Centre for Resilience in Environment, Water and Waste	0	Non Residential	2022	BG193	UoE
Streatham On Campus	Spreytonway UPP	0	Residential	2020	BG194	UPP
Streatham On Campus	Clydesdale Rise - Block A	0	Residential	1990	BK001	UoE
Streatham On Campus	Holland Hall - All blocks	0	Residential	2005	BK004	UoE
Streatham On Campus	Nash Grove - All blocks	0	Residential	1990	BK021	UoE
Streatham On Campus	Pennsylvania Court - All blocks	0	Residential	2005	BK027	UoE
Streatham On Campus	Ransom Pickard - All blocks	0	Residential	1967	BK033	UoE
Streatham On Campus	Rowe House - All blocks	0	Residential	1990	BK035	UPP
Streatham On Campus	Lafrowda - All blocks	0	Residential	2012	BK096	UPP
Streatham On Campus	UPP East Park - All blocks	0	Residential	2020	BK120	UPP
Streatham Off Campus	Birks Central	0	Residential	1965	BG004	UoE
Streatham Off Campus	Birks Grange	0	Residential	2006	BG006	UoE
Streatham Off Campus	Kay House	0	Other	1965	BG043	UoE
Streatham Off Campus	Moberly UPP	0	Residential	2020	BG195	UPP
Streatham Off Campus	UPP Duryard - All blocks	0	Residential	2012	BK103	UPP
Streatham Off Campus	UPP Birks - All blocks	0	Residential	2011	BK105	UPP
Streatham Off Campus	INTO Duryard - All blocks	0	Residential	0	BK115	INTO
0	Duryard PV	0	0	0	0	UoE
0	Large scale PV array	0	0	0	0	UoE
0	Streatham Elec Infrastructure	0	0	0	0	UoE
0	St Luke's Elec Infrastructure	0	0	0	0	UoE

C3 Annual investment expenditure – Inflation allowance

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Spend	£8,903,552	£21,158,333	£26,165,822	£25,749,742	£17,912,970	£19,885,434	£13,610,339	£6,538,960	£12,026,222	£10,519,686	£7,610,751	£10,547,105	£3,020,547	£4,068,962	£2,876,758	£1,617,581	£407,032	£407,032	£193,026,828
Spend with inflation	£9,354,295	£22,785,210	£28,882,171	£29,133,469	£20,773,553	£23,637,532	£16,582,877	£8,166,265	£15,394,581	£13,802,740	£10,235,614	£14,539,300	£4,267,954	£5,893,070	£4,270,564	£2,461,341	£634,831	£650,701	£231,466,069

Inflation assumed at 2.5% per year.

Appendix D

Cost by building

						Construction costs (inc VAT & OB)					
Building	Building Owner	GIA (m2)	Total building spend (inc VAT & OB)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)	ASHP	Elec boiler	Lighting	Fabric	Heating system controls	PV
Amory Building	UoE	11027	£16,785,000	£13,988,000	£2,797,000	£1,190,366	£0	£390,560	£11,268,036	£860,807	£277,447
Biosciences Greenhouse	UoE	370	£62,000	£52,000	£10,000	£52,040	£0	£0	£0	£0	£0
Building:One	UoE	2955	£617,000	£514,000	£103,000	£305,808	£0	£208,479	£0	£0	£0
Byrne House	UoE	592	£413,000	£344,000	£69,000	£0	£33,296	£0	£247,134	£63,507	£0
Chagford *changes included in Lydford cost	UPP	873	£0	£0	£0	£0	£0	£0	£0	£0	£0
Christow *changes included in Lydford cost	UPP	873	£0	£0	£0	£0	£0	£0	£0	£0	£0
Clayden	UoE	294	£502,000	£418,000	£84,000	£52,040	£0	£0	£347,213	£19,113	£0
Clydesdale Court - All blocks	UoE	1500	£923,000	£769,000	£154,000	£0	£0	£0	£769,030	£0	£0
Clydesdale House	UoE	463	£400,000	£333,000	£67,000	£52,040	£0	£0	£251,469	£30,107	£0
Computer Building (Laver Data Centre) – No changes proposed	UoE	422	£0	£0	£0	£0	£0	£0	£0	£0	£0
Cornwall House	UoE	2405	£1,322,000	£1,102,000	£220,000	£678,422	£0	£99,411	£0	£187,774	£135,707
Cornwall House Pool – No changes proposed	UoE	123	£0	£0	£0	£0	£0	£0	£0	£0	£0
Sir Christopher Ondaatje Devon Cricket Centre	UoE	1201	£216,000	£180,000	£36,000	£180,270	£0	£0	£0	£0	£0
Devonshire House	UoE	4619	£6,171,000	£5,143,000	£1,028,000	£678,422	£0	£0	£4,103,752	£360,546	£0
Estate Services Centre	UoE	855	£1,435,000	£1,196,000	£239,000	£180,270	£0	£0	£949,120	£66,727	£0
Family Centre	UoE	285	£210,000	£175,000	£35,000	£52,040	£0	£0	£104,043	£18,539	£0
Forum	UoE	15093	£1,537,000	£1,281,000	£256,000	£1,190,366	£0	£0	£0	£0	£90,072
Garden Hill House	UoE	532	£1,295,000	£1,079,000	£216,000	£62,448	£0	£0	£975,088	£41,529	£0
Geoffrey Pope	UoE	6889	£6,932,000	£5,777,000	£1,155,000	£678,422	£0	£0	£4,560,294	£537,748	£0
Great Hall	UoE	3151	£4,317,000	£3,598,000	£719,000	£305,808	£0	£0	£2,924,098	£245,968	£121,973
Harrison Building	UoE	8968	£6,623,000	£5,519,000	£1,104,000	£1,190,366	£0	£0	£3,223,441	£700,072	£404,924
Hatherly Building	UoE	3737	£2,149,000	£1,791,000	£358,000	£0	£112,221	£0	£1,277,585	£401,155	£0

						Construction costs (inc VAT & OB)					
Building	Building Owner	GIA (m2)	Total building spend (inc VAT & OB)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)	ASHP	Elec boiler	Lighting	Fabric	Heating system controls	PV
Henry Wellcome Building for Biocatalysis	UoE	910	£143,000	£119,000	£24,000	£62,448	£0	£57,131	£0	£0	£0
Higher Hoopern Cottage	UoE	121	£490,000	£408,000	£82,000	£52,040	£0	£0	£348,584	£7,895	£0
Higher Hoopern Farm	UoE	657	£1,212,000	£1,010,000	£202,000	£62,448	£0	£0	£895,945	£51,285	£0
Hope Hall	UoE	2119	£3,244,000	£2,703,000	£541,000	£305,808	£0	£0	£2,232,221	£165,420	£0
Innovation Centre	UoE	1745	£216,000	£180,000	£36,000	£180,270	£0	£0	£0	£0	£0
Innovation Centre - Phase 2	UoE	3648	£367,000	£306,000	£61,000	£305,808	£0	£0	£0	£0	£0
Institute of Arab and Islamic Studies	UoE	1711	£216,000	£180,000	£36,000	£180,270	£0	£0	£0	£0	£0
Kay Building (Labs)	UoE	222	£715,000	£596,000	£119,000	£52,040	£0	£17,807	£479,787	£14,419	£31,901
Knightley	UoE	634	£1,610,000	£1,342,000	£268,000	£62,448	£0	£56,851	£1,173,168	£49,494	£0
Lafrowda Cottage	UoE	95	£274,000	£228,000	£46,000	£0	£20,179	£0	£201,990	£6,180	£0
Lafrowda House	UoE	582	£1,268,000	£1,057,000	£211,000	£62,448	£0	£48,204	£900,938	£45,405	£0
Laver Building	UoE	4604	£11,975,000	£9,979,000	£1,996,000	£678,422	£0	£172,555	£8,595,830	£359,385	£172,583
Lazenby	UoE	380	£1,120,000	£933,000	£187,000	£52,040	£0	£0	£856,554	£24,723	£0
Lopes Cottage	UoE	230	£519,000	£433,000	£86,000	£52,040	£0	£0	£365,870	£14,962	£0
Lopes Hall	UoE	2675	£1,839,000	£1,533,000	£306,000	£0	£112,221	£0	£1,082,453	£287,149	£50,569
Lydford	UPP	873	£633,000	£528,000	£105,000	£62,448	£0	£0	£396,585	£68,148	£0
Mardon Hall	UoE	3330	£4,720,000	£3,933,000	£787,000	£305,808	£0	£0	£3,367,561	£259,948	£0
Mary Harris Memorial Chapel	UoE	407	£261,000	£218,000	£43,000	£0	£0	£2,306	£215,181	£0	£0
Newman Building	UoE	1847	£2,263,000	£1,886,000	£377,000	£305,808	£0	£87,166	£1,284,539	£144,186	£64,218
Northcote House	UoE	4609	£6,274,000	£5,228,000	£1,046,000	£678,422	£0	£0	£4,086,481	£359,822	£103,861
Northcott Theatre	UoE	1790	£1,727,000	£1,439,000	£288,000	£305,808	£0	£0	£993,682	£139,699	£0
Old Library	UoE	5334	£3,705,000	£3,088,000	£617,000	£678,422	£0	£0	£1,922,410	£416,393	£70,056
Peter Chalk Centre	UoE	1229	£586,000	£488,000	£98,000	£180,270	£0	£0	£212,189	£95,932	£0

						Construction costs (inc VAT & OB)					
Building	Building Owner	GIA (m2)	Total building spend (inc VAT & OB)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)	ASHP	Elec boiler	Lighting	Fabric	Heating system controls	PV
Physics Building	UoE	6629	£13,779,000	£11,483,000	£2,296,000	£678,422	£0	£328,641	£9,803,439	£517,462	£154,257
Queen's Building	UoE	7312	£10,861,000	£9,051,000	£1,810,000	£678,422	£0	£0	£7,590,004	£570,813	£211,609
Redcot	UoE	495	£993,000	£828,000	£165,000	£52,040	£0	£0	£743,199	£32,220	£0
Reed Hall	UoE	2065	£1,364,000	£1,137,000	£227,000	£0	£76,660	£0	£838,265	£221,662	£0
Reed Mews Wellbeing	UoE	250	£492,000	£410,000	£82,000	£0	£20,179	£0	£373,594	£16,241	£0
Reed Mews Health Centre	UoE	289	£343,000	£286,000	£57,000	£52,040	£0	£0	£214,729	£18,786	£0
Roborough	UoE	1618	£850,000	£708,000	£142,000	£0	£76,660	£0	£457,835	£173,648	£0
Sports Hall	UoE	5217	£4,549,000	£3,791,000	£758,000	£678,422	£0	£0	£2,550,792	£407,280	£154,257
Streatham Court New	UoE	3971	£1,365,000	£1,138,000	£227,000	£678,422	£0	£0	£0	£309,951	£148,869
Streatham Farm	UoE	1681	£1,423,000	£1,186,000	£237,000	£0	£76,660	£0	£928,466	£180,383	£0
Streatham Lodge	UoE	114	£90,000	£75,000	£15,000	£0	£29,260	£0	£34,845	£10,744	£0
Washington Singer	UoE	4827	£2,275,000	£1,896,000	£379,000	£0	£112,221	£0	£1,265,221	£518,161	£0
Sir Henry Wellcome Bdg for Mood Disorders Research – No changes proposed	UoE	707	£0	£0	£0	£0	£0	£0	£0	£0	£0
Widecombe *changes included in Lydford cost	UPP	873	£0	£0	£0	£0	£0	£0	£0	£0	£0
Xfi Building	UoE	1549	£216,000	£180,000	£36,000	£180,270	£0	£0	£0	£0	£0
Baring Court	UoE	2896	£2,343,000	£1,953,000	£390,000	£305,808	£0	£113,781	£1,189,216	£226,036	£117,646
St Luke's Chapel	UoE	196	£110,000	£92,000	£18,000	£0	£0	£0	£91,957	£0	£0
Club Alley	UoE	192	£638,000	£532,000	£106,000	£52,040	£0	£0	£466,902	£12,517	£0
College House	UoE	2277	£1,408,000	£1,173,000	£235,000	£0	£0	£0	£1,086,652	£0	£86,504
Dance Studio	UoE	118	£255,000	£213,000	£42,000	£52,040	£0	£0	£152,948	£7,685	£0
Haighton Library	UoE	2028	£2,402,000	£2,002,000	£400,000	£305,808	£0	£0	£1,537,362	£158,290	£0
Holnicote Annexe	UoE	281	£483,000	£403,000	£80,000	£0	£0	£0	£402,741	£0	£0
Holnicote Wing	UoE	613	£385,000	£321,000	£64,000	£0	£33,296	£0	£287,706	£0	£0

						Construction costs (inc VAT & OB)					
Building	Building Owner	GIA (m2)	Total building spend (inc VAT & OB)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)	ASHP	Elec boiler	Lighting	Fabric	Heating system controls	PV
North Cloisters	UoE	3652	£1,130,000	£942,000	£188,000	£0	£112,221	£0	£437,415	£392,030	£0
Exeter Medical School Building	UoE	2780	£469,000	£391,000	£78,000	£305,808	£0	£0	£0	£0	£85,270
Richards Building	UoE	1898	£1,339,000	£1,116,000	£223,000	£180,270	£0	£0	£648,073	£148,135	£139,313
Smeall Building	UoE	764	£507,000	£423,000	£84,000	£62,448	£0	£0	£300,504	£59,627	£0
South Cloisters	UoE	5442	£5,651,000	£4,709,000	£942,000	£678,422	£0	£0	£3,606,108	£424,830	£0
St Luke's Sports Centre	UoE	1955	£2,681,000	£2,234,000	£447,000	£305,808	£0	£0	£1,669,423	£152,612	£106,110
Staff House	UoE	411	£529,000	£441,000	£88,000	£0	£0	£0	£440,989	£0	£0
Living Systems Institute	UoE	9145	£814,000	£678,000	£136,000	£678,422	£0	£0	£0	£0	£0
Research, Innovation, Learning & Development Centre	Leasehold	4045	£367,000	£306,000	£61,000	£305,808	£0	£0	£0	£0	£0
Clinical Skills Resource Centre, RD & E, Heavitree	Leasehold	1462	£216,000	£180,000	£36,000	£180,270	£0	£0	£0	£0	£0
Tensile Tennis Courts – No changes proposed	UoE	4312	£0	£0	£0	£0	£0	£0	£0	£0	£0
Changing Pavilion	UoE	347	£62,000	£52,000	£10,000	£52,040	£0	£0	£0	£0	£0
Russell Seal Fitness Centre	UoE	2135	£216,000	£180,000	£36,000	£180,270	£0	£0	£0	£0	£0
Helium Liquefier Building	UoE	134	£269,000	£224,000	£45,000	£52,040	£0	£0	£172,241	£0	£0
Life Support Systems Building – No changes proposed	UoE	248	£0	£0	£0	£0	£0	£0	£0	£0	£0
INTO Building	INTO	2865	£367,000	£306,000	£61,000	£305,808	£0	£0	£0	£0	£0
Engineering Research Centre – No changes proposed	Leasehold	1078	£0	£0	£0	£0	£0	£0	£0	£0	£0
Owlets	UoE	717	£75,000	£63,000	£12,000	£62,448	£0	£0	£0	£0	£0
Mireille Gillings Neuroimaging Centre	Leasehold	384	£62,000	£52,000	£10,000	£52,040	£0	£0	£0	£0	£0
South West Institute of Technology	UoE	417	£0	£0	£0	£0	£0	£0	£0	£0	£0
Creative Quadrant – Included within Streatham Court	UoE	0	£0	£0	£0	£0	£0	£0	£0	£0	£0
Centre for Resilience in Environment, Water and Waste – No changes proposed	UoE	1486	£0	£0	£0	£0	£0	£0	£0	£0	£0

						Construction costs (inc VAT & OB)					
Building	Building Owner	GIA (m2)	Total building spend (inc VAT & OB)	Construction (inc VAT & OB)	Design fees (inc VAT & OB)	ASHP	Elec boiler	Lighting	Fabric	Heating system controls	PV
Spreytonway UPP	UPP	4235	£367,000	£306,000	£61,000	£305,808	£0	£0	£0	£0	£0
Clydesdale Rise - Block A	UoE	2855	£1,058,000	£882,000	£176,000	£305,808	£0	£0	£352,779	£222,869	£0
Holland Hall - All blocks	UoE	10910	£2,432,000	£2,027,000	£405,000	£678,422	£0	£0	£0	£851,661	£496,318
Nash Grove - All blocks	UoE	2033	£1,912,000	£1,593,000	£319,000	£180,270	£0	£0	£1,254,001	£158,701	£0
Pennsylvania Court - All blocks	UoE	3966	£951,000	£793,000	£158,000	£305,808	£0	£0	£0	£309,595	£176,941
Ransom Pickard - All blocks	UoE	1595	£2,123,000	£1,769,000	£354,000	£180,270	£0	£61,177	£1,402,855	£124,510	£0
Rowe House - All blocks	UPP	3379	£2,628,000	£2,190,000	£438,000	£305,808	£0	£0	£1,620,224	£263,773	£0
Lafrowda - All blocks	UPP	13222	£3,072,000	£2,560,000	£512,000	£1,190,366	£0	£0	£0	£1,032,141	£337,253
UPP East Park - All blocks	UPP	10342	£814,000	£678,000	£136,000	£678,422	£0	£0	£0	£0	£0
Birks Central	UoE	1595	£306,000	£255,000	£51,000	£254,840	£0	£0	£0	£0	£0
Birks Grange	UoE	7100	£678,000	£565,000	£113,000	£565,352	£0	£0	£0	£0	£0
Kay House	UoE	1490	£306,000	£255,000	£51,000	£254,840	£0	£0	£0	£0	£0
Moberly UPP	UPP	6561	£678,000	£565,000	£113,000	£565,352	£0	£0	£0	£0	£0
UPP Duryard - All blocks	UPP	4733	£678,000	£565,000	£113,000	£565,352	£0	£0	£0	£0	£0
UPP Birks - All blocks	UPP	21209	£1,190,000	£992,000	£198,000	£991,971	£0	£0	£0	£0	£0
INTO Duryard - All blocks	INTO	13245	£1,190,000	£992,000	£198,000	£991,971	£0	£0	£0	£0	£0
Duryard PV		0	£915,000	£763,000	£152,000	£0	£0	£0	£0	£0	£0
Large scale PV array		0	£18,000,000	£18,000,000	inc.	£0	£0	£0	£0	£0	£0
Streatham Elec Infrastructure		0	£6,865,000	£5,721,000	£1,144,000	£0	£0	£0	£0	£0	£0
St Luke's Elec Infrastructure		0	£462,000	£385,000	£77,000	£0	£0	£0	£0	£0	£0
Total (excluding Inflation)			**£205,289,000**	**£171,085,000**	**£34,204,000**	**£26,910,951**	**£815,075**	**£1,644,069**	**£102,532,756**	**£13,566,398**	**£3,737,656**

Appendix E

Thermal Modelling


hysopt
hydronic
system
optimisation

Project 253 – Amory, Streatham campus

Hysopt - Hydronic system optimisation

University of Exeter

03/08/2021

hysopt

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AGENDA

Introduction	1	Project scope, documentation and data
Model implementation	2	Model implementation and loadmatch
Existing situation	3	Simulation of the existing situation and remarks
Optimisations	4	Optimisation possabilities, pareto and conclusion

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Introduction

PROJECT SCOPE

- to provide the performance impact of proposed building fabric level improvements on the performance of the new heating installation;
- optimise the existing LTHW and DHW systems to deliver lowest return temperatures and therefore allow maximum contribution of the heat pumps;
- to provide the optimum hydraulic integration and control strategies for the addition of the heat pumps to the existing installation;
- to provide optimal sizing and selection of heat pumps;
- quantify resulting carbon savings and energy costs in order to support strategic and commercial decision making.

DOCUMENTS

The simulation is based on the assumptions in this report and information supplied by the various parties

- **PID of the system**
- **Floorplans**
- **Excel sheet with power capacities of the end units**
- **Excel sheet with monthly gas consumption data**
- **Excel sheet with building simulation data (from Arup)**

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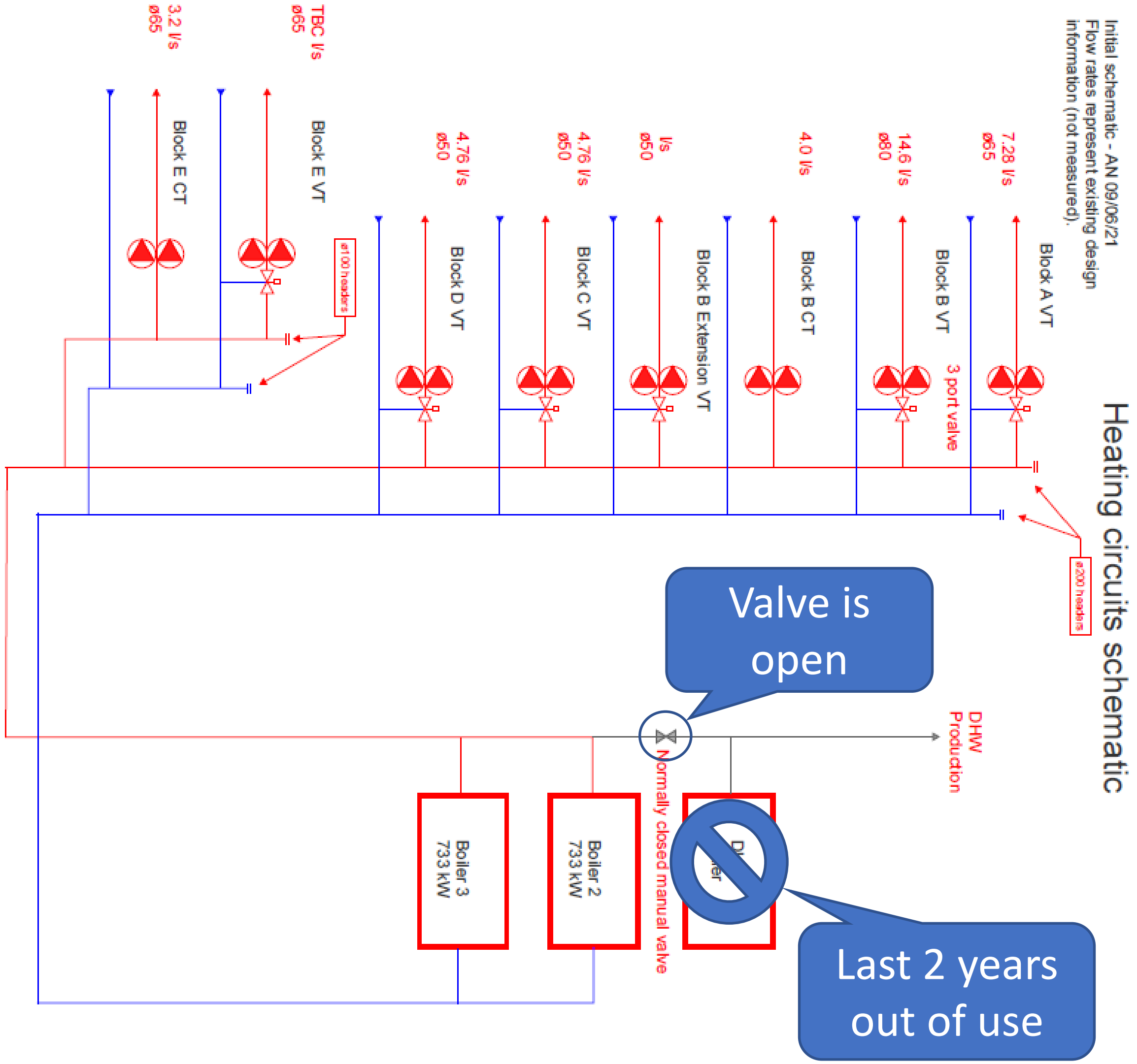
INTRODUCTION

1.309.267 kWh	Yearly LTHW consumption (gas meter)
1.583 kW	Power capacity boilers for LTHW and DHW
132.386 kWh	Yearly DHW consumption

