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# University of Worcester
# Heat Decarbonisation Plan

211072

**Executive Summary Report**

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# 1.0 Executive Summary

## 1.1 Purpose of the Report

The University of Worcester (UoW) declared a Climate Emergency to improve sustainability and are committed to being Net Zero Carbon by 2030. In order to help achieve this target, the heating strategy for the Estate needs to be assessed with the end goal of moving away from the current strategy of individual gas fired boiler plant for each building, moving towards decarbonised energy centres for each campus with district heating networks, where feasible serving each building on the campus.

At present, due to the decarbonisation of the electricity grid and the UoW's move to a zero-carbon electricity tariff, proven heat pump technology currently offers the most efficient solution to providing low carbon heating to the buildings across the campuses.

In order to produce this document significant amount of background work was required for each of the 33No buildings located on University Campuses only, this included:

- Data Gathering – Meter Readings, Operational & Maintenance Manuals, As Built Information
- Mechanical & Electrical Surveys – Building & Plantrooms
- Thermographic Surveys
- Base Build Energy Modelling
- Intervention Modelling
- Digital Twin Pilot for the Sheila Scott Building.

The HDP is intended to be a live document to report status, define next steps and to track progress.

## 1.2 Existing Building Operation & Carbon Associated with Heat Reduction

Prior to any of the suggested interventions within this report, it is fundamental that all building heating systems are operating correctly and efficiently, buildings should be monitored using the BMS to verify the current blended return water temperature.

Following system monitoring, the first practical task for the site would be to seek out short circuits, absent TRV's and poor control routines that are currently resulting in high return water temperatures. Addressing the return water temperature will need the support of maintenance operatives and the incumbent BMS specialist to achieve this and undertake local modifications in buildings to address any issues identified, this will ensure that the existing building systems are compatible with Low Zero Carbon (LZC) technology connection and district heating networks, reducing the overall site return temperatures where possible.

The best form of reducing carbon associated with heat, is to not use the heat in the first instance, there are numerous ways of achieving this reduction:

- **Lower space temperature set point**, encouraging students and staff to increase their clothing levels. UoW are currently reviewing their heat and comfort policy with the view of implementing lower space temperatures across the Estate.

  https://www.worcester.ac.uk/documents/heating-and-comfort-policy.pdf
- **Reduce the operating hours of the heating systems**, avoiding the need to heat entire spaces and buildings to accommodate reduced occupancy levels during early mornings and late evenings. Encourage remote working and learning where feasible.
- **Reduce hot water circulation**, turning off the hot water circulation pumps during periods of no demand, this will reduce pipework losses and potential reduce the risk of overheating in the summer. Perhaps state times that buildings will not have hot water.
- **Hot water storage**, ensuring hot water is not stored at greater than 60degC.
- **Maximise space usage & occupancy**, co-ordinate timetabling where possible to ensure room occupancy is maximised during off peak periods, the Digital Twin Pilot will help determine occupancy usage and maximise the use of space.
- **Digital Twin Pilot feedback**, the University has implemented a cutting-edge digital twin pilot of the Sheila Scott building, to be used as a testbed in the monitoring of real-time granular data representing internal user focussed environmental conditions and its reaction to data-based change interventions aimed at reducing energy consumption and associated operational carbon emissions. The outcomes and benefits to be attained from the implementation of digital twin technology will further inform a viable business case to support its potential expansion across other building types.

*Input, review and alterations, required by Estates to ensure building operation is optimised and efficient.*

## 1.3 Recommended Existing Building Services Improvements

Prior to connecting buildings to an LZC technology and/or a district heating network, it is fundamental that the buildings heating systems are operating correctly, suggested tasks to be undertaken as detailed in the below table:

| Task | Resource |
|---|---|
| BMS monitoring to verify the current return temperature and zonal space temperatures | UoW Maintenance Operatives & BMS Incumbent |
| Install sub-meters on DHW circuit. | Mechanical Contractor / BMS Incumbent |
| Arrange for record drawings of the existing heating distribution systems to be carried out / services laser scanning. | Mechanical Consultant, Contractor or Specialist |
| Replace single pipework heating systems and convoluted pipework distribution runs. | Mechanical Contractor |
| Seek out short circuits, absent TRV'S & poor control routines. | UoW Maintenance Operatives & BMS Incumbent |
| Install heating zone control valves and space temperature sensors (wireless preferred) | Mechanical Contractor & BMS Incumbent |
| Install flow restriction devices on outlets such as showers and taps, to reduce the amount of hot water consumed and associated heat. | UoW Maintenance Operatives |
| Install insulation on exposed sections of heating and hot water pipework distribution, reducing pipework losses, | UoW Maintenance Operatives / Mechanical Contractor |

Table ES1 – Existing Building Improvements

**Refer to the individual building reports for specific improvements required for each building.**

## 1.4 Proposed Interventions & Existing Systems Improvements

### 1.4.1 Reduce Base Heat Load by Enhancing Building Fabric

Irrespective of buildings being existing or new build, reducing the base heating load by taking a fabric first approach is always encouraged, it is appreciated that improving the fabric of existing building stock can be costly, disruptive, and timely, this has been considered for the recommended decarbonisation plan.

The thermographic surveys undertaken have highlighted poor performing fabric and junctions on buildings across the Estate, this information can be used as a tool to tackle the worst offending building and specific elements of the building. As opposed to wholesale improvements of entire elements such as external wall which can be costly and disruptive, improvements that can be programmed as part of the Universities on-going building maintenance.

It is encouraged to improve fabric deficiencies as part of the on-going building maintenance to reduce the base heating load and associated energy prices. Furthermore, improving the thermal efficiency of wholesale elements is recommended as part of the on-going maintenance where feasible. A cost breakdown has been provided in section 15 for possible improvements which could be undertaken when feasible.

Discussions held with UoW have established that the buildings need to remain operational for the majority of the year, with disruptive works ideally being undertake during a 6 week period over the summer holidays. With prohibitive costs and disruptive works associated with upgrading wholesale fabric elements and changing heat emitters such as radiators and air handling unit heating coils, this limits the opportunity to provide a low-grade heating solution in the short term.

*Specialist input will be required for each building as summarised below:*

- *Building Surveyor, Builder and/or Architect, advice on wholesale replacement of building elements such as wall, roofs, etc. to establish improvement options and constraints posed by the existing buildings.*

  *The Thermographic Survey has highlighted fabric deficiencies, some of which the UoW Estates Department may be able to rectify, some deficiencies may require specialist advice from a builder, building surveyor or architect.*
- *Services Consultant, undertake calculations to establish carbon savings for the various fabric improvement options considered.*
- *Cost Consultant, to establish detailed cost for the various options considered.*

### 1.4.2 Heat Reduction Associated with Hot Water Generation

Site surveys and discussions with UoW have identified that some buildings hot water demand are no longer as high as they once were, with sanitaryware being removed over the years. Despite the buildings now being low hot water usage, large amount of stored water and extensive hot water distribution pipework remain, resulting in additional heat for cylinder and pipework losses.

It has also been identified that a large proportion of buildings, generally halls of residences have a high percentage of heat consumed associated with hot water generation.

Based on the above findings the following interventions are recommended to assist in reducing the heating load:

- Replace domestic hot water storage and distribution pipework with local electric water heaters where the requirement for storage no longer represents the buildings hot water demand.
- Where hot water storage is required to offset high peak periods, replace LTHW hot water generation with electric immersion heaters where the existing electrical load allows.
- Where storage is required on 'high hot water demand' buildings such as halls of residences, the provision of solar thermal panels is suggested to reduce the heat required for hot water generation.
- Ensure all hot water pipework distribution where remaining is adequately lagged to reduce pipework heat loss.

It is noted that hot water generation plant for the majority of the buildings is in good condition and well within their life expectancy. It would be cost prohibitive to replace the current hot water cylinders with cylinders with solar thermal and electric immersion capabilities, as part of the maintenance replacement strategy it is suggested that solar ready and electric immersion capable cylinders are provided.

**<u>Refer to the individual building reports for specific improvements required for each building.</u>**

*Specialist input will be required for each building as summarised below:*

- *Services Consultant, undertake hot water assessments to establish local hot water generation required, solar thermal requirement and associated electrical alterations required.*
- *Cost Consultant, to establish detailed cost for the various hot water alterations proposed.*

### 1.4.3 Standalone Buildings

There are several buildings that are remote from the 3No main campuses, these building are:

- Barrington House
- Forensic House
- Oldbury House
- Fern Halls
- Jenny Lind

Given the distance of the buildings from the proposed Energy Centres, connection to the district heating is not proposed, due to the extensive work that would be required to connect a small building load in relation to the wider UoW Estate.

A local commercial heat pump is proposed to each of the buildings, this will significantly reduce the carbon associated with the building. Given these buildings are student accommodation and relatively small, the occupancy is manageable, further investigation will be required at the next design stage to determine whether the existing heat emitters are capable of operation at lower system temperatures, or if wider, taller or triple panel radiators are required. This is a disruptive task, although replacements could be carried out as part of the normal life cycle refurbishment gateways.

The commercial heat pump needs to be coupled to a thermal store and provided with a secondary heat source for back-up to make up any shortfall, the existing boilers can be used as a top-up in the short term, when the gas boiler is at the end of its life, replaced by an electric boiler or immersion heater to ensure the hot water can be stored at 60degC.

**<u>Refer to the individual building reports for specific improvements required for each building.</u>**

*Specialist input will be required for each building as summarised below:*

- *Building Surveyor, Builder and/or Architect, advice on wholesale replacement of building elements such as wall, roofs, etc. to establish improvement options and constraints posed by the existing buildings.*

  *The Thermographic Survey has highlighted fabric deficiencies, some of which the UoW Estates Department may be able to rectify, some deficiencies may require specialist advice from a builder, building surveyor or architect.*
- *Services Consultant,* establish alterations to the heating and hot water systems and associated electrical alteration.
- *Cost Consultant, to establish detailed cost for the system alterations and heat pump installation.*

### 1.4.4 District Heating Networks

The proposal to provide district heating network(s) distributing heat to each of the buildings, emanating from a single energy centre or multiple energy centres depending on the route which UoW wish to proceed with. Serving multiple buildings using district heating networks(s) has the following benefits:

- Reduces the overall plant and space required over semi-decentralised and de-centralised systems and multiple areas of disruptive construction works.
- Diversified load, resulting on reduced overall heating loads and associated plant sizing.
- Avoids the need for multiple planning approval requirements.
- Avoids issues with acoustics for sleeping accommodation and noise sensitive buildings.
- Maintenance catchment area reduced.

In order to connect to a district heating network builders work and plantroom modifications will be required including the installation on a plate heat exchanger to provide a hydraulic break between the building and district heating network.

The heat metering data has highlighted that the existing boiler plant installed within the Edward Elgar building is significantly under utilised. The installed boiler and capacity is 4No. boilers @ 1200KW each, the peak metered heat delivery is 2320 kW. The individual heat demand from the remaining buildings on St. Johns Campus totals 1175 kW, therefore the total heat demand can be provided by the Edward Elgar boiler room whilst maintaining 100% capacity in the event of a boiler failing. The more buildings added to a central energy centre the further diversity is enhanced which results in further reduction in gas usage.

| Existing EE DH | C02 Saving (tonne) | % |
|---|---|---|
| Phase 1 - All Academic Buildings | 4.53 | 0.9% |
| Phase 2 All Student Accomdation exc AE Housmann & Elizabeth Brown | 11.9 | 1.5% |
| Phase 3 - All buildings connected | 13.8 | 1.7% |

The heat metering data has highlighted that the existing boiler plant installed within the Arena is significantly underutilised. The installed boiler and capacity is 3No. boilers @ 850KW each, the peak metered heat delivery is 480kW. The individual heat demand from the remaining buildings on Severn Campus totals 327 kW, therefore the total heat demand can be provided by the Arena boiler room whilst maintaining 100% capacity in the event of a boiler failing.

The carbon savings associated with connecting the Severn Campus building to the existing Arena is negligible.

It is recommended that UoW apply for Government funding available for extending the existing district heating system, all building will be ready to connect to a low zero carbon heat pump.

*Specialist input will be required as summarised below:*

- *Structural Engineer and Architect, advice on structural changes for incoming district heating mains to each building.*
- *Services Consultant, district heating network design, individual plantroom modifications and energy centre design including electrical upgrades.*
- *Cost Consultant, to establish detailed cost for the system alterations, district heating network and energy centre construction and installation.*

#### 1.4.5 Heating Generation

Several sources of heat generation were considered as part of the recommended heat decarbonation route, refer to section 4.1 which provides background information on the sources of heat which have been discounted.

The following sources of heat generation have been considered as feasible for UoW Estate.

- Commercial (Low Temperature) Air Source Heat Pumps
- Industrial (High Temperature) Air Source Heat Pumps
- (High Temperature) River Source Heat Pumps – Study Undertaken by Element Energy.

We would recommend that UoW continue to consider both Industrial (High Temperature) Air Source Pumps & River Source Heat Pump solutions in parallel. Both systems operate at high temperatures which minimises disruptive changes such as changing heat emitters and extensive fabric improvements, unlike the commercial low temperature solution which is key to UoW operation. This approach enables UoW to improve the fabric elements and change heat emitters as part of the on-going building maintenance, which will eventually allow heating systems to operate at lower temperatures, improving the overall efficiency of the heat pumps.

The UoW should continue to explore the river source heat pump option, with the detailed proposal by Element Energy progressed once funding is available in April. Once the detailed appraisal has been finalised, UoW can consider the best route and pros and cons of becoming an energy provider or remaining as an energy customer.

The option within this report provides UoW with a scalable, manageable, and modular approach using multiple energy centres and district heating networks for each campus. UoW will own and manage the energy centres and district heating networks, with a phased approach plantrooms can be flexible to include new and emerging technologies. The capital investment to develop the heat pump energy centres and district heating networks can be phased to meet the UoW's investment plan and funding streams, thus being a 'no regret' investment approach without being tied into contracts.

The phasing of the plan for Industrial Air Source Heat Pumps will result in the transition of individual building gas-based heating systems to electricity driven heat pump-based district heating networks for each campus.

The following graphs and tables indicated the % carbon reduction and running costs associated with all 3 campuses per year.

Figures ES1 & ES2 indicates the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 2 – Extend Existing District Heating from Edward Elgar

   As can be seen from the below chart these slightly improve the carbon emission, results in a **carbon saving of 14 tonnes/annum,** and results in **reduced utility costs by £5,200/annum**
3. Iteration 3 – Replacing individual gas fired boilers for industrial air source heat pumps via a district heating network.

   As can be seen from the below chart these completely removes the requirement for gas heating, results in a **carbon saving of 606 tonnes/annum,** although results in **higher utility costs of £415,000/annum**
4. Iteration 4 – Undertaking all fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 214 tonnes/annum,** also results in **reduced utility costs by £293,000/annum.**
5. Iteration 5 – Undertaking emitters replacement to improve the efficiency of ASHPs and reduce utility costs.

   As can be seen from the below chart undertaking the heaters replacement, results in a further **carbon saving of 72 tonnes/annum,** also results in further **reduced utility costs by £99,000/annum.**

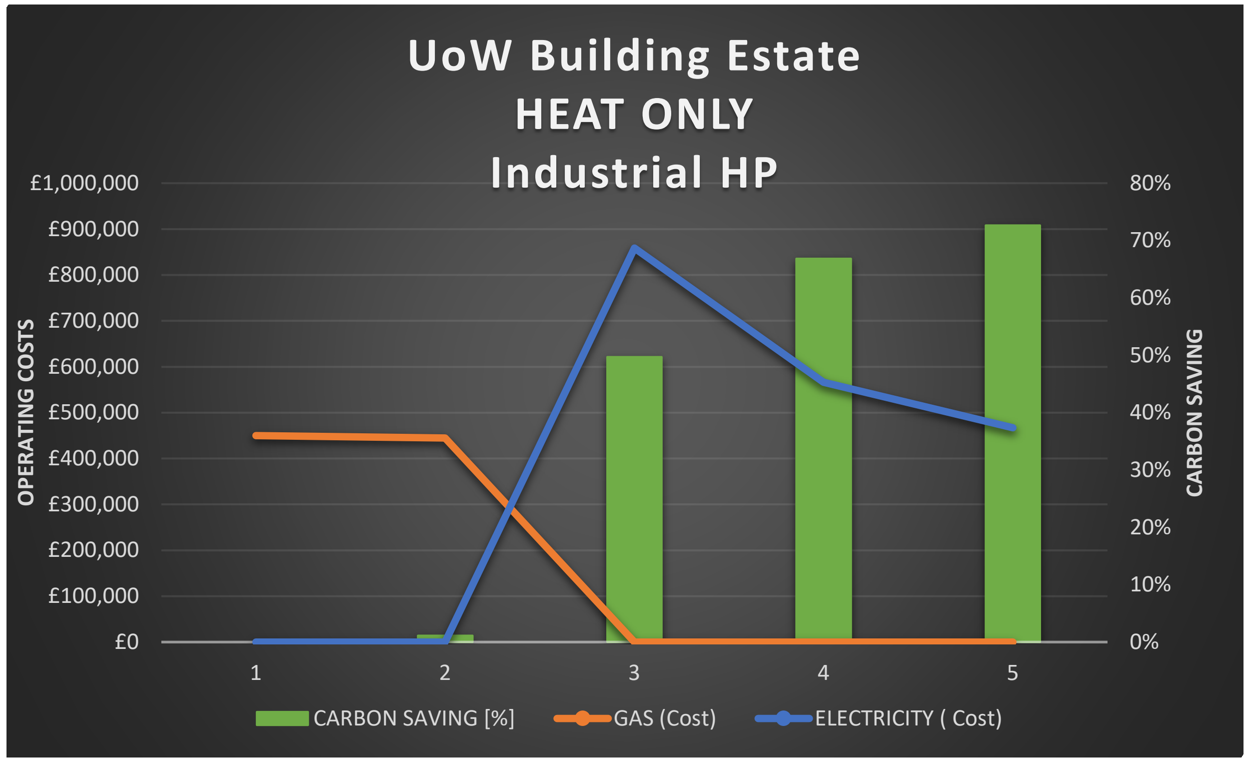



Figure ES1 – Building Estate – Industrial Air Source Heat Pump – Operating Costs

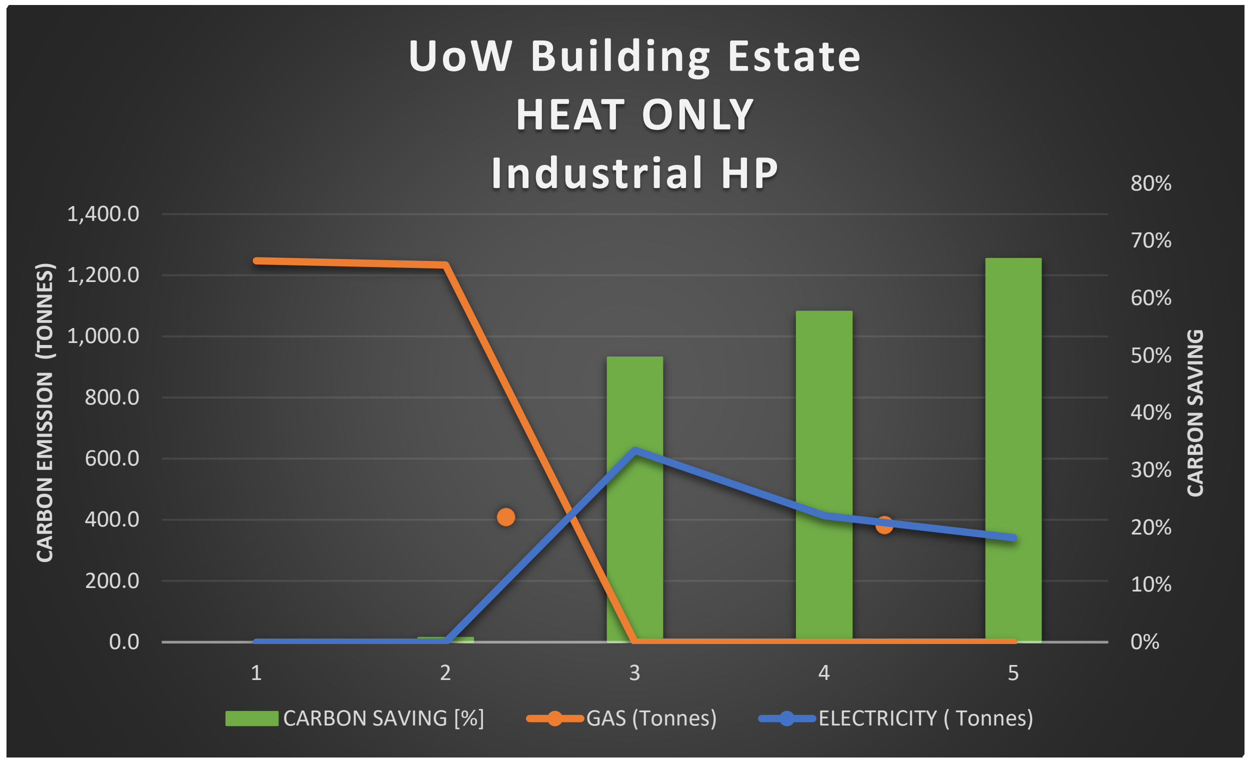



Figure ES2 – Building Estate – Industrial Air Source Heat Pump – Carbon Reduction

#### 1.4.6 Long Term Target – Industrial Heat Pumps Operating at Lower Temperature

To further decarbonise the heat generated across the Estate, it is key to reduce the heating system operating temperatures of the district heating network resulting in an increased efficiency of the high temperature heat pumps resulting in further carbon savings and reduced energy prices. Installing high temperature heat pumps offers the greatest carbon saving over all interventions, UoW can benefit from these carbon savings whilst addressing fabric deficiencies and improving the fabric elements.

Fabric improvements can be disruptive, expensive and can affect the operation of buildings, although fabric improvements are fundamental to reduce the base heating load and offset future rises in energy costs, fabric improvements could be carried out as part of the normal life cycle refurbishment gateways. The most effective and sustainable way to reduce carbon associated with heat or electricity for that matter is to not use it in the first place.

In addition the above, operating a district heating network at lower temperatures significantly extends the longevity of the pipework, operating at circa 50degC as oppose to 80degC, can result in a lifespan of approximately 3 times longer.

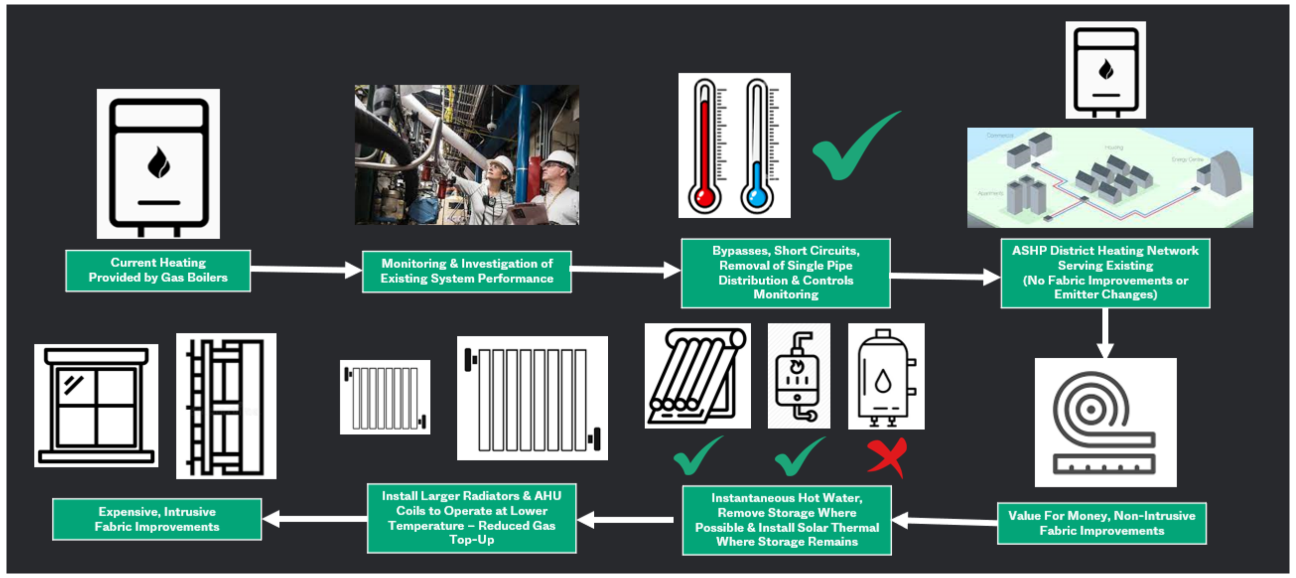



Figure ES3 – Building Intervention Roadmap

## 1.5 Cost Plan

### 1.5.1 Existing System Modifications / Improvements

The suggested modifications to the existing systems are required prior to connecting buildings to an LZC technology and/or a district heating network, it is fundamental that the buildings heating systems are operating correctly. It isn't possible to associate a carbon saving with each of the suggested alterations, improvements should result in a reduction in carbon, it is recommended that UoW monitor any changes.

The costs provided in the below table are high level at this stage, once the extent of works required for each building is established following intrusive survey works the cost plan can be refined by a cost consultant at the next stage of design.

### 1.5.2 Building Interventions

The main intervention proposed for UoW is providing an Energy Centre for each campus, each campus will have a district heating network. All works associated with the individual plantroom alterations have been included within the Campus Energy Centres & District Heating Cost Plan.

Additional interventions proposed on a building-by-building basis have been indicated in the below table.

Stripping out pipework routed within the ground and ceiling voids can be disruptive and costly, if completed as a standalone element of work. Costs associated with strip-out works could be minimised by draining the systems down, isolating and leaving in situ.

The costs provided in the below table are high level at this stage, once the extent of works required for each building is established following intrusive survey works the cost plan can be refined by a cost consultant at the next stage of design.

### 1.5.3 Future Fabric Improvements and Radiator Replacement

The below table provides high level costs associated with making wholesale improvements to the various construction elements, those highlighted in green offer the best carbon saving and value for money and should be targeted in the first instance.

To further increase the efficiency of the industrial air source heat pump the radiators and heating coils should be replacement with the larger equivalent to run at lower temperatures, these works can be undertaken as part of the on-going system maintenance.

# University of Worcester Heat Decarbonisation Plan

| | | | TOTAL BUDGET COST: Future Building Fabric Improvement Options | | | | | | TOTAL BUDGET COST: Future Heat Emitter Replacement | | TOTAL BUDGET COST: Existing Systems Rectification | | | | | | | | TOTAL BUDGET COST: Hot Water Alterations | | | | TOTAL BUDGET COST: Commercial ASHP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location | GIFAm2 | External Wall Cladding | Internal Wall Cladding | Roof/Loft Insulation | Windbreak Lobby | Secondary Glazing | Double Glazing | Radiator Replacement | AHU Heater Battery & MVHR Replacement | Existing BMS System Interrogation & Monitoring | Install Domestic Hot Water Sub-Meters | Record Drawings Production | Replace Single Pipe Heating Systems | Seeking Shorts Circuits, Missing TRV'S, Poor Control Routines Etc | Install Heating Zone Controls Valves and Sensors | Install Flow Restrictor On Water Outlets | Install Insulation on Exposed Heating & Hot Water Pipework | Solar Thermal Panels | Replacements Cylinder(s) | Central Hot Water Strip-Out | Electric Hot Water Installation | Standalone Commercial Heat Pump & Thermal Store |
| 1 | Abberley House | 546 | £77,225 | n/a | n/a | n/a | n/a | £73,040 | £13,650 | n/a | £2,000 | £500 | £3,000 | n/a | £2,000 | £2,730 | £100 | £13,650 | n/a | n/a | n/a | n/a | n/a |
| 2 | AE Houseman Hall | 3165 | n/a | n/a | £37,333 | n/a | n/a | £183,398 | £79,125 | n/a | £3,000 | £500 | £4,000 | n/a | £3,000 | £15,825 | £300 | £79,125 | n/a | n/a | n/a | n/a | n/a |
| 3 | Ankerdine Hall | 819 | £83,732 | n/a | n/a | n/a | n/a | £90,943 | £20,475 | n/a | £2,000 | £500 | £3,000 | n/a | £2,000 | £4,095 | £100 | £20,475 | n/a | n/a | n/a | n/a | n/a |
| 4 | Art House | 1855 | n/a | n/a | n/a | n/a | n/a | n/a | £46,375 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | £200 | n/a | n/a | n/a | n/a | n/a | n/a |
| 5 | Avon Hall | 2388 | £275,584 | n/a | £28,463 | n/a | n/a | £344,575 | £59,700 | n/a | £3,000 | £500 | £4,000 | n/a | £3,000 | £11,940 | £300 | £59,700 | £32,663 | n/a | n/a | n/a | n/a |
| 6 | Barrington House | 672 | n/a | £71,500 | £6,546 | n/a | n/a | £65,395 | £16,800 | n/a | £1,500 | £500 | £2,000 | n/a | £1,500 | £3,360 | £100 | £16,800 | £28,283 | £15,000 | n/a | n/a | £30,000 |
| 7 | Binyon Building | 2058 | £178,375 | n/a | £24,636 | n/a | n/a | £184,415 | £51,450 | n/a | £2,500 | £500 | £3,500 | £205,800 | £2,500 | £10,290 | £200 | £51,450 | n/a | n/a | £20,580 | £4,000 | n/a |
| 8 | Binyon North | 360 | £96,734 | n/a | £4,807 | n/a | n/a | £102,190 | £9,000 | n/a | £1,000 | £500 | £2,000 | £36,000 | £1,000 | £1,800 | £100 | £9,000 | n/a | n/a | £3,600 | £1,500 | n/a |
| 9 | Bishop Bosel Hall | 3834 | n/a | n/a | £24,636 | n/a | n/a | £301,950 | £95,850 | n/a | £3,000 | £500 | n/a | n/a | £3,000 | £19,170 | £300 | £95,850 | n/a | n/a | n/a | n/a | n/a |
| 10 | Chancellor Hall | 3236 | n/a | n/a | £28,810 | n/a | n/a | £274,120 | £80,900 | n/a | £3,000 | £500 | n/a | n/a | £3,000 | £16,180 | £300 | £80,900 | n/a | n/a | n/a | n/a | n/a |
| 11 | Charles Darwin | 1586 | n/a | n/a | £29,158 | £81,906 | n/a | £149,270 | £39,650 | £20,000 | £2,500 | £500 | £4,000 | n/a | £2,500 | £7,930 | £200 | £39,650 | n/a | n/a | n/a | n/a | n/a |
| 12 | Charles Hastings Building | 5612 | n/a | £693,013 | n/a | £56,733 | £202,125 | n/a | £140,300 | £40,000 | £4,000 | £500 | n/a | n/a | £4,000 | £28,060 | £500 | £140,300 | n/a | n/a | n/a | n/a | n/a |
| 13 | Conference Centre | 663 | £85,712 | n/a | £23,766 | n/a | n/a | £200,860 | £16,575 | n/a | £2,500 | £500 | £4,000 | £66,300 | £2,500 | £3,315 | £100 | £16,575 | n/a | n/a | £6,630 | £7,500 | n/a |
| 14 | Edward Elgar | 13480 | £1,376,416 | n/a | £274,062 | £353,551 | n/a | £1,517,600 | £337,000 | £25,000 | £7,500 | £500 | £15,000 | £1,348,000 | £7,500 | £67,400 | £1,000 | £337,000 | n/a | n/a | n/a | n/a | n/a |
| 15 | Evesham & Pershore Hall | 1401 | £148,292 | n/a | n/a | n/a | n/a | £114,730 | £35,025 | n/a | £3,000 | £500 | £4,000 | n/a | £3,000 | £7,005 | £200 | £35,025 | n/a | n/a | n/a | n/a | n/a |
| 16 | Fern Hall | 760 | n/a | £112,059 | £13,852 | n/a | n/a | £65,395 | £19,000 | n/a | £1,500 | £500 | £2,000 | n/a | £1,500 | £3,800 | £100 | £19,000 | n/a | n/a | n/a | n/a | £30,000 |
| 17 | Forensic House | 218 | £55,295 | n/a | £5,360 | n/a | n/a | £61,023 | £5,450 | n/a | £1,500 | £500 | £2,000 | n/a | £1,500 | £1,090 | £100 | £5,450 | n/a | n/a | n/a | n/a | £10,000 |
| 18 | Hines Building | 1410 | £144,048 | n/a | n/a | £38,962 | n/a | n/a | £35,250 | n/a | £2,500 | £500 | £3,500 | £141,000 | £2,500 | £7,050 | £200 | £35,250 | n/a | n/a | £14,100 | £3,000 | n/a |
| 19 | Jenny Lind | 4031 | £483,341 | n/a | £52,229 | n/a | n/a | £232,375 | £100,775 | n/a | £4,000 | £500 | £6,000 | n/a | £4,000 | £20,155 | £300 | £100,775 | n/a | n/a | £40,310 | £19,500 | n/a |
| 20 | Ledbury Hall | 2275 | £362,787 | n/a | £32,115 | n/a | n/a | £423,390 | £56,875 | n/a | £3,000 | £500 | £4,000 | n/a | £3,000 | £11,375 | £300 | £56,875 | £31,563 | n/a | n/a | n/a | n/a |
| 21 | Mulberry House | 936 | n/a | £182,294 | n/a | £56,733 | £36,053 | n/a | £23,400 | n/a | £2,000 | £500 | n/a | n/a | £2,000 | £4,680 | £100 | £23,400 | n/a | n/a | £9,360 | £4,500 | n/a |
| 22 | Oldbury House | 330 | n/a | £150,639 | £4,807 | n/a | n/a | £51,480 | £8,250 | n/a | £1,500 | £500 | £2,000 | n/a | £1,500 | £1,650 | £100 | £8,250 | n/a | n/a | n/a | n/a | £7,500 |
| 23 | Peirson Centre | 3244 | £215,981 | n/a | £58,554 | n/a | n/a | £274,120 | £81,100 | £30,000 | £4,000 | £500 | n/a | n/a | £4,000 | £16,220 | £300 | £81,100 | n/a | n/a | £32,440 | £4,500 | n/a |
| 24 | Riverside Building | 1835 | n/a | £193,292 | £59,534 | n/a | n/a | £118,635 | £45,875 | £45,000 | £3,000 | £500 | n/a | n/a | £3,000 | £9,175 | £200 | £45,875 | n/a | n/a | n/a | n/a | n/a |
| 25 | Sheila Scott Building | 1118 | £112,425 | n/a | £39,421 | n/a | n/a | £93,225 | £27,950 | n/a | £3,000 | £500 | £4,000 | n/a | £3,000 | £5,590 | £100 | £27,950 | n/a | n/a | £11,180 | £13,500 | n/a |
| 26 | Sports Centre | 2475 | £251,631 | n/a | £38,551 | £38,962 | n/a | £437,305 | £61,875 | £20,000 | £3,000 | £500 | n/a | n/a | £3,000 | £12,375 | £300 | £61,875 | n/a | n/a | n/a | n/a | n/a |
| 27 | Student's Union | 1274 | £180,998 | n/a | £39,421 | £123,844 | n/a | £278,548 | £31,850 | £10,000 | £2,500 | £500 | £3,500 | n/a | £2,500 | £6,370 | £200 | £31,850 | n/a | n/a | £12,740 | £6,000 | n/a |
| 28 | The Garage | 712 | £131,550 | n/a | £6,546 | n/a | n/a | £160,380 | £17,800 | n/a | £1,500 | £500 | £2,000 | n/a | £1,500 | £3,560 | £100 | £17,800 | n/a | n/a | £7,120 | £4,500 | n/a |
| 29 | Thomas Telford | 360 | £38,917 | n/a | £13,156 | £38,962 | n/a | £114,098 | £9,000 | n/a | £1,500 | £500 | £2,000 | n/a | £1,500 | £1,800 | £100 | £9,000 | n/a | n/a | £3,600 | £4,500 | n/a |
| 30 | University Arena | 9256 | n/a | £431,856 | £167,391 | n/a | n/a | £524,700 | £231,400 | £70,000 | £5,000 | £500 | n/a | n/a | £5,000 | £46,280 | £500 | £231,400 | n/a | n/a | n/a | n/a | n/a |
| 31 | Vesta Tilley Hall | 1050 | £87,622 | n/a | n/a | n/a | n/a | £355,080 | £26,250 | n/a | £2,000 | £500 | £3,000 | n/a | £2,000 | £5,250 | £200 | £26,250 | n/a | n/a | n/a | n/a | n/a |
| 32 | Windrush Hall | 679 | £61,893 | n/a | n/a | n/a | n/a | £250,718 | £16,975 | n/a | £2,000 | £500 | £3,000 | n/a | £2,000 | £3,395 | £100 | £16,975 | n/a | n/a | n/a | n/a | n/a |
| 33 | Woodbury Building | 3589 | £494,608 | n/a | £125,520 | n/a | n/a | £534,710 | £89,725 | n/a | £4,000 | £500 | £6,000 | £358,900 | £4,000 | £17,945 | £500 | £89,725 | n/a | n/a | £35,890 | £12,000 | n/a |
| | **TOTAL by Option** | | **£4,943,165** | **£1,834,652** | **£1,138,674** | **£789,652** | **£238,178** | **£7,577,665** | **£1,930,675** | **£260,000** | **£88,000** | **£16,000** | **£91,500** | **£2,156,000** | **£88,000** | **£376,860** | **£7,800** | **£1,884,300** | **£92,508** | **£15,000** | **£197,550** | **£85,000** | **£77,500** |

Table ES2 – Individual Building Intervention Cost Summary

Note: The above table does not include duplicate buildings the duplicate building, costs for duplicate buildings should be added to the cost plan / budget.

