climate change
Scotland's centre of expertise connecting climate change research and policy

Zero emissions heating in new buildings across Scottish Islands

Dominika Knox, Alexandra Mostovaya-Urushadze, Jeff Bryan, Delta-EE

Freya Burns, Isabella Impesi, Hannah Dunne, Stephen Strachan, Changeworks

October 2022

DOI: http://dx.doi.org/10.7488/era/2938

1. Executive summary

1.1 Introduction

The Scottish Government requires new buildings to use zero direct emissions heating (ZDEH) systems from 2024, as part of the New Build Heat Standard regulation. This is to help meet its greenhouse gas emissions targets and achieve net zero emissions by 2045.

Through the Islands (Scotland) Act 2018, the Scottish Government is required to assess the impacts of any new policy on island communities to understand the challenges of implementation.

ClimateXChange commissioned Delta-EE and Changeworks, on behalf of the Scottish Government, to undertake research to understand which zero direct emissions technologies are best suited to the unique consumer and geographical characteristics of Scottish islands and remote communities. Impacts on local infrastructure and supply chains are also considered as well as factors that may constrain the uptake of these technologies.

The outputs of this work are derived from a combination of a literature review and interviews with local authorities, housing associations, builders and heating installation and maintenance companies who operate in these areas.

1.2 Key findings

For island and remote communities, this research found:

- Island regions are ahead of the legislation in terms of installing ZDEH technologies in new build properties. These technologies include electric storage heaters, direct electric heaters, electric boiler, air and ground source heat pumps. Many communities began installing ZDEH systems a decade ago because there is no connection to the mains gas network.

- Local authorities and housing associations use measures such as insulation, air tightness and natural ventilation and light in buildings, to reduce energy consumption. Furthermore, they are already installing electric heating technologies over fossil fuels alternatives.

- The introduction of the New Build Heat Standard in 2024 will not have a significant impact on the heating technologies that are being installed in new build properties, because these are already suitable.

- Electric storage heating and heat pumps are the most common ZDEH technologies across these regions. The suitability of different technologies varies with location, type of housing and the availability of specialists to install and maintain the system.

- Island communities are already implementing lessons learned from the use of ZDEH technologies. As standard, heat pumps installed in coastal and island locations are coated with enhanced corrosion protection to shield against coastal weather.

- There are no consumer behaviours specific to island and remote communities that would prevent the adoption of ZDEH technologies in new buildings.

- There are no significant cost barriers to the adoption of ZDEH technologies in private new buildings. While the more expensive ZDEH technologies have a higher capital cost than fossil fuel-based systems, the difference in total lifecycle is marginal. No circumstances where bioenergy would be more appropriate over ZDEH systems for new buildings covered by the regulation were identified in this work.

- Costs are a significant factor when selecting a ZDEH technology for social housing due to pressured budgets. The main cost pressures come from higher maintenance costs and additional travel requirements to island and remote locations for specialist contractors.

- A lack of sufficient specialists across these regions could be a constraining factor in both newbuild and retrofit situations. While there are specialists across Scotland, including on islands and in remote locations, many are reluctant to travel from the mainland to island regions due to the additional cost of travel and accommodation.

- The main vulnerability of the electricity network infrastructure in these communities is the limited interconnectivity with the mainland. Most have a single point of connection.

- The electricity network across the whole of Scotland would need to be reinforced in many areas to accommodate a significant increase in the uptake of ZDEH technologies, but this is also the case across most of mainland Scotland and not a barrier to ZDEH on the Scottish Islands.

Overall, the research has demonstrated that the uptake of ZDEH technologies in new buildings in island and remote areas of Scotland do not face more significant barriers than in other parts of Scotland.

2. Glossary

Term	Definition
A/A HP	Air-to-air heat pump
ASHP	Air source heat pump
BESS	Battery energy storage system
Direct electric heating	Direct electric heating refers to devices where one unit of electrical input results in a single unit of heat output. There are largely two forms of direct electric heating: storage heaters and direct acting electric heaters.
DH	District Heating
DNO	Distribution Network Operator
EV	Electric vehicle
GSHP	Ground source heat pump
HP	Heat pump
HVDC	High-voltage direct current
iDSO	Independent distribution system operator
ICP	Independent connection provider
kV	Kilovolt
LCT	Low-carbon technology
LPG	Liquified petroleum gas
LV	Low voltage
MW	Megawatts
MVHR	Mechanical Ventilation with Heat Recovery
NBHS	New Build Heat Standard
OEM	Original equipment manufacturer
TES	Thermal energy storage
ZDEH	Zero direct emissions heating

Contents

3. Introduction

3.1 Introduction

This report presents research carried out by Delta-EE and Changeworks to understand the impacts the proposed New Build Heat Standard (NBHS) will have on island regions/remote communities and to ensure that the proposed regulations can meet the needs and unique challenges of decarbonising heat in island/remote communities. The research was commissioned by ClimateXChange on behalf of the Scottish Government and carried out June – October 2022.

3.2 Policy Context

The Scottish Government has a legally binding target to reduce greenhouse gas emissions by 75% by 2030 and achieve net-zero emissions by 2045. To help reach these targets, the Scottish Government have outlined regulations, New Build Heat Standard (NBHS), which will require building warrant applications for new buildings from 2024 to use zero direct emissions heating (ZDEH). Through the Islands (Scotland) Act 2018, the Scottish Government is required to assess the impacts of any new policy on island communities to understand the challenges to implementation.

To assess the impacts, the Government needs to understand the characteristics of new build developments in island communities and which ZDEH technologies will meet their requirements in the most cost-effective manner. The supply chain will need to be ready and fit for purpose to deliver to island regions, from the supply of the physical technology, to transport and logistics of equipment and labour, to installing and maintaining the equipment. The infrastructure of electricity networks in the island regions will need to be able to support the delivery of ZDEH technologies. Understanding what other challenges NBHS might mean for island regions is critical for the Scottish Government, as well as understanding which areas may already have high levels of ZDEH technologies.

3.3 Project aims

This research presents a more detailed picture of the current characteristics of new build domestic and non-domestic properties across the Scottish islands and how their heating systems may differ from housing developments on the mainland. It provides the Scottish Government with an understanding of which heating technologies are currently best suited to the unique characteristics of island housing and how network infrastructure and supply chains may need to adapt to in line with the regulations.

The outputs of this work are derived from a combination of a literature review and interviews with local authorities, housing associations, builders and heating installation and maintenance companies.

The full methodology for the research in this project is outlined in section 11.

4. Technical characteristics

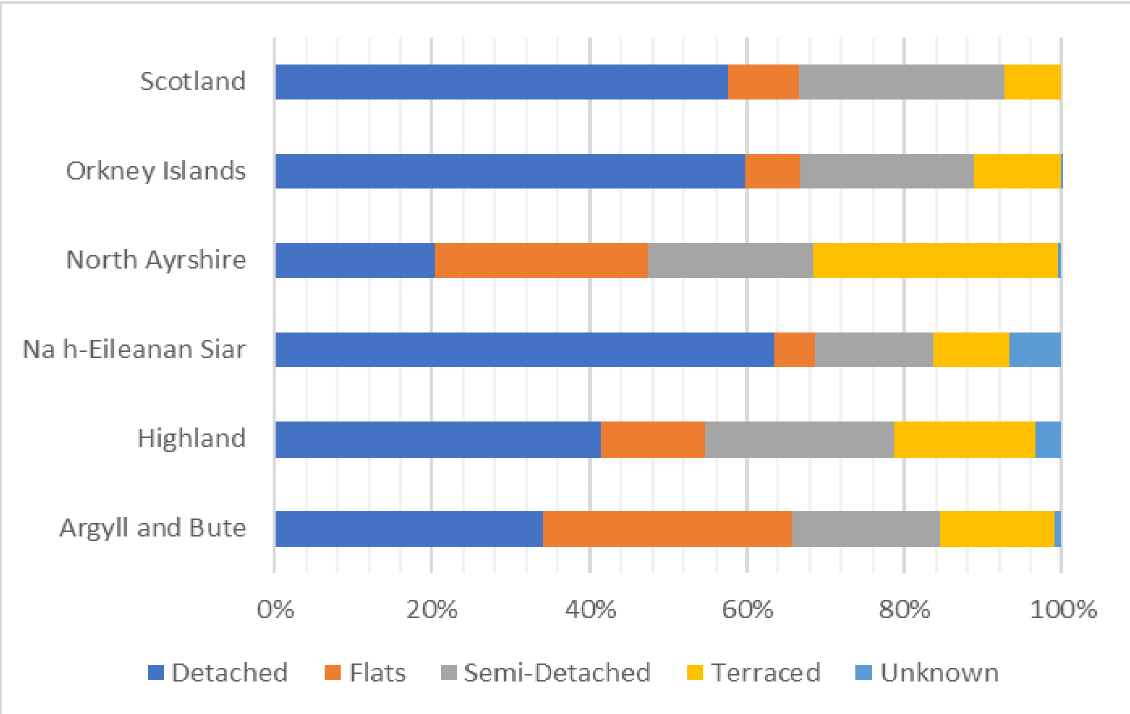
This section provides key findings from the research to explain the characteristics of new domestic and non-domestic building types that are specific to island and remote communities, and how suited the available ZDEH technologies are to meet these demands.