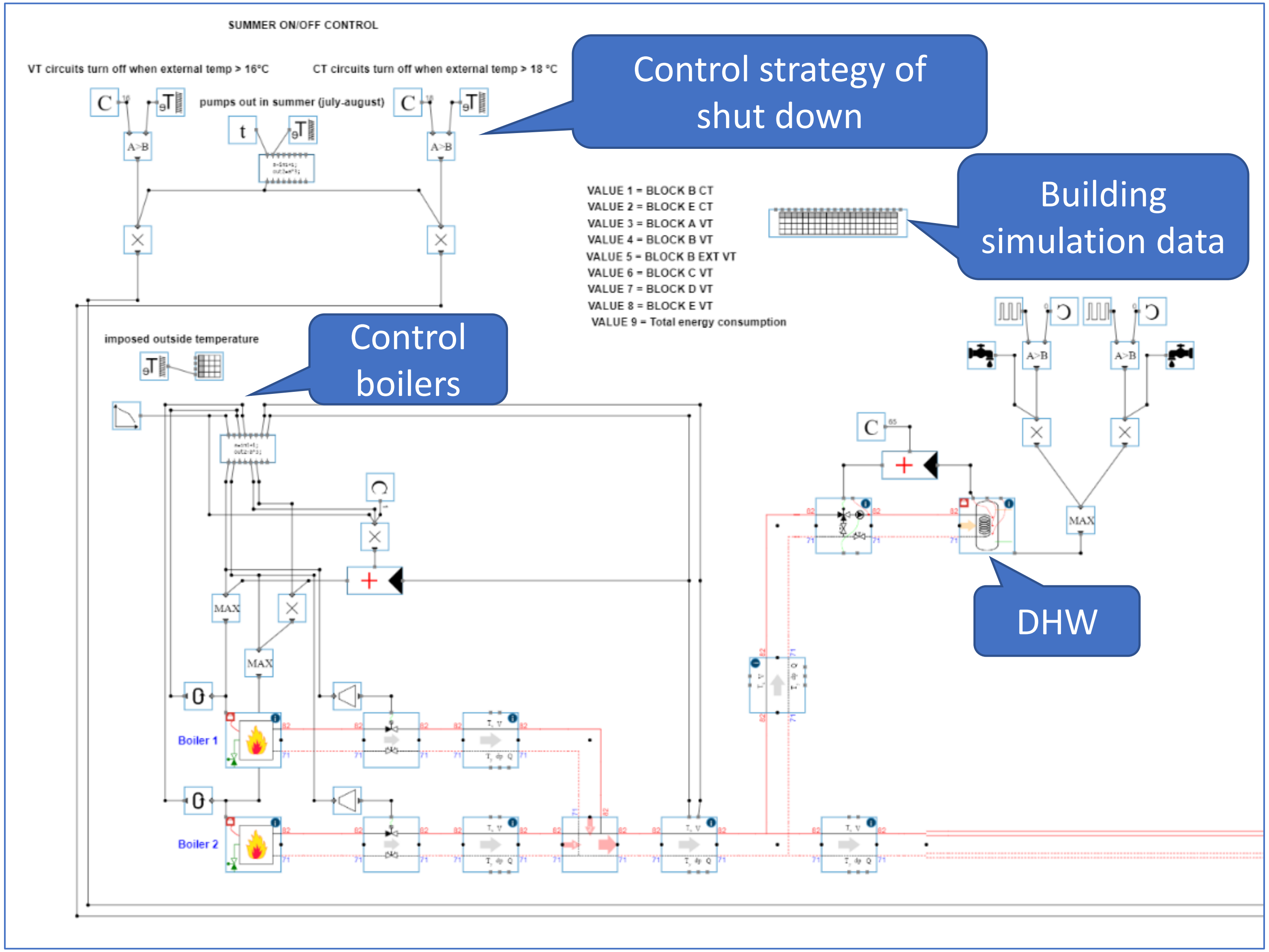
Model implementation

Model implementation: PID → Hysopt model



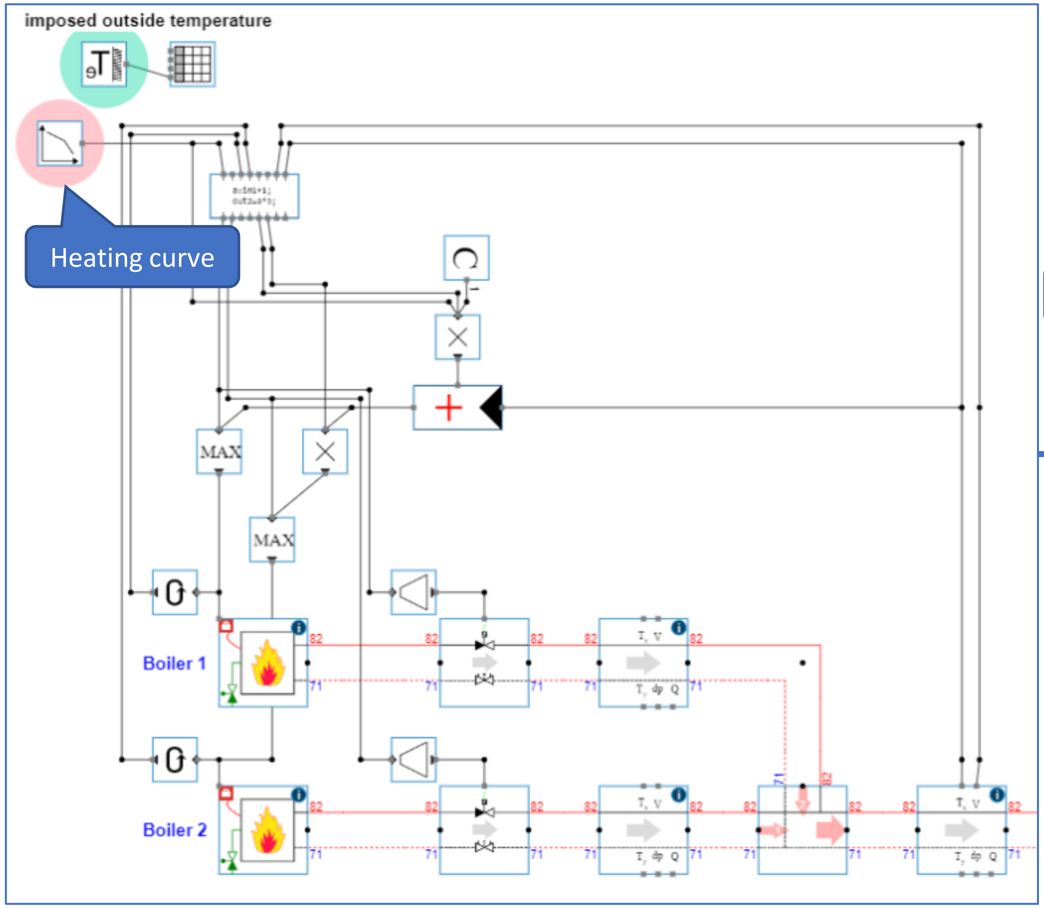
hysopt

Model implementation: PID → Hysopt model

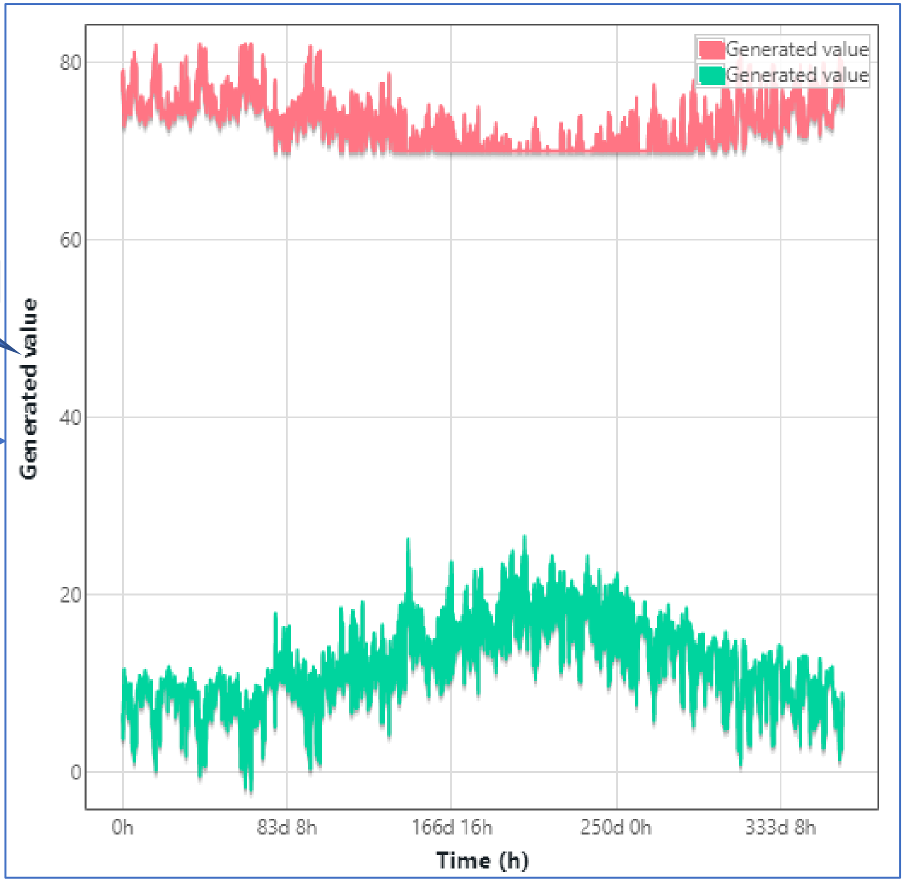


hysopt

Model implementation: PID → Hysopt model

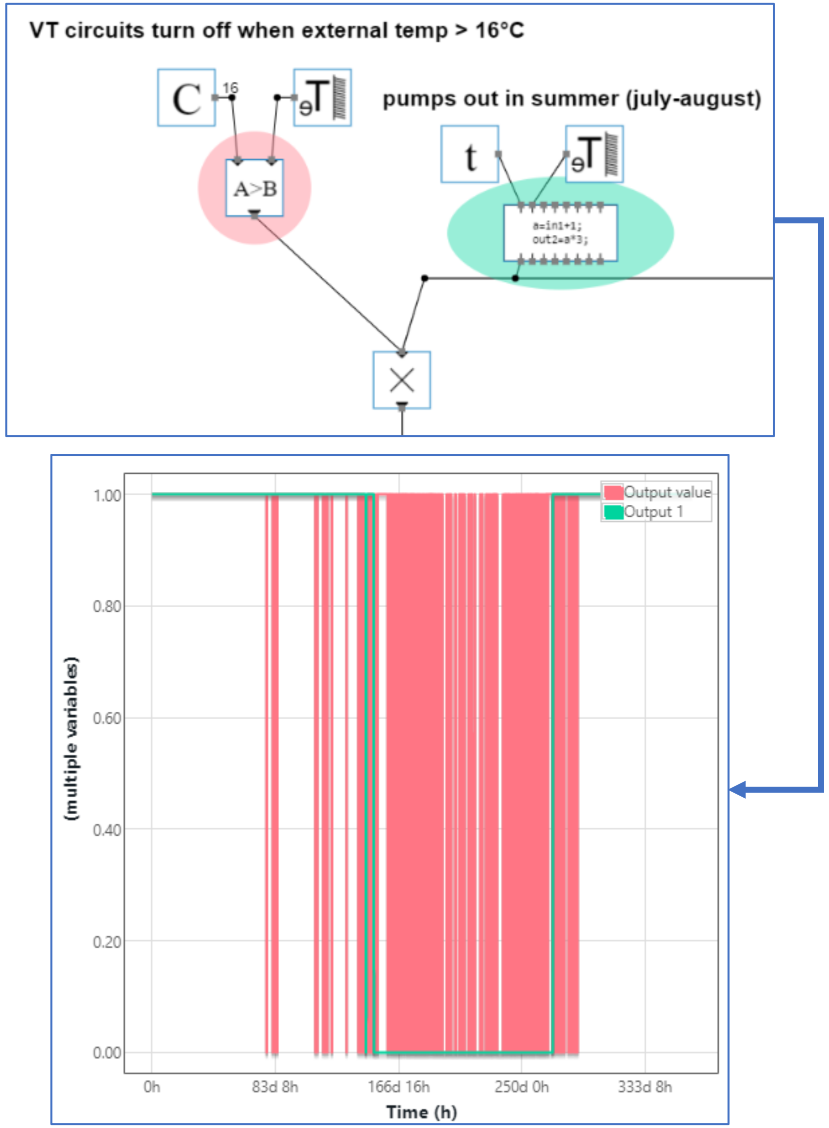


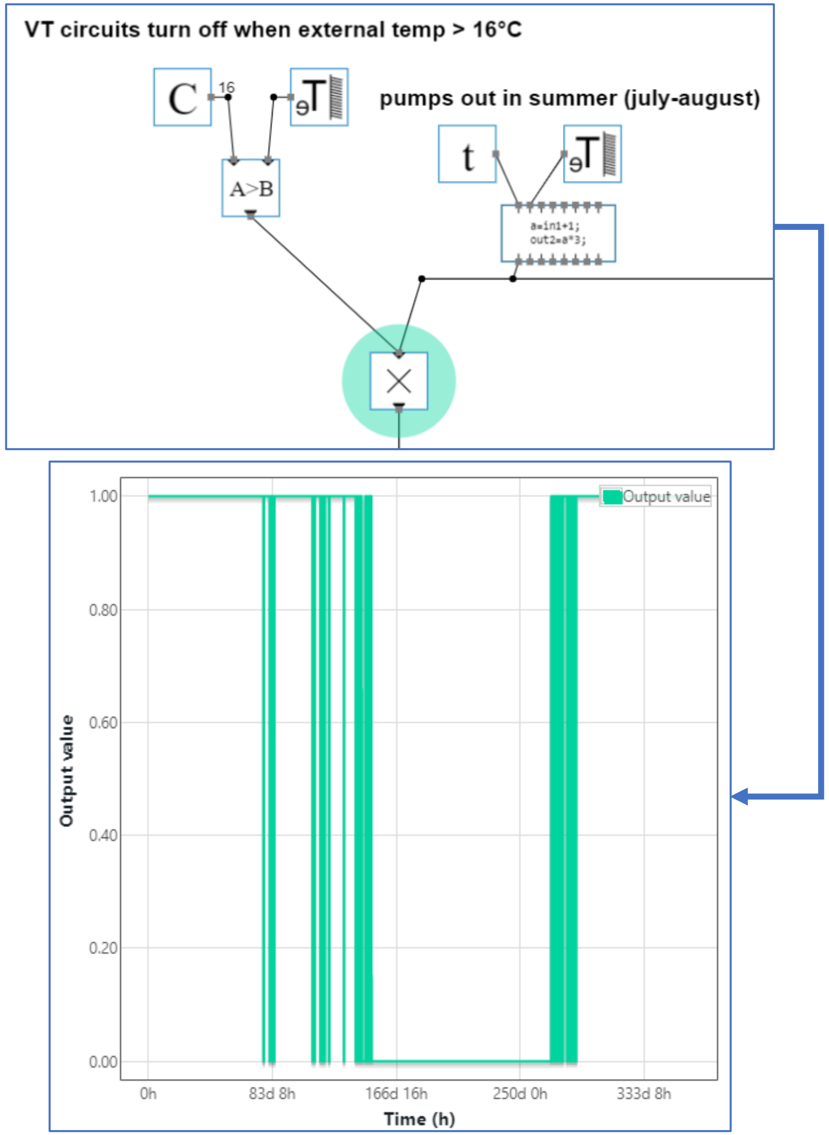
Temperature



hysopt

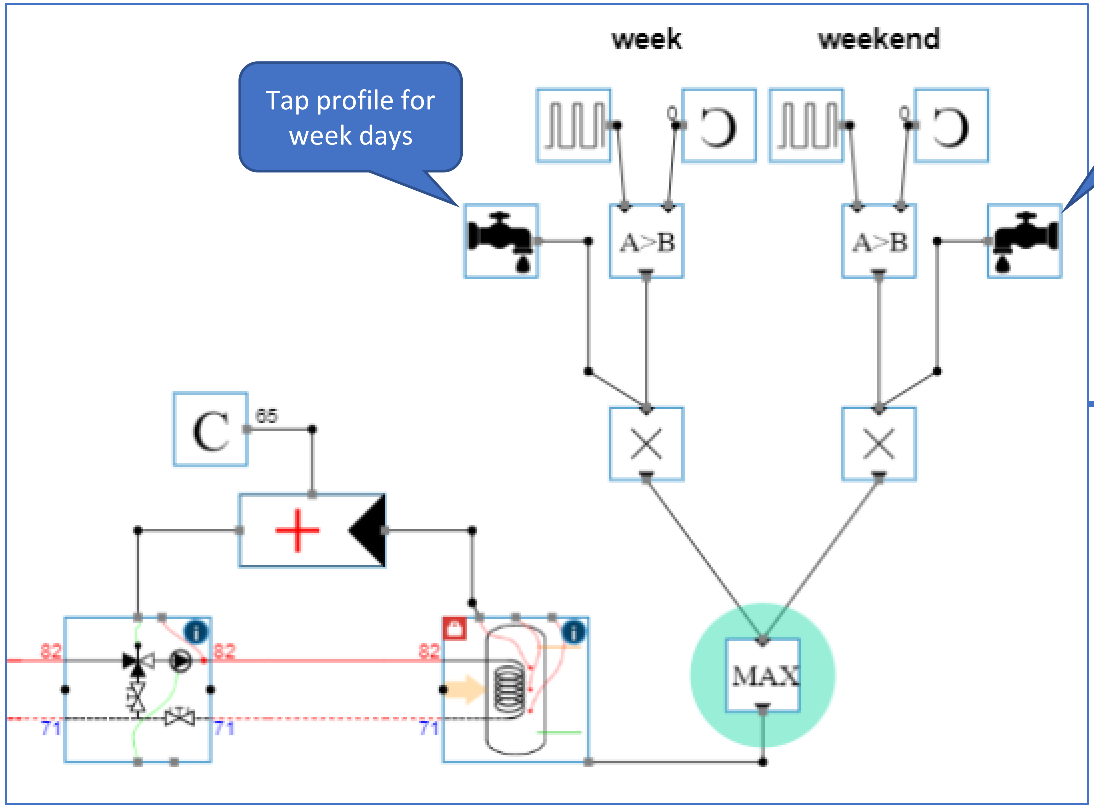
Model implementation: PID → Hysopt model

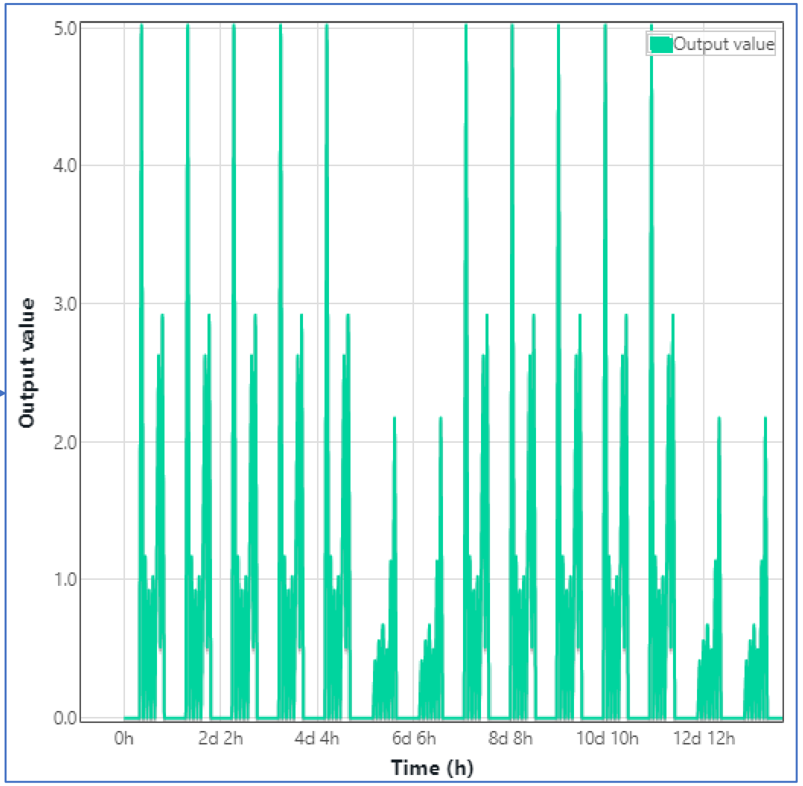




hysopt

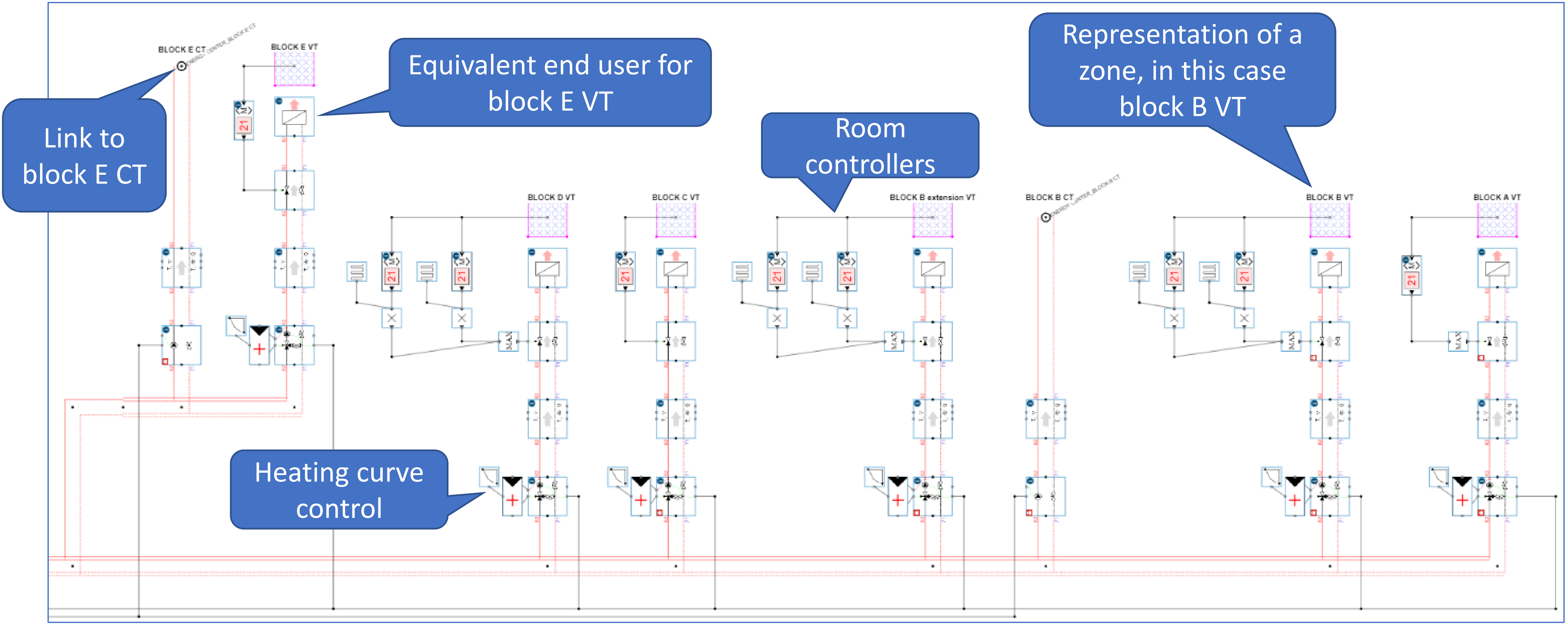
Model implementation: PID → Hysopt model





