Ricardo Energy & Environment

Small Islands Energy System Overview

Local Carbon Energy Systems Framework

Report for Highlands and Islands Enterprise

HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

ED | | Date

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Highlands and Islands Enterprise

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Contact:

Simon Morris
Ricardo Energy & Environment
18 Blythswood Square, Glasgow, G2 4BG,
United Kingdom

e: simon.morris@ricardo.com

Ricardo-AEA Ltd is certificated to ISO9001 and ISO14001

Author:

Georgiev, Martin

Approved By:

Simon Morris

Date:

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Executive summary

Highlands & Islands Enterprise (HIE), have commissioned the research into the status of the energy systems of a shortlist of Scottish Islands. This is a scoping study aimed at improving the understanding of energy systems of a shortlist of small, remote islands in the HIE region, many of which rank in the bottom 10% for geographic access. Opportunities to strengthen the resilience of island communities by developing their energy systems are discussed. The objective of this study is to identify where there are common themes across these islands and discuss opportunities to strengthen the resilience of island communities by developing their energy systems. An important step in ensuring Scotland reaches net zero by 2045.

Scotland's islands are recognised as places where inhabitants take responsibility for shaping their future; where there are business and social enterprise sectors that are innovative, strong and growing; where community asset ownership and service delivery are well established and supported. A secure, reliable and resilient energy system is an important cornerstone to enable Scotland's islands to preserve and grow their populations and economies.

Islands were shortlisted for this study using the following criteria:

- Population must be greater than 10.
- There must be a minimum of five and maximum of 300 households.

This resulted in a sample of 49 islands, seven of which were off-grid. Ranging from the smallest population in Erraid, to the largest in Sanday.

A representative from each island was identified by HIE and invited to be interviewed about their energy systems. This covered energy generation and demand mix, security of supply, projections on changes to energy demand and population and key considerations on each island. Those islands with well-established and active community groups or those with paid employees, were often able to provide a greater level of detail on factors relating to their energy system.

The study gathered information relating to:

- Electricity system.
- Energy demand.
- Heat provision.
- Transport/access.
- Communications and deprivation indicators.

Data analysis was carried out within the limits of the public data sources available and data from the interviews, but in many cases was limited by issues relating to spatial resolution.

Island innovation

On several the study islands there are local energy system developments operating under a range of different business models that are recognised internationally, putting Scotland on the map for its innovative approaches to decentralised, local energy.

- Conventional business models for renewable generators are that the revenues from the generator through the sale of electricity are used to pay back the capital cost of the generator.
- Some technology developers have fully funded the project costs for the installation of their technology, as part of their research and development costs.
- Local ownership of low carbon technology can build knowledge, experience and expertise within the community.

- Further, many island communities benefit financially from renewable generators, either through direct ownership or through community benefit payments provided by larger commercial installations.
- On off-grid islands, some electricity systems are operated and/ or owned by the community group on the island.

Island themes

Energy

Across the islands, characteristics identified of the energy system include:

- A large proportion of the island properties meet their heat demand via electricity or oil which pushes energy costs up.
- The additional electricity demand required for meeting heat loads, at a higher cost in the North of Scotland, than the rest of the UK, increase the likelihood of islander experience fuel poverty.
- The building stock was found to be generally EPC D or lower, both of which suggests that energy efficiency projects would be beneficial to all island communities.
- Wind power was found to be by far the most common low carbon source of generation across the study islands, although solar is still prevalent.
- Across all study islands, regardless of their typology (off-grid, Shetland grid, or national grid via an island interconnector), connecting additional renewable generation is restricted. Additional local demand or grid upgrades are required if more generation is to be connected.
- For islands connected to the distribution grid, demand constraint is generally not an issue, although large electrical demand projects may require grid upgrades (e.g. from single to 3-phase, or upgrades to the 3-phase capacity).

To facilitate further renewable generation, installed capacity requires either an upgrade to the network infrastructure or an increase in local demand, for example by electrifying non-domestic, energy intensive process often found in distilleries or fish farms.

There are some network upgrades that may reduce this constraint, such as the Western Isles transmission project (450MW interconnector), the Shetland transmission project (600MW interconnector) or the Orkney transmission project (220MW interconnector). The approval for these interconnectors is subject to their being enough demand from the islands. Although there were local wind farms on these archipelagos that were successful in the recent Round 3 auctions, this was not enough to trigger the go ahead for the interconnectors[1].

There are several innovation projects that have been delivered across the study islands, such as the high-profile BIG HIT and ReFLEX projects on Orkney, trying to establish methods of dealing with generation constraint. However, it is not clear when projects such as these might be technically or commercially viable on the smaller scale of the study islands. The economics of these case studies is improved by the generators being eligible for FiT.

The significant lack of progress on decarbonising heat for domestic and non-domestic demands, represents an opportunity to reduce renewable electricity generation grid constraint by linking new or constrained renewable generators to electric heating.

These types of projects could also help tackle fuel poverty, if they can be achieved at a lower unit cost of heat than the existing higher carbon options (e.g. oil). There is still further evidence to be provided

1 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/832924/Contracts_for_Difference_CfD_Allocation_Round_3_Results.pdf

that ongoing innovation projects demonstrating this link (often utilising electric storage heaters or heat pumps) have been successful, which is important if they are to be replicated.

Communications

If distributed renewable generation is to be linked with island demand (such as domestic heat), a reliable communication link will be required. The official OFCOM download speed figures for the study islands suggest that speeds are likely to be enough, for this. However, many of the interviewees reported that mobile connectivity was 'patchy', and the broadband connection could drop out so the reliability of communications would have to be considered on an island by island basis.

As communications has a wider impact on the community, for example, those that work from home, this is a wider issue that needs to be addressed.

Island Resilience

A lack of resilience was reported and identified across the following areas:

- Transport links to the island.
- Food and fuel supplies.
- Impact of power failures on electric heating and transport provision
- For off-grid islands, the operation and maintenance of their privately-owned grids.

Several interviewees stated that communications have dropped out during power outages which had an impact on the people and businesses on the island.

Anecdotal evidence indicated that it can be difficult to attract suppliers of energy services (equipment suppliers or developers) to islands, with tenders issued that are not responded to. There are many potential reasons for this, such as unrealistic budgets being offered, restrictive commercial considerations or remote locations of the islands adding in travelling to the islands. This can result in lack of competition in the procurement of these services or even sub-optimal service provision at a higher market price. Community groups were noted as a source of semi-skilled labour that are used to maintain systems in remote locations, but specialist technicians are generally sourced from the mainland. Upskilling of islanders in system maintenance is a method of improving the system resilience and as a source of additional income and employment for communities, although it is likely that specialists will still be required to complete annual maintenance.

All islands included in this study have a 24-hour supply of power with Fair Isle being the last to attain this (October 2018). It was reported by the interviewees that the number of power outages and brownouts experienced was reducing with time and the overall perception was that security of supply is improving.

Island populations were found to have increased by an average of 8% between the 2001 and 2011 census and by 2% between the 2011 census and the interviewees estimate of current population. The census data showed examples of significant reductions in population such as on Egilsay (30%), Erraid (25%), Fetlar (29%), Papa Stour (35%), Ulva (31%).

Transport

Transport to and from the islands, particularly those across more remote locations can be carbon intensive due to the mode of travel:

- Utilising marine oil.
- Aviation fuel.
- Road vehicle fuel.

For carbon reporting, emissions from ferry travel are allocated to the ferry operator. For air travel, emissions generated during taxi, take-off and landing and allocated to the airport, but emissions from the travel are allocated to the airline. Opportunities to improve the carbon intensity of travelling to the islands require the operators of the transport systems to act, which could be in collaboration with the local community. The recently announced Highlands and Islands airport Limited (HIAL) target for a net zero zone is a positive step towards this. Low emissions plane pilot route across some of the short island hoppers, such as the Fair Isle of Foula, would be good candidate routes for trials.

Although car ownership was found to be high, the proportion of electric vehicle (EV) ownership is generally low across the study islands so there is potential to improve island wide transport emissions. As EVs have a higher capital cost, but lower operating cost, they make most economical sense for car owners who have a high mileage. It is worth noting that the Orkney isles have the highest proportion of EV ownership across the UK.

Opportunities

Several high-level themes were identified for addressing island energy system challenges across the study islands, with further research required on each island to identify solutions suitable for that island.

- Collaboration: Collaboration between geographically or situationally linked islands could bring benefits for the communities. This could be geographical or situational.
- Energy system solutions should be tailored in a way that fits not only with the energy needs of the island but the ability for the community to facilitate, deliver and engage with it.
- A large amount of previous research and feasibility work was identified that has yet to be taken forward, so there may be am opportunity to revisit this research to determine where projects have been scoped but not been developed. For example, it may simply be the case that the community are not aware of the opportunities that exist.
- A standardised methodology could allow each island/community to establish their own energy system requirements, challenges to be tackled and the steps required to write a development plan.
- Increasing resilience: Resilience planning is complimentary to this and electricity network resilience may be a worthwhile first step, with funding available from SSE.
- Decarbonising heat: High levels of energy demand and fuel poverty across the study islands can be viewed as an opportunity to promote efficiency upgrades as a low-cost improvement method. In addition, the energy demand could be supplied more efficiently, at a lower cost and carbon intensity if new, low carbon heating options (such as heat pumps) are promoted.
    - If the island community has an appetite for a larger project, these low carbon heating options could form part of a wider system level project by linking them to renewable generators and reducing the issue of generation constraint during the winter.
    - New projects that integrate renewable generation with electric heating will decarbonise current oil heating systems and, to a lesser extent, storage heating systems currently grid connected.
- Decarbonising transport: These could also be extended to incorporate the transport sector in the form of electric vehicles and in the future, there is the potential for ferries and air travel.
- Inward investment: A method of achieving integrated local energy projects is to attract large commercial energy consumers to islands, such as fish breeders, textiles, distilleries to act as anchor loads in an energy system. Their scale and predictable consumption patterns can be beneficial in the design and operation of the system, and have the wider benefits of generating jobs, developing skills and maintaining island population. For integrated energy system projects to take place, the opportunity must be commercially attractive enough to interest the private sector.
- Flexibility services: Historically new renewable generation has been incentivised through government funding (such as the Feed-in Tariff) but the future for new generators is likely to be subsidy free. As such future flexibility contracts may offer an additional revenue stream to support the development of renewable generation.

As across the UK, no single solution to decarbonisation, a mix of fuels or cost reduction for the entire energy system is appropriate. The same applies across the study islands, where the available renewable resource and demand profiles vary from island to island.

The significantly higher energy demand identified across the islands, needs further consideration as this has significant implications for fuel poverty, communities and businesses across the islands. It is recognised that there are uncertainties in the data source used, so a more detailed review may be required.

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1 Introduction

Scotland's islands are recognised internationally as beautiful and diverse, enjoying rich histories, strong culture, high levels of natural resources and landscapes which are rich in wildlife. Strong communities play a role in the continued wellbeing of these islands. Inhabitants often take an involved role in shaping an island's future; the business and social enterprise sectors need to innovate to address challenges in more remote locations; community asset ownership and service delivery within the community are well established and supported.

A reliable and resilient energy system is an important cornerstone to preserving and growing island populations and economies. Low carbon infrastructure alongside twenty-first century technology can help bridge the geographical distance that currently constrains many island ambitions. Renewable energy can power island economies which may lead to lower fuel bills, increased business, inward investment opportunities and better transport links if developed appropriately.

The Scottish Government Energy Strategy outlines a vision for a flourishing, competitive, local and national energy sector, delivering secure, affordable clean energy for Scotland's households, communities and businesses. The Strategy proposes a smarter local energy model, across heat, transport and electricity sectors linking local generation and use to help create vibrant local energy economies with an aim for Scotland to maintain its leadership in developing local energy systems, building on the global shift away from centralised generation and passive consumption to decentralised system with active consumers.

Highlands & Islands Enterprise (HIE) have commissioned the research into the status of the energy systems of a shortlist of small Scottish Islands in order to:

- Deepen HIE understanding of the energy status of islands in the Highlands and Islands region, particularly focussed on our more fragile islands.
- Use this information to assess opportunities to improve the resilience of our island communities and increase their potential for population retention, community development and economic growth through strengthening of islands energy systems.
- Identify likely timescales for necessary replacement to assess whether there are opportunities for inter-island collaboration to realise economies of scale on systems costs, to attract our supply chain to compete for work and to demonstrate local energy system models (business, technology, partnerships etc).
- Look at opportunities to link in any digital upgrade on the islands with any energy upgrades that are planned – as both are key community services to help sustain and hopefully grow our island populations.
- Provide a platform to work closely with other Team Scotland stakeholders to look at options for delivery of any identified opportunities through existing support and investment options (including the Sustainable Islands International Programme).
- Provide an evidence base for future Highlands and Islands related policy development.

This study focuses on small Scottish islands but has the potential to be replicated on larger islands. Each island has its own circumstances which present uniquely distinctive challenges. Common to all is their remoteness, peripherality and, in comparison to some other areas of Scotland, their small population density.

The report contains the following sections:

- Methodology: This details the scope of the data collected and highlights any gaps and uncertainties in the date.
- Island context: A summary of overarching factors that influence the energy systems on the islands.
- Island energy systems: Detail of the data collected regarding the island energy systems and some conclusions from this.
- Addressing Island challenges: Analysis of the results in the context of whole energy systems and project concepts that might be relevant for addressing the identified challenges.

2 Methodology

In the following sections the methodology used in the collection of data for this study will be described. The data has been summarised and analysed, with some data sets provided in Appendices. This full data set is captured in the accompanying spreadsheet 'Island Data Sheet'.

The study was split into the following four phases.

2.1 Phase 1 – High level scoping and islands shortlist

Phase 1 set out to identify a shortlist of islands using the following selection criteria:

- Islands must have a population greater than 10[2].
- A minimum of 5 households and maximum of 300 households.
- Knoydart was added to the shortlist as it has an islanded energy system.

The shortlisted islands were checked for grid connection and grid generation constraint using data from Scottish and Southern Energy such as the SSE GIS portal, the SSEPD Generation availability map[3] and the long-term development statements.

There are 88 inhabited islands in Scotland. This scoping exercise narrowed the study to 49 islands (Table 1).

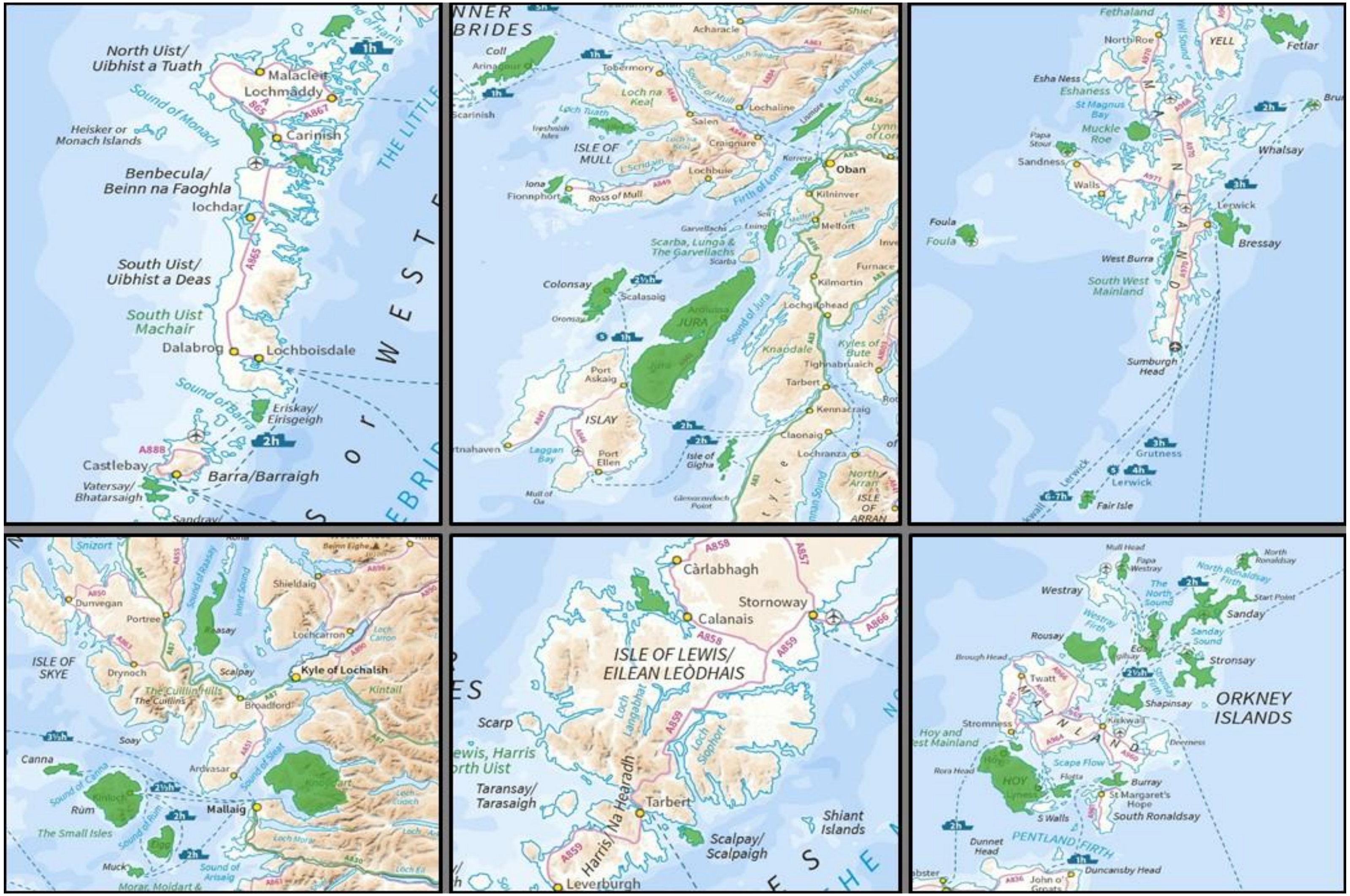
Table 1: Islands shortlisted for study

Island	Council area	Island	Council area	Island	Council area
Coll	Argyll & Bute	**Burray**	Orkney	**Foula**	Shetland
Colonsay	Argyll & Bute	**Eday**	Orkney	**Housay**	Shetland
Easdale	Argyll & Bute	**Egilsay**	Orkney	**Muckle Roe**	Shetland
Erraid	Argyll & Bute	**Flotta**	Orkney	**Papa Stour**	Shetland
Gigha	Argyll & Bute	**Graemsay**	Orkney	**Trondra**	Shetland

[2] https://www.scotlandscensus.gov.uk/
[3] https://www.ssen.co.uk/generationavailability/

Island	Council area	**Island**	Council area	**Island**	Council area
Iona	Argyll & Bute	**Hoy**	Orkney	**Baleshare**	Western Isles
Jura	Argyll & Bute	**North Ronaldsay**	Orkney	**Bernera**	Western Isles
Kerrera	Argyll & Bute	**Papa Westray**	Orkney	**Berneray**	Western Isles
Lismore	Argyll & Bute	**Rousay**	Orkney	**Eriskay**	Western Isles
Luing	Argyll & Bute	**Sanday**	Orkney	**Grimsay A**	Western Isles
Oronsay	Argyll & Bute	**Shapinsay**	Orkney	**Grimsay B**	Western Isles
Ulva	Argyll & Bute	**Stronsay**	Orkney	**Scalpay**	Western Isles
Canna	Highland	**Wyre**	Orkney	**Vatersay**	Western Isles
Eigg	Highland	**Bressay**	Shetland		
Knoydart	Highland	**Bruray**	Shetland		
Muck	Highland	**East Burra**	Shetland		
Raasay	Highland	**Fair Isle**	Shetland		
Rum	Highland	**Fetlar**	Shetland		

Figure 1: Map of the islands shortlisted for study



Phase 2 – Data collection - desk-based study
Phase 2 was the first data collection phase, focussing on collating and analysing publicly available information from internet sources.

All 49 islands were included in this stage and information relating to population, demand, heating type, renewable developments, Scottish Index for Multiple Deprivation (SIMD), fuel poverty, transport to and from island, digital connectivity and network infrastructure was sourced for all islands (sources can be found in the Appendix 1).

The distribution network operator (DNO) for the study area is Scottish and Southern Electricity networks (SSEN). They produce constraints maps which provide information on generation and demand constraints, including the islands selected for study[4] that are connected to their network.

The Fuel poverty data was only available for a resolution at 'data zone'[5] not island level. Each data zone has a minimum population of 500, maximum 1000, so a data zone covering a target island, will also include households out with the island. A more detailed study could use island specific data on fuel poverty, that might be held by the local authority.

Domestic heating systems data was taken from Energy Performance Certificates, but no data was available on non-domestic heating systems.

2.2 Phase 3 - Data collection – interview stage

Phase 3 sought to verify the information gathered in Phase 2 as well as gather additional information by interviewing island inhabitants. Interviewee's were generally members of community development trusts, or representative community organisations, whom HIE have a relationship with, or knowledge of. Contact information was provided for 40 islands of which 24 were available for interview.

The interviews were broken down into three sections:

- Section 1: Source of electricity/heat.
    - Grid connection (e.g. private wire, off-grid homes etc.).
    - Energy storage.
    - Renewables (electricity).
    - Renewables (heat).
    - Non-renewables (electricity).
    - Non-renewables (heat).
- Section 2: Supply characteristics.
    - Information on frequency of outages, time to reconnect, costs etc.
    - Restrictions (e.g. are there timed connections, consumption limits etc.).
    - Quality.
- Section 3: Demand characteristics.
    - Demand (electric + heat).
    - Community ownership.
    - Transport to/from/on the island (comments on transport options to and on the island).
    - Outlook (e.g. details on predicted developments that may change island demand).

[4] https://www.ssen.co.uk/generationavailability/. These maps provide an indication of the level of generation and demand constraint at substations and grid supply points across the distribution network. This includes the cause of the constraint. The information provided is updated periodically, so may not present a completely accurate picture at the time of this study

[5] https://www.nrscotland.gov.uk/files//geography/2011-census/geography-bckground-info-comparison-of-thresholds.pdf. It is understood that data is available at a higher resolution, but this was not available within the timeframes for this study.

- Fuel poverty (e.g. Changeworks data, island reports, anecdotal evidence).
- SIMD.
- Digital connectivity (e.g. issues relating to broadband and mobile coverage).

Information on the energy system supply chain, ownership and project finance was requested, but limited information could be provided by the interviewees.

Finally, several HIE employees who have knowledge of island energy challenges, community development, communication infrastructure and other related policy and regional information fed into this study. This included an interview with the HIE Digital Team to gain a more up to date picture of communications infrastructure on the islands.

2.3 Phase 4 – Analysis

The final phase analysed the data collected during Phases 2 and 3 to identify common themes, specific energy challenges and conclusions and highlight any potential opportunities and solutions

2.4 Island energy system study data

The research was successful in gathering data across a range of topics relating to island energy systems within a defined timeframe and scope. There are a couple of observations about the data collected.

Desk-based research on small island energy systems, is restrictive as it relies on the resources being available to publish and publicise any relevant reports and studies produced on the island. This can result in patchy information that is out of date, lacks detail on project specifics or is not available at an island resolution level. The desk-based research phase provided a high-level overview of online resources and public databases, which were then the basis of the interview process to verify the results where possible.

Publicly available data sources at the level of granularity specific for islands, is not available. To collect this data requires interviews with appropriate representatives on the island and potentially individual island audits. The resolution of publicly available datasets is usually set around a population threshold, which makes the data zones small in more urban areas and large in rural areas. Local authorities may have access to more granular datasets. For example, the Small Isles and the Ardnamurchan peninsula are all included in a single data zone in comparison to the main town of Ullapool that is split into two data zones. Any conclusions drawn from these datasets, needs to be considered carefully in the context of the island.

The accuracy and depth of the information collected from the interviews, relied on the knowledge of the interviewee. The level of energy knowledge varied greatly between interviewees and so the level of detail gathered. Much of the information provided by the interviewees was one person's account of the situation on an island and may or may not be representative across the island as a whole. The interview stage provided a wealth of qualitative data. A more detailed study might consider interviewing more than one person on the island, or completing an island audit, by visiting the island to fill the gaps in the data.

Those islands that had established community groups, had development officers and/or had engaged community trust board members, were generally well informed on issues related to island life across a range of topics. Those with less developed community groups were generally less informed and as such were able to provide significantly less detail on island energy system issues. This finding highlights that some communities have a better understanding of island systems than others and so are more likely to be able to identify issues and contribute to proposed solutions. This also means energy system solutions need to be tailored in a way that fits not only the energy needs of the island, but also the ability of the community to facilitate, deliver and engage with it.

3 Island context

A recent study for Scottish Enterprise categorised Scotland across different typologies:

- Small remote island.
- Large Island.
- Remote green village.
- Off gas grid green town.
- On gas grid commuter town.
- On gas grid industrial town.
- Large urban.
- Industrial park/ campus.

Each typology is categorised by 12 different metrics such as population density, average electricity use per m^2, gas grid availability and average heat density.

This study focuses on the small remote island typology (definitions taken from an International Local Energy Systems study funded by Scottish Enterprise (see Appendix 2)). This typology is characterised by low populations, low population density and remoteness. This section summarises contextual information for the islands in the study relating to specific resilience circumstances faced by communities in contrast to more connected populations on the UK mainland, including geographical access and population levels.