4.1 Building and heating types now and in the future

4.1.1 Building typologies and growth

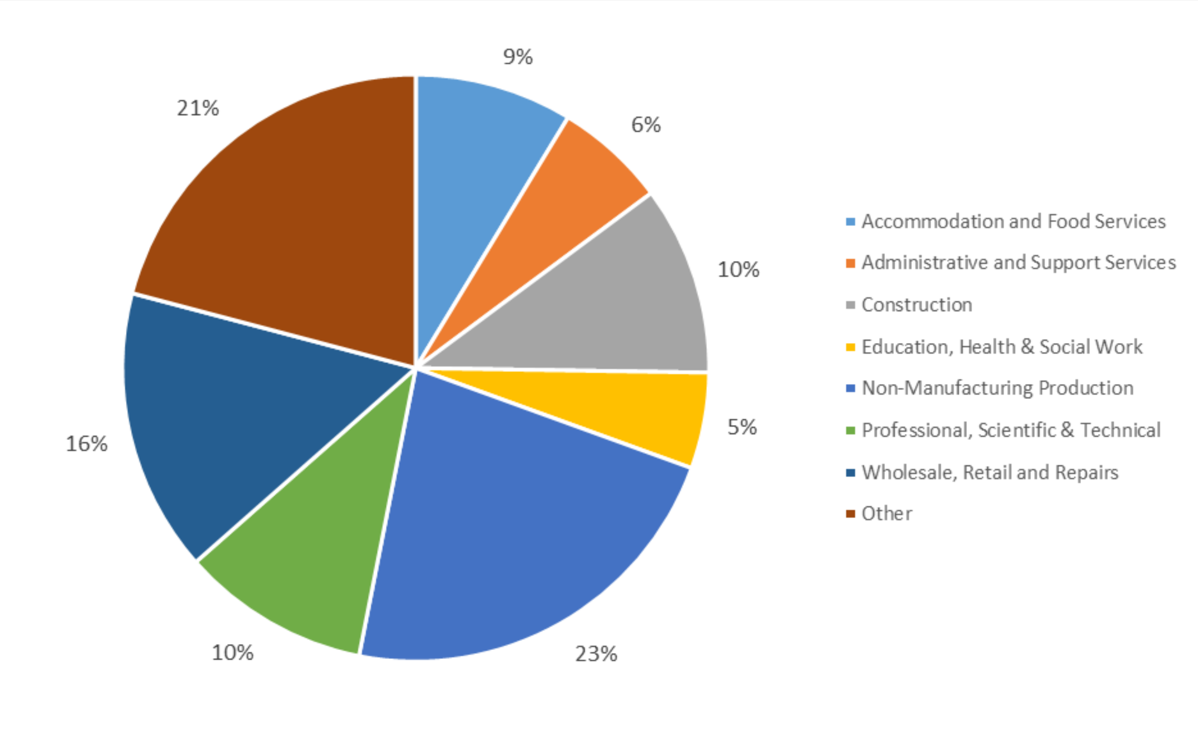
According to a 2022 dataset from the Scottish Government, detached homes are the most common domestic property type in the Western Isles (64%) and Orkney (60%), as well as in the Highlands (41%) and Argyll and Bute (34%). Terraced homes are most common in North Ayrshire (31%) with flats in second place (27%). Semi-detached homes make up about 20% in all council areas. Flats are rare in the Western Isles (5%) and Orkney (7%) [1]. A full breakdown of domestic dwellings, by type, across Island and remote regions is provided in Figure 1 below

Figure 1: Breakdown of domestic dwellings by type. Source: Scottish Government



There are approximately 220,000 non-domestic buildings in Scotland, and the building types vary widely depending on their usage [2]. There are more than 38,000 local business sites in island/ remote regions across Scotland [3]; a breakdown of the non-domestic sites by UK Standard Industrial Classification (SIC) category is presented in Figure 2.

Figure 2: Business sites by SIC category across the Island & remote communities. Source: Statistics Scotland



The Highlands have the largest number of non-domestic properties, 49% of which are in remote rural areas (23% in 'other urban' areas). In Argyll and Bute, 56% are in remote rural areas, and 27% in remote small towns. In Shetland, Orkney, and the Western Isles, all are in remote rural (66-79%) or remote small towns (21-34%). North Ayrshire is the only outlier, where 58% are in 'other urban areas' and only 9% in remote areas [3].

The Highland council area will see the main growth in number of households (projected at 40%). Shetland and Orkney are expected to grow modestly (2%). Household numbers in other council areas are expected to reduce (by around 3%) [4].

Looking at the types of households, the biggest growth is expected in households of 1 or 2 adults, with 2% growth of these types of households expected in Ayrshire and Arran (in addition to the Highlands (45%), Orkney (5%) and Shetland (4%)). Household numbers of multi-adult and families with children are expected to reduce in all council areas except Highland (26% increase) [4].

4.1.2 Current new builds

Two island-based housing associations interviewed as part of this research focus on building detached, semi-detached, or four-in-a-block houses rather than flats, while another housing association builds either semi-detached houses or flats – no single buildings. According to an installer, there are two typical buildings in Shetland: a 2/3-bedroom bungalow usually occupied by an elderly couple, or a 4-bed, 2-floor family home.

A housing trust that covers Northern Scotland, including the Highlands, builds a range of housing types - detached, semi-detached, cottage flats, and blocks of 10, though they find that there is little demand for flats in remote areas. Typical new-build properties built by a community trust in a remote, rural location are well-insulated bungalows, with an open-plan layout so that heat can easily circulate through the building.

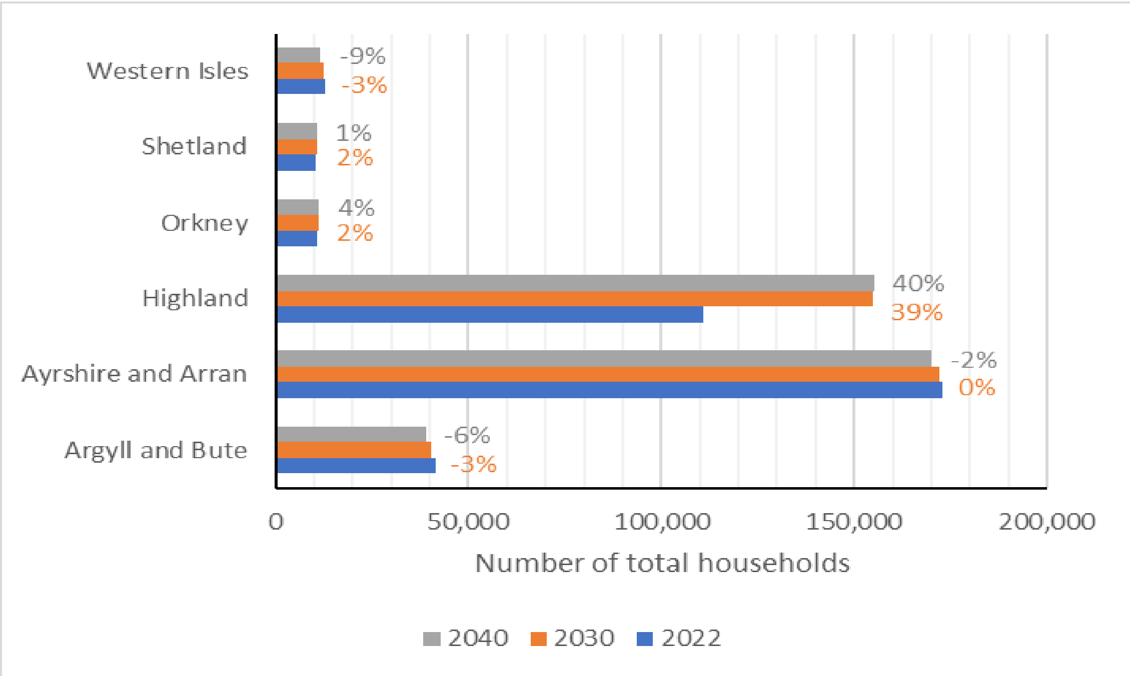
The stakeholders interviewed in Orkney believe that domestic buildings on Orkney are a few years ahead of government standards, using a fabric-first approach and increasing airtightness to almost Passivhaus[1] standards. They use wooden cladding rather than a lime render due to how exposed the houses are. One local school reduced its energy consumption by 40% using this method. An island council now has a new scheme for installing air-source heat pumps (ASHPs) in larger units (2/4 bedroom homes) rather than electric storage heating, which was the most common technology before.

Most new builds in Scotland are built using timber frame kits and concrete blocks. While the blocks can be made locally, the timber kits need to be transported to the islands or rural locations, which is an added cost. However, the weather in remote Scotland makes building difficult outside of the summer months, so timber kits remain a good choice due to how quickly they can be built.

4.1.3 Post-2024 new builds

Significant growth of domestic households is only forecasted in the Highlands region, where an additional 44,000 households are expected by 2040 [4]. The NBHS is not likely to have a significant impact on other island regions as the scale of growth forecasted across these local authorities is minimal. Figure 3 shows the breakdown of expected growth in domestic households by local authority.

Figure 3: Change in total number of households projected in 2030 and 2040. Source: Scottish Government



According to the perspective of two housing associations based on large islands, and a contractor in the Hebrides, post-2024 new builds are likely to be two-storey 3/4-bedroom family homes. There is potential for modular build in the future over timber frame kits although there are issues nationally with staff and labour shortages post-Brexit.

The community trust based on the west coast of the Highlands expect that new community buildings will have ASHPs, a wet system and solar panels, as well as battery storage. The adoption of ZDEH by this community trust is not in response to the NBHS. They see potential for small hydro generation feeding into a local district heating (DH) system. They also suggest there's a good argument for micro-heat networks in areas

[1] Passivhaus buildings use energy efficient design standards to reduce heat loss and need minimal additional heating or cooling. Any additional heating demands are met with ZDEH technologies.

such as the Western Isles where there is high generation and no substations for distribution to individual properties.

Builders in Orkney echoed this, stating that many private new builds are looking for solar thermal systems due to the cost saving in the summer. They also believe that micro-renewables are becoming more viable due to the current high energy costs of the energy crisis. Orkney has had the greatest uptake of micro-renewables per head in the entire country. Since 2008, 21% of homes in Orkney have installed micro-renewables, followed by 15% in the Western Isles [5].

One island council have noted reductions in energy consumption through the fabric first approach. They are endeavouring to get down to a U-value (the rate of transfer of heat through a structure) of 0.11 for roofs and walls, and 1 for windows – 50% more efficient than the maximum U-vales under current building regulations for non-domestic new buildings [6].

A development trust based in Orkney expects post-2024 new builds to be similar to what they're currently building: timber-framed and extremely airtight, with ASHPs. They see Orcadians as very "green-minded," so there is no appetite for fossil-based heating systems. Additionally, oil needs to be shipped to Orkney for boilers, so it can be difficult to ensure people have enough to last them through the winter or cold spells.

4.2 Heating Systems

4.2.1 Island and rural characteristics that impact heating systems

An article in the CIBSE Journal [7] speaks of the high level of salt water in the Orkney air, and the problems with strong winds that can impact the heating of building:

"There's a lot of salty water in the wind, so we have to be very careful with the spec for air source heat pumps […] The wind strips the heat out of the buildings, so we have to design them with minimal envelope penetrations […] Extract fans can really cause problems, so, in new builds, we put in centralised Mechanical Ventilation with Heat Recovery (MVHR) units with one intake and exhaust."

Multiple stakeholders across different islands found that, historically, salt air could rust outdoor units, leading to them being replaced earlier than otherwise. It is now standard to install ASHP units coated with enhanced corrosion protection in coastal locations, making them the preferred solutions for rural dwellings that had plenty of outdoor space. The enhanced corrosion protection is provided by the ASHP manufacturer, for example Mitsubishi Electric provide coastal protection models for buildings near the sea. In February 2022 the cost of an 11.2kW ASHP unit with coastal protection was £4,423, an additional £163 (3.8%) more than the cost of unit that has not been coated [8].