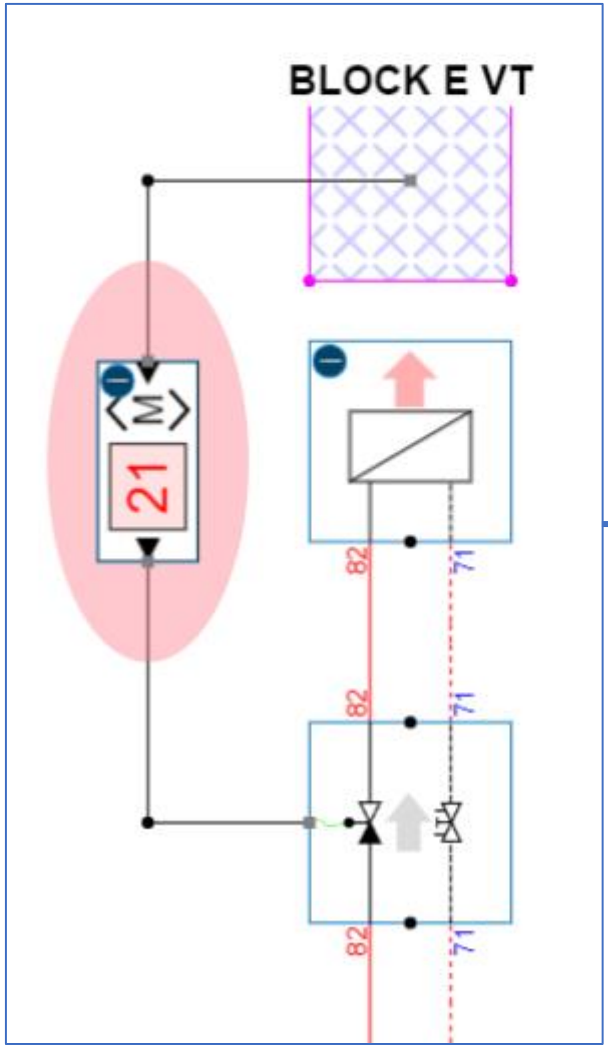
hysopt

Model implementation: PID → Hysopt model

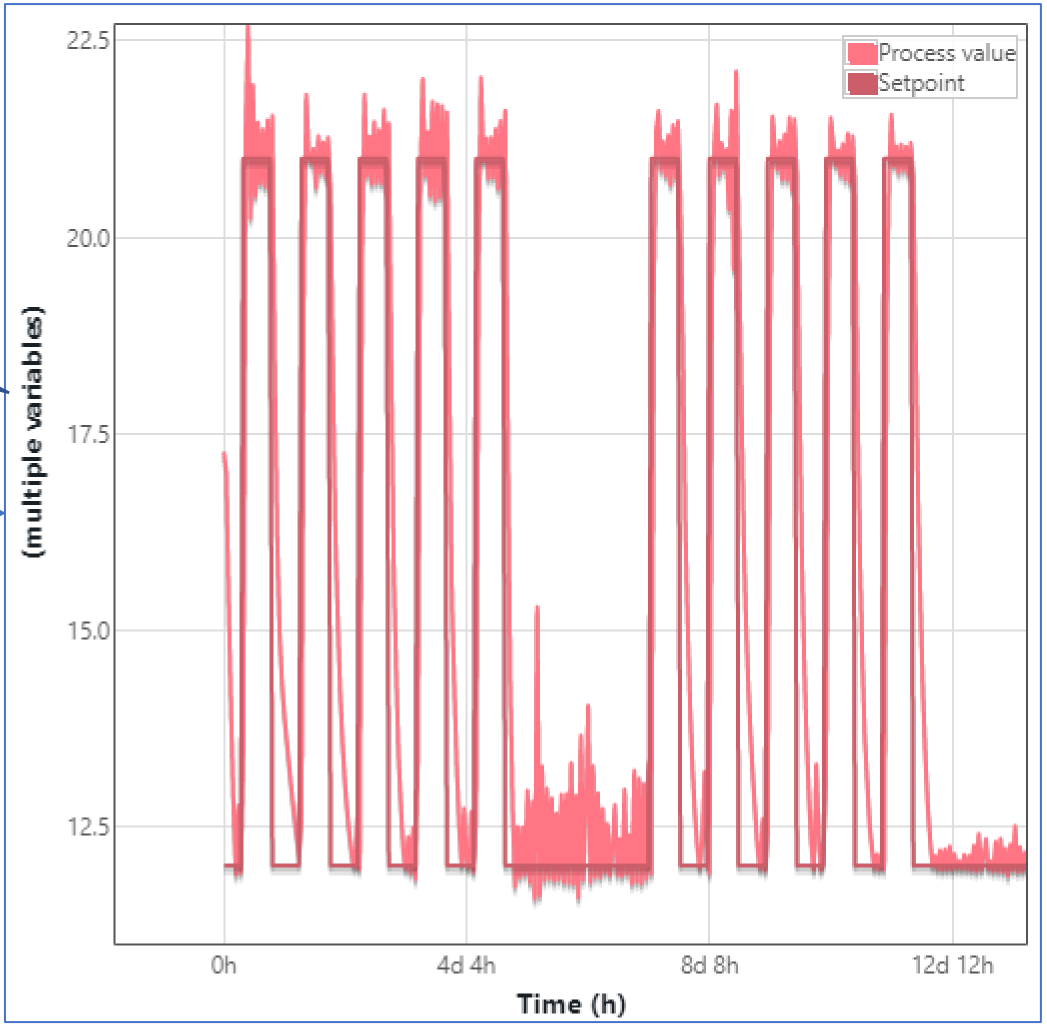


hysopt

Model implementation: PID → Hysopt model

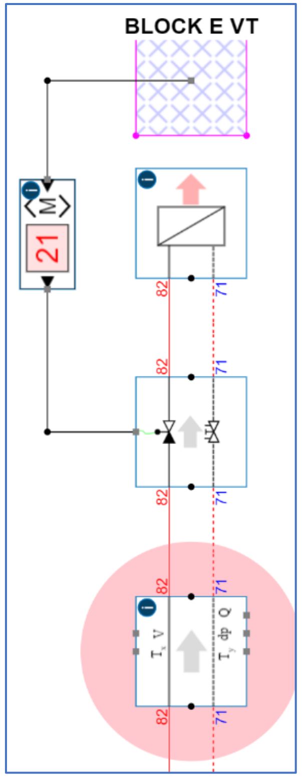


Room temperature

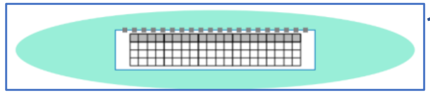


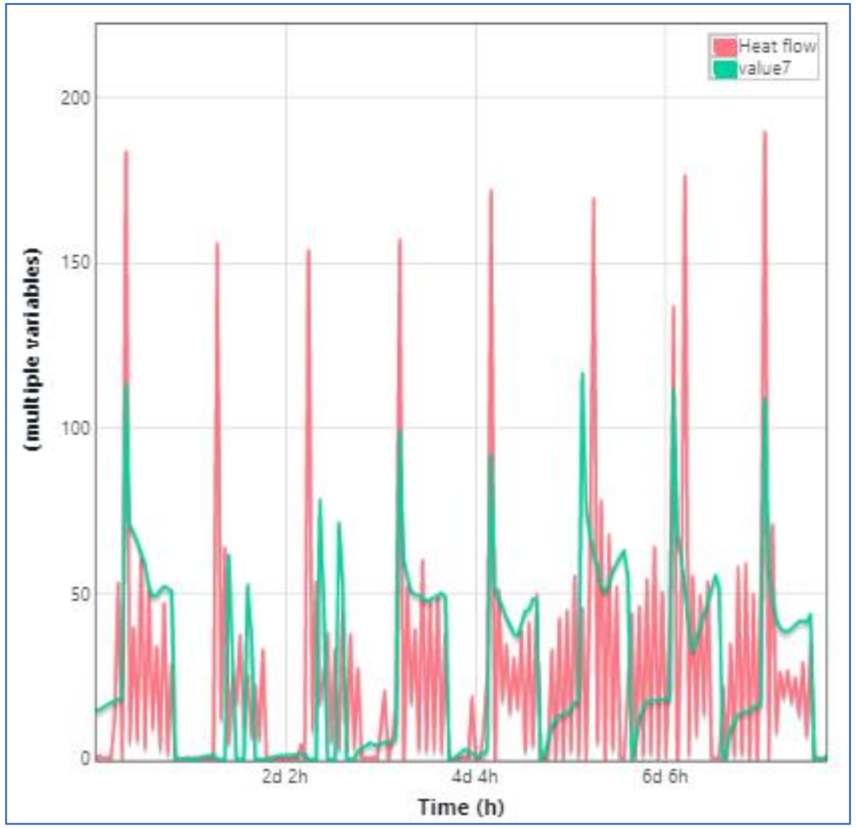
hysopt

Model implementation: PID → Hysopt model



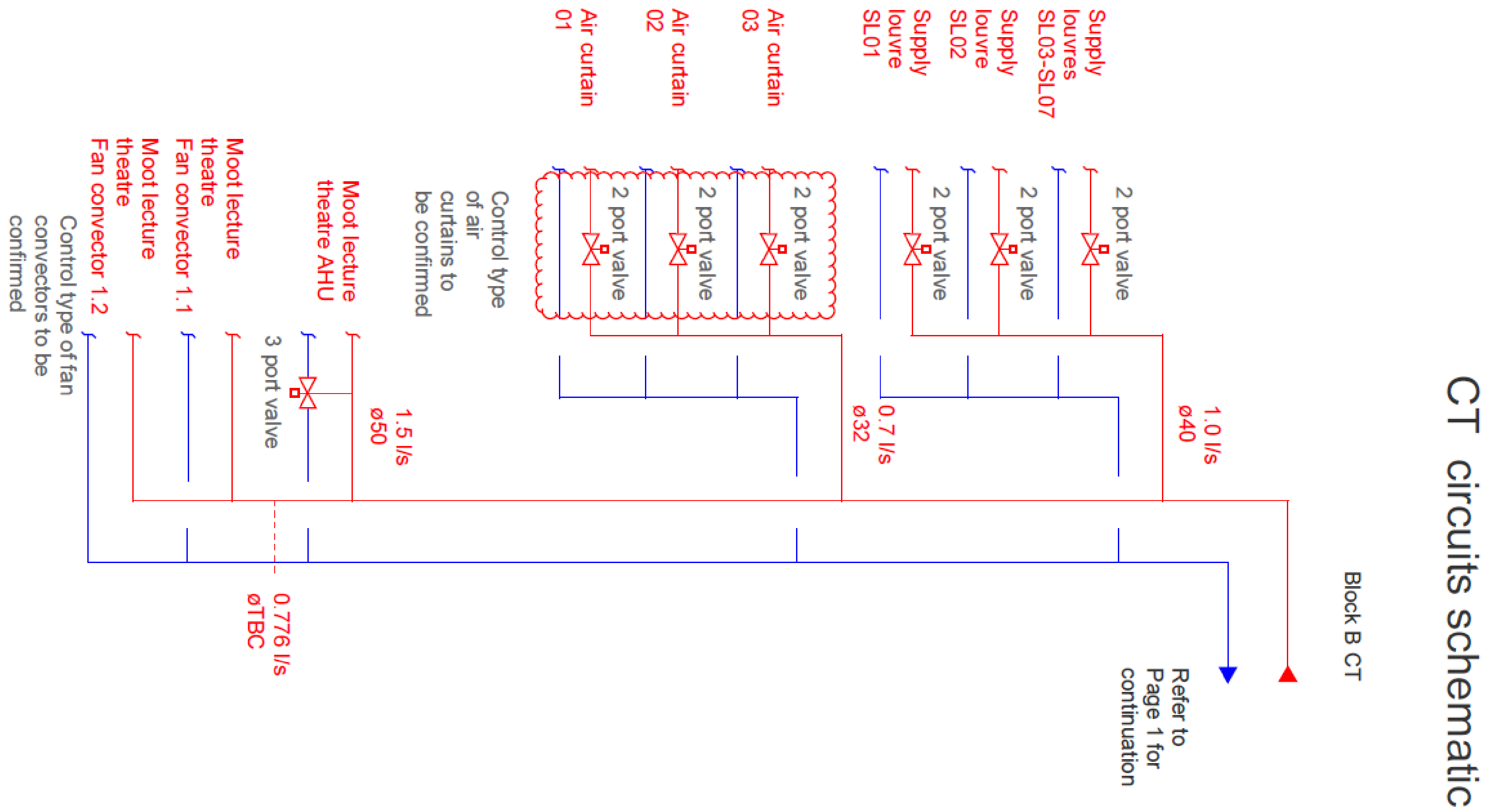
Hourly data of building simulation



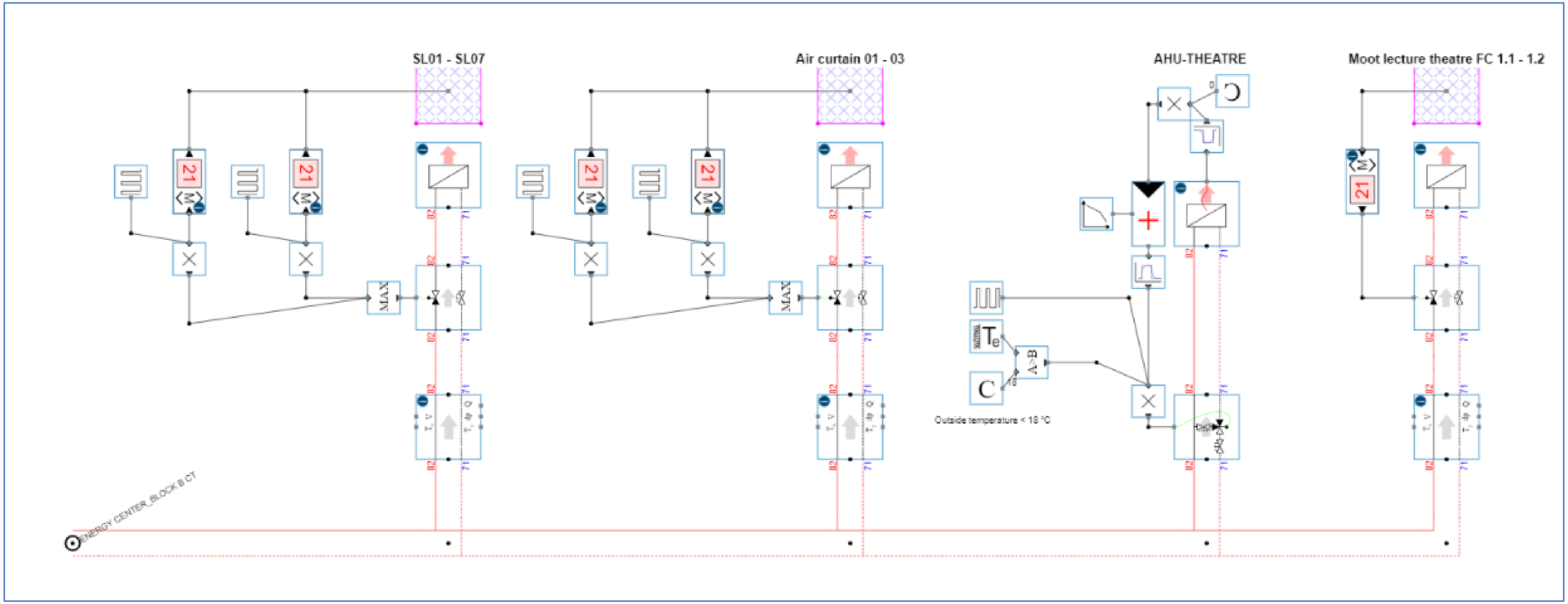


hysopt

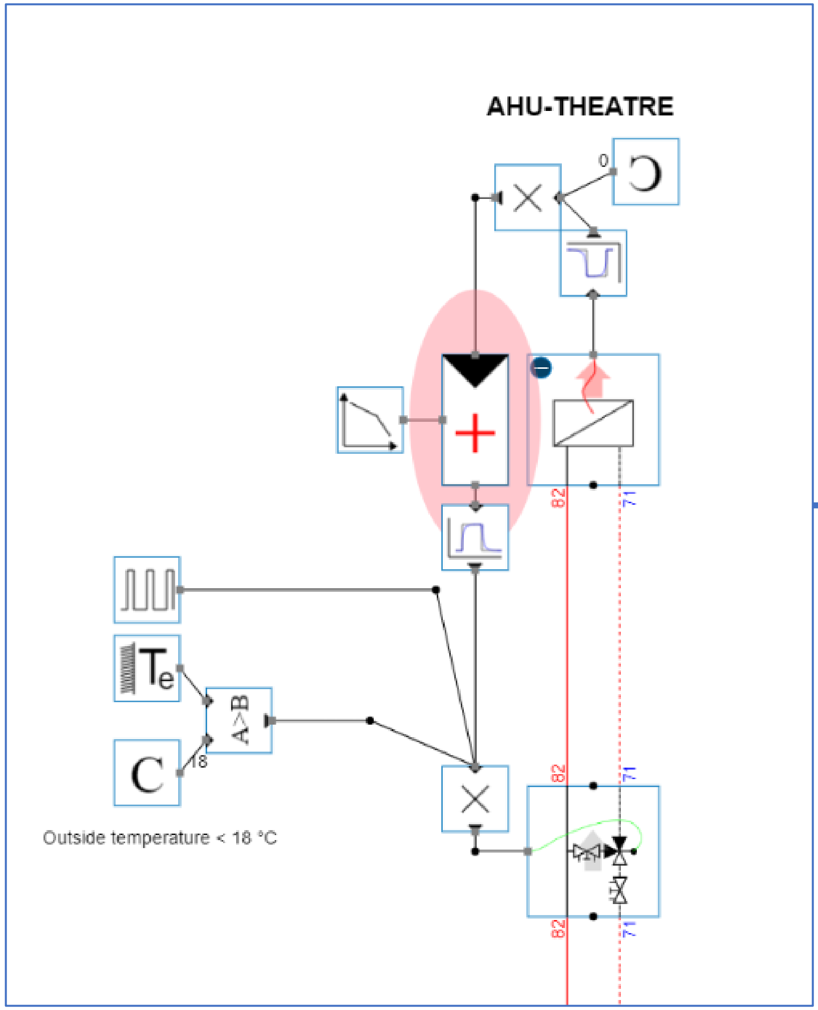
Model implementation: PID → Hysopt model

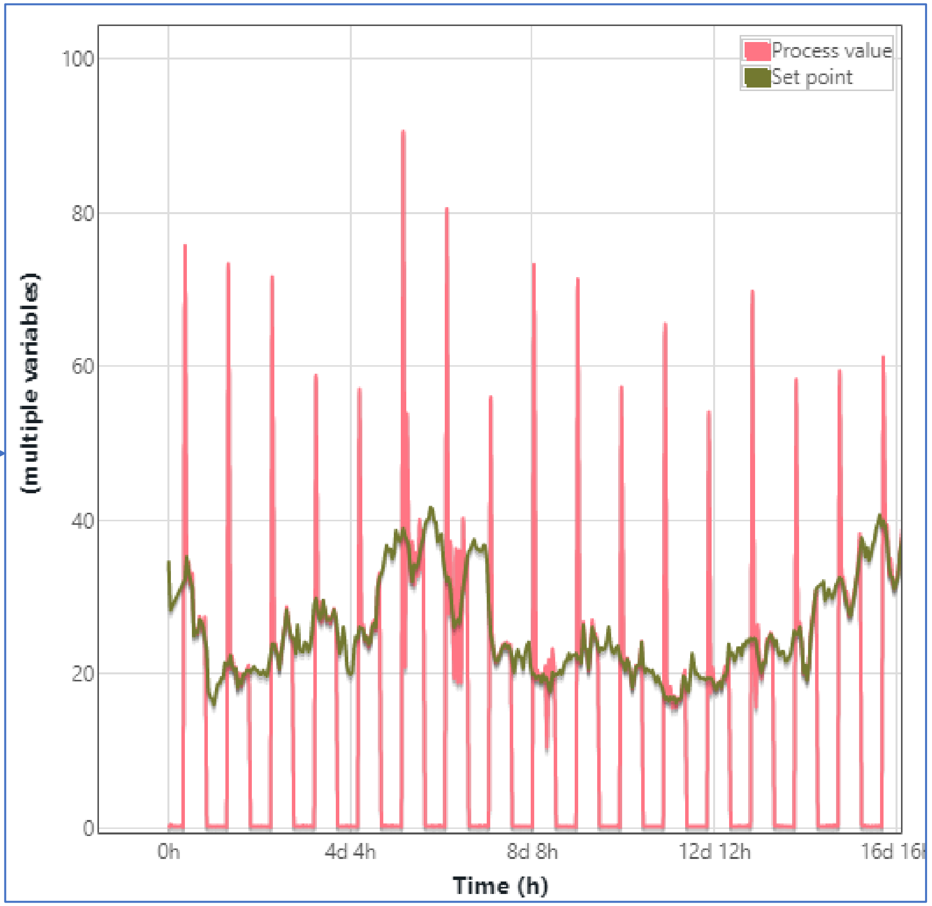


Model implementation: PID → Hysopt model



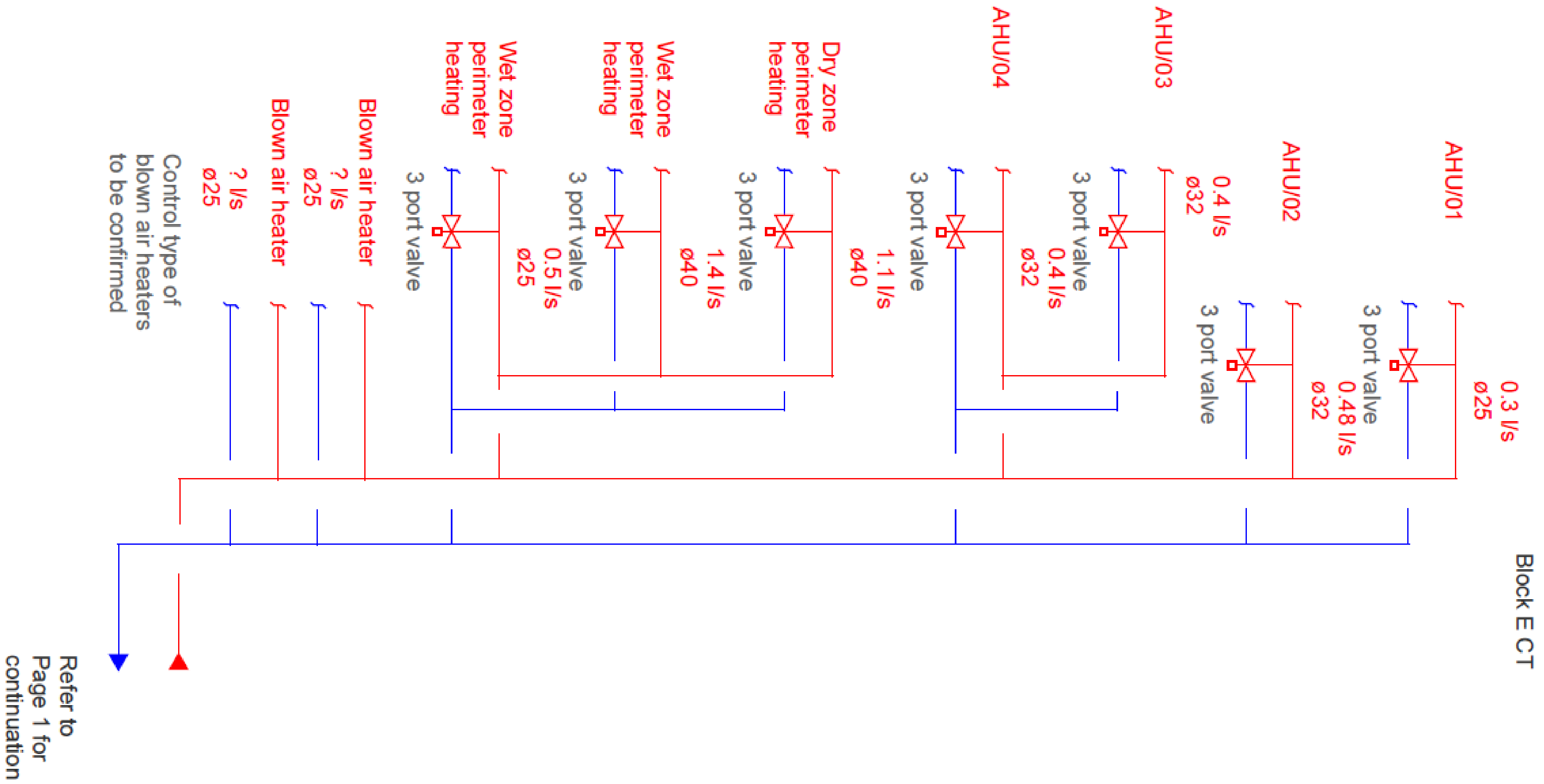
Model implementation: PID → Hysopt model





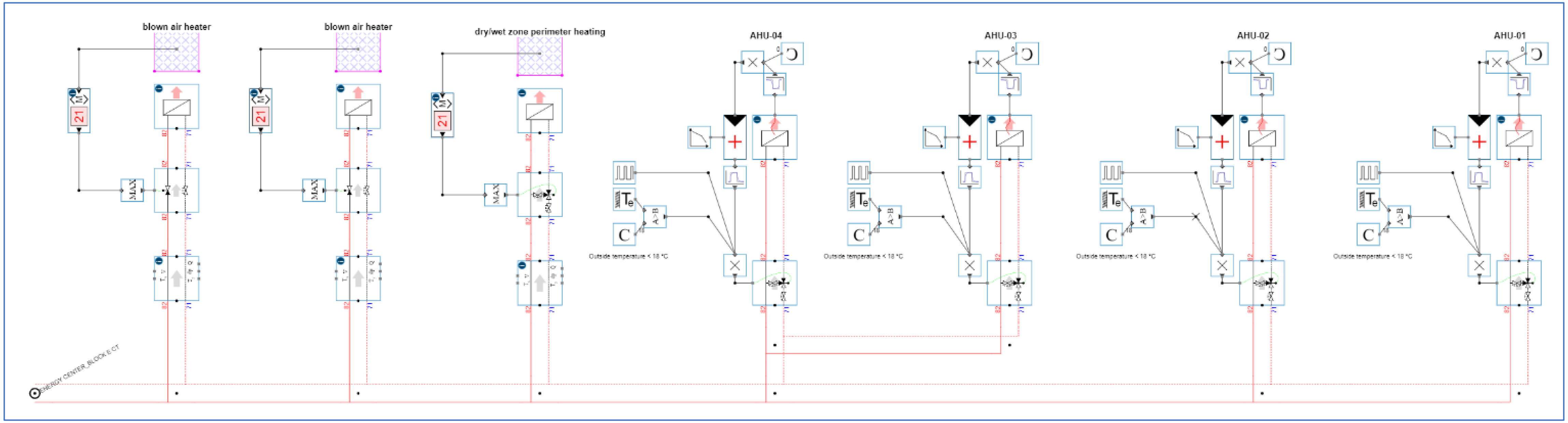
hysopt

Model implementation: PID → Hysopt model



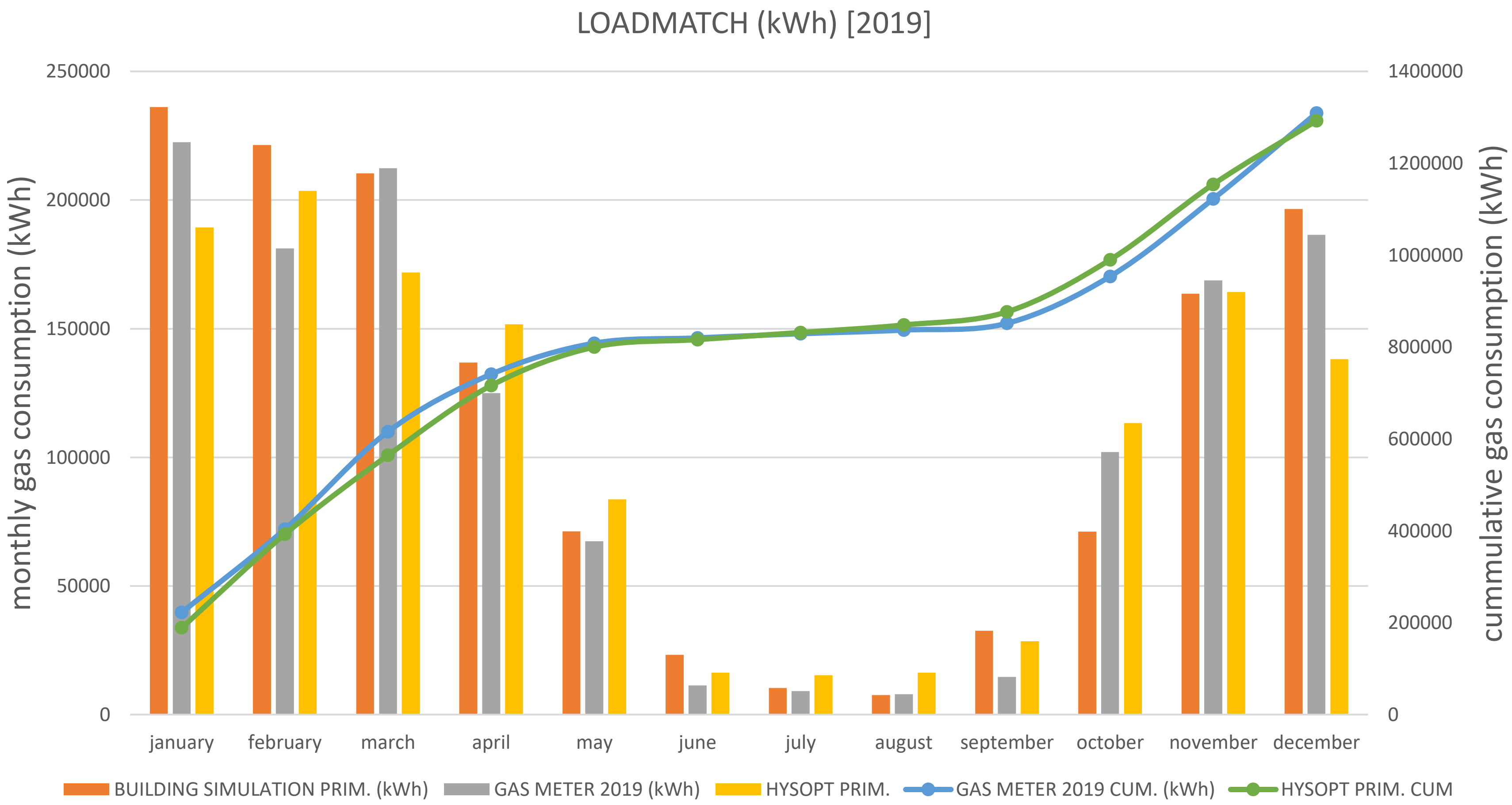
hysopt

Model implementation: PID → Hysopt model



LOADMATCH

Load Matching is the matching of the **heat demand of the building** based on measured data with the **heat demand of the simulation model.**



Existing situation

Findings

A mismatch of the power capacity of the end units occurred between the PID schematic and the list of the university which is used for the digital twin model. After a discussion with Arup we decided to go whit the power capacities of the excel file instead of the PID.

	CT		VT						Total
	Block B	Block E	Block A	Block B	Block B Ext	Block C	Block D	Block E	
detailed model flow (l/s)	2.8	5.21	3.64	6.91	1.28	1.93	1.64	1.41	24.82
detailed model power (kW)	125.4	233.2	163.1	309.25	57.3	86.2	73.5	63.1	1111.1
PID flow (l/s)	4.1	5.16	7.49	15.01	3.08	4.89	4.89	1.65	46.3
PID power (kW)	183.1	230.9	335.2	672.3	138.1	219.2	219.2	73.7	2071.7
Peak BS (kW)	199.5	64.5	364.6	539.1	145.3	307.7	132.5	169.6	1600.0

This one is overestimated and has been discussed with Arup, they share the same opinion.

