Newbuild zero direct emissions heat

Building: **Armadale Stores**
Location: **Highland**
Heating system: **Air Source Heat Pump**

Building overview

Building use: Shop, Post Office, petrol station and offices in southern Skye.
Year built: 2021
Floor area: 235 m^2
Scottish EPC rating: B
Heating system: 1x 14kW Mitsubishi Ecodan air source heat pump
Heating system cost: £60,000
Heat delivery method: Underfloor heating and radiators.

Choice of heat system

Sleat Community Trust (SCT), the owners of Armadale Stores participated in Zero Waste Scotland's (ZWS) Energy Efficiency Business Support Scheme to gain advice prior to the building's major refurbishment and expansion. A report by a local consultant advised there was insufficient land for a ground source heat pump, and that an air source heat pump (ASHP) would be the most cost effective heating system. Solar PV and other energy efficiency measures were also recommended and later specified.

Main drivers for selection:

1. Costs (and funding availability)
2. Off the gas grid

Route to implementation

The project was partly funded by the Island Green Recovery Fund (via ZWS). RHI payments were considered, but the project happened close to the scheme's closure, so resources were focused elsewhere, as it was deemed too big a challenge to put together an application in the necessary timeframe (~2 weeks). The main contractor for the build sub-contracted the heat installation. This process went very smoothly.

Implementation process:

- ZWS report by consultant
- ASHP part-funded by ZWS
- System installation subcontracted

Key barriers faced:

Cost	■■■
End user	■□□
Complexity	■■■
Product availability	■■□
Supply chain	■■□
Grid constraints	■□□
Policy & regulation	■□□

Shops
Newbuild zero direct emissions heat

Technical performance

There was a snagging issue with the hot water tank, which took longer than usual to fix due to Covid-19's impact on labour and materials availability. Apart from this issue, the system has not required any maintenance since it was installed in early 2021.

The building is noted to be warmer in the mornings and cools down over the day. The shop is also very warm in the summer, even with the underfloor heating turned down, and the door must be kept open to cool the building.

Heat metering was not installed. This means that there is no way to determine if the heat demand is as expected, and what it costs to heat the building. Therefore, many performance measures are unknown for the building. Electricity costs have provided below, and consumption is estimated based on the Energy Saving Trust's 2021 electricity cost dataset.

Performance measures for 2021:

Anticipated demand	Unknown
Estimated elec. demand	20,000 kWh /yr, 85.1 kWh / m^2 /yr
System running cost	£3,616 /yr
Maintenance costs	Nil

"In the summer, the shop is often too warm and we risk goods being spoiled."

–Business Development Officer, Sleat Community Trust

User experience

The ZWS report allowed the Trust's project team to be more aware of the energy systems and form good relationships with the subcontractor who installed the heating system. This smoothed the handover process and facilitated aftersales support.

The permanent users of the building are satisfied with the level of heat and comfort that the system provides over the year. However, the warm temperature of the shop (roughly half of the building's footprint) over the summer is a key concern for SCT. The warm environment can cause perishable food to spoil, which is a key business risk. Staff feel that installing a ventilation or cooling system would have mitigated this issue.

Lessons Learnt

1. **Free advice from ZWS made it possible to seek grant funding** and gave the owners additional knowledge, which facilitated good relationships with contractors during and after the build.
2. **Ventilation and cooling requirements should be considered at design stage,** particularly for shops, as overheating risks perishable goods being spoiled.
3. **The installation process of an ASHP can be easier in a major refurbishment,** and when installed in tandem with a new heat distribution system, compared to isolated heating system retrofits.

Food and Drink
Newbuild zero direct emissions heat

Building: **Arbikie Distillery Visitors Centre**
Location: **Angus**
Heating system: **Air Source Heat Pumps**

Building overview

Building use: Visitor Centre for Whisky Distillery, with café, restaurant, bar areas, exhibition spaces and a shop.
Year built: 2022
Floor area: 4,000 m^2
Scottish EPC rating: A+
Heating system: 6x Daikin SkyAir air source heat pumps
Heating system cost: £100,000
Heat delivery method: Underfloor heating (downstairs) and air ducts (upstairs).

Choice of heat system

The development site is off the gas grid in a location where most buildings are heated by oil. The ethos of sustainability is a primary focus for the organisation, and drove the design brief for the new building at Arbikie. Therefore, ensuring a low carbon heating system was prioritised ahead of capital costs. This made Air Source Heat Pumps (ASHPs) a clear choice for the building, with ground-source considered as a back-up option if, for any reason, ASHPs were not feasible.

Main drivers for selection:

1. Sustainability
2. Simplicity versus alternatives
3. Capital cost

Route to implementation

The whole building was funded internally, with support from a bank loan. The construction process was managed internally, and the contractor for the heating system was selected by the Arbikie team on the basis of costs and their experience.

The external ASHP system consists of six smaller heat pump units to allow for modulated heat provision, and the units are located in an enclosed area to keep them out of site from visitors.

There were no notable issues relating to the grid connection, planning, installing or commissioning the ASHP system.

Implementation process:

- ASHP selected based on sustainability ambitions
- Contractor selected based on costs and experience
- Smooth construction and installation process
- Heating system handover one week after occupation

Food and Drink
Newbuild zero direct emissions heat

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The building has only been occupied since March 2022 but there have been no faults or issues to date. The heating is controlled primarily by thermostats in the main rooms, which will have a target internal temperature of 18°C, due to the highly insulated building envelope.
The ASHP installation does not receive Renewable Heat Incentive payments and there is no building management system, so there is no way to measure heat demand specifically. Staff are not aware of estimated heat demands.

"The heating hasn't been running for long and we haven't touched the controls yet, but all the rooms are very comfortable."

– Staff member, Arbikie Distillery

User experience

The building is warm and comfortable, although it is not yet clear if this is due to the heating system or from thermal gains from the expansive glazing in the building.
Staff were shown how to operate the heating controls by the contractor a week after occupation. They found this support 'extremely helpful' and were left confident as to how to operate the system.
If the ASHP system works well, the owners are very keen to use ASHPs to heat further (proposed) buildings at this location.

Lessons Learnt

1. **Heating system performance is more difficult to determine where there are other sources of thermal gains.** In this case, the building is heated significantly by the sun.

2. **Heating design to installation can be a straightforward and low impact process**, even in large, multi-use buildings.

Food and Drink
Newbuild zero direct emissions heat

Building: **Saughton Park Café**
Location: **Edinburgh**
Heating system: **Ground Source Heat Pump**

Building overview

Building use: Café within public park.
Year built: 2019
Floor area: 274 m^2
Scottish EPC rating: C+
Heating system: GSHP
Heating system cost: Not Provided
Heat delivery method: Underfloor heating

Choice of heat system

As part of a restoration project for Saughton Park, the City of Edinburgh Council were motivated to utilise its natural energy resources to provide an exemplar, sustainable heat and power system. They received initial support from Greenspace Scotland to conduct a feasibility study for heating the park's buildings, including a new café and existing Glasshouses. A second feasibility study was funded by the Low Carbon Infrastructure Transition Programme, which considered a river-source WSHP system and small district heating scheme, but indicated that a Ground Source Heat Pump (GSHP) system was the only option that would be financially and practically feasible.

Main drivers for selection:

1. Sustainability ambitions
2. Capital and operational costs

Route to implementation

Along with the GSHP system, a micro-hydro scheme was also constructed within the park, funded by SPEN. Although this had been planned prior and separately to heating system considerations, it reduced the financial risk of operating the GSHP system by providing it with free, renewable power. The annual generation from the scheme was anticipated to exceed the electrical demand from the GSHP.

The Scottish Energy Efficiency Program (SEEP) provided funding to install a horizontal ground loop under a football pitch in the west of the park and two heat pumps for the cafe and other new buildings. SEEP also funded a 125m deep vertical ground loop under the east car park and three heat pumps for the park's Glasshouses.

The design and installation of both heat pump systems was straightforward, and benefited from the council's internal expertise, as did the process of securing grant funding for the works.

Food and Drink
Newbuild zero direct emissions heat

Implementation process:

- Two funded feasibility studies
- Micro hydro scheme installation
- GSHP installation

Key barriers faced:

Cost	■ ■ ■
End user	■ □ □
Complexity	■ ■ □
Product availability	■ □ □
Supply chain	■ ■ □
Grid constraints	■ □ □
Policy & regulation	■ ■ □

Technical performance

Following commissioning, there were several snagging issues, where errors caused the GSHP to shut down. This required visits from the installers to adjust the system's controls. The internal maintenance team were new to heat pumps and initially relied on support from the supplier to control the system, but experience has since built over time.