Some stakeholders found that connecting the HPs to the electricity grid presented problems. Although Scottish and Southern Electricity Networks (SSEN) are updating parts of the network, it's only the transmission network, not the distribution network, so the issue remains in areas where there is insufficient capacity to accommodate new connections. A contractor in Lewis echoed this, pointing out that no more turbines can be built there until there is a new interconnector. A stakeholder in Shetland found that district heating was better in that respect, though the requirement for pipework installation did raise the price. They found that, based on a 30-year life cycle, the total cost of servicing/ maintenance for district heating was £7,630 compared to £5,000 for electric storage heaters, and £15,500 for heat pumps.

The average household on Orkney pays more for energy bills compared to the mainland; this is due to an increase in consumption because of the extreme weather conditions and higher distribution use of system (DUoS) charges in island and remote locations. Airtightness is important, as well as keeping control on heat loss. Orkney, much like most islands and remote areas, does not have a gas grid, and LPG is only available from Shetland, though its delivery is weather-dependent. For these reasons, heat pumps are more common as gas isn't readily available.

Orkney also has an aging population, many of whom use gas bottle heaters for backup during power cuts, which still occur every winter. If restrictions were to be placed on the sale of fossil fuels, it may remove their current method of back-up heating.

A community trust in the Highlands found the remote rural factor to be significant, especially with respect to deliveries. This is mainly due to the transport costs and extreme weather conditions. Adverse weather conditions can create delays in the construction programme while roads can be underdeveloped and create problems for access. Small local contractors can't benefit from bulk purchasing, nor do they have the buying power to participate in larger procurement practices. This was echoed by another housing trust, who found that skills are a big issue when it comes to heating systems in general in remote locations. It's not financially viable to hire a Central Belt business to travel to the Highlands to carry out maintenance on heating systems in a couple of homes. Additionally, the local economy isn't benefitting from employment.

Due to the higher wind speeds along the West Coast, it is well suited to wind power generation. A housing trust based in the North of Scotland found that keeping that power generation and consumption "local" rather than feeding it directly into the grid is more cost-effective for local residents who are generally on lower incomes but have the higher fuel bills. Builders in Orkney felt that there shouldn't be a blanket approach to carbon intensity calculations; they felt they should have more regional variance with regards to energy generated locally. Islands are generating the most energy but paying the highest transmission charges, with Orkney currently generating around 120% of its own energy needs via wind power [9].

4.2.2 Heating systems in new builds

Based on the response from the stakeholders interviewed, ASHPs seem to be one of the most common heating technologies in private domestic new builds across the Scottish islands. This is due to the cost savings for homeowners, the familiarity of local contractors with the technology, and their suitability to the local environment. While this is true for the private and self-build domestic market, respondents who provide social housing indicated that electric storage heating is being installed as standard in local authority social housing due to their attractive CAPEX costs, lower maintenance requirements and ease of use. However, one island-based housing association always opts to install ASHP as they believe that storage heaters frequently result in tenants underheating their homes due to the high running costs. This housing association only install storage heaters in flats (predominantly four-in-a-blocks)

Electric storage heating and panel heating are also common technologies, as they require less maintenance than ASHPs and are more intuitive for their users, according to multiple stakeholders across different sectors.

District heating systems can be suitable in certain locations depending on the size of the developments connected to them. They are more suitable in areas of high heat density such as towns, rather than remote areas with dispersed heat demands. Schemes already exist – such as the Lerwick district heating scheme (Shetland Heat and Power Ltd), Shetland. One housing association found that district heating has been proven to work in high population density areas within remote regions (e.g., Lerwick), but it would not be suitable for rural, dispersed populations owing to lower heat demand density in these areas. Their suggested benchmark for district heating is 100 houses or more. If the network were to have a fault, multiple homes would be left without heating or hot water for days until a qualified contractor could arrive to fix the problem. This point was echoed by one of the contractors, specifically with respect to biomass-fuelled district heating networks. A community trust in the Highlands found that a district heating system would have cost them four times that of installing ASHPs in their developments.

A local authority in the islands stated that ground source heat pumps (GSHPs) are also a technology that, while highly efficient, can be prohibitively expensive for housing associations to install.

4.2.3 Best suited technologies and their benefits

An evaluation of battery electric storage systems (BESS) versus thermal electric storage (TES) found that TES proved profitable over BESS due to lower investment costs, and could be used in conjunction with an established district heating system to optimise the utilisation of the stored energy [10].

One housing association found that ASHPs are highly suitable only if there is a contractor located close by. Two contractors also found that ASHPs were appropriate; more so than GSHPs, where borehole drilling costs can be expensive. Two community/housing trusts had hopes for ASHPs but had concerns about dampness if levels of heating were insufficient. Most stakeholders found that electric heating was suitable everywhere and would even solve the dampness issue by drying out the environment but found a problem with the affordability of electricity rather than the suitability of the technology.

Builders in Orkney found that GSHPs used to work well for single properties during the term of the Renewable Heat Incentive (RHI), but not so much now with its removal and the CAPEX remaining constant. However, they found that GSHPs are still an option for larger, commercial buildings – they had recently installed one in a care home. They thought that the best solution for social housing is storage heaters rather than HPs, because they are affordable, and are easy to install, maintain and use. Air-to-Air heat pumps (A/A HPs) were also found to be simple to use and had few external components that could be corroded by the salt in the air.

An island-based local authority found that GSHPs do work well but are prohibitively expensive to install. Once installed, they need little maintenance besides having the pumps replaced occasionally because they are not as exposed to the salty air as ASHPs. They also agreed that panel heaters are more suitable than HPs for local authority social housing because tenants tend to tinker with the HP controls and switch over to immersion, which results in excessively high bills. The Orkney-based development trust found that ASHPs work well, and they haven’t had as much issue with the salt air in the past five years. This is because they began using Mitsubishi's Ecodan Coastal Protection model.

Another technology that is being tested in Orkney is hydrogen boilers in a local primary school. The European Marine Energy Centre produces hydrogen using wind energy that would otherwise have been curtailed. However, this project has been running for less than a year. The boilers’ performance will be assessed alongside hydrogen costs and impacts before rolling out hydrogen boilers across Orkney.

The greatest benefit to installing ASHPs felt by multiple stakeholders across several different areas was the cost saving on energy bills, however this has been less noticeable since the energy crisis began in 2021. Stakeholders have also found that ASHPs are easy to manage and provide a great level of comfort.

4.2.4 Conditions under which ZDEH technologies would not be feasible or cost-effective

One contractor pointed out uninsulated buildings (such as bus stations) as an obvious example of build types where ZDEH technology would not be cost-effective due to the low levels of insulation. The Orkney-based development trust found that heat pumps could not be installed in straw bale wall construction buildings.

One housing trust found that systems that require maintenance by people who are remote are not feasible. With larger developments, they reported that economies of scale make this a little more viable. In most rural communities, maintenance workers are reluctant, because the size of the job (a few houses) doesn't justify the long travel time. Local agencies working together to promote the need for skilled labour could be effective in attracting installers to rural areas. This and the upskilling existing installers[2] would help overcome these challenges.

The research did not identify cases where a bioenergy system may be more appropriate or necessary in place of a ZDEH system. Research into bioenergy devices and supply chains was not covered in the scope of this work, but the small current market for modern high efficiency biomass boilers means there are likely to be a similar range of supply chain issues for bioenergy systems as for ZDEH on the Scottish Islands.

5. Consumer characteristics

This section provides key findings from the research to highlight any specific needs and behaviours linked to consumers in Scottish islands and remote communities that may have an impact on the adoption of ZDEH technologies.

5.1 Island characteristics and demographics that affect the adoption of ZDEH

In remote rural Scotland the budgets households need to achieve a minimum acceptable living standard are typically 10-40% higher than elsewhere in the UK. In towns, minimum fuel bills are estimated to be 50-90% higher. In remote rural areas, those living in privately rented, older, oil-heated homes face 25-50% higher fuel costs than those in newly built, well-insulated social housing [11]. This is echoed in a report by ClimateXChange, which identified that 40% of people living in the Western Isles live in fuel poverty compared to the 24% average for households across Scotland [12].

Feedback on ASHPs from a retrofit programme in a remote rural location has been mixed. However, when ZDEH technology is installed at the time of build and the house is designed with a ZDEH system in mind and well insulated, this tends to invoke a positive response from occupiers. Installers have found that there are few characteristics impeding the adoption of ZDEH technologies. Consumer attitudes towards ZDEH are favourable in their experience – especially with customers who are building new homes. These consumers are already making a significant change by building a new home, so they are less resistant to a change in the heating system technology.

This is echoed by a housing association, who found that individuals are reluctant to give up their solid fuel heating in retrofit situations but found no resistance from tenants moving into homes with ZDEH systems already installed. A different housing association

[2] Respondent did not elaborate on the type of upskilling required. LCP Delta interpret this as a need for a better coordination of skills to ensure a wider range of ZDEH technologies are available to customers and the upskilling of specialists in other heating disciplines (e.g., electricians, boiler specialists).

also found that removing solid heating would be a challenge for rural householders who relied on peat as a free source of fuel, and another housing trust found that with incomes tending to be lower, there's more pushback against electric heating due to the high costs. There is no demographic that has been pushing back more than others. Another issue is that people in rural areas rely on personal vehicles and have a higher cost of living [13]. This makes net zero a relatively low priority for tenants with lower incomes and increases the temptation to simply switch off the heating.

It was reported that the tight-knit nature of rural communities lends itself to a positive "word-of-mouth" effect. An Orkney-based installer noted that the use of heat pumps is common across the islands, so everyone at least knows someone with one if they don't already own one themselves. People see their family and neighbours using ZDEH systems as viable technologies, and existing users recommend them to new adopters, even recommending specific brands.

5.2 Barriers to installation of ZDEH technology

5.2.1 Financial barriers

Installers generally did not believe there to be financial barriers to installing ZDEH technologies in new private domestic buildings. They found that government grants and loans removed or greatly reduced any barriers, with one installer pointing out that, when spending around £300,000 on a newly built house, the cost difference between an oil boiler and a heat pump would be around a few thousand pounds, which makes a tiny percentage difference in terms of the overall price of the home.