Results from the building simulation of the peak power capacity, provided by Arup

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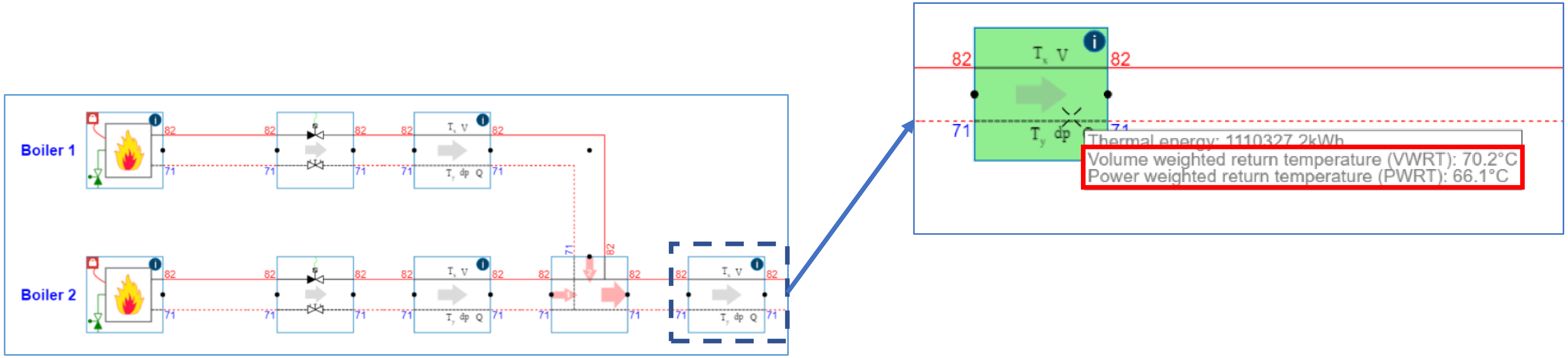
Findings

Because of the three-way valves in some of the circuits, the return temperature to the boilers is very high which causes a lower efficiency of the boilers.



Findings

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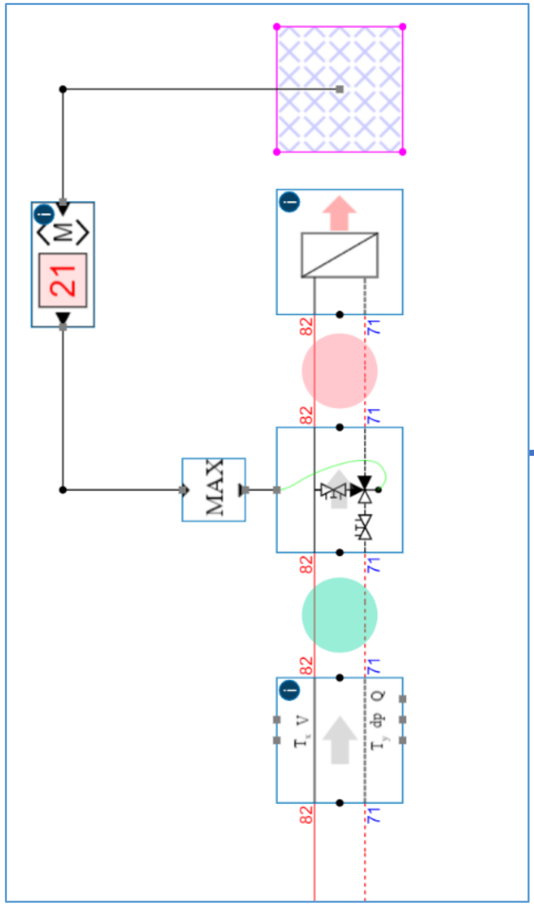
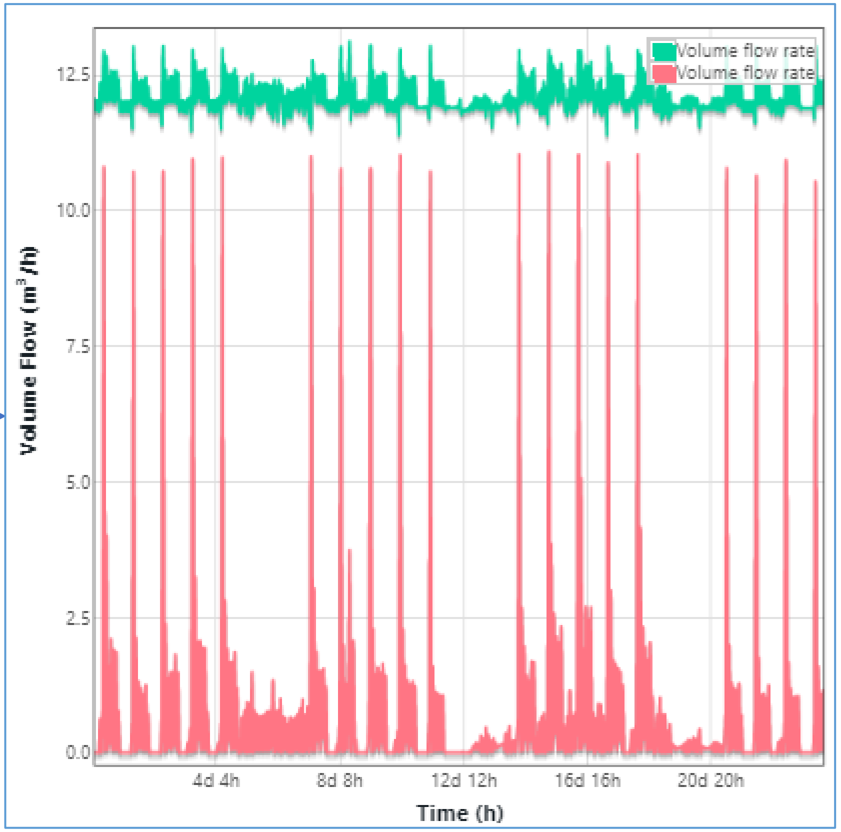
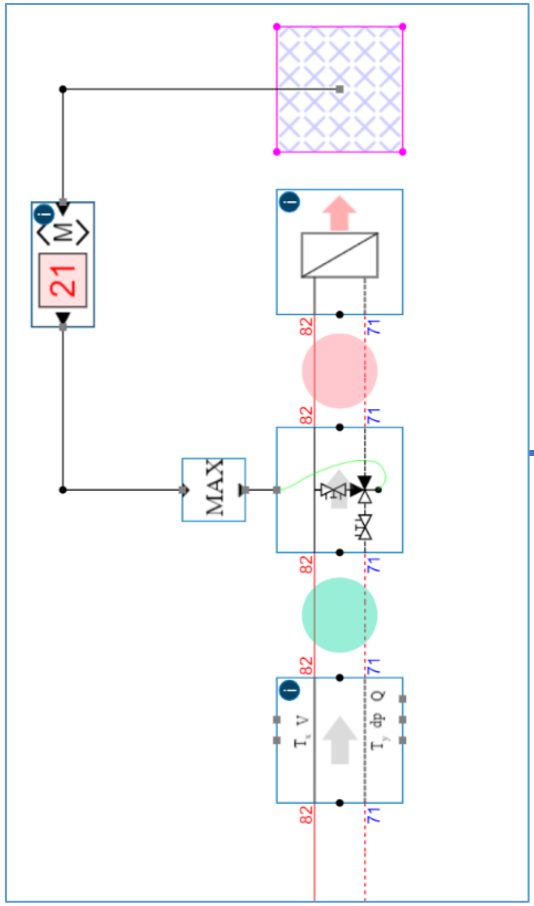


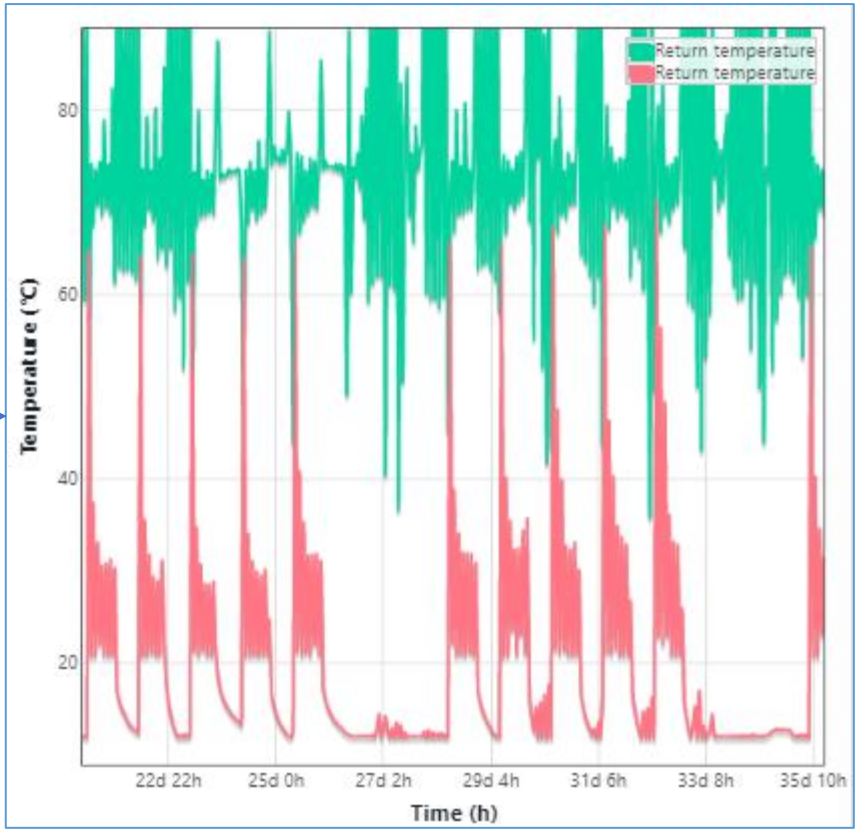


hysopt

Findings

Because of the three-way valves in some of the circuits, the return temperature to the boilers is very high which causes a low efficiency of the boilers.

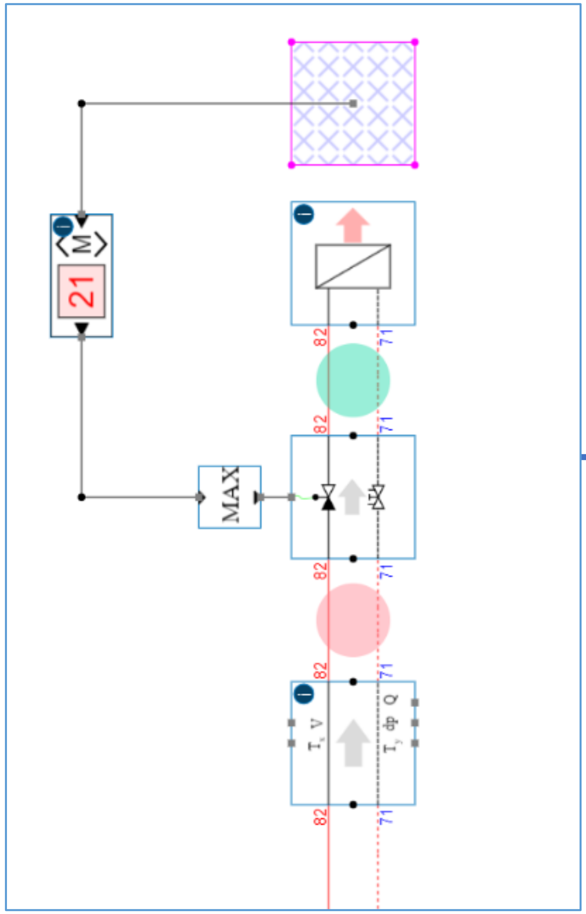


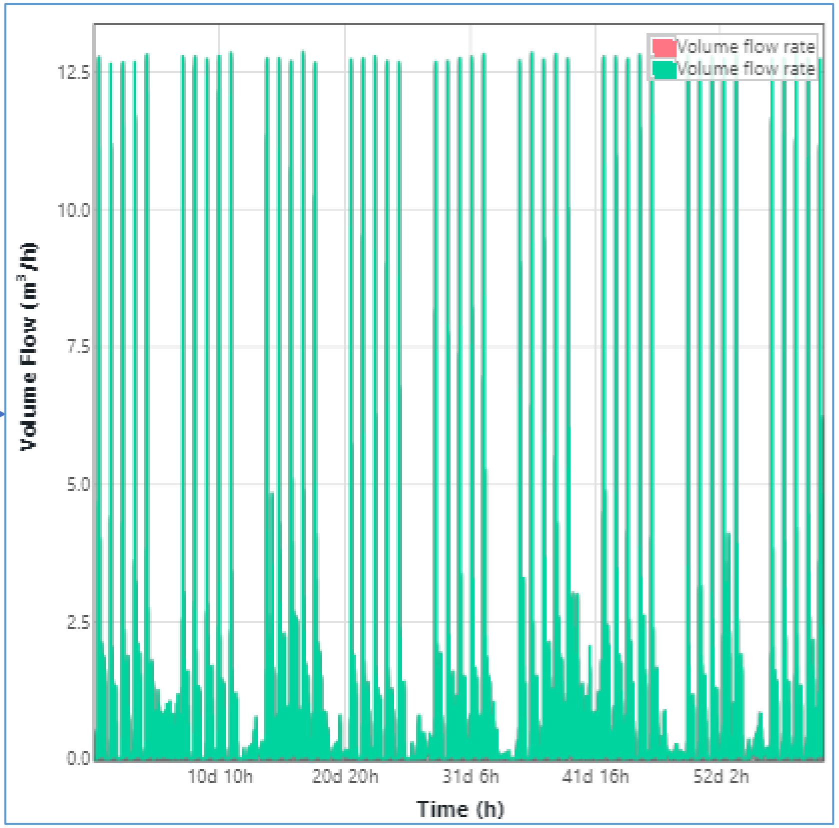


hysopt

Solution: optimisation 0

By changing the three-way valves to two-way valves we switch from constant flow to variable flow and reduce the return temperature.

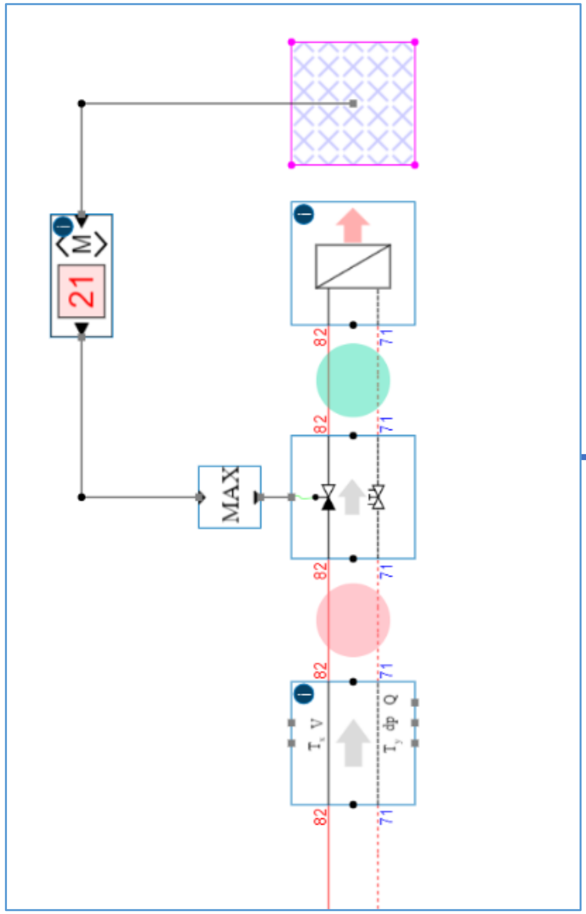


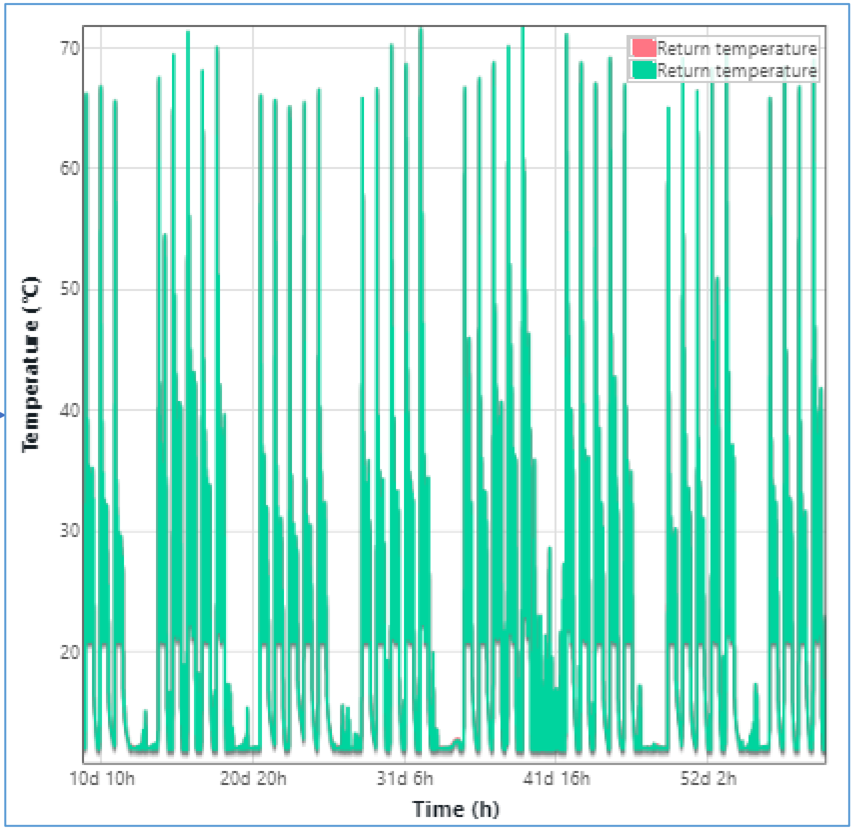


hysopt

Solution: optimisation 0

By changing the three way valves to two-way valves we switch from constant flow to variable flow and reduce the return temperature. The solution will be implemented in the optimisations of the next chapter.





Optimisations

Optimisations

Ref	Scenario	Optimise Hydraulics	Fuel type	Fabric improved	Flow temp	Thermal model
1	Switch to ASHP (low temp)	Yes	Elec	No	Low (50°C and 60°C)	As current installation
2	Switch to ASHP (low temp) + Fabric improvements	Yes	Elec	Yes	Low (50 °C)	Updated with new materials
3	Switch to ASHP (high temp)	Yes	Elec	No	High (70°C)	As current installation
4	Hybrid solution. ASHP (low temp) + Gas boilers	Yes	Elec + Gas	No	High (70°C)	As current installation

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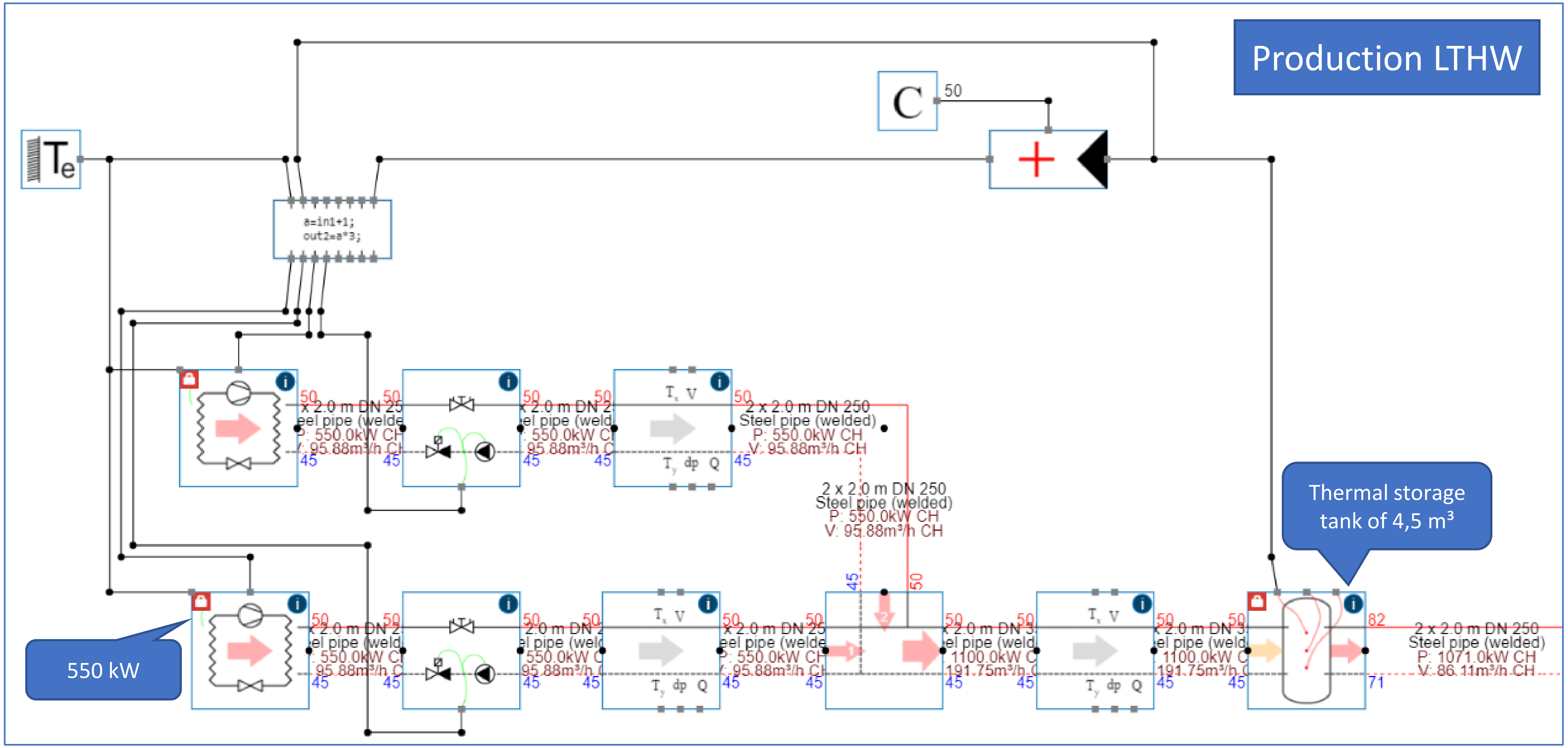
Optimisation 1: with a supply temperature of 50 °C



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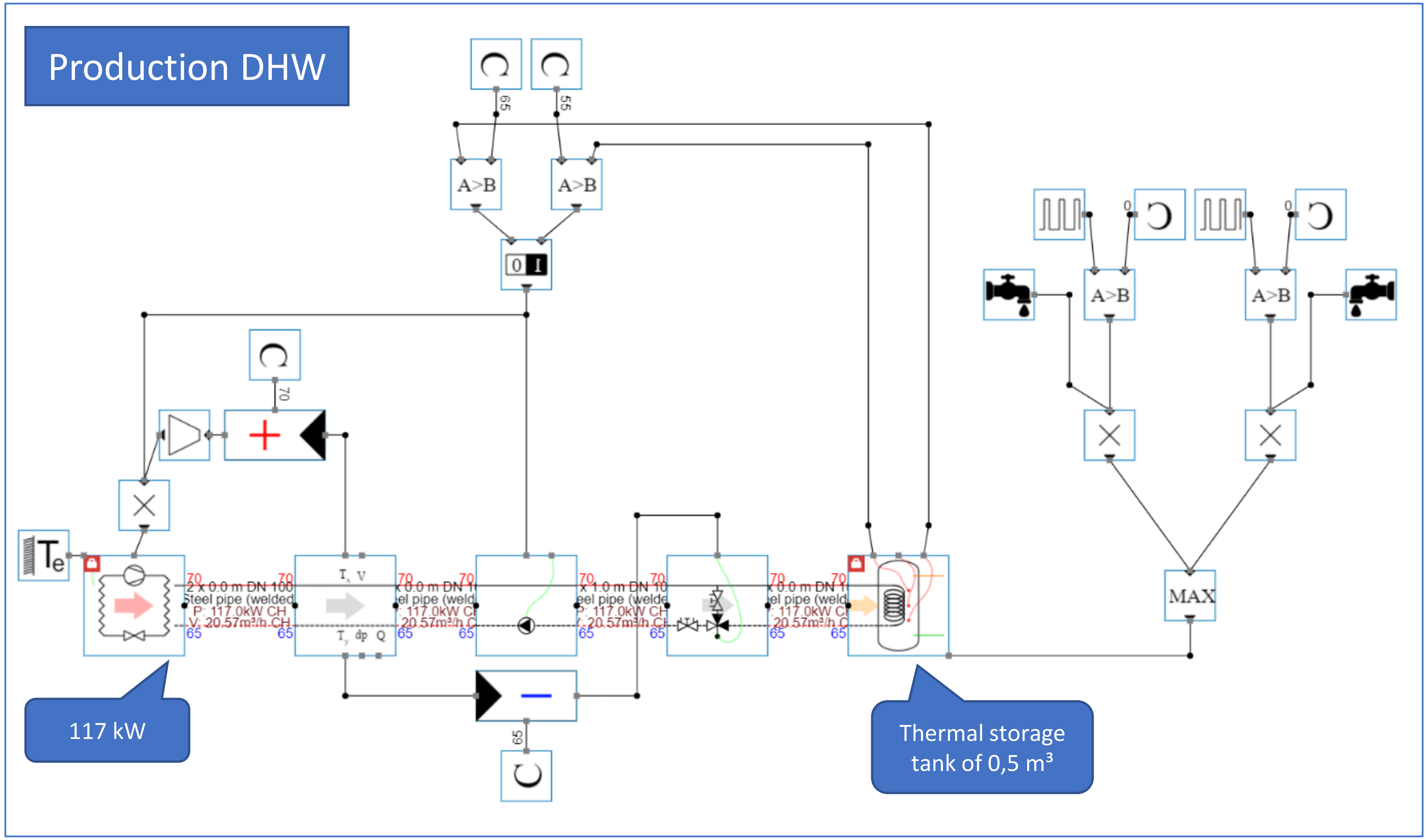
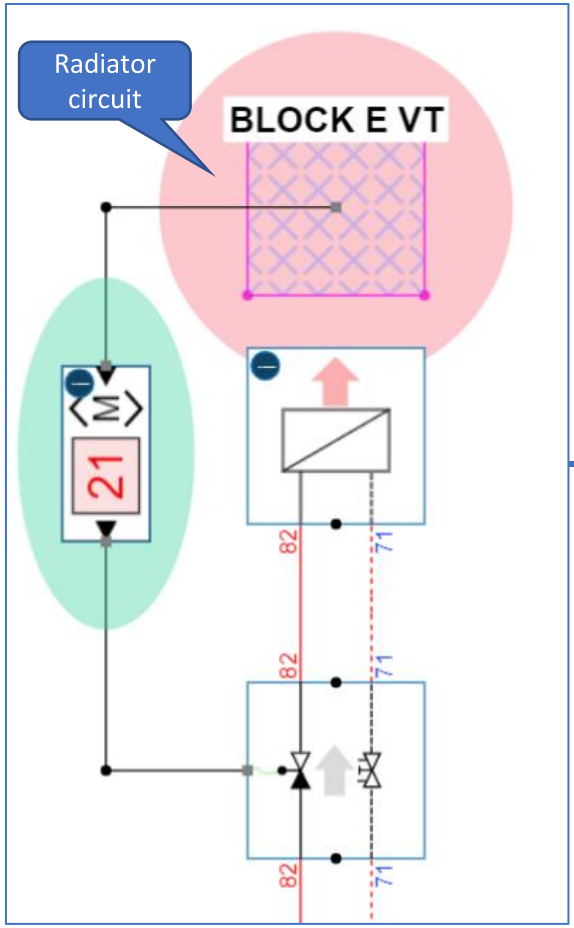
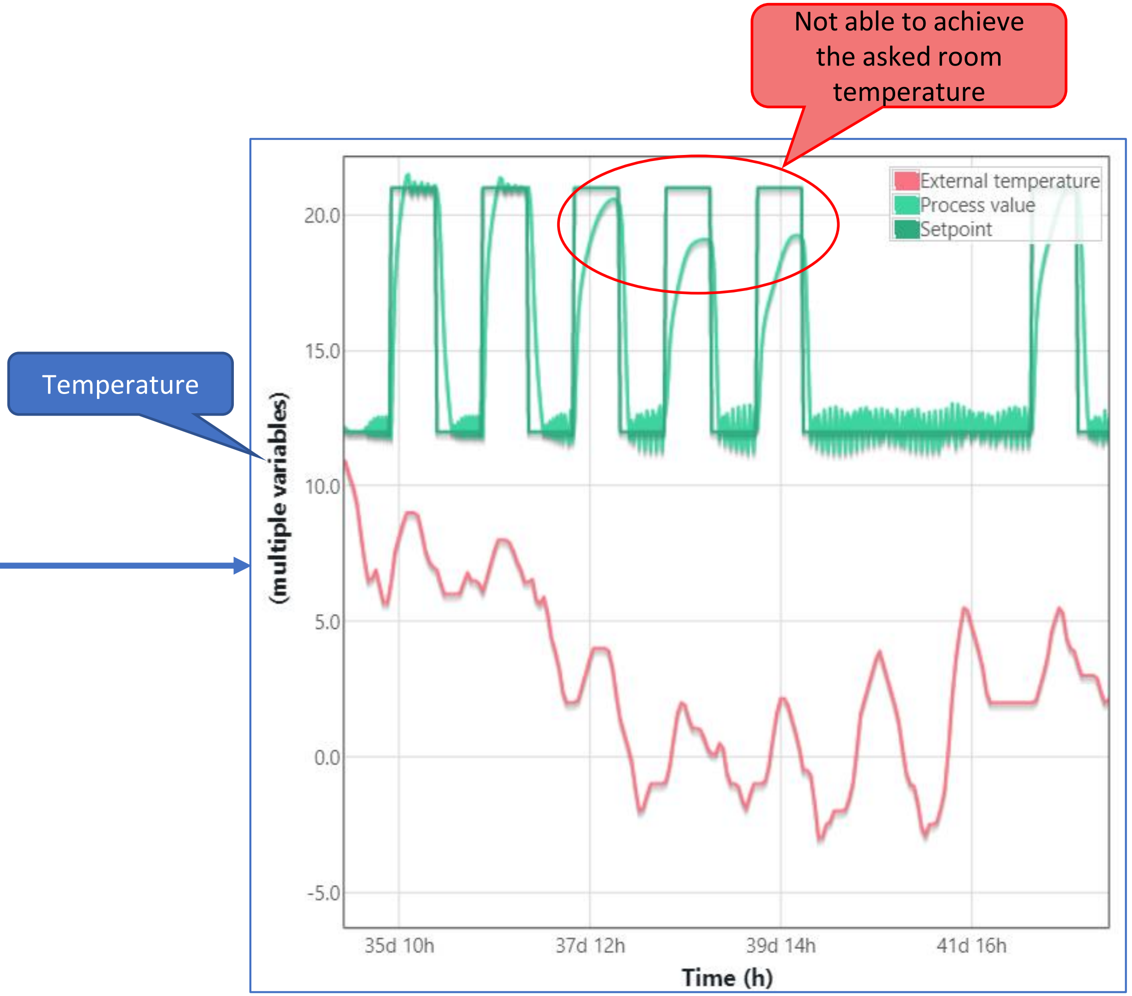
Optimisation 1: with a supply temperature of 50 °C