3.1 Geographic access to services

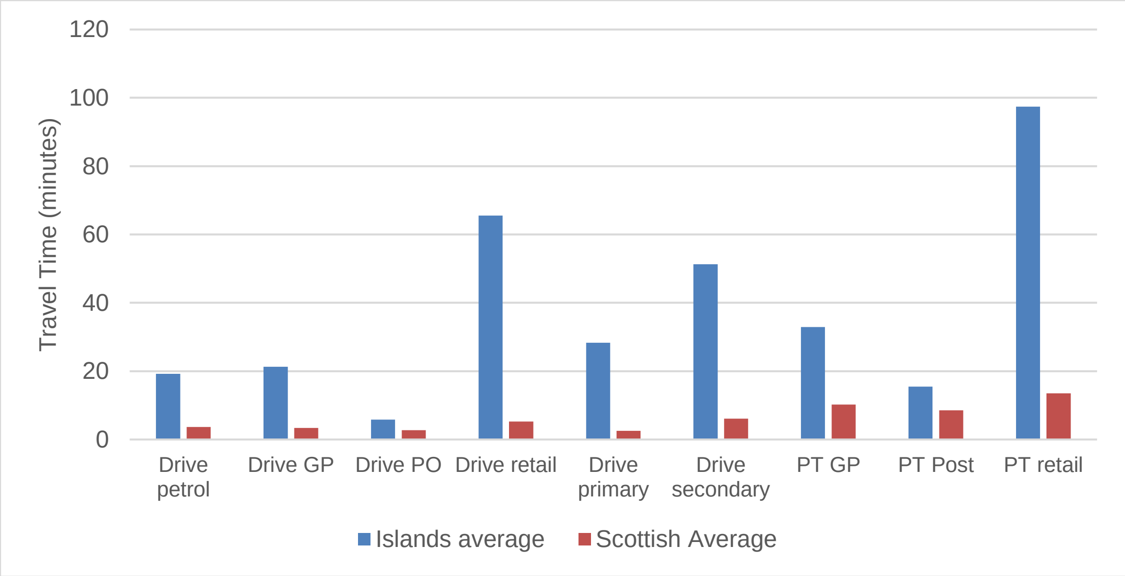
SIMD data was used to determine geographic access to services[6].The geographic access indicator is made up of the following measures of access:

- Average drive time to a petrol station in minutes.
- Average drive time to a GP surgery in minutes.
- Average drive time to a post office in minutes.
- Average drive time to a retail centre in minutes.
- Public transport travel time to a GP surgery in minutes.
- Public transport travel time to a post office in minutes.
- Public transport travel time to a retail centre in minutes.

Most islands in the study are ranked in the bottom 10% for geographic access to services (Muckle Roe and Vatersay being the exception), with Canna, Eigg, Rum and Muck scoring the lowest. This data demonstrates the level of remoteness from services that islands face. Journey times are on average 30 minutes longer for those located within an island data zone when compared to the Scottish average. This is broken down further (see Figure 2), where travel times to retail outlets and secondary schools are the highest when compared to the Scottish average (for further details see Appendix 4).

[6] for details on methodology and for more detailed results refer to Appendix 3. SIMD data is provided across 'data zones' so is not island specific. Where a data zones spans more than just the island, the figures will not be completely accurate, but will still be representative

Figure 2: Geographic access times for the sample islands and the Scottish average.



Inherent in island life are differences in transport requirements and how these are met. Journeys are longer, timetables can be inflexible and public transport less accessible. Most of the sampled islands are accessed *via* ferry and a high number are linked to other islands via causeway. Very few islands interviewed are currently accessed by plane.

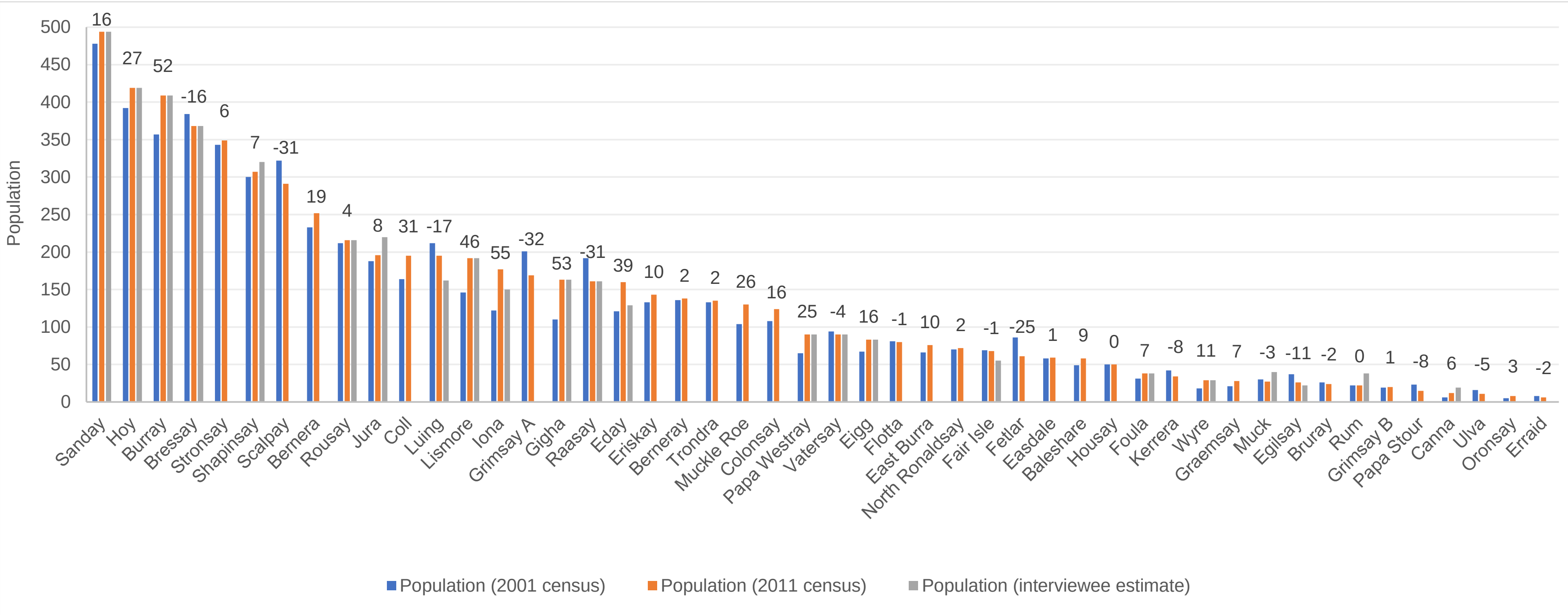
Access to the small isles (Canna, Eigg, Muck and Rum) is by ferry only. While in theory this makes the communities vulnerable to adverse weather conditions, none of the interviewees noted this as an issue. Fair Isle and Foula can be accessed by ferry and plane and both noted that travel was often disrupted by weather conditions. Access to Knoydart is by foot passenger ferry (private ownership, with a Highland Council subsidy) and travel by vehicle must be arranged by chartering the local landing craft. Weather exposure and location are both key factors affecting access to services.

Some common themes were that ferry cancelations owing to adverse weather conditions were an inconvenience, the addition of causeways was noted to improve access and logistics considerably and that most car journeys were short. Transport to/from the islands can be exposed to delays or cancellations in adverse weather conditions. In addition, travel represents a financial cost to the inhabitants not faced by the mainland population. This is also true for the local businesses as the cost of freight can be significant and can impact the competitiveness of island-based business.

3.2 Population

Of those islands where someone was available for interview, five estimated that population had increased, five estimated a decrease and six estimated it has stayed the same (Burray, Gigha, Knoydart, Papa Westray, Rousay, Scalpay), the remainder were unable to provide an estimate (Bressay, Eigg, Foula, Hoy, Lismore, Raasay, Vatersay, Wyre). According to the 2011 census, the population of 30 islands increased, it decreased on 16 islands and stayed the same on 2 islands with respect to the 2001 census. Figure 3 shows the population from the 2001 and 2011 census as well as the island interviewees estimate of current population. Where there was no one available for interview, it was assumed that the population was constant from the 2011 census.

Figure 3: Island population data from the 2001 and 2011 census in comparison to the interviewees estimate of current population.



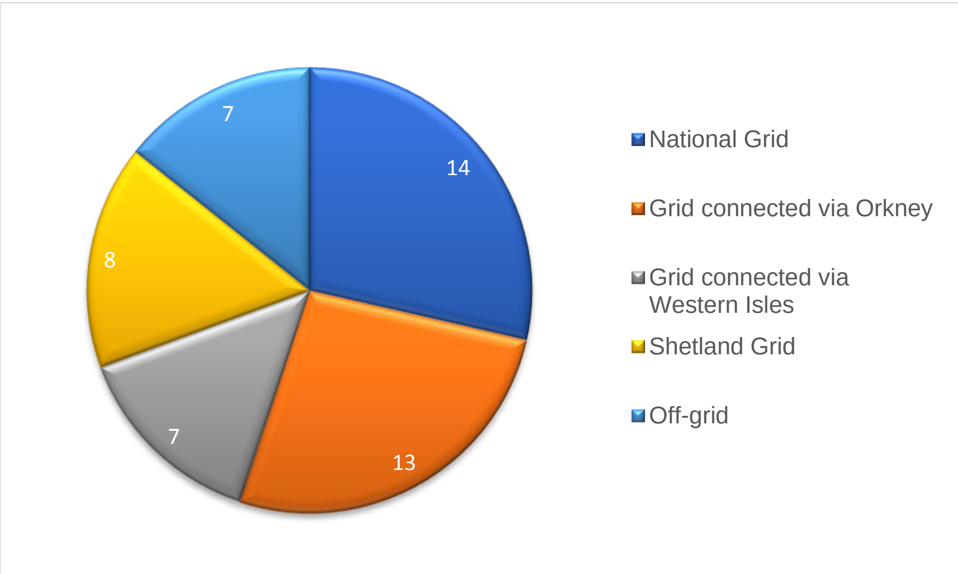
3.3 Electrical infrastructure

The status of the grid infrastructure is changing, both technically, with upgrades to subsea interconnectors and operationally, with the move from DNO to Distribution Service Operator (DSO).

The 49 study islands are connected to electricity networks in ways that have different constraints and so differing influences on generation and demand on the islands (Full island list in Appendix 6):

- Orkney interconnector: 13 of the islands are connected to the Orkney network which sits behind the two Rackwick Bay interconnectors to the mainland transmission network.
- Shetland network: 8 of the islands are connected to the Shetland network, a separate network, not currently connected to the mainland transmission network.
- Western Isles interconnector: 7 islands are connected to the Western isles, behind the interconnectors at Loch Carnan and Stockinish to Ardmore on Skye.
- Off-grid islands: 7 islands have their own microgrid that is not connected to the mainland.
- National grid: the remaining 14 islands are all connected to the mainland distribution network.

Figure 4: Breakdown of sample islands by connection type.



3.3.1 Islands connected to the Orkney Grid Network

The significant wind resource on the Orkney Isles has made it an attractive area for the installation of wind turbines and has the highest concentration of small/micro wind turbines in the UK, in addition to several larger schemes[7]. The result of this is that at times, the generating capacity is greater than demand and the islands became a net exporter of energy in 2013.

At times, the amount of electricity that could be generated on the islands, exceeds the capacity of the interconnector to the mainland or the grid connections between islands, so no further generation capacity is able to connect to the network. The primary solution implemented by the SSE to address this is Active Network Management (ANM)[8].

[7] http://www.oref.co.uk/orkneys-energy/wind/
[8] https://www.ssen.co.uk/ANM/

The Orkney ANM scheme splits the grid into zones and manages which generators can generate power at any one time, prioritising generation on a last in first out stacking order. This allows a greater number of generators to connect to the network than would be possible if they were not managed but does mean those generators connected most recently experience higher levels of curtailment than those connected first. This type of project has high costs associated with it in terms of set up and operation and so is best suited for larger scale schemes. Most DNOs across the UK now have an ANM zone as part of their network.

An upgrade to the interconnector is being consulted on, which could allow additional generation to be connected without connecting to the ANM zone which may result in an additional export capacity of > 200MW[9].

3.3.2 Islands connected to the Shetland Grid Network

Shetland have similar issues to Orkney as they also have a significant wind resource, however they are not currently connected to the UK mainland grid and so cannot export surplus power[10]. Shetland also manage the output from generators using ANM, through the Northern Isles New Energy Solutions (NINES) scheme. As on Orkney, several projects have been implemented as part of this management scheme including demand side in the form of electric heaters and a large-scale battery storage, to balance generation and demand and to improve the quality of network operation.

A needs case for the upgrade to the interconnector to 600MW by March 2024 was approved by Ofgem on the condition that the Viking Energy Wind Farm is awarded a Contract for Difference (CfD) in the 2019 allocation round[11].

3.3.3 Islands Connected to the Western Isles Grid Network

The Western Isles grid is like Orkney in that it is connected to the rest of the UK via a subsea 'interconnector' cable. The current interconnector cable is at maximum capacity which has put a hold on the ability to connect any further renewable generation, without an increase in demand. ANM solutions are also being investigated for the Western Isles. The needs case to upgrade the interconnector to 600MW by October 2023 was rejected by Ofgem owing to concerns over value for money[12]. Ofgem have suggested that they would approve a 450MW connection provided both the onshore wind projects currently being developed by Lewis Wind Power (circa 369MW capacity) are successfully awarded a CfD in the 2019 allocation round. National Grid will bear the cost of the upgrade which will ultimately be re-cooped via 'use of system charges' on consumer energy bills

3.3.4 Off Grid Islands

Seven of the sampled islands are not connected to the national grid, or the grids on Orkney, Western Isles or Shetland. Regulations governing grid upgrades require a justifiable business case for network upgrades or extensions to take place. Given the remote location of the islands and the small demand, the lack of a business case for an expensive undersea interconnector may be one reason that these islands have not been connected.

Both demand and generating potential on these islands is relatively small and because of the distance from mainland connection on these islands, this makes it unlikely that the islands will be connected to the national grid in the medium term. As a result, the seven islands have developed energy solutions that are self-contained. The demand on these islands is met a range of complementary technologies

[9] https://www.ssen-transmission.co.uk/projects/orkney/
[10] http://www.ninessmartgrid.co.uk/our-project/shetland-energy-challenge/
[11] https://www.ofgem.gov.uk/system/files/docs/2019/04/shetland_consultation_updated_30042019.pdf
[12] https://www.ofgem.gov.uk/ofgem-publications/151095

such as wind, solar and hydro generation. On these off-grid islands, there is a need for diesel generators to be connected, to balance supply and demand

3.3.5 Export Constraints on the Networks

Islands are often connected to a remote part of the network, where there is a limit on the amount of electricity that can flow through the distribution network. The direction of electricity flow is not uniform. Some islands, with less local generation are completely reliant on electricity imports to the island, the grid constraint on islands like the Orkney archipelago, where there is excess local generation, limits the amount of electricity that can be exported from the grid.

Constraints may be caused at a grid supply point (connection from distribution network to the transmission network), a substation on the distribution network that cannot allow any more electricity to pass through from one section of the network to another, or the cables the electricity is carried along. They can be triggered by several factors, such as localised voltage levels, thermal limits on the cable, upstream restrictions at transmission level or fault levels. Those islands that are connected to the mainland grid through an interconnector can have localised constraints that are less prevalent on the mainland, due to a reduced level of network connectivity.

Across the study islands, as with the rest of Scotland, any new generation wishing to connect to the network will need to pay for the upgrade to the relevant infrastructure. Typically, the generator requesting the connection would be expected to pay for reinforcement of one voltage level above the one they are connecting to (e.g. 33kV if connecting to the 11kV network). As such, grid constraints can act as a barrier to new low carbon energy development. This might mean a single new generator is required to pay some significant and expensive upgrades to overhead lines and transformers to allow them to connect.

Single phase supply

A 3-phase electricity supply allows a greater level of AC power to be distributed than single phase and are a requirement for larger demands, normally non-domestic, such as some motors or pumps.

The location of single phase, or 3-phase power lines is not publicly available and given this would cover the low voltage lines across Scotland, would be a large data set.

Interviewees were asked whether they were aware of the presence of 3-phase; only three islands reported having 3-phase electricity and two reported part coverage. This is clearly not a representative sample. Although 3-phase power is widely available across most of the distribution network, some of the more remote locations are restricted to single phase (such as on Eglisay and Vatersay).

Understanding the supply levels is important when considering future projects that will have an impact on the energy system such as fast or rapid chargers for electric vehicles (EVs), low carbon electric heating (such as heat pumps, a 15kW heat pump will require 3-phase electricity). The location of certain businesses, which include industrial processes, can be constrained by the network. More complete information about the availability of 3-phase electricity on these islands could potentially be obtained from SSEN. This could determine how much this might impact future uptake of EVs and heat pumps.

If an island, village or property/generator wished to upgrade from single to 3-phase, they would have to fund the upgrade the single-phase line back to a point where they could tee-off a 3-phase line. If, however there was a general increase in demand along a line (not from a single point), it is likely the network operator would take on the cost of upgrading the line.

3.3.6 Electricity Demand Constraint

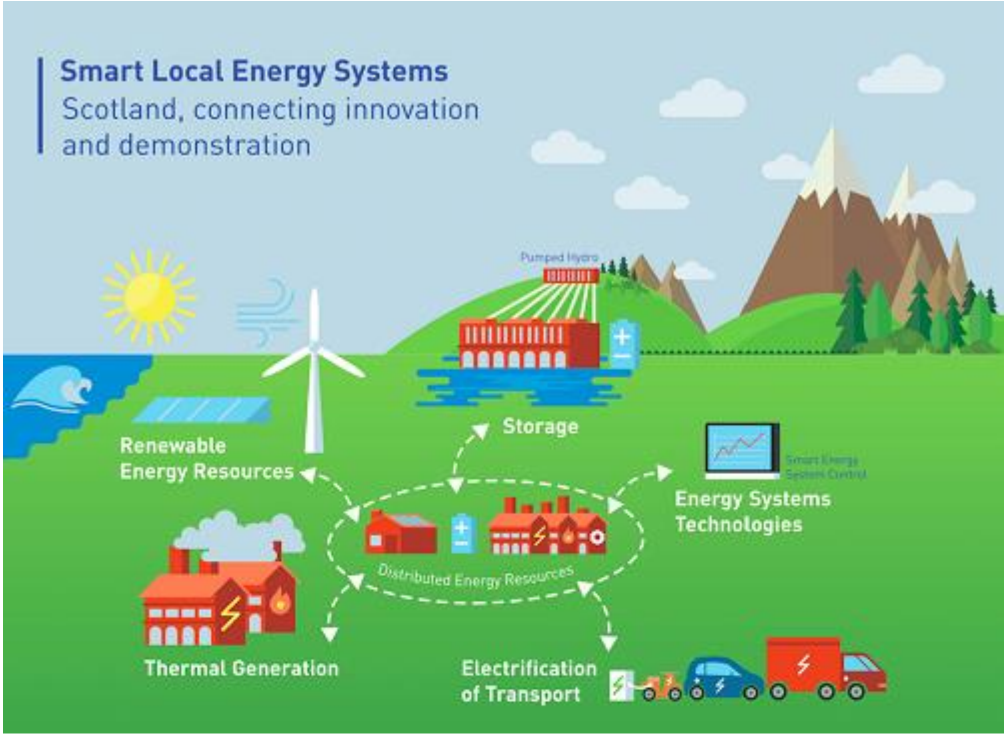
The SSEN Contracted Demand Map[13] does not show any grid supply points, bulks supply points or substations that are constrained for the connection of new demand across the grid connected islands that were reviewed as part of this study. This shows that there is capacity for additional demand to be connected anywhere across the network. Larger non-domestic loads may require network upgrades to overhead lines or transformers, but this would be an increase in demand of hundreds of kW. Demand constraints can be more of an issue in more highly populated areas. The increasing levels of distributed generation can mean bi-directional flows of power along lines that were not designed for this. An example of a project that is being used to investigate methods of addressing this issue is the Innovate UK funded Project LEO in Oxfordshire[14].

Given that many island homes will have electric heating, peak island electricity demand will be in the winter. Meeting this winter peak will set the capacity needed for the electricity network and for the generation and storage on any off-grid islands. Power failures in winter are a risk for the island population, as electric heating systems need electricity (for pumps and controls). This risk is more severe for households with younger or older occupants.

4 Island energy systems

A whole energy system is an example of energy sector coupling and considers not only energy generation, but supply and demand across multiple energy vectors, such as electricity, heat and transport (Figure 5).

Figure 5: Factors contributing to a local energy system (including some not available on Scottish Islands).



In consideration of types of island energy systems, the study assessed:

[13] https://www.ssen.co.uk/ContractedDemandMap/?mapareaid=2k
[14] http://news.ssen.co.uk/news/all-articles/2019/april/ssen-announces-ground-breaking-innovation-project-to-inform-the-future-of-local-energy-systems/

- Island Energy demand (type and scale).
- Low carbon generation.
- Security of supply.
- Cost of energy to the consumer.
- Fuel poverty.

This section summarises the findings relating to island domestic demand for electricity, heat and transport. Domestic energy demand is not published on an island scale, so estimates are needed based on alternative sources of data. Energy Performance Certificate (EPC) data analysed across the islands, showed very unreliable estimates of total energy demand and heat demand, significantly higher kWh/m^2 figures than feasible. However, as the only granular data set available for the islands, we have used the floor area and heating type data.

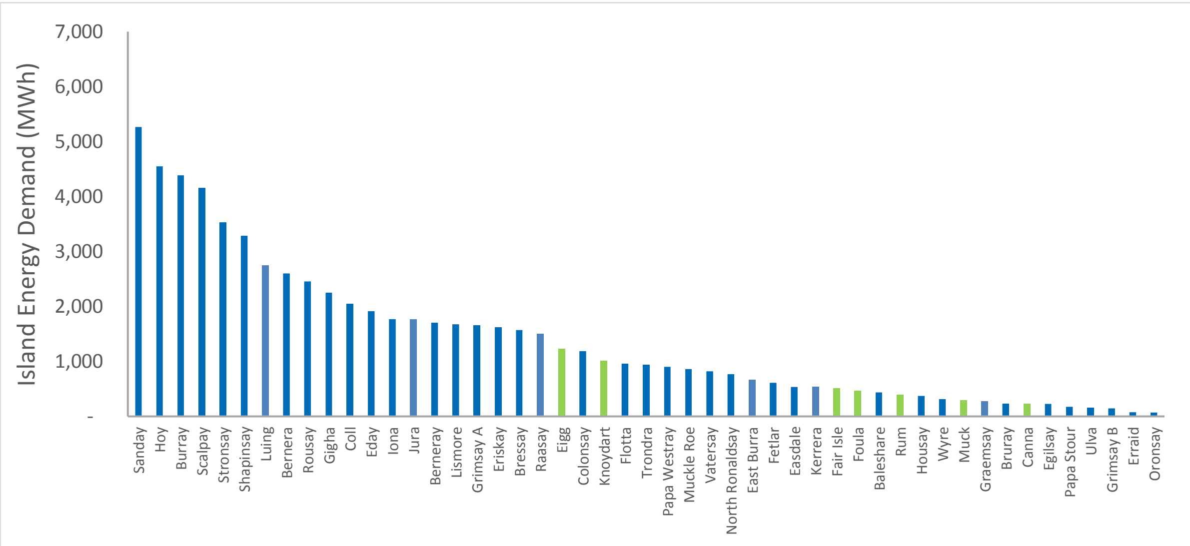
The domestic energy demand on the island was estimated by using:

- industry benchmark values for electricity demand[15].
- a heat loss calculation based on average property floor area (from EPCs) and average heat loss coefficient per m^2 of floor area[16]
- industry benchmark domestic hot water demand calculations[17]

These figures were added to give the total energy demand. The detailed methodology is shown in Appendix 5. It was important to be determine separate space heating demand and hot water demand, given the high prevalence of electric heating across the islands, which is discussed in the following sections[18].

Figure 6 presents the total domestic energy demand on each island, with the off-grid islands highlighted in green. This was calculated by multiplying the average domestic energy demand by the number of households on the island.