Housing associations and community trusts had a different view, however. The cost of electricity is a huge factor when considering ZDEH technologies over fossil fuel heating systems. Due to the implications of fuel poverty, housing associations must prioritise affordability for tenants. They are seeking to reduce the overall energy demand via fabric first approach, making storage heating more financially viable both from an installation perspective and operationally for tenants.

The installation costs (of ZDEH technologies) are not too prohibitive for community groups who have access to grant funding. However, the private purchase of an ASHP is too expensive for the average household and there is no help for people in the "middle bracket" (those who are not wealthy but have income higher than the threshold[3] for grant support). This is a significant barrier to the adoption of ZDEH heating technologies amongst self-builders, which are fairly common in certain islands. The grants available to housing associations are not available for replacement heat pumps, so early adopters (which some islands have been) are not eligible for the RHI. Housing developers in island areas need to find savings where they can, which adds pressure when designing heating systems. There is an appetite for low carbon heating systems, but locals would still like to see more generation and redistribution of local energy to lessen the dependency on the grid and reduce costs (relative to buying electricity centrally).

[3] These thresholds are indicative and were not defined by the respondent. LCP Delta have interpreted these thresholds to mean the level of income that would is not high enough to facilitate the purchase of a £14,000 ASHP system but would be high enough to preclude an owner/ occupier from full grant support.

5.2.2 Cost differences between installing ZDEH tech in remote areas vs. other Scottish locations

The Scotsman reported in 2016 that building costs on islands can be up to 30% higher than on the mainland, with prices being pushed up due to importing materials and tradespeople. Ferry cancellations can impact accessibility and drive prices higher [14]. Housing tender return information shows 43% higher building costs for Shetland compared to the standard in Perth or South Lanarkshire, 23% higher in Highland West and 28% higher in the Western Isles [15]. This was echoed in research by the Energy Saving Trust on heat network skills, which found that skills gaps were particularly acute in rural and island areas of Scotland. It was often not possible to access specialist contractors to carry out works because they did not exist in the local area and it was not cost effective for contractors to travel from further afield for smaller-cost value jobs [16]. One housing trust cited a 20% “island supplement” that needed to be added onto maintenance cost calculations.

The Scottish Government have outlined steps to tackle fuel poverty in their National Islands Plan [17] and the Fuel Poverty Act [18]. Funding for the Area Based Scheme (ABS) includes a £2,000 uplift to “reflect the greater delivery costs in remote rural areas and island communities.”

5.2.3 Non-financial barriers

One community trust in the Western Highlands reported that some residents have questioned how environmentally sustainable ZDEH technologies really are, when compared with the longer lifespan of much simpler technologies, such as a stove. Many residents feel very strongly about this, however the interviewee noted that environmental concerns are not as significant a barrier as the financial burden. Despite controls getting more user friendly in recent years, many older people refuse HPs as they do not find digital controls easy to use, preferring familiar heating methods such as solid fuel fires.

There’s an element of adjusting to a new style of heating with heat pumps, where it’s more cost efficient to leave it running all the time rather than intermittent heating (i.e. switching it off and on when it is required). Systems need to be as simple as possible for tenants and homeowners, who can get the wrong ideas about how to use their heating. As mentioned before, those in small, close-knit communities will often switch to heat pumps on word of mouth. Residents will often take on incorrect advice from their neighbours on how best to use their heating system and end up increasing their bills after attempting to save money. This suggests there is an important role for the provision of public education on the matter.

6. Infrastructure

This section provides key findings from the research to explain the local infrastructure needs for the adoption of ZDEH technologies in new buildings and to understand the regional implications for distribution network capacity in island and remote communities.

6.1 Current network infrastructure

The view of the electricity distribution network operators (DNOs) was that the network across the whole of Scotland would need to be upgraded/ reinforced to accommodate a significant increase in the uptake of ZDEH technologies. Scottish islands and remote communities are no different in that respect.

In terms of resiliency, overhead lines are the most vulnerable part of the electricity network in remote mainland locations. They are more susceptible to damage than underground cables, and extreme weather events will typically have a greater impact on rural areas.

Remote areas are also vulnerable as they have less interconnectivity; if one line gets damaged and fails, there are fewer opportunities to back-feed the connection from another source. The single point of failure is also the main vulnerability of the network across the Scottish islands.

From an electrical perspective, the network on the islands close to the mainland (e.g., Mull, Bute, Canna, Arran) are just an extension of the mainland network. Islands like Skye, Arran and Mull have good connectivity to the mainland; they have 33 kilovolt (kV) circuits and higher voltage levels.

Currently, there is a network of subsea cables connecting all the inhabited islands in Orkney and across the Southern Hebrides. SSEN, the DNO covering the islands has noted that the capacity of these subsea cables will need to be upgraded to meet significant increases in additional demand from ZDEH systems and other low carbon technologies.

Shetland is not grid connected; it stands on its own and work is underway to build a high-voltage direct current (HVDC) connection. Currently, Shetland operates a heavy oil power station, which generates full time. There is also renewables generation in combination with the centralised power station.

SSEN operate generation facilities in seven island “regions” where, 50 years ago, the primary source of energy was diesel generators.

- Kirkwall (Orkney)
- Battery point (Lewis)
- Arnish (Lewis)
- Loch Carnan (South Uist)
- Barra Power Station (Barra)
- Tiree Power Station (Tiree)
- Bowmore (Islay)

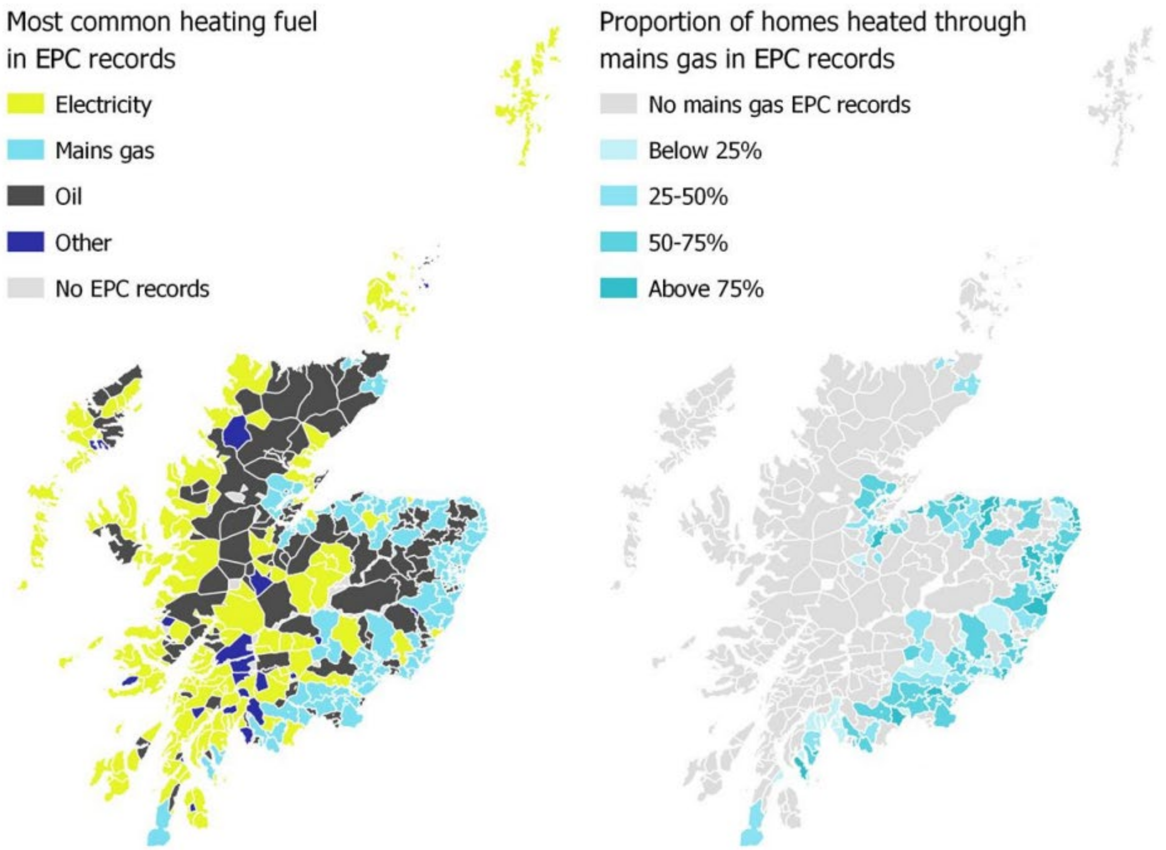
These islands have since been connected to the mainland via subsea cables, so these diesel power stations now serve as the primary back up. As these islands are now only connected to the network by a single feed, the network runs on these diesel generators in the event of failure and during planned outages, until supply is restored.

Due to the lower voltage levels on some of the islands and in remote locations, network operators have limited visibility of power flows on parts of the Low Voltage (LV) network, beyond the 33kV and 11kV levels. This limits the ability of the network operators to fully understand the demand on those parts of the network.

6.2 Future network infrastructure

SSEN note that none of the islands or remote communities are particularly demand constrained. A significant number of homes on the islands are already using electricity for their primary heating source (typically storage heating), so demand is currently not a challenge for the networks on the islands; the main issue for the network is generation export. Figure 4 below shows the high levels of electric heating in rural and island communities across Scotland.

Figure 4: Primary heating fuels for homes in the North of Scotland licence area in 2020. Source: Scottish & Southern Electricity Networks



The Scottish House Condition Survey provides data on the proportion of domestic buildings that are off gas grid for each local authority [19]. Table 1 provides a breakdown of the number of domestic off gas buildings in island and remote local authority areas.

Table 1: Proportion of domestic buildings which are off the gas grid. Source: Scottish Government

Local Authority	Number of off gas domestic buildings	% of buildings that are off gas grid
Argyll and Bute	21,000	50%
Dumfries and Galloway	28,000	40%
Na h-Eileanan Siar	11,000	88%
Highland	66,000	61%
Orkney Islands	10,000	100%
Scottish Borders	15,000	28%
Shetland Islands	10,000	100%

SSEN is working on the premise that no more renewable generation can be connected, on most of the islands, unless it's matched by corresponding new demand. This creates a potential scenario where the addition of ZDEH technologies may enable additional renewable generation in the islands.

SSEN acknowledges that the network will need to be upgraded in the future to accommodate the load growth from heat pumps and electric vehicles. The key from a network perspective is the timing of the investment. They have proposed £329.2 million worth of network investments across the Scottish islands between 2023 and 2028 as part of their RIIO-ED2[4] business plan [20].