Following resolution of these initial issues, no maintenance has been required other than annual services. The GSHP system itself consists of two heat pumps, so that if one fails, the other will still be able to heat the café.

There have been long-term issues around monitoring of the micro-hydro scheme and the GSHP's energy consumption. These arose due to issues with the park's electricity import meter, and with the council's internal operational processes. As a result, the overall performance of the GSHP is not being monitored at present, and data has not been provided.

> *"It was important to the local community to install renewable energy systems at the park, and they are now really proud of this."*
> ***– Project Manager, Saughton Park Restoration Project***

User experience

Aside from the snagging issues which affected the heat supply, the café's heating system is noted to work well and provide sufficient warmth and comfort year-round.

The restoration project received a lot of support from the park's community, who are really proud to have the GSHP and micro-hydro systems in place.

Lessons Learnt

1. **Having internal technical knowledge was a key enabler during the early stages of the project,** by aiding decision making and the process of securing grant funding.

2. **Investigating and installing the park's GSHP system was made financially viable through grant funding.** Internal and local enthusiasm for implementing sustainable energy systems drove the decision to apply for grant funding, which was complex and time-consuming.

3. **Training and the hand-over process don't necessarily provide immediate confidence in operating heat pumps,** this builds with hands-on experience.

Business
Newbuild zero direct emissions heat

Building: **National Manufacturing Institute Scotland (NMIS)**
Location: **Renfrewshire**
Heating system: **District Heat Network**

Building overview

Building use: Centre of excellence for manufacturing research and industry-academia-public sector collaboration.
Year built: 2022
Floor area: c. 11,000 m^2
Scottish EPC rating: A+
Heating system: 1,200kW water source heat pump using district heat from wastewater treatment plant
Heating system cost: £860,000

Choice of heat system

NMIS will be the University of Strathclyde's first newbuild to align with its carbon and climate neutrality targets, and Scotland's first large scale factory with carbon neutral energy consumption. As it is a centre of excellence, the University wanted to design an innovative space that was cost-effective, sustainable and suited to the needs of its users. Although heat is considered to be just one aspect of wider power and suitability requirements, the University is conscious of the issues around pricing, resilience and security of energy supply, and keen to mitigate these.

The NMIS site is part of the Advanced Manufacturing Innovation District Scotland (AMIDS), a collaborative project led by Renfrewshire Council. Sustainable solutions, including district heating and renewable generation, were key to the Council's aspirations for AMIDS. Heating options considered included ground source, river source and wastewater heat networks. A low temperature heat network drawing heat from a local wastewater treatment plant was ultimately selected for AMIDS, which aligns NMIS' own net-zero goals.

Main drivers for selection:

1. Resilient, carbon neutral energy
2. Innovation
3. Costs
4. User comfort
5. Scalability

Route to implementation

Renfrewshire Council commissioned a series of studies to develop the concept from feasibility through to detailed design and delivery. This process was iterative and collaborative with partners including the University.

The University agreed to be one of two anchor loads, which helped de-risk the project, aiding its viability and allowing the Council to invest and obtain match

Business
Newbuild zero direct emissions heat

> *"We want our people to work in amazing spaces, we don't want them to have to think about heating."*
> ***- Executive Lead for Sustainability, Strathclyde University***

funding from the Low Carbon Infrastructure Transition Programme. Construction of the heat network is due to complete later in 2022.

In order to minimise heat demand and operational costs, the building has been designed with high thermal efficiency, batteries and 800kW of rooftop solar PV. It will have an electric boiler as a back-up system.

Implementation process:

- Feasibility studies
- Developing concept and business case
- Collaboration between Council, University and other partners
- Securing funding
- Design, construction, operation and maintenance managed by Renfrewshire Council

Key barriers faced:

Cost	
End user	
Complexity	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The building is due to be operational by late 2022, but anticipated performance has been estimated as follows.

Performance measures for 2023:

Anticipated heating demand	400 MWh /yr, 36.4 kWh /m^2 /yr
Anticipated running cost	£14,000 /yr

User experience

NMIS will have a building manager who will ensure that heat and comfort levels are maintained. The intention is that users should be comfortable at all times and not have to think about heating. This will be facilitated via control by the Building Management System.

Lessons Learnt

1. **Larger organisations have the power to influence local policy** and energy strategy for development zones, especially where they feel this is necessary to meet their own sustainability policy. In this case, collaboration between the local authority and partners including an 'informed client' led to a sustainable energy solution and gas fired heating being avoided.

2. **The University acted as an early enabler by agreeing to take heat from the scheme.** This de-risked the scheme and demonstrated that collaboration, innovation and ambition can help deliver net zero.

3. **Heat is only one of many concerns around sustainable development for high-profile organisations**. Other priorities include resilience against climate change, energy supply volatility, as well as placemaking, wellbeing and nature-based solutions.

Storage or distribution
Newbuild zero direct emissions heat

Building: **DataVita**
Location: **North Lanarkshire**
Heating system: **Direct Electric & Variable Refrigerant Flow**

Building overview

Building use: Data Centre
Year built: 2016
Floor area: 8,000 m^2
Scottish EPC rating: E
Heating system: 2kW Dimplex Electric panel heaters and Mitsubishi 6.3kW and 10kW VRF systems
Heating system cost: £18,000
Heat delivery method: Individual panel heaters and VRF.

Choice of heat system

As a power intensive industry, electric heating was chosen. 40 2kW electric panel heaters are installed across the general use areas and a network of 12 standalone VRF systems are used for heating offices. VRFs were selected for offices due to the anticipated need to cool the offices as well as heat. No other options were considered as alternatives not available.

Main drivers for selection:

1. Limited heat requirement and need for cooling.
2. Cost of heating system considering limited requirement.
3. Flexibility of panel heaters for dispersed areas.
4. Risk to business of using gas and water-based distribution systems.

Route to implementation

The use of well established solutions meant that no barriers were experienced. The site was privately funded by DataVita's parent company and early on a decision to invest >£30M in the building site and grid infrastructure, effectively part-funded a new primary substation predominantly for their own power requirements. Hence grid constraints will not limit the site in the future. The building was designed for future growth and has strategic points in the building where heat recovery can be easily retrofitted.

Implementation process:

- Operational review completed to establish heating requirement
- M&E Consultant completed the design
- M&E Contractor completed the installation

Key barriers faced:

Cost	■□□
End user	■□□
Complexity	■□□
Supply chain	■□□
Grid constraints	■■□
Policy & regulation	■□□

Storage or distribution
Newbuild zero direct emissions heat

> *"The data centre now has a substantial rejected heat load which we will be looking to embrace to replace the existing heating systems with heat recovered from the data halls" –* ***Operations Director, Data Vita***

Technical performance

Data centres generally do not require much heat given the heat generated by the servers and the limited space that requires heating for a small workforce. As a new building, they required heat to ensure comfortable temperatures for staff areas in the winter before securing clients and therefore heat-generating servers.

In the winter electric panel heaters are needed most of the time, which is operationally costly given the inefficiency of the panels and lack of thermostatic control.

Given the growth of the business the heat produced from the servers is now ~300-400kW, more than is required to heat the auxiliary areas of the building (10s kW), such that heat is vented from the building. They are planning on retrofitting a heat recovery system to use this 'free heat' and remove the electric panel heaters altogether, to reduce costs. They intend to keep the VRF in office spaces but disable the heating mode and using for cooling only. Given the building design, heat recovery will be simple to retrofit.

Performance measures for 2021:

Anticipated heat demand	117,630 kWh/yr, 14.7 kWh / m^2/ yr
Actual heat demand	Unknown
System running cost	17,604 £/yr
Maintenance costs	1100 £/yr

User experience

Electric panel heaters are very simple to understand and use, however they require manually switching on and off which is an annoyance and time-sink. For the majority of the year there is limited need for heat in the general use areas. However, in the winter these areas can be uncomfortably cold, until the heaters are manually turned on. With hindsight, better controls would have been installed to centrally manage heating requirements, keep occupants comfortable at all times and maintain the building fabric. The VRFs for heating the offices have central control (scheduled and locked to avoid occupant over-ride) and provide higher occupant comfort.