### 1.5.4 Campus Energy Centres & District Heating Networks

The below tables provide a budget cost breakdown for the works associated with providing an Energy Centre and district heating network to each of the 3No campuses.

St Johns Campus

| | |
|---|---|
| HV Electrical Infrastructure Works | £ 265,000 |
| LV Electrical Works | £ 230,000 |
| BMS / Controls | £ 340,000 |
| ASHP Supply & Installation | £ 1,390,000 |
| Mechanical & Electrical Plantroom Installation | £ 630,000 |
| District Heating Network | £ 2,452,750 |
| Energy Centre Construction | £ 375,000 |
| Individual Boiler Room Alterations | £ 690,000 |
| | **£ 6,372,750** |
| Contractors General Preliminaries @ 15% | £ 955,913 |
| Contractors Oh&p @ 8% | £ 509,820 |
| | **£ 1,465,733** |
| Design & Pricing Contingency @ 2.5% | £ 195,962 |
| Construction Risk Contingency @ 5% | £ 391,924 |
| | **£ 587,886** |
| Total Budget Cost | **£ 8,426,369** |

Severn Campus

| | |
|---|---|
| HV Electrical Infrastructure Works | £ 210,000 |
| LV Electrical Works | £ 215,000 |
| BMS / Controls | £ 280,000 |
| ASHP Supply & Installation | £ 565,000 |
| Mechanical & Electrical Plantroom Installation | £ 480,000 |
| District Heating Network | £ 665,000 |
| Energy Centre Construction | £ 300,000 |
| Individual Boiler Room Alterations | £ 260,000 |
| | **£ 2,975,000** |
| Contractors General Preliminaries @ 15% | £ 446,250 |
| Contractors Oh&p @ 8% | £ 238,000 |
| | **£ 684,250** |
| Design & Pricing Contingency @ 2.5% | £ 91,481 |
| Construction Risk Contingency @ 5% | £ 182,963 |
| | **£ 274,444** |
| Total Budget Cost | **£ 3,933,694** |

City Campus

| | |
|---|---|
| HV Electrical Infrastructure Works | £ 50,000 |
| LV Electrical Works | £ 215,000 |
| BMS / Controls | £ 280,000 |
| ASHP Supply & Installation | £ 750,000 |
| Mechanical & Electrical Plantroom Installation | £ 560,000 |
| District Heating Network | £ 670,250 |
| Energy Centre Construction | £ 300,000 |
| Individual Boiler Room Alterations | £ 180,000 |
| | **£ 3,005,250** |
| Contractors General Preliminaries @ 15% | £ 450,788 |
| Contractors Oh&p @ 8% | £ 240,420 |
| | **£ 691,208** |
| Design & Pricing Contingency @ 2.5% | £ 92,411 |
| Construction Risk Contingency @ 5% | £ 184,823 |
| | **£ 277,234** |
| Total Budget Cost | **£ 3,973,692** |

- The installation costs of the HV infrastructure does nor include reinforcements of the WDO infrastructure
- Costs have been benchmarked against similar schemes
- Cost based on 1Q22
- Cost is for industrial air source heat pumps
- Excludes design and professional fees
- Excludes inflation
- Excludes VAT

| Campus name | Heat generated by gas, carbon footprint tCO2e | DHN carbon footprint tCO2e | Improvement | DHN system cost, £ | £1000/tCO2e |
|---|---|---|---|---|---|
| St Johns | 815 | 418 | 49% | £8,426,369 | 21.3 / tCO2e |
| Severn | 188 | 91 | 52% | £3,933,694 | 40.2 / tCO2e |
| City | 245 | 118 | 51% | £3,973,692 | 31.6 / tCO2e |
| **Total** | **1,248** | **627** | **50%** | **£16,333,755** | **26.1 / tCO2e** |

Table ES3 – Campus Energy Centre Carbon Reduction & Costs

## 1.6 River Source Heat Pump – Element Energy Appraisal

### 1.6.1 Commentary on Proposal Element Energy Proposal

UoW have obtained partial funding from BEIS to appoint an independent consultant Element Energy to complete an initial feasibility study to use the River Severn as primary heat source. The proposal is to construct a central energy centre located on Severn Campus, this will house Water Source Heat Pumps, thermal storage and top-up / back up electric boilers.

The water source heat pumps will generate high temperature heat up to 80degC, heating is then distributed via a district heating network to each building located across the 3No campuses. There are also ambitions to provide heat beyond UoW Estate, with options to extend the network local housing associations, Worcester County Council and potentially other stakeholders.

Similar to the industrial air source heat pumps operating at higher temperature avoids the need to immediately improve building fabric improvements and heat emitter changes to reduce the base heating load and reduce operating temperatures.

We would recommend that UoW continue to consider both Industrial (High Temperature) Air Source Pumps & River Source Heat Pump solutions in parallel. Both systems operate at high temperatures which minimises disruptive changes such as changing heat emitters and extensive fabric improvements, unlike the commercial low temperature solution which is key to UoW operation. This approach enables UoW to improve the fabric elements and change heat emitters as part of the on-going building maintenance, which will eventually allow heating systems to operate at lower temperatures, improving the overall efficiency of the heat pumps.

The UoW should continue to explore the river source heat pump option, with the detailed proposal by Element Energy progressed once funding is available in April. Once the detailed appraisal has been finalised, UoW can consider the best route and pros and cons of becoming an energy provider or remaining as an energy customer.

The option within this report provides UoW with a scalable, manageable, and modular approach using multiple energy centres and district heating networks for each campus. UoW will own and manage the energy centres and district heating networks, with a phased approach plantrooms can be flexible to include new and emerging technologies. The capital investment to develop the heat pump energy centres and district heating networks can be phased to meet the UoW's investment plan and funding streams, thus being a 'no regret' investment approach without being tied into contracts.

### 1.6.2 River Source Heat Pump Risks

Whilst the River Source Heat Pump is a good solution, greatly reducing UoW carbon footprint, there are a number of risks associated with the proposal that need to be carefully considered by the various stakeholders at UoW.

- WCC, Sanctuary & other stakeholders could pull out at any time prior to exchanging contracts, affecting the cost model and revenue.
- Large upfront investment of £20M+.
- 50% maximum funding available, this could be less resulting in the University covering the shortfall.
- With the University owning the energy centre and district heating network, will the University have a dedicated maintenance team or will this be contracted to an external company?
- Limitation on the amount of abstraction from the river, this could limit the expansion of the district heating network, impact income and increase electricity bills due to the electric boilers operating more frequently.
- If fabric improvements are made to buildings, the baseline load will be reduced potentially affecting the cost plans and revenue.
- BEIS could withdraw funding at any time, during the detailed proposal or design.
- Environmental agency could refuse the scheme during the approval process.
- Plantroom positioned in the lowest risk area for flooding, this still remains a risk.
- Pipework routes across the river, authorities & planning approval.
- New technology could emerge making this a better solution for the University.

### 1.6.3 River Source Heat Pump & Air Source Heat Pump Comparison

At this stage there are two potential options to be further considered by UoW, the River Source Heat Pump solution generating heat from a single Energy Centre serving all campuses or Industrial Air Source Heat Pump generating heat from several Energy Centres, one per campus.

The below tables highlight the advantages and disadvantages for each of the options.

| Industrial Air Source Heat Pump | |
|---|---|
| **Advantages** | **Disadvantages** |
| All district heating distribution is located on campus, therefore no approvals required from third parties / authorities. | No revenue streams |
| No large upfront investment required, works can be phased to suit funding. | Lower co-efficient of performance when operating at higher temperature, although we recommend UoW make fabric improvements and changes emitters in the future to lower the operating temperatures, improve system COP and extend the longevity of the district heating network. |
| Scalable, manageable and modular approach using multiple energy centres and district heating networks for each campus. | During winter air source heat pumps undergoing de-frost circles to prevent the units freezing, multiple units are required to ensure heat is provided to the network. |
| Flexibility for connecting emerging & future technology, providing green energy and to the University and other buildings. | Multiple plantrooms constructed taking up more overall space and increased capital cost. |
| Green technology in line with the Governments guidance to generate heat via heat pumps utilising heating networks where possible. | |

| River Source Heat Pump | |
|---|---|
| **Advantages** | **Disadvantages** |
| Potential revenue stream | Risks associated with approvals from the Council, Network Rail & Environmental Agency, particularly the pipework crossing. |
| Green technology in line with the Governments guidance to generate heat via heat pumps utilising heating networks where possible. | Large upfront investment. |
| Single plantroom construction and reduced maintenance catchment area. | Demolishing or improving existing building stock may result in penalties as this will reduce the amount of energy consumed and contracted to by the University. |
| Funding available if the energy centre serves County Council buildings. | If the Energy Centre is managed by a third-party supplier UoW will be tied into conditions such as return temperature, usage etc if not met could result in penalties as this will reduce the amount of energy consumed and contracted to by the University. |

#### 1.6.4 River Source Heat Pump Energy Operator VS Energy Customer

The River Source Heat Pump proposal has options to extend the provision of heat distribution beyond the UoW Estate, with options to extend the network to local housing associations, Worcester County Council and potentially other stakeholders.

The proposal is to locate the Energy Centre on Severn Campus, as such UoW have the option to become an energy supplier, not only to the UoW Estate but also the local stakeholders interested.

There are a number of factors that need to be carefully considered by UoW if becoming a local Energy Supplier is attractive.

| UoW As Energy Operator | | UoW As Energy Customer | |
|---|---|---|---|
| **Advantages** | **Disadvantages** | **Advantages** | **Disadvantages** |
| Revenue stream | Risks associated with approvals from the Council, Network Rail & Environmental Agency, particularly the pipework crossing. | Energy generation owned & maintained by others. | No revenue streams |
| Green credentials | Large upfront investment. | Energy supply guaranteed by others. | University will be tied into a contract, failing to meet specific requirements will results in financial penalties. |
| Flexibility for connecting emerging & future technology, providing green energy and to the University and other buildings. | No current expertise within the University to become an energy provider. | No large upfront investment required. | Demolishing existing building stock could result in penalties as this will reduce the amount of energy consumed and contracted to by the University. |
| | Increased / dedicated workforce required. | | The University will be limited to the future technologies they are able to implement across the campuses. |
| | Risk of stakeholders pulling out prior to contractual agreements. | | |

## 1.7 Digital Twin Pilot – Sheila Scott Building

The University of Worcester has embarked on a decarbonisation journey targeting 42no buildings. In support of this the University has appointed CPW to develop a 3D digital twin pilot of the Sheila Scott building.

The Sheila Scott building is a single storey teaching block constructed during the 1980's and is currently used as a Nursing Clinical Skills and Simulation Centre. It comprises training rooms, administrative, utility and plant spaces. used in accordance with a pre-booked schedule by the Registrar. Indoor environmental conditions, namely temperature and ventilation are managed by the Estates and Energy management departments.

A digital twin in simple terms is a virtual digital representation of a physical asset hosted on a server. The physical asset in this case being the Sheila Scott building with the virtual model serving as a real time digital counterpart that is updated in real-time from a host of sensors located within the building. Data collected from the digital twin can be used for planning, operations, cost management, space utilisation management and the design of future buildings and spaces.

Digital twins are now widely used in manufacturing, supply chain, healthcare, retail and financial services industries. It is now being taken up by the construction and infrastructure sectors where it is being used to understand how building assets, power and heat networks are performing in real-time, thereby allowing performance to be tweaked to optimise efficiencies, energy consumption, reduce carbon emissions and inform future capital expenditure.

The digital twin may operate at various levels of complexity, allowing simple manual control of the physical heating assets, allowing gathered data to enable machine learning and AI to help decision making. It may also be used as a remote training tool, assisting maintenance and replacement strategies. Advanced digital twins may be used for simulation and prototyping applications.

The University currently uses an Integrated Work management System (IWMS) called Archibus which is independent to the digital twin. However, data from the digital twin will be presented in a data holding table hosted on the Microsoft Azure cloud server from which Archibus can access data when required for the production of reports or further analysis.

The digital twin developed is aligned with the latest digital twin standards to allow the following as a minimum:

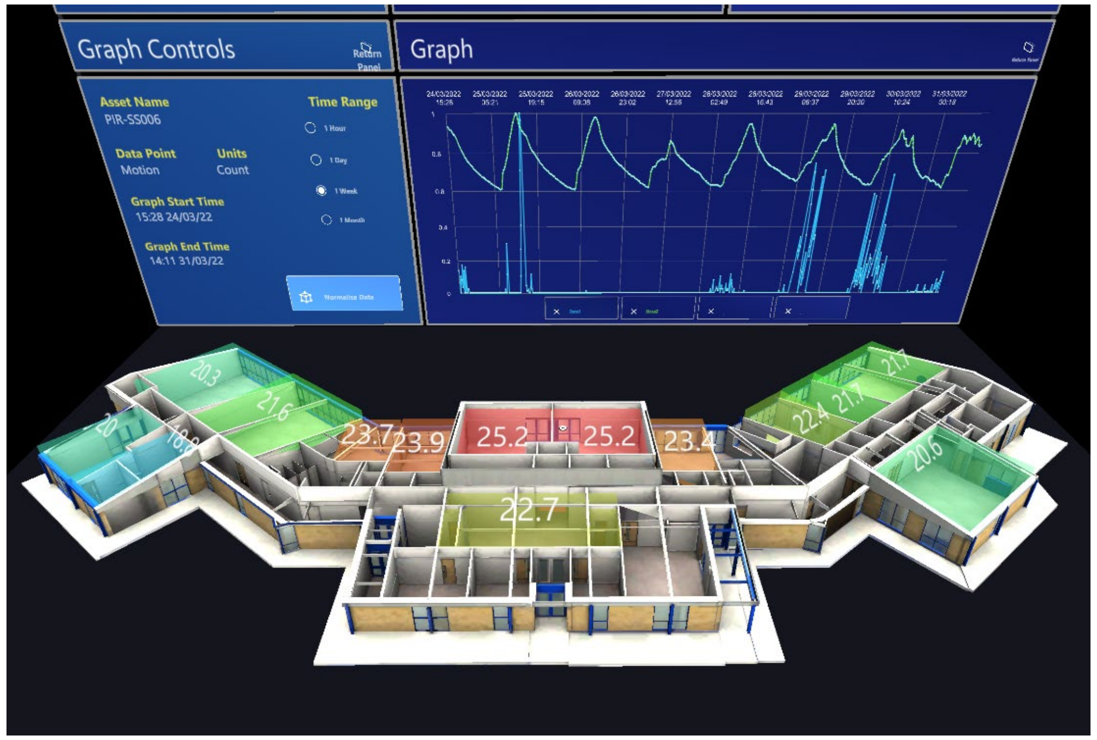
1. Connection to and understanding of the building through the collection of data
2. Analyse and learn from the data
3. Use insights to make informed decisions
4. Continually optimise buildings and spaces
5. Effectively measure performance and consider success rates
6. Innovate and transform

The client's brief has allowed for the following sensors and devices to be installed, to provide real time data to the digital twin.

| Space description | Quantity | Device added |
|---|---|---|
| Offices | 8 | Indoor air quality sensors for:<br>Temperature, humidity and CO2 levels;<br>Occupancy detectors |
| Seminar rooms | 6 | |
| Skills rooms | 4 | |
| Corridors and lobbies (circulation) | 8 | People counter |

The digital twin will also represent a repository for heating related assets within the building. This can be used as a resource for asset management, maintenance planning, training, and preventive maintenance records.

Access will allow 3D visualisation and interrogation of the digital twin spatially, graphically or by tabular analysis of the historical and live data streams, as indicated below. The data streams will currently include live indoor air quality and presence as indicated above.




GUI showing room temperatures; Graph shows correlation between temperature and occupancy

Further opportunities have been identified whereby the functionality and benefits of the digital twin may be significantly enhanced by the interfacing with further systems which are present within the Sheila Scott building. These are summarized below:

| Future digital twin actor | System name and status | Benefit |
|---|---|---|
| Automatic energy meter readers for electricity and gas | Dynamat2050<br>The system is widespread at the University. An API is required to allow interfacing of the metered data with the digital twin. | Will allow real time energy consumption based on the granularity of the meter readings, allowing alerts and automatic counter measures. |
| Environmental standalone heating control system | Bosch<br>The data from this controller is uploaded onto the Bosch cloud server in Germany. | Will allow real time control of fuel for heating in response to space usage, and live environmental conditions. |
| UoW Energy market and carbon emissions platform | TEC<br>This data is available on request via email or web browser. | Allow the automatic display carbon footprint figures based on the live carbon factors of gas and electricity |

## 1.8 Recommendations & Conclusion

- The proposal to achieve substantial carbon emission reductions using heat pump technology utilising district heating networks along with several systems interventions and is viable and recommended to the UoW as a roadmap to their Net Zero Carbon aspiration.
- The proposal to extend existing and provide new district heating network(s) to heat each building, emanating from a single or multiple energy centres depending on the route which UoW wish to proceed with. Serving multiple buildings using district heating networks(s) has the following benefits:
  - Reduces the overall space and plant required over semi-decentralised and de-centralised systems and multiple locations of disruptive construction works.
  - Reduces the overall costs over semi-decentralised and de-centralised systems and multiple locations of disruptive construction works.
  - Avoids the need for multiple planning approval applications.
  - Avoids issues with acoustics for sleeping accommodation and noise sensitive buildings.
  - Maintenance catchment area reduced.
- In terms of heat generation, there are several options available to UoW:
  - Industrial (High Temperature) Air Source Heat Pumps
  - Commercial (Low Temperature) Air Source Heat Pumps
  - (High Temperature) River Source Heat Pumps

  We would recommend that UoW continue to consider both Industrial (High Temperature) Air Source Pumps & River Source Heat Pump solutions in parallel. Both systems operate at high temperatures which minimises disruptive changes such as changing heat emitters and extensive fabric improvements, unlike the commercial low temperature solution which is key to UoW operation. This approach enables UoW to improve the fabric elements and change heat emitters as part of the on-going building maintenance, which will eventually allow heating systems to operate at lower temperatures, improving the overall efficiency of the heat pumps.
- The UoW should continue to explore the river source heat pump option, with the detailed proposal by Element Energy progressed once funding is available in April. Once the detailed appraisal has been finalised, UoW can consider the best route and pros and cons of becoming an energy provider or remaining as an energy customer.
- The option within this report provides UoW with a scalable, manageable and modular approach using multiple energy centres and district heating networks for each campus. UoW will own and manage the energy centres and district heating networks, with a phased approach plantrooms can be flexible to include new and emerging technologies. The capital investment to develop the heat pump energy centres and district heating networks can be phased to meet the UoW's investment plan and funding streams, thus being a 'no regret' investment approach without being tied into contracts.
- Appoint the relevant parties to provide advice and assess/confirm the system alterations and fabric improvements on a building by building basis including:
  - Investigate, interrogate and monitor the existing systems to ensure they are operating correctly, efficiently and as designed.
  - Following the investigation works, undertake recommended remedial works identified for the existing system to ensure they are fit to connect to a district heating network(s).
  - Rectify easy win fabric deficiencies identified as part of the thermographic survey which will reduce heat loss and associated carbon.
- It is envisaged that a period of 1 – 3 years will be required to implement the previous 3 items raised, this will allow UoW to monitor emerging technologies, funding streams and ultimately finalise their decarbonise approach.
- Achievable carbon reduction possibilities:
  - Industrial Air Source Heat Pump, reducing carbon by 606 Tonnes / annum at a cost of £16,586,263 or £26.3K/Ton Co2
  - Industrial Air Source Heat Pump, with fabric improvements and radiators changes reducing carbon by 907 Tonnes / annum at a cost of £35,038,923 or £38.6K/Ton Co2
- Fabric improvements, although disruptive, costly, timely and can affect the operation of buildings, due to the adverse factors, UoW are reluctant to carry out immediate wholesale improvements to the existing building stock. Fabric improvements are recommended as part of the on-going building maintenance to further reduce the base heating load and offset future rises in energy costs. The most effective and sustainable way to reducing carbon associated with heat or electricity for that matter is to consume it in the first place.

## 2.0 Introduction

# University of Worcester Heat Decarbonisation Plan

The University of Worcester (UoW) declared a Climate Emergency to improve sustainability and are committed to being Net Zero Carbon by 2030. In order to help achieve this target, the heating strategy for the estate needs to move away from the existing gas fired heating to a decarbonised heating network.

CPW have been appointed to provide a heat decarbonisation plan (HDP) for the UoW Estate formed of 3No campuses and various remote buildings, totalling to 42No buildings.

At present, due to the decarbonisation of the electricity grid, and the University's move to a zero-carbon electricity tariff, heat pump technology currently offers the most efficient solution to provide low carbon heat to the buildings.

The Estate currently consists of 3No campuses; St Johns Campus, Severn Campus & City Campus, there are also several standalone buildings remote from the campuses. The buildings consist of halls of residences, academic and office buildings, all varying in age some buildings constructed in the 1700's and are of a listed nature, most buildings range from 1940-2000's, the remaining buildings are fairly modern constructed between 2000 – 2009.

Fabric improvements have been made to buildings constructed prior to 2000, notwithstanding this a significant proportion of the building stock has poor thermal performance due to the deficiencies in construction methods compared to high fabric performance methods used today. Detailed aspects of poor performing fabric and junctions are evident from the thermographic survey completed for each building, this helps highlight specific areas of weakness and improvements that can be targeted as part of the Universities on-going building maintenance.

Most of the buildings have standalone plantrooms, consisting of natural gas boilers generating heat for space heating, hot water generation and air handling plant. Avon Hall & Ledbury Hall share a boiler room, Edward Elgar serves several buildings local to the boiler room providing a mini district heating network.

The various heating systems associated with each building generally operate at higher temperatures up to 82degC, heat emitters are generally radiators, some buildings utilise fan coil units and underfloor heating. Most buildings have indirect hot water cylinders served from a dedicated constant temperature heating circuit.

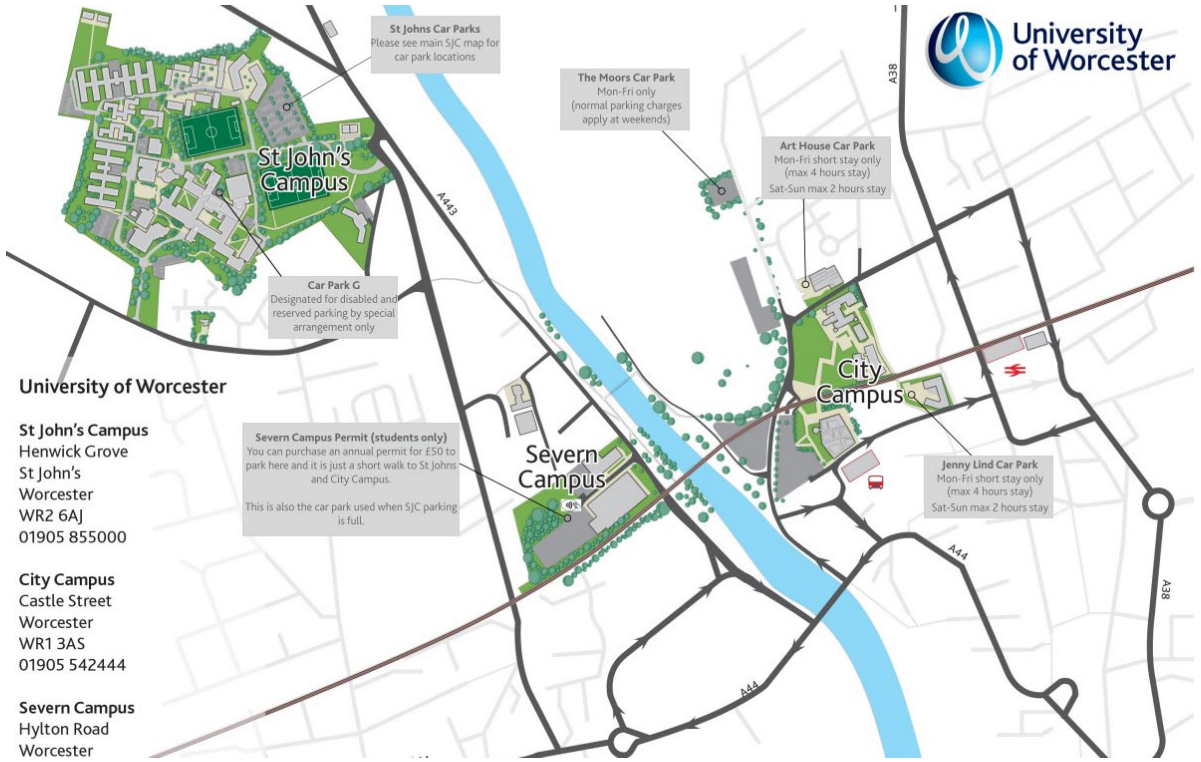



Figure 1 – Overall University of Worcester Campus Map

Current industry direction of travel is a useful barometer on the relevance of the solutions proposed within this report.

The 2021 Building Regulations for England emphasises a fabric first approach to reduce primary energy use and carbon emissions, and the alignment of buildings with a heat pump future focusing upon low temperature hot water (LTHW) compatible with efficient heat pumps.

The recently published CIBSE Code of Practice CP 1 again focuses on making district heating efficient, low temperature operation and compatible with future systems, heat pumps primarily but keeping pathways open.

The recently opened Green Heat Network Fund operated by BEIS states a core metric of 100gCO2e/kWh thermal energy delivered to consumer as a carbon gate for funding eligibility.

Seminars and panel session by various built environment professional institutions, industry bodies, and other MEP consultants, all agree with a general trend toward the achievement of decarbonisation with a demand reduction approach, coupled with low carbon heat pump technology, to drive the way we build and serve buildings in a low carbon and sustainable solution.

The fundamental paradigm shift that is being proposed at UoW is very much aligned with this agenda and has been structured to keep the UoW's options as open as possible, thereby facilitating the application of emerging and future technology related to smart integration and energy solutions.

Heat pumps are a proven solution for the electrification of buildings and enable the current gas-fired heating system to be replaced by a low carbon technology, offering a large carbon reduction.

## 3.0 Report Methodology

The methodology employed in this Heat Decarbonisation Plan is based on the established be lean, be clean, be green energy hierarchy with particular emphasis on ensuring that greenhouse gas emitting fuel sources are eliminated or at least minimised. Further measures may then be employed to mitigate the effects of residual carbon emissions. The overall objective being to define a roadmap for the achievement of a full functional building with net zero carbon emissions.

By net zero carbon, we mean that the amount of carbon emissions associated with the buildings annual operational energy is zero; this being achieved using low carbon and/or renewable energy technologies and using carbon removal methods for any residual emissions.

In summary the report shall address the following strategic actions:

- Demand reduction
- Efficient supply of energy
- Use of low carbon and renewable energy technologies

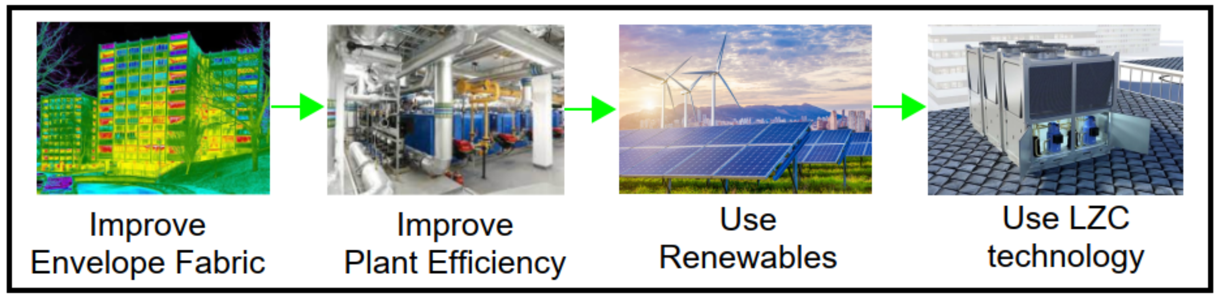



Figure 2 – Indicative Delivery Roadmap

## 4.0 Calculation Methodology

Energy demand calculations are based on the gas consumption metering data supplied by the University via the automatic meter reading system, Dynamat2050, used by the University. Since gas is the primary fuel for heating, half hourly gas consumption data was downloaded for the year 2019. This year was chosen to reflect consumption full occupancy and normal behavioural use patterns of consumption, avoiding years affected by the Covid-19 pandemic. When 2019 data was inconclusive, then 2018 data was used.

This data was reviewed to identify and compensate for inconsistencies due to meter failure, which were seen to result in delayed data downloads, amalgamated readings which were non-representative of real demand and gaps in data.

The adjusted half hourly data was then input into specialist energy systems analysis software, “EnergyPro” to build a model of the existing heating systems and simulate performance of the plant to match the demands established by the metered data. In the absence of HH data, then the annual gas energy consumption was modelled using real weather data for Worcester and standard use profiles for the building type.

Alternative heat energy generation systems where then modelled, using manufacturers heat pump performance data to generate realistic COP’s based on historical weather record data for each hour of the year, therefore allowing a more realistic seasonal efficiency for the heat pumps to be considered.

The building fabric analysis was performed using the Passivehaus performance platform (PHPP) as a building energy simulation tool to model the buildings physical parameters, thermal performances of each component, weather dependency, heating and ventilations systems and location to determine the existing energy performance and the effects on this, of various fabric improvement interventions. These interventions included upgrades to wall, windows, roofs in support of a fabric first approach to recue overall energy demand. The reduction in calculated energy consumption for each intervention was then used to reduce the meter data used to model the alternative low carbon energy generation plant.

## 5.0 Digital Twin Pilot

### 5.1 Introduction

The University of Worcester has embarked on a decarbonisation journey targeting 42no buildings located on the City, Severn and St Johns Campuses. In support of the decarbonisation strategy the University has appointed CPW to develop a digital twin pilot of the Sheila Scott building on the St John campus with the objectives being to reduce energy consumption and associated operational carbon emissions.

The University has selected the Sheila Scott as the target building for the digital twin pilot, to be used as a testbed and future showcase of the outcomes and benefits to be attained from the implementation of digital twin technology. It aims to do this by way of data collection, data analytics and pattern recognition to inform of potential building system operational interventions to achieve the objectives.

Refer to the appended digital twin report for further detail.

### 5.2 Digital Twin Overview

A digital twin in simple terms is a virtual digital representation of a physical asset hosted on a server. The physical asset in this case is the Sheila Scott building and the virtual model of it serves as a real time digital counterpart that is updated in real-time from a host of sensors located within the building. Data collected from digital twin can be used for planning, operations, cost management, space utilisation management and the design of future buildings.

Digital twins are now widely used in manufacturing, supply chain, healthcare, retail and financial services industries. It is now being taken up by the construction and infrastructure sectors where it is being used to understand how building assets, power and heat networks are performing in real-time, thereby allowing performance to be tweaked to optimise efficiencies, energy consumption, reduce carbon emissions and inform future capital expenditure.

The digital twin may operate at various levels of complexity, allowing simple manual control of the physical heating assets, allowing gathered data to enable machine learning and AI to help decision making. It may also be used as a remote training tool, assisting maintenance and replacement strategies. Advanced digital twins may be used for simulation and prototyping applications.

### 5.3 Sheila Scott Building Digital Twin Development

A digital twin requires a detailed 3D model of the asset to be represented. As there were no digital architectural or engineering computer aided drawing (CAD) files of the building, on which to base the digital twin, a 3D laser scan of the building was carried out internally and externally to produce an accurate 3D data representation (Point cloud) of the building upon which a 3D  building information model (BIM) model could be constructed. The BIM product used for the model was the construction industry standard, Autodesk Revit.

3D Point cloud representation of the Sheila Scott building

Once the 3D Revit model was constructed, it was then populated with asset identifiers to provide a building information model (BIM) with enhanced data content representative of the University's asset records. The assets for this project are heating related which means that boilers, pumps, hot water cylinders and emitters have their associated data embedded within the model.. This now represents a foundation level digital twin which could be navigated and interrogated on demand.

To raise the functionality of the digital twin and develop an operational interactive environment, various sensors are added to the building which transmit live data to a digital twin IoT hub allowing users to visualise the live relational asset that mirrors reality. The IoT hub is the cloud based platform used to host the model. In this case Microsoft Azure is used as the platform. This now represents a intermediate level digital twin which could be used for real time data analytics at the point of need.

The digital twin may operate at various levels of complexity, allowing simple manual control of the physical heating assets, using gathered data to enable machine learning and AI to help decision making. It may also be used as a remote training tool, assisting maintenance and replacement strategies. Advanced digital twins may be used for simulation and prototyping uses.

The graphical user interface (GUI) for the digital twin is an augmented reality headset, from which the digital twin model may be visualised, interrogated, and analysed. The Microsoft HoloLens AR headset has been used as the GUI for this project.

To decide on how the data received from the sensors will be presented within the GUI and the type of analysis to be made available, we held a number of meetings with the University stakeholders to determine the specific uses or use cases that they were aiming to achieve. The stakeholders are the people, departments, teams, or groups who may directly or indirectly be affected by the Digital Twin. This process is described further within the report.

In summary the digital twin will allow:

1. Connect to and understand buildings through the collection of data
2. Analyse and learn from the data
3. Use insights to make informed decisions
4. Continually optimise buildings and spaces
5. Effectively measure performance and consider success rates
6. Innovate and transform

The ITT for campus energy audits and digital strategy pilot listed the following requirements: under Lot 3 – Pilot digital twin and decarbonisation strategy.

**Part A**
Implement a digital twin pilot project in Sheila Scott Building based on finding from 'Stage 1 Improvement Report, June 2021' The project must include

1) As-built, survey of the Shelia Scott building to capture existing building fabric, structure and key heating assets (production & emitters) by utilising the latest laser technology.
2) As-built 3D modelling of the Shelia Scott building including the following –
   a) Visible building structure and fabric components (walls, windows, doors, floors, ceilings, roof, beams, columns),
   b) Plant room,
   c) Heat emitters and visible distribution,
   d) Lighting fixtures
3) The attribution of data within the modelled environment, including key information relating to maintainable assets (heat-related).
4) Hardware supply and install –
   a) Occupancy sensors x 15
   b) Thermostats x 10
   c) CO2 Sensors 10
   d) People counter x 5
   e) Gateways x 4
5) Communications and implementation of the above hardware to a designated IoT Hub (ARRIA), to support the translation of raw data into a useable and readable format within the UoW's management system (Archibus) and BMS (Trend).
6) The implementation of the completed Building Information Model within the University's Digital Twin environment (Archibus).
7) The University will upgrade its current Archibus license to allow the integration of Smart Cloud IoT and Graphical Workflow Engine add-ons. Please allow for providing training to the University on the use and implementation of the pilot project within Archibus.

## 5.4 Sheila Scott Building

The Sheila Scott building is a single storey teaching block constructed during the 1980's and is currently used as a Clinical Skills and Simulation Centre. Before being acquired by the University it was a primary school and therefore featured a simple architectural layout and non-complex building services systems.

The Sheila Scott Building is located on the east side of St Johns Campus forming part of the wider Worcester University estate and was originally constructed in the 1980s.

Since construction there have been no building extensions or amendments, nor has there been any fabric improvements since.

The thermal performance of the building envelop elements is significantly below the thermal performance standards expected today, with a current DEC rating of C 53.

The buildings' space heating and domestic hot water is generated from 2no. 100kW natural gas fired condensing boilers, directly feeding heating circuits with the domestic hot water (DHW) being generated via indirect hot water cylinders. The heating system is regularly maintained and according to the maintenance records achieves good combustion efficiencies and appears to be in good working order.

Heat is provided to internal spaces using a mixture of single and double panel radiators, overdoor heaters, fan convector units and radiant panels.

Energy consumption metering data indicates the following annual operational electricity and gas consumption figures and their associated carbon footprint. It should be noted that gas is used for space and water heating only, with the small kitchen using electric appliances for light cooking.

| **Annual Consumption metric (2019)** | **Electricity** | **Gas** |
|---|---|---|
| Energy consumption (kWh) | 47,103 | 36,269 |
| Carbon emission (tonne CO2e) | 10 | 6.6 |
| **Total scope 2 carbon footprint (tonne CO2e)** | 16.6 | |

The Sheila Scott building comprises of training rooms, administrative, utility and plant spaces. Rooms are used in accordance with a pre-booked schedule by the Registrar and the indoor environmental conditions, namely temperature and ventilation are managed by the Estates and Energy management departments.