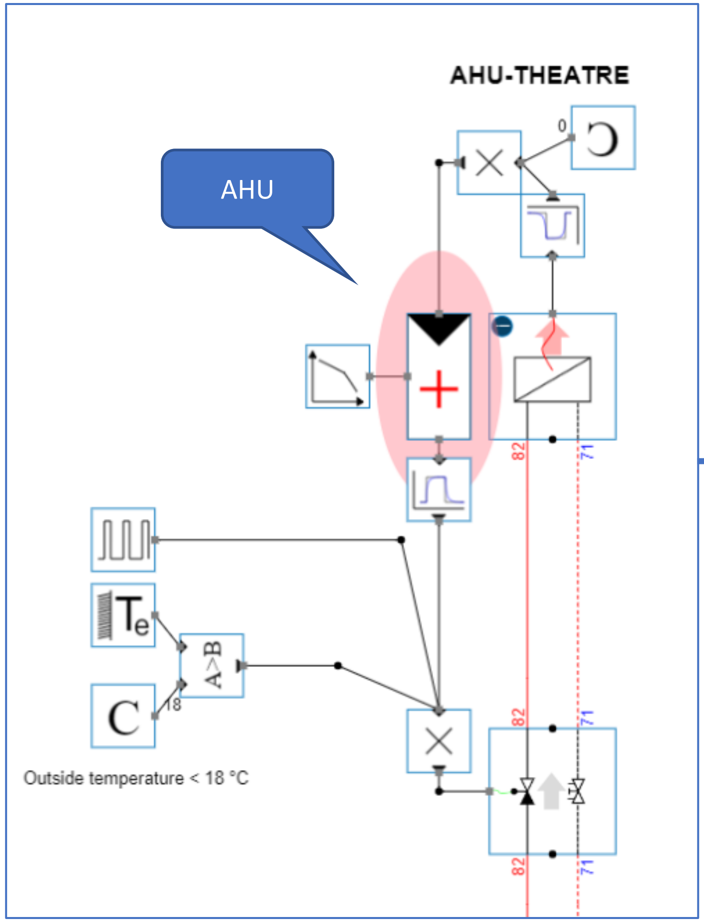


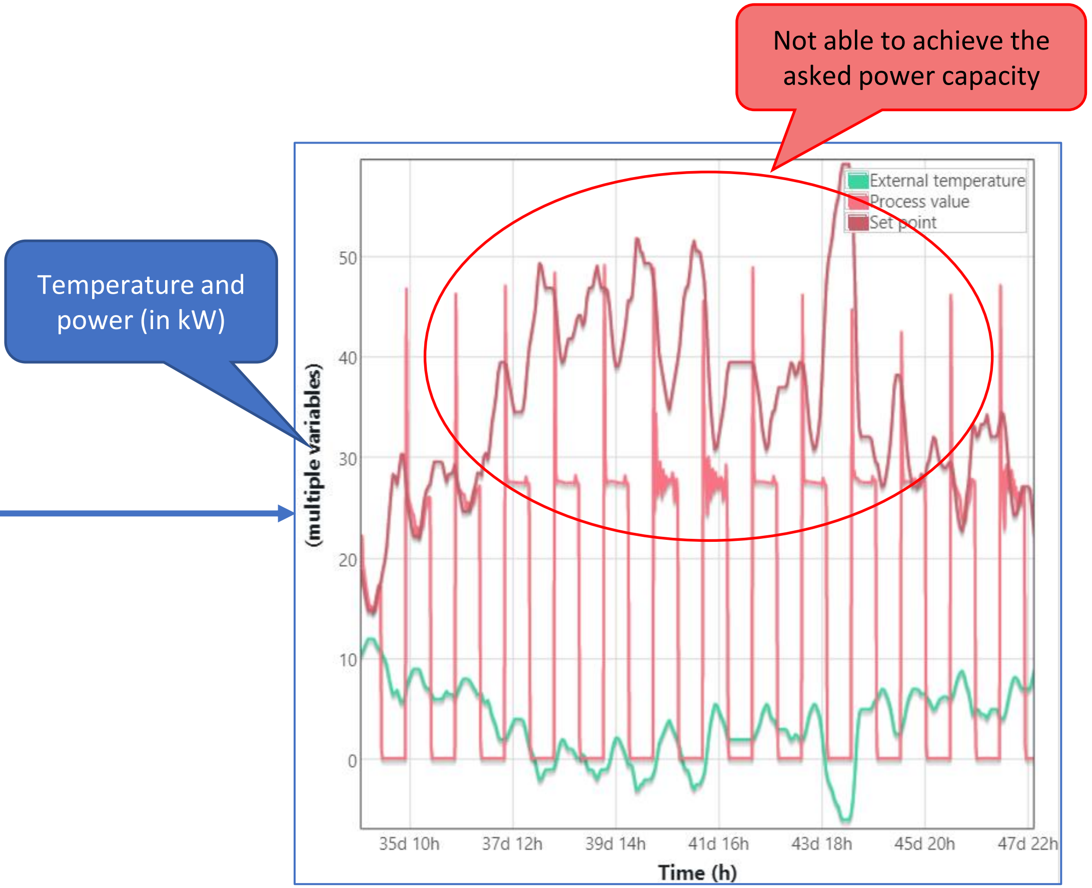
Optimisation 1: with a supply temperature of 50 °C





Optimisation 1: with a supply temperature of 50 °C

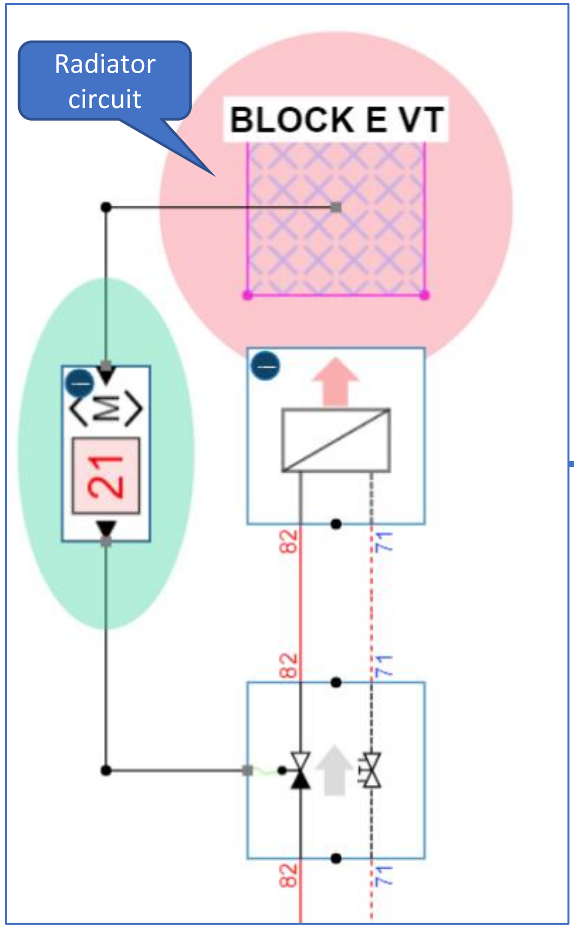




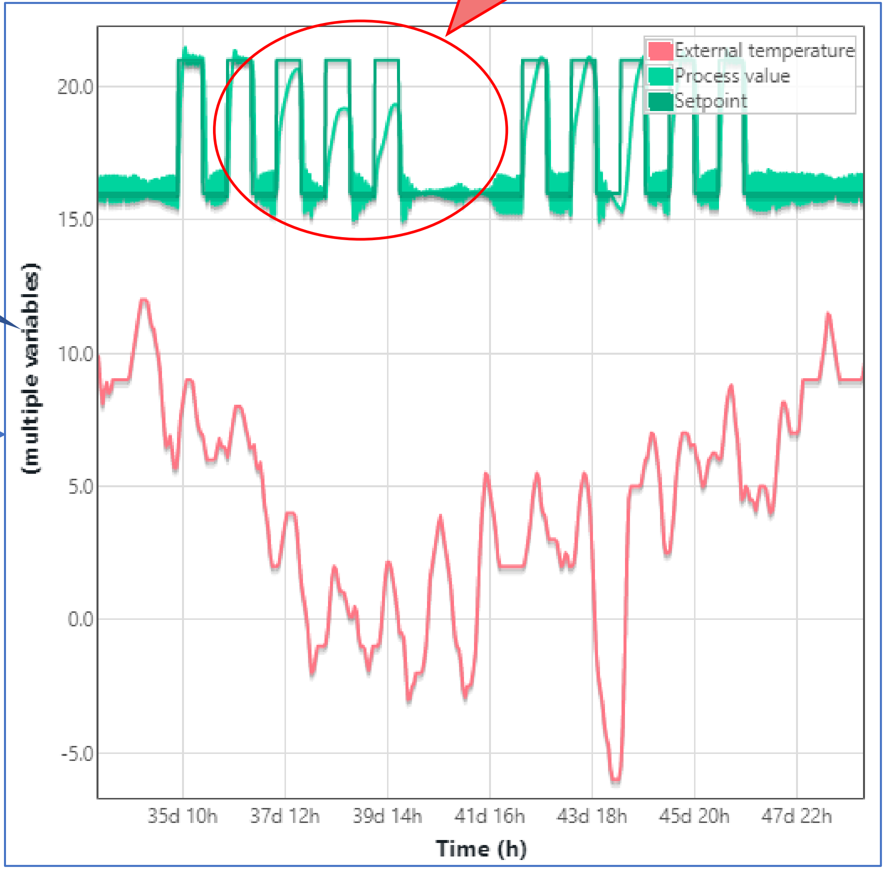
Optimisation 1: with a supply temperature of 50 °C with higher night set point of 16 °C

Not able to achieve the asked room temperature

Radiator circuit



Temperature



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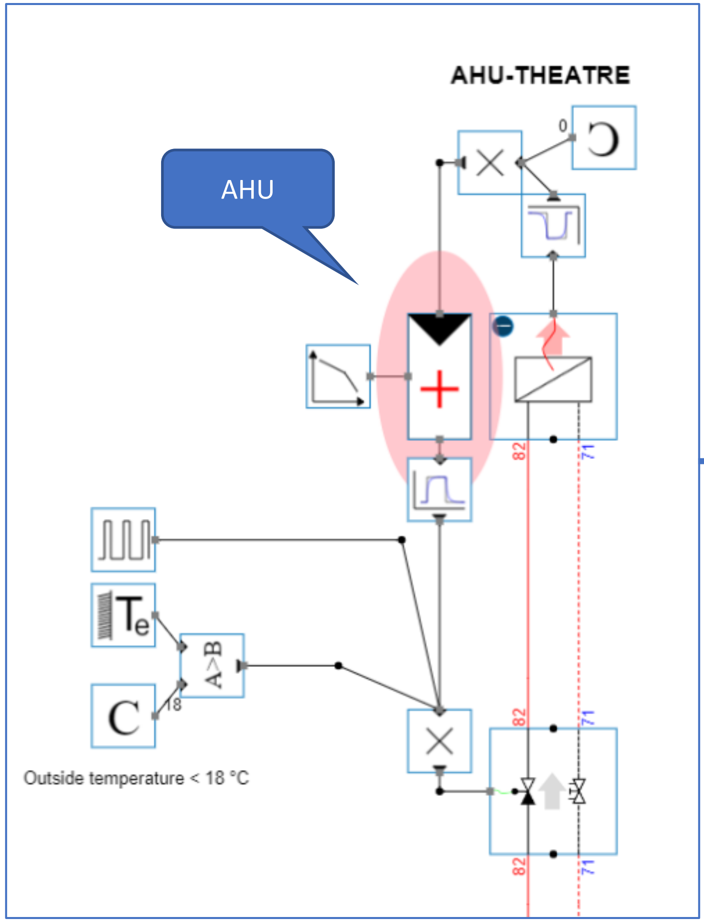
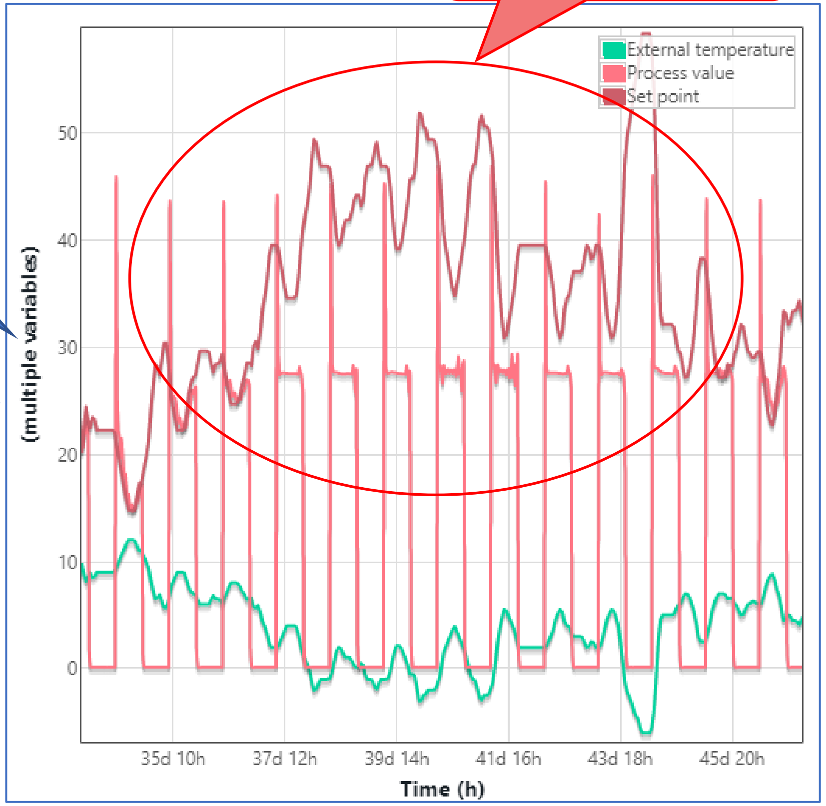
Optimisation 1: with a supply temperature of 50 °C with higher night set point of 16 °C

AHU

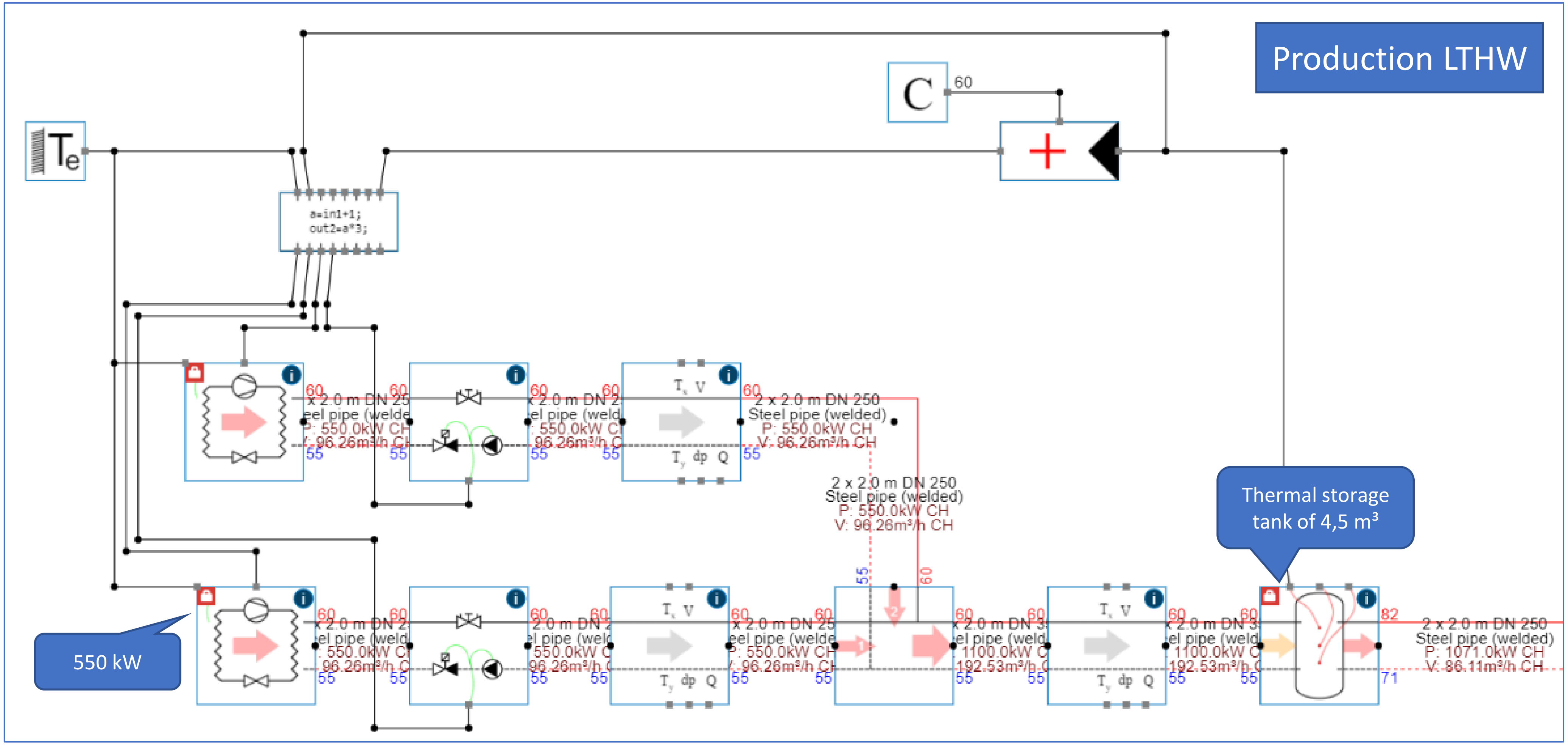


Temperature and power (in kW)

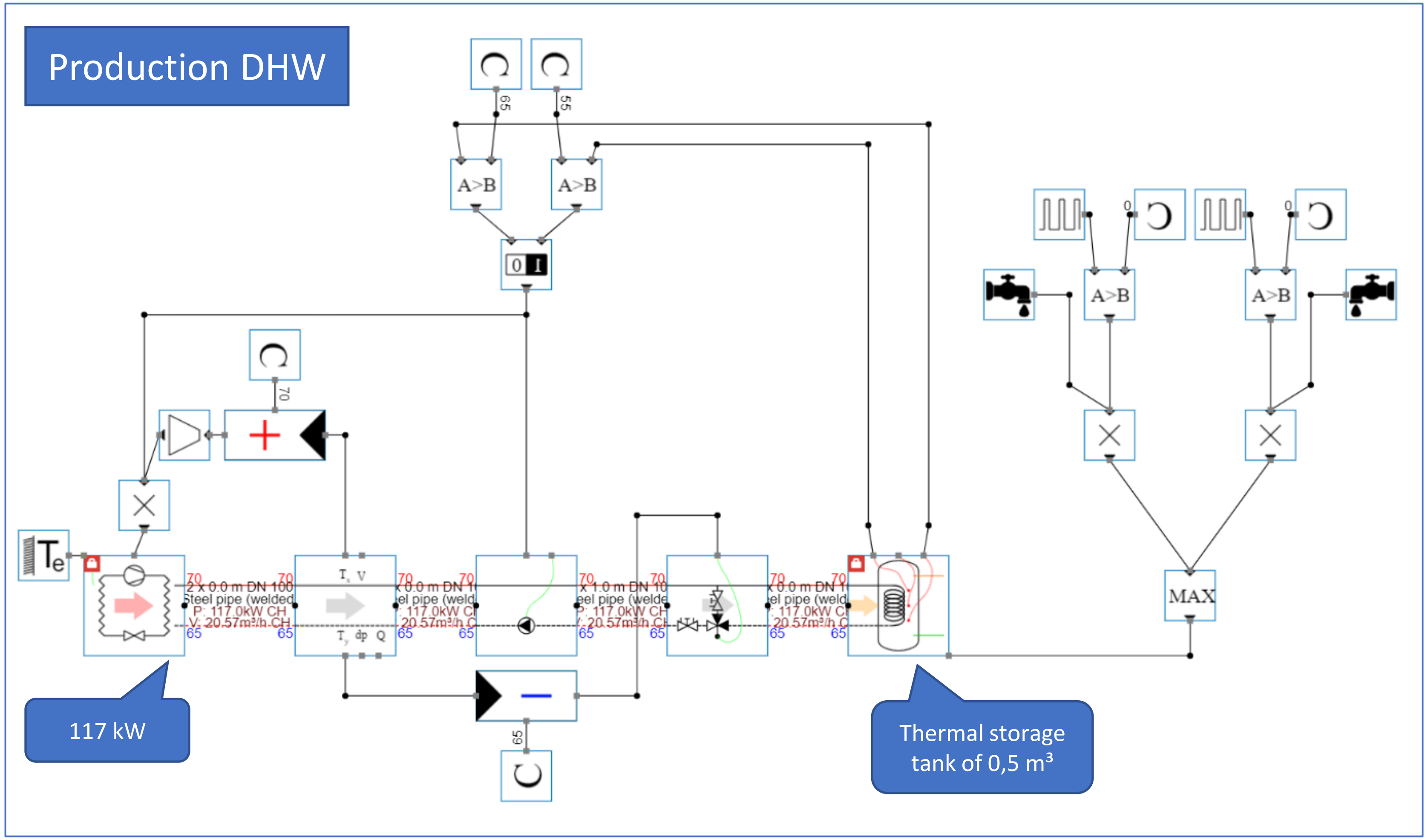
Not able to achieve the asked power capacity