Lessons Learnt

1. **Early grid infrastructure investment** was made to ensure power was available and futureproof the site. This was seen as an investment rather than a constraint for the development.
2. **Remote and centralised control is key for heating systems,** to create a comfortable working environment, maintain fabric efficiency, easily operate and manage running costs.
3. **Planning at the design phase for heat recovery** will lead to a simpler retrofit in the future.

Hotels and hostels
Newbuild zero direct emissions heat

Building: **Kilbride Hostel**
Location: **Na h-Eileanan Siar (Western Isles)**
Heating system: **Ground Source Heat Pump**

Building overview

Building use: Hostel accommodation on South Uist.
Year built: 2018
Floor area: 200 m^2
Scottish EPC rating: C+
Heating system: 1x 230V Nibe F1155-12 GSHP
Heating system cost: Unknown
Heat delivery method: Underfloor heating

Choice of heat system

The hostel developers selected a GSHP system as funding from the Outer Hebrides Leader Program and the Community Landlord Storas Uibhist Community Fund was available to cover its capital costs, and because it had no external above-ground parts. This was important to the hostel as it was felt to minimise the likelihood of system maintenance and complications arising due to adverse weather. A Ground Source Heat Pump (GSHP) was also preferred over an air source heat pump as it was regarded as a more efficient system over the long-term.

Main drivers for selection:

1. Most suitable zero emissions option
2. Grant funding available

Route to implementation

The GHSP installation was subcontracted from the main build of the hostel. The installers brought the materials with them to site in stages as the project progressed. This was done to ensure the team would be available for the installation and the equipment would not sit idle on site.

Despite the hostel's remote island location, there were no supply chain issues. The owners were heavily involved during the GSHP system's implementation, and even did some of the ground work themselves.

A key challenge experienced during the installation arose due to impacts of the weather - digging trenches for the ground array was challenging due to consistent rainfall, as they kept filling with water.

Implementation process:

- Grant funding secured
- GSHP install managed by subcontractors.

Hotels and hostels
Newbuild zero direct emissions heat

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The GSHP system has performed very well since it was installed and has not had any unexpected outages.

The system is controlled by internal temperature sensors which indicate when the heat pump needs to increase performance to maintain internal conditions.

As part of the system's maintenance contract, the maintenance company can log into the system remotely via Wi-Fi, in order to check on performance and investigate potential issues.

Annual heat demand and cost data has not been made available.

"Overall, we are very satisfied with the performance of the heat pump." ***– Owner, Kilbride Hostel***

User experience

Heat output from the system is noted to have been constant over the year, and the owners are very satisfied with its performance. All of the controls are easily accessible within the building, and temperature sensors are located throughout, to indicate when the heat output should be moderated.

The maintenance company performed some initial training on the system when it was installed. However, the owner is keen to learn more about the system to be able to adapt and fix any potential issues.

Lessons Learnt

1. **The absence of external, above-ground parts is a perceived advantage of GSHP systems compared to ASHPs**, particularly in costal locations when external conditions can be unfavourable.

2. **Staged construction can de-risk development of GSHP.** The construction of horizontal loop GSHP trenches can be developed one by one to avoid trenches filling with water.

3. **Sensors are useful for system control and comfort.** Internal Temperature sensors have helped the users to determine when the system needs to moderate its performance, in order to maintain comfort levels.

Residential Institutions
Newbuild zero direct emissions heat

Building: **Dundreggan Rewilding Centre Accommodation**
Location: **Highland**
Heating system: **Air Source Heat Pump**

Building overview

Building use: An accommodation block for residential visitors to Trees for Life's (TFL's) Dundreggan Rewilding Estate.
Year built: 2022
Floor area: 360 m^2
Scottish EPC rating: Unknown

Heating system: c. 12 kW ASHP
Heating system cost: c. £40k
Heat delivery method: radiators

Choice of heat system

As a rewilding centre for the Caledonian forest, sustainable development was a key driver for the Estate's energy systems. Planning was originally sought for a biomass network for the site's new and existing buildings, but following a feasibility study, individual Air Source Heat Pumps (ASHPs) systems were recommended based on cost-effectiveness. The study identified that heritage assets increased the complexity and risk of ground- or water- source options. TFL staff presented the option of an ASHP for the accommodation to the charity's board, who endorsed the decision.

Main drivers for selection:

1. Climate
2. Capital and running costs
3. Ease of operation
4. Feasibility study recommendation

Route to implementation

The building's energy system is funded through the Low Carbon Infrastructure Transition Programme. The application required further external consultation but the funding is invaluable to a small charity, who would not have been able to ensure the development met their sustainability aspirations without it.
SSEN have funded the extensive grid connection upgrades required to accommodate the two new buildings on the Estate, but the specification of heat pumps didn't impact the cost of the upgrades.
The building is currently under construction and due to complete by December 2022. There have been no issue to date with the build.

Implementation process:

- Feasibility study
- System design
- Liaison with SSEN
- Grant application
- Construction in progress

Residential Institutions
Newbuild zero direct emissions heat

Locogen

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The building is due to be operational by 2023, but anticipated performance has been estimated as follows.

Performance measures for 2023:

Anticipated heat demand	25,480 kWh /yr, 70.7 kWh/ m^2 /yr
Anticipated running cost	£5,100 /yr
Anticipated maintenance	£400 /yr

Lessons Learnt

1. **Heat networks are not always the most suitable option for sites with several buildings.** Due to the spatial spread of the buildings on this Estate, the originally-intended biomass heat network would have unjustifiable capital costs and energy losses compared to the individual ASHP systems solution that was ultimately specified.

2. **External support was required for acquiring funding and decision-making relating to energy systems.** The project would not have been possible without grant-funding, and the charity did not have the internal expertise to make decisions relating to heating and energy systems in new buildings.

Non-residential institutions
Newbuild zero direct emissions heat

Building: **Acharacle Primary School**
Location: **Highland Council**
Heating system: **Direct Electric, then Air Source Heat Pump**

Building overview

Building use: Primary School for the remote Acharacle community.
Year built: 2009
Floor area: 1,366 m^2
Scottish EPC rating: Unknown
Heating system: 2x 14kW Mitsubishi Ecodan ASHP
Heating system cost: £87,225
Heat delivery method: Wet heating with in-wall heat emitter system.

Choice of heat system

The Highland Council chose to build this school to PassivHaus standard, to meet innovation ambitions and tap into available funding available at the time. Aspects including triple glazing and very high airtightness resulted in a very low anticipated heat demand. As such, direct electric cylinders were chosen due to their low capital costs. In 2018, ASHPs were retrofitted in order to reduce running costs, as energy use was higher than expected.

Main drivers for selection:

1. Funding available
2. Anticipated low demand
3. Lower running costs

Route to implementation

The original heating system was funded externally through the PassivHaus funding awarded to the building.
Originally, there was a push to have no heating system at all, with just occupants and equipment providing space heat, but the contractor pushed for heating based on the building's location. An ASHP was noted to be the ideal heating system, but as the site was to have a small wind turbine as well, it was expected that the turbine would provide electricity to offset the costs of direct electric heating.
Given the PassivHaus design and off-site construction, intense planning and preparation was required, and all building services had to be designed in detail at an earlier than normal stage.
The ASHPs were installed in 2018 to reduce running costs of the direct electric heating. This process was managed internally.

Implementation process:

- Design & Build contractor specified heating system to meet PassivHaus brief.
- After 9 years, ASHP installed.

Non-residential institutions
Newbuild zero direct emissions heat

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The building's high-quality construction and high airtightness continues to allow low heat demands, although increases the need for (natural) ventilation.

The original heating system was reliable, but due to the removal of the school's wind turbine, the increased consumption of grid electricity led to higher costs operational costs, which justified the installation of ASHPs. The environment displays in each room were also noted to be a constant power drain, with a small impact on electricity demand (and bills).

The ASHP were easily integrated with the existing heat distribution system and have had no snagging or performance issues and are facilitating a financial payback. Heating costs are not accounted separately from electricity costs, so electricity is considered below.