The rooms are served by a central heating system (no cooling) and are naturally ventilated, supplemented with some local extract ventilation. The areas to be digitally twined include.

| **Ref.** | **Space description** | **Quantity** | **Device added** |
|---|---|---|---|
| 1 | Offices | 8 | yes |
| 2 | Corridors and lobbies (circulation) | 8 | yes |
| 3 | WC's and shower rooms | 4 | no |
| 4 | Technical rooms (plant, server, electrical and meter rooms) | 4 | yes |
| 5 | Seminar rooms | 6 | yes |
| 6 | Skills rooms | 4 | yes |
| 7 | Storerooms | 13 | no |

## 5.5 Sheila Scott Building Sensors and Devices

The client's brief has allowed for the following sensors and devices to be installed, to provide real time data to the digital twin. The final location, type and detailed function of the sensors are as shown on the sensor layout and data sheets (refer to appendix).

| Ref. | Device description | Location | Quantity | Type | Function |
|---|---|---|---|---|---|
| 1 | Indoor air quality sensor | Rooms and lobby | 10 | wireless | Combined temperature, humidity and CO2 sensor |
| 2 | Occupancy detector | Rooms | 15 | wireless | IR detector to detect movement |
| 3 | People counter | Circulation | 5 | wireless | Break beam people counter for bi-directional travel |
| 4 | Smart server | Plantroom | 1 | wired | Local processing and connectivity to University network |
| 5 | Wireless gateway | Plantroom | 1 | Wireless and wired | Data connectivity with field devices |

Digital twin hardware

Field device layout

Bi-directional beam break people counter

Indoor Air Quality sensor


Occupancy detector

Examples of field device

## 5.6 Digital Twin Architecture

The digital twin architecture is similar to any smart asset, in that it comprises of field devices, communication gateways and a remote IoT hub for storage and processing. The field devices may be sensors, detectors or actuators located around the building, selected to fulfil the specific use case scenarios. These are generally easy to deploy as many are battery operated and wireless, and therefore negates any wiring and power supply requirements.

The field devices communicate over an encrypted local long range proprietary wireless data network (LoRaWAN) with gateways and local servers strategically located within the building. These are connected over the external University data network via the internet and VPN to the cloud based Microsoft Azure platform where the high level processing, machine learning and AI algorithms use the field data to satisfy the use case outcomes.

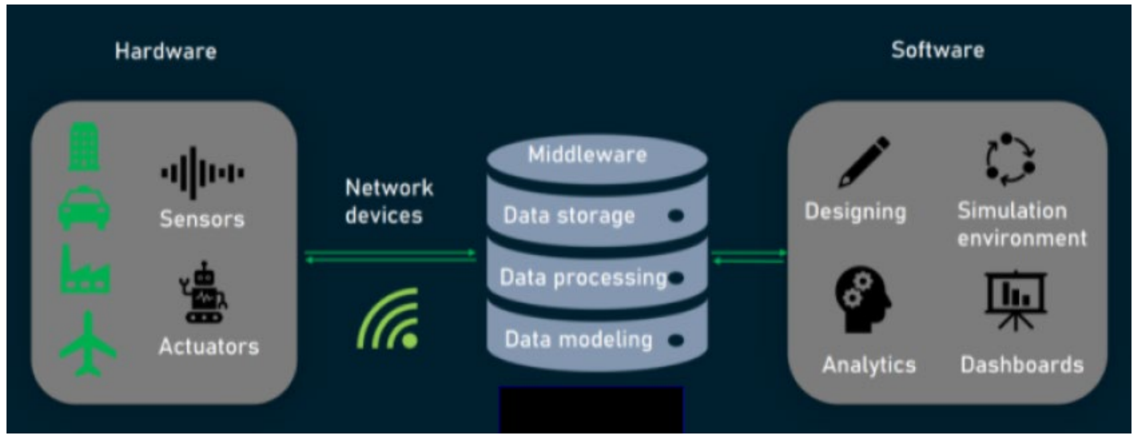



Figure 2 – Digital Twin typical architecture

## 5.7 Digital Twin Behaviour -Use Cases

The use case is a written description of how users will perform tasks in the digital twin. From a user's point of view, it outlines the behaviour of the digital twin (the system) as it responds to a user request. Each use case is represented as a sequence of simple steps, beginning with a user's goal and ending when that goal is fulfilled.

The use case template has been completed with input from the following parties to develop a robust set of guidance documents for the development of the digital twin system and its graphical user interface (GUI).

The use cases are defined by the stakeholders and involve the actors as described below:

- Stakeholders – the people who will be directly or indirectly affected by the use case.
- Actors – person, system or entity that is involved in the process to be completed by the Digital Twin.

## 5.8 Actors and Stakeholders

The actors are the people, system or entity that is involved in the process to be actioned by the Digital Twin. This may include the user of the Digital Twin who is examining people traffic data to understand the movement frequency or may be a data system that is pushing data into the Digital Twin.

The stakeholders are the people, departments, teams, or groups who may directly or indirectly be affected by the Digital Twin use case and may therefore have an interest in the outcome of the use case. Identification of all stakeholders was recommended to the University to ensure that the Digital Twin design fulfils expectations, as additional requirements may become apparent that were not obvious or mentioned by the users. These additional requirements may be achievable using the current hardware.The current actors for the Sheila Scott Digital Twin are understood to be:

- Stakeholders
- Archibus integrated workplace management system (IWMS)
- Sensors and detectors

Potential future actors that have been identified by CPW, but not mentioned within the clients' brief include the following:

- Automatic meter readings system (Dynamat)
- Environmental heating system controller (Bosch)
- UoW Energy market and carbon emissions platform (TEC)
- Lighting control system (Honeywell)
- Fire alarm system (Honeywell)
- Access control and security system (Salto)
- UoW weather station

The current stakeholders for the Sheila Scott DT are understood to be:

- Sustainability team
- Service Development/Facilities
- Information Technology (IT)
- Academic Registrar
- Energy management team

Potential future stakeholders that have been identified by CPW, but have not been involved in the development of the Digital Twin use cases include the following:

- Estates
- Facilities Management
- Health and Safety
- Security
- Operations
- Users (lecturer, Clinical technicians, students)

## 5.9 Use Case Overview

The use case is a written description of how users will perform tasks in the digital twin. From the user's perspective the use case is a summarised breakdown of the behaviour of the digital twin (the system) as it responds to a user request. Each use case is represented as a sequence of simple steps, beginning with a user's objective or organisational benefit to be achieved and ending when that goal is fulfilled i.e. the main success scenario.

The use case templates below have been completed following brief workshop sessions with the stakeholders and should be considered as working progress. A completed use case is intended to inform and manage the client's expectations and to provide details to the developers for the delivery of the Digital Twin user interfaces and data processing requirements amongst other uses.

Brief details for a typical simplified use case template is outlined below, followed by specific use cases developed with the client. The use case template is flexible and may be simplified or be more complex depending on the application.

| Ref | Use Case Descriptor | Details |
|---|---|---|
| 1.0 | ID | short title with active verb phrase |
| 1.1 | Description | One to two sentences that briefly describe the use case, including the primary actor's goal |
| 1.2 | Primary Actor | Designate the actor whose goal is satisfied in this use case, and has the most significant interest in the outcome |
| 1.3 | Supporting/Additional Actors | List other actors that play a supporting role in the use case and impact the outcome |
| 1.4 | Stakeholders | List the various entities who may not directly interact with the system but they may have an interest in the outcome of the use case. |
| 1.6 | Organisational Benefit | The expected value that the organisation will receive from having the functionality described |
| 1.7 | Trigger | Describe the event that initiates the use case |
| 1.12 | Frequency | Indicate how often the use case is expected to occur. This information aids designers and developers in understanding data capacity requirements |
| 1.13 | Special Requirements | Describe any additional factors that impact the execution of the use case. These could be environmental, regulatory, organisational or market-driven in nature |

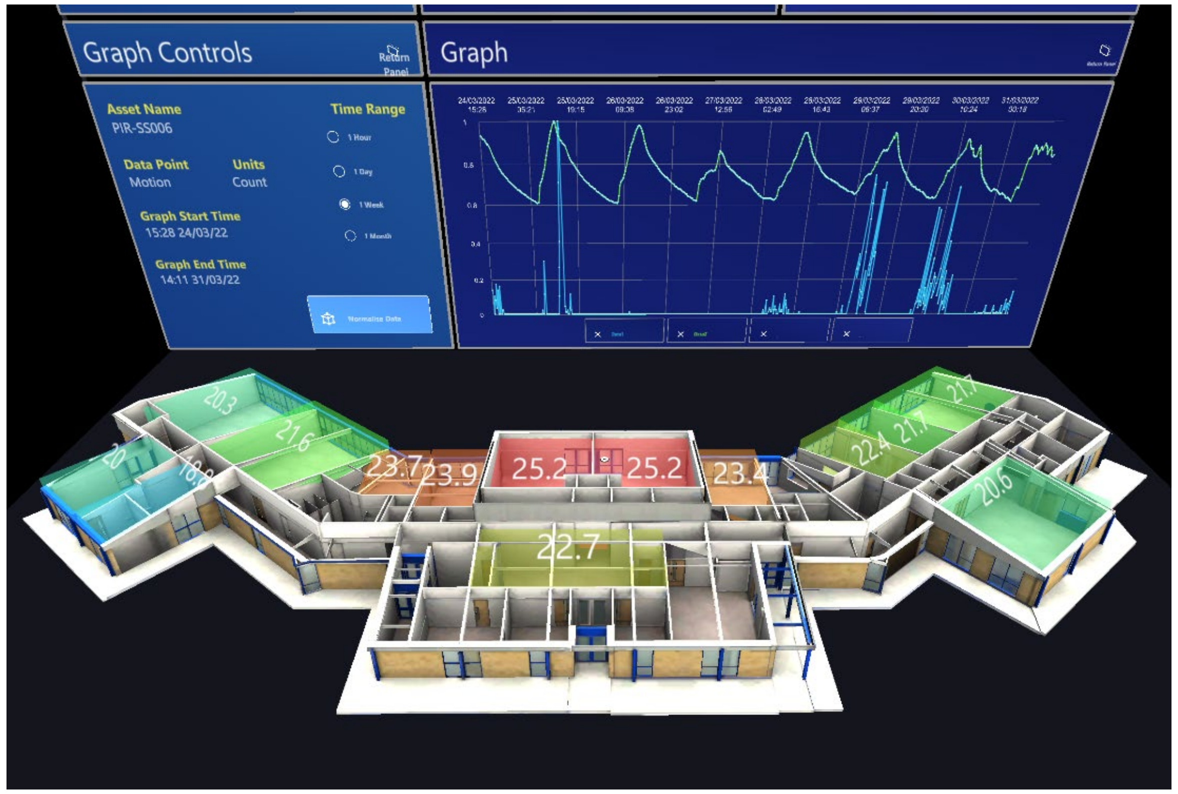
## 5.10 User Interface

The digital twin hosted on the Microsoft Azure iot hub will be accessible via the latest spatial computing AR headset, the Microsoft HoloLens.Access will allow 3D visulisation and interrogation of the digital twin spatially, graphically or by tabular analysis of the historical and live data streams. The data streams will currently include live indoor temperature, humidity, CO2 concentration and occupancy data.

Figure 9 – HoloLens AR headset with image of view when wearing headset

The illustrations below are a preliminary representation of the GUI which will be visible when wearing the HoloLens headset.

Further detailed graphic images and access details will be provided following completion and delivery of the digital twin.




GUI showing room temperatures; Graph shows correlation between temperature and occupancy


GUI showing room temperatures and desk level control panel

## 6.0 Decarbonisation Considerations

The UoW's carbon agenda requires a migration from the gas-fired heat energy to a decarbonised heating network. To make this a reality, there needs to be a detailed plan produced for the works.

The decarbonisation plan is focused on carbon savings using technologies that are proven, established, and widely used. The process of electrifying heat using heat pump technology will only result in energy savings once a series of building interventions are undertaken, thereby completing the requirements for a holistic heat pump strategy.

The UoW campuses lend themselves to a district heating network, St Johns Campus has several existing 'mini' district heating networks in operation, these can be connected directly to the wider district heating network recommended and connected to low carbon heat pumps.

The heat metering data has highlighted that the existing boiler plant installed within the Edward Elgar building is significantly under utilised. The installed boiler and capacity is 4No. boilers @ 1200KW each, the peak metered heat delivery is 2320 kW. The individual heat demand from the remaining buildings on St. Johns Campus totals 1175 kW, therefore the total heat demand can be provided by the Edward Elgar boiler room whilst maintaining 100% capacity in the event of a boiler failing. The more buildings added to a central energy centre the further diversity is enhanced which results in further reduction in gas usage and a reduced maintenance catchment area.

It is recommended that UoW apply for Government funding available for extending the existing district heating system, all building will be ready to connect to a low zero carbon heat pump.

Heat decarbonisation concepts can be proven in terms of measured energy performance and allow new and developing technologies to be tested in a no regret investment scenario as part of a mixed energy network whilst retaining connection to the existing heating systems.

The holistic detailed plan to be developed will seek to:

- Be fully detailed in terms of its data and analysis.
- Be practical and affordable.
- Be robust both in terms of technical capability and cost.
- Remain open to integration of future energy technology, smart technology, and market developments.
- Set targets and methods to monitor performance once operational.
- Provide confidence that the solutions developed, and lessons learnt can be successfully developed across the rest of the campus.
- Provide a series of clearly defined work packages that can be undertaken by the University.

## 6.1 Existing Building Operation & Carbon Associated with Heat Reduction

Prior to any of the suggested interventions within this report, it is fundamental that all building heating systems are operating correctly and efficiently, buildings should be monitored using the BMS to verify the current blended return water temperature.

Following system monitoring, the first practical task for the site would be to seek out short circuits, absent TRV's and poor control routines that are currently resulting in high return water temperatures. Addressing the return water temperature will need the support of maintenance operatives and the incumbent BMS specialist to achieve this and undertake local modifications in buildings to address any issues identified, this will ensure that the existing building systems are compatible with Low Zero Carbon (LZC) technology connection and also a district heating network reducing the overall site return temperatures where possible.

The best form of reducing carbon associated with heat, is to not use the heat in the first instance, there are numerous ways of achieving this reduction:

- Minimise opening windows where possible and ensure windows are closed daily during the winter where possible given the Universities post Covid 19 protocol.
- Lower space temperature set point, encouraging students and staff to increase their clothing levels. UoW are currently reviewing their heat and comfort policy with the view of implementing lower space temperatures.

  https://www.worcester.ac.uk/documents/heating-and-comfort-policy.pdf
- Reduce the operating hours of the heating systems, avoiding the need to heat entire spaces and buildings to accommodate reduced occupancy levels during early mornings and late evenings.
- Turning off the hot water circulation pumps during periods of no demand, this will reduce pipework losses and potential reduce the risk of overheating in the summer. Perhaps state times that buildings will not have hot water.
- Ensuring hot water is stored no greater than 60degC.
- Encourage remote working and learning where feasible.
- Co-ordinate timetabling where possible to ensure room occupancy is maximised during off peak periods, the Digital Twin Pilot will help determine occupancy usage and maximise the use of space.
- The University has implemented a cutting-edge digital twin pilot of the Sheila Scott building, to be used as a testbed in the monitoring of real-time granular data representing internal user focussed environmental conditions and its reaction to data-based change interventions aimed at reducing energy consumption and associated operational carbon emissions. The outcomes and benefits to be attained from the implementation of digital twin technology will further inform a viable business case to support its potential expansion across other building types.
- Reduce the base heating loads by improving the building fabric and junction deficiencies. Unlike the previous points highlighted which are essentially changes in user behaviour improving the fabric of existing building stock can be costly, disruptive and timely, which is why this may not be palatable in the short term. It is encouraged to improve fabric deficiencies as part of the on-going building maintenance.

*Input, review and alterations, required by Estates to ensure building operation is optimised and efficient.*

## 6.2 Existing Building Services Improvements Required

Prior to connecting buildings to an LZC technology and/or a district heating network, it is fundamental that the buildings heating systems are operating correctly, suggested tasks to be undertaken as detailed in the below table:

| Task | Resource |
|---|---|
| BMS monitoring to verify the current return temperature and zonal space temperatures | UoW Maintenance Operatives & BMS Incumbent |
| Install sub-meters on DHW circuit. | Mechanical Contractor / BMS Incumbent |
| Arrange for record drawings of the existing heating distribution systems to be carried out / services laser scanning. | Mechanical Consultant, Contractor or Specialist |
| Replace single pipework heating systems and convoluted pipework distribution runs. | Mechanical Contractor |
| Seek out short circuits, absent TRV'S & poor control routines. | UoW Maintenance Operatives & BMS Incumbent |
| Install heating zone control valves and space temperature sensors (wireless preferred) | Mechanical Contractor & BMS Incumbent |
| Install flow restriction devices on outlets such as showers and taps, to reduce the amount of hot water consumed and associated heat. | UoW Maintenance Operatives |
| Install insulation on exposed sections of heating and hot water pipework distribution, reducing pipework losses, | UoW Maintenance Operatives / Mechanical Contractor |

**Refer to the individual building reports for specific improvements required for each building.**

## 6.3 Heat Sources Considered

The source of heat needs to be as 'warm' as possible when we want to extract heat from it (mainly the winter).

- Air source, where heat is extracted from the external air, is the simplest and cheapest in terms of expenditure in terms of capital plant. However, it is the least efficient. When the heating is required in the winter the external air is relatively cold. This has two impacts, the efficiency of the system reduces when the heating is required, and the heat output reduces when the heating is most needed in the building. The reduced output results in either significantly oversized plant for much of the year, or the introduction of another heating method to boost the performance on very cold days. Air source heat pumps are available in Industrial (High Temperature) and Commercial (Low Temperature).
- Water Source heating works by using a nearby body of water as a heat source. This could be a river, lake, or the sea; some systems even work with slurries and effluent waste. Water in a closed loop from the body of water is pumped to a refrigerant based heat pump system, where the heat is transferred to a secondary heat distribution circuit used for the buildings space heating and hot water systems.

  The water in the closed loop is returned to the water source at a lower temperature. Like ASHPs and GSHPs, Water Source Pumps can provide both heating and cooling to buildings but have a much greater Coefficient of Performance (COP) of around 10.
- Ground source, where heat is extracted from the earth, is much more stable in terms of year round temperature than the ambient air and can therefore be a much more efficient source for the heat during the colder winter months.
  - One option consists of 'slinky' coils installed in the first metre below ground. This requires significant areas of ground that is not under car parks or buildings. Given the overall heating requirement of the various campuses and the land available, this would only be practical on City Campus only for several buildings not all
  - The second method of boreholes provide a more viable solution in terms of land usage and available energy but at a significantly increased capital cost. The bores holes would be at 100 metres depth and is not impacted by the ambient air temperature. This means that there is the potential for long term storage of heat (inter-seasonal storage), however on the negative side it also means that the overall energy in / out of the ground array needs to be balanced over the year; that is, you can't extract heat that isn't being replenished over the medium term.
  - The third option is a development of the borehole's technology utilising boreholes typically 200metre depth; however, these are drilled (using oil and gas industry technology) at an angle such that the point where they enter the ground is a much smaller area than a traditional bore hole array. This allows more of the ground to be accessed, minimises the impact on land that can be developed by the University, and allows the boreholes to be located closer to the energy centres they serve.

  Waste heat should be re-used wherever possible; however, this is mainly at a building by building level and should be used to recover heat to the local building systems to gain optimal efficiency. Where significant levels of cooling are required in buildings, then the waste heat from the cooling process could be recovered directly to heat other buildings or areas, or alternatively delivered back to the ground array (if present) to allow storage for later use.
- Biomass boiler uses wood chip pellets in a modern wood-fuel boiler as the primary fuel source. These are highly efficient, clean and smokeless. Wood-fuel is almost carbon neutral as an energy source (the tree growing process effectively absorbs the CO2 that is emitted during combustion).

  Biomass boilers require bulk fuel storage on site to avoid constant deliveries and mechanical handling systems between storage silo and boiler plant are recommended. These requirements create the need for a substantial amount of external plant space and an additional underground fuel storage bunker. Furthermore, the logistics of fuel deliveries and ongoing maintenance costs could be a potential issue.

  Biomass fuels are sourced from woodland, energy crops, clean wood waste and tree surgery across the region.
- Hydrogen energy plant (HEP) essentially consists of an electrolyser and a fuel cell stack. Electricity and water are supplied to the HEP, with hydrogen gas being produced by the electrolysis of water. If the source of electricity is from a renewable energy source, then the gas is described as green hydrogen. The hydrogen is produced at low pressure and may be used as a direct clean combustible fuel or further compressed and stored for use on demand. The hydrogen may also be synthesised with carbon dioxide from industrial processes or direct air capture to produce synthetic sustainable e-fuels such as e-methanol, e-methane or e-ammonia when synthesised with nitrogen. Oxygen gas is also a by-product of electrolysis and may also be stored or released to atmosphere.

  Re-electrification of hydrogen is achievable using the fuel cell to provide power when renewable energy is unavailable therefore providing security of supply. Low grade heat is also a by-product of the fuel cell which may be used to support heating systems. The described processes are completely free of CO2 emissions.

| Technology | Brief Description | Benefits | Issues/Limitations | Applicable |
|---|---|---|---|---|
| **Industrial Air Source Heat Pump**  | Industrial heat pumps operate similar to commercial heat pumps. Industrial heat pumps are usually custom made, manufactured for a specific application and use ammonia (or carbon dioxide) as a refrigerant resulting in improved efficiency and higher discharge water temperatures. | The ability to operate at higher discharge temperatures reduces the need to make alterations within the buildings. | COP decreases significantly at higher temperatures resulting in higher operating costs and they are much less proven technology which carry a greater capital cost.<br>The type of refrigerants used need very stringent H&S management and dedicated plant locations. | Operating at higher temperatures is not in the long term thinking for the Estate development and doesn't align to the latest Building Regulations.<br>Although to achieve the greatest carbon reduction in the short term, this is solution is feasible, temperatures can be lowered in the future once the fabric is improved and emitters changed.<br>With limited manufacturers available unproven technology may be perceived as a risk to sensitive building operations.<br>✓ |
| **Commercial Air Source Heat Pump**  | Electric driven air source heat pumps extract thermal energy from the surrounding air and transfer it to the working fluid (air or water). | Efficient use of fuel.<br>Relatively low capital costs.<br>No combustion or potentially dangerous gases produced.<br>Commercial units have been in the marketplace and are a proven technology.<br>Operate most efficiently at lower flow and return temperatures. | Requires defrost cycle in extreme conditions.<br>Additional plant space required for thermal stores.<br>Noise can be heard from the external condenser<br>The efficiency of air source heat pump decreases when the external air temperature decreases. | Given the extensive, disruptive and costly works associated with fabric improvements and internal changes to heat emitters on a large scale for campuses this option has been discounted.<br>✗<br>Commercial heat pumps are proposed for buildings remote from the campuses as the works associated is more manageable at a smaller scale.<br>✓ |
| **River Source Heat Pump**  | RSHP systems work by extracting heat from a body of water and converting it into Useful energy to heat buildings. They use a series of submerged pipes containing a working fluid such as a refrigerant to absorb the heat from a river, sea or borehole. | Minimal maintenance.<br>Unobtrusive proven technology.<br>Flexible installation options to meet available site footprint. | Distance from River Severn requires extensive pipe works through both public and private domains.<br>Use is highly regulated by the Environment Agency (EA), who impose strict limits on the water discharge temperature. Abstraction licence is required which the EA can revoke at any time. | Detailed appraisal to be developed by Element Energy for consideration of having the Riversource Heat Pump as the heat source for the University.<br>✓ |

| Technology | Brief Description | Benefits | Issues/Limitations | Applicable |
|---|---|---|---|---|
| **Solar Thermal**<br> | Solar thermal energy can be used to contribute towards space heating and hot water requirements.<br><br>The two most common forms of collector are panel and evacuated tube. | Low maintenance<br><br>Little/no ongoing costs | Requires an annual building domestic hot water demand for sizing and consumption<br><br>Panels ideally inclined at 30º to the horizontal facing a southerly direction | Provided for buildings which have storage due to high peak periods of demand.<br><br>✓ |
| **Hydrogen Electrolyser & Fuel Cell Plant**<br> | Green hydrogen is produced using an electrolyser and renewable energy, the only by product being oxygen. The hydrogen may be stored for use on demand, combusted or used to generate electricity and heat energy using a fuel cell. | Zero CO2 emissions if fired on pure hydrogen and low CO2 emissions if fired on other hydrocarbon fuels<br><br>Virtually silent operation since no moving parts<br><br>High electrical efficiency<br><br>Excess electricity can be exported back to the grid<br><br>Benefits from being part of an energy centre/district heating scheme | Expensive<br><br>Pure hydrogen fuel supply and distribution infrastructure limited in the UK<br><br>Sufficient base thermal and electrical demand required<br><br>Some additional plant space required<br><br>Reforming process, used to extract hydrogen from alternative fuels, requires energy, lowering overall system efficiency | Given this solution is still a technology which is being developed and without a high level of renewable energy generation on-site this is not viable at present. If UoW decide to progress with individual energy centres, this technology can be implement once available.<br><br>✗<br><br>Not at present. |
| **<u>Bio-Renewable Energy Sources (Automated feed – wood-fuel boiler plant)</u>**<br> | Modern wood-fuel boilers are highly efficient, clean and almost carbon neutral (the tree growing process effectively absorbs the $CO_2$ that is emitted during combustion). Automated systems require mechanical fuel handling and a large storage silo. | Stable long term running costs<br><br>Potential good CO2 saving | Large area needed for fuel delivery and storage<br><br>Reliable fuel supply chain required<br><br>Regular maintenance required<br><br>Significant plant space required | Large area required for storage and quantity of deliveries required aren't practical and guaranteed from a local source due to the amount of buildings serving.<br><br>✗ |
| **<u>Ground Source Heat Pump</u>**<br> | GSHP systems tap into the earth's considerable energy store to provide both heating and cooling to buildings. A number of installation methods are possible including horizontal trench, vertical boreholes, piled foundations or plates/pipe work submerged in a large body of water. The design, installation and operation of GSHPs is well established. | Minimal maintenance.<br><br>Unobtrusive technology.<br><br>Flexible installation options to meet available site footprint.<br><br>Income generated from Renewable Heat Incentive (RHI) scheme. | Large area required for horizontal pipes.<br><br>Limited land available currently available on the site.<br><br>Significant year round simultaneous heating and cooling demand required to replenish the ground. | At this stage without seasonal cooling demand profiles the viability cannot be proven.<br>The availability of space would require additional heat sources to meet demand.<br><br>✗ |

Table 1 – Considered Heat Sources

## 6.4 River Source Heat Pump – Element Energy Appraisal

### 6.4.1 Commentary on Proposal Element Energy Proposal

UoW have obtained partial funding from BEIS to appoint an independent consultant Element Energy to complete an initial feasibility study to use the River Severn as primary heat source. The proposal is to construct a central energy centre located on Severn Campus, this will house Water Source Heat Pumps, thermal storage and top-up / back up electric boilers.

The water source heat pumps will generate high temperature heat up to 80degC, heating is then distributed via a district heating network to each building located across the 3No campuses. There are also ambitions to provide heat beyond UoW Estate, with options to extend the network local housing associations, Worcester County Council and potentially other stakeholders.

Similar to the industrial air source heat pumps operating at higher temperature avoids the need to immediately improve building fabric improvements and heat emitter changes to reduce the base heating load and reduce operating temperatures.

We would recommend that UoW continue to consider both Industrial (High Temperature) Air Source Pumps & River Source Heat Pump solutions in parallel. Both systems operate at high temperatures which minimises disruptive changes such as changing heat emitters and extensive fabric improvements, unlike the commercial low temperature solution which is key to UoW operation. This approach enables UoW to improve the fabric elements and change heat emitters as part of the on-going building maintenance, which will eventually allow heating systems to operate at lower temperatures, improving the overall efficiency of the heat pumps.

The UoW should continue to explore the river source heat pump option, with the detailed proposal by Element Energy progressed once funding is available in April. Once the detailed appraisal has been finalised, UoW can consider the best route and pros and cons of becoming an energy provider or remaining as an energy customer.

The option within this report provides UoW with a scalable, manageable, and modular approach using multiple energy centres and district heating networks for each campus. UoW will own and manage the energy centres and district heating networks, with a phased approach plantrooms can be flexible to include new and emerging technologies. The capital investment to develop the heat pump energy centres and district heating networks can be phased to meet the UoW's investment plan and funding streams, thus being a 'no regret' investment approach without being tied into contracts.

### 6.4.2 River Source Heat Pump Risks

Whilst the River Source Heat Pump is a good solution, greatly reducing UoW carbon footprint, there are a number of risks associated with the proposal that need to be carefully considered by the various stakeholders at UoW.

- WCC, Sanctuary & other stakeholders could pull out at any time prior to exchanging contracts, affecting the cost model and revenue.
- Large upfront investment of £20M+.
- 50% maximum funding available, this could be less resulting in the University covering the shortfall.
- With the University owning the energy centre and district heating network, will the University have a dedicated maintenance team or will this be contracted to an external company?
- Limitation on the amount of abstraction from the river, this could limit the expansion of the district heating network, impact income and increase electricity bills due to the electric boilers operating more frequently.
- If fabric improvements are made to buildings, the baseline load will be reduced potentially affecting the cost plans and revenue.
- BEIS could withdraw funding at any time, during the detailed proposal or design.
- Environmental agency could refuse the scheme during the approval process.
- Plantroom positioned in the lowest risk area for flooding, this still remains a risk.
- Pipework routes across the river, authorities & planning approval.
- New technology could emerge making this a better solution for the University.

### 6.4.3 River Source Heat Pump & Air Source Heat Pump Comparison

At this stage there are two potential options to be further considered by UoW, the River Source Heat Pump solution generating heat from a single Energy Centre serving all campuses or Industrial Air Source Heat Pump generating heat from several Energy Centres, one per campus.

The below tables highlight the advantages and disadvantages for each of the options.

| Industrial Air Source Heat Pump | |
|---|---|
| **Advantages** | **Disadvantages** |
| All district heating distribution is located on campus, therefore no approvals required from third parties / authorities. | No revenue stream |
| No large upfront investment required, works can be phased to suit funding. | Lower co-efficient of performance when operating at higher temperature, although we recommend UoW make fabric improvements and changes emitters in the future to lower the operating temperatures, improve system COP and extend the longevity of the district heating network. |
| Scalable, manageable and modular approach using multiple energy centres and district heating networks for each campus. | During winter air source heat pumps undergoing de-frost circles to prevent the units freezing, multiple units are required to ensure heat is provided to the network. |
| Flexibility for connecting emerging & future technology, providing green energy and to the University and other buildings. | Multiple plantrooms constructed taking up more overall space and increased capital cost. |
| Green technology in line with the Governments guidance to generate heat via heat pumps utilising heating networks where possible. | |

| River Source Heat Pump | |
|---|---|
| **Advantages** | **Disadvantages** |
| Potential revenue stream | Risks associated with approvals from the Council, Network Rail & Environmental Agency, particularly the pipework crossing. |
| Green technology in line with the Governments guidance to generate heat via heat pumps utilising heating networks where possible. | Large upfront investment. |
| Single plantroom construction and reduced maintenance catchment area. | Demolishing or improving existing building stock may result in penalties as this will reduce the amount of energy consumed and contracted to by the University. |
| Funding available if the energy centre serves County Council buildings. | If the Energy Centre is managed by a third party supplier UoW will be tied into conditions such as return temperature, usage etc if not met could result in penalties as this will reduce the amount of energy consumed and contracted to by the University. |

#### 6.4.4 River Source Heat Pump Energy Operator VS Energy Customer

The River Source Heat Pump proposal has options to extend the provision of heat distribution beyond the UoW Estate, with options to extend the network to local housing associations, Worcester County Council and potentially other stakeholders.

The proposal is to locate the Energy Centre on Severn Campus, as such UoW have the option to become an energy supplier, not only to the UoW Estate but also the local stakeholders interested.

There are a number of factors that need to be carefully considered by UoW if becoming a local Energy Supplier is attractive.

| UoW As Energy Operator | | UoW As Energy Customer | |
|---|---|---|---|
| **Advantages** | **Disadvantages** | **Advantages** | **Disadvantages** |
| Revenue stream | Risks associated with approvals from the Council, Network Rail & Environmental Agency, particularly the pipework crossing. | Energy generation owned & maintained by others. | No revenue stream |
| Green credentials | Large upfront investment. | Energy supply guaranteed by others. | University will be tied into a contract, failing to meet specific requirements will results in financial penalties. |
| Flexibility for connecting emerging & future technology, providing green energy and to the University and other buildings. | No current expertise within the University to become an energy provider. | No large upfront investment required. | Demolishing existing building stock could result in penalties as this will reduce the amount of energy consumed and contracted to by the University. |
| | Increased / dedicated workforce required. | | The University will be limited to the future technologies they are able to implement across the campuses. |
| | Risk of stakeholders pulling out prior to contractual agreements. | | |

## 6.5 Proposed District Heating Network(s) Solution

The largest campus, St Johns already has part of the campus served by district heating networks.


Figure 3 – St Johns Campus, Existing District Heating Networks

Edward Elgar boilers also provide heating and hot water to Binyon Building, Binyon North, Hines Building, Sports Centre & Students Union.

Ledbury Hall boilers also provide heating and hot water to Avon Hall.

Edward Elgar & Ledbury Hall boiler rooms have the highest annual carbon emissions, as part of the phasing plan, connecting these buildings to the district heating network will offer the largest improvement in carbon emissions in the shortest time.

The heat metering data has highlighted that the existing boiler plant installed within the Edward Elgar building is significantly under utilised.  The installed boiler and capacity is 4No. boilers @ 1200KW each, the peak metered heat delivery is 2320 kW. The individual heat demand from the remaining buildings on St. Johns Campus totals 1175 kW, therefore the total heat demand can be provided by the Edward Elgar boiler room whilst maintaining 100% capacity in the event of a boiler failing.  The more buildings added to a central energy centre the further diversity is enhanced which results in further reduction in gas usage.