Demand in the Western Isles is currently around 25 megawatts (MW). SSEN is expecting an extra 40MW of demand on some of the islands by 2050 due to decarbonising heat and transportation. That represents a doubling, or sometimes trebling, of demand.

In future, Shetland will be transmission connected, but that will be a single connection. A backup power station is currently under construction to ensure resiliency.

The Western Isles will also be transmission connected (up to 1,800 MW) as a generation exporter, but that won't occur until 2030. These upgrades will be tied to the distribution system to provide an extra level of resilience for the islands, while also providing some extra capacity for ZDEH/ low-carbon technology (LCT) growth.

To improve their understanding of power flows, both SSEN and SPEN are currently installing additional monitoring and observation equipment to the LV network. This will be supplemented by smart meter data as radio tele-switches are replaced with smart meters.

Greater visibility will enable efficient heat pump connections and will also provide greater understanding of the impacts of installing LCTs and ZDEH technologies, providing the DNOs with a better understanding of the long-term needs for the island and remote communities.

6.3 Differences with mainland Scotland

SPEN and SSEN noted that there are minimal differences when upgrading or reinforcing the network on the islands or in remote communities, relative to mainland Scotland.

6.3.1 Costs

The main difference in cost is a result of the method of connection. The subsea cables are the most expensive component of upgrading or reinforcing the network on the Scottish islands. The cost of replacing a single subsea cable is dependent on several factors and will differ from cable-to-cable. Of the £329m of proposed investment for the island networks during the RIIO-ED2 price control (2023 – 2028), £184m (56%) will be invested in subsea cables [20].

Additionally, SSEN noted that the more extreme environment means the subsea cables do not last as long as cables on the mainland. On the mainland, cables typically last more than 40 years, but subsea cables will have to be replaced every 10 to 15 years due to the dynamic environment.

For remote mainland communities, the cost of upgrading or reinforcing the network can be greater than in urban areas. Remote communities typically have longer low-voltage

[4] RIIO (Revenue = Incentives + Innovation + Outputs) is Ofgem's price control framework; an incentive-based methodology for regulating gas and electricity networks. RIIO-ED2 is the price control for the electricity distribution network.

circuits and smaller secondary transformers; if the transformer becomes overloaded and needs to be upgraded, that represents a much higher cost, per customer, than in urban areas. Costs in both island and remote communities will vary significantly from community to community or island to island.

6.3.2 Resource and equipment

The DNOs stated that there are no significant differences in the way they implement connectivity upgrades or investment on the islands or across remote communities. Upgrades and reinforcements in places such as Stornoway or Kirkwall are treated very much in the same way as an upgrade in Aberdeen or Dundee.

Due to the geographical location, it can take longer to physically move equipment to some of the islands. However, there are no logistical or physical differences when implementing work on the islands. The physical plant used on the islands is the same as the plant used on the mainland; there are no specialist transformers, circuits, utility poles, or cables, and all the cables have the same ratings.

Both network operators have resource situated on some of these islands and across remote communities, not a significant number of staff, but enough to manage the workload. A significant increase in workload would require additional people/ resources, but the network operator expects and is planning for the retrofit of ZDEH/ LCTs to present a much greater challenge than accommodating additional demand from ZDEH technologies in new buildings.

The network operator is already managing large networks on some of the bigger islands, and they have processes in place for managing the challenge of getting equipment to the islands. These processes may need to be scaled up in future to ensure the network is fit to meet the increased demand from the electrification of heat and transportation.

Securing connections for new buildings is easier for the network operator on the Scottish islands. For new properties, a customer uploads a request on to the network operator's platform and they respond to the applicant with a connection offer. Depending on the size of that new development and the network capacity margin on that particular island, it may be more difficult to secure a grid connection.

Due to the remote geographical location, it may be less likely for customers across the Scottish Islands to secure a connection through an independent distribution system operator (iDSO) or independent connection provider (ICP), that is more of an option for consumers on the mainland.

7. Supply chain & logistics

This section provides key findings from the research to explain the impact of adopting ZDEH technologies in all new budlings across island and remote communities and ability of supply chains and the workforce to meet the demand.

7.1 Heating options on Scottish islands/remote areas and their cost

7.1.1 Heating options

The majority of Scottish islands and remote areas are not supplied by mains gas. Heating options consist of combustion systems fuelled by heating oil, LPG and solid fuels, or electric heating (e.g., direct electric boilers, storage heaters, or heat pumps). Several installers based on Scottish islands began installing electric/ ZDEH heating a decade ago and the installation of fossil fuel combustion systems has been phased out.

Anecdotally, installers and respondents from the electricity network operator noted that a significant proportion of homes on the islands already have low emission heating systems. As a result, installers do not expect to see any additional costs due to the New Build Heat Standard regulation in 2024 as they have already been installing them into new build houses for a while.

In Orkney, storage heaters and ASHPs are more popular options amongst the locals as the supply of oil involves deliveries which can be challenging in winter months due to bad weather. Their back-up power source in case of power cuts is a gas bottle heater.

As previously mentioned in section 4.2.2, electric storage heaters are often the preferred heating system for social housing due to the lower CAPEX costs and ease of use, relative to other ZDEH technologies.

7.1.2 Costs differences

Table 2 below provides a summary of the estimated costs for different heating systems in some island/ remote communities, with these costs including the cost of the technology and the installation of the system. The domestic estimates were provided by local installers and are based on the cost a heating system in a private new build property. Non-domestic estimates were provided by a local authority and are based on historical estimates received.

Table 2: CAPEX and installation cost estimates for heating technologies in island/ remote communities

Heating Technology	Building type	Cost range (£GBP)
Oil boiler	Domestic	£9,000 – £13,000
ASHP	Domestic	£14,000 – £19,000
Oil boiler	Non-domestic	£100,000 – £200,000
ASHP	Non-domestic	~£500,000
GSHP	Non-domestic	£600,000 – £800,000

As shown in Table 2, for heating system costs for new build houses on islands, installers reported that an ASHP usually costs on average £3,000 to £4,000 more than fitting an oil boiler. The average cost of an ASHP for a new build house varies depending on the house size and other factors. Several installers stated that even though oil boilers are cheaper to install than a heat pump, the difference in the total cost over the full lifetime of the heating system is marginal. They also mentioned that running costs for ASHPs were lower than for oil boilers before the energy crisis.

Since the overall cost of an ASHP is only a few thousand pounds more expensive than for an oil boiler for private new build properties, it is reported that customers do not see this as a barrier to adopting ZDEH technology when buying a new build home. However, for social housing, one of the local authorities interviewed as part of this research stated 25%-30% increased cost for supply of technology to islands compared to mainland.

Like private homes, council newbuild non-domestic properties on the Scottish islands and remote locations have not been fitted with oil boilers for a long time. One of the islands councils stated that price of an oil system for newbuild non-domestic buildings is around £200,000 compared to £500,000 for an ASHP. GSHPs cost for commercial buildings is between £600,000 and £800,000 due to high costs of drilling boreholes. The drilling costs used to be partially off-set by the revenue from the RHI, however since it has ceased ASHPs are becoming more popular.

7.2 Maintenance of ZDEH technology compared to a fossil fuel heating system

7.2.1 Installer view

The average cost of an oil boiler service is estimated to be £100 per year/ per service [21]. The total cost will vary from company to company and is dependent on several factors, such as location. The average cost of a service for a heat pump in Scotland is between £150 - £250. The installers interviewed provided estimates between £120 and £600. The lowest estimate was provided by a local installer in the Scottish Islands, while the highest estimate was provided by an installer on the mainland and accounts for the additional costs such as travel and accommodation.

Anecdotally, several installers from Orkney and Shetland stated that an oil boiler requires more regular maintenance to function efficiently compared to an ASHP. Installers are more likely to be called to repair oil boilers compared to ASHPs. Also, oil boiler parts can be more expensive, therefore, oil boiler lifetime maintenance costs can be higher than the maintenance costs for heat pumps. Heat pump manufacturers provide up to a 7-year warranty, however, installers noted that even 10-year-old heat pumps can function well with only small issues. Installers from Orkney and Shetland also do not believe maintenance is more challenging on islands. As they only work on islands, they have developed an efficient system to respond to maintenance requests quickly and efficiently. One installer pointed out that outdoor heat pump units are more prone to corrosion because of strong winds and sea spray. However, this issue has been mitigated by installing units with corrosion protection as standard. The only potential issue is availability and shipping of spare parts. Installers in Orkney and Shetland have limited stock of spare parts for heat pumps and shipment of new parts can take on average 3-4 days longer compared to the mainland.

One installer based in Oban who services nearby islands on the west coast had a slightly different experience. They stated that there are difficulties with installing and maintaining ZDEH in remote/ island locations mainly due to the geography. They also stated that heat pump manufacturers do not supply warranties to offshore locations, leading to technology being installed without a warranty on the islands. They needed to acquire an additional written guarantee from the original equipment manufacturer to ensure that the ZDEH technologies they install are covered by a warranty. They also felt that the supply chains in mainland GB for fossil fuels heating systems are more established than the supply chains for ZDEH technologies. Replacing a major component in the established GB supply chain would typically cost hundreds of pounds, whereas replacement electrical components for ASHPs could cost more than a thousand pounds in the islands.

7.2.2 Housing associations, local authorities, and new build contractor’s view

From the perspective of housing associations and local authorities, other electric heating technologies are easier to maintain than ASHPs. One of the housing associations described it as “fit and forget” in terms of how little maintenance is needed for storage heaters. They also mentioned that travel expenses with current fuel prices and the time installers spend travelling need to be factored into the maintenance cost on islands.

New build contractors have different opinions on maintenance costs. One contractor noted a service plan, when paired with a 7-year heat pump warranty, could reduce costs and found that that was cheaper than having to pay for an electrician to install a storage heater. As noted in section 7.2.1, the widely accepted view is that heat pump maintenance is more expensive, per service, than an oil boiler, but the total lifetime maintenance costs are cheaper as heat pumps require fewer maintenance/ service interventions. They also found an issue with finding heating engineers with availability to service the ASHPs, with waiting times of up to 6 weeks.

7.3 Demand for sufficiently qualified contractors and installers on Scottish islands and remote locations

In 2021, employment in the Highlands and Islands accounted for 9% of total employment in Scotland. In the Highlands and Islands, 56,900 job openings across all sectors are forecast from 2024 to 2031 [22]. This is compared to 723,700 job openings forecast for the whole of Scotland. Forecasts for the Highlands and Islands suggest a requirement for 4,000 people to fill job openings in the construction sector, and 400 people to fill jobs in electricity, gas, steam, and air conditioning supply between 2024 and 2031. Density of Skills Shortage Vacancies (SSVs) was 16% in the Highlands and Islands in 2020, compared to 21% across Scotland [22].