Performance measures:

Demand pre ASHP (2009-17)	94,127 kWh /yr, 68.9 kWh/ m^2 /yr
Demand with ASHP (2019-21)	68,339 kWh /yr, 50.0 kWh/ m^2 /yr
Running costs (2020)	£12,772 /yr

"Incredible air tightness and a high-performance superstructure result in an extremely low heat demand. After over ten years it's still one of the Council's best performing buildings and we're really proud of it." – **Energy Engineer, Highland Council**

User experience

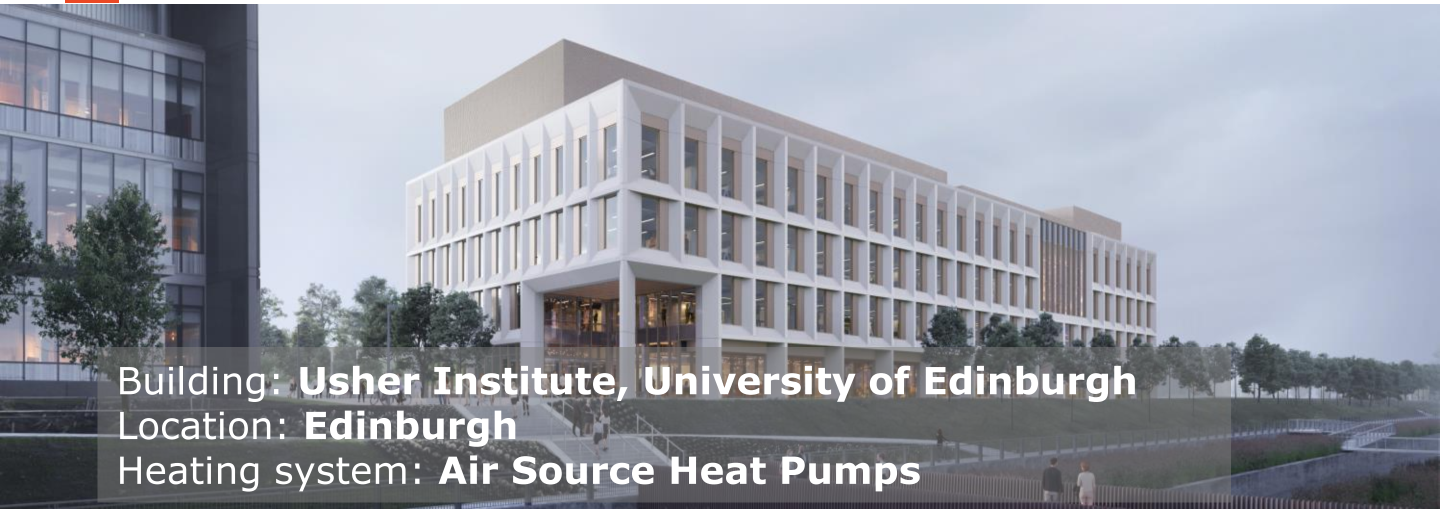
Satisfaction with heat delivery in the building is generally high, although where issues have arisen, impacts have been exacerbated by the time taken for contractors to reach the school's remote location. In particular, end-users complained that the building was stuffy after window actuators were broken for a prolonged period. Although not directly a heating issue, this exemplifies that heating and ventilation are grouped together by occupants when considering comfort.

Lessons Learnt

1. **Good construction and high fabric performance** has ensured that heat demand has remained low over the last decade. This also allowed for lower capital costs for heating system upgrades.

2. **Occupants tend to consider ventilation in tandem with heat**, as both interact to impact their comfort levels.

3. **The impacts of energy monitoring systems should be considered at design stage,** particularly sensors which are have a non-negligible demand.



Building: **Usher Institute, University of Edinburgh**
Location: **Edinburgh**
Heating system: **Air Source Heat Pumps**

Building overview

Building use: An office development enabling research and data-driven innovation in health and social care
Year built: Expected in 2023
Floor area: 13,900 m^2
Scottish EPC rating: A
Heating system: ASHP and direct electric hot water heating
Heating system cost: Unknown
Heat delivery method: Low temperature hot water

Choice of heat system

The Usher Institute will be located in the Edinburgh BioQuarter adjacent to a large hospital, research facilities and significant future development sites. The site is ideal for a district heating network (DHN) development. Building heating system options, including gas boilers, combined heat and power (CHP), heat pumps, and local DHN connection, were assessed at an early RIBA stage. Multi stakeholder DHN development was deemed high risk within the project timeframe. Small scale gas CHP was not in line with the University's Net Zero strategy. Air source heat pumps (ASHP) were selected as the preferred option.

Consideration was given to the risks and benefits of maintaining a gas boiler back-up, alongside a desire to eliminate fossil fuels from the site. The University decided on a containerised back-up solution instead, which is likely to become the norm. The University will continue to work with regional partners on the long term viability of a low carbon DHN at the BioQuarter site.

Main drivers for selection:

1. An 'all-electric' heating strategy supported their Net Zero objectives.
2. An ASHP was cost effective from a project delivery viewpoint.
3. A containerised back-up heating system required for resilience.

Route to implementation

The project was developed in-line with the University of Edinburgh's Sustainable Design Guidelines and followed a typical RIBA progression through the governance gateways.
Funding was received from the Scottish Funding Council (SFC) to develop an advanced dynamic simulation model and a 'digital twin' of the building, which will allow improved continuous commissioning of building heating systems post completion.

Non-residential institutions
Newbuild zero direct emissions heat

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The building's hot water circuit will operate at 45°C/40°C flow and return temperatures. The hot water will be pre-heated from 10°C to 44°C by ASHPs and further heated to 65°C by electrical resistance calorifiers. A key issue for the design was risk assessing the cooling and ventilation strategy, which impacted significantly on energy performance and the building energy performance target. During design development the dynamic modelling software was used to model overheating risks across a range of occupancy profiles and weather conditions. A mechanical ventilation strategy was adopted over natural or mixed mode to minimise overheating risks, despite additional capital and operating costs. The building fabric was improved to LETI standards, reducing the energy for heating by 12% (largely offset by additional space cooling requirements).

Performance measures:

Anticipated heat and hot water demand	261,000 kWh/yr 18 kWh/m^2/yr
Estimated cost for heat and hot water	£52,200/yr

> *"Our first modern all-electric building has driven a culture shift in our approach to low carbon heat"*
> ***Head of Energy & Utilities, University of Edinburgh***

User experience

The user experience was a key consideration during the early design stage and sensitivities in occupancy were found to have a big impact on user comfort. Significant discrepancies were found between compliance modelling outcomes and dynamic simulation modelling outcomes, highlighting how sensitive building energy performance and design choices are to occupancy patterns. The compliance model understated potential heat gains by a factor of 2.5.

Lessons Learnt

1. **Invest in dynamic simulation modelling at an early design stage.** This will ensure building energy performance and environmental conditions are well understood. This also means the project will take longer, cost more and require expertise at a much earlier phase.

2. **Ventilation was key to avoid overheating.** A mechanical ventilation strategy lowered the risk of overheating based on modelling of occupancy patterns.

3. **A significant cultural shift was required to enable all-electric heating.** Moving away from gas heating and back-up systems was not an easy decision.

Building overview

Building use: Museum
Year built: 2018
Floor area: 8,445 m^2
Scottish EPC rating: Unknown

Heating system: GSHP
Heating system cost: Unknown
Heat delivery method: Underfloor heating and radiant panels system

Choice of heat system

Given the status of the V&A Dundee as Scotland's design museum and a landmark for the city, the design brief for the building's energy systems was focused on sustainability, energy efficiency and innovation.
The buildings' M&E Consultants conducted a feasibility study to assess the options for a zero emissions heating system, which led to the specification of Ground Source Heat Pumps (GSHPs) as a heating and cooling solution, with roof-mounted air source heat pumps as a back-up. A water source heat pump from the adjacent river Tay was also considered but deemed to be less cost effective and more technically challenging. The specified heating system was also deemed advantageous as it would have no aesthetic impact on the building's exterior.

Main drivers for selection:
1. Zero emissions operations
2. Ability to provide heat and cooling
3. No visible external parts to impact aesthetics

Route to implementation

The building was designed to have a high thermal mass, in order provide a base level environment to assist the heating and air handling systems to maintain the stable temperature and humidity levels needed in the galleries.
Design and construction of the GSHP was complex, as the building relies on 30 boreholes each with a depth of 200m. The heat pump is designed to operate in reverse during the summer to cool the building and recharge the boreholes.

Implementation process:
- Feasibility study by consultant
- System design by consultant
- Construction

Non-residential institutions
Newbuild zero direct emissions heat

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

Since the building was opened in 2018, the heating system has been performing largely as intended, with no unexpected maintenance.