Figure 6: Total island domestic energy demand



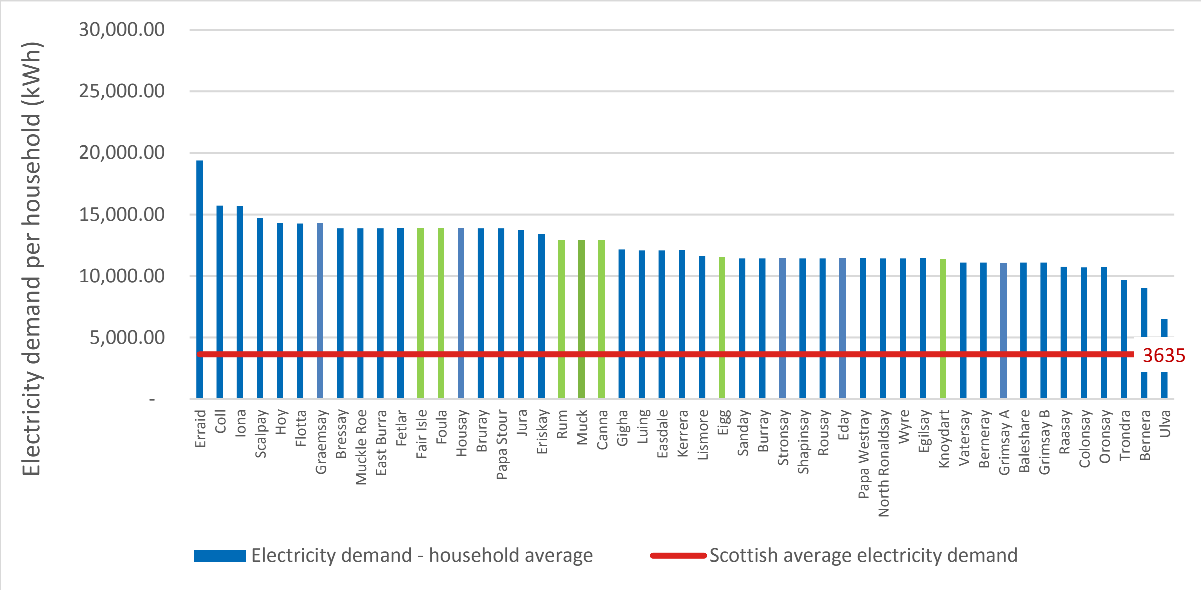
[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/678653/Sub-national_electricity_and_gas_consumption_summary_report_2016.pdf
[16] https://www.bsria.co.uk/information-membership/bookshop/publication/rules-of-thumb-guidelines-for-building-services-5th-edition/
[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48188/3147-measure-domestic-hot-water-consump.pdf
[18] EPC data was analysed across the islands. The heat and electricity demand data that was recorded in a large number of the EPCs was incorrect, indicating some invalid EPC modelling had been completed and submitted to the EPC register.

The total energy demand largely reflects the number of properties on each island rather than differences in energy demand per household. The top three islands in terms of both population and energy demand are Sanday, Hoy and Burray, while the smallest on both indicators are Erraid and Oronsay.

4.1 Electricity demand

This section breaks out the electricity demand from total island demand summarised above. Figure 7 shows the average household electrical demand on each island against the Scottish average of 3635 kWh/year[15]. Again, the off-grid islands are highlighted in green.

Figure 7: Mean domestic electrical demand by island (modelled).



Electric heating for domestic properties is prevalent on these islands. On average 55% of domestic properties are heated by electric heating[19], compared to less 12% for the whole of Scotland[20]. To account for the electricity usage resulting from the electric heating, the proportion of electric heating systems on each island, was multiplied by the heating demand and the hot water demand per household. This was added to the Scottish average electricity demand (after subtracting 12% for average electricity demand, to account for the share of electric heating across Scotland). For islands like Canna, Muck and Rum where no data was available, or islands like Colonsay, Eigg, Iona and Oronsay where only a very small number of records were available the proportion of electric heaters has been taken as the overall average across all islands.

It is recognised that these figures are only indicative, as they combine figures from different sources, however, they do give a clear indication that the average household electricity consumption across the islands is significantly higher than the average Scottish demand.

It should be noted that official statistics quoting domestic electricity demand also differ significantly from the calculated results. BEIS bases its calculations on electricity consumption of 3800kWh/year per household[21], roughly in line with the Scottish average. Ofgem's highest estimate for electricity consumption is 7100kWh/year[22]. The estimated average annual household consumption of 12,432kWh/year from this study, suggesting that the figures used to inform UK policy do not account fully for the electricity consumption on the islands.

[19] 2011 census data
[20] https://www.gov.scot/publications/energy-efficient-scotland-future-low-carbon-heat-gas-buildings-call-evidence/pages/4/
[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/812626/Press_Notice_June_19.pdf
[22] https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values

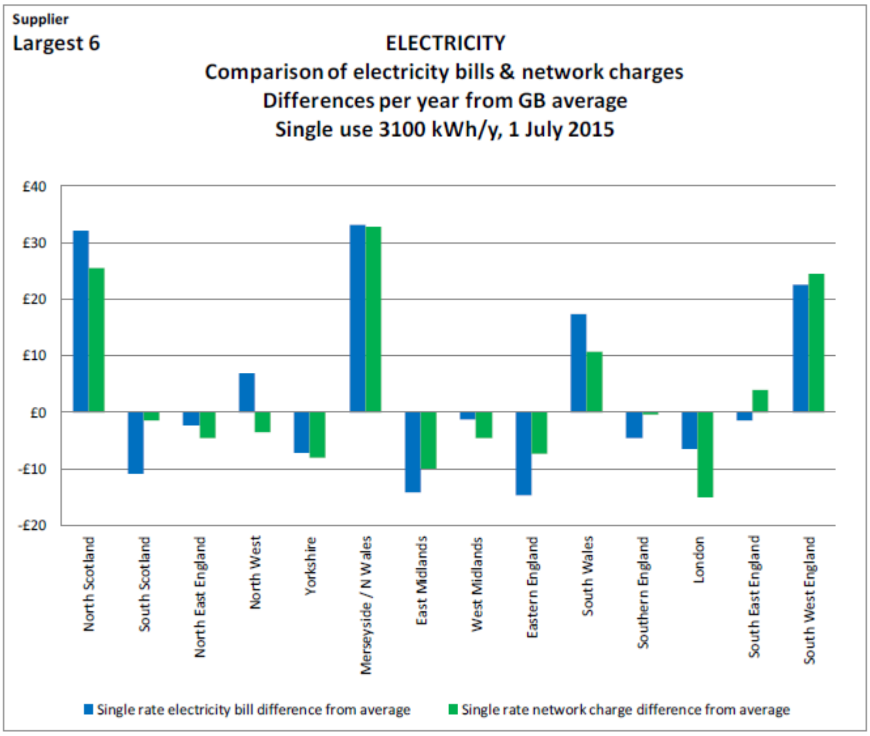
Non-domestic electricity demand figures are not publicly available, and it is not possible to estimate these using any standard metrics. The islands non-domestic electricity demand is seasonal (tourism, some fish farming), which can work well for the energy system. The grid is designed to supply peak load, which is normally domestic demand on the coldest and darkest days of the year. The summer months, when domestic demand is lower, coincide with increases in demands from tourism.

4.1.1 Electricity consumer costs

For islands connected to the grid electricity prices will be set by two factors: regulation (for network charges) and competition (between electricity suppliers).

Operating the distribution network across rural area results in more infrastructure and greater losses, so costs are higher, which has resulted in higher network charges[23]. These additional costs are reflected in the regional differences in electricity price and are not calculated or available at island resolution, rather the DNO area. The graph below demonstrates this disparity of pricing in the North of Scotland DNO area operated by SSEN compared to the rest of the UK.

Figure 8: Comparison of electricity bill and network charge differences from the GB averages (OFGEM 'Regional differences in network charges' report 2015).



Higher network charges and the estimated higher than average consumption rate on small islands shows that annual electricity bills on the study islands will be much higher than mainland UK and Scottish bills. Assuming an average electricity consumption of 12,432kWh/year (the average is obtained from the modelled electricity consumption) and difference between GB average and North Scotland of £32 for 3100/kWh, the difference between island average bills and GB average bills is around £130/year.

The Common Tariff Obligation[24] ensures electricity suppliers in the North of Scotland are not able to charge comparable domestic consumers different prices solely based on their location within the area.

23 https://www.ofgem.gov.uk/sites/default/files/docs/2015/10/reg_charges_final_master_version_23_october_2015.pdf

24 https://www.gov.uk/government/consultations/hydro-benefit-replacement-scheme-and-common-tariff-obligation-three-year-review-of-statutory-schemes-consultation

This is designed to protect consumers in remote rural areas or islands from the relatively high costs of supplying electricity in these areas. Further, some attempt has been made by OFGEM to subsidise the cost of electricity in 'North Scotland' through the Hydro Benefit Replacement Scheme. This scheme protects domestic and non-domestic consumers from the high costs of distributing electricity in the North of Scotland. In 2015/16, it provided an assistance amount of £57m to consumers in the North of Scotland and in 2016/17 this increased to £58m. This is worth around £41 per household, although does not apply to off-grid communities.

The range of domestic electricity prices stated during the interview phase were between 14p/kWh and 25p/kWh[25], the latter is for an off-grid island. For comparison, OFGEM figures for average UK domestic tariffs[26] in 2017 were 16.3p/kWh. Whilst these interviews indicate the study islands electricity prices are close to the national average, only a few islands responded with their electricity prices, so these figures are not conclusive. Several islanders also noted the lack of supplier switching activity, which indicates that islanders may not be on the most optimum tariff rate available.

Electricity prices for off-grid consumers are higher than the UK average. The electricity price needs to cover capital costs, maintenance costs, operation costs and distribution costs for the generation and supply of electricity, with prices set by a mix of short term and long-term market forces. On off-grid networks, public financial support may have contributed to the energy system costs, so influencing the electricity price. Where the DNO can socialise operating costs across a larger number of consumers, the operating costs of the off-grid schemes must be recouped through a smaller pool of customers. The operating costs of the off-grid schemes were not known by those interviewed, but it is recognised that these are likely to be higher per person than on the mainland. On an off-grid island, operations and maintenance are often carried out at least in part, by the islanders.

Off grid electricity systems will not require a licence for distribution or supply of electricity. This means that the regulation and price controls that apply on grid do not apply and there is no collection or review of pricing by Ofgem. Costs relating to the operating, maintenance and upgrade may lead to electricity pricing at a level that puts off grid electricity consumers at risk of fuel poverty.

Off grid Islands noted much higher costs than on-grid islands at between 25p/kWh (domestic) and 40p/kWh (non-domestic). While it is the case that electricity costs are higher than for grid connected consumers, the off-grid renewable powered systems do reduce costs if compared to fuel imports that might otherwise be required to power diesel generators. Further data gathering is required to understand the nature of charging structure used by off-grid islands. In some instances, public finance has been provided to cover the costs of system upgrades, which means the electricity prices are not truly reflective of the generation and supply costs. Optimising off-grid electricity charging models is an option for potential collaboration and knowledge sharing.

HIE research in 2016 on Minimum Income Standards for remote/rural areas in Scotland[27] and the factors influencing the retention of young people in the highlands and islands, identified living costs, including energy costs, were a key consideration[28].

Conclusions

- Electricity demand across the islands is considerably higher than the Scotland average.
- Although there is considerable variation in price estimates provided, Ofgem figures shows the electricity price across North Scotland (so impacting the islands in this study) is considerably higher than UK average.

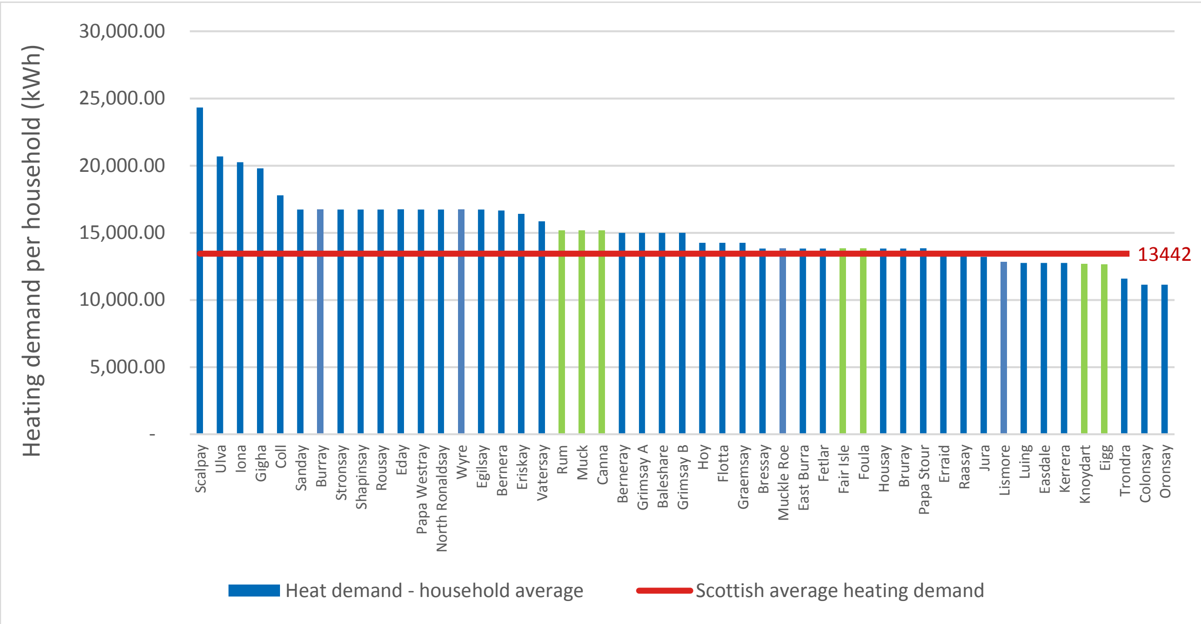
[25] Electricity prices are normally quoted without 5% VAT. So interviewees will have cited these without VAT
[26] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/743709/QEP_Q2_2018.pdf
[27] http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/a-minimum-income-standard-for-remote-rural-scotland---a-policy-update.html
[28] http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/young-people-and-the-highlands-and-islands--attitudes-and-aspirations-research.html

- UK Government estimates for average electricity domestic demand across demand are considerably lower than island estimates based on the proportion of electric heating on the islands.
- The combination of higher electricity demand and higher electricity costs will put islanders at greater risk of fuel poverty.
- As off-grid electricity pricing is not regulated and the costs for operating, maintaining and upgrading the network are borne by a smaller pool of consumers, there is further risk of fuel poverty on off-grid islands.

4.2 Heat demand

This section breaks out the heat demand from total island energy demand summarised above. Figure 9 shows the average heat (space and hot water) demand per household on each island against the Scottish average of 13,442kWh/year.

Figure 9: Summary of domestic heat demand by island



The heat demand does not differ dramatically from the Scottish average. Overall, it is slightly higher, and it could be speculated that this is due to a larger average size of the dwellings, prevalence of detached properties or exposure to slightly harsher weather condition[29].

Despite the similar heat demand these islands have compared to the Scottish average, the fact that nearly 55% of them are electrically heated suggests that heating costs are much higher than the average in Scotland.

Focusing on the remaining 45% of the properties, data on the cost of heat is more complex as there are multiple potential fuel sources and combinations of fuel sources. More detailed analysis is required

[29] It should be noted that the employed estimation method relies on degree days. Inevitably, there are differences in the heat demand based on geographic location. Sensitivity analysis using degree day data from the weather stations on Shetland and Isla have been modelled, and the results heat demand varied by 15%. This is a significant figure, however the degree data for each location was of limited reliability. For our analysis average degree day figures was used.

to determine average heating costs across different fuel types, which will vary from island to island as the supply of fuel from LPG, wood, peat or coal will vary from island to island.

Conclusions

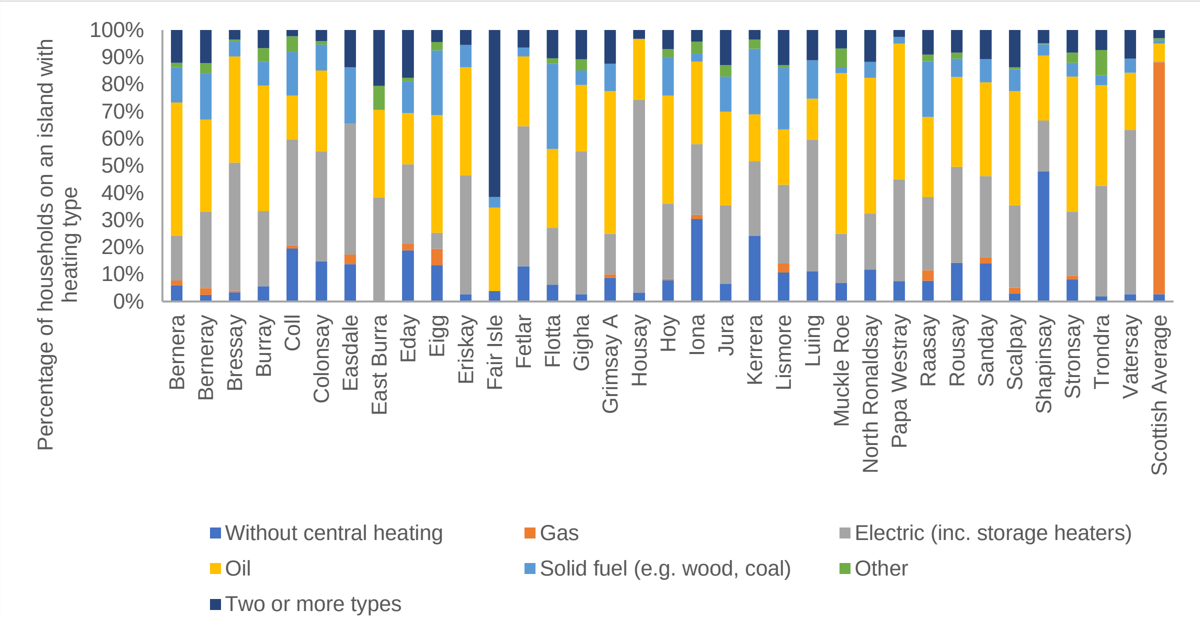
- Average island domestic heating demand like the Scottish average.
- In 4.1 we saw that electricity costs were higher than UK average and it is expected that fuel costs (LPG, wood, peat of coal) would also be higher than average.
- The higher than average heating costs, demonstrate an increasing risk of fuel poverty on the islands.

4.2.1 Domestic Central Heating

Information relating to central heating type was collected from the 2011 Census data. Figure 10 shows the central heating mix for the households on each of the study islands.

There is clear difference between the heating types found on the study islands and the national average. As the islands are not connected to the gas grid, the main heating fuel for most islands is electric (including storage heaters) or oil. The next most common is solid fuel (including wood and coal) followed by no central heating and finally gas central heating. As no islands are connected to a gas grid, gas heating refers to bottled gas.

Figure 10: Percentage of households on each island that have heating type: oil, electric, gas, solid fuel, other or without central heating[30].



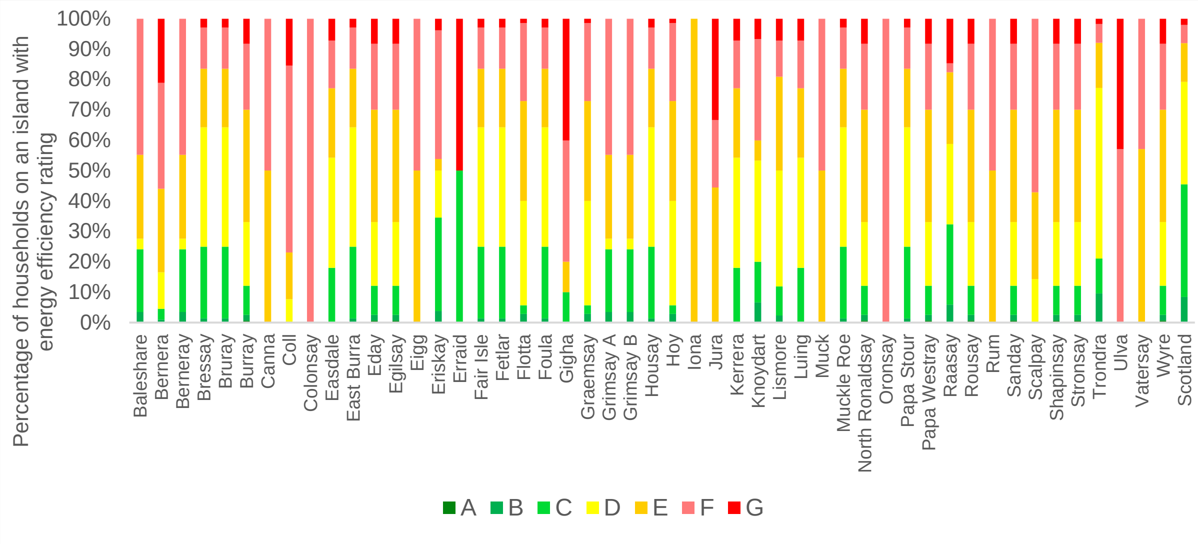
The graph shows there is a considerable number of islanders without central heating, particularly on Shapinsay. There is also a disproportionately high number of households with more than two types of heating type on the Fair Isle.

There are several islands what show a high degree of electricity used for heating, such as Easdale, Vatersay and Housay. Further decarbonisation of the electricity supply will decarbonise these islands more.

The following diagram shows the EPC banding of properties across the islands.

[30] Other includes waste combustion and from a heat network data

Figure 11: Proportion of domestic properties on each island with different energy efficiency ratings[31].



Building fabric can play a large part in the amount of energy that is required to adequately heat the property. Rural building stock can be older and often classed as hard to treat for energy efficiency improvements. For example, many traditional rural homes will have been built with solid walls, which limits the use of cavity wall insulation and results in extra costs for the householder to achieve improvements in energy efficiency. This is confirmed to some degree by the EPC data for each island, which shows that energy efficiency ratings for domestic properties are generally D or lower (Figure 11). In addition to poor energy efficiency, there may be additional costs for islanders to improve their energy efficiency owing to the cost of transporting materials via ferry. This highlights an opportunity for a programme to determine the required energy efficiency measures across the different building stock and then to implement an improvement scheme suitable to each island.

No islands reported have a district heating scheme although it is known that some communities have considered them. High temperature district heating schemes are better suited to high densities of population and reduced distances between properties. Low temperature district heating systems require well insulated properties. All domestic heating provision is currently through individual householder systems.

Conclusions

- The current mix of heating fuels is largely oil and electric on the study islands, so a higher proportion of carbon emissions than across the whole of Scotland, which is largely gas.
- Moving to lower emission heating fuels in the short to medium term means moving to electricity (heat pumps of direct electrical heating) or biomass, although biomass is not always available on islands.
- There is an opportunity for low carbon heating upgrades that can also reduce cost and therefore contribute to reducing the incidence of fuel poverty. Shifting to more efficient electric heating, such as modern storage heaters or heat pumps would also build in a reduction in carbon intensity as electricity (whether island off grid or national grid) reduces in carbon intensity.
- Heat pumps offer an opportunity to deliver electric heating more efficiently but require well insulated properties and low temperature radiators to work effectively as well as enough levels of training of householders in their operation.

[31] The data is the number of domestic properties with different energy efficiency ratings as a proportion of the number of properties with EPC assessments between October 2012 and May 2017 in each post code sector. Post code sector covers an area larger than the individual islands and so the percentage coverage of records over number of households per island ranges from 1% (Colonsay and Iona) and 1570% (Egilsay).

- There are several examples of innovation projects looking to supply heat electrically at lower cost, but the evidence on their performance is not yet publicly available and the business model of these projects, which rely on the Feed in Tariff, may not be replicable under the current policy framework.
- There may be opportunities to look at small district heating systems, amongst smaller groups of houses, using shared ground loop systems or using non-domestic sites as anchor loads.

4.2.2 Non-Domestic Heat Demand

Island respondents reported between 1 and 30 different businesses on their islands, but in many cases, there were several small, sole trader trade type operations that have a small impact on the energy system. Across the study islands, this means there are likely to be in excess of 700 businesses across the islands[32]. For a demand audit to be completed for the number of islands included in this study, it may be appropriate to limit the scope to the larger loads on each island. These could include commercial premises with high energy batch process demand such as whisky distilleries (e.g. Jura, Burray, Colonsay and Raasay) or breweries and more consistent loads such as for fish farms. The scale of the demand is very much dependent on the size of the business and the processes involved and so developing estimates of demand requires further understanding of these processes.

Batch processes requiring high heat demand for short periods, are often met by fossil fuels such as heating oil. Fish farms are often reliant on diesel generators as it is not possible to connect them to the network given their remote location. There are solutions to decarbonising these, such as heat pumps for distilleries[33], or Liquified Natural Gas (LNG) and off-grid renewable generation for fish farms. These solutions are being explored by the different sectors.

Where there is an anchor heat load on an island, there may be an opportunity to connect the heating system to a small localised district heating network. The suitability of district heating is very site specific and requires long term supply agreements to be in place, so a focused island by island approach would be needed, which may come through the development of Local Heat and Energy Efficiency strategies across Scotland[34]. There is one case study of this approach on Islay (Bowmore distillery).

Non-domestic demand data varies from business to business, so from island to island as the industry on each island is different and so the energy requirements are different. In many cases non-domestic consumers may be unaware of their own demand profiles. As such, support for businesses to better understand their consumption is likely to be beneficial, both to the business and for the purposes of understanding island energy demand.

The Scottish Government Resource Efficient Scotland (RES)[35] programme will currently work with any SME (note, not all fish farms and distilleries are SMEs, so might not be eligible for RES support) that engages with them to complete a desk-based audit, or if clusters of businesses on an island are coordinated by a third party, can deliver site audits across a whole island. As well as leading to improvements in energy efficiency and reducing operating costs for the business, this will allow a detailed picture of non-domestic demand to be developed on an island.

Conclusions

- Non-domestic heating will range from small businesses with consumption like homes, through guest houses and hotels, to a small number of industrial users. So, characterisation of these loads is a challenge given that limited data is available.
- Waste heat presents an opportunity for providing a source of low-cost heating, this may come from distilleries or breweries. Further analysis of those islands that have distilleries could

[32] Assuming an average 15 businesses per island
[33] https://pale-blu.com/tag/greenstills/
[34] https://www.gov.scot/publications/local-heat-energy-efficiency-strategies-phase-1-pilots-technical-evaluation-report/pages/3/
[35] https://www.resourceefficientscotland.com/

confirm whether the distilleries operate during the heating season and could identify whether they are sufficiently close to any residential properties for a district heating scheme.