It is recommended that UoW apply for Government funding available for extending the existing district heating system, all building will be ready to connect to a low zero carbon heat pump.

| Existing EE DH | C02 Saving (tonne) | % |
|---|---|---|
| Phase 1 | 4.53 | 0.9% |
| Phase 2 | 11.9 | 1.5% |
| Phase 3 | 13.8 | 1.7% |

| | | DATUM ALL BUILDINGS ENERGY/CARBON | | | EXISTING DH + Standalone Ph1 ENERGY/CARBON | | 1.PHASE 1 ENERGY/CARBON | | | 1.PHASE 2 ENERGY/CARBON | | | 1.PHASE 3 ENERGY/CARBON | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Building name | Total Gas consumption | | Gas based carbon footprint | Total Gas consumption | Gas based carbon footprint | Total Gas consumption | Pipework Losses | Gas based carbon footprint | Total Gas consumption | Pipework Losses | Gas based carbon footprint | Total Gas consumption | Pipework Losses | Gas based carbon footprint |
| | | kWh/a | | tCO2e/a | kWh/a | tCO2e/a | kWh/a | 1.00 | tCO2e/a | kWh/a | 1.00 | tCO2e/a | kWh/a | 1.00 | tCO2e/a |
| | St Johns Campus | | | | | | | | | | | | | | |
| 1 | Abberley Hall | 26,066.0 | | 4.8 | | | | | | 26,074.6 | | 4.8 | 26,074.4 | | 4.8 |
| 2 | AE Housman Hall | 259,396.0 | | 47.5 | | | | | | 259,396.0 | | 47.5 | 254,231.1 | | 46.5 |
| 3 | Elizabeth Barrett Browning | 259,396.0 | | 47.5 | | | | | | 259,396.0 | | 47.5 | 254,231.1 | | 46.5 |
| 4 | Ankerdine Hall | 52,854.0 | | 9.7 | | | | | | 52,723.3 | | 9.6 | 52,723.3 | | 9.6 |
| 5 | Berrow Hall | 52,854.0 | | 9.7 | | | | | | 52,723.3 | | 9.6 | 52,723.3 | | 9.6 |
| 6 | Malvern Hall | 52,854.0 | | 9.7 | | | | | | 52,723.3 | | 9.6 | 52,723.3 | | 9.6 |
| 7 | Sarah Siddons Hall | 52,854.0 | | 9.7 | | | | | | 52,723.3 | | 9.6 | 52,723.3 | | 9.6 |
| 8 | Wulfstan Hall | 52,854.0 | | 9.7 | | | | | | 52,723.3 | | 9.6 | 52,723.3 | | 9.6 |
| 9 | Avon Hall | 205,019.9 | 0.49 | 37.5 | | | | | | 205,040.0 | | 37.5 | 205,040.0 | | 37.5 |
| 10 | Binyon Building | 171,095.7 | 0.09 | 31.3 | 171,095.7 | 31.3 | 171,095.7 | | 31.3 | 171,095.7 | | 31.3 | 171,095.7 | | 31.3 |
| 11 | Binyon North | 57,966.4 | 0.03 | 10.6 | 57,966.4 | 10.6 | 57,966.4 | | 10.6 | 57,966.4 | | 10.6 | 57,966.4 | | 10.6 |
| 12 | Charles Darwin | 67,740.0 | | 11.6 | 67,740.0 | 12.4 | 62,389.4 | | 11.4 | 62,389.4 | | 11.4 | 62,389.4 | | 11.4 |
| 13 | Conference Centre | 105,360.0 | | 19.3 | 105,360.0 | 19.3 | 105,371.1 | | 19.3 | 105,371.1 | | 19.3 | 105,371.1 | | 19.3 |
| 14 | Edward Elgar Building | 1,307,399.2 | 1,928,948.0 | 239.3 | 1,307,399.2 | 239.3 | 1,307,399.2 | | 239.3 | 1,307,399.2 | | 239.3 | 1,307,399.2 | | 239.3 |
| 15 | Evesham / Pershore Hall | 31,255.0 | | 5.7 | | | | | | 31,431.1 | | 5.8 | 31,431.1 | | 5.8 |
| 16 | Hines Buildings | 70,648.3 | 0.04 | 12.9 | 70,648.3 | 12.9 | 70,648.3 | | 12.9 | 70,648.3 | | 12.9 | 70,648.3 | | 12.9 |
| 17 | Ledbury Hall | 210,247.1 | 415,267.0 | 38.5 | | | | | | 187,485.6 | | 34.3 | 187,485.6 | | 34.3 |
| 18 | Peirson Centre | 321,445.0 | | 58.8 | 321,445.0 | 58.8 | 311,587.8 | | 57.0 | 311,587.8 | | 57.0 | 311,587.8 | | 57.0 |
| 19 | Sheila Scott Building | 36,269.0 | | 6.6 | | | | | | 36,269.0 | | 6.6 | 36,269.0 | | 6.6 |
| 20 | Sports Centre | 163,616.1 | 0.08 | 29.9 | 163,616.1 | 29.9 | 163,616.1 | | 29.9 | 163,616.1 | | 29.9 | 163,616.1 | | 29.9 |
| 21 | Student's Union | 158,222.3 | 0.08 | 29.0 | 158,222.3 | 29.0 | 158,222.3 | | 29.0 | 158,222.3 | | 29.0 | 158,222.3 | | 29.0 |
| 22 | Thomas Telford Building | 6,295.0 | | 1.20 | 6,295.0 | 1.2 | 5,595.6 | | 1.0 | 5,595.6 | | 1.0 | 5,595.6 | | 1.0 |
| 23 | Vesta Tilley Hall | 87,428.0 | | 16.0 | | | | | | 82,440.9 | | 15.1 | 82,440.9 | | 15.1 |
| 24 | William Morris | 87,428.0 | | 16.0 | | | | | | 82,440.9 | | 15.1 | 82,440.9 | | 15.1 |
| 25 | Windrush Hall | 87,675.0 | | 16.0 | | | | | | 82,440.9 | | 15.1 | 82,440.9 | | 15.1 |
| 26 | Teme Hall | 87,675.0 | | 16.0 | | | | | | 82,440.9 | | 15.1 | 82,440.9 | | 15.1 |
| 27 | Woodbury Building | 380,656.0 | | 69.7 | 380,656.0 | 69.7 | 371,789.8 | | 68.0 | 371,790.0 | | 68.0 | 371,790.0 | | 68.0 |
| Totals | | 4,452,569 | | 814 | 2,810,444 | 514 | 2,785,682 | | 509.8 | 3,829,093 | | 700.7 | 4,373,824 | | 800.4 |
| Electricity | 0.000212 | | | | | | | | | | | 802.30 | | | |
| Gas | 0.000183 | | | | | | | | | | | | | | |

Achievable Carbon Savings - Existing District Heating Network from the Edward Elgar Boilers

### 6.5.1 District Heating System Operation

Any district heating solution is often compromised in practice by either connecting poorly designed / commissioned buildings to the network, or operational solutions for local problems having unintended impact on the system performance, all of which results in reduced efficiency. This is less of an impact when using central boilers and CHP, however, it becomes a critical issue when considering heat pumps, due to their sensitivity to flow and return temperatures in terms of their operating efficiency.

The main cause of concern is the poor operation in buildings which results in excess district heating water flow to a building with a very small temperature difference (across the flow and return circulation). This is usually due to constant flow systems, short circuits, bypasses introduced, or controls over delivering to achieve a condition without regard to the impact on efficiency. Conditions can be met without compromising efficiency; however, this requires careful design and operation without the focus on efficiency being lost due to short cuts or expediency.

The best way to keep this focus is to ensure that single party ownership of the district heating system resides with a key person who would be the guardian of the system and would be able to ensure focus on energy efficiency is maintained equally to the focus upon performance delivery in the buildings. This person should have the data available to them to monitor the system in detail and look for factors affecting the performance of the buildings such as high return temperatures, excessive energy consumption, high flow temperature set point etc. They would also be the gate keeper (and have the requisite authority) for connecting new buildings to the system, ensuring the designers, Contractors and commissioning teams achieve the required efficiency standards before connecting a new building to the district heating network.

The proposal to provide district heating network(s) distributing heat to each of the buildings, emanating from a single energy centre or multiple energy centres depending on the route which UoW wish to proceed with. Serving multiple buildings using district heating networks(s) has the following benefits:

- Reduces the overall plant and space required over semi-decentralised and de-centralised systems and multiple areas of disruptive construction works.
- Diversified load, resulting on reduced overall heating loads and associated plant sizing.
- Avoids the need for multiple planning approval requirements.
- Avoids issues with acoustics for sleeping accommodation and noise sensitive buildings.
- Maintenance catchment area reduced.

### 6.6 Operating Costs Variation

Heat pump driven system will result in a fundamental change to the method used to produce heat for UoW.

Currently, the heat production has been provided from local gas fired heating plant with metered gas being provided from the utility supplier via direct gas pipe network to the respective building plant rooms.

The heat pump solution will result in the transition of a gas-based heating system to a heat pump based district heating scheme. Since the phasing will be implemented without the building fabric of the UoW buildings being initially enhanced, reliance on either the current gas heating systems will remain as a support of the commercial heat pump system during cold whether when the heating demands are greater, or the emitters will require full replacement which shall be disruptive to the buildings operations.

It is expected that due to the transition from gas as a primary fuel to electricity for the decarbonisation of heating, there will be a variation in the consumption costs due to the difference in the unit cost of gas and electricity. Since the commercial heat pumps, may still require top-up heat from the existing gas heating systems (for the reasons mentioned above), there will be a reduction in the consumption of gas, associated with subject buildings but unless demand reduction of the heat is undertaken there will be an increase in electricity consumption in order to reduce the total carbon emissions.

This gap in consumption costs that will exist is principally due to the variance in the unit market supply prices for gas and electricity and often referred to as the 'Spark Gap'. It represents the variance in gas and electricity consumption costs because of the route taken to Net Zero Carbon (NZC) as illustrated on the roadmap to NZC within the appendix.

The following outlines the secured cost of gas and electricity for 2023.

| UoW Secured 2023 Energy Prices | £ |
|---|---|
| Unit Gas Prices (£/kWh) | 0.066 |
| Unit Electricity Prices (£/kWh) | 0.29 |

Table 2 - Summary of UoW 2023 secured energy prices from Energy Broker TEC

Additional factors to be considered for the future movement of costs, will be the anticipated introduction of the carbon tax on gas prices to incentivise the electrification of heat and hence encourage decarbonisation on commercial grounds. The continued elevated cost of electricity in comparison to the cost of gas, also presents the basis of an outline business case for the take up of electricity generating renewable energy schemes.

## 7.0 Existing Buildings

Due to the number of buildings associated with this heat decarbonisation plan, a separate report has been provided for each building detailed interventions specific to each building.

The Estate currently consists of 3No campuses; St Johns Campus, Severn Campus & City Campus, there are also several buildings remote from the campuses. The buildings consist of halls of residences, academic and office buildings, all varying in age some buildings constructed in the 1700's and are of a listed nature, the majority of buildings range from 1940-2000's, the remaining buildings are fairly modern constructed between 2000 – 2009.

This HDP includes 33No building across the estate, within the 33No buildings assessed there are replicas in terms of building construction, layout and services installation. These buildings will differ in terms of heat demand profiles due to building orientation, for the purpose of the overall heat decarbonisation plan, profiles and systems for these buildings are assumed to be the same. Replica buildings have been identified in each of the individual building reports.

Fabric improvements have previously been made to buildings constructed prior to 2000, notwithstanding this a significant proportion of the building stock has poor thermal performance due to the deficiencies in construction methods compared to high fabric performance methods used today.

The majority of the buildings have standalone plantrooms, consisting of natural gas boilers generated heat for space heating and hot water generation. The hours of operation vary between buildings, hours of operation have been highlighted within the individual reports.

**St Johns Campus**

St Johns Campus is general surrounded by residential areas and a primary school and comprises of a mixture of student residences, academic and offices buildings.

There are several open spaces with hard landscaping, car parking and footpaths, the campus is generally quite compact limiting options for a central energy centre.

The campus already has several buildings served by district heating networks.

Edward Elgar boilers serve the following via a district heating network:

- Edward Elgar
- The Hines Building
- Student Union
- Binyon Building
- Binyon North
- Sports Centre

Ledbury Hall boilers serve the following via a district heating network:

- Ledbury Hall
- Avon Hall

St Johns Campus is served by a UoW owned private HV power network with connections to the wider national electricity HV grid. Power is distributed via a series substations located around the campus.

The University have short term plans to demolish the following buildings:

- Bredon
- Binyon North

There aren't any known plans for future construction on the campus.

**City Campus**

City Campus is located near to a train line and generally surrounded by office's with some residential buildings and comprises of a mixture of student residences, academic and offices buildings.

There is a large open plan grassed area at the front of the campus which could be utilised for a new energy centre to serve the campus.

Each of the buildings have standalone boiler rooms provided heating and hot water.

City Campus is served by 2No Western Power Distribution (WPD) substations.

There are no known plans for future construction on the campus.

**Severn Campus**

Severn Campus is located alongside the River Severn and generally surrounded by residential areas and comprises of academic buildings.

There are currently large areas of car-parking, although there is known development on the campus, location of the energy centre will need to be agreed with the UoW stakeholders, although there appears to be space for external plant on the Arena external plant deck.

Each of the buildings have standalone boiler rooms provided heating and hot water.

Severn Campus is served by 1No Western Power Distribution (WPD) substations, the below developments require an additional substations as part of the infrastructure works required.

The University are currently re-developing Berrows House.

The University are currently designing a new International Inclusive Cricket Centre sited opposite the Arena.

The future schemes have standalone energy centres with the heat being generated by Air Source Heat Pump, making the building low carbon, once the ASHP exceed their life expectancy they can be reconnected to the district heating network proposed making heat generation for the campus more efficient.

## 8.0 Data Gathering & Available Information Overview

UoW provided access to all data available for the Estate as a whole and individual buildings.

Meetings and liaison with UoW were on-going throughout the process with UoW answering queries and providing additional information where available.

The energy data received from UoW for electricity and gas has mainly been obtained from their energy metering platform as described below. Energy consumption metering data was available from this platform in most cases. however, a number of buildings were not covered by this system. For these, the UoW provided a record of monthly consumption data in the form of excel spreadsheets, recorded over a period of 12 months from the main incoming utility meters and obtained by UoW from their utility bills. In these cases, most buildings have a single utility electricity meter and MPAN provided by the DNO and a single utility gas meter and MPRN provided by the gas operator. In one case, one building had 6no separate utility meters for separate sections of the building. These were amalgamated to provide a cumulative set of annual gas consumption figures.

Generally, meter readings were downloaded from 1/01/2019 until the 31/12/2019 to ensure that the consumption data used was during normal University occupancy and usage i.e., pre-Covid 19 pandemic period. For instances where the 2019 data appeared inconsistent, then 2018 meter data was used.

Energy modelling has been performed on the basis of the data received, to inform the total building heat loss, energy consumption, cost of consumption to determine baseline annual energy consumption density and carbon footprint.

The University has confirmed that all gas consumption is solely for the supply of gas for space heating systems and domestic hot water generation. Gas is not used for cooking, within student residences with electric cooking facilities.

### 8.1.1 Energy Metering - Dynamat

Access was granted to Dynamat2050 which was the UoW's energy metering platform operated by Energy Metering Technology (EMT) Ltd. EMT have installed several hundred automatic meter reading (AMR) devices over all their campus's measuring and transmitting half hourly data to their xcloud based platform. The AMR devices are coupled to electricity, gas, heat and water meters for each building, and although most records go back to 2013, several only have records for a few years.

The gas meter reading obtained were available in cubic metres and in kWh, with the electricity in kWh. Consumption for both fuels were downloaded in KWh and used as a basis for system modelling and carbon footprint calculations.

The Dynamat2050 was found to be a useful tool for accessing primary fuel consumption data. The platform is well organised with a user friendly graphical user interface. The only issue encountered was that for some meter data, the AMR readings appeared to be static indicating no consumption or faulty metering. In some cases, we had received confirmation from the UoW that some buildings were seldomly used, and this had reflected in the lack of gas consumption. In other cases, it appears that the AMR device had gone into fault resulting in a dump of meter readings when it was back online. This resulted in spurious consumption profiles which had to be adjusted prior to modelling. This was quite a time consuming process in all cases as it meant that each HH data reading over a complete year, had to be reviewed prior to use.

### 8.1.2 Building Information

UoW provided electronic copies of all information held on individual buildings including as-built building construction data and as-built Mechanical & Electrical drawings, Operational & Maintenance manuals. Information was also provided on fabric improvements over the years, namely window replacements, enhancing roof insulation and cavity wall fills, these have been highlighted in the individual building reports and incorporated within the energy base modelling.

CPW also reviewed all hard copy information within the archive located in the Hines Building.

Construction information obtained was very limited, as such the u-values used for the energy base modelling has been based on building age, the Building Regulation construction elemental u-values currently at the time of building construction have been used.

### 8.1.3 Building Operational Information

UoW has provided details of their Heating and Comfort policy to inform us of the periods of operation of the space heating and domestic hot water systems during the summer and winter modes of operation. This applies to the various building types on the university campuses including Office's buildings, Teaching buildings, Study Centres, Accommodation blocks and Recreational facilities.

The internal building temperature setpoint ranges during winter is also stated as is the summer temperature setpoint in areas where comfort cooling is provided.

The following information from the policy has been used within the modelling:

Heating Season: 1$^{st}$ October to 30$^{th}$ April.

Heating is switched on at 8am; switched off at 5.30pm, 9pm, 11pm for Offices, Teaching, Accommodation respectively.

Heating setpoints between 19°C - 21°C.

Domestic Hot Water is switched on at 6am, 7.30am, 8am for Accommodation, Offices & Teaching, Sports Arena; switched off at 9pm, 10pm, 11pm for Offices & Teaching, Sports Arena, Accommodation respectively.

Heating and DHW is 24hours at the Peirson Study Centre.

UoW are currently reviewing their heat and comfort policy with the view of implementing lower space temperatures across the Estate.

https://www.worcester.ac.uk/documents/heating-and-comfort-policy.pdf

## 8.2 Thermographic Survey

### 8.2.1 Introduction

Thermographic surveys have been undertaken to support the Heat Decarbonisation Plan (HDP), this includes 33no buildings on the City, Severn and St. Johns Campuses being assessed.

The thermal imaging of the buildings has been requested to allow greater understanding of the thermal condition and performance of the buildings envelopes and to inform any interventions that may be required to improve energy efficiency and reduce carbon emissions.

The thermographic surveys carried out at the 3No campuses were ground based, focussing on the performance of walls, windows, and doors, under crofts and roof where possible. Since the survey was carried out at grade, roof images were only taken when visible from the ground, as in the case of single storey buildings visible from an elevated viewpoint, or buildings with a steep pitched roof.

The surveys were carried out during January and February 2022 with suitable weather conditions as described further within the report and as required in the guidance documents referenced below. The report methodology outlines the process used to ensure that all pre-conditions were present, building occupants advised and images processed to ensure that only thermal features out of the ordinary, were highlighted.

As requested UoW confirmed that the heating was in operation 48 hours prior to surveys being undertaken.

Please refer to the appendices for the full Thermographic Report.

### 8.2.2 Common Building Fabric Irregularities

The surveys have ascertained any of the following issues with the existing building stock:

1. *Discontinuity of thermal insulation:*

   On a thermal image this will appear as a sudden change in thermal continuity in an unexpected location. It may identify where insulation may have been missed, incorrectly installed, or may have failed since installation

2. *Thermal bridging:*

   This will appear as a hot spot or area, which should ordinarily be cool, representing an unwanted thermal bridge as a consequence of faulty design or construction, or material failure (such as water ingress).

3. *Air leakage:*

   This may also appear as a hot area around an opening indicating a weakness in door/window joints, seals or integrity. Thermography can be used very effectively to locate air leakages where the fabric appears to be well sealed.

4. *Moisture:*

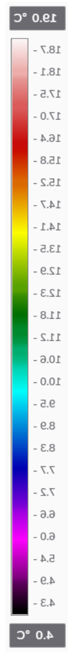
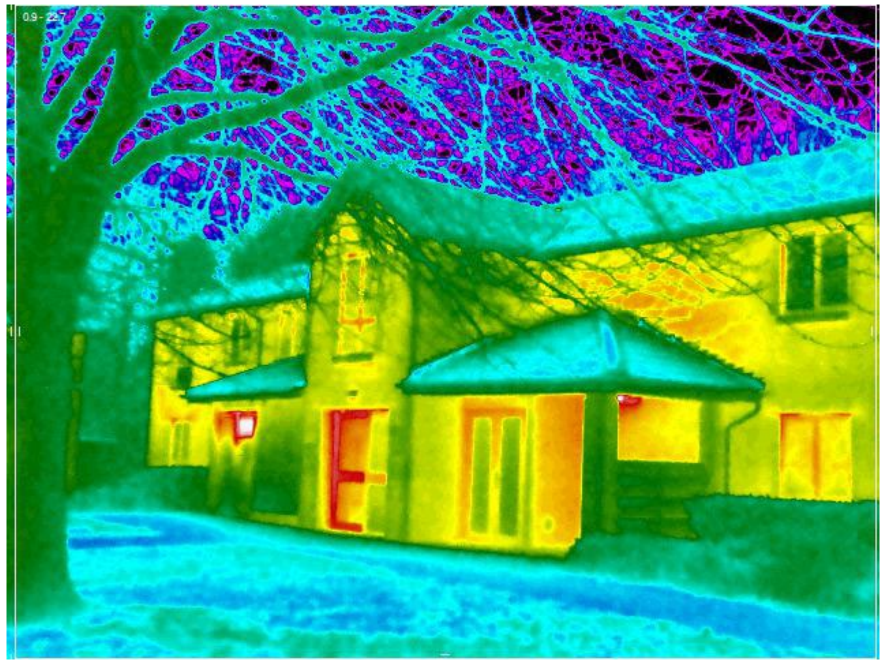
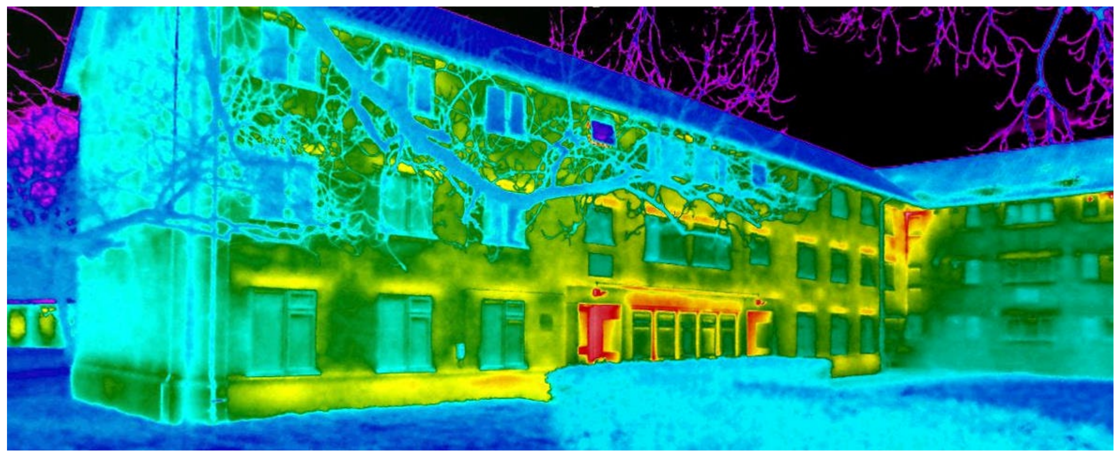
   The presence of moisture in materials is detectible due to its different thermal conductivity, which will produce small but measurable temperature variations in a surface. For example, rising damp may make outside walls cooler than expected, and inside walls warmer.

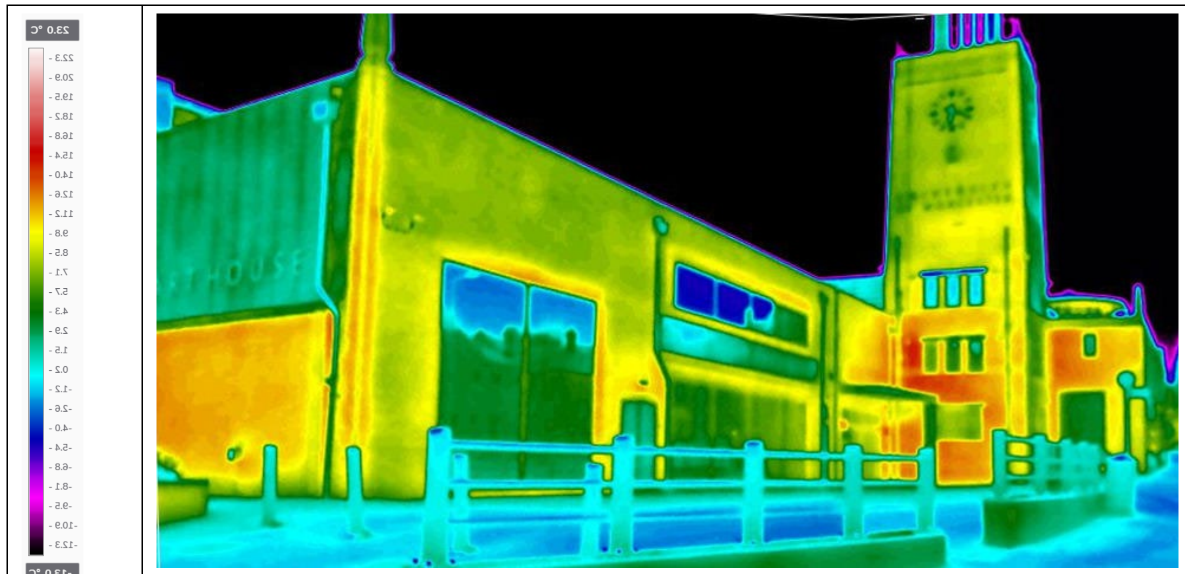
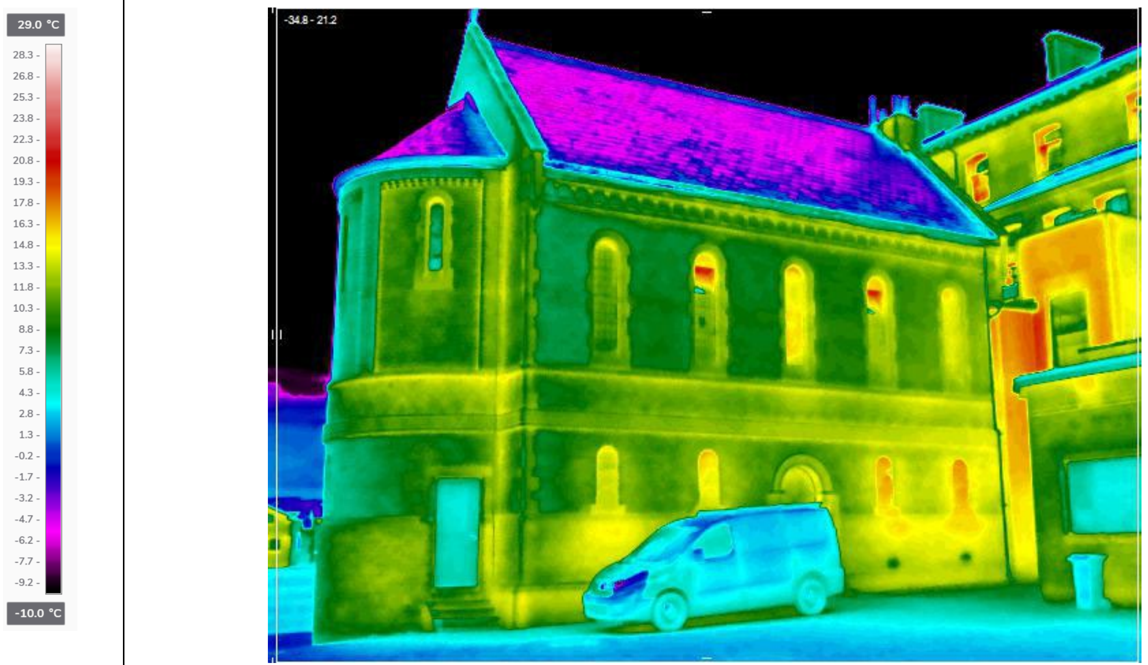
The thermographic surveys can be used as a tool to tackle the worst offending buildings and specific elements of the building. As opposed to wholesale improvements of entire elements such as external wall which can be costly and disruptive, improvements that can be programmed as part of the Universities on-going building maintenance.

It is encouraged to improve fabric deficiencies as part of the on-going building maintenance to reduce the base heating load and associated energy prices.

### 8.2.3 Sample Images

The following is a sample of the thermal images obtained on the above campuses, further images are available in the main report appended to this report.

| Image Ref | Thermal image |
|---|---|
|  |  |
| 0459 | **Abberley Halls**<br>Areas of heat loss indicated above ground roof structures indicate poor continuity of thermal insulation. Wall panel beside double door also poor insulated. |
|  |  |
| 0485 | **Pershore / Evesham Halls**<br>Heat losses through thermal bridging of window headers and glazing is noticeable, otherwise even temperatures both horizontally and vertically on the elevations indicate good overall levels of insulation. |

| | |
|---|---|
|  | |
| 0305 | **University Arts House**<br>Overall, even levels of surface elevation temperatures both horizontally and vertically indicate good overall levels of insulation. Poor thermal performance apparent on lower levels of tower and lower left wall below cladding. |
|  | |
| 0358 | **Charles Hastings Building**<br>The chapel building appears to have overall even levels of heat dissipation and good thermal performance for the roof, however the newer construction to the right shows elevated surface temperatures at all levels indicating greater heat loss and poor thermal insulation. |

## 8.3 Maintenance Information

CPW have also reviewed maintenance asset registers to understand age/condition of plant which is important when considering life cycle replacement and improvements to the building services.

The heating system is regularly maintained and according to the maintenance records achieve good combustion efficiencies and appears to be in good working order. Lord Combustion undertake annual inspections on the heating and hot water plant, they also attend on a reactive basis. It is understood that Lord Combustion also monitor and maintain the water quality of the heating system as and when required.

Existing plant is generally in good working order, refer to the maintenance asset schedule and individual building reports for specific details of plant condition and age.

## 8.4 Existing Energy Records

Table 3 summarises the existing building gas consumption as recorded from 2019 metering data. The buildings have been ranked from worse to best performing.

**St Johns Campus**

| Building name | GIA | Carbon Emissions as Proportion of campus | Annual Adjusted Carbon Emission as Proportion of campus |
|---|---|---|---|
| St Johns Campus | | tCO2e/a | |
| Edward Elgar Building | 12,238 | 193.4 | 30.34% |
| Woodbury Building | 3,259 | 69.7 | 10.94% |
| Peirson Centre | 2,916 | 58.8 | 9.22% |
| AE Housman Hall | 2,694 | 47.5 | 7.45% |
| Ledbury Hall | 1,978 | 27.4 | 4.30% |
| Avon Hall | 1,799 | 26.7 | 4.19% |
| Binyon Building | 1535 | 25.3 | 3.97% |
| Sports Centre | 2,308 | 24.2 | 3.80% |
| Student's Union | 1,247 | 23.4 | 3.67% |
| Conference Centre | 655 | 19.3 | 3.03% |
| Barrington house | 485 | 17.8 | 2.79% |
| Vesta Tilley Hall | 948 | 16.0 | 2.51% |
| Windrush Hall | 605 | 16.0 | 2.51% |
| Charles Darwin | 1,205 | 11.6 | 1.82% |
| Hines Buildings | 1,081 | 10.4 | 1.64% |
| Ankerdine Hall | 746 | 9.7 | 1.52% |
| Binyon North | 328 | 8.6 | 1.35% |
| Fern Hall (6ABCD) | 633 | 7.6 | 1.19% |
| Sheila Scott Building | 1,059 | 6.6 | 1.04% |
| Oldbury House | 209 | 5.5 | 0.86% |
| Evesham / Pershore Hall | 1,210 | 4.9 | 0.77% |
| Abberley Hall | 522 | 4.8 | 0.75% |
| Thomas Telford Building | 428 | 2.0 | 0.31% |
| Forensic House | 143 | 0.2 | 0.03% |
| | 40,231 | 637.4 | |

Table 3 – St Johns Campus Carbon Ranking

Notes:

This does not include the duplicate buildings i.e. Elizabeth Browning and AE Housman both rank the same.

AE Housman is one of the most recently constructed buildings, although ranks high for the St Johns Campus, the likely cause of this is due to high hot water consumption.

**City Campus**

| Building name | GIA | Annual Carbon Emission for Gas consumed | Carbon Emissions as Proportion of campus |
|---|---|---|---|
| City Campus | | tCO2e/a | |
| Charles Hastings Building | 4,422 | 109.9 | 44.93% |
| Bishop Bosel Hall | 3,385 | 58.4 | 23.88% |
| Jenny Lind | 4,111 | 52.3 | 21.38% |
| Chancellor Hall | 2,534 | 19.9 | 8.14% |
| Mulberry house | 788 | 4.1 | 1.68% |
| University Art House | 2,068 | 0.0 | 0.00% |
| | 17,308 | 245 | |

Table 4 – City Campus Carbon Ranking

Notes:

There is a significant difference between Bishop Bosel and Chancellor Hall, both of which were constructed at the same time, although one of the builingd has an extra floor such a disparity isnt expected, further investigation required.

**Severn Campus**

| | | Annual Carbon Emission for Gas (base) | Carbon Emissions as Proportion of campus |
|---|---|---|---|
| Severn Campus | | tCO2e/a | |
| University Arena | 4,723 | 87.0 | 46.10% |
| Riverside Building | 1,987 | 77.9 | 41.28% |
| The Garage | 808 | 23.8 | 12.61% |
| | 7,518 | 189 | |

Table 5 – Severn Campus Carbon Ranking

**The focus of the decarbonisation is reducing current heat demand and the carbon associated with gas fired heating plant. The carbon ranking has been used to inform the phasing suggested later within the report, the poorest performing buildings have been targeted to be connected to the proposed energy centre first, this will offer UoW the greatest carbon reductions as soon as possible.**

# University of Worcester Heat Decarbonisation Plan

Each of the buildings' primary heating and percentage fabric, ventilation and domestic hot water loads has been calculated mainly from the information gathered during the site survey, using the mass flow rates, flow and return temperatures recorded on the operating and maintenance 'As-Built' record drawings and schematics where available although this information was limited.

The energy consumption for each system within the building has been calculated and tabulated in the below table and used as the basis of the carbon offsetting calculations.