However, small sections of the building, including communal and reception areas have experienced colder temperatures and drafts. To address this, the building management team elected to install electric fan coil systems to provide additional heat.

Actual heating demand and cost values were not available to share.

Performance measures for 2021:

Anticipated heat demand	800 MWh /yr, 94.7kWh / m^2 / yr
Actual demand	Unknown

> *"The stable supply of heat from the heat pumps, along with the carefully integrated air handling systems has led to the very efficient operation of the building's energy systems."*
> **– General Manger for Health and Safety and Facility Maintenance, V&A Dundee**

User experience

Aside from the cold spots within the building, there have been no other issues with comfort.

The system is monitored and controlled automatically by the Building Management System (BMS) and heat output is adjusted based on internal and external conditions. For example, during the Covid-19 pandemic the BMS was re-programed maximise the delivery of fresh air, which to help keep carbon dioxide levels at a level similar to being outdoors.

Furthermore, given the fact that the building is a museum that contains valuable objects that must be stored at specific temperatures, the use of the BMS crucial.

Lessons Learnt

1. **For buildings where aesthetic impact is a priority, GSHPs provide an advantage by having no external parts.**
2. **In large projects, design of heating systems can be very complex.** Several iterations of feasibility stages may be required to get buy-in from all stakeholders, and to ensure that the design meets a range of requirements.
3. **Sustainability aspirations can drive energy system and building fabric design beyond building regulation requirements.**

Building: **Regional Performance Centre for Sport Dundee**
Location: **Dundee**
Heating system: **District Heat Network**

Building overview

Building use: Sports Facilities
Year built: 2020
Floor area: 14,693 m^2
Scottish EPC rating: Hub Building D, Athletics Building F

Heating system: District heating system with 600kW GSHP, 50kW solar thermal, 0.5MW CHP, 2.4MW gas boiler.
Heating system cost: £27.4M
Heat delivery method: Underfloor heating system

Choice of heat system

The Caird Park District Heat Network (DHN) was devised as part of the redevelopment of Dundee's Regional Performance Centre for Sport (known as the RPC Dundee), which is the anchor load for the network.
The main driver behind selecting the heating system was the 2015 update to the Scottish Building Standards, which required carbon emissions in new buildings to be reduced by c. 43% versus the previous standards.

This significant reduction in carbon emissions required the use of multiple low carbon technologies. The combination of Ground Source Heat Pump (GSHP), solar thermal, Combined Heat and Power (CHP) and a gas boiler was selected to maximise the use of the natural resources available. The CHP system was included to reduce the cost of electricity for the GSHP and providing addition heat capacity.

Main drivers for selection:
1. Drive to meet building standards
2. Innovation
3. Grant funding opportunity

Route to implementation

Following the establishment of the RPC Dundee as the anchor load for the DHN, a 3.5MW energy centre was created, comprising GSHP, CHP, rooftop solar thermal, and a gas boiler. This was part funded by the Low Carbon Infrastructure Transition Programme.
The GSHP system comprises of 120 bore holes drilled 200 meters below the RPC Dundee Velodrome and is currently Scotland's largest geothermal array.

Assembly and leisure
Newbuild zero direct emissions heat

Implementation process:
- Feasibility study
- System Design
- Construction process

Key barriers faced:

Cost	■■□
End user	■□□
Complexity	■■■
Product availability	■□□
Supply chain	■■□
Grid constraints	■□□
Policy & regulation	■■□

Technical performance

The heat network and its individual components have been performing well since installation, and no unexpected maintenance has been required.
A few areas of the RPC Dundee have experienced colder temperature and drafts, which has been rectified by use of electrical heaters.
The provided values below are the fuel costs for the whole RPC Dundee building demand, not just for heating.

Performance measures for 2021:

Actual electricity demand	538,631 kWh /yr 361 kWh / m^2 /yr
Actual gas demand	1,980,940 kWh /yr, 1,329 kWh / m^2 /yr
System running cost	£114,384 / yr

User experience

Generally, the building users are very satisfied with the performance of the system and no major complaints have been reported.

As the heating system is centrally controlled, some staff members have reported that having local panels to control individual room temperatures would have been preferred.

"We're now at feasibility stage for extending the heat network to connect with other high heat demand properties nearby, which will create further operational efficiencies, enable further investment in low carbon technologies and reduce reliance on the gas back up system." – **Sustainability and Climate Change Manger, Dundee City Council**

Lessons Learnt

1. **Meeting building regulations can be challenging and required a multi-technology solution as a trade off between costs and emissions.** In this case, a combination of four technologies was utilised.
2. **Multi technology district heating systems can perform well in situ,** despite complex design and integrating requirements.
3. **Risks to end-user comfort and satisfaction are higher in large buildings with centrally controlled heating systems**.

Assembly and Leisure
Newbuild zero direct emissions heat

Building: **Lochore Meadows Visitor Centre**
Location: **Fife**
Heating system: **Water Source Heat Pump**

Building overview

Building use: Visitor Centre for country park in central Fife.
Year built: 2017
Floor area: 359 m^2
Scottish EPC rating: B

Heating system: 24 kW Kensa WSHP
Heating system cost: £97k
Heat delivery method: underfloor heating

Choice of heat system

A Water Source Heat Pump (WSHP) was chosen for the Visitors Centre as the site is located within 100m of a loch. A gas connection was possible but would have involved digging a route through the country park, and did not align with Fife Council's climate agenda. Other heat pumps were considered, but they were not thought to offer the same year-round efficiencies.

Main drivers for selection:

1. Water source available
2. Aligned to Council climate agenda
3. Gas connection disruptive

Route to implementation

The council's internal engineering team designed the system and managed the installation. A closed loop system was specified to avoid requiring permits from SEPA, and due to water quality concerns. A Kensa heat pump with twin-compressors was selected due to their reputation and to provide inbuilt redundancy. A 12kW electric boiler was specified for back-up and to periodically boost hot water to avoid legionella risks.

Internally, wet distribution pipe sizes were increased to allow the radiators to run at the same flow/return temperatures as the heat pump. This increased the system efficiency and reduced the required buffer vessel capacity – a benefit given the small size of the plant room. Externally, the system was designed to have a single manifold in an accessible location, to minimise the number of underground pipework joins, to reduce and simplify maintenance requirements.

The key, unexpected challenge during the installation of the WSHP was sinking the heat collectors into the loch – this required multiple ballasting attempts.

Assembly and Leisure
Newbuild zero direct emissions heat

The BMS installer went bust during the project, so another company was required to finish installing and commissioning the controls.

Implementation process:

- Designed and managed internally
- WSHP install subcontracted to local MCS installer

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

As a snagging issue, the extractor fans in the kitchen had to be programmed to switch off at night to stop heat escaping from the building. The collector array depressurised after 6 months, due to a leak in the plantroom that was quickly resolved. Apart from this, the system has required very little maintenance, which is in line with the expectations of the council.

The system's performance is monitored continually, and quarterly meter readings are taken for Renewable Heat Incentive payments.

Performance measures for 2021:

Anticipated demand	70,046 kWh /yr 195.1 kWh / m^2 /yr
Actual demand	72,807 kWh /yr, 202.8 kWh / m^2 /yr
System running cost	14,900 £/yr
Maintenance costs	600 £/yr

> *"I was expecting there to be no heat when the loch froze over, but the visitor centre remained warm."* **– Mechanical Engineer, Fife Council**

User experience

The installation has proved successful and popular, and the heat pump can provide ample warmth even when the loch is frozen over. The visitor centre remains a comfortable temperature throughout the year.

The loch is used for watersports, and a small area above the collector array has been buoyed off. The impact on the amenity of the loch is negligible.

Lessons Learnt

1. **WSHPs can be a cost-effective and low-maintenance heat source when designed well.** This system benefited from careful design of internal and external circulation systems which maximised efficiency and reduced needs for parts and maintenance.

2. **Submerging plastic pipework for WSHP collector systems can be difficult** – ballasting requirements should be included in WSHP system specifications.

3. **The impact of ventilation systems on space heating should be included at design stage.** Overlooking ventilation leads to significant energy losses. This can be mitigated through controls or adapting working practices.