According to ESP (Energy Skills Partnership), there is a skills gap in the Highlands and Islands for heat pump training. They are developing a mobile training centre that can be used for industry up-skilling or re-skilling and have a National Transition Training Fund for people who have lost their jobs/at risk of redundancy because of COVID-19, specifically for upskilling into the zero-carbon heat sector.

In research on heat network skills, one scheme manager reported that local contractors were sent to Denmark to train in how to maintain the newly built heat networks [16]. However, the contractors eventually retired, and it was not found to be cost effective to train a new generation of contractors as the network had few maintenance requirements. Another heat network manager found that new contractors took longer to complete works and required supervision, which resulted in higher costs than otherwise would have been in less remote areas.

7.3.1 Installer and contractor's view

Installers based in Orkney and Shetland believe that there are not enough heat pump installers on those islands. The installers interviewed reported that there are only four heat pump installer organisations in Orkney, and they are in very high demand. One installer has a 6 month waiting time for heat pump installations. Another installer based in Oban believes there are enough qualified installers in Scotland to cover the additional demand that will happen because of the NBHS coming in 2024, but there are not enough that would be willing to travel to remote/ island locations. From the installer's perspective, the additional costs of travel, accommodation and longer turnaround times will prevent many installers from the mainland working in the islands.

Installers generally agree about the lack of installers and new build contractors to meet the demand on islands and remote locations. One of the contractors found that labour was being lost to offshore oil rigs, where the wages are higher, and the work is easier. They foresee a struggle to encourage workers back unless the wages were to increase, citing unpleasant outdoor conditions (e.g. rain, cold, midges) amongst the reasons that people were reluctant to work outside on the islands.

7.3.2 Housing association and local authorities' view

A housing association based on Bute have not experienced delays in heat pump installations due to lack of installers. This is due to good relationships with local construction companies and installers.

Several housing associations and local authorities from islands and remote locations expressed a different opinion and believe there is lack of heat pump installers. They stated that when policies or standards are introduced or encouraged by the Scottish Government (e.g., PAS2035/MCS), contractors can drop out due to a lack of interest or funds to upskill. Highlands and Islands Enterprise are working to bring labour in, but there has been a UK-wide skills shortage across all sectors post-Brexit. They believe that in Shetland, there is an even greater lack of expertise compared to the mainland, and the location makes it difficult for contractors/labourers to travel either a 14-hour ferry or an expensive flight. An island-based housing association has been trying to facilitate upskilling through additional training, but contractors are already busy and find that the money they would make is small compared to the training costs. Since the pandemic, older generations have retired early, and incoming electricians and heating engineers are only learning about new ZDEH technologies. Local authorities and housing associations/trusts need to come together and agree on a marketing strategy to promote the volume of work that is coming, which needs to be well communicated across all agencies to be successful. One housing association interviewed believes that relocation packages need to be created to attract skilled labour into island regions.

One stakeholder in Skye worked with contractors from the mainland. However, they had a difficult experience with these contractors as they rushed the heat pump installations and left tenants with technical issues.

7.4 Level of knowledge relevant stakeholders need to specify the most suitable ZDEH technology for the new buildings

In an interview with the Energy Saving Trust, one interviewee explained that limited experience and knowledge of low carbon heat networks can lead to a risk-averse attitude among design consultants. This prevented them from recommending innovative heating solutions. The consultants they had worked with reverted to solutions they had tried and tested elsewhere rather than considering more novel solutions that the interviewee felt might have better future-proofed the network. [16].

Installers believe that some housing associations can do a better job of explaining the benefits of heat pumps to their tenants. Together with local authorities, they seem to prioritise the heating system options with the lowest CAPEX as opposed to an option with the lowest total lifecycle costs. One installer believes that local authorities are being advised by people/ companies who have little-to-no direct or relevant experience, which leads to poor decision-making.

Housing developers work closely together with heat pump installers and together they have the knowledge to advise on the most suitable ZDEH technology for new build properties. However, one of the installers believes that housing associations often do not give enough weight to advice from installers and maintenance companies dealing directly with ZDEH technologies. They often end up choosing new heating systems for their tenants that were not the best suited or most efficient technology for that property type.

Several housing associations believe that planning authorities need to be aware of the geographical, climactic, and financial limitations to new build design standards such as Passivhaus in remote locations (i.e., ventilation issues in areas with consistently high winds). For example, one housing association would like to build 2-storey houses but the local planning department prefers traditional 1.5 storey (single storey with room-in-roof). Room in roof causes problems due to cold bridging and difficulties insulating around dormer windows.

8. Case studies

8.1 Case study: heat pump installation cost differences between mainland and island locations in Scotland

This case study demonstrates the differences in installing heat pumps in mainland Scotland and in island locations (specifically the west coast of Scotland), and associated cost differences. The information was provided by an installation company based in Inverness. Costs are provided for an average price for full installation, average maintenance price and likely lifetime of the installed ASHP for a 3-bedroom house from both location types (Table 1, below).

Table 3: Comparison of typical air source heat pump installation between mainland Scotland and Scottish island location for a 3-bedroom bungalow.

	Mainland installation	**Island installation**
Average price for full installation (£)	£12,000 – £15,000	£14,000 - £18,000
Average annual maintenance price, per service (£)	£250	£300 - £600
Likely lifetime of the installed heat pump (years)	7-15 years	7-15 years (if treated with corrosion protection)

Overall, the installer stated that one of the main reasons for higher overall costs for a heat pump installation on Scottish islands is the additional travel requirements, sometimes using ferries. As well as the additional distance, the installer has to carry more materials with them as merchants do not always deliver to islands. To prevent overloading their vehicle, the installer stated that they often need a second van and driver to accompany them, thus increasing costs. The installer believed this issue is faced by many other installers but is not widely talked about.

Specifically, the differences in the **installation cost** noted above are due to additional travel costs including fuel and ferry fares, lack of local merchants delivering materials and overnight stay costs. In addition, the accommodation options are limited by larger number of tourists during summer, which also affects the price of accommodation available. In winter, harsher weather can result in delays or cancellations of ferries consequently delaying the installations.

Travel costs associated with islands and potential overnight stay costs also affect the **maintenance costs**, as cited above. The installer stated that they try to do maintenance for more than one property during one trip, if possible, to reduce travel costs and improve efficiency. The most common maintenance issue (as is common across Scotland) is user error, as some customers change the settings and do not know how to reset them. Also, not all properties have good internet availability – an issue more likely to be experienced in remote areas - to link remote access controls. Both issues can increase the maintenance requirements and costs.

As mentioned in previous sections, Scottish islands often experience harsh weather and ASHPs need to be treated to prevent corrosion. In this case, the installer stated that if treated with a corrosion protection, the heat pump has the same lifetime expectancy as one installed on mainland Scotland.

8.2 Case Study: District Heating Networks in Shetland and Skye

Lochalsh and Skye Housing Association (LSHA) and Hjaltland Housing Association (HHA) in Shetland have properties connected to district heating networks. This case study provides the experiences of the two organisations with district heating.

8.2.1 Lochalsh and Skye Housing Association (LSHA)

In 2008, LSHA were awarded funding to purchase an area of land on which to develop their own woodchip biomass district heating network. The system was designed to heat 128 new build properties.

Originally, the network was owned and managed by LSHA, though pressures on existing staff with limited experience of such an enterprise resulted in losses of £80k per year. LSHA subsequently entered into a partnership with Angus Biofuels in 2012 to manage the plant and supply fuel. They also assisted with upgrades to the woodchip boiler, including installation of thermal storage, requiring an additional 11 properties be added to the network.

Heat interface unit (HIU) systems and radiators cost approximately £4,000 per property compared to around £15,000 for a single domestic ASHP system. Maintenance is also much cheaper than individual heat pump systems. The price per kWh of the biomass district heating system is currently 14p and, although this is considerably cheaper than current electricity prices, the housing association believe that gas-fired combined heat and power networks are cheaper for the end user. Due to lack of availability of local biomass supplies in the area, the woodchip is currently supplied from Tayside, which does have financial and carbon implications.

8.2.2 Hjaltland Housing Association (HHA)

HHA has187 domestic properties connected to the Lerwick District Heating Scheme (LDHS), of which 155 were new builds. This scheme services over 1,200 commercial and domestic properties using a heat from waste facility owned by Shetland Islands Council. The LDHS is managed by SHEaP (Shetland Heat, Energy and Power) and owned by Shetland Charitable Trust, meaning there are no shareholders or private investment and so prices are kept low for the end-user.

HHA estimate that the total lifecycle cost to them, over a 30-year period per property, for this type of heating system (HIU and radiators, as HHA are not responsible for the energy centre) is £10,316 compared to £5,869 for High Heat Retention (HHR) storage heaters and £19,442 for an ASHP. Annual maintenance costs for this type of system are £89 per property compared to £48 for HHR storage heaters and £150 for ASHPs.

For consumers, the current tariff is 6.9p/kWh, making it the cheapest form of heat in Lerwick [23]. Despite higher lifecycle and maintenance costs the housing association would still opt to connect properties to the LDHS wherever possible because of the significant benefit in terms of p/kWh.

8.2.3 Learnings

- Both HHA and LSHA highlighted the implications of a single point of failure in a district heating scheme causing numerous properties to be without heat. This is further exacerbated in remote locations with limited availability of professionals

for emergency repairs. Both systems have back up oil-fired boilers to assist during outages or times of peak demand.
- Whilst heat networks are suitable for properties clustered in an area, they are not suitable for dispersed properties in remote locations, which are common on Shetland and Skye. There is therefore a limitation as to how much district heating schemes can be used. LSHA have voiced an interest in exploring small-scale networks, including shared GSHPs providing heat and hot water to residents in multi-occupancy buildings.
- There has been a lack of forward-thinking regarding replacement cycles for HIUs and needing to install upgrades in numerous homes at the same time can put pressure on local contractors. That said, LSHA noted that this was preferrable to replacing entire ASHP systems for multiple properties at the same time.

8.2.4 Looking to the future

The primary challenge identified by both stakeholders was the requirement to find other heat sources for the future. In 14 years, the current biomass plant in Portree on Skye will have reached the end of its operational life and as such, LSHA are not connecting any new homes, even as 30 new properties are being built 100m from the facility. It was noted that heat from waste would be a suitable alternative fuel based on the projected growth of Portree, though there is pushback from some locals who do not want to be based near such a facility.