| | Building name | Building Type | GIA | Annual heat demand (base) | | Annual heat demand (wall upgrade-external cladding) | | | | | Annual heat demand (roof upgrade-roof/loft insulation) | | | | | Annual heat demand (infiltration and window upgrade -option 1-enhanced double glazing) | | | | | Annual heat demand (infiltration and window upgrade -option 2-triple glazing) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lot one - St Johns Campus | | | | kWh/a | tCO2e equivalent | kWh/a | tCO2e equivalent | tCO2e improvement | Associated budget cost £ | £1000/ tCO2e | kWh/a | tCO2e equivalent | tCO2e improvement | Associated budget cost £ | £1000/ tCO2e | kWh/a | tCO2e equivalent | tCO2e improvement | Associated budget cost £ | £1000/ tCO2e | kWh/a | tCO2e equivalent | tCO2e improvement | Associated budget cost £ | £1000/ tCO2e |
| 1. | Forensic House | Academic | 143 | 42,401 | 8.6 | 42,401 | 8.6 | 0.0 | 0.0 | n/a | 16,765.0 | 3.4 | 5.2 | 5,360.4 | 1.03 | 37,512.0 | 7.6 | 1.0 | 48,833.4 | 49.12 | 36,810 | 7 | 1.1 | 81,389.0 | 71.59 |
| 3. | Abberley Hall | Accommodation | 522 | 39,302 | 8 | 35,456 | 7.2 | 0.8 | 77,224.6 | 98.75 | 39,302 | 8.0 | 0.0 | 6,230.1 | 0.00 | 27,484 | 5.6 | 2.4 | 62,153.9 | 25.87 | 26,008 | 5 | 2.7 | 103,589.8 | 38.32 |
| 4. | AE Housman Hall | Accommodation | 2,694 | 139,488 | 28 | 134,797 | 27.4 | 1.0 | 202,903.8 | 212.72 | 134,445 | 27.3 | 1.0 | 37,333.3 | 36.41 | 101,420 | 20.6 | 7.7 | 174,895.1 | 22.59 | 93,964 | 19 | 9.3 | 291,491.8 | 31.49 |
| 5. | Ankerdine Hall | Accommodation | 746 | 48,929 | 10 | 38,667 | 7.9 | 2.1 | 83,732.0 | 40.13 | 48,929 | 9.9 | 0.0 | 27,071.0 | 0.00 | 35,345 | 7.2 | 2.8 | 79,005.3 | 28.60 | 33,879 | 7 | 3.1 | 131,675.5 | 43.03 |
| 6. | Avon Hall | Accommodation | 1,799 | 294,669 | 60 | 249,998 | 50.8 | 9.1 | 275,584.4 | 30.34 | 283,853 | 57.7 | 2.2 | 28,462.5 | 12.94 | 206,628 | 42.0 | 17.9 | 328,944.0 | 18.38 | 195,201 | 40 | 20.2 | 548,240.0 | 27.11 |
| 8. | Binyon Building | Academic | 1535 | 370,622 | 75 | 305,077 | 62.0 | 13.3 | 178,374.6 | 13.38 | 312,057 | 63.5 | 11.9 | 24,635.9 | 2.07 | 229,504 | 46.7 | 28.7 | 159,528.6 | 5.56 | 215,646 | 44 | 31.5 | 265,881.0 | 8.44 |
| 9. | Binyon North | Academic | 328 | 125,565 | 26 | 96,224 | 19.6 | 6.0 | 96,734.1 | 16.21 | 110,198 | 22.4 | 3.1 | 4,807.0 | 1.54 | 81,866 | 16.6 | 8.9 | 79,643.9 | 8.96 | 77,561 | 16 | 9.8 | 132,739.8 | 13.60 |
| 11. | Charles Darwin | Academic | 1,205 | 138,658 | 28 | 134,987 | 27.4 | 0.7 | 45,109.6 | 60.43 | 132,449 | 26.9 | 1.3 | 29,158.3 | 23.10 | 90,035 | 18.3 | 9.9 | 170,951.6 | 17.29 | 82,256 | 17 | 11.5 | 284,919.3 | 24.84 |
| 12. | Conference Centre | Academic | 655 | 193,122 | 39 | 160,735 | 32.7 | 6.6 | 85,711.7 | 13.02 | 135,441 | 27.5 | 11.7 | 23,766.2 | 2.03 | 155,798 | 31.7 | 7.6 | 178,560.5 | 23.53 | 152,126 | 31 | 8.3 | 297,600.9 | 35.70 |
| 13. | Edward Elgar Building | Academic | 12,238 | 2,832,046 | 576 | 2,171,181 | 441.5 | 134.4 | 1,376,415.5 | 10.24 | 2,066,978 | 420.3 | 155.6 | 274,062.3 | 1.76 | 2,652,688 | 539.4 | 36.5 | 1,534,854.8 | 42.09 | 2,599,323 | 529 | 47.3 | 2,558,091.3 | 54.06 |
| 15. | Evesham / Pershore Hall | Accommodation | 1,210 | 204,098 | 41 | 133,109 | 27.1 | 14.4 | 148,291.7 | 10.27 | 204,098 | 41.5 | 0.0 | 16,286.9 | 0.00 | 142,813 | 29.0 | 12.5 | 105,497.7 | 8.47 | 135,122 | 27 | 14.0 | 175,829.5 | 12.54 |
| 16. | Ledbury Hall | Accommodation | 1,978 | 302,182 | 61 | 261,927 | 53.3 | 8.2 | 362,787.0 | 44.32 | 289,886 | 58.9 | 2.5 | 32,115.2 | 12.85 | 206,544 | 42.0 | 19.4 | 390,122.7 | 20.06 | 195,559 | 40 | 21.7 | 650,204.5 | 29.99 |
| 18. | Peirson Centre | Academic | 2,916 | 595,286 | 121 | 522,815 | 106.3 | 14.7 | 215,980.6 | 14.66 | 499,190 | 101.5 | 19.5 | 58,553.7 | 3.00 | 430,019 | 87.4 | 33.6 | 274,451.1 | 8.17 | 413,052 | 84 | 37.1 | 457,418.5 | 12.34 |
| 20. | Sheila Scott Building | Academic | 1,059 | 245,174 | 50 | 235,050 | 47.8 | 2.1 | 112,425.2 | 54.61 | 188,962 | 38.4 | 11.4 | 39,420.6 | 3.45 | 183,271 | 37.3 | 12.6 | 274,451.1 | 21.80 | 175,927 | 36 | 14.1 | 457,418.5 | 32.49 |
| 21. | Student's Union | Hospitality | 1,247 | 342,736 | 70 | 314,694 | 64.0 | 5.7 | 180,998.3 | 31.74 | 273,668 | 55.6 | 14.0 | 39,420.6 | 2.81 | 249,331 | 50.7 | 19.0 | 274,451.1 | 14.45 | 241,064 | 49 | 20.7 | 457,418.5 | 22.13 |
| 22. | Sports Centre | Sports Hall | 2,308 | 354,420 | 72 | 328,892 | 66.9 | 5.2 | 251,630.8 | 48.48 | 317,601 | 64.6 | 7.5 | 38,550.9 | 5.15 | 294,677 | 59.9 | 12.1 | 404,581.7 | 33.31 | 292,254 | 59 | 12.6 | 674,302.8 | 53.34 |
| 24. | Thomas Telford Building | Academic | 428 | 60,086 | 12 | 59,168 | 12.0 | 0.2 | 38,917.0 | 208.49 | 59,604 | 12.1 | 0.1 | 13,156.0 | 134.24 | 45,785 | 9.3 | 2.9 | 274,451.1 | 94.38 | 45,138 | 9 | 3.0 | 457,418.5 | 150.49 |
| 25. | Vesta Tilley Hall | Accommodation | 948 | 87,145 | 18 | 77,174 | 15.7 | 2.0 | 87,622.3 | 43.22 | 87,145 | 17.7 | 0.0 | 12,808.1 | 0.00 | 71,015 | 14.4 | 3.3 | 332,286.9 | 101.31 | 68,182 | 14 | 3.9 | 553,811.5 | 143.63 |
| 27. | Windrush Hall | Accommodation | 605 | 57,233 | 12 | 49,839 | 10.1 | 1.5 | 61,893.5 | 41.17 | 57,233 | 11.6 | 0.0 | 14,025.7 | 0.00 | 39,503 | 8.0 | 3.6 | 332,286.9 | 92.17 | 37,757 | 8 | 4.0 | 553,811.5 | 139.85 |
| 28. | Woodbury Building | Offices/academic | 3,259 | 942,660 | 192 | 741,087 | 150.7 | 41.0 | 494,608.2 | 12.07 | 633,712 | 128.9 | 62.8 | 125,519.6 | 2.00 | 832,656 | 169.3 | 22.4 | 505,794.3 | 22.61 | 807,018 | 164 | 27.6 | 842,990.5 | 30.56 |
| 30. | Barrington house | Accommodation | 485 | 105,041 | 21 | 76,589 | 15.6 | 5.8 | 0.0 | 0.00 | 92,166 | 18.7 | 2.6 | 6,546.4 | 2.50 | 90,707 | 18.4 | 2.9 | 57,566.9 | 19.75 | 89,052 | 18 | 3.3 | 95,944.8 | 29.51 |
| 31. | Oldbury House | Accommodation | 209 | 92,990 | 19 | 69,864 | 14.2 | 4.7 | 0.0 | 0.00 | 64,434 | 13.1 | 5.8 | 4,807.0 | 0.83 | 80,000 | 16.3 | 2.6 | 43,107.9 | 16.32 | 77,886 | 16 | 3.1 | 71,846.5 | 23.39 |
| 32. | Fern Hall (6ABCD) | Accommodation | 633 | 132,872 | 27 | 129,732 | 26.4 | 0.6 | 0.0 | 0.00 | 128,800 | 26.2 | 0.8 | 13,851.8 | 16.73 | 106,208 | 21.6 | 5.4 | 57,566.9 | 10.62 | 103,652 | 21 | 5.9 | 95,944.8 | 16.15 |
| 33. | Hines Buildings | Offices | 1,081 | 153,036 | 31 | 100,677 | 20.5 | 10.6 | 144,047.6 | 13.53 | 153,036 | 31.1 | 0.0 | 0.0 | n/a | 147,595 | 30.0 | 1.1 | 158,779.5 | 143.52 | 139,434 | 28 | 2.8 | 264,632.5 | 95.68 |
| | | | 40,231 | | | | | | | | | | | | | | | | | | | | | | |
| Lot two (1) - City Campus | | | | | | | | | | | | | | | | | | | | | | | | | |
| 34. | Bishop Bosel Hall | Accommodation | 3,385 | 156,133 | 32 | 156,133 | 31.7 | 0.0 | 0.0 | n/a | 156,133 | 31.7 | 0.0 | 24,635.9 | n/a | 130,907 | 26.6 | 5.1 | 303,369.0 | 59.14 | 118,188 | 24 | 7.7 | 505,615.0 | 65.53 |
| 35. | Chancellor Hall | Accommodation | 2,534 | 124,113 | 25 | 120,590 | 24.5 | 0.7 | 209,436.1 | 292.37 | 124,113 | 25.2 | 0.0 | 28,810.4 | n/a | 103,903 | 21.1 | 4.1 | 274,451.1 | 66.79 | 93,876 | 19 | 6.1 | 457,418.5 | 74.40 |
| 36. | Charles Hastings Building | Academic | 4,422 | 617,538 | 126 | 370,744 | 75.4 | 50.2 | 0.0 | 0.00 | 617,538 | 125.6 | 0.0 | 77,671.0 | n/a | 481,658 | 97.9 | 27.6 | 202,125.0 | 7.32 | 481,658 | 98 | 27.6 | 202,125.0 | 7.32 |
| 37. | Mulberry house | Offices | 788 | 160,922 | 33 | 98,420 | 20.0 | 12.7 | 0.0 | 0.00 | 160,922 | 32.7 | 0.0 | 10,373.0 | n/a | 127,022 | 25.8 | 6.9 | 36,035.0 | 5.23 | 127,022 | 26 | 6.9 | 36,035.0 | 5.23 |
| 38. | Jenny Lind | Academic | 4,111 | 765,789 | 156 | 619,924 | 126.1 | 29.7 | 483,340.9 | 16.30 | 634,177 | 128.9 | 26.8 | 52,228.7 | 1.95 | 621,949 | 126.5 | 29.2 | 231,074.3 | 7.90 | 602,530 | 123 | 33.2 | 385,123.8 | 11.60 |
| 39. | University Art House | Academic/Studio/Exh | 2,068 | 282,304 | 57 | 256,547 | 52.2 | 5.2 | 205,952.5 | 39.32 | 226,085 | 46.0 | 11.4 | 66,839.4 | 5.85 | 222,876 | 45.3 | 12.1 | 207,200.4 | 17.15 | 218,462 | 44 | 13.0 | 345,334.0 | 26.60 |
| Lot two (2)- Severn Campus | | | | | | | | | | | | | | | | | | | | | | | | | |
| 40. | The Garage | Academic | 808 | 353,347 | 72 | 324,422 | 66.0 | 5.9 | 131,549.9 | 22.37 | 150,893 | 30.7 | 41.2 | 6,546.4 | 0.16 | 324,000 | 65.9 | 6.0 | 138,997.7 | 23.29 | 322,892 | 66 | 6.2 | 231,662.8 | 37.41 |
| 41. | Riverside Building | Academic | 1,987 | 356,354 | 72 | 352,341 | 71.6 | 0.8 | 0.0 | 0.00 | 344,745 | 70.1 | 2.4 | 59,534.1 | 25.22 | 307,593 | 62.5 | 9.9 | 95,620.8 | 9.64 | 300,687 | 61 | 11.3 | 159,368.0 | 14.08 |
| 42. | University Arena | Sports Facility | 4,723 | 492,883 | 100 | 485,926 | 98.8 | 1.4 | 0.0 | 0.00 | 470,153 | 95.6 | 4.6 | 167,391.1 | 36.22 | 367,395 | 74.7 | 25.5 | 498,118.5 | 19.52 | 356,949 | 73 | 27.6 | 830,197.5 | 30.04 |
| | | | 24,826 | | | | | | | | | | | | | | | | | | | | | | |

| | |
|---|---|
| Electricty carbon factor, t/kWh | 0.000212 |
| Gas carbon factor, t/kWh | 0.000183 |

Table 6 – Heat Usage Split

## 9.0 Building Viability

The current status of UoW regarding was determined to identify how heat is provided to each of the buildings, and how easily they could be changed to a heat pump strategy. As previously mentioned, data regarding flow temperatures, energy and hot water demands of the buildings has been collated from metering outputs, building schematics surveys and Operational & Maintenance manuals where available, typical demand usage has been used for various building applications has been used where data is non-existent. A site survey was also conducted to review each plant room, to confirm the provided data was still correct, identify any issues which may need resolving prior to the heat pump solution being installed, assess space capacity and feasibility of retro fitting.

Prior to any of the suggested interventions within this report, it is fundamental that all building heating systems are operating correctly and efficiently, buildings should be monitored using the BMS to verify the current blended return water temperature. The blended return water temperature is important as this gives an indication of the current viability for connecting to low temperature heat sources.

Following system monitoring, the first practical task for the site would be to seek out short circuits and poor control routines that are currently resulting in high return water temperatures. Addressing the return water temperature will need the support of maintenance operatives and the incumbent BMS specialist to achieve this and undertake local modifications in buildings to address any issues identified.

There are several essential operational improvements that would be required to enable the improvement of system performance as outlined in the headings of following tables. The extent of modifications to hydraulic pipework would be limited to resolution of low loss headers, short circuit bypasses and replacement of single pipework heating systems, these modifications will achieve the suitable conditions for heat pumps and district heating networks to perform efficiently.

Prior to connecting buildings to an LZC technology and/or a district heating network, it is fundamental that the buildings heating systems are operating correctly, suggested tasks to be undertaken as detailed in the below table:

| Task | Resource |
|---|---|
| BMS monitoring to verify the current return temperature and zonal space temperatures | UoW Maintenance Operatives & BMS Incumbent |
| Install sub-meters on DHW circuit. | Mechanical Contractor / BMS Incumbent |
| Arrange for record drawings of the existing heating distribution systems to be carried out / services laser scanning. | Mechanical Consultant, Contractor or Specialist |
| Replace single pipework heating systems and convoluted pipework distribution runs. | Mechanical Contractor |
| Seek out short circuits, absent TRV'S & poor control routines. | UoW Maintenance Operatives & BMS Incumbent |
| Install heating zone control valves and space temperature sensors (wireless preferred) | Mechanical Contractor & BMS Incumbent |
| Install flow restriction devices on outlets such as showers and taps, to reduce the amount of hot water consumed and associated heat. | UoW Maintenance Operatives |
| Install insulation on exposed sections of heating and hot water pipework distribution, reducing pipework losses, | UoW Maintenance Operatives / Mechanical Contractor |

*Please note the above costs and time periods are indicative and require defining at the next stage of design.*

**St Johns Campus**

| Building Name | Eliminate Short Circuits | Modify Hydraulic pipework | Replace single pipe heating systems | Reconfigure Control Valves | Optimise Variable Pump Control | Change DHW Plant |
|---|---|---|---|---|---|---|
| Edward Elgar | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Ledbury Hall | ✓ | ✓ | | ✓ | ✓ | |
| Woodbury | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Peirson Centre | ✓ | ✓ | | ✓ | ✓ | ✓ |
| AE Housman | ✓ | ✓ | | ✓ | ✓ | |
| Sheila Scott | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Conference Centre | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Barrington House | | ✓ | | ✓ | ✓ | |
| Vesta Tilley Hall | ✓ | ✓ | | ✓ | ✓ | |
| Charles Darwin | ✓ | ✓ | | ✓ | ✓ | |
| Ankerdine Hall | ✓ | ✓ | | ✓ | ✓ | |
| Fern Hall (6ABCD) | | ✓ | | ✓ | ✓ | ✓ |
| Evesham / Pershore | ✓ | ✓ | | ✓ | ✓ | |
| Oldbury House | | ✓ | | ✓ | ✓ | |
| Abberley Hall | ✓ | ✓ | | ✓ | ✓ | |
| Windrush Hall | ✓ | ✓ | | ✓ | ✓ | |
| Thomas Telford | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Forensic House | | ✓ | | ✓ | ✓ | |
| Binyon North | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Binyon Building | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Avon Hall | ✓ | ✓ | | ✓ | ✓ | |
| Hines Building | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Sports Centre | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Students Union | ✓ | ✓ | | ✓ | ✓ | |

Table 7 – St Johns Campus Summary of Essential Modifications
Note: The above table does not include duplicate buildings the duplicate buildings.

**City Campus**

| Building Name | Eliminate Short Circuits | Modify Hydraulic pipework | Replace single pipe heating systems | Reconfigure Control Valves | Optimise Variable Pump Control | Change DHW Plant |
|---|---|---|---|---|---|---|
| Charles Hastings | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Bishop Bosel Hall | ✓ | ✓ | | ✓ | ✓ | |
| Jenny Lind | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Chancellor Hall | ✓ | ✓ | | ✓ | ✓ | |
| Mulberry House | ✓ | ✓ | | ✓ | ✓ | ✓ |
| University Art House | | | | | | |

Table 8 – City Campus Summary of Essential Modifications

**Severn Campus**

| Building Name | Eliminate Short Circuits | Modify Hydraulic pipework | Replace single pipe heating systems | Reconfigure Control Valves | Optimise Variable Pump Control | Change DHW Plant |
|---|---|---|---|---|---|---|
| University Arena | ✓ | ✓ | | ✓ | ✓ | |
| Riverside Building | ✓ | ✓ | | ✓ | ✓ | |
| The Garage | ✓ | ✓ | | ✓ | ✓ | ✓ |

Table 9 – Severn Campus Summary of Essential Modifications

Remove Low Loss Headers [Medium disruption]

Low loss headers result in the elevation of return temperatures and are therefore detrimental to a heat pump strategy, which requires low return temperatures. Low loss headers behave like a large, short circuit or bypass and need splitting to separate flow and return sections. It is recommended that these are replaced with plate heat exchangers as part of ongoing maintenance prior to the heat pump installation commencing.

Remove Single Pipe Heating Systems [High Disruption]

Single pipe heating distribution systems result in the elevation of return temperatures and poor control are therefore detrimental to a low temperature heat pump strategy and district heating network, which requires low return temperatures. It is recommended that single pipe heating systems are replaced with traditional two pipe heating systems as part of ongoing maintenance enabling the high temperature heat pump to operate at lower temperatures in the future.

Control valve configuration [Low disruption]

Although both 3 port and 2 port control valves provide adequate control of heating coils, the 3 port valves result in high return temperatures as they bypass at part load, therefore any 3 port valves should be replaced with 2 port valves.

Variable speed pumping [Low disruption]

Control of pump speeds will allow optimisation of the energy that is delivered and is essential when changing to 2 port control. It will also ensure that pump motor energy is only expended when heat energy is required, allowing motor output to be matched to the secondary system energy demand.

Change Domestic Hot Water (DHW) to Electric or Plate heat Exchangers [High disruption]

It is recommended to replace domestic hot water storage and distribution with local electric water heaters where the requirement for storage no longer represents the buildings hot water demand. Replace hot water storage in 'low hot water demand' buildings with plate heat exchangers operating at 57°C/20°C complete with an electric heater installed on the hot water return. Where storage is required on 'high hot water demand' buildings such as halls of residences, an electric immersion or electric boiler would be required to ensure the hot water storage achieves 60°C, to further reduce demand the provision of solar thermal panels are suggested to further reduce the heat required for hot water generation.

Change Air handling Unit (AHU) Coils [High disruption]

Revised AHU frost and reheat coil selections are required to achieve the required heat output whilst working with lower temperatures and increased heating water temperature differentials (ΔT). These will be physically larger than the existing frost and reheat coils. Where packaged AHU's and MVHR's are installed, these would require wholesale replacement in order to provide larger heating coils, replacement of the units would be recommended as part of the maintenance regime or when the units are at the end of their useful life.

Replacing heat emitters [High disruption]

There is a mixture of radiator types across the buildings, in most instances there is scope to replace these with larger surface area radiators, whether this be taller, double panel or triple panel radiators. Replacing existing radiators with larger radiators will allow the building to operate at lower temperatures whilst satisfying the buildings heat demand. Once radiators are replaced, buildings can be connected to a commercial heat pump system which requires lower operating temperatures to operate efficiently. Undertaking radiator replacements will be disruptive to the users and building operations and as such will likely be carried out under phased and planned works. In the interim period prior to emitter replacement 'top-up' heat will be required, this could take the form of the existing boilers which would offer resilience and allow the works to be planned to suit the age/condition of plant and future works.

To ensure that the best weather compensation and the lowest district heating temperatures are achieved in the summer, the domestic hot water generation systems across the buildings will need altering / upgrading / replacing as necessary to ensure these do not become the limiting factor preventing heat pump operation by lowering temperatures.

Reduce return temperatures [Low disruption]

Return temperatures above 55ºC will prevent the heat pumps from being able to deliver any energy into the network. A major element of the high return temperatures in the secondary system within the buildings can be attributed to unplanned fixed by-passes or short circuits in the pipework system. The temperature can be reduced once the fabric is improved and the emitters have been replaced with larger.

## 10.0 Interventions Considered

### 10.1.1 Reduce Base Heat Load by Enhancing Building Fabric

Irrespective of buildings being existing or new build, reducing the base heating load by taking a fabric first approach is always encouraged, it is appreciated that improving the fabric of existing building stock can be costly, disruptive, and timely, this has been considered for the recommended decarbonisation plan.

The thermographic surveys undertaken have highlighted poor performing fabric and junctions on buildings across the Estate, this information can be used as a tool to tackle the worst offending building and specific elements of the building. As opposed to wholesale improvements of entire elements such as external wall which can be costly and disruptive, improvements that can be programmed as part of the Universities on-going building maintenance.

It is encouraged to improve fabric deficiencies as part of the on-going building maintenance to reduce the base heating load and associated energy prices.

Discussions held with UoW have established that the buildings need to remain operational for the majority of the year, with disruptive works ideally being undertake during a 6 week period over the summer holidays. With prohibitive costs and disruptive works associated with upgrading wholesale fabric elements and changing heat emitters such as radiators and air handling unit heating coils, this limits the opportunity to provide a low-grade heating solution in the short term.

*Specialist input will be required for each building as summarised below:*

- *Building Surveyor, Builder and/or Architect, advice on wholesale replacement of building elements such as wall, roofs, etc. to establish improvement options and constraints posed by the existing buildings.*

  *The Thermographic Survey has highlighted fabric deficiencies, some of which the UoW Estates Department may be able to rectify, some deficiencies may require specialist advice from a builder, building surveyor or architect.*
- *Services Consultant, undertake calculations to establish carbon savings for the various fabric improvement options considered.*
- *Cost Consultant, to establish detailed cost for the various options considered.*

### 10.1.2 Heat Reduction Associated with Hot Water Generation

Site surveys and discussions with UoW have identified that some buildings hot water demand are no longer as high as they once were, with sanitaryware being removed over the years. Despite the buildings now being low hot water usage, large amount of stored water and extensive hot water distribution pipework remain, resulting in additional heat for cylinder and pipework losses.

It has also been identified that a large proportion of buildings, generally halls of residences have a high percentage of heat consumed associated with hot water generation.

Based on the above findings the following interventions are recommended to assist in reducing the heating load:

- Replace domestic hot water storage and distribution pipework with local electric water heaters where the requirement for storage no longer represents the buildings hot water demand.
- Where hot water storage is required to offset high peak periods, replace LTHW hot water generation with electric immersion heaters where the existing electrical load allows.
- Where storage is required on 'high hot water demand' buildings such as halls of residences, the provision of solar thermal panels is suggested to reduce the heat required for hot water generation.

It is noted that hot water generation plant for the majority of the buildings is in good condition and well within their life expectancy. It would be cost prohibitive to replace the current hot water cylinders with cylinders with solar thermal and electric immersion capabilities, as part of the maintenance replacement strategy it is suggested that solar ready and electric immersion capable cylinders are provided.

*Specialist input will be required for each building as summarised below:*

- *Services Consultant, undertake hot water assessments to establish local hot water generation required, solar thermal requirement and associated electrical alterations required.*
- *Cost Consultant, to establish detailed cost for the various hot water alterations proposed.*

### 10.1.3 District Heating Networks

The proposal to provide district heating network(s) distributing heat to each of the buildings, emanating from a single energy centre or multiple energy centres depending on the route which UoW wish to proceed with. Serving multiple buildings using district heating networks(s) has the following benefits:

- Reduces the overall plant and space required over semi-decentralised and de-centralised systems and multiple areas of disruptive construction works.
- Diversified load, resulting on reduced overall heating loads and associated plant sizing.
- Avoids the need for multiple planning approval requirements.
- Avoids issues with acoustics for sleeping accommodation and noise sensitive buildings.
- Maintenance catchment area reduced.

The heat metering data has highlighted that the existing boiler plant installed within the Edward Elgar building is significantly under utilised.  The installed boiler and capacity is 4No. boilers @ 1200KW each, the peak metered heat delivery is 2320 kW. The individual heat demand from the remaining buildings on St. Johns Campus totals 1175 kW, therefore the total heat demand can be provided by the Edward Elgar boiler room whilst maintaining 100% capacity in the event of a boiler failing.  The more buildings added to a central energy centre the further diversity is enhanced which results in further reduction in gas usage.

The heat metering data has highlighted that the existing boiler plant installed within the Arena is significantly underutilised. The installed boiler and capacity is 3No. boilers @ 850KW each, the peak metered heat delivery is 480kW. The individual heat demand from the remaining buildings on Severn Campus totals 327 kW, therefore the total heat demand can be provided by the Arena boiler room whilst maintaining 100% capacity in the event of a boiler failing.

It is recommended that UoW apply for Government funding available for extending the existing district heating system, all building will be ready to connect to a low zero carbon heat pump.

*Specialist input will be required as summarised below:*

- *Structural Engineer and Architect, advice on structural changes for incoming district heating mains to each building.*
- *Services Consultant, district heating network design, individual plantroom modifications and energy centre design including electrical upgrades.*
- *Cost Consultant, to establish detailed cost for the system alterations, district heating network and energy centre construction and installation.*

#### 10.1.4 Heating Generation

Several sources of heat generation were considered as part of the recommended heat decarbonation route, refer to section 4.1 which provides background information on the sources of heat which have been discounted.

The following sources of heat generation have been considered as feasible for UoW Estate.

- Commercial (Low Temperature) Air Source Heat Pumps
- Industrial (High Temperature) Air Source Heat Pumps
- (High Temperature) River Source Heat Pumps – Study Undertaken by Element Energy.

We would recommend that UoW continue to consider both Industrial (High Temperature) Air Source Pumps & River Source Heat Pump solutions in parallel. Both systems operate at high temperatures which minimises disruptive changes such as changing heat emitters and extensive fabric improvements, unlike the commercial low temperature solution which is key to UoW operation. This approach enables UoW to improve the fabric elements and change heat emitters as part of the on-going building maintenance, which will eventually allow heating systems to operate at lower temperatures, improving the overall efficiency of the heat pumps.

The UoW should continue to explore the river source heat pump option, with the detailed proposal by Element Energy progressed once funding is available in April. Once the detailed appraisal has been finalised, UoW can consider the best route and pros and cons of becoming an energy provider or remaining as an energy customer.

The option within this report provides UoW with a scalable, manageable and modular approach using multiple energy centres and district heating networks for each campus. UoW will own and manage the energy centres and district heating networks, with a phased approach plantrooms can be flexible to include new and emerging technologies. The capital investment to develop the heat pump energy centres and district heating networks can be phased to meet the UoW's investment plan and funding streams, thus being a 'no regret' investment approach without being tied into contracts.

The phasing of the plan for Industrial Air Source Heat Pumps will result in the transition of individual building gas-based heating systems to electricity driven heat pump-based district heating networks for each campus.

The following graphs and tables indicated the % carbon reduction and running costs associated with all 3 campuses per year.

Figures ES1 & ES2 indicates the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 2 – Extend Existing District Heating from Edward Elgar

   As can be seen from the below chart these slightly improve the carbon emission, results in a **carbon saving of 14 tonnes/annum,** and results in **reduced utility costs by £5,200/annum**
3. Iteration 3 – Replacing individual gas fired boilers for industrial air source heat pumps via a district heating network.

   As can be seen from the below chart these completely removes the requirement for gas heating, results in a **carbon saving of 606 tonnes/annum,** although results in **higher utility costs of £415,000/annum**
4. Iteration 4 – Undertaking all fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 214 tonnes/annum,** also results in **reduced utility costs by £293,000/annum.**
5. Iteration 5 – Undertaking emitters replacement to improve the efficiency of ASHPs and reduce utility costs.

   As can be seen from the below chart undertaking the heaters replacement, results in a further **carbon saving of 72 tonnes/annum,** also results in further **reduced utility costs by £99,000/annum.**

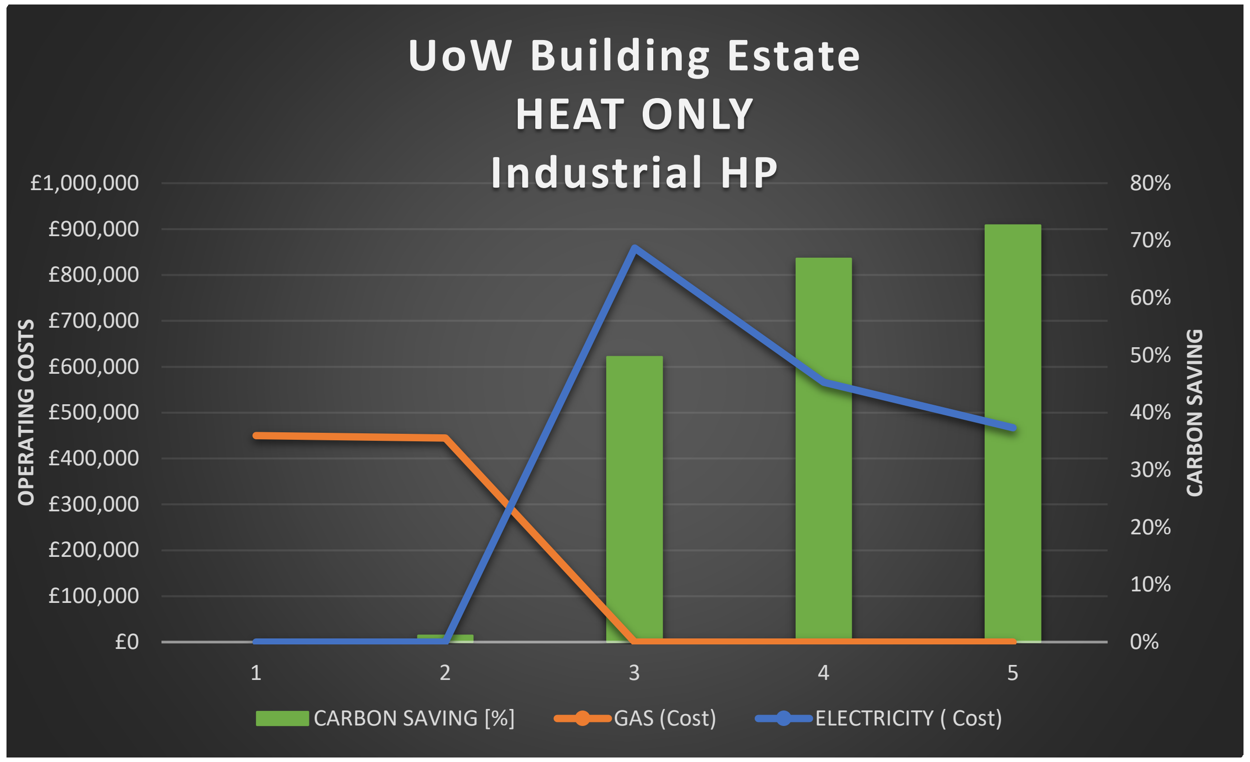



Figure 4 – Building Estate – Industrial Air Source Heat Pump – Operating Costs

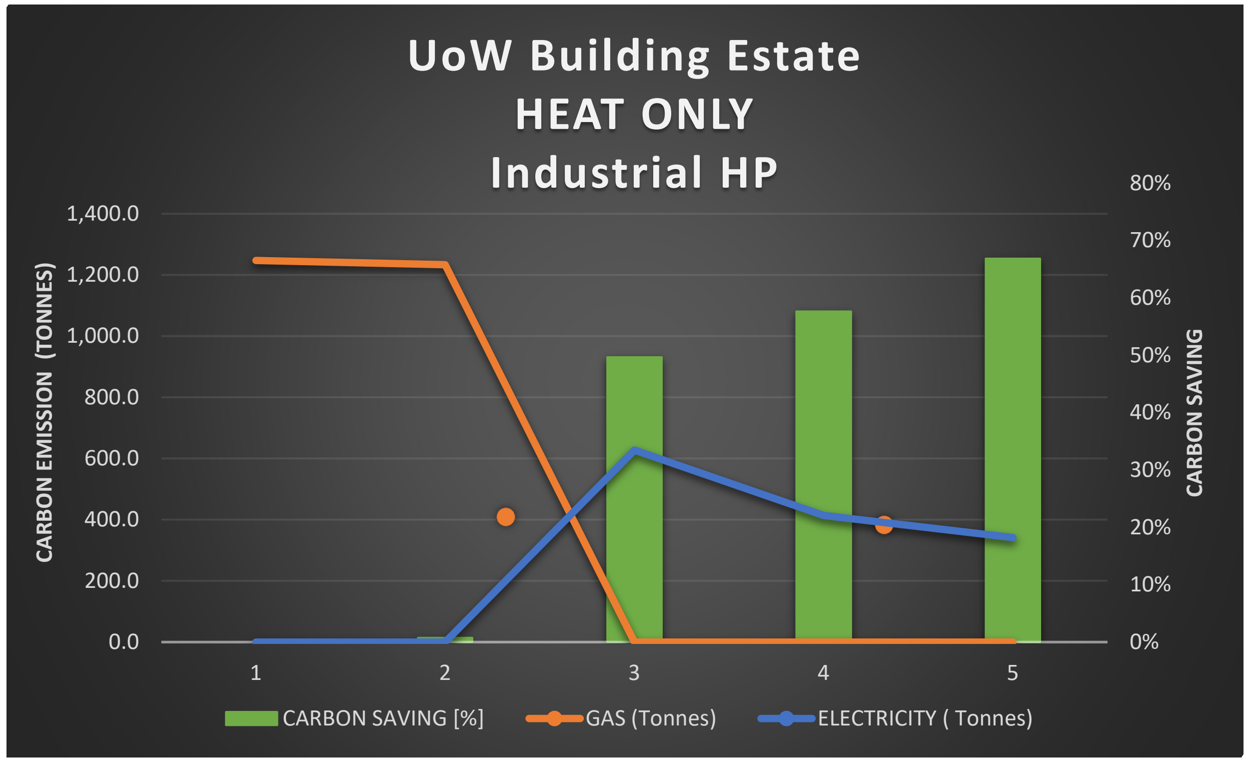



Figure 5 – Building Estate – Industrial Air Source Heat Pump – Carbon Reduction

#### 10.1.5 Long Term Target – Industrial Heat Pumps Operating at Lower Temperature

To further decarbonise the heat generated across the Estate, it is key to reduce the heating system operating temperatures of the district heating network resulting in an increased efficiency of the high temperature heat pumps resulting in further carbon savings and reduced energy prices. Installing high temperature heat pumps offers the greatest carbon saving over all interventions, UoW can benefit from these carbon savings whilst addressing fabric deficiencies and improving the fabric elements.

Fabric improvements are disruptive, expensive and can affect the operation of buildings, although fabric improvements are fundamental to reduce the base heating load and offset future rises in energy costs, fabric improvements could be carried out as part of the normal life cycle refurbishment gateways. The most effective and sustainable way to reduce carbon associated with heat or electricity for that matter is to not use it in the first place.

There is a mixture of radiator types across the buildings, in most instances there is scope to replace these with larger surface area radiators, whether this be taller, double panel or triple panel radiators. Replacing existing radiators with larger radiators can be costly and disruptive although this will allow the building to operate at lower temperatures whilst satisfying the buildings heat demand. Once radiators are replaced, the efficiency of the high temperature heat pump will transfer to further carbon savings and reduction in energy prices. Operating a district heating network at lower temperatures significantly extends the longevity of the pipework, operating at circa 80degC equates to an expected life span of 35 years, whereas operating at circa 50degC equates to an expected life span of 100 years.

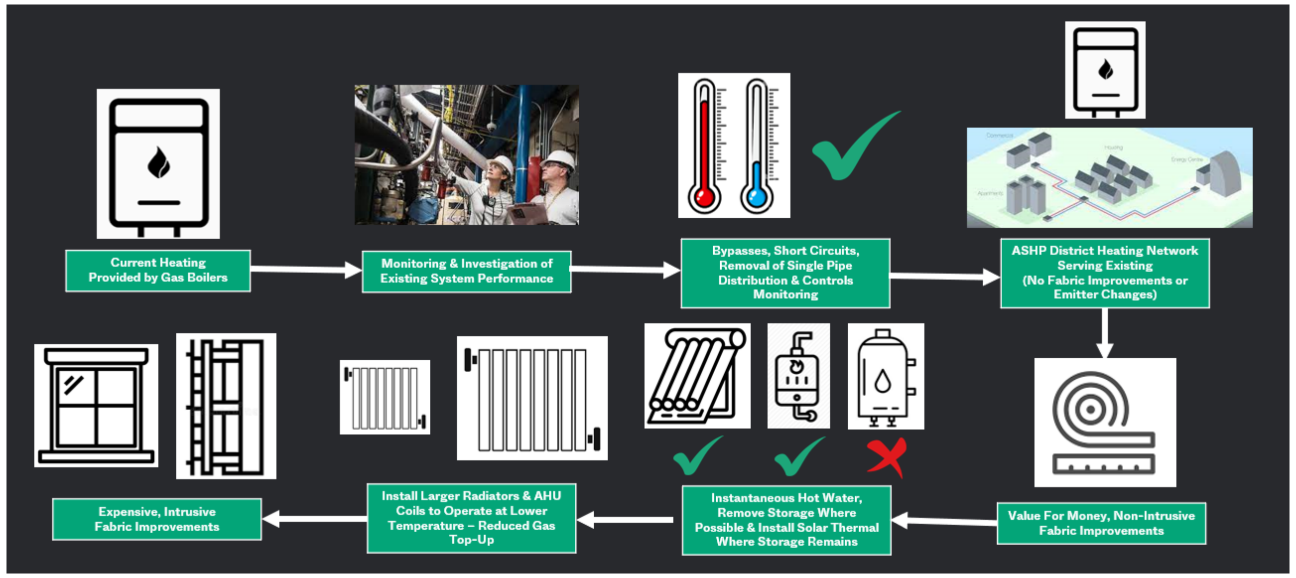



Figure 6 – Building Intervention Roadmap

## 11.0 Heat Pump Technology and Innovation

### 11.1 Air Source Heat Pump Technology

A heat pump is a device used to transfer thermal energy from a cooler space to a warmer space using the refrigeration cycle, in the opposite direction in which heat transfer would normally take place. This is made possible with the application of external power. Heat pumps are commonly named after the heat source and are often referred to as air source heat pumps, ground source heat pumps, water source heat pumps etc.

Heat pumps are also often used in district heating systems where large-scale heat pumps are combined with thermal energy storage to allow the integration of variable renewable energy, and to mitigate the effect of peak energy demand. Therefore, they are regarded as a key technology for smart energy systems with high proportions of renewable energy. In Europe, more than 1500 MW have been installed since the 1980s, of which about 1000 MW were in use in Sweden in 2017.

To provide heat, a heat pump works by extracting heat energy from the external ambient air and transferring it to refrigeration coolant. Heat energy can be extracted from ambient air even at sub-zero temperatures. The coolant is then compressed, which increases the temperature significantly; the hot coolant is then moved to the indoor unit of the heat pump, which then passes air over the hot coolant to warm the space.

When the heat pump is operating in the cooling mode, the refrigerant is reversed by the aptly named reversing valve and flows through the indoor coil as a low temperature liquid. As the blower passes air from the conditioned space through the coil, the indoor air, being warmer than the refrigerant, transfers heat to the refrigerant, thereby cooling the air.