Assembly and Leisure
Newbuild zero direct emissions heat

Building: **Pickaquoy Leisure Centre**
Location: **Orkney**
Heating system: **Ground Source Heat Pump**

Building overview

Building use: Sports and Leisure Centre, Swimming Pool
Year built: 2014
Floor area: 5,043 m^2
Scottish EPC rating: C

Heating system: GSHP
Heating system cost: Not provided
Heat delivery method: Underfloor heating, air handling unit.

Choice of heat system

As part of a 'schools investment project', Orkney Council rebuilt two schools, one of which originally had a swimming pool. In order to replace the lost pool, a major extension was added to the Pickaquoy Leisure Centre.

Under the council's carbon management plan, all of the newbuilds in this project were targeting BREEAM 'Excellent' and EPC 'A' ratings. Oil boilers were quickly discounted on this basis, and biomass was briefly considered but consistency of fuel supply to the island was deemed too big a risk. As the council felt that ASHPs were unsuitable for the local climate, a Ground Source Heat Pump (GSHP) system became the clear choice for the pool and the other new buildings in the investment project.

Main drivers for selection:

1. Carbon management plan
2. Other technologies unsuitable

Route to implementation

The same engineers and contractors were used to design and build the GSHP systems for all buildings in the investment project, which provided some economies of scale.

The boreholes for the pool's GSHP are positioned under the carpark, and were tested prior to surfacing the carpark.

An LPG back-up system was originally specified, but as the existing Leisure Centre building had an oil boiler, this was used instead. Similarly, a new grid connection was not required as the existing building's supply had been oversized to allow for future expansion.

Implementation process:

- Project requirements defined by Council
- Contractors hired to design and build GSHP system

"The ground source heat pumps work well and we plan to use them again for future newbuilds." – ***Energy Manager, Orkney Council***

Key Barriers Faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

Minor snagging issues were handled by an engineer who the council employed specifically for commissioning. The heating system is serviced every six months as part of the buildings' maintenance contract, which also includes on-call support as needed.
The GSHP system is a cascade of four heat pumps, so when individual compressors have failed, the system has still been operational. The system's heat output is monitored by the supplier.
As the heat pumps and pool treatment system are located in the same plant room, the heat pump casing and ancillary pipework have rusted and require regular maintenance.
The hot water loads for the pool did not allow the building to reach targeted EPC A rating, but the pool's heat pumps are metered for RHI purposed and the council have noted good performance compared to other swimming pools.

User experience

The heating system works reliably all year round, and the Trust who operate the pool are also incentivised to minimise use of the back-up oil boiler via RHI payments.
The pool is usually kept at 28°C, although its temperature can be adjusted for certain activities, such as competitions or lessons for disabled swimmers, which takes several days.
The viewing platform has an ongoing issue with overheating, but this is related to the air handling system rather than the GSHP system itself.

Lessons Learnt

1. **Having a swimming pool can penalise the EPC rating for a leisure centre,** due to additional water heating loads for pool heating.

2. **The environment that GSHP equipment is installed in should be considered, in order to maximise system life and avoid unnecessary maintenance.** In swimming pools, heat pumps and ancillaries should not be co-located with water treatments plant.

Shops
Zero direct emissions heat retrofit

Building: **Waitrose Comely Bank**
Location: **Edinburgh**
Heating system: **Air Source & Water Source Heat Pumps**

Building overview

Building use: Supermarket
Year built, retrofitted: built pre-2000, retrofit due in Q3 2022.
Floor area: 40,989 m^2

Heating system: 400kW water source and air source heat pump cascade.
Heating system cost: ~£250,000
Heat delivery method: Air handling and destratification system.

Choice of heat system

In order to meet their Net Zero target by 2035, the John Lewis Partnership plan to replace gas heating across their entire estate (which constitutes John Lewis and Waitrose stores) with zero emissions alternatives. Waitrose Comely Bank will be retrofitted later in 2022 with a cascade Water Source-, Air source Heat Pump (ASHP,WSHP) system, given that its existing heating and cooling system was due to be replaced. It will be their first Scottish location to meet this target.
The supermarket has a high cooling demand due to the requirement to refrigerate goods, and this produces a significant amount of waste heat. As such, the goal for the new system was to use as much of this waste heat as possible to heat the store efficiently. This led to the specification of a cascade WSHP-ASHP system, which extracts waste heat from the refrigeration systems via a closed water loop, to drive a water-to-water heat pump. The heat supply can be boosted by an external ASHP, to provide sufficient energy to heat the supermarket's internal environment.
This solution, which has been funded internally, is highly innovative, with none installed to date, but plans for 30 to be installed in 2022.

Main drivers for selection:
1. Internal goal for Net Zero by 2035
2. System replacement due existing assets end of life
3. Minimising energy usage and costs

Route to implementation

The cascade WSHP-ASHP has required a complex, collaborative design process as it requires a custom specification to meet the building's heat demands whilst integrating with the existing refrigeration system.

Shops
Zero direct emissions heat retrofit

External building services engineers were engaged to design the new heating system and its interface with the existing refrigerating system. The WSHP is custom made in the UK, as it is tailored to the refrigeration load and temperatures and the required heat output.
Obtaining the WSHP's electrical components, particularly fans and compressors, has been the main challenge experienced through the implementation process. Additionally, structural works on the building's roof have been required in order to accommodate the new system.

Implementation process:

- Identify the building's heating and cooling demands
- Engage externally to design and deliver the system
- Installation
- Phased commissioning process

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

"The new system will be so efficient that we don't expect heat bills to increase." – ***Senior Manager of Technical Services, John Lewis Partnership***

Technical performance

The system is expected to be highly efficient, with a coefficient of performance of 6-8. It has been designed to deliver the full heat demand for the building, although the gas boilers will be kept for back-up.
A Building Management System will allow full control and monitoring of the energy system remotely. Heat and cooling loads will be sub-metered.

User experience

When the system is installed later in 2022, the goal will be to minimise disruption to the supermarket's users and products. This will require a phased commissioning process which will include a shutdown of the refrigeration system, which would be undertaken outside of trading hours to minimise disruption to the customer and avoid food waste.

Lessons Learnt

1. **Corporate Net Zero targets and a focus on energy- and cost-efficiency are driving complex, innovative heating solutions.** This system is anticipated to have similar heating costs to current gas bills.

2. **Waste heat from supermarket refrigeration systems provides an opportunity for highly efficient heating.** This requires design of bespoke, integrated systems, which take longer to design and can be more costly and prone to supply chain issues.

Services
Zero direct emissions heat retrofit

Building: **West Lothian Civic Centre**
Location: **West Lothian**
Heating system: **Biomass Boiler**

Building overview

Building use: Police Scotland, Scottish Fire and Rescue, NHS, social care services, Crown Office and the Scottish Courts Service. Operated by West Lothian Council.
Year built, retrofitted: 2009, 2016
Floor area: 19,019 m^2
Scottish EPC rating: C

Heating system: Biomass boiler
Heating system cost: Not provided
Heat delivery method: Air handling units and trench heating

Choice of heat system

The decision to retrofit biomass was driven by the Council's desire to reduce emissions. Biomass boilers were selected for this and 5 other public buildings through a joint-procurement exercise. Biomass was deemed to be the easiest replacement option for a constrained site, and the most cost effective, partly due to Renewable Heat Incentive payments. Air Source Heat Pumps were considered but deemed unsuitable due to the large scale of the building.

Main drivers for selection:

1. Costs
2. Ease of retrofit
3. Emissions reduction

Route to implementation

The system was funded by the council on a 'spend to save' basis and procured under a Scottish Government framework. The works took around eight weeks to complete, but installation of the biomass plant room and fuel store was executed in one day, in order to minimise disruption to the activities of Police Scotland and the Scottish Courts Service, who utilise the secure compound where the plant was to be located. The requirement for a prefabricated plant room limited the number of viable bids from contractors. In order to obtain planning permission, emissions modelling was required to demonstrate agreeable levels.

Implementation process:

- Contractor selected from design, build, operate bids
- Continuous stakeholder updates
- Simple integration with gas system

Key barriers faced:

Costs	
End user concerns	
Complexity	
Supply chain	
Site constraints	
Grid constraints	
Policy & regulation	

Technical performance

Minor snagging was experienced and controls took time to get right. Maintenance is now required more regularly than previously. Key faults have been in relation to fuel loading, but these have always been quickly addressed by the contractor. The system has generally performed as expected, and would be chosen again on a technical basis.