- Coordinated support from Resource Efficient Scotland could potentially improve the efficiency of business on remote islands.

4.3 Projected electricity and heat demand

It is important to understand future island energy demand to steer any energy system development work. Community and economic growth on an island will require a growth in energy supply to accommodate this. Conversely, if there is no available increase in the supply of energy, this may restrict the ability for a community to grow. Reducing the cost of energy will help retain and recruit householders and businesses.

On most grid connected islands, increases in demand are not constrained as can be seen from the SSEN demand heat maps, so there would not seem to be any significant constraints to new developments on grid connected islands. However, there may need to be some grid infrastructure upgrades on grid connected islands if there are significant increases in demand requirements. For example, if a doubling of demand capacity on an island is required, then this might have a localised constraint that is not apparent from the SSEN heat map. This would require engagement directly with SSEN to determine on an island by island basis.

Off-grid islands do need to consider both grid infrastructure and generation infrastructure upgrades for all new demands on the island. The balance of generation and supply in the energy system, being more critical on an off-grid network. Previous off grid systems will have benefited from the FIT, as this has closed to new applicants, new business models may be needed to expand the off-grid system. Interviewees noted changes to island demand that are replicated across several islands and are likely to result from:

- Increased need for houses to accommodate an increasing population.
- Developing business and community expansion.
- Development of a cottage community hospital.
- Increase in marine tourism (overnight berthing, pontoons, moorings).
- New and growing distillery businesses.
- Breweries.
- Fish farms.
- Refurbishment of visitor attraction facilities which will bring on new demand.
- New tourism accommodation.

4.4 Fuel poverty

Fuel poverty is generally considered to be a significant issue in rural and island communities owing to lower incomes, poor housing conditions (older construction, often poorly insulated) and the types heating energy (oil boilers or conventional electrical heating). The current fuel poverty definition used in Scotland states:

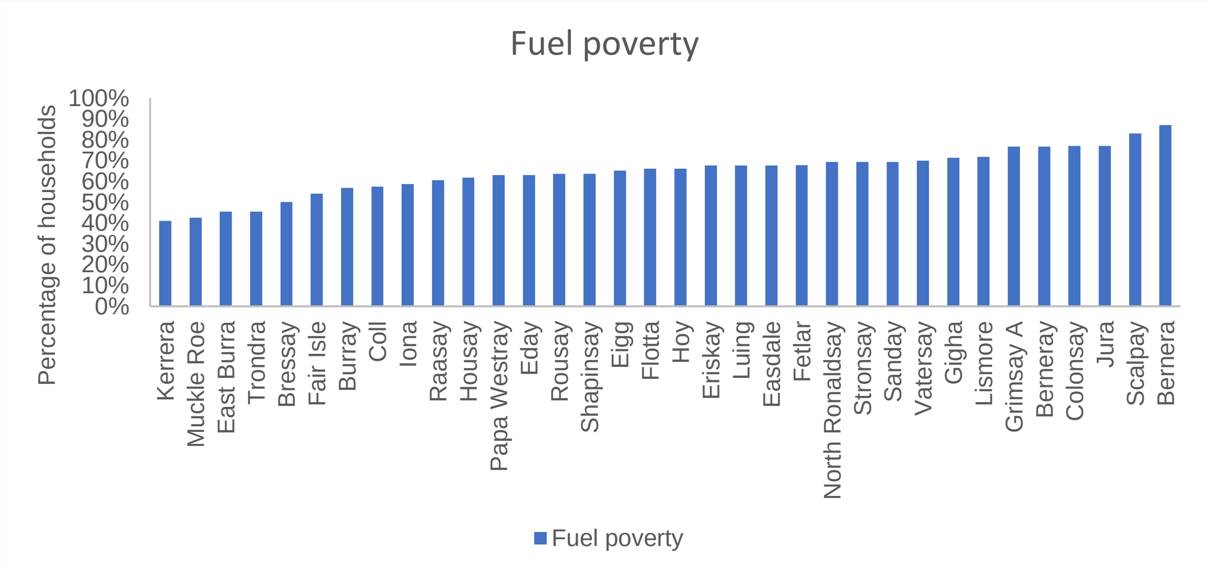
"A fuel poor household is one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth"[36].

[36] The 2017 Scottish Fuel Poverty Definition Review Panel has recommended that a future fuel poverty definition should be based on a Minimum Income standard (MIS) and be based on after-housing costs income. This revised definition states that households in Scotland are in fuel poverty if: 1) *They need to spend more than 10% of their after-housing costs income on heating and electricity in order to attain a healthy indoor*

In 2016, a minimum acceptable standard of living in remote rural Scotland typically required between a tenth and a third more household spending than in urban parts of the UK. The additional costs come from a range of sources. In particular, the costs of travelling, heating one's home and paying for goods and their delivery are much higher for many rural residents, especially those in the remotest areas (i.e. the islands). Our research and assessments of electricity and heat use show that these costs are much more than a tenth and a third more (see Figure 12).

Figure 12 summarises the extent of fuel poverty across the study islands sorted from the lowest (Kerrera) to the highest (Bernera). No correlation was found between the level of fuel poverty and the proportion of electric and oil heating systems. It is very likely that the overall higher levels of fuel poverty in comparison with the rest of Scotland are underpinned by the higher proportion of such heating systems, however the differences between individual islands are likely due to other economic factors.

Figure 12: Graph of % of households in fuel poverty. Islands ordered in ascending order or fuel poverty[37].



It is likely that several factors influence fuel poverty such as fuel cost, EPC rating and household income and so no clear relationship is seen between heating type and fuel poverty. Furthermore, the data available is for the heating type across all households against the percentage of households in fuel poverty, it does not show the heating type of households in fuel poverty. In order to better understand the drivers of fuel poverty on Scottish islands, island specific studies that look at the household's energy demand, heating type, fuel cost, household income and social factors are required.

Fuel poverty prevalence was found to range from 42% to 87% of the households across the study islands[38]. Previous work has shown that fuel poverty levels in areas like the Western Isles are the highest in Western Europe[39]. The report stated that 71% of households in the study were in fuel poverty, in comparison to the national average of 27%.

Conclusions

- The cost of living can be higher for those living in a rural area in comparison to some parts of the mainland UK[40].

environment that is commensurate with their vulnerability status; and 2) *If these housing and fuel costs were deducted, they would have less than 90% of Scotland's Minimum Income Standard as their residual income from which to pay for all the other core necessities commensurate with a decent standard of living. It should be noted that the proposed definition does not take into account the rural MIS*

[37] Data available for 34 of 49 study islands.

[38] https://www.changeworks.org.uk/resources/fuel-poverty-mapping-at-a-small-area-level-1

[39] http://tighean.co.uk/downloads/Fuel%20Poverty%20Report%202014_Email-Layout.pdf

[40] The 2017 Scottish Fuel Poverty Definition Review Panel has recommended that a future fuel poverty definition should be based on a Minimum Income standard (MIS) and be based on after-housing costs income. This revised definition states that households in Scotland are in fuel poverty

- Some interviewees identified that consumers on the islands don't switch energy supplier which may indicate that they are not on the most cost-effective tariff available to them, so a short-term opportunity may be to support this.
- Interviewees indicated some households were in extreme poverty, so analysis of fuel bills, building type, occupancy levels, benefit claims details by the councils could be taken to characterise this in more detail, targeting the most vulnerable households are prioritised through any public support schemes.
- There is no direct correlation between the prevalence of a heating system on an island and the level of fuel poverty, but it is recognised, that one is an influence on the other.

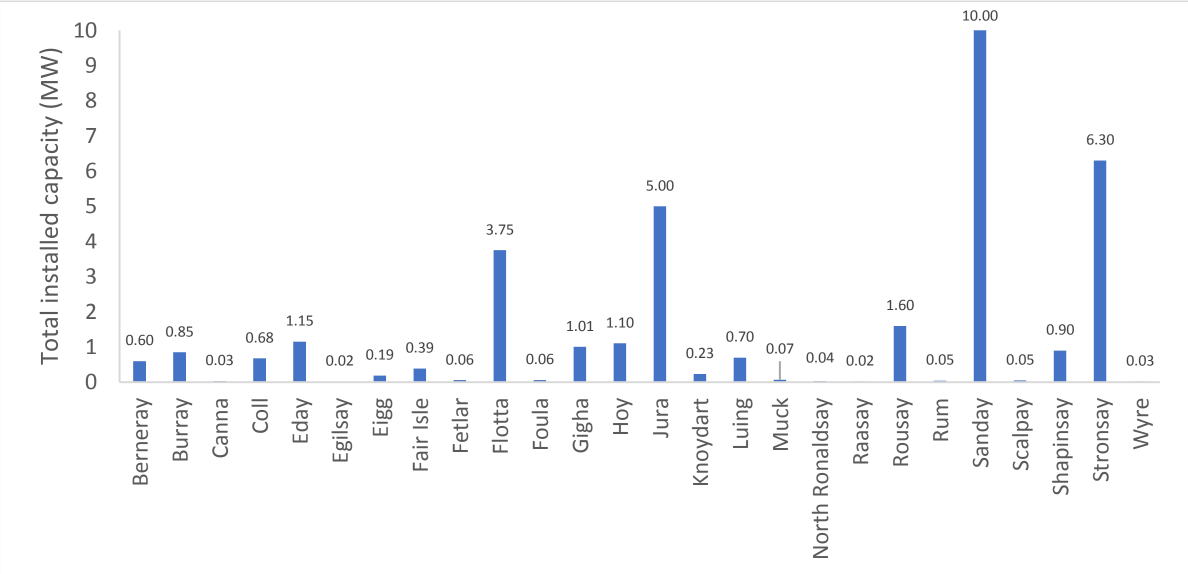
4.5 Energy infrastructure

Energy infrastructure is an essential enabling mechanism for future population and community growth. The reliable, secure and low-cost generation and distribution of power and heat, as well as supporting services, transport and communications strongly influence population retention and opportunities for businesses to grow.

4.5.1 Electricity generation

Taking information from publicly available data sources and from interviews, wind energy was found to be the most common form of electricity generation present on the islands (27 islands), solar second most common (20 islands) with hydro the least common (7 islands). This generation mix is likely to be resource driven as the wind resource is high on the sample islands, so wind turbines become more cost effective. The high proportion of solar installs may be due to early adopters benefiting from the feed in tariff. The small number of hydro schemes is likely due to the small size and therefore small catchment area on these islands.

Figure 13: Total installed capacity of wind, solar and/or hydro power. Summary of data provided during the interview phase, from the Restats database and the renewable energy planning database. Islands where no information was available are not shown.



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if: 1) *They need to spend more than 10% of their after-housing costs income on heating and electricity in order to attain a healthy indoor environment that is commensurate with their vulnerability status*; and 2) *If these housing and fuel costs were deducted, they would have less than 90% of Scotland's Minimum Income Standard as their residual income from which to pay for all the other core necessities commensurate with a decent standard of living. It should be noted that the proposed definition does not take into account the rural MIS*

It is expected that there is likely to be a significant number of small-scale (<50kW) wind, solar and hydro installations not captured by publicly available data sets. This is primarily due to data with poor geographical resolution on MCS-FIT scale generation and there was limited knowledge on the true extent of generating plant by the interviewees. Although a feasibility across the islands has not been completed, it is likely that overall only a fraction of the wind and solar PV potential has been developed.

The large wind resource in comparison to a relatively small local demand for electricity, coupled with a constrained network has led to the under development of island renewable potential and sometimes constraint of existing renewable generators[41]. There is likely to be considerable potential for increased generating capacity on islands if there is a local demand or the network capacity can carry the power.

The 2019 Committee on Climate Change Net Zero report[42] detailed that no one solution to decarbonisation or cost reduction for the energy system is appropriate and that a mix of electrification, low carbon gas/liquid fuels as well as biomass should be incorporated. The same will apply across islands, where the available renewable resource varies from island to island and the demand profiles are different, often driven by key anchor demands on an island.

All islands in this study group face a level of generation constraint as does most of Scotland. No grid connected islands have a constraint in terms of demand. The cost of grid upgrades on islands, that would be borne by the new generators, may be proportionally higher if undersea cabling is required. Where there are several generators trying to connect to the network but cannot due to constraint at the transmission level (such as on the Western Isles[43]), then the Transmission Service Operator is required to complete an assessment of the value for money of the upgrade and make a case to the regulator. If a number of generators apply to connect at a similar time the 'interactivity process[44] is invoked as one connection quote may have a material impact on another.

Operating System lifespans

Renewable generators on islands can have shorter lifespans, higher operational costs and high levels of maintenance than on the mainland for several reasons:

- Higher wind speeds and gusts during winter storms can result in greater maintenance requirements for wind turbines.
- The salt rich sea air increases the rate of corrosion on exposed metals.
- Proximity to the coast is likely to increase wear on components such as wind turbine blades due to high sand content.
- Logistical challenges of getting maintenance crews to the islands and then waiting for weather windows to carry out maintenance tasks.

However, in some cases such as with wind power, the higher winds speeds mean greater electricity generation figures and significantly higher capacity factors.

When considering a whole energy system, there are various component parts which have different lifespans so different replacement schedules. Inverters have a lifespan of 5-10 years, wind and hydro

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[41] A resource assessment across the islands has not been completed as part of this study, or a planning assessment, however it is widely recognised that some islands with high wind speeds have more wind development on them than other islands. For the UK as a whole, no one solution to decarbonisation or cost reduction for the energy system is appropriate and that a mix of electrification, low carbon gas/liquid fuels as well as biomass should be incorporated. The same will apply across islands, where the available renewable resource varies from island to island and the demand profiles are different, often driven by key anchor demands on an island.

similar wind speeds

[42] https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

[43] https://www.ssen-transmission.co.uk/projects/western-isles/

[44] https://www.ssen.co.uk/Connections/InteractivityProcess/

generation may have a lifespan of ~20 and 40 + years respectively. Electrical storage systems vary depending on type (lead acid 8-10 years, lithium ion 10-20 years, flow batteries up to 25 years).

Off grid communities such as Foula highlighted the issue of component obsolescence (control and communications systems, inverters and even wind turbine manufacturers) and the lack of ability to find replacement parts for their systems. In terms of off-grid systems, these components are the responsibility of the network owners and can be more specialist.

There are 15 islands that have community owned wind generators that will be due for replacement or upgrade in the early 2030s.

Table 2: Community energy projects with assets due for replacement in the early 2030s

Island	Technology	Estimated end of life
Easdale	Solar	2031
Eday	Wind	2031
Eigg	Wind, Solar and Hydro	2028
Flotta	Wind	2032
Gigha	Wind	2031
Hoy	Wind	2031
Jura	Hydro	2032
Muck	Wind and Solar	2033
Papa Westray	Wind	2031
Raasay	Wind	2033
Rousay	Wind	2031
Sanday	Wind	2032
Shapinsay	Wind	2031
Stronsay	Wind	2031

This does not cover all generators across all islands. A more focussed assessment of relevant islands will identify more generators. Operation of community owned generators is often managed by the community, particularly on the more remote islands where islanders are trained by the equipment suppliers to carry out routine maintenance tasks. This experience and the presence of a strong community group is likely to have an impact on their ability to operate a wider energy systems project effectively.

Overcoming constraints

A range of solutions have been deployed to manage localised constraints. In Orkney, generators face generation constraints and the local communities who own generators that are constrained, have sought to reduce the constraint by adding additional demand, linked to the generator via a communications link that triggers increases in the new demand, when the generators may otherwise be curtailed.

One such project is Heat Smart Orkney referred to above which added additional electrical domestic heating systems to properties. Like the Heat Smart Orkney project, the 'Surf and Turf'[45] project (on Eday) and subsequent 'BIG HIT'[46] projects (on Shapinsay) aimed to reduce generation curtailment but across a wider area, by adding electrolysers that produce hydrogen when the generators would otherwise be constrained. As the results come through from these projects the learning will be valuable for other grid constrained areas of Scotland.

These projects are large in scale and in the medium term will only be replicated with public sector support in the context of expanding the hydrogen economy in Scotland. In the Western and Shetland Isles similar approaches are being considered. One project in the Western Isles, SWIFTH2, which aims to convert wind power to hydrogen for the purpose of fuelling a new generation of hydrogen ferries operating on islands sailings. A further project, the Outer Hebrides Local Energy Hub (OHLEH) looks to add value to wind energy through the production of oxygen for the aquaculture industry and hydrogen fuel for a refuse collection vehicle respectively. Both projects are still in the development phase.

Grid connected islands such as Gigha and Stronsay have explored installing large scale battery systems to alleviate constraints on existing generators, maximising vital community income from their Feed in Tariff or ROC eligible accredited generators. Large scale battery projects reducing curtailment levels are not yet economically viable. There is a level of innovation in the deployment of battery systems at community scale to reduce curtailment, so may be appropriate for demonstrator funding.

All the off-grid islands have some form of storage as a necessity to maximise renewable penetration and balance the energy system on the island. Two of the off-grid islands (Eigg and Fair Isle) also have flywheels installed by a division of the Williams Formula One team. Unlike batteries or hydrogen storage, flywheels can store energy over a very long-time frames without degradation and are used to manage frequency fluctuations. The Isle of Eigg system has also benefited from the installation of an ultracapacitor to further protect the battery banks from rapid charging and discharging which extends the operating life of the banks and improves the power supply. These privately funded projects have helped to transfer knowledge and expertise into the community.

Previously funded studies

Several communities also identified feasibility work to support the development of further enabling energy infrastructure on the islands. It is expected that the development work provided by the interviewees represents a small sample of what has been completed (see Appendix 8 for more details on studies).

There is a breadth of studies that have been completed across the islands that detail energy system development opportunities, upgrade requirements, demand changes and constraints that could potentially be built upon when considering any changes to the energy system. This work is often supported by public sector funding and it may be the case that several issues or projects have been identified, but the community has not been able to finance implementation, has the capacity to take the project forward, or the projects have stalled for other reasons.

4.5.2 Heat generation

There is a lack of publicly available information on low carbon heat generation installations and capacity (heat pumps, biomass or solar thermal) at the low spatial resolution required for islands. The interviewees were unaware of the general status of domestic heating on their island, but some were

[45] http://www.surfnturf.org.uk/page/introduction
[46] https://www.bighit.eu/about/

able to provide examples of individual properties that had low carbon heating or state that there was no local carbon heat on the island. There are examples of larger scale community projects (such as on the Isle of Luing that has a heat pump in a community building), but no other non-domestic low carbon heating solutions.

Some anecdotal evidence on heat pumps and biomass was collected. 15 islands were reported to have at least one domestic heat pump and 10 islands were reported to have a least one biomass installation.

The lack of forestry on most of the sample islands indicates that biomass heating is generally unsuitable. Viable woodchip installations generally source their fuel from within 80km[47]. Localised exceptions are likely to exist such as where a consumer owns their own forestry, but no examples were identified. The Biomass Suppliers list could be used to identify suppliers[48].

There have been some innovative approaches to low carbon heat provision developed on islands. To reduce the amount of curtailment imposed on a community owned turbine REWIRED (Rousay, Egilsay and Wyre community group), introduced an element of flexible heat demand to the network. The 'Heat Smart Orkney' project[49] introduced electric storage heaters to domestic properties that could be switched on remotely, if the turbine was about to receive a signal to reduce its output. There was an additional aim of using this project to help reduce the level of fuel poverty on the islands.

While this project was implemented because of constraints imposed by the Active Network Management scheme implemented across Orkney, the concept has also been applied to much smaller schemes, such as on Eigg and Foula, with varying degrees of success. It is not clear if the Heat Smart Orkney project has demonstrated success or if replicating this project would be economically viable given the additional infrastructure required to operate and manage them. The Mull Access project also aimed to divert excess renewable generation to household storage heaters at times of grid constraint.

These findings highlight two points, first that there has been little in the way of data recording of heating projects, which makes monitoring and intervention difficult. Second that there has been a lack of progress towards the decarbonisation of heat on the study islands. There have been a significant number of studies funded looking at heating systems on Scottish islands, such as a detailed review of the heat loads on Iona, however, the lack of development of these projects indicates they may not have been viable under the current policy and market framework[50]. Although there is a significant proportion of heat from electricity for domestic use, there is still a lot of high carbon heating, both domestic and non-domestic. There is a need to deliver projects that decarbonise heat domestically, across the both domestic and non-domestic consumers. This would require fuel switching.

Electrification of heat (either heat pumps or direct heating) provides the most obvious solution to this, however would need to be coupled with potential upgrades to the local distribution network. There is a limit to the number of heat pumps you can have on a single-phase distribution network (up to 15kW from a single unit), so network upgrades (as well as improvements to minimise heat losses within the property) may be required.

If island population increases, this obviously has an impact on the heating demand on the network too, so increases the likelihood of upgrades to the local electrical distribution network.

4.5.3 Energy generation business models

There were a range of different business models identified across the study islands for the energy generation assets on the islands, some projects combine one or more of these models:

[47] http://www.yougen.co.uk/blog-entry/2703/Can+you+source+or+supply+your+own+wood+fuel+for+your+biomass+boiler+and+keep+your+RHI+payments%273F/
[48] https://biomass-suppliers-list.service.gov.uk/
[49] http://rewdt.org/index.php?link=projects&id=2
[50] A summary of some of the number of studies across Scotland can be found here: http://www.evaluationsonline.org.uk/evaluations/Documents.do?action=download&id=946&ui=basic

- Community owned projects in receipt of public finance, soft loans or community investment.
- Demonstrator projects that have received significant public sector finance.
- Privately owned generators receiving government incentives through the FIT or RHI.
- Commercially owned systems generating power for on-site use.
- Community/private collaborations such as the Fair Isle community collaboration with Scottish Water Horizons.

The detail behind these business models, level of public finance, gearing, loan terms etc. are not publicly available. The interviews did provide some qualitative information:

- Community ownership ranged from large scale (up to 900kW) to domestic scale installations to off-grid whole systems.
- Scottish Water were identified as having ownership of installations and have recently published a zero-carbon plan[51].
- Off-grid communities tend to own their entire system.

At the scale of generation across the islands, it can be assumed that the FIT and RHI will have contributed to income and the business case. Many domestic scale technology installations will be funded through either private equity, equipment supplier finance or bank loans.

Most community installations received some form of EU, Scottish or UK government backed funding, or other public finance such as the Big Lottery, community investment or loan finance from social and senior lenders.

There are innovative examples of technology demonstrators on the study islands that are not yet commercially viable and so are reliant on public finance. These projects are of value in leading the way in the development of low carbon energy systems and developing essential homegrown supply chain knowledge and expertise. The longer term aim of these projects is to develop the solution so that it can be replicated across other island communities with less reliance on innovation funding.

An example of the scale of the cost involved is the Orkney BIG HIT project on Eday and Shapinsay, a large-scale hydrogen demonstrator project that has been implemented thanks to EUR 5million of EU grant funding for this stage alone[52]. The project could not have gone ahead without public sector financial support and it is unlikely to have been implemented at a scale small enough to benefit a single island community.

Technology developers have fully financed test equipment and have worked alongside communities to enhance their expertise. An example of this is the Stortera project on Knoydart. The objective of the project is to ensure that the demonstration equipment improves the resilience of local energy supplies.

The closure of the FIT to new projects will reduce the number of new installations[53] and the Smart Export Guarantee is not expected to provide any additional revenues to small scale generators. New models for subsidy free development are emerging. These include:

- Private wire connections and long-term power purchase agreements with large electricity users.
- Large projects that have lower costs per MW installed.
- Use of battery systems to add new income streams for grid support services and match time of generation with highest electricity prices.

In addition, falling equipment prices, particularly for solar PV and batteries and to a lesser degree wind turbine, assist all the subsidy free business models.

[51] https://www.scottishwater.co.uk/en/About-Us/News-and-Views/010919-Net-Zero-Emissions-Drive
[52] http://www.orkney.gov.uk/Service-Directory/Renewable/big-hit.htm
[53] The FIT also provided

Of these 1) and 2) are not possible on small islands. Option 3) is possible but does add capital cost to the project so this model will need careful assessment, though battery systems also help improve energy resilience.

This suggests that additional new models are needed for small scale systems, including for islands. This is a topic that Scottish Government and BEIS are looking at.

Conclusions

- Renewable generation projects on islands have in the main benefited from government support, whether through renewable incentives or innovation funding.
- There are some examples of technology developers funding demonstrator projects.
- To fill the revenue gap resulting from the FiT closure, new generation projects need to look at increasing the revenue, which is where selling heat and electricity directly to the consumer has a part to play, potentially as part of an energy system.
- Further work is underway to identify and trial new business models for small scale local energy systems.

4.6 Security of supply

For the ongoing resilience of an island, security of supply of power is important. Until recently the Fair Isle community did not have 24-hour power and were required to have periods of system shutdown. None of the islands in the study were noted to have similar time constraints on power usage but all islands in the study did note some security of supply issues.

Ten islands reported a significant issue and eight islands reported minor or infrequent issues This information represents a snapshot in time and is subject to change in line with improvement works carried out by the network operator.