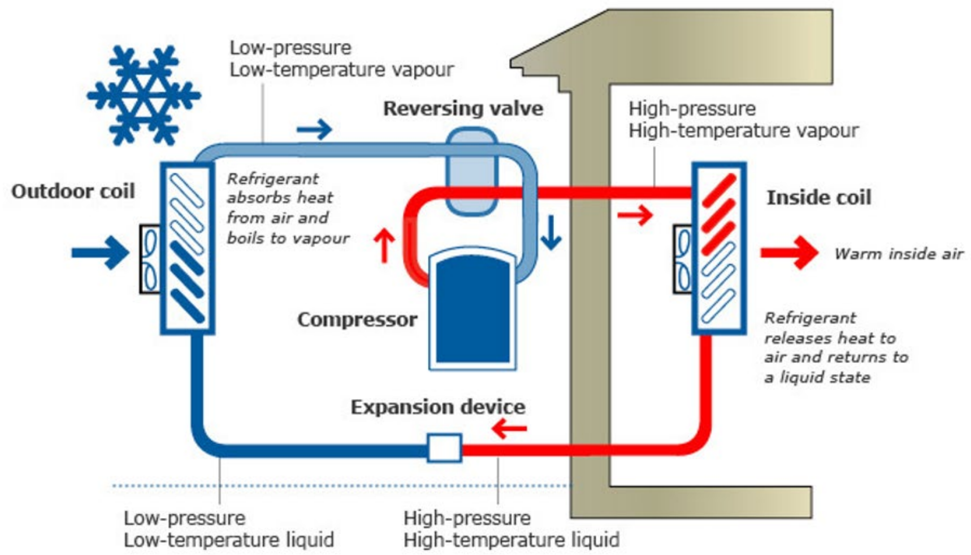



Figure 7 - Typical generic heat pump schematic

The efficiency of a heat pump is expressed as a coefficient of performance (COP), or seasonal coefficient of performance (SCOP). The higher the number, the more efficient a heat pump is and the less electrical energy it consumes. For example, an air-source heat pump with a COP of three will supply three kilowatts of heat energy for the consumption of one kilowatt of electricity resulting in significant carbon savings.

Air source heat pumps are used to move heat between two heat exchangers, one outside the building which is fitted with fins through which air is forced using a fan and the other which either heats the air inside the building directly or heats water which is then circulated around the building through heat emitters which release the heat to the building. These devices can also operate in a cooling mode where they extract heat via the internal heat exchanger and eject it into the ambient air using the external heat exchanger.

Air source heat pumps are relatively easy and inexpensive to install and have therefore historically been the most widely used heat pump type. In mild weather COP may be around 4.5 for outdoor air temperatures of around 7°C, however at lower outdoor temperatures around 0 °C an air-source heat pump may still achieve a COP of 2.5. The average COP over seasonal variation is typically 2.5-2.8, with exceptional models able to exceed this in mild climates.

#### 11.1.1 Commercial Air source heat pump

Air source heat pumps are used to move heat between two heat exchangers, one outside the building which is fitted with fins through which air is forced using a fan and the other which either heats the air inside the building directly or heats water which is then circulated around the building through heat emitters which release the heat to the building. These devices can also operate in a cooling mode where they extract heat via the internal heat exchanger and eject it into the ambient air using the external heat exchanger.

Air source heat pumps are relatively easy and inexpensive to install and have therefore historically been the most widely used heat pump type. In mild weather COP may be around 4.5 for outdoor air temperatures of around 7°C, however at lower outdoor temperatures around 0 °C an air-source heat pump may still achieve a COP of 2.5. The average COP over seasonal variation is typically 2.5-2.8, with exceptional models able to exceed this in mild climates.

#### 11.1.2 Industrial Heat Pumps

Industrial heat pumps operate similar to commercial heat pumps and may be used to replace the air and ground heat source variants described above. Industrial heat pumps are usually custom made, manufactured for a specific application and use ammonia (or carbon dioxide) as a refrigerant resulting in improved efficiency and higher discharge water temperatures. They are therefore able to provide a range of discharge temperatures from 55°C up to 80°C, however their COP decreases significantly at higher temperatures resulting in higher operating costs. The following figure 5a has been based on data received from two established UK industrial refrigeration heat pump specialist companies, and clearly demonstrates the reduction in Seasonal Coefficient of Performance (SCOP) at higher discharge temperatures.

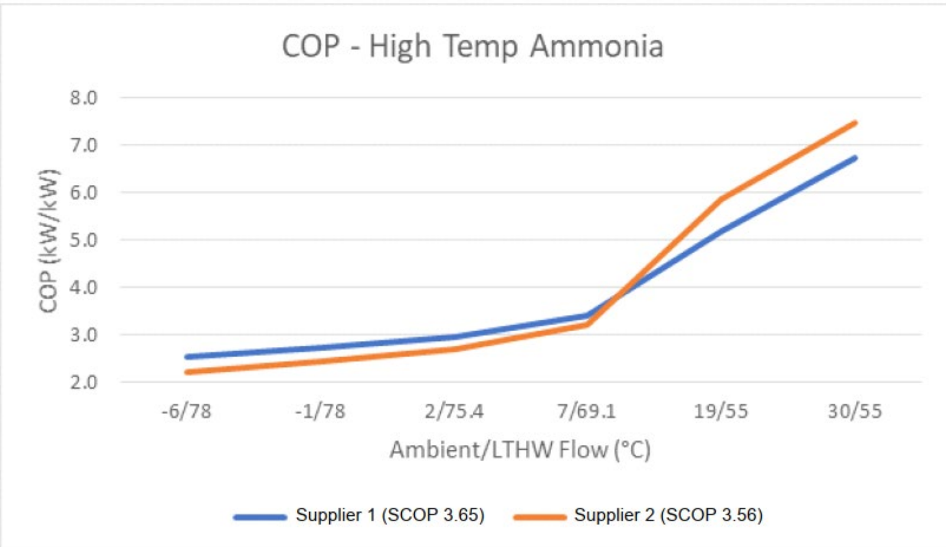



Figure 8- Typical high temperature heat pump efficiency curve

This indicates that without fabric improvements that the proposed solution can meet 100% of the site load.

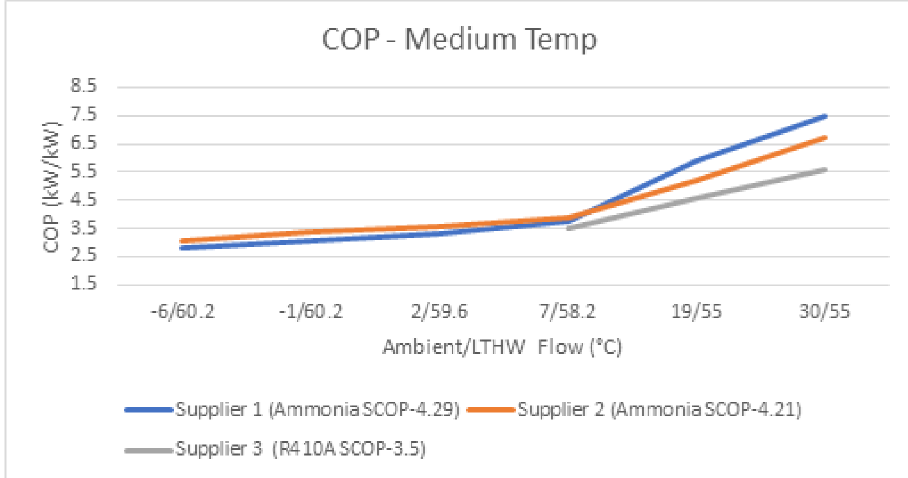



Figure 9 - Typical low/medium temperature heat pump efficiency curve

This indicates that after fabric improvements that the proposed solution can meet 100% of the site load.

Industrial heat pumps are larger and more expensive than their commercial equivalent and require specialist maintenance due to the ammonia refrigerant which is both flammable and poisonous. On the positive side, ammonia is environmentally friendly with a Global Warming Potential (GWP) and an Ozone Depletion Potential (ODP) rating of zero. It is recommended that they be located in a dedicated plant room separate from occupied buildings with suitable firefighting and personal safety measures. Access should also be restricted to suitably trained maintenance staff and/or specialist refrigeration engineers.

### 11.2 Water Source Heat Pump Technology

Water Source heating works by using a nearby body of water as a heat source. This could be a river, lake, or the sea; some systems even work with slurries and effluent waste. Water in a closed loop from the body of water is pumped to a refrigerant based heat pump system, where the heat is transferred to a secondary heat distribution circuit used for the buildings space heating and hot water systems.

The water in the closed loop is returned to the water source at a lower temperature. Like ASHPs and GSHPs, Water Source Pumps can provide both heating and cooling to buildings but have a much greater Coefficient of Performance (COP) of around 10.

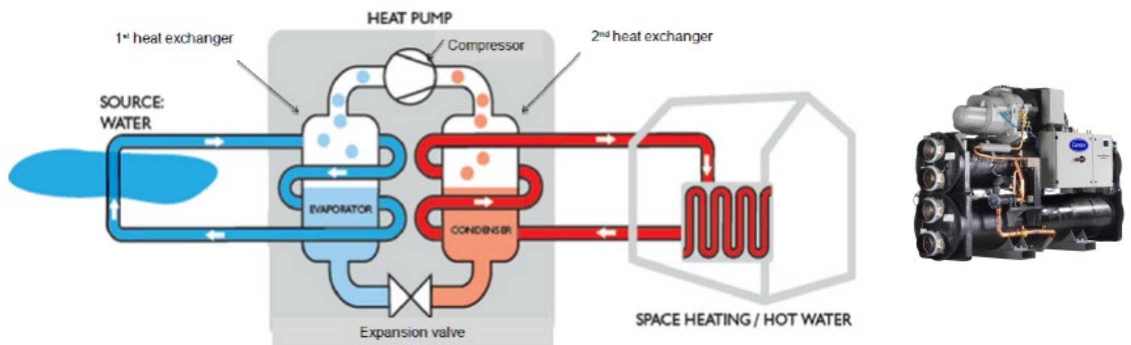



Figure 10 – Typical water source heat pump arrangement

Unlike ASHPs water source heat pumps are less noisy and is less obtrusive than GSHPs. However, the use of these units is highly regulated by the Environment Agency (EA), who impose strict limits on the water discharge temperature. An abstraction licence is required, and the EA can revoke this at any time.

## 11.3 Ground Source Heat Pump Technology

A ground-source heat pump (GSHP) draws heat from the soil or from ground water which remains at a relatively constant temperature all year round below a depth of about 10m. Traditional vertical borehole systems are drilled to a typical depth of circa 100m. A well maintained traditional borehole GSHP system will typically have a COP of 4.0 at the beginning of the heating season and a seasonal COP of around 3.0 as heat is drawn from the ground. GSHP are more expensive to install due to the need for the drilling of boreholes for vertical placement of heat exchanger piping or the digging of trenches for horizontal placement of the piping that carries the heat exchange fluid (water-glycol mixture).

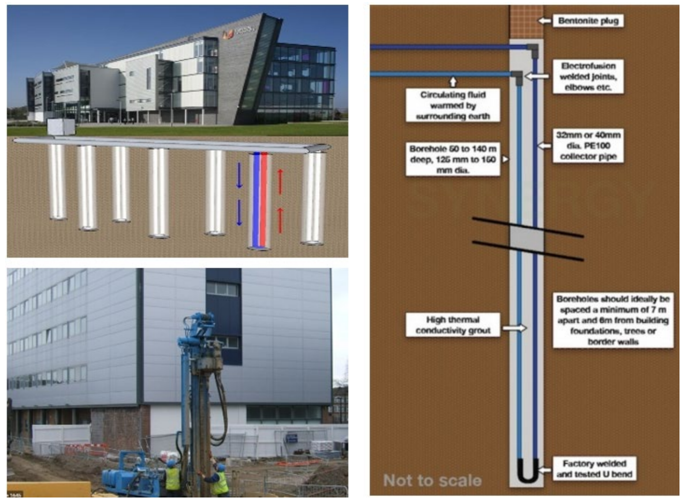



Figure 11 – Typical vertical boreholes for ground heat source

Figure 11 – Typical horizontal trenches for ground heat source

A GSHP can also be used to cool buildings during hot days, thereby transferring heat from the dwelling back into the soil via the ground loop.

## 12.0 Current Heating Plant Room Locations

Most buildings contain a decentralised plant room, with two mini district heating networks serving multiple buildings. The plant rooms generally contain boilers and domestic hot water generation.

Any future heat network connections will need to be connected to the existing plant rooms.

**St Johns Campus – Halls of Residences**


Figure 12 – St Johns Campus - Existing Heating Plant Room Locations

**St Johns Campus – Academic Buildings**


Figure 13 – St Johns Campus - Existing Heating Plant Room Locations

**City Campus**

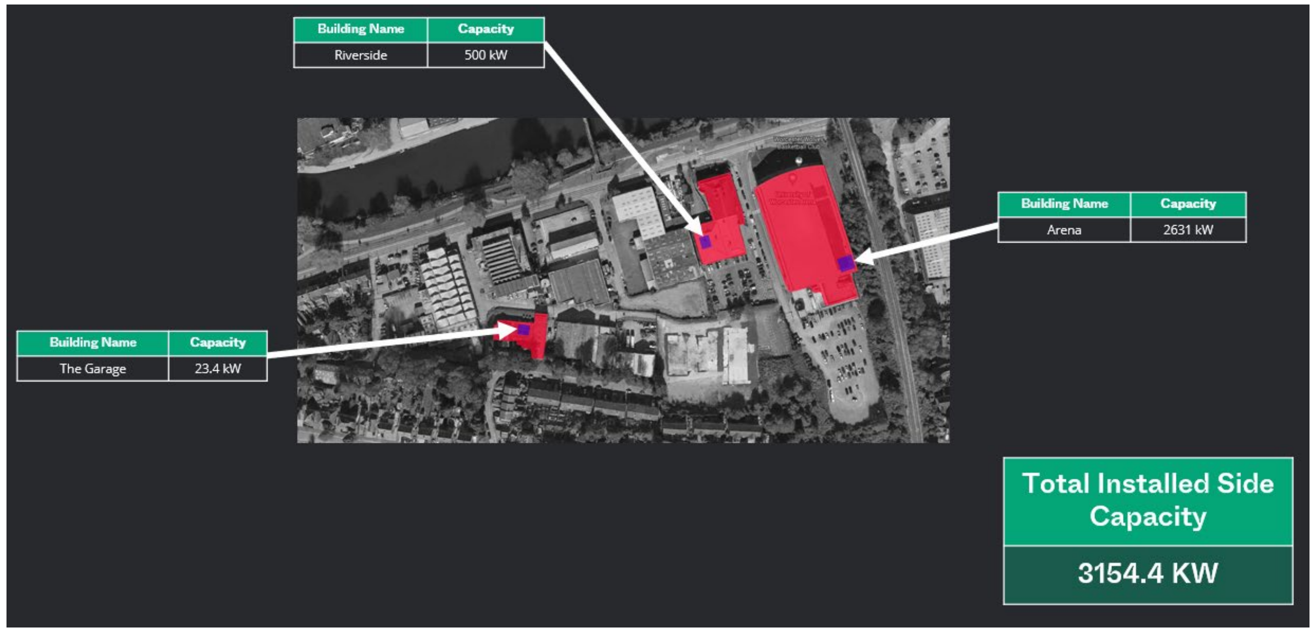



Figure 14 – City Campus - Existing Heating Plant Room Locations

**Severn Campus**

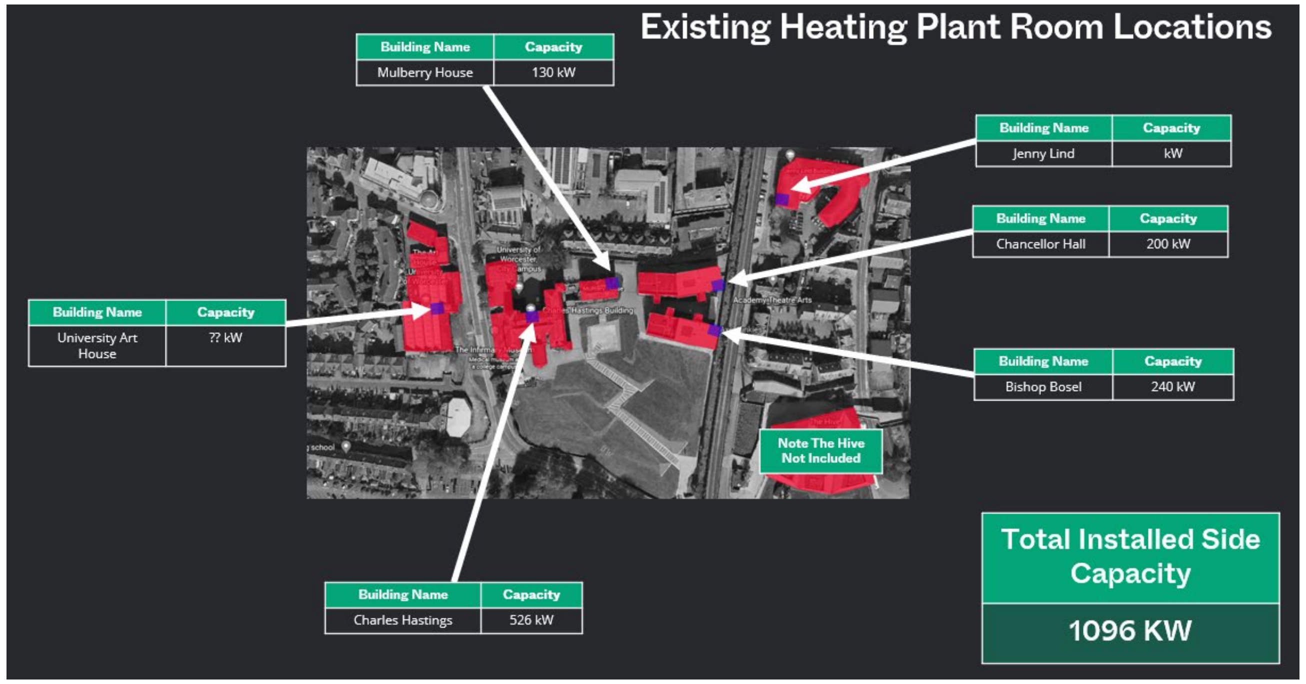



Figure 15 – Severn Campus - Existing Heating Plant Room Locations

## 13.0 Energy Centre Location Options

With any future heat pump driven heating system plant locations will be key to ensure that there is sufficient external area to locate the plant. The locations need to consider and disruption, noise and future access and maintenance. St Johns Campus and City Campus are well developed sites, Severn Campus is undergoing regeneration which will take place over the coming years. All campuses have planning rules and due consideration will be required with any new developments in particular plant that could be noise generating.

Should the buildings not be connected to a central energy centre and district heating network external plant space will be required either at a local building level (decentralised) or shared across several buildings (semi-decentralised).

At present, although subject to structural and planning assessments, recommended central energy centres location have been suggested for the various campuses below.

### 13.1 Suggested Campus Central Energy Centres

Utilising an energy centre solution typically minimises capital (and operating costs) from a maintenance perspective when compared to that of decentralised solution. They can also be constructed to be modular and scalable as more demand is connected to the heat network.

The following figures represent possible indicative energy centre locations for each of the campuses.

**St Johns Campus**

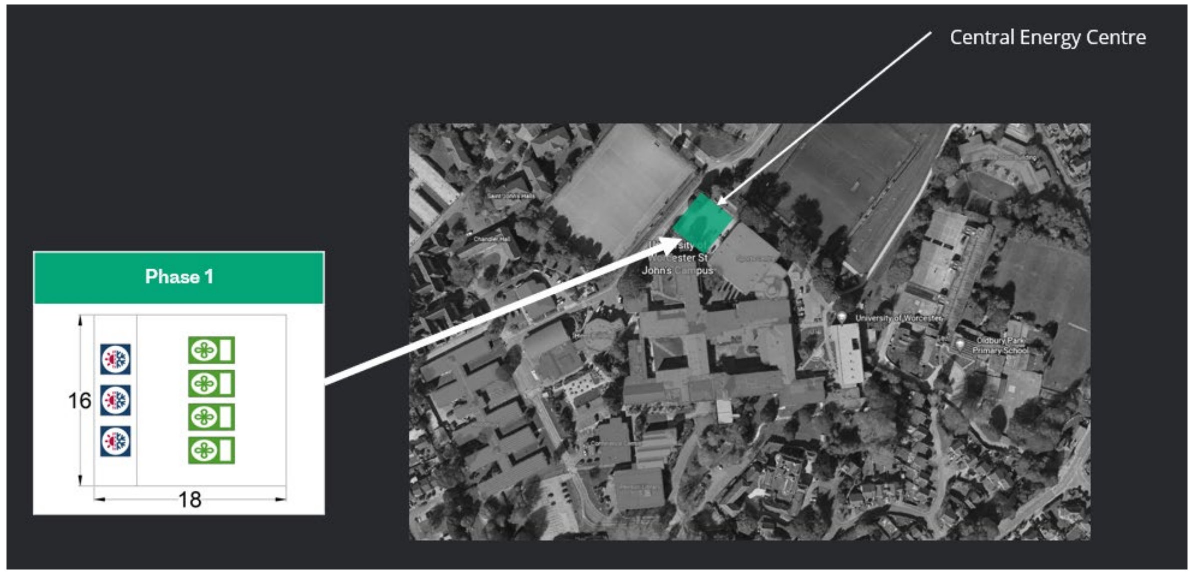



Figure 16 – St Johns Campus Proposed Central Energy Centre Location.

**City Campus**

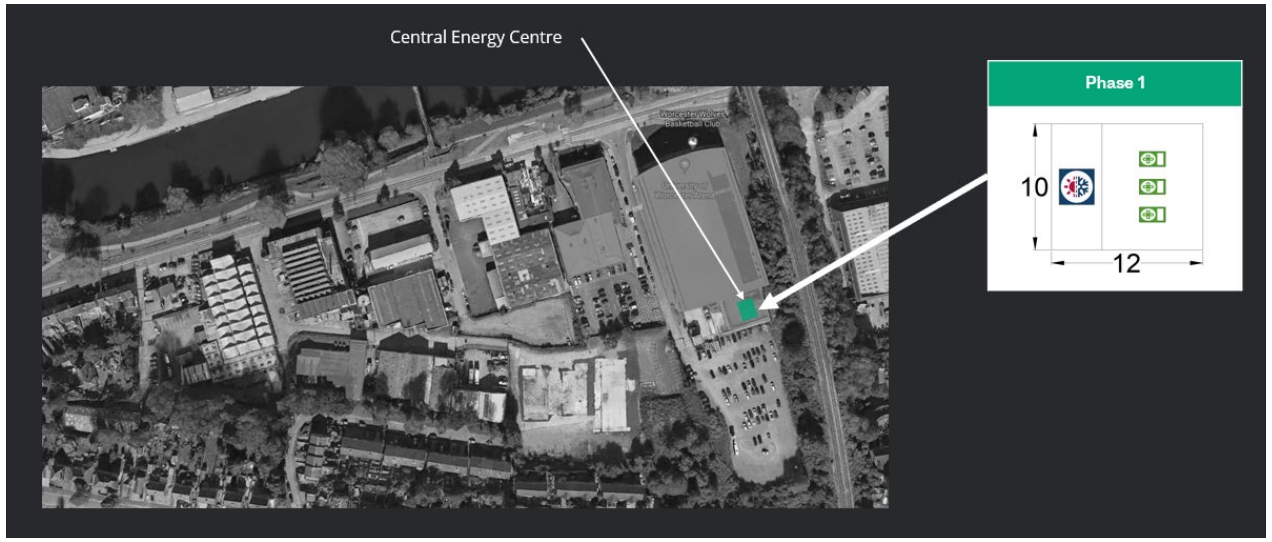



Figure 17 – Severn Campus Proposed Central Energy Centre Location.

**Severn Campus**

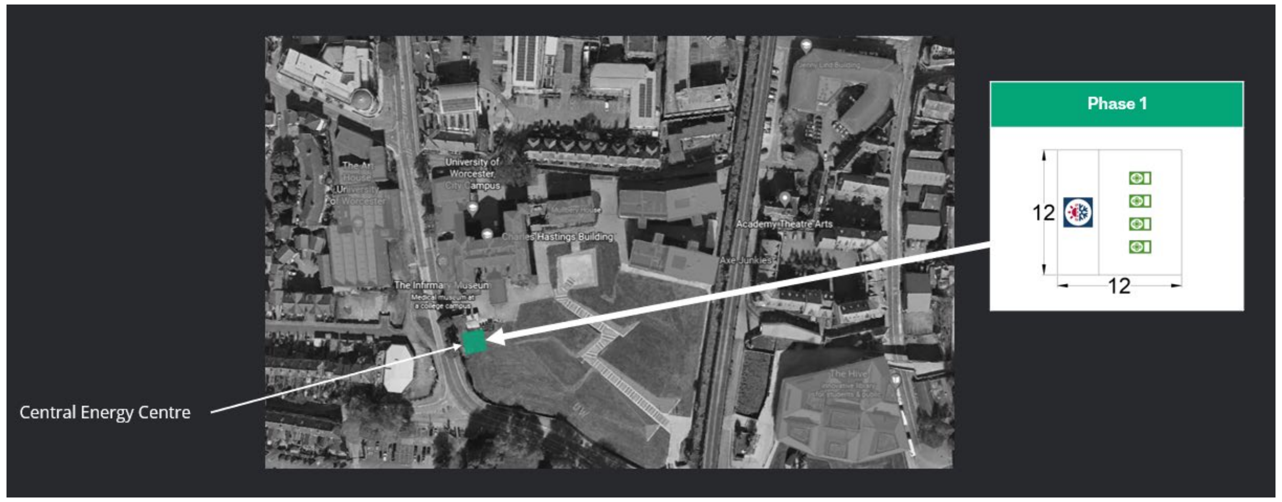



Figure 18 – Severn Campus Proposed Central Energy Centre Location.

## 13.2 Decentralised & Semi-Decentralised Options Considered

The ability to locate plant in a decentralised and semi-decentralised approach and the requirements are shown in following figures, which demonstrate these options are not viable due to space constraints and acoustics and a central energy centre should be pursued.

**St Johns Campus – Halls of Residence**


Figure 19 – St Johns Campus Decentralised Plant Requirements

**St Johns Campus – Academic Buildings**


Figure 20 – St Johns Campus Decentralised Plant Requirements

**City Campus**

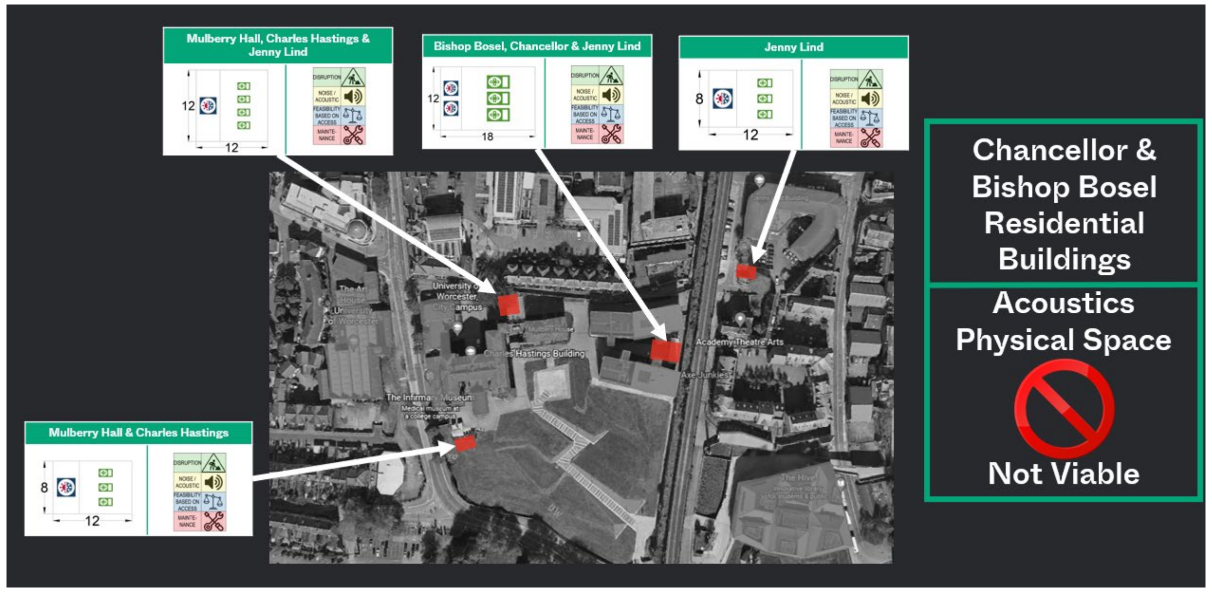



Figure 21 – St Johns Campus Decentralised Plant Requirements

**Severn Campus**

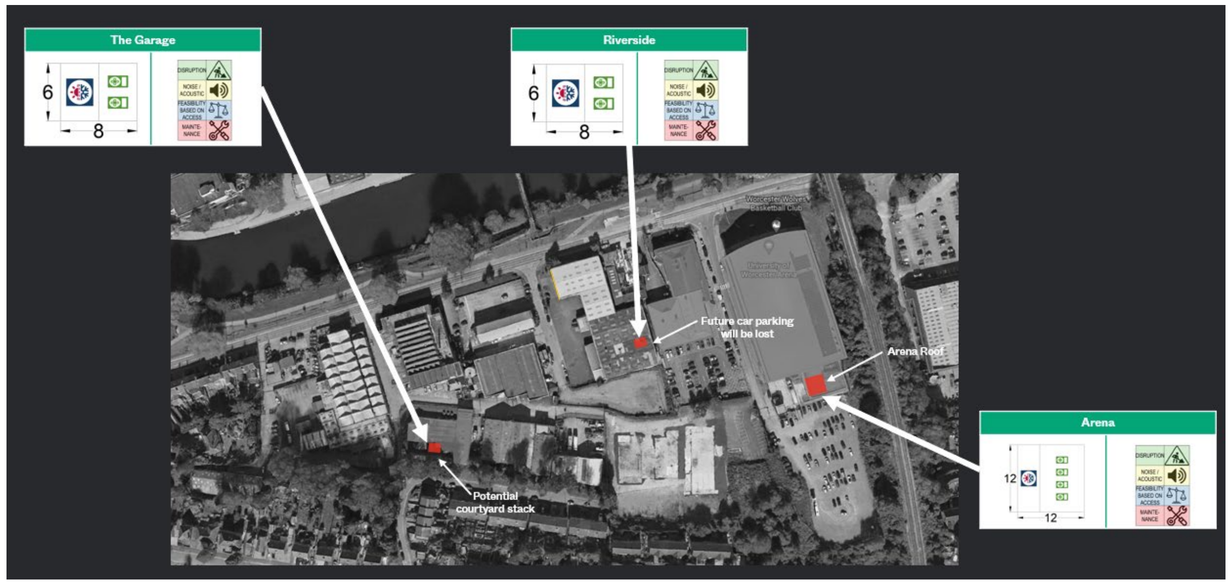



Figure 22 – St Johns Campus Decentralised Plant Requirements

## 14.0 Industrial & Commercial Air Source Heat Pumps Modelling

Following appraisal of the energy data collected, preliminary calculations performed, and a review of the proposed energy network configuration, two options were modelled to compare running costs and reduction in carbon

1. Industrial (High Temperature) Air Source Heat Pump
2. Commercial (Low Temperature) Air Source Heat Pump

Each campus was modelled, essentially following the same trend. In summary, when comparing the Industrial High Temperature Heat Pump **without** major, costly and disruptive fabric changes with a Commercial Low Temperature Heat Pump **with** major, costly and disruptive fabric changes, the running costs and carbon saving are almost identical.

**Confirming that the Industrial High Temperature Heat Pump is the best solution in terms of carbon reduction, running costs and upfront capital costs.**

The following graphs indicate the iterations performed for both systems across the campuses.

Figures 23 indicate the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.

2. Iteration 2 – Extend Existing District Heating from Edward Elgar

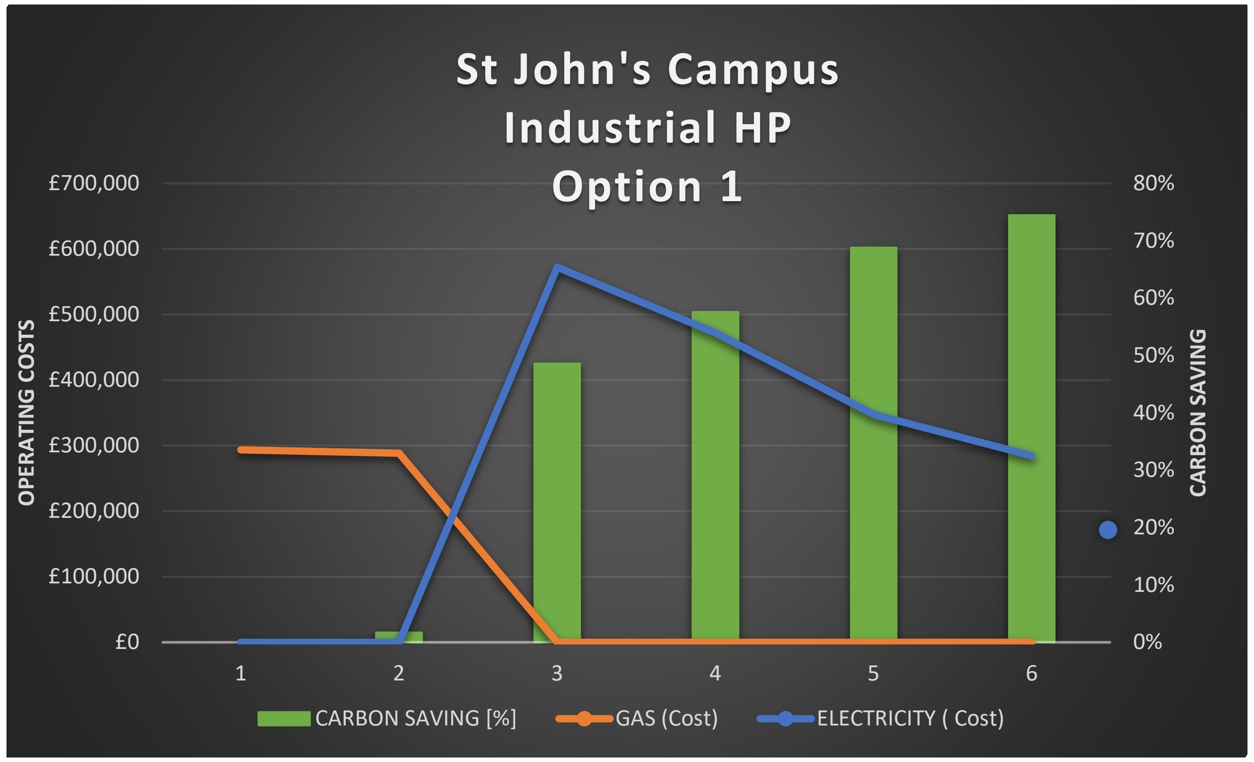
   As can be seen from the below chart these slightly improve the carbon emission, results in a **carbon saving of 14 tonnes/annum,** and results in **reduced utility costs by £5,200/annum**
3. Iteration 3 – Replacing individual gas fired boilers for industrial air source heat pumps via a district heating network.

   As can be seen from the below chart these completely removes the requirement for gas heating, results in a **carbon saving of 396 tonnes/annum,** although results in **higher utility costs of £284,477/annum.**
4. Iteration 4 – Undertaking easy fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 73 tonnes/annum,** also results in **reduced utility costs of £99, 856/annum.**
5. Iteration 5 – Undertaking all fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 92 tonnes/annum,** also results in **reduced utility costs of £124,700/annum.**
6. Iteration 6 – Undertaking emitters replacement to improve the efficiency of ASHPs and reduce utility costs.

   As can be seen from the below chart undertaking the heaters replacement, results in a further **carbon saving of 46 tonnes/annum,** also results in further **reduced utility costs by £63,000/annum.**



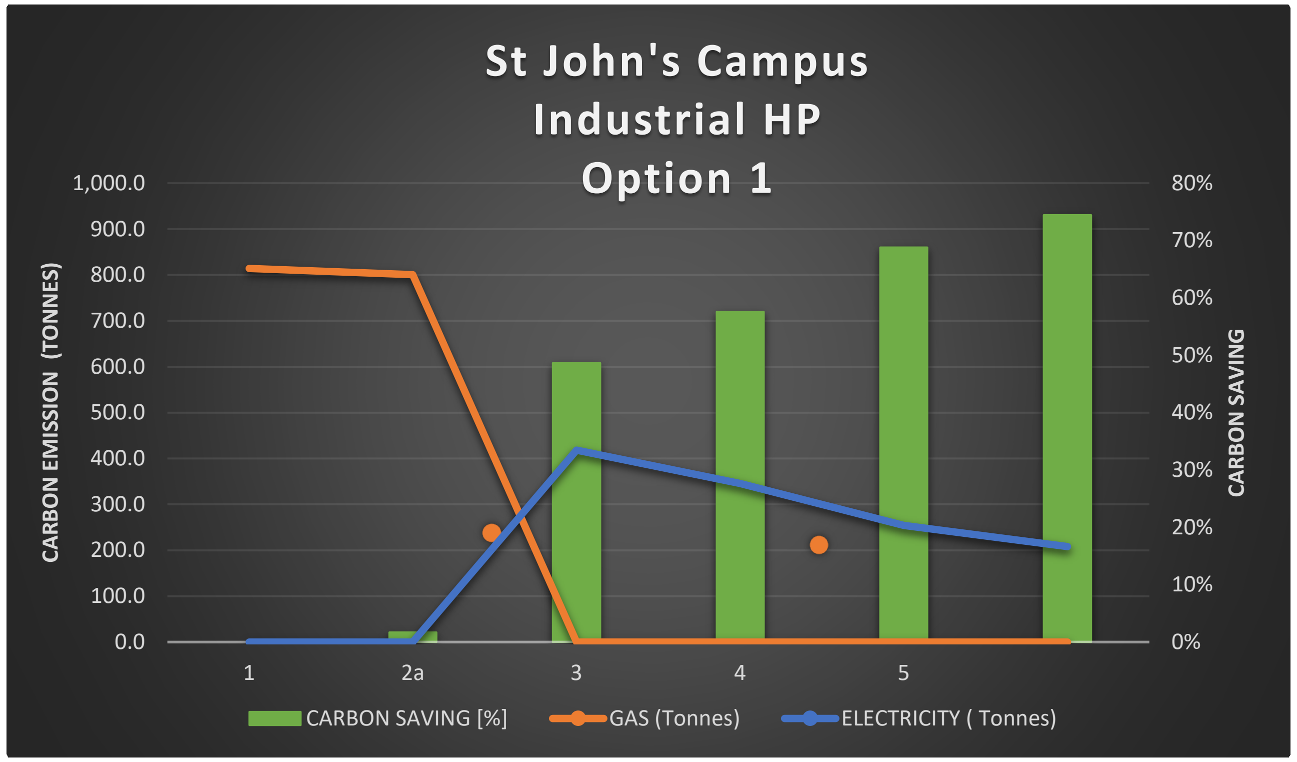




Figure 23 – St Johns Campus High Temperature Heat Pump Operating Costs & Carbon Reduction

Figures 24 indicate the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 2 – Install commercial heat pump via a district heating network. with gas top up.

