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ARISAIG COMMUNITY TRUST

HIGH LEVEL RENEWABLE ENERGY OPTIONS APPRAISAL

18th March 2021

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EXECUTIVE SUMMARY

Scene Connect Ltd. (Scene) was appointed to produce a high level renewable energy options appraisal for the Arisaig Community Trust (ACT) in the West Highlands. The report explores the potential for the community to reduce their carbon-footprint and generate additional sources of income from renewable generation or supply.

Data for the study was collected primarily through consultation with ACT, integrating annual energy readings with industry standard energy profiles across different building types. Renewable energy generation profiles were modelled to develop energy scenarios for matching local demand. The local Distribution Network Operator (DNO) was contacted to understand the potential to connect additional renewable generation assets to the grid. A bespoke energy modelling tool using *Microsoft Excel* was built to run and compare multiple energy system scenarios according to a number of energy, financial, and carbon emissions metrics. The headline results from these models are outlined below (all figures are per annum).

Scenario 1: Supplying baseline demand with renewable generation (240kW solar, 100kW wind)	
Proportion of demand met by renewables	14.9 %
Grid-electricity cost offset by renewables	£ 75,661
Income from renewables exports	£ 1,574 (assumes Octopus export rate)
Carbon emissions offset by renewable generation	118 tonnes CO_2e

Scenario 2: Residential heat-pump upgrades	
Estimated number of residences to receive heat pumps	188 homes
Additional electricity demand compared to baseline	+ 30 %
Carbon emissions offset from heat-pump upgrades	481 tonnes CO_2e
Cost savings achieved	- £ 71,480 (without domestic RHI)
	£1,599,420 (with domestic RHI for 7 years)

Scenario 3: Selling electricity to EV charging customers (grid and solar)	
Demand of EV chargers (high-use scenario)	17,938 kWh
Net revenue from selling grid electricity to EV customers	£ 1,435[1]
Proportion of demand met through solar energy	65 %
Net revenue from selling solar electricity to EV customers	£ 2,912
Carbon emissions offset from solar supply	1.47 tonnes CO_2e
Income from exported solar electricity	£ 8,931 (assumes Octopus export rate)
Or	
Cost savings if electricity was stored rather than exported	£ 15,426

[1] Assumes an electricity price of £0.17/kWh and a EV charging price of £0.25/kWh.

The returns for **Scenario 1** are very modest, relative to the scale of investment, and these do not yet consider the cost of borrowing.

The returns for **Scenario 2** are highly dependent on the Renewable Heat Incentive, with the scheme, there is significant benefit; without costs would increase. The domestic RHI closes to new entrants in March 2022, so any community members interested in considering a heat pump would be advised to progress this promptly. In addition, the Energy Saving Trust is currently offering loans on a first-come, first served basis to support home technologies, with a grant element, to help with the up-front capital cost.

A highly positive financial and environmental case can be made for **Scenario 3**. This would comprise an energy system of a 240kW solar PV array, a battery storage system (~30kWh in size), and the 5 existing EV charging stations near the shoreline.

The financial outcomes of the scenarios above represent the on-going costs and benefits of each scheme only. They do not account for the capital or operating costs of any of the low-carbon installations or assets mentioned (heat pumps, batteries, wind turbines, solar PV arrays). For example, a 240kW solar array and 30kWh battery storage system as illustrated in Scenario 3, can be expected to cost over £300k, including all design, project management, construction, but excluding VAT.

Next Steps:

We recommended that in the first instance ACT liaise with *ChargePlace Scotland* to enquire into the process of switching their EV chargers to a paid-for scheme, and to decide the particular tariff(s) for customers (e.g. unit costs, standing charge, minimum charge, overstay charge)[2]. A unit tariff of £0.25/kWh used in this model was illustrative only.

Secondly, securing an Enablement Grant from CARES will allow ACT to explore in detail the more complicated and intensive renewable generation and low-carbon heating development options outlined in Scenarios 1 and 2, respectively[3], if these are of interest. It could also, or alternatively, be used to develop the energy system approach for Scenario 3, including e.g. identifying an appropriate site and agreeing Heads of Terms with the landowner, then preparing designs and cable routing, detailed energy modelling based on a specific site layout, and engaging with the planning authority. This grant awards successful applicants with up to £25,000 of funding to conduct non-capital feasibility studies and engagement works - precisely what is required in order to take these initial scenarios to the next stage. ACT is recommended to contact their CARES Local Development Officer[4].