Those islands not connected to a wider network do not benefit from the stability of a wider network to provide balancing services, stabilise frequencies and voltages, or from the support of the DNO. Specific technical issues on islands such as on Rum and to a certain extent Muck were also noted. There are three off-grid island upgrades taking place at the time of writing for Canna, Fair Isle and Foula, these will have a positive impact on quality of supply and this impact should be measured.

The interviews highlighted some key differences in off-grid system quality. For example, the Isle of Eigg reported that the system was operating well and that there was high customer satisfaction, which is in stark contrast to the Isle of Rum where there are significant issues with the system.

On most islands it is recognised that the security of supply and power quality issues are improving. As a result, the resilience of these islands from an energy perspective is improving. The frequency and length of outages is reducing and are often caused by external factors such as bird strikes to overhead lines, an issue that was raised time and again. However, island resilience was found to be an issue in several cases with incidents where power outages cause communications to drop out and one incident which led to panic buying of food supplies.

Conclusions

- Across the island groups that are grid connected there was a consensus that the grid is becoming more resilient over time and that outages are decreasing.
- According to the islanders, those that do occur are likely to be caused by faults from bird strikes to overhead lines, rather than frequency fluctuations or voltage drops. This needs verification from SSEN.

- If there is an outage, it can take longer to repair and while there are systems put in place by the DNO to manage this there is still a question over grid resilience on some islands.
- There are public sector service sites (fire, ambulance, police, airport, medical) that utilise some form of energy storage or back up generation. It is likely that the backup power exists to ensure continuity of critical services so there is a potential for these systems to provide network stability services to improve network resilience.

4.7 Transport

The following section provides an overview of the energy contribution of ferry, plane, car and freight transport options to island energy demand. Also issues relating to island transport options were collected during the interview phase.

4.7.1 Air travel

Air travel figures were not collected in this study, but the OREF report estimated that air travel for services to the Scottish mainland accounted for 0.6% (2GWh) of total transport consumption and inter-island flights accounted for 1.5% (5GWh). Combined, air travel made up 0.9% of the total energy consumption on Orkney. Only 3 of these small islands have airports (Foula, Fair Ilse, Papa Stour).

As with the ferries, it is assumed that the refuelling of the smaller inter island flights takes place off island in many cases. Carbon emissions for air travel are calculated on a per km per passenger basis and vary considerably from plane to plane. The industry standard methodology for allocating emissions associated with air travel, sets out that taxi and take off (or landing and taxi) are allocated to the airport from which the plane is departing or arriving into (and so if calculating island emissions, they would be included).

Not all islands within this study have an airport but some of the more remote islands such as Foula and Fair Isle rely on this essential service to travel to and from their islands, with refuelling taking place off island. Ferry services are in place for some islands with airports, but this increases journey times significantly.

Conclusions

- Air travel is an essential service to many island communities and there are opportunities to reduce the carbon intensity of travel to the islands.
- Reducing the number of flights, would require improving journey times by ferry.
- Reducing the reliance on the plane engines for taxiing, a mechanism used at larger airports, with say an electric vehicle towing the plane to the runway.
- Moving to a lower carbon emissions vehicle, such as electric planes or planes using biofuels.
- When carbon accounting, the island emissions do not include travel to and from the island, they are allocated to the airline, so if targeting a reduction in carbon emissions travelling to the island, airlines should be engaged.

4.7.2 Ferries

Few of the study islands are connected to the mainland by road (except for Muckle Roe to mainland Shetland and Vatersay to Barra). In these cases, there is a reliance on ferry and air transport to travel to and from the islands. Transport to/from an island is often disconnected from the supply of energy for other services on the island as marine fuel oil is imported. For the smaller islands, the refuelling of the ferries often takes place off-island

Marine fuel oil has a high energy and carbon content. This study has not looked at consumption on each island, but the 2014 report by OREF[54] estimated that ferry energy consumption figures for their mainland services accounted for 54% (184GWh) of total transport consumption (344GWh) and inter-island services accounted for 9% (31GWh). Combined, ferry consumption made up 28% of the total energy consumption on Orkney (757GWh). The report noted that this figure is likely to be a significant under estimate as ferries are often refuelled at ports outside of the Orkney Isles. From this it can be assumed that ferries are likely to account for a significant proportion of energy consumption related to island life.

As with air travel, the ferry operators and owners control the carbon intensity of their energy consumption and so the carbon emission for travel to and from the island.

Conclusions

- Ferguson Marine are developing two separate low carbon platforms for small roll-on roll-off ferries, one that will run on LNG[55] and one as a hydrogen hybrid[56]. These have potential to reduce carbon emissions from travel to the island, although the amount of energy used will depend on the efficiency of the ferries.
- Further developments are underway internationally looking at larger ferries using other fuel sources, such as ammonia. Again, this could play an important role in decarbonising travel to the islands.
- Hydrogen and ammonia would be produced from renewable electricity, air and water – so can be provide by island energy systems.
- Ferries have a very long operating life. It is therefore likely that new ferries brought online now, will be operational in 2045, so impacting 2045 carbon emissions targets.

4.7.3 EV car ownership

Most of the car ownership is expected to be traditional fossil fuel-based fuels, but respondents did report some existing EV usage (1 on Papa Westray, 3 on Rousay, 4 on Shapinsay, 1 on Vatersay and a proposed electric bike scheme on Eigg). Respondents recognised the scope for EV ownership but voiced concern over the price. On some of the more remote islands, there is a reliance on older vehicles which can be maintained locally and are robust enough to drive on rough terrain. Whilst there are some low emissions vehicles on the market designed for off-road use, they are at a premium price.

The electricity required to charge an EV is relatively low, so relatively cheap to fuel, but would need to be accounted for, and managed, in small off-grid energy systems (e.g. by staggering charging times). As an example, a Nissan Leaf has a 15kW demand and a 40kWh battery, with a single charge providing more than 150 miles travel. Therefore 10,000 miles would require approximately 2,800kWh, which could be generated by a 6kW wind turbine in 20 days.

Any grid outage on an island will impact on the ability to charge an EV, with potentially significant consequences for travelling around the island, however as has been highlighted, the number of outages across the islands has reduced over time, and many island road journeys will be short.

EVs do have a higher capital cost that conventional cars, but a lower operating cost (fuel and maintenance), so are better suited for car owners who do a lot of miles annually. Therefore, for those on islands who do not leave the islands, they will be less attractive, however for those who travel to and from the island regularly by car, it is likely to more attractive.

54 http://www.oref.co.uk/wp-content/uploads/2015/05/Orkney-wide-energy-audit-2014-Energy-Sources-and-Uses.pdf

55 https://www.cmassets.co.uk/project/100m-dual-fuel-ferries/

56 https://news.st-andrews.ac.uk/archive/ferguson-marine-to-develop-renewables-powered-hydrogen-ferry-hyseas-iii/

The qualitative information gathered during the interview stage indicated that the percentage car ownership is high and that journey times are often short. This indicates that EVs could be a relevant technology to islanders. EVs have additional benefits such as increasing electrical demand, so potentially reducing generation constraint as well as providing Vehicle to Grid (V2G) services. This introduces an element of energy storage into an energy system which has the potential to increase its flexibility. EVs have lower maintenance requirements which reduces ongoing costs to the owner but reduces the reliance on local garages which will have an impact on the island economy.

Table 3 summarises the number of EV charge points across the study islands and it can be seen that few islands have charging points on them. The mainland (or main island) charging network is better developed, although still sparse in areas.

Table 3: Charging points on or near to study islands by council area and charging speed (slow 6-12hours; fast 3-4hours; and rapid 30-60minutes)[57]

Council	Location	Slow (3kW)	Fast (7kW)	Fast (22kW)	Rapid (43kW)	Rapid (50kW)
Argyll & Bute	Colonsay	0	4	0	1	2
	Fionnphort	0	0	0	1	2
	Oban	0	0	6	2	4
Highland	Mallaig	0	0	0	1	2
	Broadford	0	0	0	1	2
Orkney	South Ronaldsay	0	3	0	1	2
	Shapinsay	0	2	0	0	0
	Mainland Orkney	4	9	13	4	8
Shetland	Fetlar	0	2	0	0	0
	Mainland Shetland	0	24	2	1	2
Western Isles	Barra	0	1	0	1	2
	Eriskay	0	0	1	0	0
	South Uist	1	1	0	0	0
	Benbecula	0	4	0	1	2
	North Uist	0	2	0	1	2
	Harris	0	5	2	1	2
	Lewis	3	8	12	2	3

Only one of the study islands in the Western Isles (Eriskay) has an EV charging point, however there are 55 charging points across the Western Isles. Here, the charging network does not serve the individual islands, but does allow travel across the islands and to the mainland by EV. This issue is repeated across the study areas where charging points are not available on the islands, however

[57] https://www.zap-map.com/live/

mainland ferry terminals (Oban, Mallaig, Fionnphort etc.) often have charging infrastructure which allows onward travel. This indicates that for EV uptake domestic slow charging is likely to be the main option for domestic use at present.

It is not clear at this stage how the EV charge network will be developed over time, but it is likely to continue to expand with consumer demand. Hydrogen for transport has been put forward as an alternative/complimentary solution to decarbonising transport[58]. At the time of writing the only development of hydrogen transport infrastructure on the Scottish islands has occurred in Orkney as part of the BIG HIT demonstrator project.

Conclusions

- There are some examples of EV use but wider uptake needs significant infrastructure upgrades to the charging infrastructure.
- It is possible that to maintain resilience of domestic transport, plug in hybrids could be an appropriate solution.
- Whilst EVs require less maintenance, this maintenance does often need to be carried out by mechanics with access to specialist equipment, so island garages may need investment in new equipment.
- Consumer confidence in electric vehicles and charging infrastructure is likely to be even more important than on the mainland.

4.7.4 Freight vehicles

As on the mainland, island communities have a significant volume of freight traffic. This is generally in the form of vehicles located off island but are used to transport food and essential supplies to the islands. These vehicles are generally expected to be lorries consuming diesel.

4.8 Communication infrastructure

Digital exclusion may lead to depopulation or reduced business interest, which will have an impact on the level of demand and subsequently on the attractiveness of an island to investment in new generating equipment.

In addition, in a subsidy free generation market, future local energy systems will likely include an element of demand management, behind the meter billing, or virtual pooling of generating assets (e.g. virtual power plants). None of these innovations are possible without robust communications as they rely on the flow of information between the various facets of the energy system.

At the time of writing, the 2017 OFCOM dataset on connectivity speeds was the most up to date dataset available with island level resolution. These data incorporate updates from 2016 and it should be noted that significant upgrades to the broadband network have occurred since then. There have been several initiatives to improve broadband speeds with the main ones summarised below:

- The UK Government's 'Better Broadband Scheme[59]' scheme allowed people apply for a voucher to pay for satellite or wireless broadband upgrades to 2Mb/s. This scheme ends in 2019.

[58] https://www.gov.scot/publications/scottish-energy-strategy-future-energy-scotland-9781788515276/
[59] https://basicbroadband.culture.gov.uk/

- Scottish Government in partnership with the UK Government launched the 'Digital Scotland Superfast Broadband' scheme that is due to finish in 2019. Over 90% of premises in Scotland were able to access superfast broadband (over 24Mb/s) in April 2018 [60].
- The follow on to the Digital Scotland scheme is the Scottish Government's 'R100' scheme that is due for procurement in Q1 2019. This highly ambitious programme aims to provide 30Mb/s download speeds to 100% of properties in Scotland.

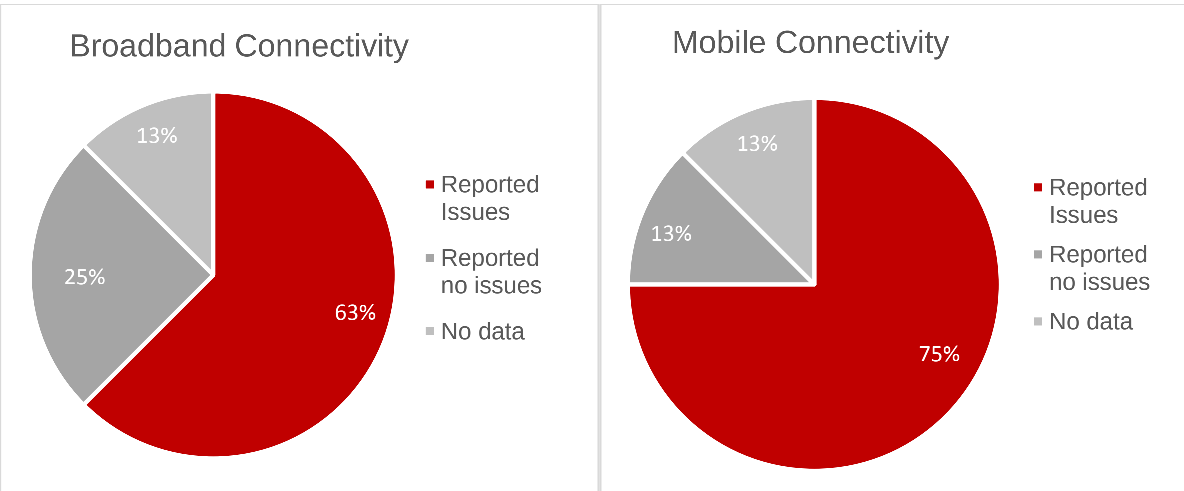
It is not clear at this stage how the progress highlighted above relates to the islands as this level of detail is not yet available. What is clear is that progress has been made in improving connectivity in Scotland and that there are schemes currently operating that aim to improve the situation further.

This study found that on average, the number of premises below the Universal Service Offering (USO) across all islands is between 60% and 95% (for more information and sources see Appendix 7). This highlights a real issue of 'digital exclusion' and is likely to hinder development in the islands as they will struggle to retain or attract people and businesses. This USO is a moving target as the definition of 'decent broadband' was 2Mb/s in 2010[61] which has moved to 10Mb/s in 2018. The figures suggest that a relatively high percentage of islands do not receive 2Mb/s and so can be considered well below the USO and falling further behind with time.

The other metric that was gathered during this study on broadband download speeds was the number of islands that disagreed with the official OFCOM figures. It has already been shown that the official figures highlight digital exclusion as a significant issue in the study islands, what this metric shows is that the reality for the islanders may be even more challenging. On average, a third of islands in each council area thought the broadband speeds were slower that the official figures suggested. It should be re-iterated that this evidence is qualitative and is therefore subject to the opinions of the interviewees, however the consistency of the response indicates that the reported service figures are not representative.

Across the sample islands, mobile signal was reported to be generally 'patchy', and the broadband signal is generally slow and unreliable. Bressay and Vatersay should be highlighted as possible exceptions to this. Broadband provision through the BT network is generally described as poor and while satellite systems are often better, the cost can be prohibitive. A summary of islands stating connectivity issues is provided below (Figure 14).

Figure 14: Percentage of islands reporting connectivity issues (interview phase)



[60] https://www.scotlandsuperfast.com/latest-stories-and-events/stories/scotland-reaches-95-fibre-coverage/
[61] https://www.ofcom.org.uk/__data/assets/pdf_file/0028/95581/final-report.pdf

These figures represent the interviewee's understanding of the situation on the island and do not necessarily represent the download speeds experienced across the entire island, as this figure depends on the distance from a property to an exchange. In addition, after the infrastructure has been implemented individuals must apply for a connection before they can benefit from it. 11 of the study islands currently have access to fibre broadband with two more (Bernera and Coll) currently in the planning phase.

According to the interviewees, despite the improvement works that have been completed to date, there still appears to be a significant issue with connectivity on the study islands. This may be due to a lack of awareness of why connection speeds are slow and barriers such as applying for an upgraded connection.

4.8.1 Off grid system communications

With regards to broadband, Knoydart were the only off-grid community that stated they were happy with the quality of their connection. Internet is provided by 'Hebnet' (a community interest company) that provides line of sight satellite broadband and the interviewee stated that the connection speeds were significantly better than those experienced on the 'mainland'. This has not been verified independently and it is not clear how this was determined.

Mobile coverage was noted as poor or 'patchy' by all the off-grid islands, with Knoydart noting that there is no mobile coverage in the village. The response from Knoydart also noted that the community manage well without mobile coverage thanks to the good WI-FI signal that allows them to make calls through the internet. This may be a solution that could be replicated for other remote communities. Anecdotally, the off-grid communities also reported that when their energy systems fail, the broadband system also fails which highlights the reliance between the two systems. This highlights the importance of back-up power supplies and electricity storage.

Conclusions

- Effective communications links rely on a resilient energy system as power cuts can lead to drops in coverage.
- In extreme cases this could result in safety issues, however unreliable communications will have the effect of limiting business growth potential and could impact population numbers in the future.
- For controlling generators and demands on the network, relatively small data packets are often required, such as through an active network management system. Reliable communication infrastructure is key. It has been reported that faults on the Orkney ANM scheme are due to communications failures.
- As new energy systems develop, which may require real time substation monitoring or blockchain transactions, increasing broadband capacity may be required, but now a lack of broadband capacity is not felt to be impacting local energy systems.

4.9 Supply chain

There is a long list of suppliers of equipment for energy systems on the islands, across the range of different technologies installed. Work recently completed for Scottish Enterprise identified over 150 suppliers of equipment and service suppliers to the low carbon sector in Scotland. It was identified that over 100 of these supplied to an Island Rural Community. There will be many more outside of Scotland that supply into island communities.

Table 4 summarises some of the companies involved, some of whom are part of the Sustainable Islands International programme delivered supported by Highlands and Islands Enterprise, Scottish Enterprise and Scottish Development International. There will be may others.

Table 4: List of some of the supply chain involved in delivering energy projects on the study islands.

Island	Organisation	Type
Flotta	Opus Plus Ltd	Consultancy
	ScotRenewables	Services supplier
	Enercon	Equipment supplier
Burray	Orkney Sustainable Energy Ltd	Consultancy
	Vestas-Celtic Wind Technology	Equipment supplier
Coll	Atmos Consulting	Consultancy
Iona	Scene	Consultancy
	Ramboll	Consultancy
Jura	Mor Hydro Ltd	Consultancy
	GPS PE Pipe Systems	Equipment supplier
Muck	Synergy	Consultancy
	SSEN	Services Supplier
	G.G. MacKenzie Contractors	Services supplier
	Evance Wind Turbines	Equipment supplier
	Wind and Sun	Equipment supplier
Vatersay	Wood Group	Consultancy
Canna	CHAP Ltd	Services supplier
Eigg	Scottish Hydro Contracting	Equipment Supplier
	E-Connect Ventures Ltd	Services supplier
Eday	ITM Power	Equipment supplier
	Community Energy Scotland	Consultancy
Scalpay	Energee Services	Services supplier
Fair Isle	Great Glen Consulting	Consultancy
	Arcus	Consultancy
	Harbon Turbines	Manufacturer
	Harper McLeod	Legal
	Scott Moncrief	Finance

For some lower value projects, such as energy efficiency, mechanisms for delivering these locally more cost effectively, can include bulk purchase of supplies. For example, bulk procurement of insulation for multiple homes can bring down costs significantly and local installers can be trained. This happened on Rousay, but could equally be applied on different islands, with different technologies.

A programme of works across multiple properties offers an opportunity for economies of scale. For example, if multiple domestic properties were to have installed Air Source Heat Pumps, bulk procurement and a programme of installs on multiple properties in the same location will reduce costs. In this example, there would also be an opportunity for local suppliers to continue with the ongoing annual maintenance requirements (for more information on collaboration opportunities see Section 5.1)

Anecdotal evidence indicates that it is difficult to attract suppliers to islands. This risks a lack of competition for work, meaning the services provided may not be optimal and a lack of competition can impact on price. To fully understand the reasons behind this, it is necessary to look at the wide supply chain and the procurement process carried out, however it likely to be due to a number of reasons:

- There are considerable logistical considerations for delivering projects on islands, particularly involving the supply of large pieces of equipment, where access is primarily by ferry, adding to costs.
- Scheduling work in advance to hit weather windows for delivery is important, but risky.
- Allowances need to be made for travel uncertainty, such as weather disruption, which can increase risks to suppliers.
- Communities may not be experienced in procurement and so may not have a clear understanding of budgeting, tendering, liability and a range of other commercial issues that impact the likelihood of a supplier choosing to bid for work.
- For complex energy system projects, the development risk is high, so there will be fewer developers willing to invest in the early development stages of an energy system on a remote island. These stages may potentially require potentially requiring grant funding. Since the decline in the FIT and ROC, the industry has also seen a decline in the numbers of manufacturers of smaller scale wind generators (several have gone out of business such as Endurance[62], C&F[63] and Harbon[64]).

It is suggested that this is an area that could warrant further investigation to explore options for increasing levels of supply chain interaction and competition with projects across the islands.

Conclusions

- There would appear to be a healthy supply chain of energy system goods and services across the islands, however there are some reports of issues attracting suppliers to the islands.
- Procurement support may be required for island generators or off-grid operators to ensure there are no barriers in the process to suppliers bidding for work.

4.10 The role of community groups

Community developed and owned energy schemes have been a success and form the basis of off grid and many on grid energy projects. The Scottish Government set a target for 1GW of community energy in 2020 and 2GW in 2030.

Those islands that have funded development officers were generally well informed on issues related to island life across a range of topics. Understandably, those islands without development officers were

[62] https://www.nfuonline.com/news/latest-news/endurance-wind-turbines-nfu-guidance/
[63] https://www.independent.ie/business/irish/cf-group-shuts-wind-turbine-business-after-being-hit-by-tariff-issues-and-red-tape-in-japan-38026053.html
[64] https://beta.companieshouse.gov.uk/company/07320151

generally less informed and as such were able to provide significantly less detail on island issues. Some communities therefore have a better understanding of island systems than others and so are more likely to be able to identify issues and propose solutions.

If developing a new energy system project, public sector funding may be available for the provision of project manager. However, operation and maintenance tasks can often lie with the community group. This can be challenging for small island communities as they often have several projects running concurrently, however this can be an opportunity for additional income for those completing the maintenance.

Islanders often have several different jobs to balance and there can be a relatively high turnover with staff moving to/off the island (highlighted during the interview phase), so managing the transition between operators, when they are not certified engineers, is important to ensure that there is not loss of understanding in how a local generator operated by the community works. Understanding the capacity within a community should be an important consideration during the early stages of project feasibility work to ensure the long-term viability of a scheme.

Conclusions

- Communities can play more of an integral role is an energy system on an island.
- Where these is additional support within the community, this can play a role in improving the operation of the local energy system.
- Succession planning is important for anyone playing a key role in operating the energy system.

4.11 Off grid islands

Seven of the 49 study islands are off-grid. Communities on these islands have deployed a range of solutions to the issue of energy supply, based on the specific challenges faced on the island. There is an opportunity to make best use of the lessons learned, knowledge sharing on information relating to operations and maintenance, insurance, liabilities, financing and supply chain.

In off-grid islands, balancing supply and demand of power and heat is critical, so any additional energy demands, must be met with additional energy supply. Parallel growth in energy infrastructure is essential to allow for communities and businesses to thrive in rural remote areas.

On off-grid islands a reasonable solar or wind resource combined with the reducing capital costs, can make renewable generators price competitive with diesel generation.

Specifically, for off grid islands where the network is owned and operated by the local community, there can be limits on the time islanders have available to operate the systems, as well as on the available skill base. Combined with the absence of a network operator (and the resulting support provided) requires that the communities are largely self-reliant, and often need to contract in external support to maintain their systems. This can be challenging as contractors may have to travel significant distances to reach the island and may face delays because of the impact adverse weather conditions on travel.

5 Addressing island challenges

This section outlines some project concepts that might be relevant to explore further to address some of the challenges identified with energy systems on the target islands. There are additional ideas included that reflect on the changes in the energy sector and how they might link to energy systems on islands. These are presented in the timescale that it would be possible to implement solutions to addressing the challenges, with the earlier ones being able to be introduced in the short term.

5.1 Collaboration

The remote nature of islands, their unique circumstances and sometimes limited human resource highlights an opportunity for communities on the islands to collaborate with others in similar situations or with a common goal to help strengthen their efforts. Further, in order to realise the local energy systems vision set out by the Scottish Government in which consumers are protected including those that are more vulnerable, working in partnership will be key. There is an opportunity to strengthen links across island groups and also between communities, citizen groups, businesses, local authorities, academic institutions and other representative bodies to ensure that no one is left behind in this transition and that social, environment, economic and community benefits are maximised.

Examples where this is would be the biggest opportunity are:

Off-Grid Islands

Seven of the 49 study islands are off-grid; Canna, Eigg, Fair Isle, Foula, Knoydart (energy island), Muck and Rum. have deployed a range of solutions to the issue of energy supply, based on the individual challenges faced and on the availability of funding. Excluding Knoydart, they are currently collaborating on the EU Clean Islands Initiative. This will demonstrate the success of collaboration and there is an opportunity to support this collaboration moving forward.

Areas of focus for collaboration should include operations, maintenance, insurance, liabilities, supply chain, procurement opportunities to benefit from economies of scale for support services and equipment.

Europe, Arctic Circle and beyond

Developing further links with Europe and the Arctic Circle. A high proportion of public sector funding for demonstrator projects in Scotland has come from the EU and with this funding has come strong ties with EU innovation bodies, EU technology providers, as well as international recognition for the projects carried out. These links could be built upon to draw on international expertise, attract inward investment as well as funding if possible.