   As can be seen from the below chart these results in a **carbon saving of 31 tonnes/annum,** although results in **higher utility costs of £80,822 /annum.**
3. Iteration 3 – Undertaking easy win  fabric improvements to reduce the base heating load.

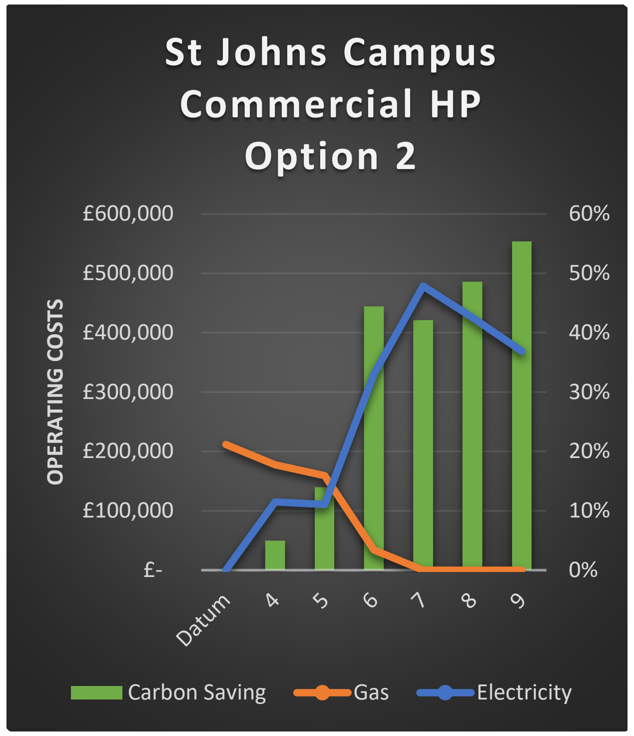
   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 53 tonnes/annum,** also results in **reduced utility costs of 22,385/annum.**
4. Iteration 4 – Enlarge heat emitters & coils with gas top up for hot water only.

   As can be seen from the below chart enlarging emitters lowers the temperature of the ASHP, results in a further **carbon saving of 185 tonnes/annum,** although results in **higher utility costs of £72 237/annum.**
5. Iteration 5 – all gas removed and replaced with electric hot water generation.

   As can be seen from the below chart removing gas completely, due to high domestic water demand results, in higher **carbon emission of 12 tonnes/annum,** also results in **increase of utility costs of £114,000/annum**
6. Iteration 6 – all gas removed and replaced with electric hot water generation and undertaking easy win  fabric improvements to reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 39 tonnes/annum,** also results in **reduced utility costs of £52,877/annum.**
7. Iteration 7 – maximum (costly & disruptive) fabric improvements  to further reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 41 tonnes/annum,** also results in **reduced utility costs of £56,720annum.**



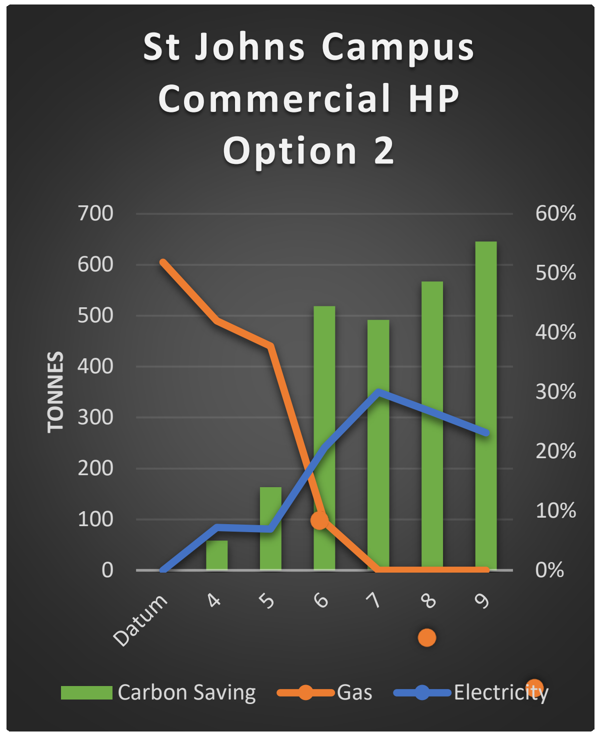




Figure 24 – St Johns Campus Low Temperature Heat Pump Operating Costs & Carbon Reduction

Figures 25 indicate the reduction in carbon associated with heat and increase in utility costs for the following iteration:

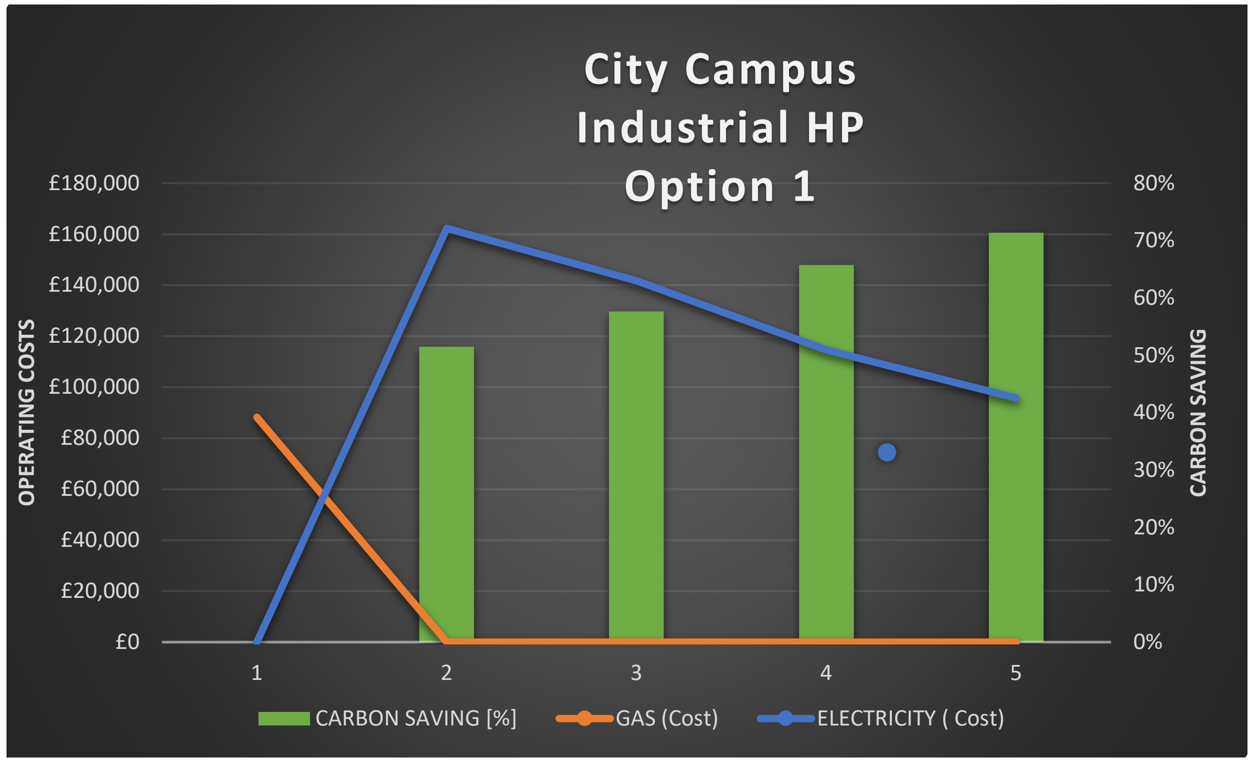
1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 2 – Replacing individual gas fired boilers for industrial air source heat pumps via a district heating network.

   As can be seen from the below chart these completely removes the requirement for gas heating, results in a **carbon saving of 119 tonnes/annum,** although results in **higher utility costs of £74,095 /annum.**
3. Iteration 3 – Undertaking easy fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 15 tonnes/annum,** also results in **reduced utility costs of £20,510/annum.**
4. Iteration 4 – Undertaking  all fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of  20 tonnes/annum,** also results in **reduced utility costs of £27,200/annum.**
5. Iteration 5 – Undertaking emitters replacement to improve the efficiency of ASHPs and reduce utility costs.

   As can be seen from the below chart undertaking the heaters replacement, results in a further **carbon saving of 14 tonnes/annum,** also results in further **reduced utility costs by £18,900/annum**



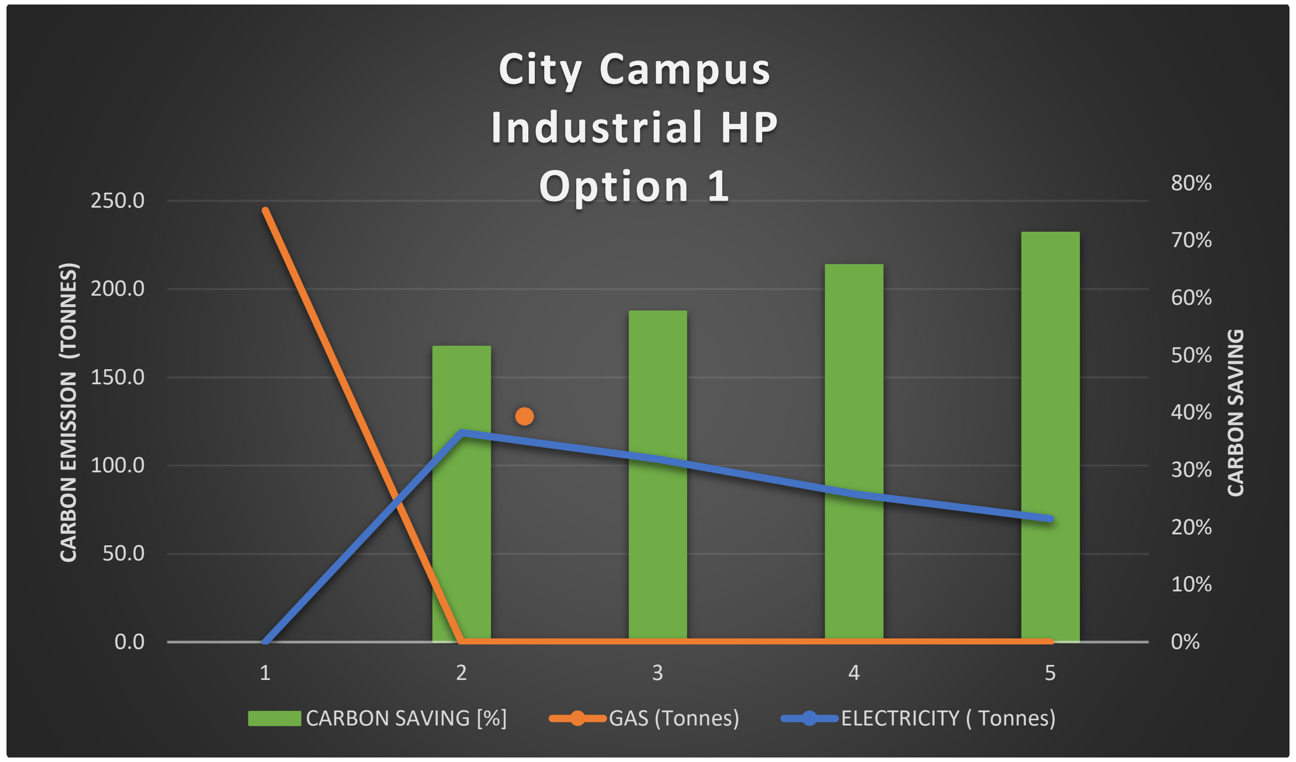



Figure 25 – City Campus High Temperature Heat Pump Operating Costs & Carbon Reduction

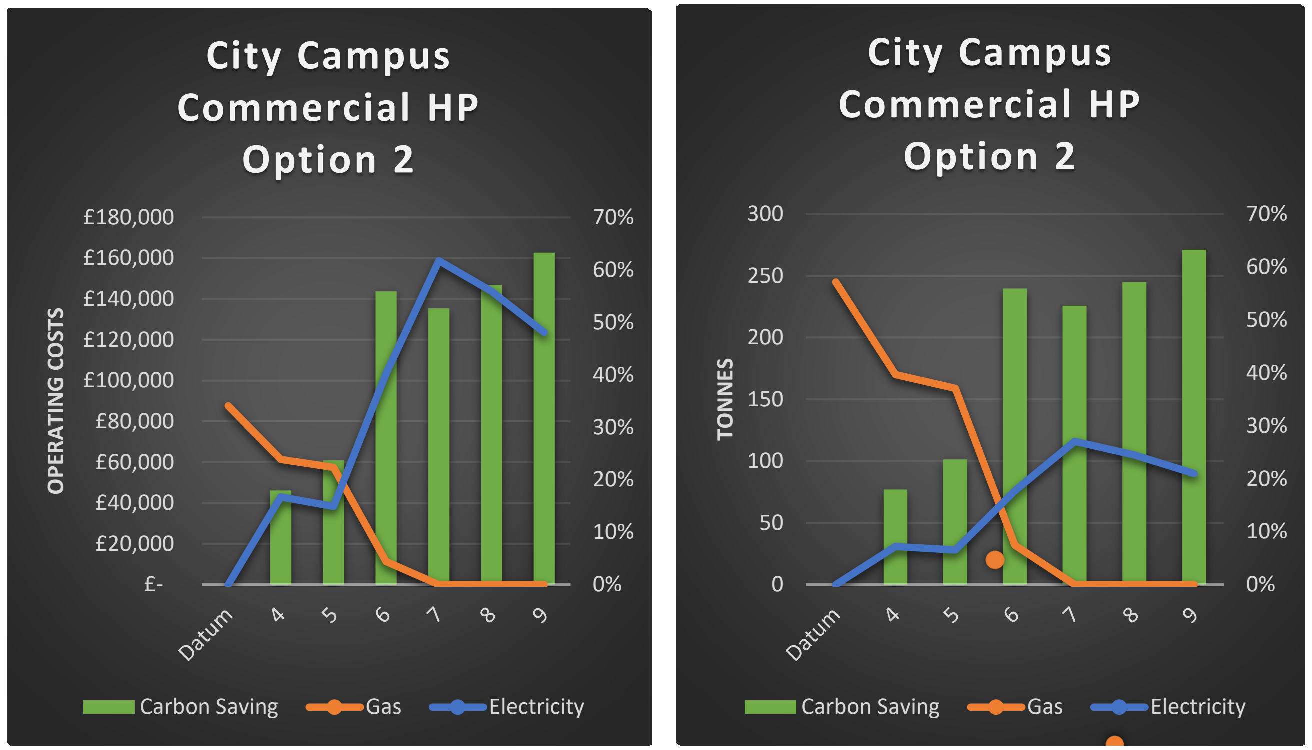



Figure 26 – City Campus Low Temperature Heat Pump Operating Costs & Carbon Reduction

Figures 26 indicate the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 4 – Install commercial heat pump via a district heating network. with gas top up.

   As can be seen from the below chart these results in a **carbon saving of 44 tonnes/annum,** although results in **higher utility costs of £16,730 /annum.**
3. Iteration 5 – Undertaking easy win fabric improvements to reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 58 tonnes/annum,** also results in **reduced utility costs of 8,550/annum.**
4. Iteration 6 – Enlarge heat emitters & coils with gas top up for hot water only.

   As can be seen from the below chart enlarging emitters lowers the temperature of the ASHP, results in a further **carbon saving of 79 tonnes/annum,** although results in **higher utility costs of £18,950/annum.**
5. Iteration 7 – all gas removed and replaced with electric hot water generation.
6. As can be seen from the below chart removing gas completely, due to high domestic water demand results, in higher **carbon emission of 8 tonnes/annum,** also results in **increase of utility costs of £44,000/annum**
7. Iteration 8 – all gas removed and replaced with electric hot water generation and undertaking easy win fabric improvements to reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 11 tonnes/annum,** also results in **reduced utility costs of £15,100/annum.**
8. Iteration 9 – maximum (costly & disruptive) fabric to further reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 15 tonnes/annum,** also results in **reduced utility costs of £19,970 annum.**

Figure 27 indicates the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 2 – Replacing individual gas fired boilers for industrial air source heat pumps via a district heating network.

   As can be seen from the below chart these completely removes the requirement for gas heating, results in a **carbon saving of 98 tonnes/annum,** although results in **higher utility costs of £56,112/annum.**
3. Iteration 3 – Undertaking easy fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 11.1 tonnes/annum,** also results in **reduced utility costs of £15,237/annum.**
4. Iteration 4 – Undertaking all fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 3.8 tonnes/annum,** also results in **reduced utility costs of £5,255/annum.**
5. Iteration 5 – Undertaking emitters replacement to improve the efficiency of ASHPs and reduce utility costs.

   As can be seen from the below chart undertaking the heaters replacement, results in a further **carbon saving of 12.5 tonnes/annum,** also results in further **reduced utility costs by £17,100/annum**

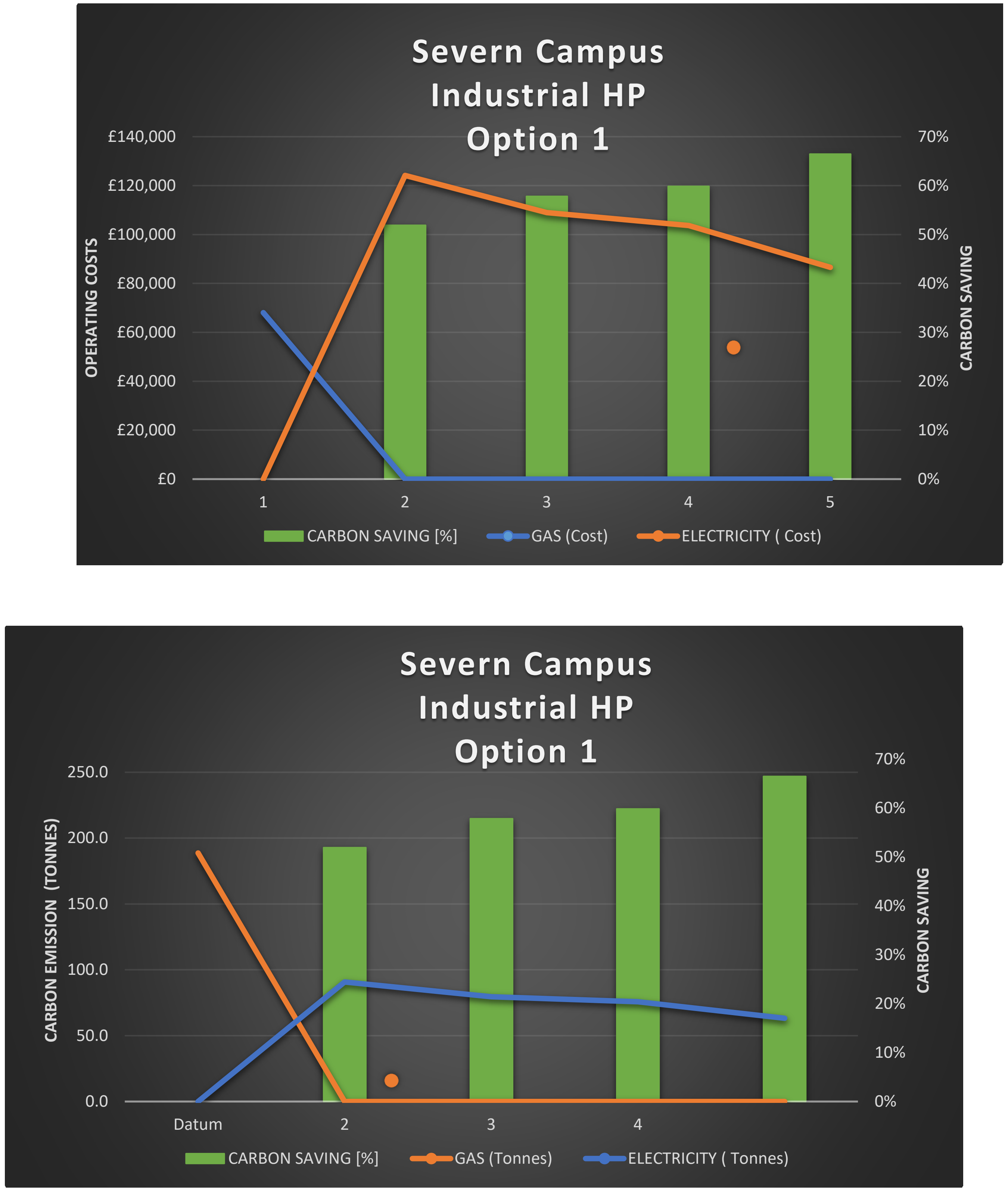


Figure 27 – Severn Campus High Temperature Heat Pump Operating Costs & Carbon Reduction

Figures 28 indicate the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 4 – Install commercial heat pump via a district heating network. with gas top up.

   As can be seen from the below chart these results in a **carbon saving of 30 tonnes/annum,** although results in **higher utility costs of £14,205 /annum.**
3. Iteration 5 – Undertaking easy win fabric improvements to reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 27 tonnes/annum,** also results in **reduced utility costs of 11,990 /annum.**
4. Iteration 6 – Enlarge heat emitters & coils with gas top up for hot water only.

   As can be seen from the below chart enlarging emitters lowers the temperature of the ASHP, results in a further **carbon saving of 51 tonnes/annum,** although results in **higher utility costs of £20,646/annum.**
5. Iteration 7 – all gas removed and replaced with electric hot water generation.
6. As can be seen from the below chart removing gas completely, due to high domestic water demand results, in higher **carbon emission of 1 tonnes/annum,** also results in **increase of utility costs of £21,955/annum**
7. Iteration 8 – all gas removed and replaced with electric hot water generation and undertaking easy win fabric improvements to reduce the base heating load.

   As can be seen from the below chart undertaking easy win fabric improvements, results in a further **carbon saving of 10 tonnes/annum,** also results in **reduced utility costs of £13,730/annum.**
8. Iteration 9 – maximum (costly & disruptive) fabric improvements to further reduce the base heating load. As can be seen from the below chart undertaking fabric improvements, results in a further **carbon saving of 2 tonnes/annum,** also results in **reduced utility costs of £3,924annum**
9.

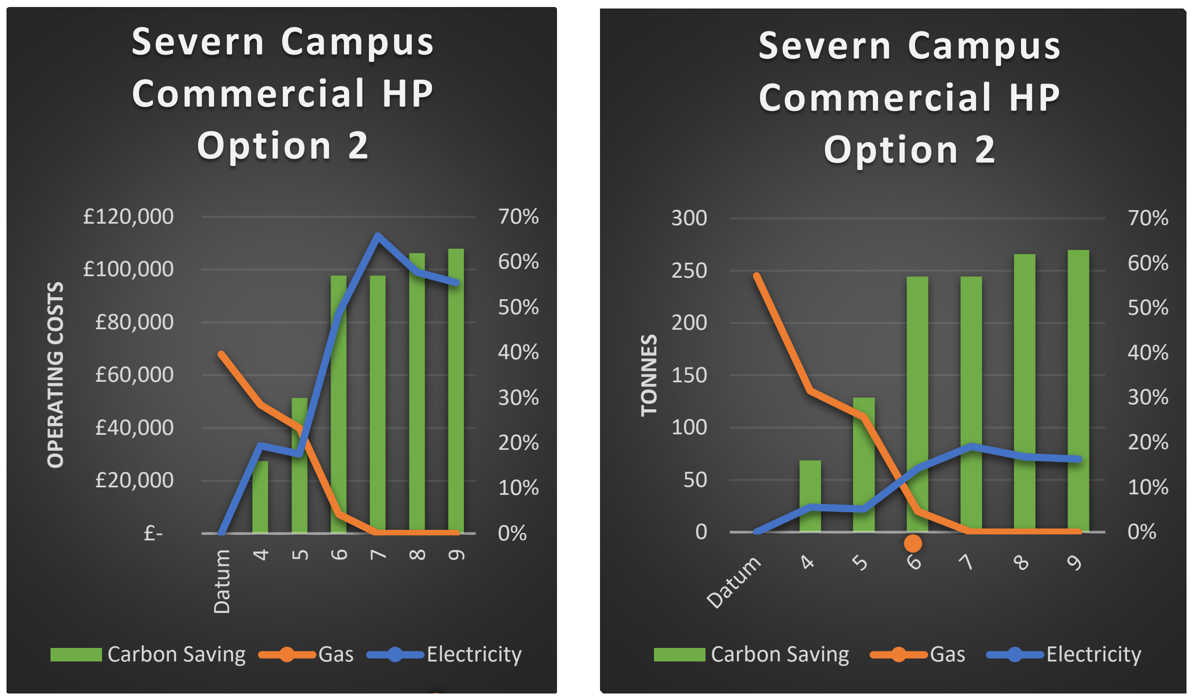


Figure 28 – Severn Campus Low Temperature Heat Pump Operating Costs & Carbon Reduction

## 15.0 Electrical Infrastructure Requirements

The heat decarbonisation strategy will require a new Energy Centre containing the heat pumps, thermal stores, circulation pumps and associated electrical switchgear and controls.

With the switch from gas heating to electric heating the electrical loads for each of the campuses will increase.

Preliminary power estimates have been established and initial contact with Western Power Distribution (WPD) has been made, the findings have been summarised below for each campus.

**St Johns Campus**

St Johns Campus has its own private HV network with several sub-stations located across the campus.

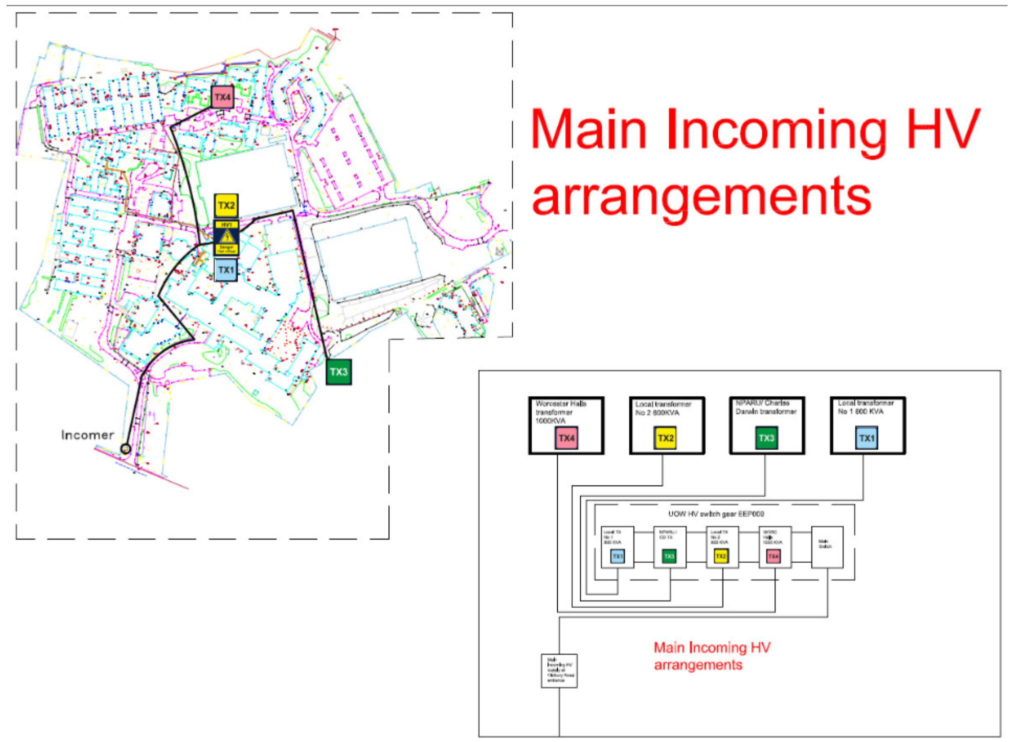



Figure 29 – St Johns Campus Electrical HV Arrangement

The initial electrical load calculations indicate an increased electrical load of approximately 1.4MVA for St Johns Campus, therefore a new transformer will be required to accommodate the proposed Energy Centre.

The substation would comprise of a ring main unit and low loss transformer and a dedicated LV distribution panel to serve the Energy Centre.

Discussions will need to take place at the next stage to review the current peak demands and further model the site wide demand profile in conjunction with the require heating and cooling demand profile.

There will also be a requirement for additional power in some buildings for instantaneous point instantaneous point of use domestic electric water heaters. It is anticipated that this will be available within the spare capacity of the LV distribution system of each building. However, further analysis of the available spare capacity will be required once the electric water heating loads and solution is developed.

**City Campus**

City Campus is fed from 2No electrical substations owned by Western Power Distribution.

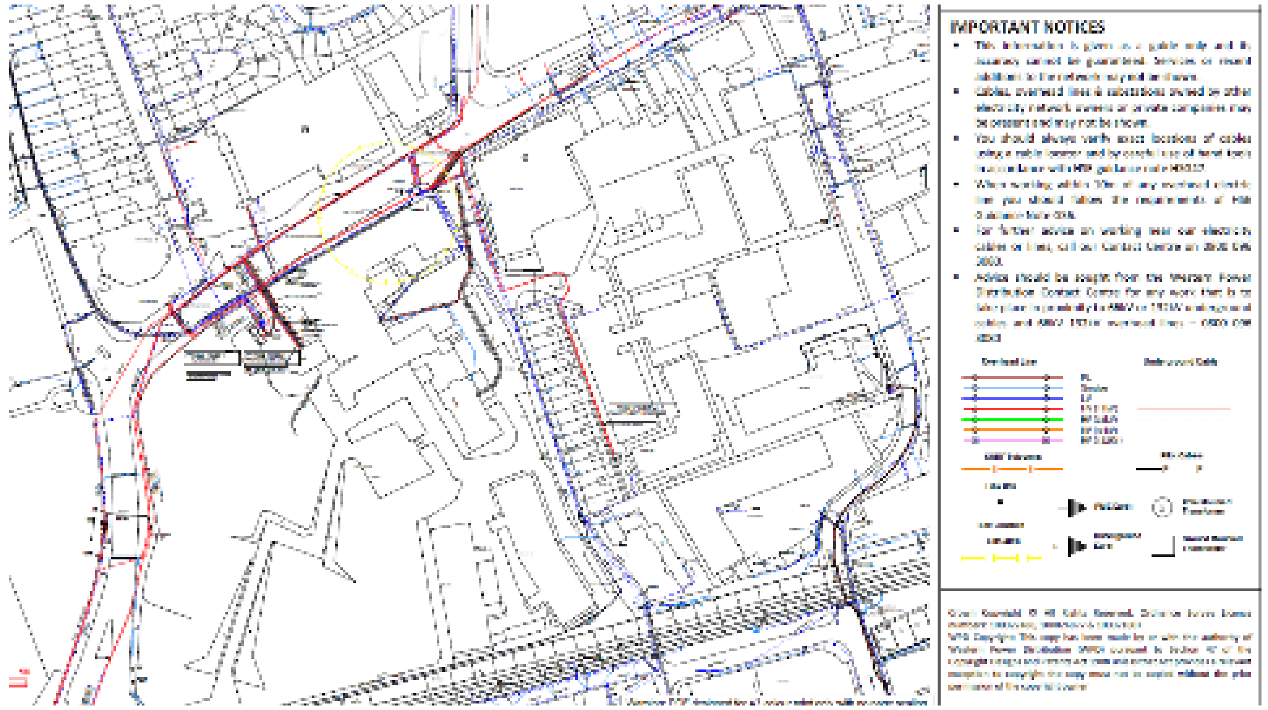



Figure 30 – City St Campus Electrical HV Arrangement

The initial electrical load calculations indicate an increased electrical load of approximately 0.5MVA for City Campus, discussions with WPD suggest that there is spare capacity available within the existing substation to accommodate the additional electrical load.

There will also be a requirement for additional power in some buildings for instantaneous point of use domestic electric water heaters. It is anticipated that this will be available within the spare capacity of the LV distribution system of each building. However, further analysis of the available spare capacity will be required once the electric water heating loads and solution is developed.

**Severn Campus**

Severn Campus is fed from 1No electrical substation owned by Western Power Distribution.

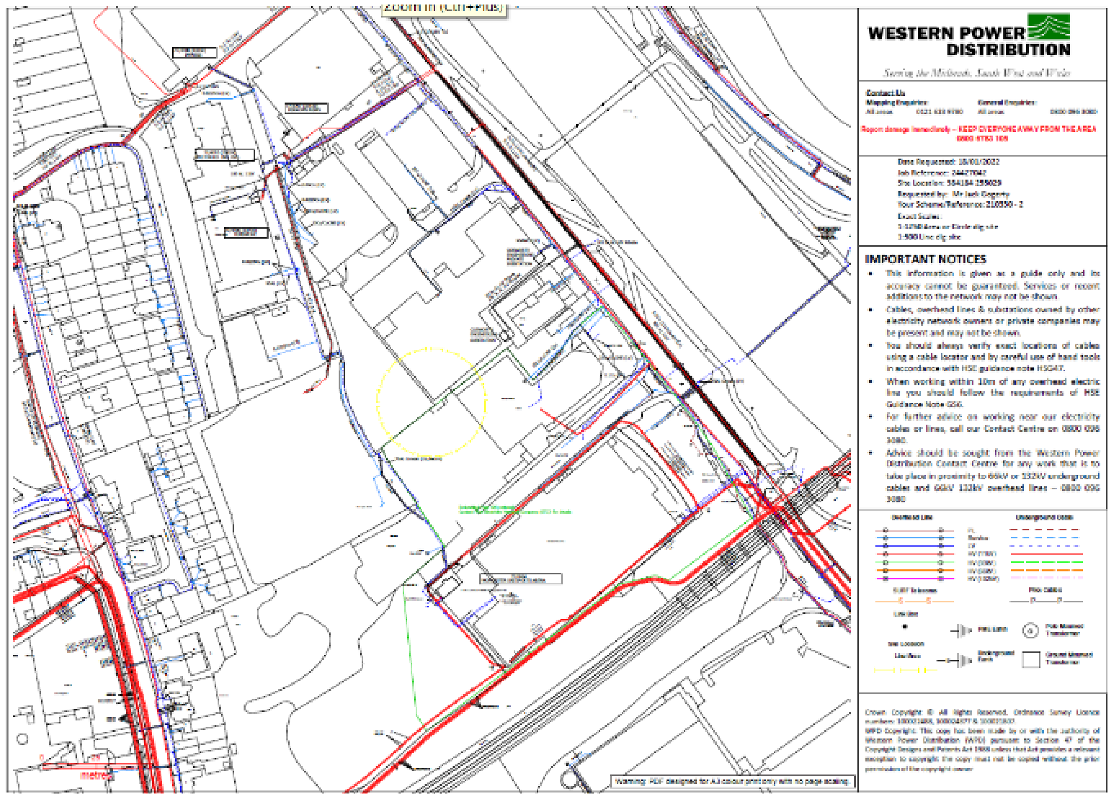



Figure 31 – Severn Campus Electrical HV Arrangement

The initial electrical load calculations indicate an increased electrical load of approximately 0.4MVA for Severn Campus, discussions with WPD suggest that there is no spare capacity within the existing substation, therefore an additional substation will be required for the additional electrical load.

The substation would comprise of a ring main unit and low loss transformer and a dedicated LV distribution panel to serve the Energy Centre.

Discussions will need to take place at the next stage to review the current peak demands and further model the site wide demand profile in conjunction with the require heating and cooling demand profile.

There will also be a requirement for additional power in some buildings for instantaneous point of use domestic electric water heaters. It is anticipated that this will be available within the spare capacity of the LV distribution system of each building. However, further analysis of the available spare capacity will be required once the electric water heating loads and solution is developed.

## 16.0 District Heat Network & Energy Centre Phasing Plan

Prior to undertaking any works associated with heat networks, the building services alternations will need to take place, eliminating short circuits/bypasses, control valves and plant room modifications as previously detailed.