Unexpectedly, interference from birds necessitated armoured insulation on external pipes, as seagulls had made holes in the original insulation which lead to water within the pipes freezing.

> *"The buildings' 600 occupants couldn't tell the heating system had changed at all."* **– Energy and Climate Change Manager, West Lothian Council**

User experience

Construction time on-site was limited in order to minimise disruption to activities within the secure compound. The main impact of the system is the resulting loss of two parking spaces, which had to be regained from landscaped areas, in order to ensure that building users were not affected.

As the original gas boiler was retained for peak loads, a back-up system is available for biomass down-time. Therefore, any issues with the system have not generally been noticed by users. In five years, there has only been one occasion where the heat supply has failed completely, but this was resolved within three hours.

Lessons Learnt

1. **It is possible to retrofit heating systems with negligible impacts to the comfort of the occupants in large buildings.**
2. **Legal advice on the fuel supply and maintenance contract** assured that the customer was financially protected over the long term.
3. **Checking ground conditions is important even for existing sites.** More pre-tender surveys would have benefitted this project.

Building: **The Loch Ness Hub**
Location: **Highland**
Heating system: **Air Source Heat Pump**

Building overview

Building use: Tourism and transport hub for the Great Glen Way, with public toilets.
Year built, retrofitted: 2000, 2020
Floor area: 50m^2
Scottish EPC rating: Unknown

Heating system: 1x 7kW Valiant Arotherm ASHP
Heating system cost: £14,780
Heat delivery method: Radiators

Choice of heat system

The Glenurquhart Rural Community Association (GURCA), took over the building after it had been unoccupied for two years. The original heating system was storage panel heaters, which were about 20 years old and not functioning well. A report from Resource Efficient Scotland determined that an Air Source Heat Pump (ASHP) would be a cost-effective replacement. The project was funded by CARES and the SSE Highland Sustainability Fund.

Main drivers for selection:

1. Existing system operating poorly
2. Reduced operational costs

Route to implementation

A competitive bid process was used to select the heat contractor, and very few bids were returned. The project manger noted that this is a common issue in the Highlands. The winning contractor was chosen as GURCA had worked with them successfully before.
The heating system installation took place at the same time as the refurb of the public toilets, so two contractors had to work around each other. The project budget had to be spent by the end of the financial year, which meant the project timeline was tight.

Implementation process:

- Installation grant funded
- Competitive bid process
- Familiar contractor selected

Key barriers faced:

Costs	
End user concerns	
Complexity	
Supply chain	
Site constraints	
Grid constraints	
Policy & regulation	

> *"We chose a heating contractor who we'd worked with before as we knew that they were reliable."* **– Project Manager, Loch Ness Hub retrofit**

Technical performance

The system was handed over from the contractor to the building manager in March 2021 and has operated without fault since.

The building does not meter heat as it doesn't receive Renewable Heat Incentive payments or have a Building Management System. This means that there is no way to determine if the heat demand is as expected, and what it costs to heat the building. Therefore, most performance measures are unknown for the building.

User experience

The building manager is technically minded and got to grips well with the system. The building is closed to the public in the winter, but the manager is still present over this period and has noted that the building is comfortable.

There is a feeling among GURCA that the building, which has solar PV, could be operating at lower costs if a battery had been installed to store PV energy. They may seek funding for this in the future.

Lessons Learnt

1. **Needing to spend grant funding by a deadline created pressure** to meet tight timeframes for the refurb, and created risk by necessitating a retrospective planning application for the ASHP.

2. **Even for small sites, good project management and coordination is important.** In this case, it allowed two contractors to work closely on site with no issues.

3. **This project was only possible due to the will of volunteers** within a very strongly linked community. This includes the initial community buyout of the building. It has since proven community assets can be bought and operated for strategic local development.

Building: **University Hospital Ayr**
Location: **East Ayrshire**
Heating system: **Biomass boiler**

Building overview

Building use: District general hospital providing inpatient, day and outpatient care.
Year built, retrofitted: 1981, 2018
Floor area: 38,362 m^2
Scottish EPC rating: E → unknown

Heating system: 1x 1.5MW Hertz Biofire biomass boiler
Heating system cost: £1.4M
Heat delivery method: Radiators

Choice of heat system

NHS Ayrshire & Arran decided to install a biomass boiler to significantly reduce the carbon emissions associated with running the hospital. They were aware of local biomass fuel supply options and did not feel that there was an alternative low carbon technology that could meet the required flow temperatures of the existing heating system.

Main drivers for selection:

1. Carbon savings
2. Provides required temperatures
3. Local fuel supply

Route to implementation

A consultant was appointed to design the boiler, and a containerised system was specified due to site constraints. Onsite construction time had to be minimised and the project funding (from the Scottish Government Carbon and Energy Fund) also had to be spent within a year, so planning permission was sought after construction started. Due to these impacts, only one contractor returned a tender. The design and installation process was overseen by an NHS consultant. There were no issues and the project adhered to its timeline.

Implementation process:

- System designed by consultant
- Installed by contractor
- Live tie-in to existing system

Key barriers faced:

Costs	
End user concerns	
Complexity	
Supply chain	
Site constraints	
Grid constraints	
Policy & regulation	

Residential institutions
Zero direct emissions heat retrofit

> *"The system has been fantastic but we would not install biomass again on an environmental basis."* – **Energy Manager, Ayr Hospital**

Technical performance

There was one snagging issue with the system, as the Building Management System (BMS) had issues connecting with the new external plant. This took a year to resolve. During this time, there was reduced oversight and control of the biomass plant and its performance, but the system ran well under its automated programme.

The gas system has been retained to provide ~15% of heat annually, but the biomass has exceeded expectations and has had a very high runtime. Apart from quarterly services, the grate in the boiler required replacement three times, but this was done under the maintenance contract at no cost.

Performance measures:

Measure	2017	2019
Actual demand	Unknown	5.9 GWh /yr, 153.8 kWh/ m^2 /yr
Running cost	£235k/yr	£264k/yr
Maintenance cost	Unknown	£14k/yr
Direct emissions	1941 T/yr	98 T/yr

User experience

The hospital's energy team are very pleased with the biomass system. It is noted to have provided comfortable temperatures and 'performed really well' over the past winter. The installation receives Renewable Heat Incentive payments, which have been greater than expected, so the financial payback from the system is positive too.

As it was crucial that the installation of the biomass system had no impact on the operation of the hospital, a live tie in to the existing heat distribution system was required. Because of this (and the back-up gas system), building users have not been impacted by the new biomass system at all.

Lessons Learnt

1. **Constrained timescales can have wider effects**. In this case funding constraints meant the choice of contractors was limited by the short project timeline.

2. **Accepted impacts to building interruptions can impact the choice of heating system.** A live-tie in was required for this site, and the gas system has been retained at full capacity.

3. **In larger buildings, good communication between internal teams is key**, and could have mitigated the issue with the BMS system in this case.

Non-residential Institutions
Zero direct emissions heat retrofit

Building: **Glenurquhart Care Centre**
Location: **Highland**
Heating system: **Air Source Heat Pump**

Building overview

Building use: Non-residential care centre for Drumnadrochit's elderly residents.
Year built, retrofitted: 2000, 2020
Floor area: c. 900m^2
Scottish EPC rating: Unknown
Heating system: 2x 12kW Valiant Arotherm ASHP
Heating system cost: £40,000
Heat delivery method: Radiators

Choice of heat system

The Drumnadrochit community was one of four communities supported by Local Energy Scotland (LES) to produce a Local Energy Plan. Replacing the Care Centre's storage heaters was one of the actions arising from the plan. Electric heating was proposed to avoid the disruption of installation a wet-heating system, but LES advised the community to consider an Air Source Heat Pump (ASHP) due to its superior operating costs and emissions.

Main drivers for selection:

1. Benefit to the local community
2. Lower running costs
3. Existing system operating poorly

Route to implementation

The bid for the heating system retrofit required that contractors work over evenings and weekends, to minimise disruption to the Centre's users. As a result, only a few contractors returned tenders.

The system was funded by LES and two other grants, as well as internal funds. Grant funding from LES had to be spent within a year, so due to limited resources, there was not time to acquire planning permission before installing the system.