Optimisation 1: with a supply temperature of 60 °C



Optimisation 1: with a supply temperature of 60 °C with night setpoint of 16 °C



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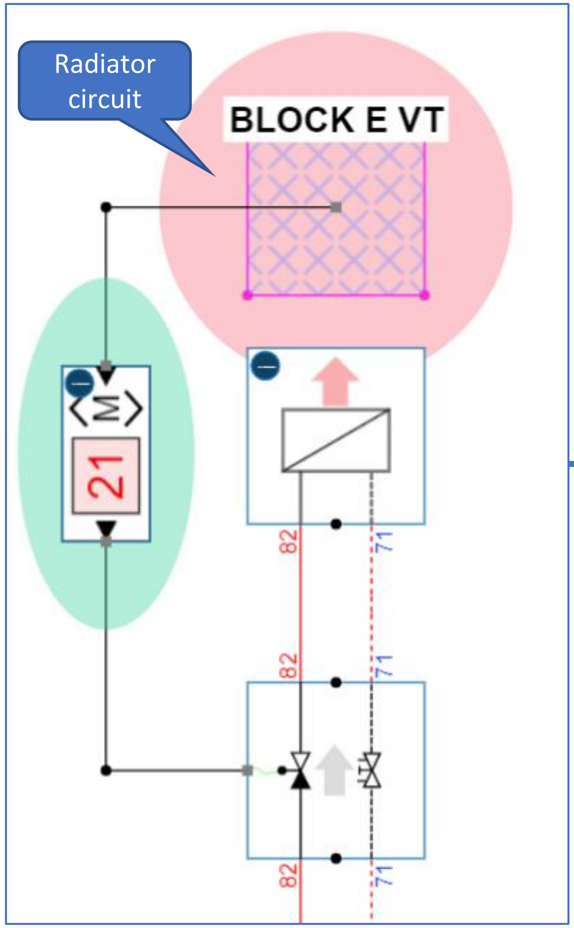
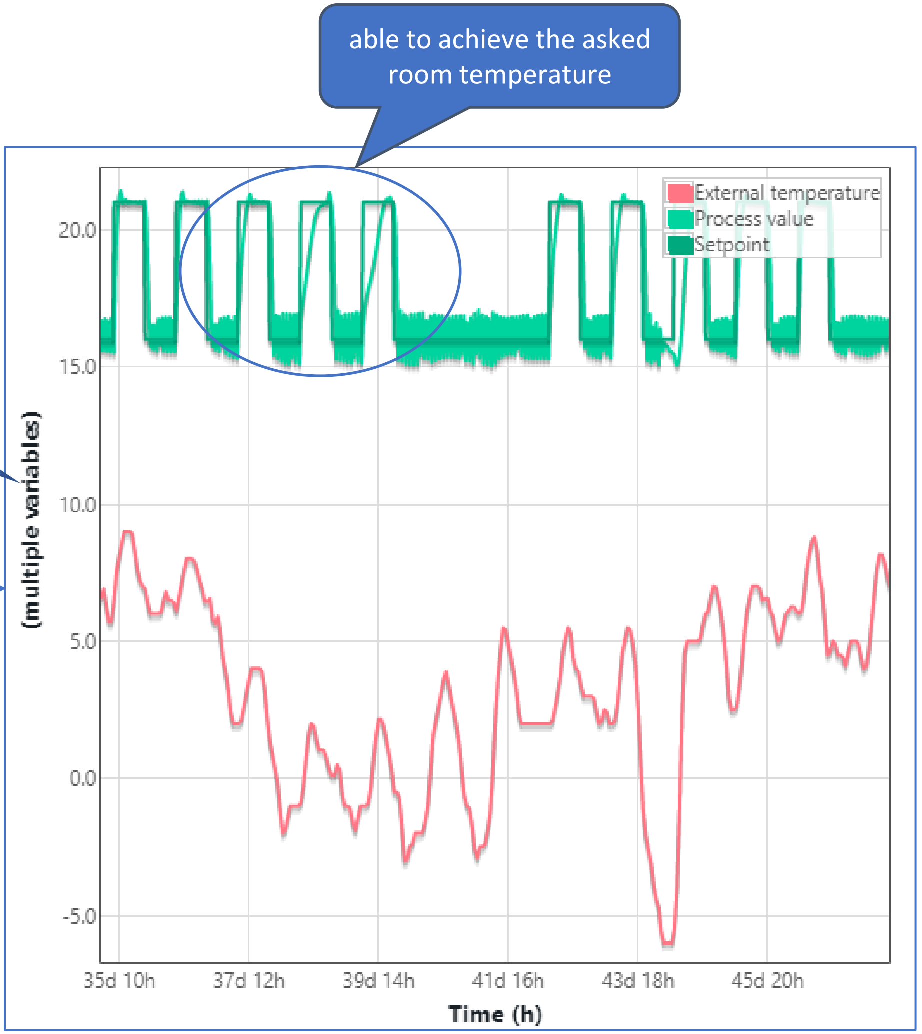
Optimisation 1: with a supply temperature of 60 °C with night setpoint of 16 °C





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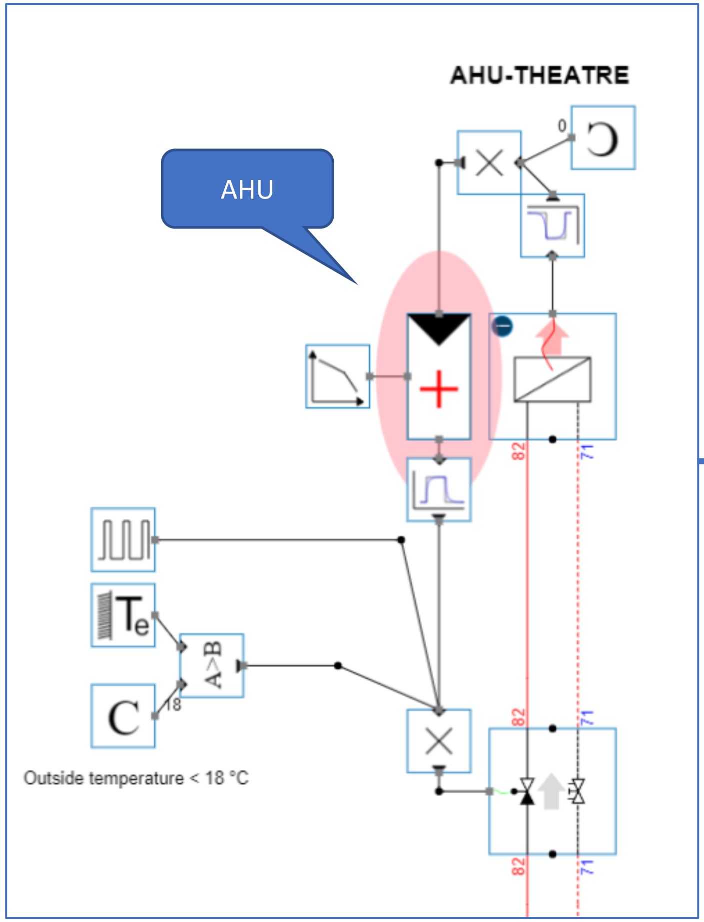
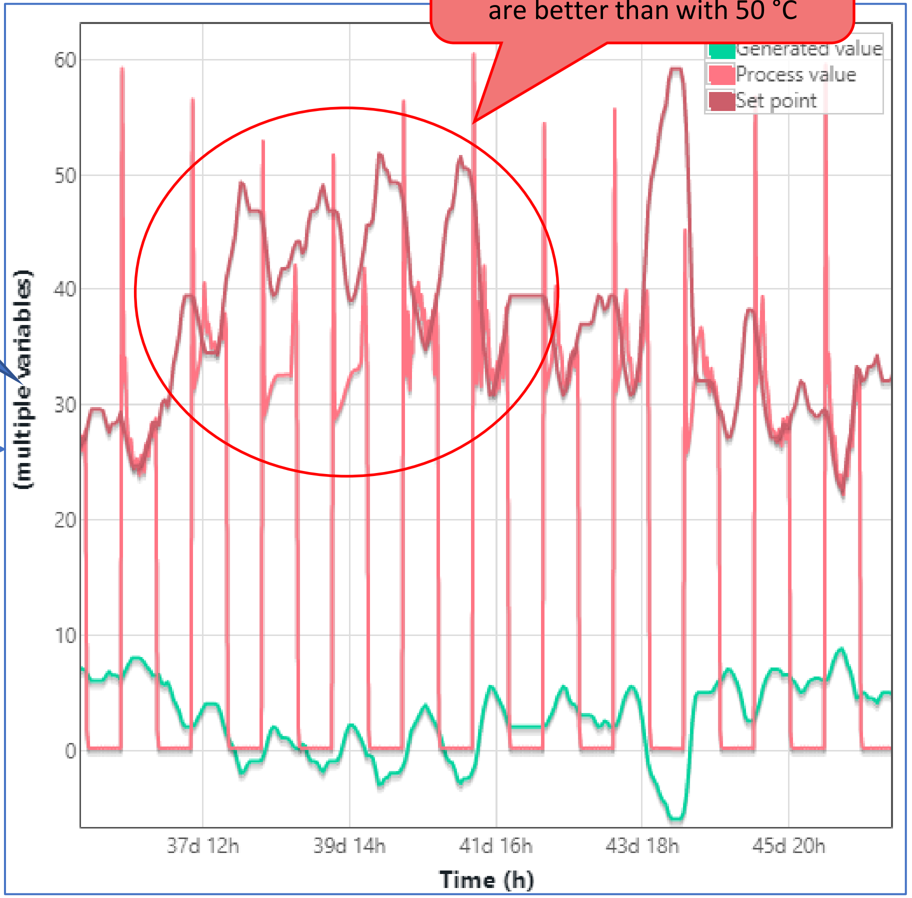
Optimisation 1: with a supply temperature of 60 °C with night setpoint of 16 °C



Temperature and power (in kW)

Not able to achieve the asked power capacity, but the results are better than with 50 °C



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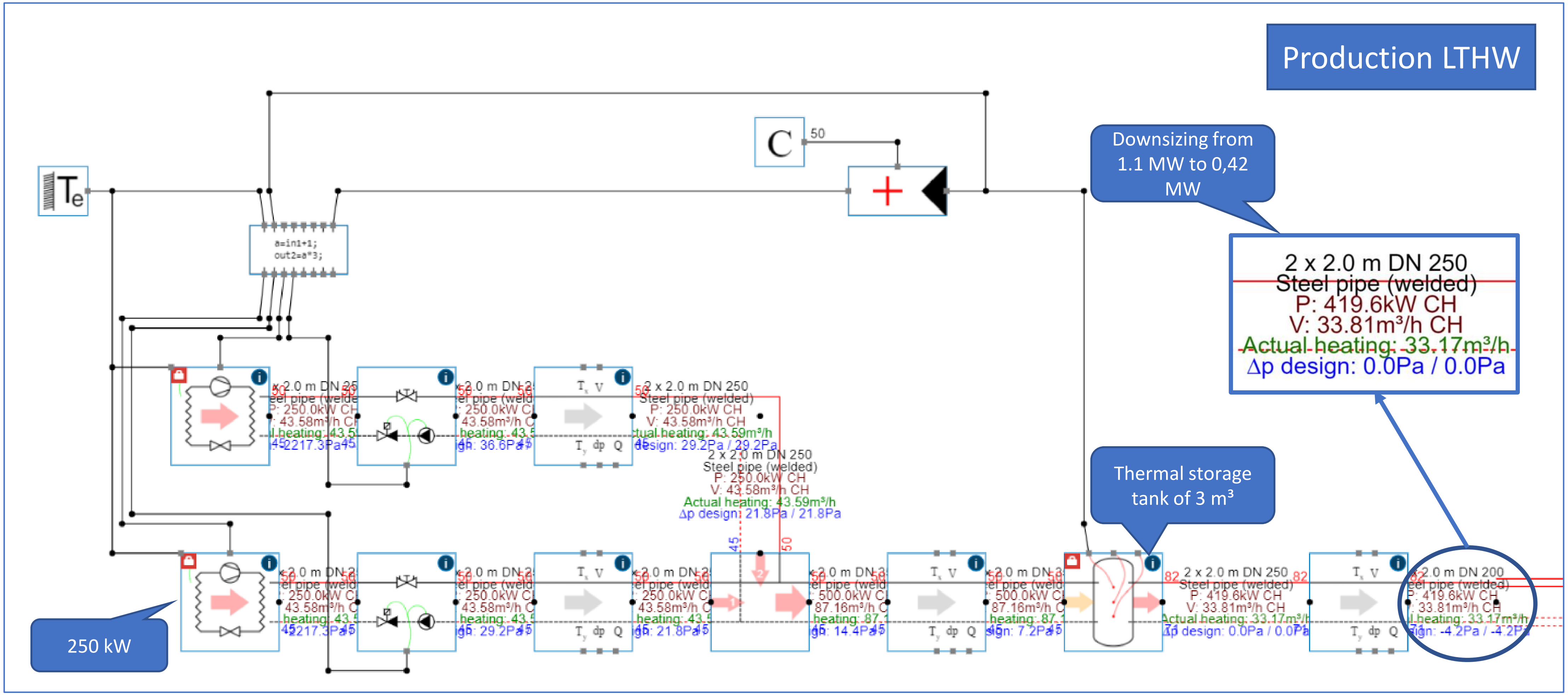
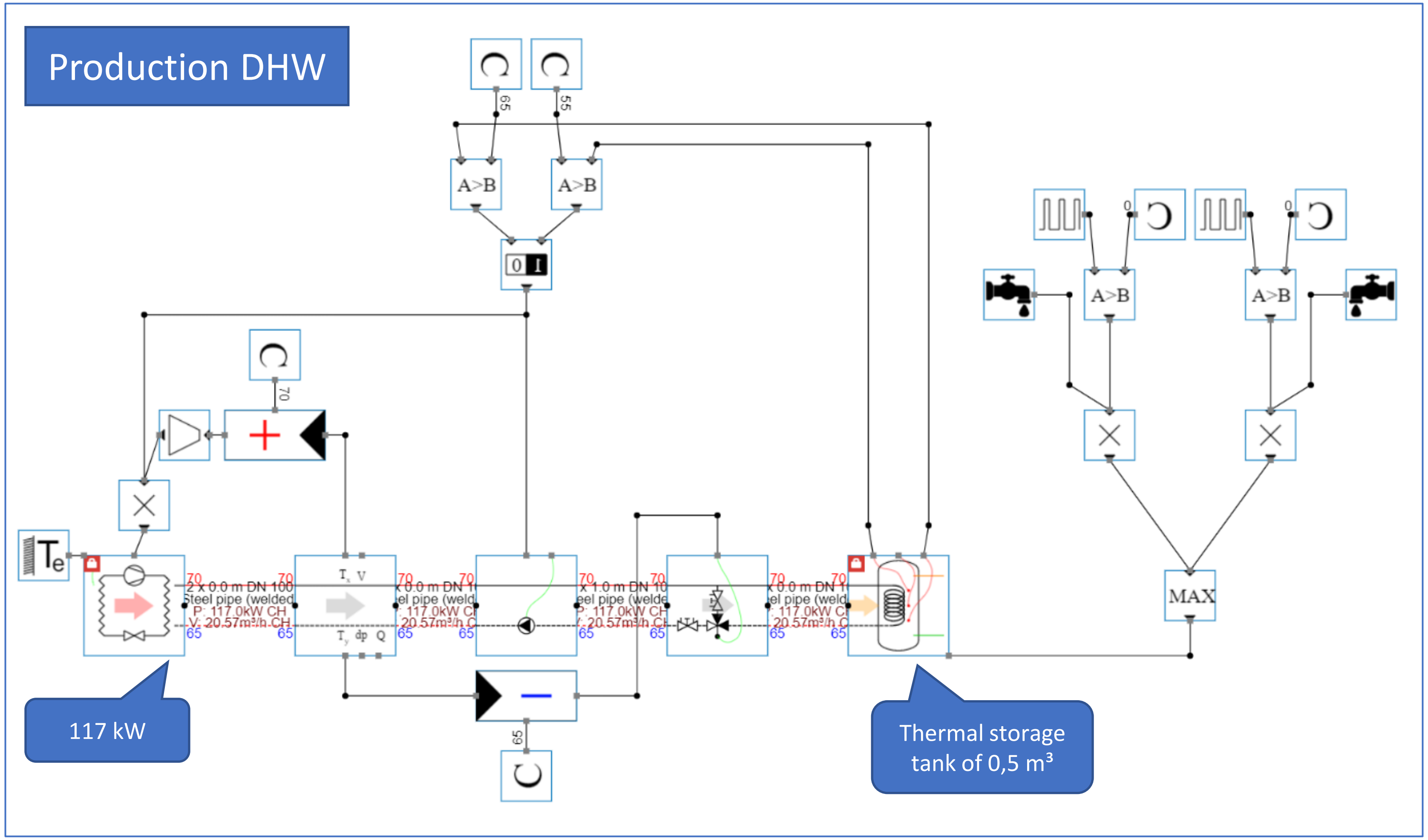
Optimisation 2: new fabric and supply temperature of 50 °C

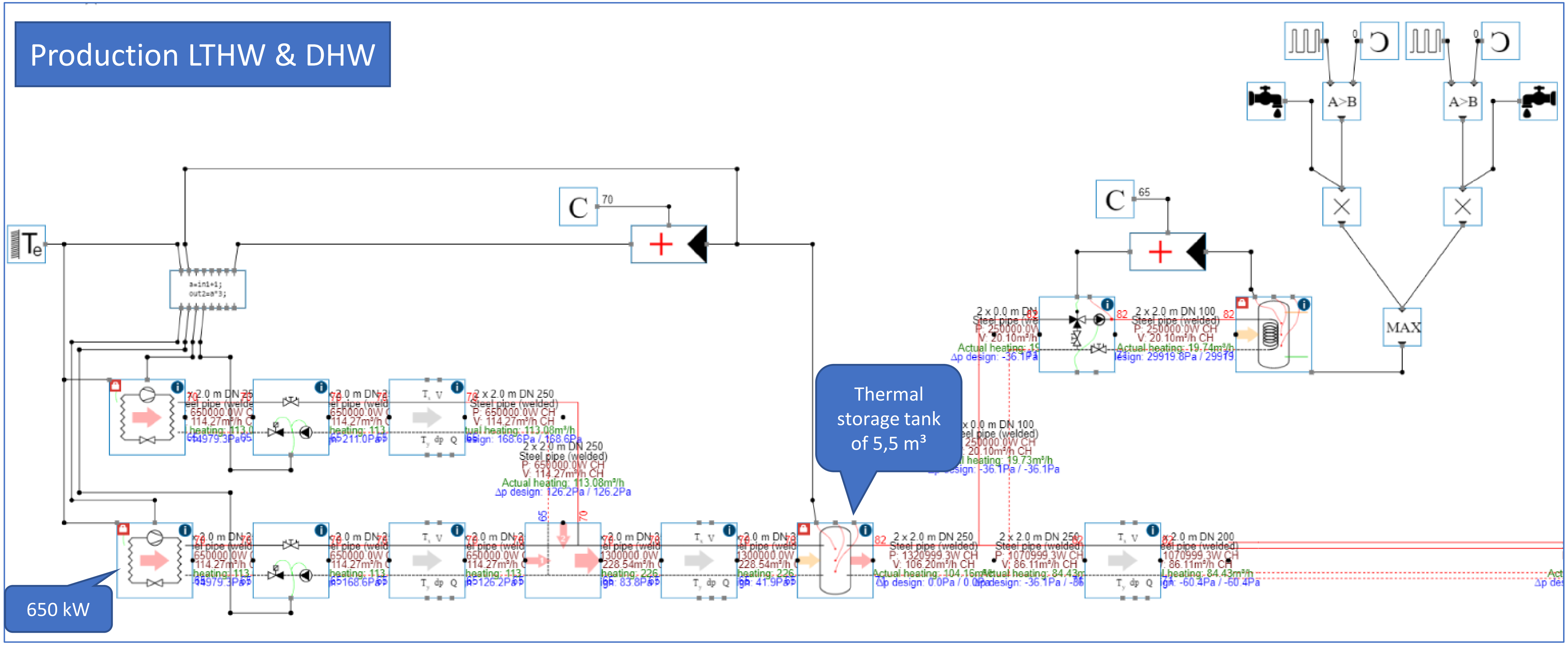


hysopt

Optimisation 2: new fabric and supply temperature of 50 °C



Optimisation 3: old fabric and supply temperature of 70 °C



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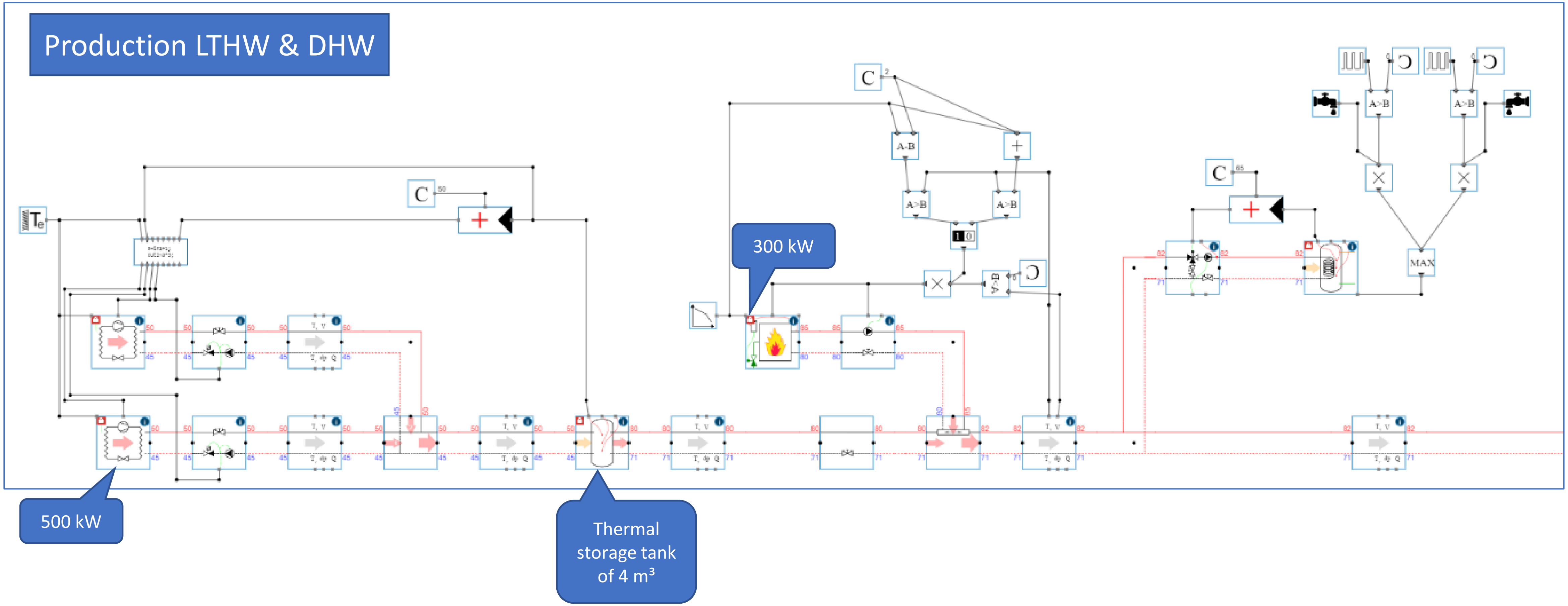
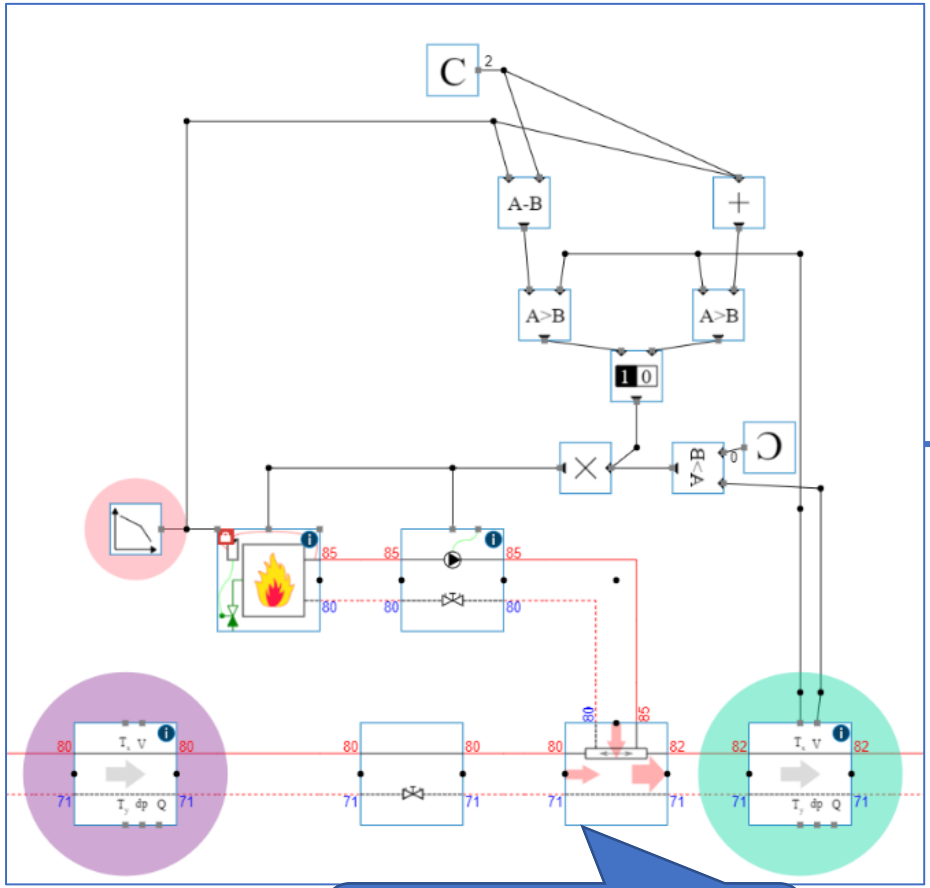
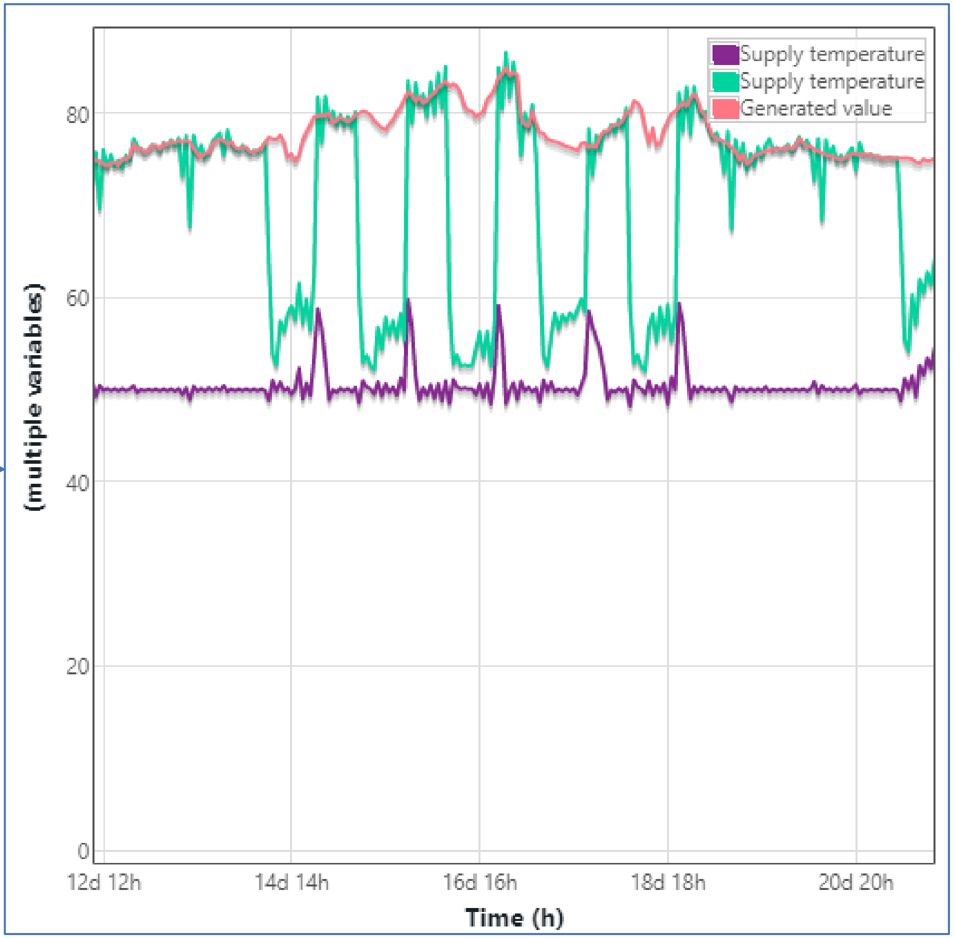
Optimisation 4: old fabric and supply temperature of 82°C