It is proposed to tackle the worst performing buildings in accordance with the carbon ranking table produced. In parallel to the building services modifications, building fabric improvements and the infrastructure works can commence on developing the district heat network.

The heat metering data has highlighted that the existing boiler plant installed within the Edward Elgar building is significantly under utilised. The installed boiler and capacity is 4No. boilers @ 1200KW each, the peak metered heat delivery is 2320 kW. The individual heat demand from the remaining buildings on St. Johns Campus totals 1175 kW, therefore the total heat demand can be provided by the Edward Elgar boiler room whilst maintaining 100% capacity in the event of a boiler failing. The more buildings added to a central energy centre the further diversity is enhanced which results in further reduction in gas usage.

It is recommended that UoW apply for Government funding available for extending the existing district heating system, all building will be ready to connect to a low zero carbon heat pump.

A local district heating network will be formed by the creation of a central energy centre with pipework then installed and the first buildings in Phase 1 connected. Depending on the chosen option this new network will be served by Air Source Heat Pumps (ASHPs), with boost from the existing gas fired boilers where buildings heating emitters have not been changed.

The proposed heat network would be looped to ensure flexibility within the infrastructure and allow for future connections to be made and if required existing buildings to be able to supplement the network with heat via existing gas boilers, should resilience require.

Focussing the energy centre to a single location also allows for the electrical infrastructure improvements to be taken to a single point and not multiple upgrades across each building.

As buildings are added to the district heating network the overall blended mean return water temperature will reduce thus improving the efficiency of the heat network.

**St Johns Campus**


Figure 32 – St Johns Campus Heat Network Development Phase 1 (0-3 years)

It is suggested that the following buildings are connected as soon as possible within the construction programme, these will offer the largest carbon reduction when connecting to the Energy Centre.

1) Edward Elgar Boiler Room - also serves Binyon Building, Binyon North, Hines Building, Sports Centre & Students Union. These buildings equate to approximately 44% of the St Johns Campus carbon emissions associated with heat, connecting to the energy centre would see a large reduction in carbon emissions.
2) Woodbury Building – the second worst performing building on the campus, with 11% of the associated carbon emissions, based on a m2 basis the building performs the worst, connecting to the energy centre would see a significant reduction in caron emissions. Given the poor performance of the building and utilisation of land, UoW may wish to consider demolishing Woodbury which would result in an 11% reduction of carbon associated with heat.
3) Peirson Library – the third worst performing building on the campus, with 9% of the associated carbon emissions, based on a m2 basis the building performs the worst, connecting to the energy centre would see a significant reduction in carbon emissions.

Remaining buildings can be connected to suit the construction phasing UoW operations.

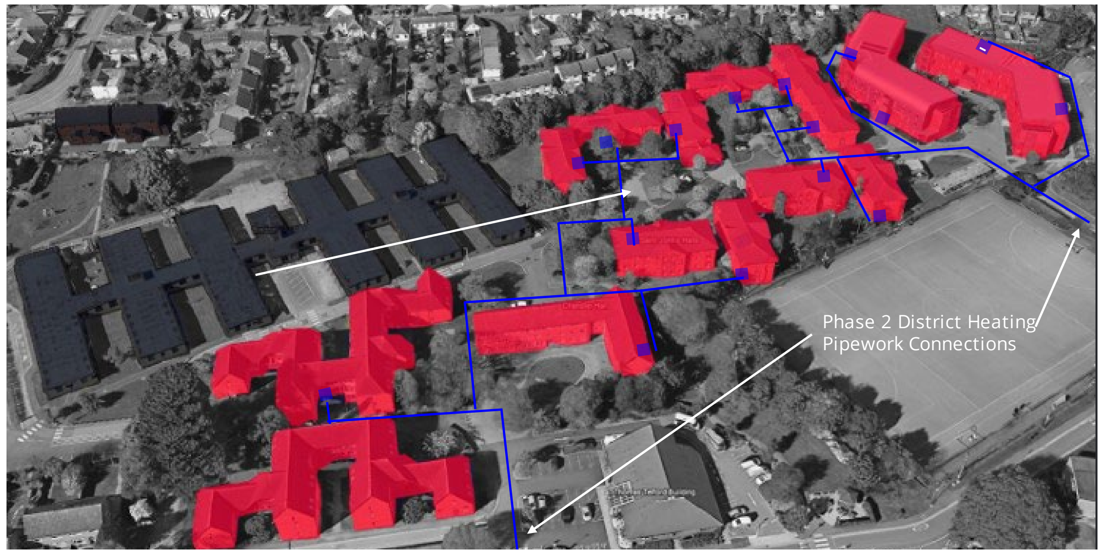



Figure 33 – St Johns Campus Heat Network Development Phase 2 (4 - 5 years)

It is suggested that district heating network is extended to each end of the Halls of Residences, providing flexibility in terms of phasing. It is recommended that the following buildings are connected next, these will offer the largest carbon reduction when connecting to the Energy Centre.

1) Ledbury Hall - also serves Avon Hall, these buildings equate to approximately 8.5% of the St Johns Campus carbon emissions associated with heat, connecting to the energy centre would see a significant reduction in carbon emissions.
2) AE Housman & Elizabeth Brown, these buildings equate to approximately 7.5% of the St Johns Campus carbon emissions associated with heat, connecting to the energy centre would see a significant reduction in carbon emissions.

Remaining building can be connected to suit the construction phasing UoW operations.

**Severn Campus**

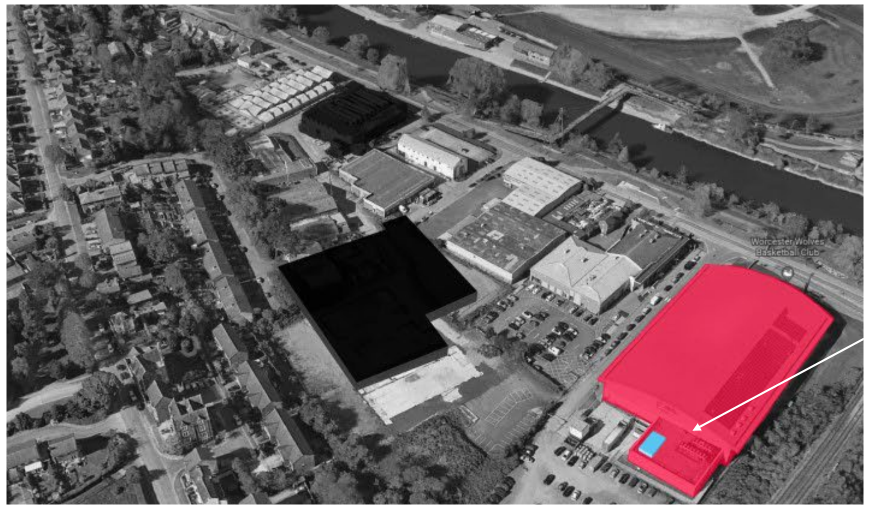


Figure 34 – Severn Campus Heat Network Development Phase 1 (6 - 7 years)

It is suggested that The Arena is connected as soon as possible within the construction programme, this will offer the largest carbon reduction when connecting to the Energy Centre.

As the proposed Energy Centre is locate on the Arena roof and this building equates to approximately 46% of the Severn Campus carbon emissions associated with heat, connecting to the energy centre would see a large reduction in carbon emissions.


Figure 35 – Severn Campus Heat Network Development Phase 2 (7 - 8 years)

It is suggested that district heating network is extended to the Riverside Building,

This building generates similar carbon emissions to The Arena at 41%, connecting to the energy centre would see a large reduction in carbon emissions.

UoW to confirm if the garage forms part of the master planning proposed for this site, the Garage may not be connected to the district heating network.

**City Campus**

Figure 36 – City Campus Heat Network Development Phase 1 (9 - 10 years)

It is suggested that The Charles Hastings building is connected as soon as possible, this will offer the largest carbon reduction when connecting to the Energy Centre. This building equates to approximately 45% of the City Campus, connecting to the energy centre would see a large reduction in carbon emissions.


Figure 37 – City Campus Heat Network Development Phase 2 (11 - 12 years)

It is suggested that district heating network is the extended Bishop Bosel & Chancellor Hall.

These buildings generate 33% of the sites carbon emissions, connecting to the energy centre would see a large reduction in carbon emissions.

Due to the Jenny Lind building being located remote from the campus and the heating systems no longer reflecting how the building is utilised, it is recommended that the builing has a standalone commercial heat pump system.

## 16.1 Industrial Air Source Heat Pump, Carbon Savings & Costs Estate Wide

Figures 38 & 39 indicates the reduction in carbon associated with heat and increase in utility costs for the following iteration:

1. Iteration 1 – Datum, Existing heating provided via gas fired boilers.
2. Iteration 2 – Replacing individual gas fired boilers for industrial air source heat pumps via a district heating network.

   As can be seen from the below chart these completely removes the requirement for gas heating, results in a **carbon saving of 490 tonnes/annum,** although results in **higher utility costs of £400,000/annum.**
3. Iteration 3 – Undertaking all fabric improvements suggested to reduce the base heating load.

   As can be seen from the below chart undertaking all fabric improvements, results in a further **carbon saving of 150 tonnes/annum,** also results in **reduced utility costs by £230,000/annum.**

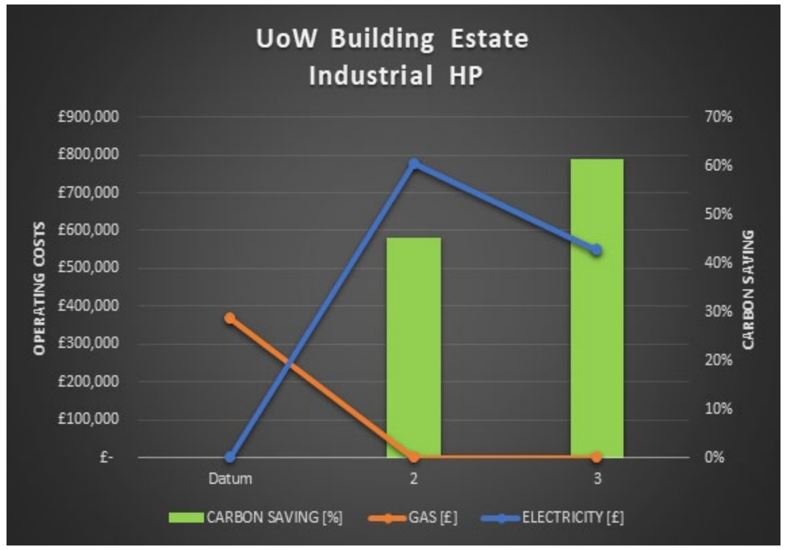



Figure 38 – Building Estate – Industrial Air Source Heat Pump – Operating Costs

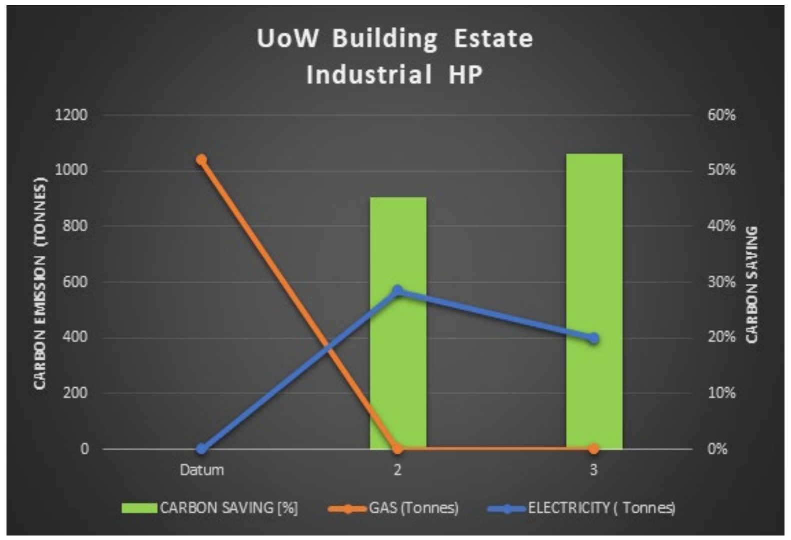



Figure 39 – Building Estate – Industrial Air Source Heat Pump – Carbon Reduction

## 17.0 HDP Delivery Resource Requirements

UoW has a dedicated engineering team and are responsible for day to day technical issues and small projects.

As this HDP forms part of an initial stage analysis of decarbonisation options, it is currently pre-mature, hence potential projects, project duration and procurement methods will be determined at the next stage.

Once this has been determined, a responsibility matrix will be drafted to allocate the various stage responsibilities to the responsible incumbents within the Estates, this will assist in informing the roles and responsibilities required and whether external support is required.

## 18.0 Recommended Fabric Improvements

Irrespective of buildings being existing or new build, reducing the base heating load by taking a fabric first approach is always encouraged, it is appreciated that improving the fabric of existing building stock can be costly, disruptive, and timely, this has been considered for the recommended decarbonisation plan.

The thermographic surveys undertaken have highlighted poor performing fabric and junctions on buildings across the Estate, this information can be used as a tool to tackle the worst offending building and specific elements of the building. As opposed to wholesale improvements of entire elements such as external wall which can be costly and disruptive, improvements that can be programmed as part of the Universities on-going building maintenance.

It is encouraged to improve fabric deficiencies as part of the on-going building maintenance to reduce the base heating load and associated energy prices.

Discussions held with UoW have established that the buildings need to remain operational for the majority of the year, with disruptive works ideally being undertake during a 6 week period over the summer holidays. With prohibitive costs and disruptive works associated with upgrading wholesale fabric elements, this limits the opportunity to provide a low-grade heating solution in the short term.

*In the absence of construction information, the u-values within this report for each construction element has been based on the age of the building, therefore further intrusive investigation works are required to establish the exact construction make up and associated u-value, this will inform future fabric improvements and limitations.*

For extensive and wholesale fabric improvements the following interventions should be considered, input from and Architect would be required at the next stage of design if improvements taken forward.

**Tackle Deficiencies Highlighted from the Thermographic Survey**

Review the thermographic survey findings on a building-by-building basis, identify worst performing deficiencies and establish a plan to improve the issues highlighted.

**Improve Air Tightness**

Investigate windows, doors and junctions for gaps that may have formed due to building movement and age, sealing gaps will reduce heat loss. In addition, service penetrations and builderswork holes should identified and filled further reducing heat loss.

**Roof Insulation**

Provide or enhance roof insulation levels as far as practically possible, roof insulation is generally the easiest intervention to implement with minimal disruption to the building operation.

**External Walls**

Enhance external wall performance, there are several methods to be considered:

- External Cladding – avoids internal disruption and building can continue to operate, although costly and timely.
- Cavity Fill – The easiest and cheapest of the three options, further investigation required for building which have cavities that can be insulated.
- Internal Cladding – this will require buildings or parts of building to be closed during noisy and disruptive works. For listed buildings this is likely to be the only solution for improving external walls.

Enhancing external wall elements can be costly and disruptive depending on the method being employed, if improvements are made the implications need to be considered by UoW.

**Windows**

Replace existing single and double-glazing windows with a modern high performing equivalent.

Triple glazing has been considered within the fabric interventions although the uplift in cost does not outweigh the improvement between high performing double glazing and triple glazing.

Listed buildings will likely require secondary glazing due to the listed nature of the buildings.

Excessive curtain walling and large windows should be reviewed with sections of glazing provided with insulated panels.

## 19.0 Outline Cost Analysis

UNAPPROVED

#### 19.1.1 Existing System Modifications / Improvements

The suggested modifications to the existing systems are required prior to connecting buildings to an LZC technology and/or a district heating network, it is fundamental that the buildings heating systems are operating correctly. It isn't possible to associate a carbon saving with each of the suggested alterations, improvements should result in a reduction in carbon, it is recommended that UoW monitor any changes.

The costs provided in the below table are high level at this stage, once the extent of works required for each building is established following intrusive survey works the cost plan can be refined by a cost consultant at the next stage of design.

#### 19.1.2 Building Interventions

The main intervention proposed for UoW is providing an Energy Centre for each campus, each campus will have a district heating network. All works associated with the individual plantroom alterations have been included within the Campus Energy Centres & District Heating Cost Plan.

Additional interventions proposed on a building-by-building basis have been indicated in the below table.

Stripping out pipework routed within the ground and ceiling voids can be disruptive and costly, if completed as a standalone element of work. Costs associated with strip-out works could be minimised by draining the systems down, isolating and leaving in situ.

The costs provided in the below table are high level at this stage, once the extent of works required for each building is established following intrusive survey works the cost plan can be refined by a cost consultant at the next stage of design.

#### 19.1.3 Future Fabric Improvements and Radiator Replacement

The below table provides high level costs associated with making wholesale improvements to the various construction elements, those highlighted in green offer the best carbon saving and value for money and should be targeted in the first instance.

To further increase the efficiency of the industrial air source heat pump the radiators and heating coils should be replacement with the larger equivalent to run at lower temperatures, these works can be undertaken as part of the on-going system maintenance.

| # | Location | GIFAm2 | TOTAL BUDGET COST: Future Building Fabric Improvement Options – External Wall Cladding | Internal Wall Cladding | Roof/Loft Insulation | Windbreak Lobby | Secondary Glazing | Double Glazing | TOTAL BUDGET COST: Future Heat Emitter Replacement – Radiator Replacement | AHU Heater Battery & MVHR Replacement |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Abberley House | 546 | £77,225 | n/a | n/a | n/a | n/a | £73,040 | £13,650 | n/a |
| 2 | AE Houseman Hall | 3165 | n/a | n/a | £37,333 | n/a | n/a | £183,398 | £79,125 | n/a |
| 3 | Ankerdine Hall | 819 | £83,732 | n/a | n/a | n/a | n/a | £90,943 | £20,475 | n/a |
| 4 | Art House | 1855 | n/a | n/a | n/a | n/a | n/a | n/a | £46,375 | n/a |
| 5 | Avon Hall | 2388 | £275,584 | n/a | £28,463 | n/a | n/a | £344,575 | £59,700 | n/a |
| 6 | Barrington House | 672 | n/a | £71,500 | £6,546 | n/a | n/a | £65,395 | £16,800 | n/a |
| 7 | Binyon Building | 2058 | £178,375 | n/a | £24,636 | n/a | n/a | £184,415 | £51,450 | n/a |
| 8 | Binyon North | 360 | £96,734 | n/a | £4,807 | n/a | n/a | £102,190 | £9,000 | n/a |
| 9 | Bishop Bosel Hall | 3834 | n/a | n/a | £24,636 | n/a | n/a | £301,950 | £95,850 | n/a |
| 10 | Chancellor Hall | 3236 | n/a | n/a | £28,810 | n/a | n/a | £274,120 | £80,900 | n/a |
| 11 | Charles Darwin | 1586 | n/a | n/a | £29,158 | £81,906 | n/a | £149,270 | £39,650 | £20,000 |
| 12 | Charles Hastings Building | 5612 | n/a | £693,013 | n/a | £56,733 | £202,125 | n/a | £140,300 | £40,000 |
| 13 | Conference Centre | 663 | £85,712 | n/a | £23,766 | n/a | n/a | £200,860 | £16,575 | n/a |
| 14 | Edward Elgar | 13480 | £1,376,416 | n/a | £274,062 | £353,551 | n/a | £1,517,600 | £337,000 | £25,000 |
| 15 | Evesham & Pershore Hall | 1401 | £148,292 | n/a | n/a | n/a | n/a | £114,730 | £35,025 | n/a |
| 16 | Fern Hall | 760 | n/a | £112,059 | £13,852 | n/a | n/a | £65,395 | £19,000 | n/a |
| 17 | Forensic House | 218 | £55,295 | n/a | £5,360 | n/a | n/a | £61,023 | £5,450 | n/a |
| 18 | Hines Building | 1410 | £144,048 | n/a | n/a | £38,962 | n/a | n/a | £35,250 | n/a |
| 19 | Jenny Lind | 4031 | £483,341 | n/a | £52,229 | n/a | n/a | £232,375 | £100,775 | n/a |
| 20 | Ledbury Hall | 2275 | £362,787 | n/a | £32,115 | n/a | n/a | £423,390 | £56,875 | n/a |
| 21 | Mulberry House | 936 | n/a | £182,294 | n/a | £56,733 | £36,053 | n/a | £23,400 | n/a |
| 22 | Oldbury House | 330 | n/a | £150,639 | £4,807 | n/a | n/a | £51,480 | £8,250 | n/a |
| 23 | Peirson Centre | 3244 | £215,981 | n/a | £58,554 | n/a | n/a | £274,120 | £81,100 | £30,000 |
| 24 | Riverside Building | 1835 | n/a | £193,292 | £59,534 | n/a | n/a | £118,635 | £45,875 | £45,000 |
| 25 | Sheila Scott Building | 1118 | £112,425 | n/a | £39,421 | n/a | n/a | £93,225 | £27,950 | n/a |
| 26 | Sports Centre | 2475 | £251,631 | n/a | £38,551 | £38,962 | n/a | £437,305 | £61,875 | £20,000 |
| 27 | Student's Union | 1274 | £180,998 | n/a | £39,421 | £123,844 | n/a | £278,548 | £31,850 | £10,000 |
| 28 | The Garage | 712 | £131,550 | n/a | £6,546 | n/a | n/a | £160,380 | £17,800 | n/a |
| 29 | Thomas Telford | 360 | £38,917 | n/a | £13,156 | £38,962 | n/a | £114,098 | £9,000 | n/a |
| 30 | University Arena | 9256 | n/a | £431,856 | £167,391 | n/a | n/a | £524,700 | £231,400 | £70,000 |
| 31 | Vesta Tilley Hall | 1050 | £87,622 | n/a | n/a | n/a | n/a | £355,080 | £26,250 | n/a |
| 32 | Windrush Hall | 679 | £61,893 | n/a | n/a | n/a | n/a | £250,718 | £16,975 | n/a |
| 33 | Woodbury Building | 3589 | £494,608 | n/a | £125,520 | n/a | n/a | £534,710 | £89,725 | n/a |
| | TOTAL by Option | | £4,943,165 | £1,834,652 | £1,138,674 | £789,652 | £238,178 | £7,577,665 | £1,930,675 | £260,000 |

| # | Location | TOTAL BUDGET COST: Existing Systems Rectification – Existing BMS System Interrogation & Monitoring | Install Domestic Hot Water Sub-Meters | Record Drawings Production | Replace Single Pipe Heating Systems | Seeking Shorts Circuits, Missing TRV'S, Poor Control Routines Etc | Install Heating Zone Controls Valves and Sensors | Install Flow Restrictor On Water Outlets | Install Insulation on Exposed Heating & Hot Water Pipework | TOTAL BUDGET COST: Hot Water Alterations – Solar Thermal Panels | Replacements Cylinder(s) | Central Hot Water Strip-Out | Electric Hot Water Installation | TOTAL BUDGET COST: Commercial ASHP – Standalone Commercial Heat Pump & Thermal Store |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Abberley House | £2,000 | £500 | £3,000 | n/a | £2,000 | £2,730 | £100 | £13,650 | n/a | n/a | n/a | n/a | n/a |
| 2 | AE Houseman Hall | £3,000 | £500 | £4,000 | n/a | £3,000 | £15,825 | £300 | £79,125 | n/a | n/a | n/a | n/a | n/a |
| 3 | Ankerdine Hall | £2,000 | £500 | £3,000 | n/a | £2,000 | £4,095 | £100 | £20,475 | n/a | n/a | n/a | n/a | n/a |
| 4 | Art House | n/a | n/a | n/a | n/a | n/a | n/a | £200 | n/a | n/a | n/a | n/a | n/a | n/a |
| 5 | Avon Hall | £3,000 | £500 | £4,000 | n/a | £3,000 | £11,940 | £300 | £59,700 | £32,663 | n/a | n/a | n/a | n/a |
| 6 | Barrington House | £1,500 | £500 | £2,000 | n/a | £1,500 | £3,360 | £100 | £16,800 | £28,283 | £15,000 | n/a | n/a | £30,000 |
| 7 | Binyon Building | £2,500 | £500 | £3,500 | £205,800 | £2,500 | £10,290 | £200 | £51,450 | n/a | n/a | £20,580 | £4,000 | n/a |
| 8 | Binyon North | £1,000 | £500 | £2,000 | £36,000 | £1,000 | £1,800 | £100 | £9,000 | n/a | n/a | £3,600 | £1,500 | n/a |
| 9 | Bishop Bosel Hall | £3,000 | £500 | n/a | n/a | £3,000 | £19,170 | £300 | £95,850 | n/a | n/a | n/a | n/a | n/a |
| 10 | Chancellor Hall | £3,000 | £500 | n/a | n/a | £3,000 | £16,180 | £300 | £80,900 | n/a | n/a | n/a | n/a | n/a |
| 11 | Charles Darwin | £2,500 | £500 | £4,000 | n/a | £2,500 | £7,930 | £200 | £39,650 | n/a | n/a | n/a | n/a | n/a |
| 12 | Charles Hastings Building | £4,000 | £500 | n/a | n/a | £4,000 | £28,060 | £500 | £140,300 | n/a | n/a | n/a | n/a | n/a |
| 13 | Conference Centre | £2,500 | £500 | £4,000 | £66,300 | £2,500 | £3,315 | £100 | £16,575 | n/a | n/a | £6,630 | £7,500 | n/a |
| 14 | Edward Elgar | £7,500 | £500 | £15,000 | £1,348,000 | £7,500 | £67,400 | £1,000 | £337,000 | n/a | n/a | n/a | n/a | n/a |
| 15 | Evesham & Pershore Hall | £3,000 | £500 | £4,000 | n/a | £3,000 | £7,005 | £200 | £35,025 | n/a | n/a | n/a | n/a | n/a |
| 16 | Fern Hall | £1,500 | £500 | £2,000 | n/a | £1,500 | £3,800 | £100 | £19,000 | n/a | n/a | n/a | n/a | £30,000 |
| 17 | Forensic House | £1,500 | £500 | £2,000 | n/a | £1,500 | £1,090 | £100 | £5,450 | n/a | n/a | n/a | n/a | £10,000 |
| 18 | Hines Building | £2,500 | £500 | £3,500 | £141,000 | £2,500 | £7,050 | £200 | £35,250 | n/a | n/a | £14,100 | £3,000 | n/a |
| 19 | Jenny Lind | £4,000 | £500 | £6,000 | n/a | £4,000 | £20,155 | £300 | £100,775 | n/a | n/a | £40,310 | £19,500 | n/a |
| 20 | Ledbury Hall | £3,000 | £500 | £4,000 | n/a | £3,000 | £11,375 | £300 | £56,875 | £31,563 | n/a | n/a | n/a | n/a |
| 21 | Mulberry House | £2,000 | £500 | n/a | n/a | £2,000 | £4,680 | £100 | £23,400 | n/a | n/a | £9,360 | £4,500 | n/a |
| 22 | Oldbury House | £1,500 | £500 | £2,000 | n/a | £1,500 | £1,650 | £100 | £8,250 | n/a | n/a | n/a | n/a | £7,500 |
| 23 | Peirson Centre | £4,000 | £500 | n/a | n/a | £4,000 | £16,220 | £300 | £81,100 | n/a | n/a | £32,440 | £4,500 | n/a |
| 24 | Riverside Building | £3,000 | £500 | n/a | n/a | £3,000 | £9,175 | £200 | £45,875 | n/a | n/a | n/a | n/a | n/a |
| 25 | Sheila Scott Building | £3,000 | £500 | £4,000 | n/a | £3,000 | £5,590 | £100 | £27,950 | n/a | n/a | £11,180 | £13,500 | n/a |
| 26 | Sports Centre | £3,000 | £500 | n/a | n/a | £3,000 | £12,375 | £300 | £61,875 | n/a | n/a | n/a | n/a | n/a |
| 27 | Student's Union | £2,500 | £500 | £3,500 | n/a | £2,500 | £6,370 | £200 | £31,850 | n/a | n/a | £12,740 | £6,000 | n/a |
| 28 | The Garage | £1,500 | £500 | £2,000 | n/a | £1,500 | £3,560 | £100 | £17,800 | n/a | n/a | £7,120 | £4,500 | n/a |
| 29 | Thomas Telford | £1,500 | £500 | £2,000 | n/a | £1,500 | £1,800 | £100 | £9,000 | n/a | n/a | £3,600 | £4,500 | n/a |
| 30 | University Arena | £5,000 | £500 | n/a | n/a | £5,000 | £46,280 | £500 | £231,400 | n/a | n/a | n/a | n/a | n/a |
| 31 | Vesta Tilley Hall | £2,000 | £500 | £3,000 | n/a | £2,000 | £5,250 | £200 | £26,250 | n/a | n/a | n/a | n/a | n/a |
| 32 | Windrush Hall | £2,000 | £500 | £3,000 | n/a | £2,000 | £3,395 | £100 | £16,975 | n/a | n/a | n/a | n/a | n/a |
| 33 | Woodbury Building | £4,000 | £500 | £6,000 | £358,900 | £4,000 | £17,945 | £500 | £89,725 | n/a | n/a | £35,890 | £12,000 | n/a |
| | TOTAL by Option | £88,000 | £16,000 | £91,500 | £2,156,000 | £88,000 | £376,860 | £7,800 | £1,884,300 | £92,508 | £15,000 | £197,550 | £85,000 | £77,500 |

Table 10 – Individual Building Intervention Cost Summary

Note: The above table does not include duplicate buildings the duplicate building, costs for duplicate buildings should be added to the cost plan / budget.

### 19.1.4 Campus Energy Centres & District Heating Networks

The below tables provide a budget cost breakdown for the works associated with providing an Energy Centre and district heating network to each of the 3No campuses.

St Johns Campus

| | |
|---|---|
| HV Electrical Infrastructure Works | £ 265,000 |
| LV Electrical Works | £ 230,000 |
| BMS / Controls | £ 340,000 |
| ASHP Supply & Installation | £ 1,390,000 |
| Mechanical & Electrical Plantroom Installation | £ 630,000 |
| District Heating Network | £ 2,452,750 |
| Energy Centre Construction | £ 375,000 |
| Individual Boiler Room Alterations | £ 690,000 |
| | **£ 6,372,750** |
| Contractors General Preliminaries @ 15% | £ 955,913 |
| Contractors Oh&p @ 8% | £ 509,820 |
| | **£ 1,465,733** |
| Design & Pricing Contingency @ 2.5% | £ 195,962 |
| Construction Risk Contingency @ 5% | £ 391,924 |
| | **£ 587,886** |
| Total Budget Cost | **£ 8,426,369** |

Severn Campus

| | |
|---|---|
| HV Electrical Infrastructure Works | £ 210,000 |
| LV Electrical Works | £ 215,000 |
| BMS / Controls | £ 280,000 |
| ASHP Supply & Installation | £ 565,000 |
| Mechanical & Electrical Plantroom Installation | £ 480,000 |
| District Heating Network | £ 665,000 |
| Energy Centre Construction | £ 300,000 |
| Individual Boiler Room Alterations | £ 260,000 |
| | **£ 2,975,000** |
| Contractors General Preliminaries @ 15% | £ 446,250 |
| Contractors Oh&p @ 8% | £ 238,000 |
| | **£ 684,250** |
| Design & Pricing Contingency @ 2.5% | £ 91,481 |
| Construction Risk Contingency @ 5% | £ 182,963 |
| | **£ 274,444** |
| Total Budget Cost | **£ 3,933,694** |

City Campus

| | |
|---|---|
| HV Electrical Infrastructure Works | £ 50,000 |
| LV Electrical Works | £ 215,000 |
| BMS / Controls | £ 280,000 |
| ASHP Supply & Installation | £ 750,000 |
| Mechanical & Electrical Plantroom Installation | £ 560,000 |
| District Heating Network | £ 670,250 |
| Energy Centre Construction | £ 300,000 |
| Individual Boiler Room Alterations | £ 180,000 |
| | **£ 3,005,250** |
| Contractors General Preliminaries @ 15% | £ 450,788 |
| Contractors Oh&p @ 8% | £ 240,420 |
| | **£ 691,208** |
| Design & Pricing Contingency @ 2.5% | £ 92,411 |
| Construction Risk Contingency @ 5% | £ 184,823 |
| | **£ 277,234** |
| Total Budget Cost | **£ 3,973,692** |

- The installation costs of the HV infrastructure does nor include reinforcements of the WPD infrastructure
- Costs have been benchmarked against similar schemes
- Cost based on 1Q22
- Cost is for industrial air source heat pumps
- Excludes design and professional fees
- Excludes inflation
- Excludes VAT

| Campus name | Heat generated by gas, carbon footprint tCO2e | DHN carbon footprint tCO2e | Improvement | DHN system cost, £ | £1000/tCO2e |
|---|---|---|---|---|---|
| St Johns | 815 | 418 | 49% | £8,426,369 | 21.3 / tCO2e |
| Severn | 188 | 91 | 52% | £3,933,694 | 40.2 / tCO2e |
| City | 245 | 118 | 51% | £3,973,692 | 31.6 / tCO2e |
| **Total** | **1,248** | **627** | **50%** | **£16,333,755** | **26.1 / tCO2e** |

Figure 40 – Campus Energy Centre Carbon Reduction & Costs

## 20.0 Definition of carbon terminology

The following terms (low carbon, zero carbon, net zero carbon) are widely used when discussing decarbonisation with several meanings in circulation. For clarity, this report is written based on the following understanding.

**Low Carbon**

This refers to any solution or technology that reduces carbon emissions as far as is practicable possible when compared to the status quo.

For example, heat pumps are a low carbon heat source requiring electricity to power a reverse thermal energy transfer process to deliver heat as an alternative to fossil fuel based generators e.g. gas CHP or boilers. In this case, energy, and carbon emissions due to the heat pump operation are reduced as far as possible.

**Zero Carbon**

This refers to any solution or technology where no carbon is emitted during its operation and therefore no carbon needs to be captured or offset.

For example, a building or asset operating entirely on solar without the use of any fossil fuels can label its energy as operationally zero carbon.

**Net Zero Carbon**

This refers to any solution where carbon emissions are reduced as far as is practicable possible and where any remaining emissions are offset.

For example, heat pumps can become net zero carbon in operation, if the electricity powering them is from a green energy source e.g. solar PV or wind turbines. It can also be regarded as net zero carbon if any remaining emissions from the electricity consumed are offset by other measures such as planting trees or carbon capture.

Net Zero Carbon is also often defined in terms of the complete lifecycle of the building or asset over a span of 60-years to include both embodied and operational carbon. This definition is not being used in this report.

## 21.0 Next Steps

**The following activities will be required to inform the next phase of project development.**

| No. | Task Description | Desired Outcome |
|---|---|---|
| 1 | Perform heating circuits and hot water fed data logging within each building. | Determine accurate heating and domestic hot water load profiles. |
| 2 | Investigate, identify, and rectify heating system short circuits within each building. Maintenance and BMS specialist input to be used. | Achieve immediate energy savings, performance benefits and carbon emissions reductions as a result. |
| 3 | Review proposed phasing and implementation of plant room modifications. | Determine the route to reducing the blended return water temperature and make buildings suitable for heat pumps. |
| 4 | Detailed study required on the electrical infrastructure to inform whether network upgrades are required to support the selected heat pump strategy and maximum demand expectations. | Option specific design detail and costs for electrical infrastructure upgrade to avoid transmission triad charges |
| 5 | Undertake further district heating system modelling to determine optimised thermal storage and heat pump capacities | Option Specific design detail for selected option. |
| 6 | Perform intrusive building envelop investigations to determine construction u-values and air permeability tests for each building. | Confirm precise locations of fabric deficiencies, quantify actual on-site performance deficiencies to inform actual energy losses, identify cost of envelope improvements interventions and associated elemental carbon savings for each building |
| 7 | Implement an iterative process of reducing the heating temperature. Alternatively, a digital twin can be developed to simulate the building reaction to the adjustment of the multiple variables to establish an efficient and less disruptive process for determining the most efficient system operation process. This would be recommended for each building type. | Determine the effect on the internal building temperatures, occupancy, external conditions. |
| 8 | Rate the benefit according to improvement cost, energy, and carbon savings data for each building. | Inform the phasing of the works to suit the UoW's stepped investment programme. |
| 9 | Provide detailed heating system schematics. | To be provided for the selected system option to be developed. |
| 10 | Electrical capacity and usage profile study to be carried out. | To be provided for the selected system option to be developed. |
| 11 | Hold workshop with client team to explore the cost funding options and preferred pathway to implementation of phasing and options. | Detailed phasing plan. |
| 12 | Provide details on integration of local low temperature heat network and hot water systems. | Provide schematics and calculations to support solution. |

| No. | Task Description | Desired Outcome |
|---|---|---|
| 13 | Provide detail on carbon benefits and operational cost impacts to further refine decision making. | To be provided for the selected system option to be developed. |
| 14 | Develop the preferred option(s) to RIBA Stage 2 level of design and cost plan status. | |

## 22.0 Supporting Data / Appendices

22.1 Maintenance contracts and supporting information

22.2 Sheila Scott - Digital Twin Report

22.3 Thermographic Report

22.4 Historical Salix phase 1 HDP

22.5 Stage 0 Cost Plan

22.6 River Source Heat Pump - Element Energy Report

22.7 HDP Support Tool Inputs

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