There are also upcoming support mechanisms such as the EU Islands Facility[65]. Assuming UK parties will be eligible for EU support, the EU Islands Facility is a capacity building project to allow islands to better understand their energy demand and to take steps towards reduced consumption and decarbonisation. Progress of the facility beyond the Clean Islands Initiative should be considered by HIE and the wider Team Scotland group, when planning any programme for Scottish islands, as there may be opportunities to work in conjunction with their timelines.

Bulk procurement

Bulk procurement has the potential to offer cost savings. This can apply to equipment, materials, spare parts or services (e.g. maintenance). In section 4.5.1 we highlighted when some of the larger generators are likely to be replaced. As the age of small scale generating plant is not known, it is not clear whether such a bulk replacement scheme would be appropriate. For this type of scheme to be effective it is important to know as a minimum:

- Where the generating plant is located.
- The generating capacity.
- The date it was installed.

The bulk procurement of energy efficiency measures and support services (legal, financial, O&M) also present opportunities to reduce costs, although comes with complexities around liabilities and terms.

[65] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/lc-sc3-es-8-2019.html

Scottish Government are currently consulting on the future role of the Community and Renewable Energy Scheme and a service such as this, would be an evolution of the frameworks they have in place at present.

The Community and Renewable Energy Scheme ran a scheme to facilitate the joint procurement of large roof mounted solar schemes, with each party contracting individually with the supplier, circumventing some commercial issues of bulk procurement.

In the communications sector community satellite broadband is another possibility. There are several examples of this including Skyenet[66] and Hebnet[67] and the consensus from the interviewees is the download speeds experienced are significantly faster than those provided by BT.

Care should be taken with such an approach to ensure any bulk procurement confirms that a proposed technology is appropriate for all the sites being considered. There are risks to bulk purchasing including where failures exist in chosen technology, the impact can be widespread due to the common use of the same equipment. Assessing these risks should be part of the feasibility work.

It should be considered that replacement of a generator may not be the most appropriate, if market conditions have changed (e.g. the removal of any government incentives) or local demands have changed (thereby requiring a smaller or larger replacement generator).

5.2 Increasing island resilience

Several island respondents provided evidence of poor resilience during adverse weather conditions. These range from access to food and fuel supplies; challenging logistics for repair/supporting services and communication signals dropping out during power cuts. This can be driven by the impact of adverse weather on ferry timetables was noted as a significant inconvenience.

The cost associated with improving the vessels themselves or port facilities to increase their operational conditions is significant, so an alternative approach would be to improve the resilience of island communities, so that they are better able to deal with these challenging periods. This falls into two main categories:

- Adequate planning and infrastructure to ensure the island community has the appropriate supplies (fuel, food etc.).
- Upgrade communications (internet and mobile connectivity) on the island to a level where business can continue as normal.

Improving island resilience is a core focus for the inhabitants and could be a focus for island energy systems projects. Strategic planning is of critical importance to avoid a piecemeal approach to any resilience project that may have the unintentional effect of reducing resilience rather than improving it. Several islands are expected to be without a resilience plan and funding is available from SSEN in the form of grants to support community resilience projects[68]. Grants of up to £20,000 are available and have funded a range of projects from building resilience plans, to providing communications equipment and upgrading generators (the fund will reopen in 2020).

Resilience plans are most relevant to off-grid islands who have to operate their own electricity networks to ensure their resilience. However, a number of grid connected islands noted resilience issues including Gigha, Sanday and Vatersay. As other sectors become more reliant on the electricity network (e.g. transport) it will become increasingly important for all islands to have well established plans in place for grid outage periods.

[66] https://www.skyenet.co.uk/
[67] https://www.hebnet.co.uk/
[68] https://www.ssen.co.uk/Resiliencefund/

There is a disconnect between the requirement for resilience for remote island communities and the drive for decarbonisation. The most established way of providing power during network or renewable generator faults is via backup diesel generators as the technology is proven and fuel supplies can be stockpiled. Low carbon alternatives such as battery banks or low carbon fuels such as hydrogen or a biofuel could be considered.

5.3 Standardised approach to local energy systems planning

During the interview phase, a number of different studies looking at energy master planning or feasibility of different energy generators were highlighted. These studies will cover a wide range of solutions, some of which with business models that depended on the FIT, so may no longer be fully relevant .

A solution to support island energy system development may be to establish a standardised development methodology to guide developers, communities and the public sector through the process of addressing their energy system challenges and the development of a future energy opportunities, taking the COBEN approach to the next stage in the development of a project[69]. One that is cross sectoral and multi-vector. These could include and build upon the existing resources and could include the following development steps:

- Development of islands stakeholder group and common vision.
- Each island to complete a detailed island audit to build on the initial research.
- Complete future energy plan (electricity/ heat/ transport demand and policy context).
- Identify island issues (security of supply, cost of electricity etc).
- Identify projects addressing island issues.
- Develop action plan.

This might be something that is taken forward by councils or by community groups, but would need multi-stakeholder involvement across the public sector and the private sector. With a standardised approach this would:

- Enable consistency across island plans, so that learnings from one island plan to another are more transferrable.
- Potentially provide economies of scale for the implementation of the local energy systems plans and the subsequent identified opportunities across the plans.

Address the lack of availability of data at an island level. One possibility for gathering non-domestic energy data is through the RES business resource efficiency support service for small and medium sized enterprises.

5.4 Local supplied ancillary services

There are an increasing number of ancillary services that are being purchased by the DNOs at a substation level[70]. This will improve the resilience of the local networks as they are less reliant on the wider grid. Mechanisms by which such services can be provided include:

- Generator turn up, which could include diesel generators on the island, batteries or any hydro schemes with impoundment.
- Demand side response, which in the future could be aggregated across domestic properties.

[69] https://www.localenergy.scot/what-is-local-energy/local-energy-plans/
[70] http://news.ssen.co.uk/news/all-articles/2019/august/western-isles-and-skye-to-help-develop-the-flexible-electricity-network-of-the-future/

- Vehicle to grid, using the batteries within an EV to provide grid balancing services. Some electricity suppliers already reducing the costs of operating an EV in exchange for access to the EV battery.
- Integration of heat and power project, such as using electricity at times of high generation, but low demand to produce heat stored in water tanks or heat batteries.
- Production of hydrogen[71], whereby electrolysers increase demand on a network at times of peak generation.

Local opportunities to facilitate the provision of these services might include:

- Using local infrastructure already on an island, such as the emergency services, health services, or schools where the provision of continuous (or uninterruptable) power supply, either from a battery or a back-up generator could also be used for ancillary services. It is likely that the backup power exists to ensure continuity of critical services, so any proposal that sought to utilise this power would have to consider this carefully.
- Alternative innovative solutions like demand side management or hydrogen production are being used to alleviate grid constraints on islands, which could be revisited as an option for providing ancillary services.

SSEN recently issued an Expression of Interest for ancillary services across the Western Isles. Those flexible service contracts will require demands or generators to be able to respond to turn up or turn down as required during periods of network strain. These periods are normally around peak demand in the evening. To date, flexible contracts have been offered for 2 years to demands or generators that sit behind specific transformers on the network and require generator to turn up by a minimum of 100kW or demand to turn down by 100kW.

The DNO requires evidence that these services can be provided reliably and there are potential fines if a contract is awarded and the provider fails to deliver, so this needs to be considered with the more innovative solutions listed.

5.5 Decarbonising heat, reducing fuel poverty

Domestic heat provision is largely in the form of oil boilers or electric storage heating in individual properties which are expensive and carbon intensive.

Islands that show the highest proportion of electric heaters are:

- Erraid
- Jura
- Hoy
- Flotta
- Graemsay
- Bressay
- Muckle Roe
- East Burra
- Fetlar

According to the available data, the average share of electric heating on these islands is 69%. However, high proportion of electric heating is a defining feature of all studied islands, with an overall average of

[71] https://www.ssen.co.uk/DistributionInnovation/ahp/

53%. All of these islands lend themselves to interventions targeting energy efficiency and fuel poverty. Opportunities to reduce the reliance on oil or expensive electrical heating include:

- Energy efficiency is the first strategy to use to reduce energy bills as the returns for many measures are cost effective.
- The use of heat pumps to provide a more efficient use of energy and use less electricity than storage heaters, if the building fabric has been improved sufficiently through energy efficiency measures. Potentially the transitioning to heat pumps might need to go hand-in-hand with an upgrade to a 3-phase network.
- Capturing waste heat from industrial processes. Mapping the location of significant heat loads on islands would help identify where this would be appropriate.
- Learning from projects such as Heat Smart Orkney or Mull Access, may also provide alternative solutions to decarbonising heat, whilst reducing costs.
- Ultra-efficient building design can reduce energy demands considerably, reducing bills and providing an extra layer of economic resilience within islands communities. This approach to building is not limited to the domestic sector and would be equally applicable to commercial buildings.

5.6 Innovation and demonstration

The contained nature of island systems and the challenges presented to the communities living on them has made them attractive to developers who are working on technologies to address network issues that are likely to be experienced more widely across the rest of the grid. Several of the study islands have installed a range of innovative technologies to tackle their individual energy challenges. Islands has also been used as opportunity to demonstrate conventional technologies utilised in an innovative way.

The potential exists across the study islands for further demonstrator projects due to the contained nature of their geography, population, electricity and transport networks. Islanders also often have a closer link to their energy system as the impact of any outage us much greater than on the mainland, so they can have a better understanding of their energy needs.

This needs to be considered carefully as demonstrator projects are innovative and so less reliable. They can be short term projects with objectives that might not necessarily align with the needs of the island communities, rather the technologies being demonstrated. They also require specific expertise to ensure they are appropriately managed.

While there are clear benefits and a definite role for types of demonstrator projects, careful consideration is needed of whether smaller scale projects using commercially viable technologies offer the best solution to remote island communities. Innovation should be considered alongside the need for security of supply. The path from demonstration to commercialisation is also important, further work is required to understand further about the journey that is required to develop these systems into commercial prospects in which the finance market has the confidence to invest.

Evaluations of programmes such as the Low Carbon Infrastructure Transition Programme, Local Energy Challenge Fund, Infrastructure Challenge Fund, Innovate UK Smart Grants, Scottish Enterprise funding programmes should identify successful project concepts.

From these evaluations, the key characteristics of each project and where they were deployed, could be identified and aligned with the key characteristics on an island, which a view to supporting the replication of the successful projects.

5.7 Decarbonising transport on and to islands

An increase in EV ownership could have additional benefits for island energy systems by increasing electrical demand and introducing a level of energy storage into the system, further balancing supply and demand. The electricity demand from EVs is not significant but on a small off-grid network would be noticeable. As the cost model for EVs is higher up-front capital costs, with lower operating costs, if a large number of miles are not travelled, the economic case for investing in EVs is less clear. Therefore to facilitate the increase in EVs will require reducing the capital costs to consumers, which could potentially be delivered through local grant schemes.

Vehicle 2 Grid

The high proportion of car ownership on the study islands does present an opportunity for projects that phase out carbon intensive vehicles for EVs. These types of projects can be tied to V2G projects thereby providing some revenues to owners, which balancing the local network. The Orkney Reflex project is exploring this as a service. Those islands that would be most suited to this approach would be those where grid balancing services are required (currently those on the Western Isles). Engagement with SSEN would potentially identify where future constraint managed zones are being implemented.

This would be coupled with islands where vehicle miles are high, to make the economic case for EVs stronger. It has been highlighted that on island communities the distance to travel to various services, is higher than on the mainland, so this may equate to higher than average miles being travelled by car each year, for those who have access to a car. A travel study is required to identify which of the islands would be targeted with this approach. It may be that the local authorities already have this information.

Ferry and aeroplanes

An additional route to decarbonisation and integration of island transport is hybrid ferries (diesel/ electric, diesel/ LNG, diesel/ hydrogen) and electric planes. Electric hybrid ferries are already operating in Scotland (connecting Raasay to Skye) and diesel LNG and hydrogen hybrid ferries are currently under development as part of the EU funded Hyseas III project[72], due to be launched in 2020.

Electric plane technology has been developed to have ranges of 1,000km[73] and could be deployed in areas such as the Orkney Isles to replace the existing service. The recently announced HIAL pilot of electric planes and the Highlands & Islands Zero Carbon Aviation Zone, would potentially be bested suited to the very short flights between some of the study islands (eg Foula, The Fair Isle).

This would require local charging infrastructure, so this has the potential to deliver additional benefits of increasing electrical demand locally, reducing reliance on fuel imports and reducing carbon emissions.

5.8 Inward investment to deliver local energy system development

There is a potential business case for new local energy system projects that supply electricity or heat to consumers directly. Where those consumers can offer long term PPAs or heat purchase agreements, this makes them most attractive to investors. Examples of those offtakers that offer the level of certainty required include:

- Scottish Water.
- Highlands and Islands Airports Limited.

[72] https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/waterborne/hyseas-iii
[73] https://thedriven.io/2018/11/12/this-cheap-clean-electric-airplane-could-reshape-australian-regional-air-plane-travel/

- Local Authority buildings.
- NHS buildings.
- Care Homes.
- Light houses.
- Distilleries.
- Service providers such as BT.

For high electricity or heat consuming businesses, a reduced price of electricity or heat, could be an incentive to start up or relocate to an island. Inward investment resulting in new businesses and industry locating to the Scottish islands has the potential to stimulate growth of the local economy. There are obviously a number of factors that influence where a company might locate and there are various mechanisms for encouraging such a move.

Supply shifting is another approach that could potentially reduce costs for consumers, from peak to off-peak times. Hence another method that could be investigated to reduce the price of electricity to encourage a business to locate there, is to utilise battery storage by charging when market electricity prices are low (usually at night) and discharging when prices are high (usually at peak demand periods in the afternoon and evening). This would be suited to facilities with high predictable electricity loads, such as:

- Fish breeding.
- Textiles.
- Hotels.

The use of batteries to do this is not a commercially viable proposition at the moment, but will be in the future.

There may also be direct supply opportunities for new generators, through behind the meter or private wire connections. However, this can impact on the stability of wider network if the demand that was connected to the network is now met through a private wire. The impact on the electrical network does need to be considered, so it is more likely that a new generator would be developed if supplying a new demand.

Working with local island communities may be preferable for these loads, as it builds local cohesion, provides investment back into the local community, opens up land that might not otherwise be available and be financially competitive.

5.9 Communications

Access to communications links and the speed of the connections was investigated as the impact of 'digital exclusion'[74] extends to all aspects of island life including the energy systems technology.

There are different reasons why it could be beneficial to have an energy system that is dominated by renewables that is also part of a 'connected' system. If generation and demand can be monitored (by sending a signal to a control platform) and controlled (the same process in reverse) then a relatively consistent daily demand profile can be supplied by a variable generating source (such as wind, solar and hydro). An example would be to reduce demand during times where renewable generators cannot meet the demand (peak shaving/peak shifting). A recent invitation to tender from UK Power Networks[75] (UKPN) requires providers of flexible demand to be able to respond to an instruction to alter demand in

[74] Digital exclusion defined here as connectivity speeds significantly below that of other regions resulting in a negative impact on social connection and the viability of businesses to operate effectively.
[75] https://www.ukpowernetworks.co.uk/internet/asset/9ed338e5-b879-4642-8470-8b90e0a730bJ/Invitation+to+Tender+-+PE1-0074-2018+Flexibility+Services.pdf

30 minutes or less. There are two stages in this process with UKPN sending a signal to the provider and the provider then sending a signal to the site. While this process will take time to carry out, it should not require high connection speeds.

Another example is the firm frequency response (FFR) service from providers such as Flexitricity[76] which requires flexible sites to respond in seconds. These providers control 100's of kWs of flexible demand/generation to help stabilise zones on the national grid, but the same principles are used in small off-grid energy systems. While these services are important, they are not sending large data packets and so as with peak shifting, the signal requires a reliable (not necessarily fast) communications link.

ANM systems require continuous connections to operate 100% effectively, but the amount of data transmitted is low, so can be transmitted by broadband (fibre not required), mobile phone or satellite communications. If the data transmission is not continuous, it does not mean the systems does not operate, but it does not operate as effectively as it would otherwise. Aggregation of demands is likely to mean communication failures to one demand unit might not have a significant impact on the system.

Further analysis of the specific communications requirements of future energy systems is required to determine whether connectivity speeds might impact their implementation. However, it is likely to be the case that a reliable communications link will be more important than a fast link. Any system that requires more than 30Mb/s download speeds to function correctly (i.e. faster download speeds experienced on the islands currently), will likely be restricted to urban areas where speeds are generally higher.

As there is a disparity between the results of the recent study into provision of USO across the islands and the feedback from the islanders, further work is required to:

- Determine whether there is an issue with island communications.
- Watch market developments to determine future communications bandwidth requirements, based on future energy system needs (such as using blockchain for energy trading).

6 Conclusions

HIE commissioned this research into the status of energy systems on a shortlist of Scottish Islands. With a greater understanding of energy system status and associated issues, the research will provide an evidence base for HIE policy development relating to resilience; low carbon economic growth; and cross-sector and inter-island partnerships on digital upgrades, transport solutions and energy system planning.

The research combined information from publicly available databases and interviews consisting of islanders and HIE representatives. Working within the constraints of the available data, the research provided an overview of island energy generation and demand; issues relating to the islanders such as proximity to services, population, security of supply and fuel poverty; provided insights into the electrical infrastructure; and provided an overview of opportunities to address some of the challenges facing island energy systems.

The research highlighted a number of overarching themes and opportunities relating to island energy systems.

- Standardising the development approach. It was noted there was an appetite for further development across the study islands. It was also clear that some form of standardised

[76] https://flexitricity-20180813151206046800000002.s3.amazonaws.com/live/media/filer_public/be/14/be14292d-15ab-4a81-b9af-9ef20dbcad9c/edie-explains-frequency-response-2018-updated_final.pdf

approach/guidance to the early development stages would be beneficial for communities looking to develop a project that is most suitable for their situation.

- Island energy demand is high as is fuel poverty. Across the sample islands, energy demand was higher than the Scottish average. There are two key points from this:
    - Policy makes (eg BEIS and Ofgem) may not see the bigger impact of policy decisions and how this impacts islands. If electricity use is significantly higher than the UK average on islands where electricity is the prominent domestic heating source, then income needs to be similarly higher. If the estimated electricity demand figures of 15,000kWh in some cases are correct, at 16p/kWh (plus 5% VAT) this is an annual cost of £2,500. Therefore a disposable income of £25,000 is required to not be fuel poor.
    - This represents an opportunity to target energy efficiency and building improvements to reduce costs to the consumer, decarbonise heat and electricity and to integrate with the wider island energy system.
- Working with large consumers. Energy systems projects can often secure higher rates for generated electricity by selling directly to a local consumer than they can from selling to a supplier. As this rate is less than the consumer is likely to pay from a supplier, this local supply scenario, this may be one factor that would encourage a business to relocate. Further engagement with businesses would be required to test this hypothesis.
- Improving grid stability. In situations where there is some form of energy storage and/or connected loads in an island energy system, there may be opportunities in the future to provide services to the grid. Power or demand could be added or taken out of the system as required to balance the system.
- Island transport links – energy and carbon intensive. A significant proportion of total island energy demand is associated with transport to and from the island. Ferry transport is reliant on marine gas oil which is carbon intensive and detached from the island energy system. Steps are being made to decarbonise transport to the islands through the development of hydrogen and LNG platforms, but there is considerable scope for improvement.
- Network resilience improving. The situation is improving across the islands, but this is coming from a position of fairly low resilience. There is an opportunity to link island energy system planning into reliance projects, for example by integrating energy storage used to back up emergency services with the wider network to provide balancing services.
- Innovation as a solution. There are significant opportunities for more demonstrators projects on Scottish islands owing to the fact that they are contained in terms of their geography, population, electricity and transport networks. Care should be taken to balance the advancement of technology with the requirement of the islanders for an energy system that reliable and affordable in the long term.
- Potential for collaboration. Collaboration between geographically or situationally linked islands could bring benefits to the communities. For example, the small Isles (Eigg, Rum, Canna and Muck) could seek collaboration opportunities (geographical link) or this could be extended to all off-grid islands (situational). This collaboration could take the form of bulk procurement of generating plant or of services, provided the replacement schedules allow for this.
- Communications - superfast not necessarily required. Future energy systems that integrate renewable generators with consumers will require reliable communications links to operate effectively. The download speeds required will depend on the design of the system, but are likely to favour reliability over speeds. With the programmes in place to improve communications across Scotland, download speeds are unlikely to be prohibitive in developing integrated energy systems.

- Supply chain challenges. There is a gap in the existi and experience of the Scottish supply chain in delive island communities can struggle to obtain quotes for w to the contractor owing to issues such as logistics and travel.

A number of opportunities have been identified through this study to address some of the island energy specific challenges identified and there is significant potential to reduce the carbon intensity of island energy systems, potentially addressing island resilience and fuel poverty on the islands at the same time.

A.1.1 Appendices

Appendix 1 – Sources

Table 5: Sources

Audit section Island	Data source
Electricity/Heat Generation	· Renewable UK Database · Feed in Tariff data · Renewable Obligation Certificate data · HIE Questionnaire · Island interview
Island Energy Demand	· Internet search for commercial demand where possible, clarify during interview · Energy Performance Certificate (EPC) data · Govt. data on electricity consumption. (https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-electricity-consumption) · Island Reports · Population/households data census plus interview · HIE Questionnaire · Island interview · Estimated Heat and Hot Water Demand
Network status and performance	· Use of SSE GIS portal to determine if an island is grid connected · Use of SSE heat map to determine if an island is demand/generation constrained · Supply characteristics may be inferred if the generator mix is known · HIE Questionnaire · Island interview
	· HIE Questionnaire

Ownership model	· Island interview
Finance	· HIE Questionnaire · Island interview
Social Impact	· Scottish housing condition survey · Changeworks fuel poverty data · SIMD is at LSOA level which will not always overlap across an island. An estimate will be made using this data. COMPLETED
Supply chain	· Desk based · HIE Questionnaire · Island interview
Digital connectivity	Digital connectivity map (http://www.hie.co.uk/regional-information/digital-highlands-and-islands/can-i-get-it.html#) · HIE Questionnaire · Island interview
Community	· HIE Questionnaire · Island interview

Appendix 2 – Supply chain

Definitions of the energy system typologies as defined in the Scottish Enterprise Study[77].

Table 6: Scottish Enterprise typology work - typology definitions.

Typology	Criteria Bandings											
	Population	Population Density	Remoteness	Area Heat Density	Average Electricity Use /m	Local Grid Constraint	Heat Use Intensity	Waste Heat Availability	Gas Grid Availability	District Heating Network Coverage	Renewable Energy Resource Potential	Low Carbon Transport Infrastructure
Small Remote Island	A	A	D	A	D	D	A	C	D	A	A	A
Large Island	B	A	D	A	D	D	A	C	D	A	A	B
Remote Rural Village	A	C	D	A	D	D	A	C	D	A	B	B
Rural Market Town	B	D	C	B	C	D	B	C	C	A	B	C
Commuter Town	C	D	B	B	B	B	B	D	C	A	C	D
Mid-sized Town	C	D	B	C	A	B	C	B	B	B	C	D
Large Town / City	D	D	A	D	A	A	D	B	A	B	C	D
Industrial Park	B	D	B	D	A	A	B	A	A	A	D	D

[77] http://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=showPromoted&id=695

Table 7: Scottish Enterprise typology work - criteria descriptions.

ID	Criterion	Bands				Notes
		A	B	C	D	
1	Population	0-2,999	3,000-9,999	10,000-49,999	50,000+	Number of residents
2	Population Density (people/km^2)	0-499	500-1,499	1,500,2,499	2,500+	Number of occupants/area. Use community boundaries or wider Local Authority boundaries.
3	Remoteness	0	1-29	30-59	60+	Travel time (mins) to nearest settlement of over 10,000 people.
4	Area Heat Density (GWh/km^2/year)	0-9	10-39	40-99	100+	Average heat consumption for an area incl. both domestic and non-domestic use. Bands correspond to Scotland heat map.
5	Average Electricity Use per Meter (kWh/year)	0-1,899	1,900-4,199	4,200-7,099	7,100+	Typical Domestic Consumption Values measured in kWh/meter/year. A meter represents a household.
6	Local Grid Constraint	Fully Constrained	Partially constrained (High voltage or transmission network constrained)	Partially constrained (load or generation constrained)	Fully constrained (HV/transmission network or generation constrained)	This is measured qualitatively, based on criteria reported by SSP and SSE for each of their substations.
7	Heat Use Intensity (GWh/km^2/year)	0-99	100-399	400-999	1000+	Peak instantaneous heat demand for an area. This is the maximum load that the local heat infrastructure has to cope with.

8	Waste Heat Availability	None	Low	Medium	High	Measure of waste heat available, economically viable to extract locally from any suitable source.
9	Gas Grid Availability	0%	1-69%	70-89%	90%+	Estimated percentage of households not connected to the gas network.
10	District Heating Network Coverage	0%	1-39%	40-79%	80%+	Percentage of households with the option to connect to a district heat network either now or planned for deployment pre-2020.
11	Renewable Energy Recourse Potential	0	1-2	3-4	>4	This is the number of independent economically viable renewable resources that could be tapped in the area.
12	Low Carbon Transport Infrastructure	0-1	1-2	2-5	5+	Electric charging stations, public transport, or hydrogen refuelling stations per 10,000 people either available now or planned for deployment pre-2020

Appendix 3 – SIMD

The Scottish Index of Multiple Deprivation (SIMD) breaks Scotland down into areas (or data zones) that are made up of approximately 760 people and are ranked from 1 (worst) to 6,976 (best) for each of the indicators. This ranking process allows for a high-level evaluation of the level of deprivation seen on Scottish islands and so all seven 'domains' are evaluated in the sections below.