On Shetland, HHA are planning to connect a further 300 new build properties to the LDHS as part of a 10 year project. SHEaP is actively looking at other heat sources to increase its capacity for new connections including heat pump technology and waste heat from potential hydrogen production. In the short term it will utilise waste heat from the neighbouring power station until it is mothballed following the new Shetland HVDC connection to the Scottish Mainland.

8.3 Case Study: Orkney Islands Council's experience of ZDEH technologies

Orkney Islands Council were early adopters of ZDEH systems on the islands, attempting to make the most of their local resource and build an integrated energy system. This case study outlines the Council's experience of installing a range of ZDEH technologies in various building types.

8.3.1 Social housing

For the past 15 years, the Council have not installed oil or LPG boilers in any of their new builds, opting for ASHPs or direct electric/storage heaters. Issues arose with early heat pump systems which were damaged by the sea air and were in need of replacement sooner than anticipated. Newer installations are treated with corrosion prevention to avoid this, and the Council have to date installed ASHPs in over 300 2/4 bedroom new build social housing properties since 2005.

The Council fits the majority of smaller new build dwellings (1 or 2 bedrooms) with electric storage heaters, owing to lower capital and maintenance costs compared to wet systems and ease of use for tenants. The Council have adopted a strong 'fabric first' approach to new build (and retrofit) design, implementing energy efficient design standards which exceed current building standards. This means thermal demand in these properties is lower and storage heating is a more financially viable option for tenants.

8.3.2 Non-domestic properties

GSHPs had previously been the favoured option for larger, non-domestic properties because of the lower maintenance costs and better performance compared with ASHPs. One pilot project undertaken in the early 2000s saw a GSHP system installed in a new care home facility. However, boreholes were positioned too close together and this resulted in the ground becoming frozen, resulting in the installation of a new ground array at an additional cost. Thermal response testing (to determine the thermal properties of the ground) is now carried out on all new GSHP projects to inform the ground array design process.

As early adopters of heat pump systems, the Council have faced several unexpected challenges with heat pumps but they have encouraged the local heat pump market to develop. Currently there are several local contractors available for the installation of heat pumps, both domestic and commercial. However, contractors for boreholes are not available locally, meaning contractors from the mainland are required to stay for extended periods of time. This contributes to GSHP systems costing roughly four times that of installing an oil system.

Biomass heating systems have been considered, though it was determined by the Council that the financial and carbon costs associated with transportation of woodchip to the islands was prohibitive. Initiatives to grow fuel locally were found to be unviable due to Orkney's maritime climate.

8.3.3 Financial considerations

The Council is ambitious with its building stock and prioritises the thermal performance of new build properties. Ultimately, capital cost and the operational costs to tenants remain a key factor when considering which heating systems to install, especially considering the current energy crisis.

The Council estimate that for commercial properties the cost to install a GSHP is 4 to 6 times more than a traditional oil-fired system, and an ASHP 3 times more than the oil alternative. Increased capital costs for a GSHP were previously offset by the payments generated from the RHI, though this scheme closed for new applications in March 2021. This has pushed the Council towards ASHPs as an alternative option for smaller commercial properties. They feel that ASHPs have yet to be proven as a viable alternative for larger non-domestic buildings, due to the lower efficiency when compared to GSHPs. This may mean that for such buildings a GSHP is more cost effective over the life of the installation, despite the high CAPEX.

9. Conclusions

The majority of Scottish islands are not supplied by mains gas and thus their heating options consist of oil boilers, electric heating (e.g., storage heaters, air-source/ground-source heat pumps), LPG and solid fuels. In the absence of a gas network, a significant proportion of homes on the islands already have ZDEH systems.

Opportunities

There are several options in terms of the best suited technologies for the island/remote locations. According to most interviewees, ASHPs seem to work well for private houses. GSHPs are an option for larger commercial buildings. Many housing associations believe storage heaters are the best solution for social housing as they are affordable to install, low maintenance and easy to use. Installing ZDEH technologies in uninsulated buildings, such as a bus station, would not be cost-effective and therefore it is not recommended.

Housing development contractors usually work closely with installers and take their advice on the most suited ZDEH technology for housing developments. Installers and housing development contractors believe that some housing associations could do a better job explaining the benefits of ZDEH technologies to their tenants. In addition, they believe that some local authorities and housing associations prioritise heating options with the lowest upfront costs as opposed to options with the lowest total lifecycle costs.

In general, consumer attitudes towards ZDEH technologies are positive. Customers building new houses are likely to choose these technologies for their new home as the additional few thousand pounds for a heat pump, relative to a fossil fuel alternative, does not make a significant difference given the overall cost of a new build house. No circumstances where bioenergy would be more appropriate over ZDEH systems for new buildings covered by the regulation were identified in this work.

Overall, installers do not expect the planned NBHS regulation to have a major impact on the heating technologies installed in new build properties on island/remote locations.

Challenges

The most popular heating option by far for new build houses is an ASHP; the average cost of an ASHP for a new build house is £3,000 to £4,000 more expensive in islands than in mainland Scotland. This is mainly due to the additional transport cost (e.g. extra fuel or ferry fares) and accommodation costs for installers travelling to these remote areas.

There is also a lack of local merchants and installers to deliver the materials, which often requires an additional van and resource. These factors also account for the slightly higher costs of maintenance across the islands, relative to the mainland. Shipment of spare parts can take 3 to 4 days longer on average than on the mainland and maintenance requirements for ZDEH technologies may be more frequent across the Scottish islands as they are often subjected to more extreme weather than mainland Scotland. Strong winds carrying salt water can corrode some of the heat pump components much quicker, if not treated with corrosion protection, which is now the norm.

The majority of stakeholders interviewed believe that the number of companies installing and maintaining ZDEH installers and housing contractors on Scottish islands/ remote areas is insufficient to meet increasing demand. Across Scotland as a whole, there are enough installers to cover the additional demand resulting from NBHS in 2024, however, there might not be enough of them willing to travel to islands/remote locations. Many mainland installers may be unwilling to prioritise work in island communities over local work on the mainland due to the additional cost of travel, accommodation and longer turnaround times associated with these locations.

Network infrastructure

In order to accommodate a significant increase in ZDEH technologies, the network will have to be reinforced across the whole of Scotland. Compared to the mainland, island communities are more vulnerable due to lower interconnectivity, with a significant number of islands only having a single point of connection.

Future network upgrades/reinforcements will be similar between islands and mainland Scotland, but the cost can be greater in remote mainland areas. This is mainly due to the costs associated with subsea cable connections and/or upgrades. The total cost of upgrading/ replacing subsea network cables accounts for 56% of network investment during the RIIO ED2 price control period. Subsea cables may only last 10 to 15 years, whereas mainland cables usually last 40 years. It is important to note that costs for both island and remote locations vary significantly from one area/island to another.

In terms of the ways the connectivity upgrades are implemented, there do not seem to be any significant logistical or physical differences when implementing work on islands. The equipment and the physical plant used are the same for the mainland and islands and network companies have experienced specialists and resources in situ. The only difference would be longer distances needed to travel to move the equipment. Network operators are already planning to scale up the operations on islands and remote locations to meet the demand from the electrification of heat and increased penetration of other low-carbon technologies, such as electric vehicles.

10. Bibliography

[1]. Scottish Government. (2022). *Scottish Government Statistical Data - Dwellings by Type.* Edinburgh: Scottish Government. Retrieved from https://statistics.gov.scot/resource?uri=http%3A%2F%2Fstatistics.gov.scot%2Fdata%2Fdwellings-type

[2]. Climate Exchange. (2022). *An evidence review of data associated with non-domestic buildings.* Edinburgh: Climate Exchange.

[3]. Scottish Government. (2022). *Scottish Government Statistical Data - Business Stocks and Sites.* Edinburgh: Scottish Government. Retrieved from https://statistics.gov.scot/resource?uri=http%3A%2F%2Fstatistics.gov.scot%2Fdata%2Fbusiness-stocks-and-sites

[4]. Scottish Government. (2022). *Scottish Government Statistical Data - Household Projections.* Edinburgh: Scottish Government. Retrieved from https://statistics.gov.scot/slice?dataset=http%3A%2F%2Fstatistics.gov.scot%2Fdata%2Fhousehold-projections&http%3A%2F%2Fpurl.org%2Flinked-data%2Fsdmx%2F2009%2Fdimension%23refPeriod=http%3A%2F%2Freference.data.gov.uk%2Fid%2Fyear%2F2030&http%3A%2F%2Fstatisti

[5]. MCS. (2021). *Renewing Britain: The changing landscape of home-grown energy 2008-2021.* Daresbury: MCS. Retrieved from https://issuu.com/mcscertified/docs/mcs_renewing_britain_report

[6]. Scottish Government. (2022). *Building standards technical handbook 2022: non-domestic.* Edinburgh: Scottish Government. Retrieved from https://www.gov.scot/publications/building-standards-technical-handbook-2022-non-domestic/#:~:text=Guidance%20on%20achieving%20the%20standards,warrant%20commenced%20from%20that%20date.

[7]. CIBSE. (2021, December). *How the Orkney Islands transitioned to heat pumps*. Retrieved 2022, from CIBSE Journal: https://www.cibsejournal.com/case-studies/how-the-orkney-islands-transitioned-to-heat-pumps/

[8]. Mitsubishi Electric. (2022). *2022 Price List: Issue 3.* Mitsubishi Electric. Retrieved from https://www.fsw.uk.com/sites/www.fsw.uk.com/files/2022_les_price_list_-_issue_3_-_fsw_0.pdf

[9]. Gutteridge Haskins & Davey Limited. (2021). *A Transmission Link for Orkney.* Kirkwall: Orkney Islands Council. Retrieved from https://www.orkney.gov.uk/Files/Strategic_Projects/Orkney_%20Transmission_Link_Report_May_2021.pdf

[10]. Marczinkowski, H. M., & Østergaard, P. A. (2019). Evaluation of electricity storage versus thermal storage as part of two different energy planning approaches for the islands Samsø and Orkney. *Energy, 175*, 505-514.

[11]. Highlands and Islands Enterprise. (n.d.). *A Minimum Income Standard for Remote Rural Scotland.*

[12]. Climate Exchange. (2022). *Climate action on Scottish islands: an initial mapping of the landscape.*

[13]. Scottish Government. (2021). *The cost of remoteness - reflecting higher living costs in remote rural Scotland when measuring fuel poverty: research report.* Edinburgh: Scottish Government.