Implementation process:

- ASHP funded through several means
- Contractor worked evenings and weekends
- Planning granted retrospectively

Key barriers faced:

Costs	■ ■ ■
End user concerns	■ ■ ■
Complexity	■ ■ □
Supply chain	■ ■ ■
Site constraints	■ ■ □
Grid constraints	■ □ □
Policy & regulation	■ □ □

"It was very difficult to find a contractor who could meet the constraints of the project and we ended up with only two or three bids. However, the contactor we chose was very sympathetic to the building's use, and this smoothed the handover process as they engaged with the elderly users and provided a lot of short term support to staff after the installation."
– Project Manager, Glenurquhart Care Centre Retrofit

Technical performance

The ASHP and wet distribution system had no commissioning issues, and has not experienced any faults since they were installed, so only annual servicing has been required.
Initially, the owners did not think the ASHP was delivering the cost savings that were anticipated, as electricity bills were higher than expected. However, when this was investigated, it was found that kitchen appliances (and not the ASHP) had higher electrical loads than was previously realised, and that these were likely responsible for the higher than anticipated running costs.

User experience

The elderly users of the building and the heating contractors enjoyed interacting with each other, and this led to a smooth handover and good aftersales support.
As the centre remained open during the installation, the users were engaged in what was happening, so this became a positive educational experience.
Staff and users have noted that the ASHP operates more consistently than the old storage heaters and makes the Centre a lot warmer.

Lessons Learnt

1. **Having a Local Energy Plan was pivotal in securing grant funding for the ASHP from multiple sources.** The Plan also generated 'oven ready' projects, which are necessary when grant funded projects (and applications for this funding) have very tight timescales. Community groups rarely have this option as they often work with limited resources and without specialist knowledge.
2. **Grant funding deadlines created a large risk to the project,** as planning permission was sought, and granted, retrospectively.
3. **Finding a contractor who was willing to work evenings and weekends, enabled the care centre to install wet heating without closing the building to its vulnerable users**. This made an ASHP a viable option, against initial expectations.

Assembly and leisure
Zero direct emissions heat retrofit

Building: **Barracks Conference Centre**
Location: **Stirling**
Heating system: D**istrict Heat Network**

Building overview

Building use: Complex of three buildings with events and office space, operated by the Robertson Trust.
Year built, retrofitted: ~1840, 2019
Floor area: 1028m^2; 858m^2; 1,288m^2
Scottish EPC rating: C; D, F
Heating system: 75kW; 65kW and 95kW connections to wastewater district heating network (DHN)
Heating system cost: Unknown
Heat delivery method: Radiators

Choice of heat system

The Barracks Centre is one of 8 buildings in Stirling connected into a DHN served by a local Scottish Water Treatment Works. The Robertson Trust did not elect to join the heat network, it was a decision made by the Council, who they lease the building from. The system is a collaboration between Stirling Council and Scottish Water Horizons, and received match funding from the Low Carbon Infrastructure Transition Programme.

Main drivers for selection:

1. External decision from Council

Route to implementation

The building was derelict prior to occupation, so the Council agreed to a refurbishment before leasing to the Robertson Trust. Part of this deal was that the building would be connected to the new heat network.

The project was managed by the council, and contractors were appointed to design, install and maintain the DHN, including the point of connection to the Barracks Centre, which is a plate heat exchanger.

Internally, the heat distribution system is the responsibility of the Robertsons Trust.

There were several issues which prolonged the construction period, for example, underground data cables were damaged when routing the DHN pipework.

Implementation process:

- Agreement to the conditions of lease, including heat provision
- DHN constructed
- DHN owned and operated by Stirling Council, up to and including point of connection

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

There were snagging issues with the network over its first year, which affected the Barracks Centre as they led to outages. During these periods, heat supply to the building was interrupted, and the Robertson Trust was not initially aware that their heat supply contract entitled them to receive plug-in electric heaters from the network's maintenance contractor.
Since the initial snagging issues, the network has consistently provided an adequate heat supply. Where issues have been experienced, these have tended to be due to human error from the delivery side of the system, for example, due to the wrong button being pressed.
Annual heat demand and costs have not been provided, but the DHN connection was anticipated to lead to a 10% reduction in bills compared to an equivalent gas boiler heat supply. The Robertson Trust pays the council for their heat, and the maintenance contractors visit to take meter readings for this purpose. Approximate monthly heating costs were provided and have been scaled below.

Performance measures for 2021:

Approximate system costs	£28,200 /yr

*"We've been surprised at how well the system has performed, as we wondered if it would be suitable for the size of the building and its high ceilings." – **Venue manager, Barracks Conference Centre***

User experience

Staff felt that a more thorough handover and significantly more post-completion support could have been offered, as they did not feel confident in controlling heat in the buildings when they moved in. However, they have been 'pleasantly surprised' with how well the heat network has performed, and the levels of comfort internally, especially given the listed status of the buildings and their high ceilings.
The staff also feel that the network's maintenance team is responsive, and appreciate that they set up meetings to advise when network maintenance is required.

Lessons Learnt

1. **Good handover and post-completion support are essential** to ensure avoidable issues with heat supply do not arise.

2. **For heat networks, handover should include explanation of the heat supply contract**, so that occupants understand what they are entitled to, particularly during periods of maintenance to the network.

General Industry
Zero direct emissions heat retrofit

Building: **Dunnet Bay Distillery**
Location: **Highland**
Heating system: **Direct Electric**

Building overview

Building use: All electric distillery for premium spirits.
Year built, retrofitted: 2013, 2017
Floor area: 144m^2, 400 m^2
Scottish EPC rating: Unknown
Heating system: Direct electric space and panel heaters, wood burning stove, oil-filled electric heaters, direct electric hot water heater.
Heating system cost: Unknown
Heat delivery method: Individual heaters and underfloor heating

Choice of heat system

The site is multi-use with a distillery, bottling area, offices, and a visitor centre housed in a mix of modern steel framed warehouse and historic stone buildings with new extensions. Heat is required to keep staff and visitors comfortable in the occupied areas. Heat is provided by a mix of distributed and individually controlled heating systems.

Main drivers for selection:

1. Low cost capital, installation and running costs.
2. To improve comfort for visitors and staff.
3. Off-gas site and limited in what they can use in the distillation areas

Route to implementation

As a new business with uncertain growth, the heating system was not planned, instead a reactive approach to heating was taken in line with changing needs. Their growth has included converting one building and adding two extensions. The new parts of the building use underfloor heating (UFH), and electric heaters have been retrofitted in older parts. They are currently investigating diverting onsite solar PV to the UFH and retrofitting a battery to fully utilise the Solar PV. Overall they have faced no major barriers with the implementation of the heating systems.

Implementation process:

- Hot water heater works in combination with the rooftop solar PV.
- UFH designed with electrical engineer and architects to ensure optimum heating and comfort.
- Space heaters had to be interlinked to the distillation process to keep users safe.

General Industry
Zero direct emissions heat retrofit

Key barriers faced:

Cost	
End user	
Complexity	
Product availability	
Supply chain	
Grid constraints	
Policy & regulation	

Technical performance

The hot water system has performed very well overall, providing heating water on-demand in the kitchen and toilets. As such, a like-for-like replacement was made when the old system reached the end of its life.

The UFH exhibits good performance overall, and could only be improved by diverting onsite solar PV to maintain the heat overnight. The system is felt to be more expensive versus on-demand systems, given that it needs to be on all the time to maintain the room temperature.

The oil-filled electric radiators have a lag time with no real control.

The space heaters are noted to be very slow and ineffective at heating large areas and expensive to run.

User experience

The occupied areas can be cold in the winter and require heating to maintain comfort. There are controls on the heating systems but most are basic, not interlinked or not easy to use, which impacts the user experience.

Satisfaction with the on-demand hot water system has been high, except for when the system failed and needed replacing.

The underfloor heating temperature controllers are not easy for users to understand and could be optimised better. The system provides a good level of warmth in the winter, but is slow to react to solar gain and on sunny days overheating occurs.

The oil-filled electric radiators have a lag time between turning on and feeling warm, which can be uncomfortable in the winter. There is no control and air is stagnant in the office.

The space heaters are very slow to heat large areas, but do eventually provide comfort and are easy to use.

Lessons Learnt

1. **Plan the heating system from the start.** In hindsight ASHP would have been a better investment in terms of comfort and running cost. An Energy Strategy would have helped inform the best solution.

2. **Smarter controls could provide better comfort.**

3. **Direct electric heating is becoming expensive with rising electricity costs.** A more efficient system would reduce electricity costs.