Unfortunately, there are a number of cases where more than one island falls in a single data zone and where an island falls into a data zone that also incorporates part of the mainland. This reduces the accuracy of the results, however accepting these inaccuracies allows access to a substantial resource of depravation data. There are also some drawbacks to SIMD that are discussed in more detail below.

Table 8: Information on how SIMD can be used[78]

SIMD can be used for the following	SIMD should not be used for the following
Comparing overall deprivation of small areas	Saying how much more deprived one area is from another – the difference between two ranks can be tiny or large
Comparing the seven domains of deprivation	Comparing ranks over time – changes are relative and may not reflect actual changes in the neighbourhood
Comparing the proportion of small areas in a country?	Comparing the UK with other countries – each country measures deprivation slightly differently
Councils that are very deprived	Identifying all people who are deprived in Scotland –not everyone who is deprived lives in a deprived area
Finding areas where many people experience multiple deprivation	Finding affluent areas – lack of deprivation is not the same as being rich
Finding areas of greater need for support and intervention	

During the interview phase, Barra and Vatersay Community Ltd shared a piece of work they completed that highlights some of the issues with using SIMD for analysis of rural areas such as islands (Barra and Vatersay Community Ltd - 'community assets inequalities & disadvantages brief.docx'). A short summary is provided below.

The primary issue is that the rural population is often socially heterogeneous and sparsely distributed and the SIMD looks at small concentrations of deprivation and does not identify individual cases of material deprivation. As such, materially deprived individuals living in rural areas can be overlooked which has the potential to lead to a lack of policy support for these areas. An example of this is the Western Isles, where there are no areas in the 20% most deprived 'quintile', however the Isles have the highest levels of fuel poverty, and morbidity rates comparable to the more deprived areas of Scotland.

The insight provided above should be considered alongside the analysis in Section 3.4. SIMD does contain information that can be useful in the formation of future policy decisions, however there are limitations. For more information on SIMD refer to the online guidance[79].

SIMD Domain rank overview

45 of the sampled islands are ranked in the middle third of all data zones in Scotland, three in the bottom third and one in the top third (see Table 9).

[78] https://www.gov.scot/Resource/0050/00504809.pdf
[79] https://www2.gov.scot/Topics/Statistics/SIMD

Table 9: SIMD domain ranking

Island	Council_area	Overall SIMD16 rank	Income domain rank	Employment domain rank	Health domain rank	Education domain rank	Housing domain rank	Access domain rank	Crime domain rank
Coll	Argyll and Bute	3195	4152	4183	4518	4189	2552	41	6359
Colonsa	Argyll and Bute	4239	5472	4961	6270	4579	3428	80	6934.5
Easdale	Argyll and Bute	3607	4664	4875	5612	5096	2002	8	5764
Erraid	Argyll and Bute	3773	4250	5143	5724	4542	1293	105	5984
Gigha	Argyll and Bute	3318	3574	4588	4984	3654	2850	165	4741
Iona	Argyll and Bute	3773	4250	5143	5724	4542	1293	105	5984
Jura	Argyll and Bute	4239	5472	4961	6270	4579	3428	80	6934.5
Kerrera	Argyll and Bute	4561	6467	5657	5822	5178	4371	45	5256
Lismore	Argyll and Bute	3989	4837	5726	6272	4814	2704.5	3	6641
Luing	Argyll and Bute	3607	4664	4875	5612	5096	2002	8	5764
Oronsay	Argyll and Bute	4239	5472	4961	6270	4579	3428	80	6934.5
Ulva	Argyll and Bute	3919	4073	5442	5524	5142	2978	109	5245
Canna	Highland	3928	4992	5219	5641	5909	2038	1	6771
Eigg	Highland	3928	4992	5219	5641	5909	2038	1	6771
Knoydart	Highland	3660	3967	4415	5448	5966	2813	91	6114
Muck	Highland	3928	4992	5219	5641	5909	2038	1	6771
Raasay	Highland	3826	4364	5518	6058	5327	2435	4	6934.5
Rum	Highland	3928	4992	5219	5641	5909	2038	1	6771
Burray	Orkney Islands	4527	6013	5353	4222	3550	4593	376	6934.5
Eday	Orkney Islands	3154	4040	3995	4935	2804	2233	150	6496
Egilsay	Orkney Islands	3683	4065	4593	4931	4417	1797	231	6193
Flotta	Orkney Islands	2061	2863	2473	4087	2411	2160	43	5015
Graemsa	Orkney Islands	2061	2863	2473	4087	2411	2160	43	5015
Hoy	Orkney Islands	2061	2863	2473	4087	2411	2160	43	5015
North Ro	Orkney Islands	2665	3173	3587	4351	3916	2115	28	6363
Papa We	Orkney Islands	3154	4040	3995	4935	2804	2233	150	6496
Rousay	Orkney Islands	3683	4065	4593	4931	4417	1797	231	6193
Sanday	Orkney Islands	2665	3173	3587	4351	3916	2115	28	6363
Shapinsa	Orkney Islands	3683	4065	4593	4931	4417	1797	231	6193
Stronsay	Orkney Islands	2665	3173	3587	4351	3916	2115	28	6363
Wyre	Orkney Islands	3683	4065	4593	4931	4417	1797	231	6193
Bressay	Shetland Islands	3497	5054	3853	4416	3857	3685	185	4612
Bruray	Shetland Islands	4192	5236	6510	6396	3554	5272	20	5801
East Bur	Shetland Islands	4565	4648	6182	5141	3852	5192	384	6291
Fair Isle	Shetland Islands	4187	5381	5312	4965	5170	4480	72	5758
Fetlar	Shetland Islands	2873	3735	3866	4914	3273	3716	14	6619
Foula	Shetland Islands	4565	4648	6182	5141	3852	5192	384	6291
Housay	Shetland Islands	4192	5236	6510	6396	3554	5272	20	5801
Muckle F	Shetland Islands	5043	5578	5215	4142	3536	4961	1980	5621
Papa Sto	Shetland Islands	4391	5316	5132	5116	5737	3653	123	6831
Trondra	Shetland Islands	4565	4648	6182	5141	3852	5192	384	6291
Baleshar	Western Isles	3324	3579	4412	4649	3985	4989.5	135	6868
Bernera	Western Isles	2654	2919	3285	4564	4798	4326	19	6683
Berneray	Western Isles	3324	3579	4412	4649	3985	4989.5	135	6868
Eriskay	Western Isles	3055	2624	3832	4052	4941	5345	249	6747
Grimsay	Western Isles	3324	3579	4412	4649	3985	4989.5	135	6868
Grimsay	Western Isles	3324	3579	4412	4649	3985	4989.5	135	6868
Scalpay	Western Isles	3729	3251	4693	5315	4993	4799	288	6426
Vatersay	Western Isles	3042	3228	2751	3750	3134	3813	1316	4611

Top 10%	6275 - 6976
Top third	4604 - 6275
Mid third	2302 - 4604
Bottom third	697 - 2302
Bottom 10%	1 - 697

The following provides a breakdown of individual domain ranks:

Table 10: Domain rank summary for Scottish Islands

Domain Rank	Summary
Income	All sampled islands in the Western Isles are in the middle third for Income with the rest of the islands distributed between the top and middle thirds. There are a greater proportion of islands in the top third for Income in Argyll and Bute and Shetland.
Employment	All sampled islands in the Highlands region are in the top third for Employment, except Knoydart that is in the middle third. The rest of the islands distributed between the top and middle thirds except for Bruray and Housay in Shetland that are in the top 10% for Employment.
Health	All sampled islands in the Highlands region are in the top third for Health with the rest of the islands distributed between the top and middle thirds. Bruray and Housay in Shetland are in the top 10% for health.
Education	All sampled islands in the Highlands region are in the top third for Education. All islands in the Orkney Isles are in the middle third, with islands in Argyll and Bute, the Western Isles and Shetland distributed between the top and middle thirds.
Housing	The islands are all broadly ranked in the middle for Scotland. The Western Isles and Shetland however have a high proportion of islands ranked in the top third and Argyll and Bute, Highland and the Orkney Isles all have a high proportion of islands ranked in the bottom third for housing.
Access	47 of sampled islands are ranked in the bottom 10% for Scotland
Crime	All islands are ranked in the top third for Crime, with 28 in the top 10%.

In summary, Scottish islands generally score poorly in geographic access, housing, education and income but score well in health and very well in crime.

The following maps produced by Changeworks[80] provide an overview of fuel poverty in Scotland by region and highlight the low spatial resolution of publicly available data.

Changeworks Fuel Poverty Maps

[80] https://www.changeworks.org.uk/projects/fuel-poverty-maps

Figure 15: Changeworks fuel poverty map - Highland Region

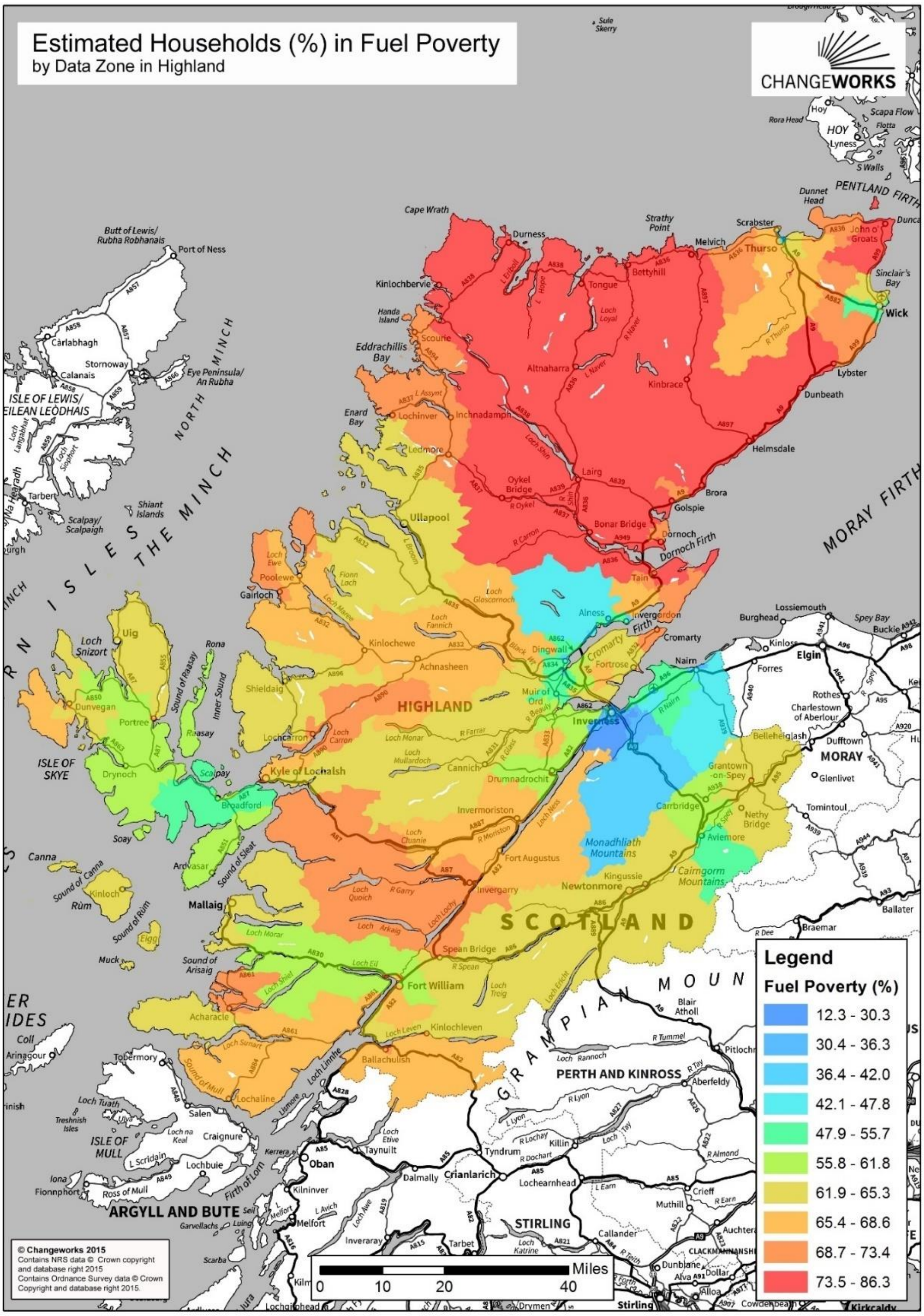


Figure 16: Changeworks fuel poverty map - Argyll and Bute Region

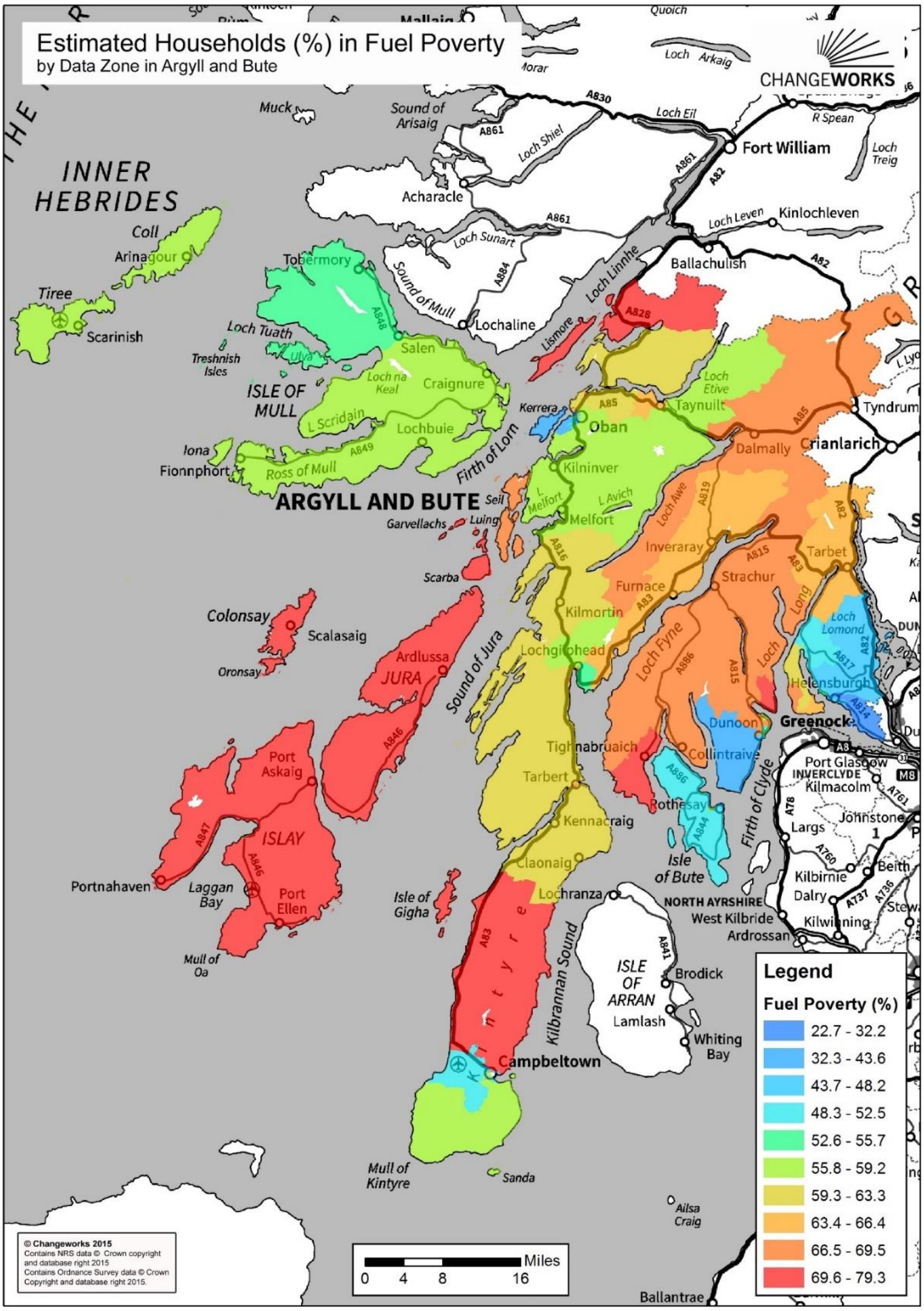


Figure 17: Changeworks fuel poverty map - Orkney Region

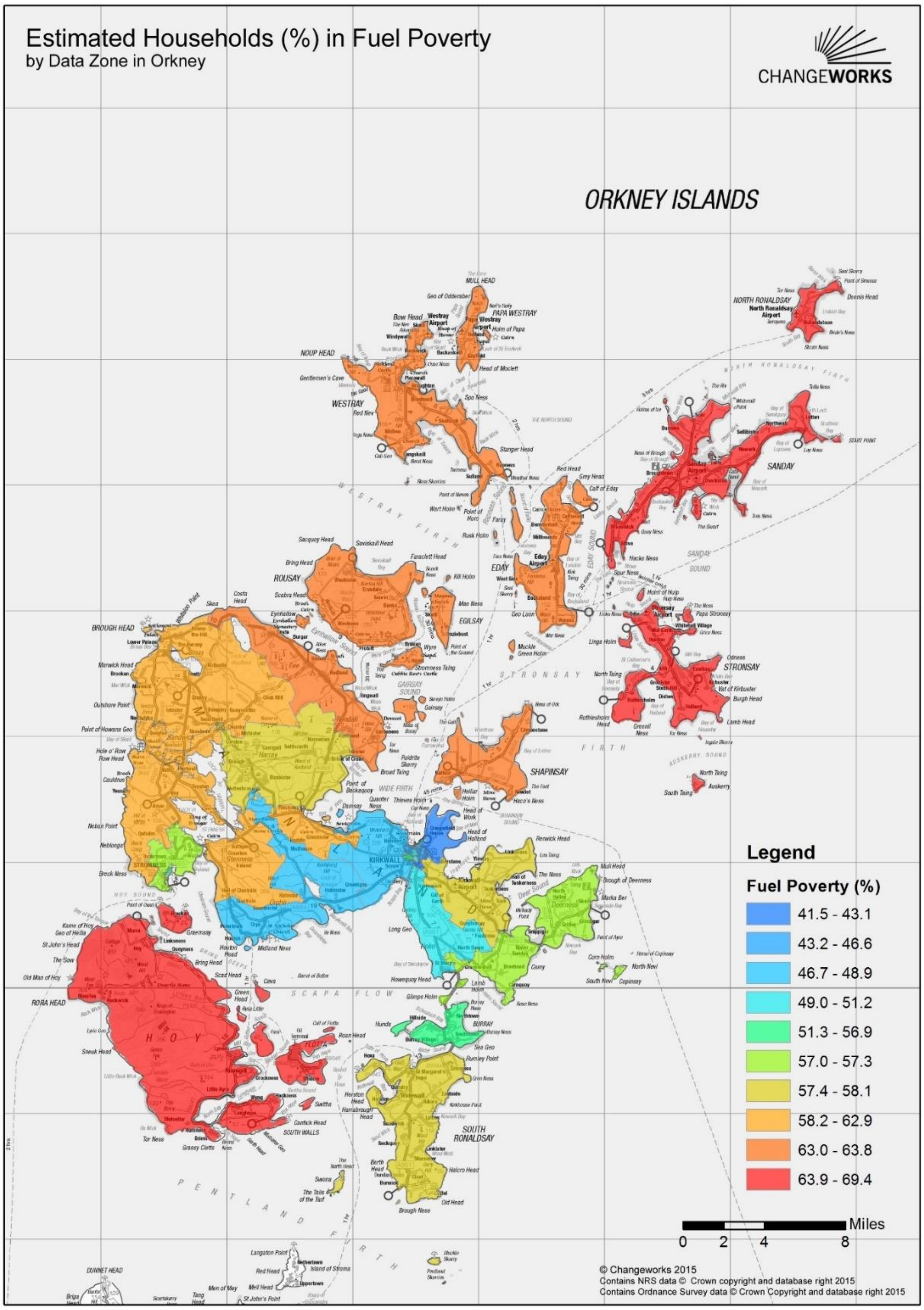


Figure 18: Changeworks fuel poverty map - Western Isles Region

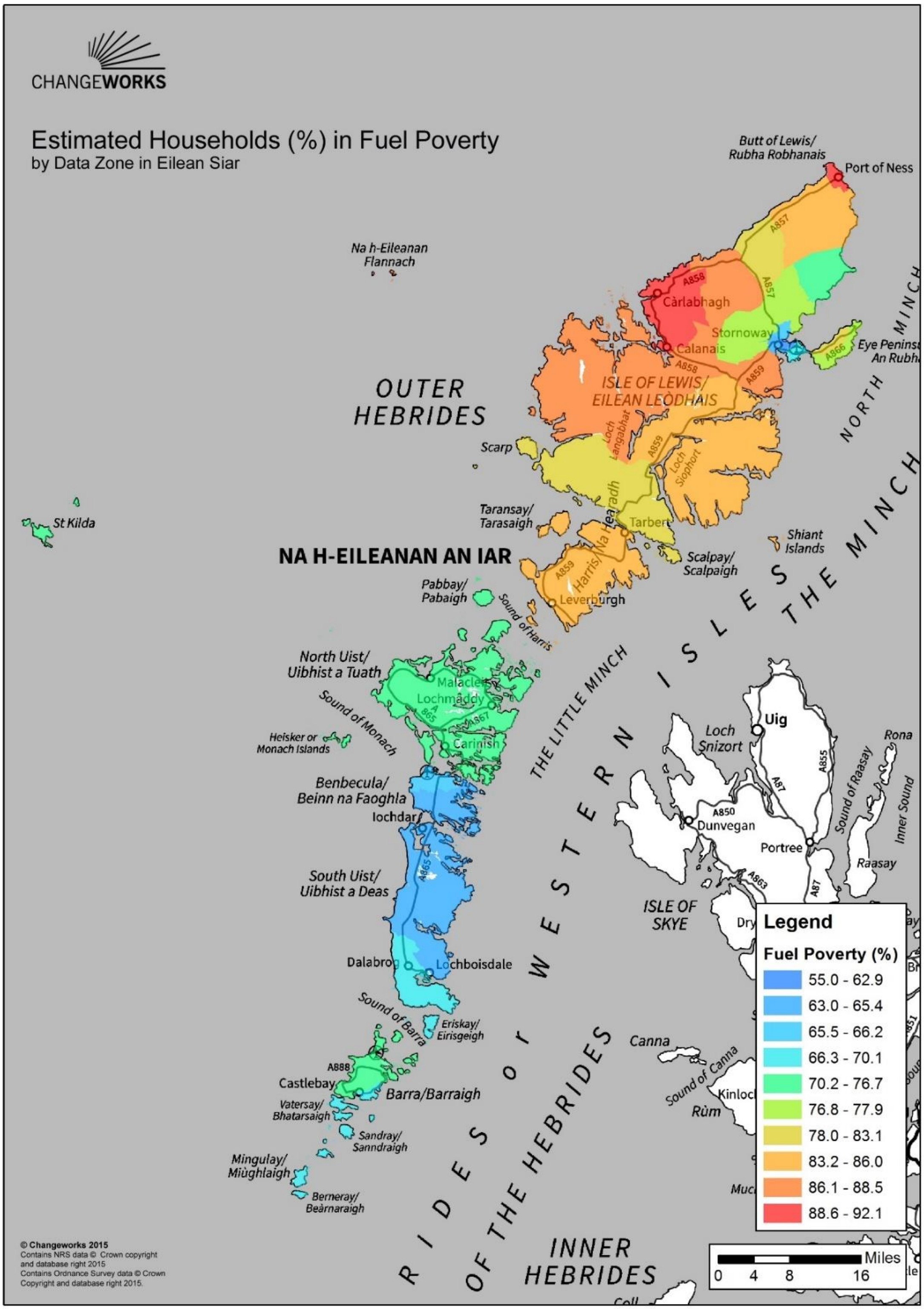
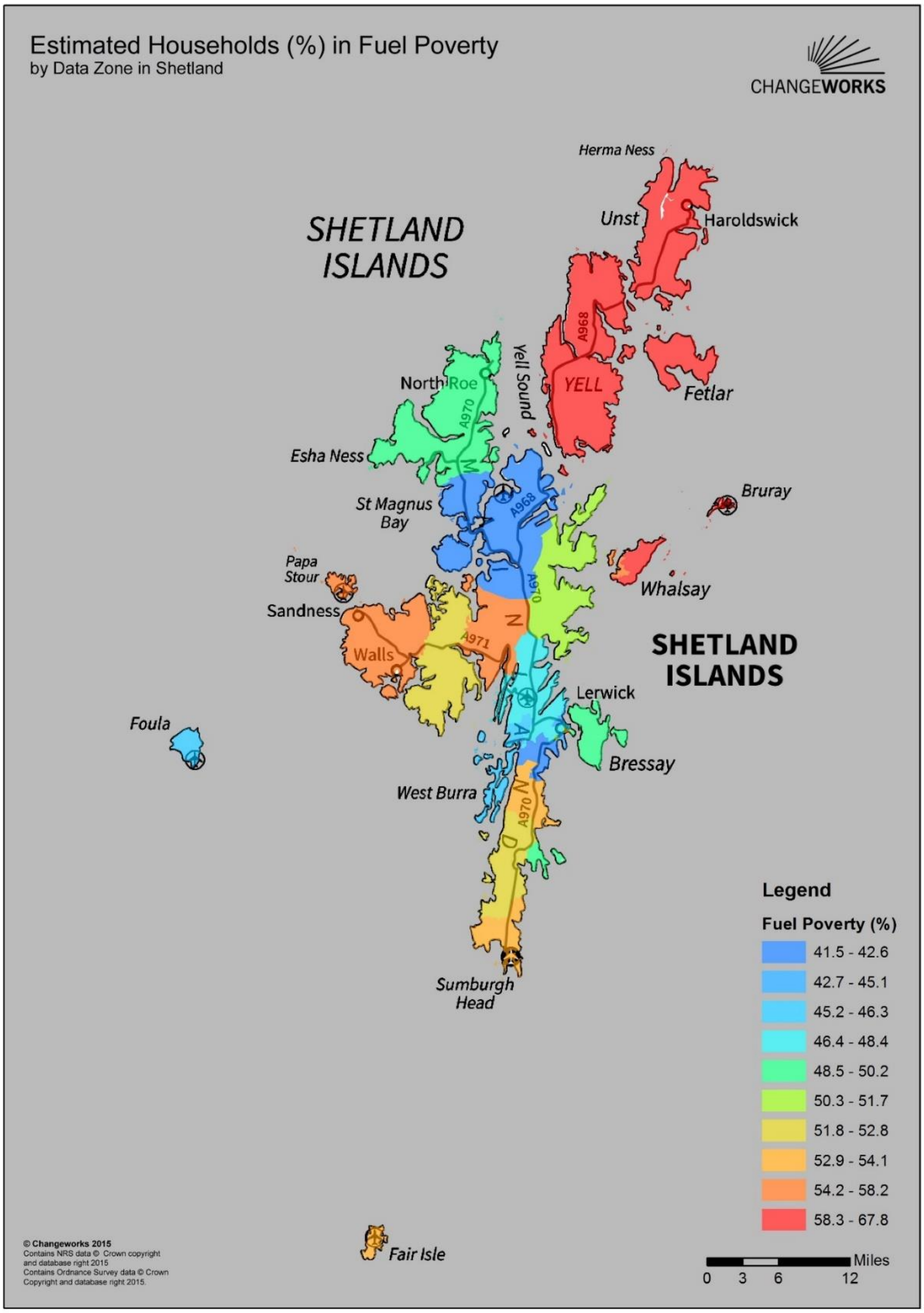


Figure 19: Changeworks fuel poverty map - Shetland Region



Appendix 4 – Geographic Access/Transport

The following section summarises the geographic access SIMD data for each council area. Seven variables were evaluated for the five council areas (Argyll and Bute, Highland, Orkney, Shetland, Western Isles):

- Average drive time to a petrol station in minutes
- Average drive time to a GP surgery in minutes
- Average drive time to a post office in minutes
- Average drive time to a retail centre in minutes
- Public transport travel time to a GP surgery in minutes
- Public transport travel time to a post office in minutes
- Public transport travel time to a retail centre in minutes

Figure 20: Geographic access indicators for islands in Argyll and Bute alongside averages for the Council area.