[14]. The Newsroom. (2016, May). How much does it cost to live on a Scottish island? *The Scotsman*.

[15]. Scottish Government. (2022). *Housing Tender Return (HTR) and Scottish Social Housing Tender Price Index (SSHTPI).* Edinburgh: Scottish Government.

[16]. Bush, D. R. (2020). *Heat network skills in Scotland.* Edinburgh: Energy Saving Trust. Retrieved from https://energysavingtrust.org.uk/wp-content/uploads/2020/10/Heat-Network-Skills-Analysis-for-Scotland.pdf

[17]. Scottish Government. (2022). *National Islands Plan : annual report 2021.* Retrieved September 13, 2022, from https://www.gov.scot/publications/national-islands-plan-annual-report-2021/pages/9/

[18]. Scottish Government. (2019). *Fuel Poverty (Targets, Definition and Strategy) (Scotland) Act 2019.* Edinburgh: Scottish Government. Retrieved from https://www.legislation.gov.uk/asp/2019/10/enacted

[19]. Scottish Government. (2021). *Scottish Housing Condition Survey: Local Authority Analysis 2017 - 2019.* Edinburgh: Scottish Government.

[20]. Scottish & Southern Electricity Network. (2022). *Scottish Islands Strategy: RIIO-ED2 Business Plan Annex 8.1.* Perth: Scottish & Southern Electricity Networks.

[21]. Heatable. (2022, July 8). *How Much Does the Average Boiler Service Cost in 2022? (UK)*. Retrieved from Heatable: https://heatable.co.uk/boiler-advice/boiler-service-costs

[22]. Skills Development Scotland. (2022). *Regional Skills Assessment: Highlands and Islands.*

[23]. Marter, H. J. (2022, May 26). Energy / Locally owned company offers best energy price deal. *Stehland News*. Retrieved from https://www.shetnews.co.uk/2022/05/26/locally-owned-company-offers-best-energy-price-deal/

[24]. Highlands and Islands Enterprise. (2020). *The Impact of COVID-19 on the Highlands and Islands.*

[25]. Kalis, G., Stephanides, P., Bailey, E., Devine-Wright, P., Chalvatzis, K., & Bailey, I. (2021). The challenges of engaging island communities: Lessons on renewable energy from a review of 17 case studies. *Energy Research & Social Science, vol. 81*, 102257. Retrieved from https://www.sciencedirect.com/science/article/pii/S2214629621003509

[26]. Nesta. (2022, June). *Modelling Heat Pump Growth in Scotland*. Retrieved from Nesta: https://www.nesta.org.uk/feature/modelling-heat-pump-growth-in-scotland/

[27]. Ricardo Energy & Environment. (2016). *Small Islands Energy System Overview.* Inverness: Highlands and Islands Enterprise. Retrieved from https://www.hie.co.uk/media/8139/hie-small-islands-low-carbon-energy-overview-final-report-for-publication-pdf-060420-a3410152.pdf

[28]. Scene Connect. (2018). *Scottish Island Community Leads the Way with Green Heating.* Scene Connect. Retrieved from https://scene.community/blog2/scottish-island-community-leads-the-way-with-green-heating

[29]. Scottish & Southern Electricity Networks. (2022). *Distribution Future Energy Scenarios 2021: Results and methodology report.* Perth: Scottish & Southern Electricity Networks.

[30]. Scottish Government. (2018). *Islands (Scotland) Act 2018.* Edinburgh: Scottish Government. Retrieved from https://www.legislation.gov.uk/asp/2018/12/enacted

[31]. Scottish Government. (2019). *Climate Change (Emissions Reduction Targets) (Scotland) Act 2019.* Edinburgh: Scottish Government. Retrieved from https://www.legislation.gov.uk/asp/2019/15/contents/enacted

[32]. Scottish Government. (2021). *Heat in Buildings Strategy - achieving net zero emissions in Scotland's buildings.* Edinburgh: Scottish Government. Retrieved from https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/

[33]. Scottish Government. (2021). *New Build Heat Standard - scoping consultation: analysis.* Edinburgh: Scottish Government. Retrieved from https://www.gov.scot/publications/scoping-consultation-new-build-heat-standard-analysis-responses/

[34]. Scottish Government. (2021). *Research into Electricity Network Constraints and the 2024 New Build Heat Standard: Final Report.* Edinburgh: Scottish Government. Retrieved from https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2021/10/research-electricity-network-constraints-2024-new-build-heat-standard/documents/research-electricity-network-constraints-2024-new-build-heat-standard-final-

[35]. Scottish Government. (2022). *Scottish Government Statistical Data - New Build Housing Starts and Completions.* Edinburgh: Scottish Government. Retrieved from https://statistics.gov.scot/resource?uri=http%3A%2F%2Fstatistics.gov.scot%2Fdata%2Fnew-build-housing-starts-and-completions

11. Appendix

11.1 Methodology

11.1.1 Research aims:

The aims of this research were:

- Review existing ZDEH technologies and assess their technical suitability for buildings in island regions based on the characteristics of new build developments, climate and energy infrastructure.
- Explore factors specific to island regions – such as need for backup supplies, network infrastructure and renewable energy supply. Identify how issues differ between different types/locations of islands (e.g. those connected by road, grid connections, population density, etc.).
- Assess challenges in installing and maintaining these technologies, including the capacity of the supply chain to do so, higher costs in island areas of installation, resilience issues.
- Examine the costs associated with the delivery of ZDEH technologies in island regions, including capital and operation costs of the technologies, and wider energy system costs such as electricity network upgrades.
- Identify where ZDEH technologies might not be feasible or cost-effective and assess suitable alternatives.
- Identify areas where market penetration of ZDEH technologies is already high and lessons can be derived.
- Produce relevant case studies of ZDEH deployment in island communities to demonstrate the challenges and issues facing island communities as well as indicative costs (ideally in domestic and non-domestic buildings).

11.1.2 Methodology

The methodology for this study was as follows:

1. **Development of a research framework** structured to enable many of the specific characteristics to be captured and analysed. The research framework was structured around:
    a. **Technical characteristics**. This includes the main types of new domestic and non-domestic buildings, the available technology solutions, utility connections, alongside the economics of operating ZDEH.
    b. **Infrastructure**. Understanding both the local infrastructure needs (e.g. availability of an electricity connection, local heat networks, etc), and also the more regional implications based around the distribution network capacity.
    c. **Consumer characteristics**. Exploring whether there are specific consumer needs and behaviour linked to the Scottish Islands and remote locations which need to be included.
    d. **Supply chain and logistics**. Consideration of all elements of the supply chain from the initial build and specification process through to ongoing operation and maintenance. This will explore skills, costs, and logistics.
2. A **literature review** to gather data and information on the topic areas featured in the research framework. An initial search for secondary sources was conducted using defined search terms that were agreed with CXC and the Scottish Government, the full list of agreed search terms is detailed in Table 4, below. The

search was further supplemented by literature provided by interviewees. A full list of the publications reviewed is detailed in the bibliography.

Table 4: List of agreed search terms

Search terms list (non-exhaustive)
Decarbonisation of remote/ island communities
Scottish Islands supply chain issues/ challenges/ transportation/ availability
Scottish Islands labour costs/ impacts
Scottish Islands skilled labour
Scottish Islands cost of living
Scottish Islands fuel poverty
New build cost differential Scottish Islands
Scottish Islands electricity network infrastructure
Scottish Islands electricity network constraint issues
Scottish Islands Heat pump installations
Scottish Islands Heat networks
Scottish Islands Low Carbon technologies/ zones/ heating
Scottish Islands zero carbon/ low carbon heating projects
Economic impacts of decarbonisation in rural/ island communities
Scottish Islands population density
Scottish Islands energy/ electricity usage
Scottish Islands housing/ building types/ stock
Scottish Islands electricity network systems planning
Scottish Island back up supplies
Scottish Island renewable energy supply/ generation
Scottish Islands electricity generation
Comhairle nan Eilean Siar (CnES) / Orkney Islands Council / Shetland Islands Council / Argyll and Bute Council

NHS Western Isles (WIHB) / NHS Orkney (OHB) / NHS Shetland (SHB) / NHS Highland
Business / Commercial / Industrial / Agricultural / Community
Capital / Investment / Income / Cost / Finance / Budget
Scottish Islands climate conditions
Scottish Islands new builds / housing developments / building developments
Scottish Islands household characteristics / demographics

3. **Stakeholder interviews** were undertaken with 17 organisations in Scotland. These interviews were semi-structured 45-minute telephone interviews and were undertaken between July and August 2022. Stakeholders were categorised under three broad groupings:
    a. Industry, including network operators, equipment installers, architects and housebuilders (10 interviews).
    b. Authorities, including local authorities, housing associations, and organisations such as Local Energy Scotland (4 interviews).
    c. Community groups, drawing on existing networks and community representatives where possible (3 interviews).

   A full breakdown of the organisation types and the geographical locality of the respondents is provided in Table 5 below.

Table 5: Breakdown of interviewee organisation type and geographical coverage

Organisation type	Region
Local Authority	Orkney & Shetland
Housing Associations	Orkney & Shetland
	Argyll & Bute
	Inner Hebrides
House Builders/ Developers	Orkney & Shetland
	Outer Hebrides
	Inner Hebrides
Community/ Housing Trust	Highlands
	Orkney & Shetland
Heat Engineers/ Installers	Argyll & Bute

	Orkney & Shetland
	Orkney & Shetland
	Highlands
	Inner Hebrides
Electricity Distribution Network Operator	North of Scotland
	South of Scotland

Part of the interviewee selection process was to ensure that the research captured a wide range of opinions, helping to form a more balanced view. Organisations who have experience with ZDEH technologies in non-domestic buildings across the islands were difficult to find during the interview period. Therefore, priority was given to capturing opinions from a wide geographical spread, in order to ensure that responses were not biased by variables specific to a particular region.

4. **Qualitative analysis**: qualitative data from both the literature review and the interviews was analysed to provide an assessment of the broader regional impacts of increased load growth from the electrification of heat across the Scottish islands and remote communities. A set of case studies were developed, drawing on identified existing building examples to highlight any potential impacts unique to the islands and to understand the differences to the mainland.

climateXchange

Scotland's centre of expertise connecting climate change research and policy

info@climatexchange.org.uk
+44(0)131 651 4783
@climatexchange_
www.climatexchange.org.uk

ClimateXChange, Edinburgh Climate Change Institute, High School Yard, Edinburgh EH1 1LZ