Optimisation 4: old fabric and supply temperature of 82°C



The shunt connection boosts the supply temperature to the asked heating curve set point



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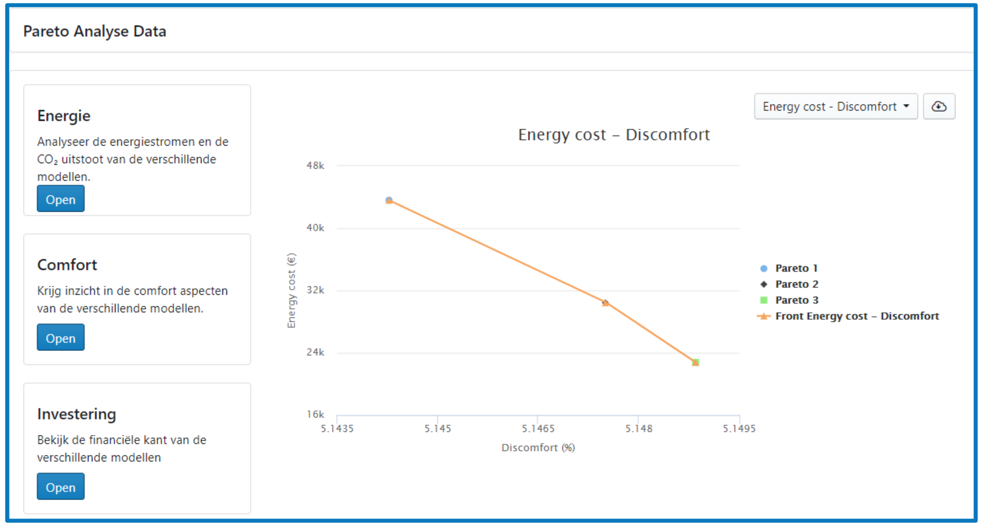
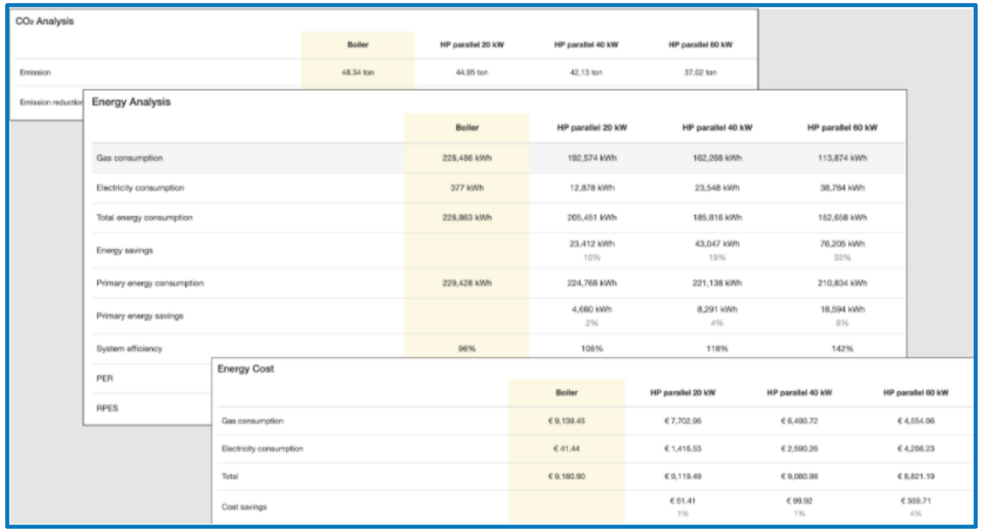
PARETO ANALYSIS

Hysopt software is capable of providing a **Pareto analysis** on the simulated models.

The software automatically calculates multiple **Key performance indicators (KPI)** and compares them with each other.

The **results** are presented and visualised in the **Pareto Dashboard** to give a clear overview and help with **analysis en decisions**.





CO_2 Analysis

	Boiler	HP parallel 20 kW	HP parallel 40 kW	HP parallel 60 kW
Emission	48.34 ton	44.95 ton	42.13 ton	37.02 ton
Emission reductio				

Energy Analysis

	Boiler	HP parallel 20 kW	HP parallel 40 kW	HP parallel 60 kW
Gas consumption	228,486 kWh	192,574 kWh	162,268 kWh	113,874 kWh
Electricity consumption	377 kWh	12,878 kWh	23,548 kWh	38,784 kWh
Total energy consumption	228,863 kWh	205,451 kWh	185,816 kWh	152,658 kWh
Energy savings		23,412 kWh 10%	43,047 kWh 19%	76,205 kWh 33%
Primary energy consumption	229,428 kWh	224,768 kWh	221,138 kWh	210,834 kWh
Primary energy savings		4,660 kWh 2%	8,291 kWh 4%	18,594 kWh 8%
System efficiency	96%	106%	118%	142%
PER				
RPES				

Energy Cost

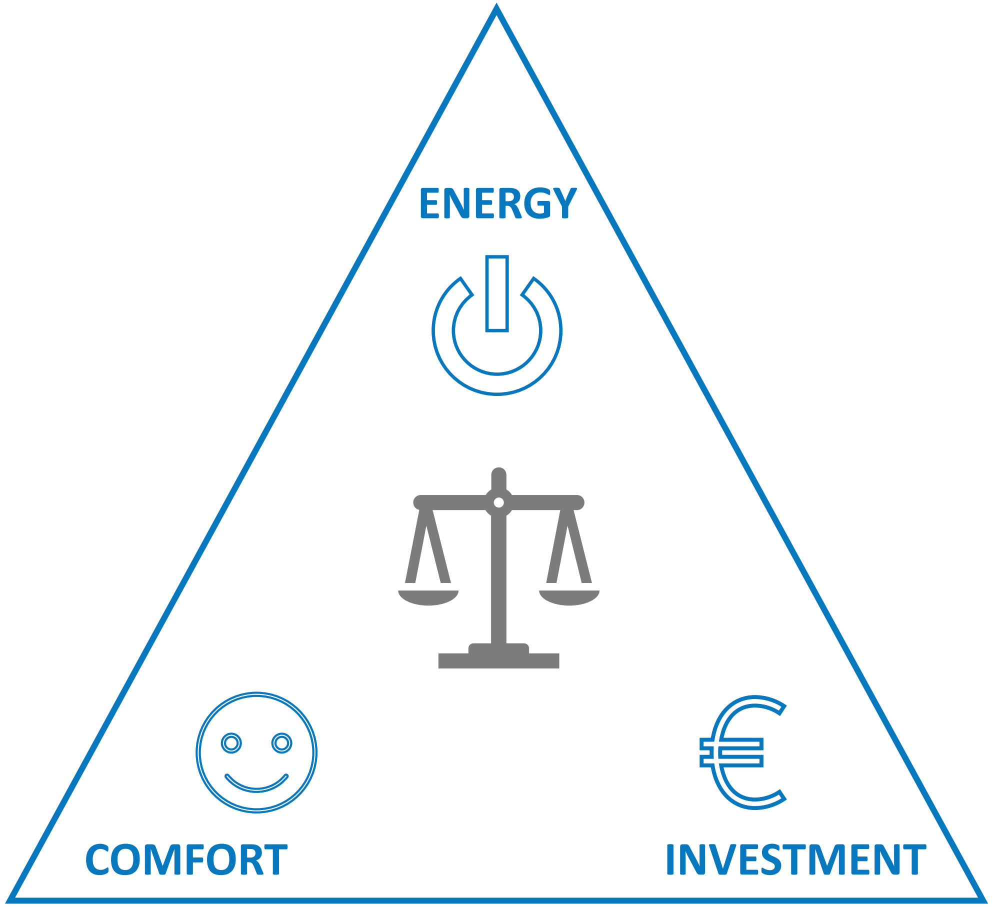
	Boiler	HP parallel 20 kW	HP parallel 40 kW	HP parallel 60 kW
Gas consumption	€ 9,139.45	€ 7,702.96	€ 6,490.72	€ 4,554.96
Electricity consumption	€ 41.44	€ 1,416.53	€ 2,590.26	€ 4,266.23
Total	€ 9,180.90	€ 9,119.49	€ 9,080.98	€ 8,821.19
Cost savings		€ 61.41 1%	€ 99.92 1%	€ 359.71 4%

PARETO PARAMETERS

Energiekost
Energy price gas - 0,04 £ / kWh
Energy price electricity – 0,16 £ / kWh
Energy price cold water – 4,3 £ / m³

Energie analyse
Efficiency electricity production – 40 %

CO_2
Emission factor gas – 0,211 kg / kWh
Emission factor electricity – 0,335 kg / kWh
Emission factor cold water – 0,298 kg / kWh



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PARETO DASHBOARD

Optimisation 0 shows the impact of changing from constant flow to variable flow

Installed Power

Heating	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Boilers thermal power	1,466 kW 100%	1,466 kW 100%	0 kW 0%	0 kW 0%	0 kW 0%	300 kW 23%
HPs condenser thermal power	0 kW 0%	0 kW 0%	1,217 kW 100%	617 kW 100%	1,300 kW 100%	1,000 kW 77%
Total	**1,466 kW**	**1,466 kW**	**1,217 kW**	**617 kW**	**1,300 kW**	**1,300 kW**

System Energy Flows

Heating system	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Building load space heating	946,516 kWh	947,931 kWh	967,865 kWh	538,100 kWh	952,438 kWh	948,299 kWh
Building load domestic hot water	140,327 kWh	140,376 kWh	141,315 kWh	145,588 kWh	139,640 kWh	136,606 kWh
Pipes thermal losses	20,669 kWh	15,097 kWh	14,469 kWh	11,081 kWh	17,863 kWh	15,604 kWh
Produced heat	1,120,714 kWh	1,118,362 kWh	1,122,584 kWh	695,968 kWh	1,110,433 kWh	1,106,641 kWh

Parasitic energy	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Pumps	18,357 kWh	11,470 kWh	9,640 kWh	2,388 kWh	15,633 kWh	13,107 kWh
Fans	0 kWh	0 kWh	0 kWh	0 kWh	0 kWh	0 kWh

PARETO DASHBOARD

Optimisation 0 shows the impact of changing from constant flow to variable flow

Installed Power

Heating	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Boilers thermal power	1,466 kW 100%	1,466 kW 100%	0 kW 0%	0 kW 0%	0 kW 0%	300 kW 23%
HPs condenser thermal power	0 kW 0%	0 kW 0%	1,217 kW 100%	617 kW 100%	1,300 kW 100%	1,000 kW 77%
Total	**1,466 kW**	**1,466 kW**	**1,217 kW**	**617 kW**	**1,300 kW**	**1,300 kW**

This shows the heating demand of the facility, in optimisation 2 the fabric is improved which causes the reduction on heating demand.

System Energy Flows

Heating system	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Building load space heating	946,516 kWh	947,931 kWh	967,865 kWh	538,100 kWh	952,438 kWh	948,299 kWh
Building load domestic hot water	140,327 kWh	140,376 kWh	141,315 kWh	145,588 kWh	139,640 kWh	136,606 kWh
Pipes thermal losses	20,669 kWh	15,097 kWh	14,469 kWh	11,081 kWh	17,863 kWh	15,604 kWh
Produced heat	1,120,714 kWh	1,118,362 kWh	1,122,584 kWh	695,968 kWh	1,110,433 kWh	1,106,641 kWh

The pump energy consumption is reduced by changing the system from constant flow to variable flow

Parasitic energy	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Pumps	18,357 kWh	11,470 kWh	9,640 kWh	2,388 kWh	15,633 kWh	13,107 kWh
Fans	0 kWh	0 kWh	0 kWh	0 kWh	0 kWh	0 kWh

PARETO DASHBOARD

Production Energy Flows

Boilers	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Usefull heat	1,120,714 kWh	1,118,362 kWh	0 kWh	0 kWh	0 kWh	836,611 kWh
Fuel Consumption	1,292,622 kWh	1,213,057 kWh	0 kWh	0 kWh	0 kWh	971,658 kWh
Efficiency	87%	92%	0%	0%	0%	86%

HPs	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Condenser heat flow	0 kWh	0 kWh	1,122,584 kWh	695,968 kWh	1,110,433 kWh	270,031 kWh
Evaporator heat flow	0 kWh	0 kWh	762,661 kWh	448,565 kWh	549,716 kWh	179,716 kWh
Electricity consumption	0 kWh	0 kWh	360,027 kWh	247,460 kWh	560,586 kWh	90,312 kWh
SCOP	0.00	0.00	3.12	2.81	1.98	2.99
Operating time	0 h	0 h	5,069 h	6,453 h	1,538 h	1,958 h

Delivered contributions

Heating	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Boilers	100%	100%	0%	0%	0%	76%
HPs	0%	0%	100%	100%	100%	24%

PARETO DASHBOARD

Optimisation 0 shows the impact of changing from constant flow to variable flow on the return temperature and so the efficiency of the boilers

Production Energy Flows

Boilers	210719 Referen[illegible] model_with DH[illegible]	[illegible]	[illegible]ation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Usefull heat	1,120,714 kWh	[illegible]	[illegible]	0 kWh	0 kWh	836,611 kWh
Fuel Consumption	1,292,622 kWh	1,213,057 kWh	0 kWh	0 kWh	0 kWh	971,658 kWh
Efficiency	87%	92%	0%	0%	0%	86%

The SCOP values are a combination of al the ASHP's in the installation. Because of the High temperature ASHP for the DHW the overal SCOP's are lower then the individual in optimisation 1 and 2

HPs	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Condenser heat flow	0 kWh	0 kWh	1,122,584 kWh	695,968 kWh	1,110,433 kWh	270,031 kWh
Evaporator heat flow	0 kWh	0 kWh	762,661 kWh	448,565 kWh	549,716 kWh	179,716 kWh
Electricity consumption	0 kWh	0 kWh	360,027 kWh	247,460 kWh	560,586 kWh	90,312 kWh
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Operating time	0 h	0 h	5,069 h	6,453 h	1,538 h	1,958 h

Delivered contributions

Heating	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Boilers	100%	100%	0%	0%	0%	76%
HPs	0%	0%	100%	100%	100%	24%

PARETO DASHBOARD

Energy Analysis

	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Gas consumption	1,292,622 kWh	1,213,057 kWh	0 kWh	0 kWh	0 kWh	971,658 kWh
Electricity consumption	18,357 kWh	11,470 kWh	369,667 kWh	249,848 kWh	576,219 kWh	103,419 kWh
Cold water consumption	4,487 m^3	4,487 m^3	4,520 m^3	4,293 m^3	4,462 m^3	4,611 m^3
Total energy consumption	1,310,979 kWh	1,224,527 kWh	369,667 kWh	249,848 kWh	576,219 kWh	1,075,077 kWh
Energy savings		86,452 kWh 7%	941,312 kWh 72%	1,061,131 kWh 81%	734,760 kWh 56%	235,902 kWh 18%
Primary energy consumption	1,338,514 kWh	1,241,731 kWh	924,167 kWh	624,619 kWh	1,440,548 kWh	1,230,206 kWh
Primary energy savings		96,783 kWh 7%	414,347 kWh 31%	713,895 kWh 53%	-102,034 kWh -8%	108,308 kWh 8%
System efficiency	83%	89%	300%	274%	190%	101%
PER	81%	88%	120%	109%	76%	88%
RPES	-11%	-3%	25%	18%	-19%	-2%

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PARETO DASHBOARD

Energy Analysis

	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Gas consumption	1,292,622 kWh	1,213,057 kWh	0 kWh	0 kWh	0 kWh	971,658 kWh
Electricity consumption	18,357 kWh	11,470 kWh	369,667 kWh	249,848 kWh	576,219 kWh	103,419 kWh
Cold water consumption	4,487 m^3	4,487 m^3	4,520 m^3	4,293 m^3	4,462 m^3	4,611 m^3
Total energy consumption	1,310,979 kWh	1,224,527 kWh	369,667 kWh	249,848 kWh	576,219 kWh	1,075,077 kWh
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System efficiency	83%	89%	300%	274%	190%	101%
PER	81%	88%	120%	109%	76%	88%
RPES	-11%	-3%	25%	18%	-19%	-2%

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PARETO DASHBOARD

Energy Cost

	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Gas consumption	£ 51,704.88	£ 48,522.30	£ 0.00	£ 0.00	£ 0.00	£ 38,866.30
Electricity consumption	£ 2,937.09	£ 1,835.13	£ 59,146.69	£ 39,975.60	£ 92,195.07	£ 16,547.11
Cold water consumption	£ 19,292.92	£ 19,292.92	£ 19,435.56	£ 18,461.20	£ 19,185.13	£ 19,825.73
Total	£ 73,934.89	£ 69,650.35	£ 78,582.25	£ 58,436.80	£ 111,380.20	£ 75,239.13
Cost savings		£ 4,284.54 6%	£ 4,647.36- -6%	£ 15,498.09 21%	£ 37,445.31- -51%	£ 1,304.24- -2%

CO_2 Analysis

	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Emission	280.23 ton	261.13 ton	125.19 ton	84.98 ton	194.36 ton	241.04 ton
Emission reduction		19.10 ton 7%	155.04 ton 55%	195.25 ton 70%	85.87 ton 31%	39.19 ton 14%

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PARETO DASHBOARD

Energy Cost

	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Gas consumption	£ 51,704.88	£ 48,522.30	£ 0.00	£ 0.00	£ 0.00	£ 38,866.30
Electricity consumption	£ 2,937.09	£ 1,835.13	£ 59,146.69	£ 39,975.60	£ 92,195.07	£ 16,547.11
Cold water consumption	£ 19,292.92	£ 19,292.92	£ 19,435.56	£ 18,461.20	£ 19,185.13	£ 19,825.73
Total	£ 73,934.89	£ 69,650.35	£ 78,582.25	£ 58,436.80	£ 111,380.20	£ 75,239.13
Cost savings		£ 4,284.54 6%	£ 4,647.36- -6%	£ 15,498.09 21%	£ 37,445.31- -51%	£ 1,304.24- -2%

The negative savings can be explained by taking in consideration that the electricity price is 4 times as high as the gas price

Because of lower heating demand (new fabric)

Because of very low SCOP

CO_2 Analysis

	210719 Reference model_with DHW	210716 Optimisation 0	210716 Optimisation 1_60 °C	210716 Optimisation 2	210716 Optimisation 3	210716 Optimisation 4
Emission	280.23 ton	261.13 ton	125.19 ton	84.98 ton	194.36 ton	241.04 ton
Emission reduction		19.10 ton 7%	155.04 ton 55%	195.25 ton 70%	85.87 ton 31%	39.19 ton 14%

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SUMMARY

Optimisation 1:

- ASHP's with a supply temperature of 50 °C aren't possible because of comfort issues
- ASHP's with a supply temperature of 60 °C are possible but:
    - The AHU's need to be replaced (new design conditions)
    - The night setpoint needs to be 16 °C instead of 12 °C

Optimisation 2:

- Because of the new fabric, a supply temperature reduction to 50 °C is possible and has the best results but:
    - The AHU's need to be replaced (new design conditions)

Optimisation 3:

- ASHP's with a supply temperature of 70 °C are possible but have a significant smaller emmission reduction then optimisation 1 & 2

Optimisation 4:

- Is possible but has the worst results and shouldn't be considered

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SUMMARY

Next step:

- When the suited optimisation is chosen, the changes will be implemented in the digital twin model
    - New valves
    - New AHU’s
    - ….
- A commisioning report can be provided with the needed pump heads and valve positions
    - Additional hours will be needed to implemented adjustments

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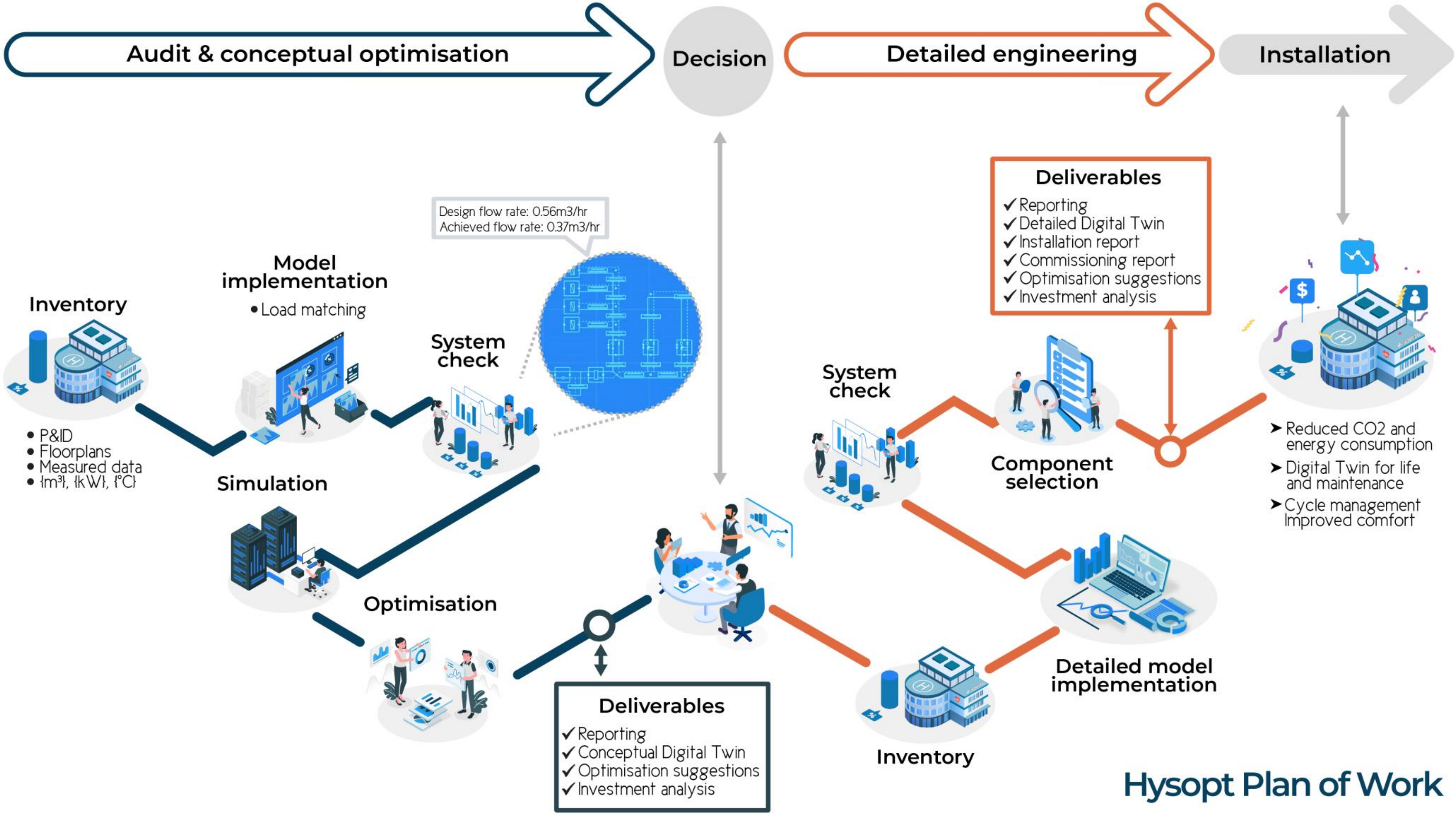
HYSOPT PLAN OF WORK



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Appendix F

RLB costing information

ARUP

02 December 2021

Capex and Life Cycle Costs for Option Appraisal

University of Exeter Decarbonisation Master Plan

Rider Levett Bucknall

AUTHORISATION

This report has been prepared by:

Dan Partridge, Quanity Surveyor

Riz Cader; Consultant

and authorised for issue by:

Steve Scott; Partner

David Quirk; Partner

Document version v1.4 *02 December 2021*

VERSION CONTROL

v1.0	Initial capex and opex costs	15-Oct-21
v1.1	Updated version	22-Oct-21
v1.2	Updated draft version with global add ons.	05-Nov-21
v1.3	Global add on rates adjusted; further clarification added to introduction. No changes to unit rates.	16-Nov-21
v1.4	Adjustments to Introduction and global add-ons to reflect comments received from University / Arup	02-Dec-21

1. INTRODUCTION & BASIS OF REPORT

Rider Levett Bucknall (RLB) was requested by ARUP to support them with cost information for various interventions to upgrade the buildings at the University of Exeter in order to reduce the carbon emissions generated by the buildings. ARUP provided a series of options, for which RLB have provided the capex and life cycle costs.

Our costs are based on a notional intervention based on a generic description; hence have not taken into account the specific requirements of a particular building. We have not taken into account any abnormal access requirements, backlog maintenance or building specific design requirements of the intervention. This is primarily because the University would like to understand the impact of each of the intervention, and as such, this is more of a comparator rather than a fully designed solution for each building.

ARUP have used the rates provided by RLB to build the overall capex and life cycle model. RLB have not been involved in deciding the intervention for each building nor have we had sight of these interventions; consequently we cannot comment on the suitability of costs for each building.

RLB have not been involved in building the overall model hence cannot comment on the interpretation and application of the rates, and the resulting overall costs.