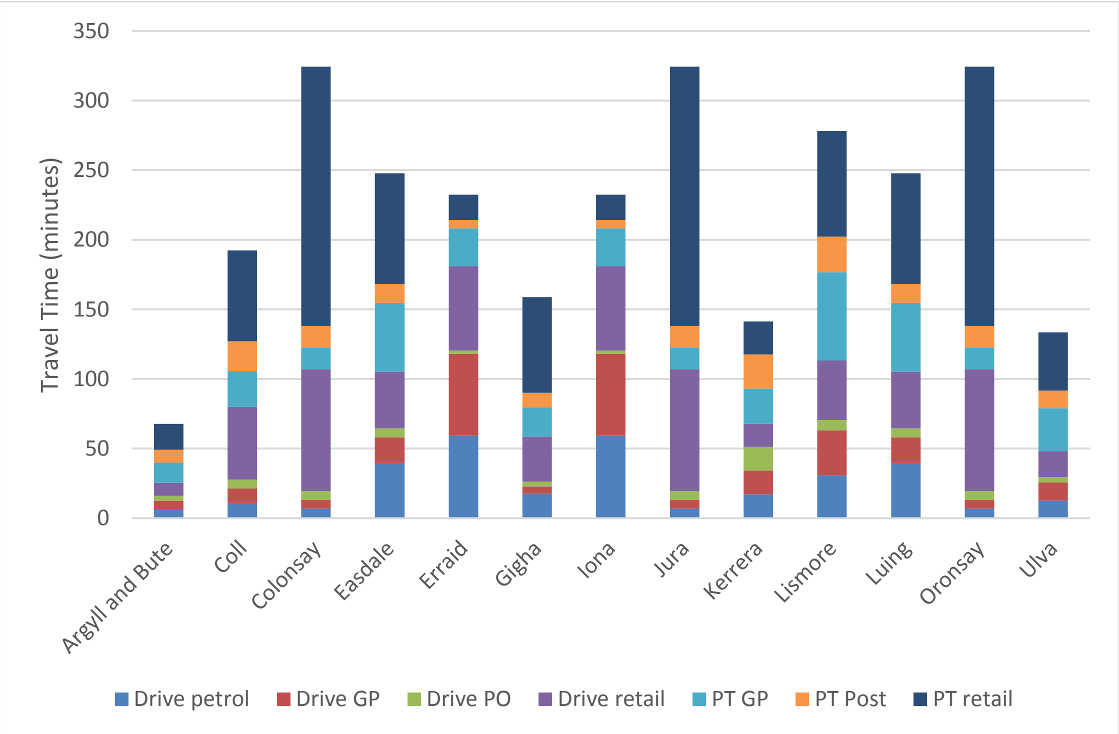


Figure 21: Geographic access indicators for islands in the Highlands alongside averages for the Council area.

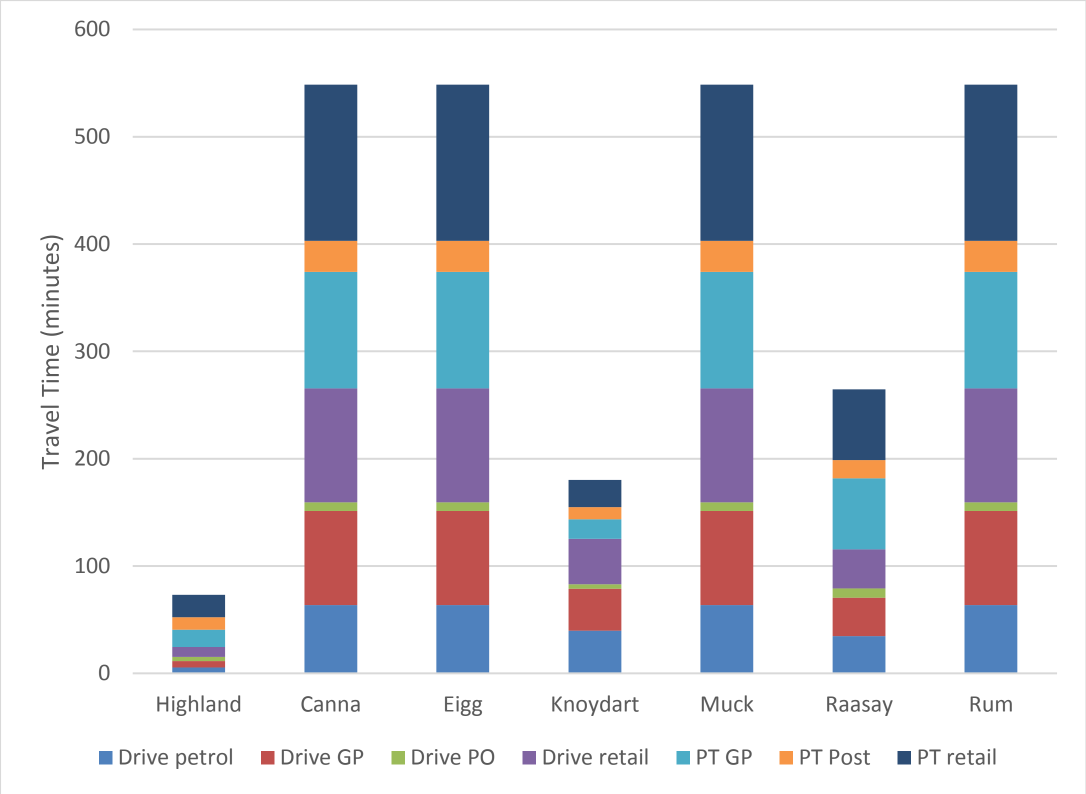


Figure 22: Geographic access indicators for islands in the Western Isles alongside averages for the Council area.

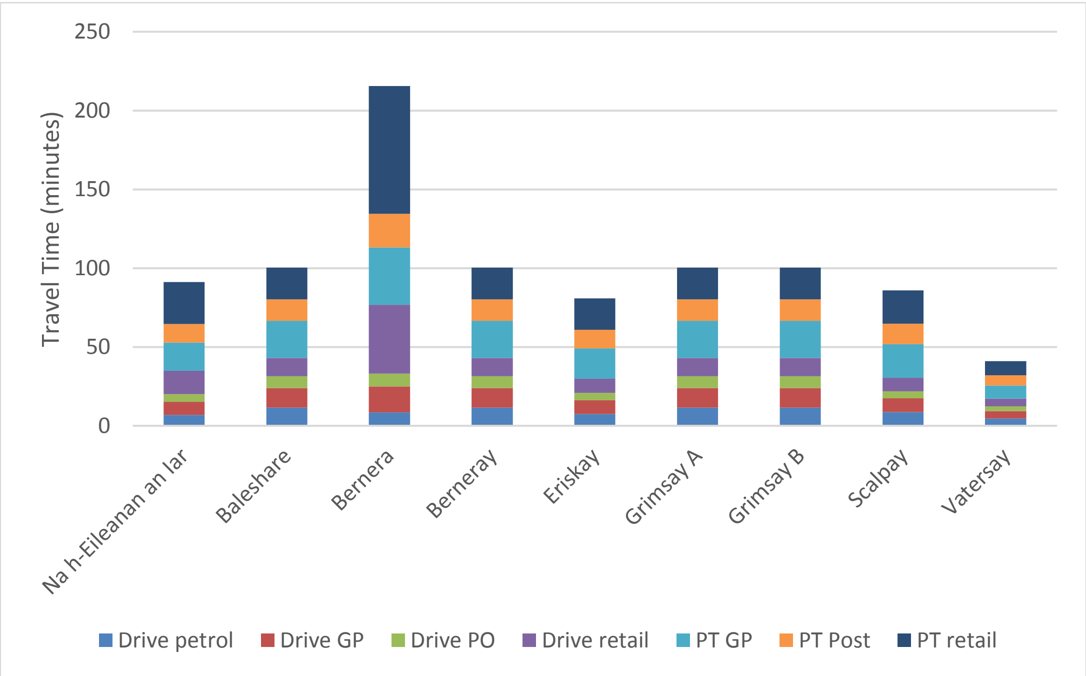


Figure 23: Geographic access indicators for islands in the Orkney Isles alongside averages for the Council area.

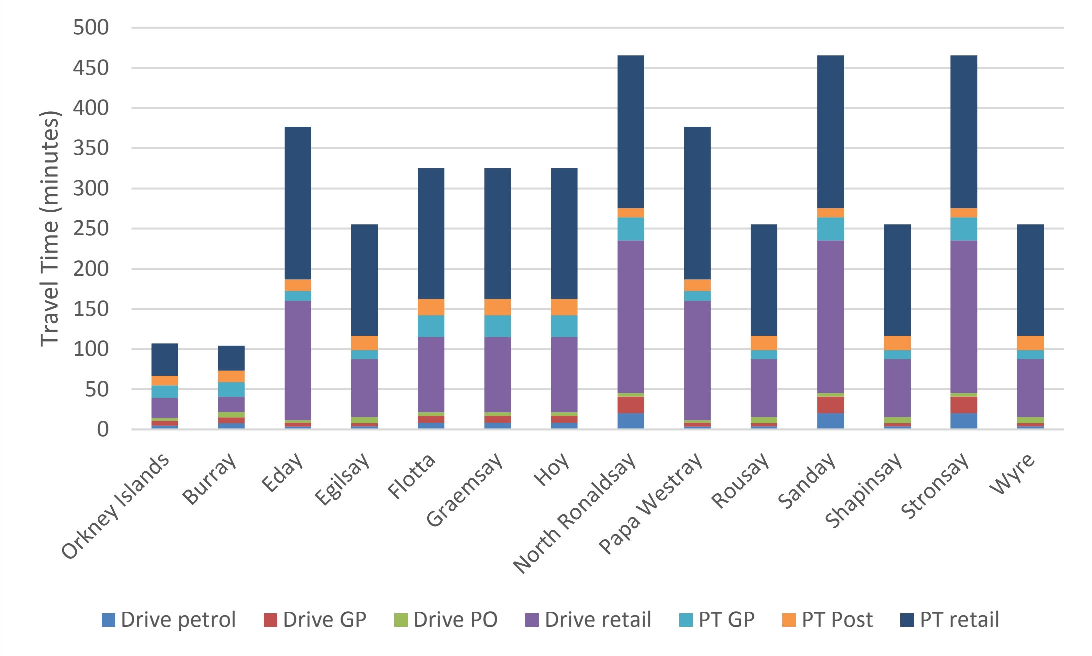
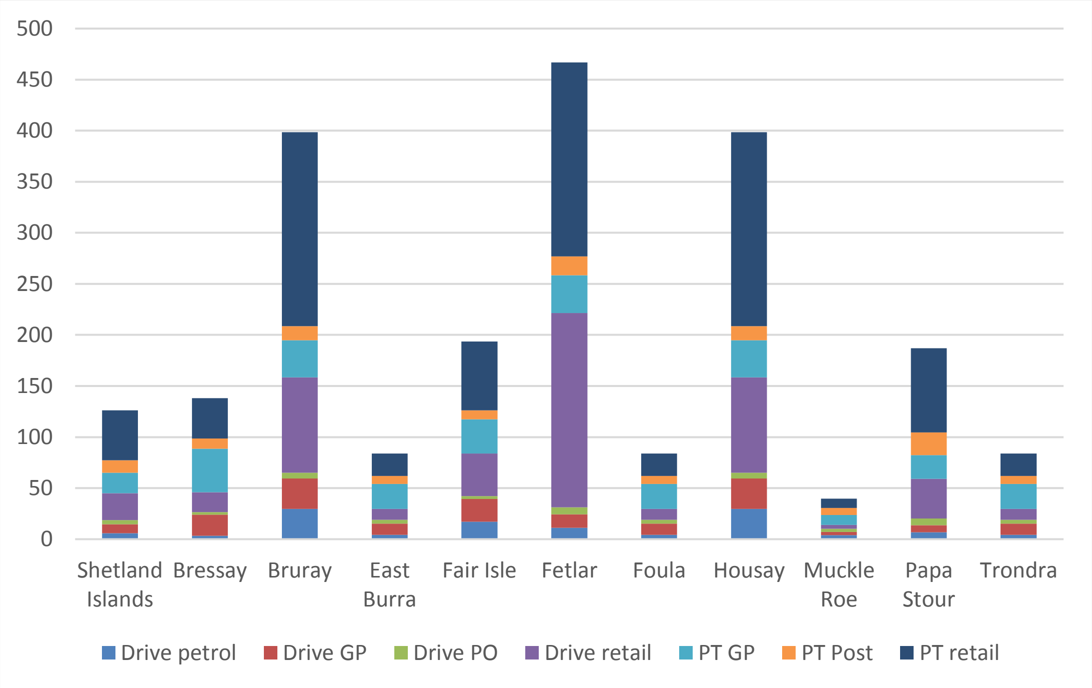


Figure 24: Geographic access indicators for islands in Shetland alongside averages for the Council area.



Appendix 5 – Island Energy Demand

Total island domestic energy demand has been estimated using:

- Scottish average values for domestic electricity (3635kWh)

- modelled hot water demand (2588kWh)
- average space heating based on floor area (taken from EPC), an average heat loss coefficient per unit of floor area and the estimated degree days for the north of Scotland.

The hot water demand has been calculated based on assumed consumption of 122 litres per day per household. An intake temperature of 10 degrees Celsius and a target temperature of 60 degrees Celsius.

To calculate the average heat demand, floor area information has been obtained from available Energy Performance Certificates (EPC). For each postcode sector (which in some cases includes more than one island) an average area has been taken. The average floor area for each post code location has been multiplied by the estimated heat loss coefficient and by the estimated degree days heat input required.

Since the proportion of electric heaters on the studied islands is much higher than the Scottish average, an adjustment has been made to account for this. The share of electric heaters across Scotland is 12% whereas on the studied islands it is 54.7%. The average domestic electricity demand of 3635kWh has been reduced by 12% to form a base electricity demand. Hence, the proportion of electric heating in each postcode sector has been multiplied by the heat demand there and added to that base electricity demand to form the actual electricity demand on in the postcode sector.

In order to arrive at the total energy demand on each island, the total energy demand per household has been multiplied by the number of properties on each island. (Table 11).

Table 11: Summary of domestic energy demand by island using EPC data. Data broken down into electricity and heat.

Island	Population	Household	Total domestic electrical demand (MWh/ Island)	Total domestic heating demand (MWh/ Island)	Total domestic Island energy demand (MWh)
Baleshare	58	21	432	465	897
Bernera	252	116	3,083	3,121	6,204
Berneray	138	82	1,689	1,816	3,505
Bressay	368	80	2,062	1,460	3,522
Bruray	24	12	309	219	528
Burray	409	195	5,343	4,485	9,828
Canna	19	11	131	248	379
Coll	195	87	3,405	2,478	5,883
Colonsay	124	70	3,154	1,476	4,630
Easdale	59	29	578	435	1013
East Burra	76	34	876	620	1,496
Eday	129	85	2,329	1,955	4,284
Egilsay	22	10	274	230	504
Eigg	83	67	795	1,484	2,279
Eriskay	143	73	1,263	1,649	2,912
Erraid	6	4	118	67	185
Fair Isle	55	26	670	474	1,144
Fetlar	61	31	799	566	1,365
Flotta	80	48	1,319	948	2,267

Foula	38	24	619	438	1,057
Gigha	163	88	3,615	2,632	6,247
Graemsay	28	14	385	277	662
Grimsay A	169	80	1,647	1,771	3,418
Grimsay B	20	7	144	155	299
Housay	50	19	490	347	837
Hoy	419	227	6,239	4,484	10,723
Iona	150	68	3,008	1,562	4,570
Jura	220	93	3,465	1,918	5,383
Kerrera	34	29	578	435	1,013
Knoydart	115	55	1,386	968	2,354
Lismore	192	90	2,216	1,539	3,755
Luing	162	148	2,948	2,219	5,167
Muck	40	14	166	498	664
Muckle Roe	130	44	1,134	803	1,937
North Ronaldsay	72	34	932	782	1,714
Oronsay	8	4	180	84	264
Papa Stour	15	9	232	164	396
Papa Westray	90	40	1,096	920	2,016
Raasay	161	78	1,477	1,469	2,946
Rousay	216	109	2,986	2,507	5,493
Rum	38	19	225	752	977
Sanday	494	234	6,411	5,382	11,793
Scalpay	291	138	5,645	4,623	10,268
Shapinsay	320	146	4,000	3,358	7,358
Stronsay	349	157	4,302	3,611	7,913
Trondra	135	54	1,099	901	2,000
Ulva	11	6	210	197	407
Vatersay	90	38	1,102	878	1,980
Wyre	29	14	384	322	706

Interviewees noted changes to island demand that are replicated across several islands This provides qualitative interview information on expected demand changes on islands.

In summary, the interviewees noted potential changes in demand are likely to result from:

- Increased need for houses to accommodate an increasing population.
- Developing business and community expansion.
- Development of a cottage community hospital.
- Increase in marine tourism (overnight berthing, pontoons, moorings).
- New and growing distillery businesses.
- Breweries.
- Fish farms.
- Refurbishment of visitor attraction facilities which will bring on new demand.
- New tourism accommodation.

Appendix 6 - Connection Type

Table 12: Breakdown of the study islands by connection type

Islands connected to mainland grid via Orkney	Islands connected to the mainland grid via Western Isles	Islands connected to Shetland Grid	Non Grid Connected (Off-Grid)
Burray	Baleshare	Bressay	Canna (Small Isles)
Eday	Bernera	Bruray	Eigg (Small Isles)
Egilsay	Berneray	East Burra	Fair Isle (Shetland)
Flotta	Eriskay	Fetlar	Foula (Shetland)
Graemsay	Grimsay A	Housay	Knoydart ('Islanded' mainland community)
Hoy	Grimsay B	Muckle Roe	Muck (Small Isles)
North Ronaldsay	Scalpay	Papa Stour	Rum (Small Isles)
Papa Westray	Vatersay	Trondra	
Rousay			
Sanday			
Shapinsay			
Stronsay			
Wyre			

Appendix 7 – Communications

Information from The Office of Communications (OFCOM[81]) allowed an evaluation of broadband connectivity speeds for each island. The metrics evaluated include the number of premises on each island that are unable to receive different download speeds (2Mb/s which is a slow download speed and 30Mb/s which is a relatively high download speed), as well as the number of premises below the Universal Service Obligation (USO) [82]. The UK government introduced legislation that will come into effect in 2020 that sets the requirements for a USO that gives consumers a right to request a broadband connection that can deliver download speeds of at least 10Mb/s and upload speeds of at least 1Mb/s (eligibility criteria apply)[83]. The USO sets reliable broadband up as an essential service that needs to be available to both urban and rural communities and aims to prevent 'social and digital exclusion', regardless of where people live or work. As stated above, the OFCOM figures are representative of the situation in 2016 and the USO is due to come into effect in 2020. Despite this gap, the USO acts as a metric to provide an indication of the service available.

[81] https://www.ofcom.org.uk/research-and-data/search
[82] https://www.ofcom.org.uk/phones-telecoms-and-internet/advice-for-consumers/broadband-uso-need-to-know
[83] https://www.ofcom.org.uk/__data/assets/pdf_file/0013/115042/implementing-broadband-uso.pdf

Further qualitative data was collected on connectivity or reliability issues with broadband and mobile coverage. Of the islands interviewed, 63% noted connectivity issues with their broadband and 75% noted coverage issues with the mobile network.

Appendix 8 – Island Reports

The following table summarises the island energy reports made available for evaluation during the study. This list is not intended to be comprehensive of development reports completed on Scottish islands.

Table 13: Island energy reports

Island	Description	Link
Canna	Small Isles Energy Audit	https://europeansmallislands.files.wordpress.com/2016/03/small-isles-energy-audit-report.pdf
Eigg	Small Isles Energy Audit	https://europeansmallislands.files.wordpress.com/2016/03/small-isles-energy-audit-report.pdf
Fetlar	Fetlar Community Development Plan	https://www.localenergy.scot/media/102487/P42221-Fetlar-Community-Development-Plan-2013.pdf
Gigha	Isle of Gigha Energy Audit Report	http://www.scottish-islands-federation.co.uk/wp-content/uploads/2016/01/Gigha-Energy-Audit-Report.pdf
Iona	Isle of Iona Energy Audit	https://europeansmallislands.files.wordpress.com/2016/03/iona-energy-audit-report.pdf
Kerrera	Isle of Kerrera Development Trust Wind Turbine	https://www.communityenergyscotland.org.uk/userfiles/file/case_studies/Case_Study_Kerrera_-_Pre_Capital.pdf
Lismore	Isle of Lismore Energy Audit 2014-15	http://www.scottish-islands-federation.co.uk/wp-content/uploads/2016/01/Lismore-Energy-Audit-Report.pdf
Luing	Isle of Luing Energy Audit	http://www.scottish-islands-federation.co.uk/wp-content/uploads/2016/01/Luing-Energy-Audit-Report.pdf
Muck	Small Isles Energy Audit	https://europeansmallislands.files.wordpress.com/2016/03/small-isles-energy-audit-report.pdf
Muckle Roe	Deep Geothermal Energy in the Shetland Isles	http://www.districtheatingscotland.com/wp-content/uploads/2015/12/CluffGeothermalReport.pdf
Papa Westray	Papa Westray Island Development Plan 2016-2026	http://www.papawestray.co.uk/development-trust/papay-development-plan-2016-2026.pdf

Island	Description	Link
Rum	Small Isles Energy Audit	https://europeansmallislands.files.wordpress.com/2016/03/small-isles-energy-audit-report.pdf
Sanday	The Sanday Plan	160108-is-SandayPlan2016
Vatersay	Local Energy Plan for Barra and Vatersay	https://www.localenergy.scot/media/110325/bv-draft-local-energy-plan-final.pdf
	COBEN Reports	Various

Ricardo
Energy & Environment

18 Blythswood Square
Glasgow
G2 4BQ
United Kingdom
t: +44 (0)1235 753000
e: enquiry@ricardo.com

ee.ricardo.com