Assumptions

1 Base date is Q3 2021.
2 Costs (Capex and Life Cycle) are based on notional works, and have not been tailored for each building/site.
3 Life cycle cost is replacement/maintenance costs over a 40 year period.
4 All costs are REAL.
5 Day 1 efficiency is maintained throughout the 40 years.
6 Minimum area for globally applied rates assumed to be 1,000m².
7 Minimum scale of project assumed to be £2m (construction capex cost).
8 We have assumed existing service risers and services distribution routes are adequately sized and do not requirement enlargement / alternative distribution routes to be created in the building fabric.
9 Costs associated with the removal of asbestos have been excluded as we do not have details of the extent of intervention required for each building and the level of asbestos removal necessary. We understand that this principal has been agreed as the basis of costing with the University.

Exclusions

1 Costs associated with the removal of asbestos have been excluded as we do not have details of the extent of intervention required for each building and the level of asbestos removal necessary. We understand that this principal has been agreed as the basis of costing with the University.
2 No allowance for fire precautions upgrades as a consequence of proposed works or as additional scope while refurbishment is undertaken.
3 No allowance for DDA or other access improvements as part of scope or as additional scope while refurbishment is undertaken.
4 No allowance for layout changes or construction of new plant rooms / compounds as a consequence of upgrade
5 works.
6 No allowance for consequential upgrade required by Building Regulations.
7 No allowance for temporary accommodation or decant of spaces. This will be a project specific cost dependent on scale and nature of accommodation being decanted.
8 No allowance for services infrastructure upgrades or increase in capacity of supplies to buildings to suit new M&E systems. We understand Arup have included an allowance for a power upgrade to the campus within their overall model
9 No allowance has been included for backlog maintenance items or works to upgrade the structure or fabric of the building beyond the specific intervention identified.
10 No allowance for FF&E, IT/AV or specialist departmental equipment.

Adjustment factors to be applied ARUP at building level

20% Complex building
45% Listed building (If building is complex and listed, then max is 65%)

1. INTRODUCTION & BASIS OF REPORT

Costs excluded from rates, but ARUP to add as 'Global Add-On'

1. VAT at 20%.
2. Making good and reinstatement of building fabric and finishes. We understand an allowance has been included by Arup for making good associated with façade work based on the estimated rate indicated in this report. However no allowance has been included for other interventions. We would envisage a level of making good will be required for all works depending on the nature of the building, the full extent of the interventions proposed and how these fit within the constraints of the existing building. This cost will need to ascertained on a building by building basis and has therefore been excluded.
3. Power infrastructure upgrade costs
4. Fees for internal University costs, design team services, specialist consultancy, surveys & investigations, planning fees and charges.
5. Optimism bias to be added at suggested 'upper bound' percentages in line with HMT Green Book recommendations for standard building projects where there is a high degree of uncertainty.

Rider Levett Bucknall

2. UNIT RATES

Use solution number in ARUP model?

Solution Nr	Solution	Unit	Comments	Further QS comments	Capex Cost	Life Cycle Costs (Total costs over 40 years)
1	Double glazed windows	m2	Timber faced aluminium windows; if scaffolding required, treat as complex building.	1 in 3 are opening lights Scaffolding excluded Based on minimum total project value of £2m	£839	£1,790
2	Triple glazed windows	m2	Timber faced aluminium windows; if scaffolding required, treat as complex building.	1 in 3 are opening lights Scaffolding excluded Based on minimum total project value of £2m	£1,114	£2,230
3	Secondary glazing (double glaze	m2	Aluminium framed glazing (internally fixed)	Based on minimum total project value of £2m	£464	£1,302
4	Internal insulation	m2	insulated plasterboard (decoration cost excluded)	includes allowance for reveals and adjusting ceilings grids / skirtings, but excludes decoration Based on minimum total project value of £2m	£140	£0
5	External insulation (cladding)	m2		Insulated render system on SFS/timber frame fixed to existing façade + allowance for reveals/trims Currently excludes scaffolding. Based on minimum total project value of £2m	£257	£626
6	Cavity insulation	m2	Blown into cavity wall (internally)	EPS beads blown into 100 thick cavity No allowance scaffolding or access, etc. Based on minimum total project value of £2m	£26	£0
7	Roof (pitched) insulation	m2	Internal insulation (at rafter level)	Allowance for removal of any existing material Installation of 300 thick mineral wool Based on minimum total project value of £2m	£36	£36
8	Roof (flat) insulation	m2	Excludes guttering and downpipes. Costs include annual roof inspection.	Overlaying existing flat roof with new insulated flat roof membrane Based on minimum total project value of £2m	£171	£210
9	Upgrade to LED Lighting	m2 (of floor)	Upgrade light fittings, and controls (zonal). Does not allow for a full upgrade of wiring.	Includes disconnection and removal of existing light fittings, and installation of new No allowance for making good or reinstatement of finishes Based on minimum total project value of £2m	£145	£300
10	PV installation	m2	Roof mounted PV panels (pitched or flat); independent converters.	No allowance for upgrading roof/envelope structure to accommodate panels Based on minimum total project value of £2m	£643	£1,060
11	ASHP (0-50KW)	nr	Remove existing boiler, replace with ASHP. Assume calorifier already present. Replace main plantroom e.g. pumps, headers, pressurisation & expansion vessels. Include BMS modifications to suit new plant. Retain existing heating system outside plantroom	Unit rate based on middle of kW range External plant to be at ground level adjacent to building, with base to be constructed if required. Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Based on minimum total project value of £2m	£31,199	£115,677
12	ASHP (50-100KW)	nr	Remove existing boiler, replace with ASHP. Assume calorifier already present. Replace main plantroom e.g. pumps, headers, pressurisation & expansion vessels. Include BMS modifications to suit new plant. Retain existing heating system outside plantroom	Unit rate based on middle of kW range External plant to be at ground level adjacent to building, with base to be constructed if required. Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Based on minimum total project value of £2m	£90,063	£303,183

Rider Levett Bucknall

2. UNIT RATES

Use solution number in ARUP model?

Solution Nr	Solution	Unit	Comments	Further QS comments	Capex Cost	Life Cycle Costs (Total costs over 40 years)
13	ASHP (100-200KW)	nr	Remove existing boiler, replace with ASHP. Assume calorifier already present. Replace main plantroom e.g. pumps, headers, pressurisation & expansion vessels. Include BMS modifications to suit new plant. Retain existing heating system outside plantroom	Unit rate based on middle of kW range External plant to be at ground level adjacent to building, with base to be constructed if required. Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Based on minimum total project value of £2m	£152,782	£499,068
14	ASHP (200-500KW)	nr	Remove existing boiler, replace with ASHP. Assume calorifier already present. Replace main plantroom e.g. pumps, headers, pressurisation & expansion vessels. Include BMS modifications to suit new plant. Retain existing heating system outside plantroom	Unit rate based on middle of kW range External plant to be at ground level adjacent to building, with base to be constructed if required. Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Based on minimum total project value of £2m	£338,940	£1,094,926
15	ASHP (500-1000KW)	nr	Remove existing boiler, replace with ASHP. Assume calorifier already present. Replace main plantroom e.g. pumps, headers, pressurisation & expansion vessels. Include BMS modifications to suit new plant. Retain existing heating system outside plantroom	Unit rate based on middle of kW range External plant to be at ground level adjacent to building, with base to be constructed if required. Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Based on minimum total project value of £2m	£594,707	£1,892,650
16	Replace heating system	m2	Replacement of heating system to modern low temperature LTHW system. No change of assets within plantroom. Only replace pipework, radiators, valves, TRVs/sensors	Allowance for surface mounted / accessible pipework/radiator to be removed/replaced New pipework, etc. to utilise existing service routes with no resizing or enhancements required Allowance for minor builders work, but no making good or reinstatement of finishes, etc. Based on minimum total project value of £2m	£107	£227
17	Electric Boilers (0-50KW)	nr	Remove existing boiler, replace with equivalent electric boiler. Excludes infrastructure/capacity upgrade or increase capacity to building supply. Include BMS modifications to suit new boiler, and upgrade of electrics from main distribution board to plantroom. Retain existing heating system outside plantroom.	Unit rate based on middle of kW range Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Three phase supply available in building with existing risers/route to be utilised for new supply from existing circuit breaker Based on minimum total project value of £2m	£12,098	£36,157
18	Electric Boilers (50-100KW)	nr	Remove existing boiler, replace with equivalent electric boiler. Excludes infrastructure/capacity upgrade or increase capacity to building supply. Include BMS modifications to suit new boiler, and upgrade of electrics from main distribution board to plantroom. Retain existing heating system outside plantroom.	Unit rate based on middle of kW range Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Three phase supply available in building with existing risers/ service routes to be utilised for new supply from existing circuit breaker with no resizing or enhancements required Based on minimum total project value of £2m	£20,756	£50,010

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2. UNIT RATES

Use solution number in ARUP model?

Solution Nr	Solution	Unit	Comments	Further QS comments	Capex Cost	Life Cycle Costs (Total costs over 40 years)
19	Electric Boilers (100-200KW)	nr	Remove existing boiler, replace with equivalent electric boiler. Excludes infrastructure/capacity upgrade or increase capacity to building supply. Include BMS modifications to suit new boiler, and upgrade of electrics from main distribution board to plantroom. Retain existing heating system outside plantroom.	Unit rate based on middle of kW range Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Three phase supply available in building with existing risers/ service routes to be utilised for new supply from existing circuit breaker with no resizing or enhancements required Based on minimum total project value of £2m	£27,854	£61,366
20	Electric Boilers (200-500KW)	nr	Remove existing boiler, replace with equivalent electric boiler. Excludes infrastructure/capacity upgrade or increase capacity to building supply. Include BMS modifications to suit new boiler, and upgrade of electrics from main distribution board to plantroom. Retain existing heating system outside plantroom.	Unit rate based on middle of kW range Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Three phase supply available in building with existing risers/ service routes to be utilised for new supply from existing circuit breaker with no resizing or enhancements required Based on minimum total project value of £2m	£40,775	£93,240
21	Electric Boilers (500-1000KW)	nr	Remove existing boiler, replace with equivalent electric boiler. Excludes infrastructure/capacity upgrade or increase capacity to building supply. Include BMS modifications to suit new boiler, and upgrade of electrics from main distribution board to plantroom. Retain existing heating system outside plantroom.	Unit rate based on middle of kW range Sufficient space internally to accommodate plant without significant realignment/adaption of building fabric Three phase supply available in building with existing risers/ service routes to be utilised for new supply from existing circuit breaker with no resizing or enhancements required Based on minimum total project value of £2m	£78,190	£181,104
22	Heating zones and control upgra	m2	Addition of zone valves and change to variable volume systems. Assume controls and sensors modified	Allowance for additional sensor and temperature controller every 50m2 with adjustment and link back to BMS (not exceeding 30m run from control) Removal of existing if required Based on minimum total project value of £2m	£39	£174

3. GLOBAL ADD-ONS

To be added at project level, after calculating the total capex and life cycle costs.

1 Asbestos			*To be added before VAT, Fees and OB*
Total refurbished GIA of buildings with Asbestos (m2)			
Asbestos removal or making safe (£/m2)		230	*Blended allowance based on estate level asbestos removal.*
Project level additional costs for asbestos	**£**	**-**	*Excluded from cost model*
2 Making Good Allowance			*To be added before VAT, Fees and OB*
Total GIA of building affected by internal refurbishment (m2)			
Rate (£/m2)		99	*Blended on replacement of floor and ceiling finishes and decoration of walls.*
Project level additional costs for making good	**£**	**-**	*Excluded from cost model*
3 Electrical Incomer Upgrade			*To be added before VAT, Fees and OB*
4km cable			
Sub-station			
Making good to surface			
Project level additional costs	**£**	**-**	*Excluded from RLB costs; included as separate cost by Arup in overall model*
4 Fees		20%	To be added by Arup in overall model before VAT and OB
	of total projects costs plus the 3 items above.		
5 Optimism bias due to high level feasibility model		39%	*To be added before VAT*
	of all costs including all items above.		
6 VAT		20%	
	of all costs including all items above.		

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AFRICA | AMERICAS | ASIA | EUROPE | MIDDLE EAST | OCEANIA

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Appendix G

Buildings list

Campus	Code	Name	Res / Non-Res	Tenure
Streatham On Campus	BG002	Amory Building	Non Residential	Freehold
Streatham On Campus	BG003	Biosciences Greenhouse	Non Residential	Freehold
Streatham Off Campus	BG004	Birks Central	Residential	Freehold
Streatham Off Campus	BG006	Birks Grange	Residential	Freehold
Streatham On Campus	BG007	Building:One	Non Residential	Freehold
Streatham On Campus	BG008	Byrne House	Non Residential	Freehold
Streatham On Campus	BG009	Chagford	Residential	Other - UPP
Streatham On Campus	BG010	Christow	Residential	Other - UPP
Streatham On Campus	BG011	Clayden	Non Residential	Freehold
Streatham On Campus	BG012	Clydesdale Court - Flats 1-4	Residential	Freehold
Streatham On Campus	BG013	Clydesdale Court - Flats 5-8	Residential	Freehold
Streatham On Campus	BG014	Clydesdale Court - Flats 9-12 (TO BE RETIRED)	Residential	Freehold
Streatham On Campus	BG015	Clydesdale Court - Flats 13-16 (TO BE RETIRED)	Residential	Freehold
Streatham On Campus	BG016	Clydesdale House	Non Residential	Freehold
Streatham On Campus	BG017	Computer Building (Laver Data Centre)	Non Residential	Freehold
Streatham On Campus	BG018	Cornwall House	Non Residential	Freehold
Streatham On Campus	BG019	Cornwall House Pool	Non Residential	Freehold
Streatham On Campus	BG020	Sir Christopher Ondaatje Devon Cricket Centre	Non Residential	Freehold
Streatham On Campus	BG021	Devonshire House	Non Residential	Freehold
Streatham On Campus	BG026	Estate Services Centre	Non Residential	Freehold
Streatham On Campus	BG027	Family Centre	Non Residential	Freehold
Streatham On Campus	BG028	Forum	Non Residential	Freehold
Streatham On Campus	BG029	Garden Hill House	Residential	Freehold
Streatham On Campus	BG030	Geoffrey Pope	Non Residential	Freehold
Streatham On Campus	BG031	Great Hall	Non Residential	Freehold
Streatham On Campus	BG032	Harrison Building	Non Residential	Freehold
Streatham On Campus	BG033	Hatherly Building	Non Residential	Freehold
Streatham On Campus	BG034	Henry Wellcome Building for Biocatalysis	Non Residential	Freehold
Streatham On Campus	BG035	Higher Hoopern Cottage	Residential	Freehold
Streatham On Campus	BG036	Higher Hoopern Farm	Non Residential	Freehold
Streatham On Campus	BG038	Hope Hall	Non Residential	Freehold
Streatham On Campus	BG039	Innovation Centre	Non Residential	Freehold
Streatham On Campus	BG040	Innovation Centre - Phase 2	Non Residential	Freehold
Streatham On Campus	BG041	Institute of Arab and Islamic Studies	Non Residential	Freehold
Streatham On Campus	BG042	Kay Building (Labs)	Non Residential	Freehold
Streatham Off Campus	BG043	Kay House	Non Residential	Freehold
Streatham On Campus	BG044	Knightley	Non Residential	Freehold
Streatham On Campus	BG045	Lafrowda Cottage	Residential	Freehold
Streatham On Campus	BG046	Lafrowda House	Non Residential	Freehold
Streatham On Campus	BG047	Lafrowda House Annex	Non Residential	Freehold

Campus	Code	Name	Res / Non-Res	Tenure
Streatham On Campus	BG049	Laver Building	Non Residential	Freehold
Streatham On Campus	BG050	Lazenby	Non Residential	Freehold
Streatham On Campus	BG051	Forum Library	Non Residential	Freehold
Streatham On Campus	BG052	Lopes Cottage	Residential	Freehold
Streatham On Campus	BG053	Lopes Hall	Residential	Freehold
Streatham On Campus	BG054	Lydford	Residential	Other - UPP
Streatham On Campus	BG055	Mardon Hall	Residential	Freehold
Streatham On Campus	BG056	Mary Harris Memorial Chapel	Non Residential	Freehold
Streatham On Campus	BG057	Newman Building	Non Residential	Freehold
Streatham On Campus	BG058	Northcote House	Non Residential	Freehold
Streatham On Campus	BG059	Northcott Theatre	Non Residential	Freehold
Streatham On Campus	BG060	Old Library	Non Residential	Freehold
Streatham On Campus	BG061	Peter Chalk Centre	Non Residential	Freehold
Streatham On Campus	BG062	Physics Building	Non Residential	Freehold
Streatham On Campus	BG063	Queen's Building	Non Residential	Freehold
Streatham On Campus	BG064	Redcot	Residential	Freehold
Streatham On Campus	BG065	Reed Hall	Non Residential	Freehold
Streatham On Campus	BG066	Reed Mews Wellbeing	Non Residential	Freehold
Streatham On Campus	BG067	Reed Mews Health Centre	Non Residential	Freehold
Streatham On Campus	BG068	Roborough	Non Residential	Freehold
Streatham On Campus	BG069	Sports Hall	Non Residential	Freehold
Streatham On Campus	BG072	Streatham Court Old	Non Residential	Freehold
Streatham On Campus	BG073	Streatham Court New	Non Residential	Freehold
Streatham On Campus	BG074	Streatham Farm	Non Residential	Freehold
Streatham On Campus	BG075	Streatham Lodge	Residential	Freehold
Streatham On Campus	BG077	Tennis Centre	Non Residential	Freehold
Streatham On Campus	BG082	Washington Singer	Non Residential	Freehold
Streatham On Campus	BG083	Sir Henry Wellcome Bdg for Mood Disorders Research	Non Residential	Freehold
Streatham On Campus	BG084	Widecombe	Residential	Other - UPP
Streatham On Campus	BG085	Xfi Building	Non Residential	Freehold
St Luke's On Campus	BG096	Baring Court	Non Residential	Freehold
St Luke's On Campus	BG097	St Luke's Chapel	Non Residential	Freehold
St Luke's On Campus	BG099	Club Alley	Non Residential	Freehold
St Luke's On Campus	BG100	College House	Non Residential	Freehold
St Luke's On Campus	BG101	Dance Studio	Non Residential	Freehold
St Luke's On Campus	BG103	Haighton Library	Non Residential	Freehold
St Luke's On Campus	BG104	Holnicote Annexe	Non Residential	Freehold
St Luke's On Campus	BG105	Holnicote Wing	Non Residential	Freehold
St Luke's On Campus	BG108	North Cloisters	Non Residential	Freehold

Campus	Code	Name	Res / Non-Res	Tenure
St Luke's On Campus	BG109	Exeter Medical School Building	Non Residential	Freehold
St Luke's On Campus	BG110	Richards Building	Non Residential	Freehold
St Luke's On Campus	BG112	Smeall Building	Non Residential	Freehold
St Luke's On Campus	BG114	South Cloisters	Non Residential	Freehold
St Luke's On Campus	BG116	St Luke's Sports Centre	Non Residential	Freehold
St Luke's On Campus	BG117	Staff House	Non Residential	Freehold
St Luke's On Campus	BG118	Teaching Block	Non Residential	Freehold
Streatham On Campus	BG144	Living Systems Institute	Non Residential	Freehold
St Luke's Off Campus	BG145	Research, Innovation, Learning & Development Centre	Non Residential	Long leasehold
St Luke's Off Campus	BG146	Clinical Skills Resource Centre, RD & E, Heavitree	Non Residential	Leasehold
Streatham On Campus	BG147	Tensile Tennis Courts	Non Residential	Freehold
Streatham On Campus	BG149	Changing Pavilion	Non Residential	Freehold
Streatham On Campus	BG150	Russell Seal Fitness Centre	Non Residential	Freehold
Streatham On Campus	BG154	Helium Liquefier Building	Non Residential	Freehold
Streatham On Campus	BG155	Cornwall House Pool Changing Block	Non Residential	Freehold
Streatham On Campus	BG157	Life Support Systems Building	Non Residential	Freehold
Streatham On Campus	BG158	INTO Building	Non Residential	Other - INTO
Streatham On Campus	BG166	Water Based Hockey Pitch Irrigation Plant Room	Non Residential	Freehold
Streatham Off Campus	BG169	Engineering Research Centre	Non Residential	Leasehold
Streatham On Campus	BG173	Owlets	Non Residential	Freehold
St Luke's Off Campus	BG176	Mireille Gillings Neuroimaging Centre	Non Residential	Leasehold
Streatham On Campus	BG191	South West Institute of Technology	Non Residential	Freehold
Streatham On Campus	BG192	Creative Quadrant	Non Residential	Freehold
Streatham On Campus	BG193	Centre for Resilience in Environment, Water and Waste	Non Residential	Freehold
Streatham On Campus	BG194	Spreytonway UPP	Residential	Other - UPP
Streatham Off Campus	BG195	Moberly UPP	Residential	Other - UPP
Streatham On Campus	BK001	Clydesdale Rise - Block A	Residential	Freehold
Streatham On Campus	BK002	Clydesdale Rise - Block B	Residential	Freehold
Streatham On Campus	BK003	Clydesdale Rise - Block C	Residential	Freehold
Streatham On Campus	BK004	Holland Hall - Block A	Residential	Freehold
Streatham On Campus	BK005	Holland Hall - Block B	Residential	Freehold
Streatham On Campus	BK006	Holland Hall - Block C	Residential	Freehold
Streatham On Campus	BK007	Holland Hall - Block D	Residential	Freehold
Streatham On Campus	BK008	Holland Hall - Block E	Residential	Freehold
Streatham On Campus	BK009	Holland Hall - Block F	Residential	Freehold
Streatham On Campus	BK010	Lafrowda - Block E	Residential	Other - UPP
Streatham On Campus	BK011	Lafrowda - Block F	Residential	Other - UPP
Streatham On Campus	BK012	Lafrowda - Block G	Residential	Other - UPP

Campus	Code	Name	Res / Non-Res	Tenure
Streatham On Campus	BK013	Lafrowda - Block H	Residential	Other - UPP
Streatham On Campus	BK014	Lafrowda - Block N	Residential	Other - UPP
Streatham On Campus	BK015	Lafrowda - Block P	Residential	Other - UPP
Streatham On Campus	BK016	Lafrowda - Block Q	Residential	Other - UPP
Streatham On Campus	BK017	Lafrowda - Block R	Residential	Other - UPP
Streatham On Campus	BK021	Nash Grove - Block A	Residential	Freehold
Streatham On Campus	BK022	Nash Grove - Block B	Residential	Freehold
Streatham On Campus	BK023	Nash Grove - Block C	Residential	Freehold
Streatham On Campus	BK024	Nash Grove - Block D	Residential	Freehold
Streatham On Campus	BK025	Nash Grove - Block E	Residential	Freehold
Streatham On Campus	BK026	Nash Grove - Block F	Residential	Freehold
Streatham On Campus	BK027	Pennsylvania Court A	Residential	Freehold
Streatham On Campus	BK028	Pennsylvania Court B	Residential	Freehold
Streatham On Campus	BK029	Pennsylvania Court C	Residential	Freehold
Streatham On Campus	BK030	Pennsylvania Court D	Residential	Freehold
Streatham On Campus	BK031	Pennsylvania Court E	Residential	Freehold
Streatham On Campus	BK032	Pennsylvania Court F	Residential	Freehold
Streatham On Campus	BK033	Ransom Pickard - Block A	Residential	Freehold
Streatham On Campus	BK034	Ransom Pickard - Block B	Residential	Freehold
Streatham On Campus	BK035	Rowe House - Block ST	Residential	Other - UPP
Streatham On Campus	BK036	Rowe House - Block WX	Residential	Other - UPP
Streatham On Campus	BK037	Rowe House - Block YZ	Residential	Other - UPP
Streatham On Campus	BK096	Lafrowda - Block A/B	Residential	Other - UPP
Streatham On Campus	BK097	Lafrowda - Block C/D	Residential	Other - UPP
Streatham On Campus	BK098	Lafrowda - Block J	Residential	Other - UPP
Streatham On Campus	BK099	Lafrowda - Block K/L	Residential	Other - UPP
Streatham On Campus	BK100	Lafrowda - Block MA/MB	Residential	Other - UPP
Streatham On Campus	BK101	Lafrowda - Block S	Residential	Other - UPP
Streatham On Campus	BK102	Lafrowda - Block T	Residential	Other - UPP
Streatham Off Campus	BK103	UPP Duryard - Yeo House	Residential	Other - UPP
Streatham Off Campus	BK104	UPP Duryard - Teign House	Residential	Other - UPP
Streatham Off Campus	BK105	Birks - Block F	Residential	Other - UPP
Streatham Off Campus	BK106	Birks - Block G	Residential	Other - UPP
Streatham Off Campus	BK107	Birks - Block H	Residential	Other - UPP
Streatham Off Campus	BK108	Birks - Block J	Residential	Other - UPP
Streatham Off Campus	BK109	Birks - Block K	Residential	Other - UPP
Streatham Off Campus	BK110	Birks - Block L	Residential	Other - UPP
Streatham Off Campus	BK111	Birks - Block M	Residential	Other - UPP
Streatham Off Campus	BK112	Birks - Block N	Residential	Other - UPP
Streatham Off Campus	BK113	Birks - Block P	Residential	Other - UPP

Campus	Code	Name	Res / Non-Res	Tenure
Streatham Off Campus	BK114	Birks - Block Q	Residential	Other - UPP
Streatham Off Campus	BK115	INTO Duryard - Block Avon	Residential	Other - INTO
Streatham Off Campus	BK116	INTO Duryard - Block Bovey	Residential	Other - INTO
Streatham Off Campus	BK117	INTO Duryard - Block Creedy	Residential	Other - INTO
Streatham Off Campus	BK118	INTO Duryard - Block Dart	Residential	Other - INTO
Streatham Off Campus	BK119	INTO Duryard - Block Exe	Residential	Other - INTO
Streatham On Campus	BK120	UPP East Park - Block A	Residential	Other - UPP
Streatham On Campus	BK121	UPP East Park - Block B	Residential	Other - UPP
Streatham On Campus	BK122	UPP East Park - Block C	Residential	Other - UPP
Streatham On Campus	BK123	UPP East Park - Block D	Residential	Other - UPP
Streatham On Campus	BK124	UPP East Park - Block E	Residential	Other - UPP
Streatham On Campus	BK125	UPP East Park - Block F	Residential	Other - UPP
Streatham On Campus	BK126	UPP East Park - Block G	Residential	Other - UPP
Streatham On Campus	BK127	UPP East Park - Block H	Residential	Other - UPP
Streatham On Campus	BK128	UPP East Park - Block J	Residential	Other - UPP
Streatham On Campus	BK129	UPP East Park - Block K	Residential	Other - UPP
Streatham On Campus	BK130	UPP East Park - Block L	Residential	Other - UPP