[2] https://chargeplacescotland.org/contact/

[3] https://www.localenergy.scot/funding/cares-enablement-grant/

[4] https://www.localenergy.scot/who-we-are/local-contacts/

1. INTRODUCTION

1.1. AIMS AND OBJECTIVES

This report has been written to provide the Arisaig Community Trust ("ACT") with a high-level options appraisal for reducing the carbon footprint of the community and generating income from renewable energy generation or supply. It details the financial and environmental impacts that both renewable energy generation assets (namely, solar and wind), low-carbon heating measures (namely heat pump upgrades) could have within their community. The report also makes an assessment regarding the potential of the existing EV charging stations in Arisaig to be supplied by a community-owned solar farm through a direct connection.

It was conducted using a combination of desk-based research, GIS mapping, data analysis from inputs from ACT representatives, and a process of technical, financial, and carbon modelling using Scene's bespoke energy modelling in *Microsoft Excel* software. Following a high-level options appraisal, the modelling ran and compared two separate scenarios, the first of which considered the installation of solar and wind energy generation assets near to Arisaig centre, and the second of which considered upgrading to low-carbon heat pumps for those homes currently using oil, coal, gas, or wood for as their heating fuel.

The outputs from this report are illustrative only and intended to provide a general indication of the most feasible and beneficial low-carbon options which ACT could pursue in the future. Further research and modelling would be required to provide more in-depth recommendations and quantifications. Given the time-frame and scope of this particular energy options appraisal, precise energy demand figures and profiles for many of the buildings modelled were not available, and reasonable estimates from reliable databases (i.e., Ofgem, CIBSE) were used otherwise. A more detailed appraisal would in the first instance obtain more accurate energy and heating demand figures to allow for more reliable modelling outputs.

1.2. ARISAIG COMMUNITY TRUST (ACT)

This energy options appraisal has been conducted on behalf of the Arisaig Community Trust ("ACT"). ACT is a Scottish registered charity, established in 2009 to guide and oversee development for the community of Arisaig[5]. In partnership with the Community Council and other research and consultancy organisations, their development projects include themes of education, culture, housing, sports and recreation, employment, and the local environment[6].

1.3. SCENE

Scene Connect Ltd. ("Scene") is a UK based social enterprise established in 2011 with the intention of furthering the community energy sector in Scotland and further afield through impact research, consultancy and innovation. The organisation works with landowners, developers and community groups to further opportunities for a range of community developments, taking a whole systems approach to energy decarbonisation, and delivering value to communities through wholly owned projects, joint ventures or negotiating benefits packages.

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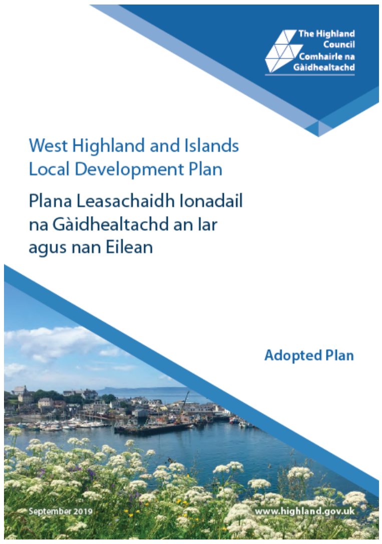
[5] https://www.arisaigcommunitytrust.org.uk/

[6] http://www.community-council.org.uk/arisaiganddistrict/

2. BASELINE

2.1. DEVELOPMENT OF RENEWABLES WITHIN THE WEST HIGHLANDS AND ISLANDS

The West Highland and Islands Local Development Plan (2019) ("WestPlan") guides future development in the Highlands over the next 20 years[7]. In determining planning applications, proposals should be in accordance with the WestPlan, taking into account other material considerations, such as Supplementary Guidance. It seeks to deliver key outcomes which safeguard and enhance communities, employment, connectivity, and transport, as well as the environment and heritage.



The WestPlan is driven by four priority outcomes:

1. Growing Communities
2. Employment
3. Connectivity and Transport
4. Environmental and Heritage

There are eight separate mentions of renewable energy throughout the document. The fourth priority of the WestPlan – Environment and Heritage – is the only one to make direct reference to the development and use of renewable energy in the Highlands: "Waste is reduced, reused, recycled, or treated as close to source as possible to generate renewable energy" (page 33). All other mentions refer to specific local developments and Placemaking Priorities within the towns of: Mallaig, Rum, Eigg, Canna, and Inverie, Achnacarry, Bunarkaig and Clunes. No reference to renewable energy or energy efficiency measures is made within the Arisaig chapter (page 101).

Point 1.56. of the Vision and Strategy Chapter 1 refers to policy in the 2012 Highland-wide Local Development Plan which encourages the maximisation of energy efficiency measures and renewable sources of energy, as part of sustainable design and community development in line with the built and natural environment.

Point 1.57 also makes reference to the Scottish Government's Draft Energy Strategy (2017) and Energy Efficiency Programme, which together include ambitious proposals to decarbonise heating systems across Scotland.

2.2. ARISAIG

The WestPlan describes Arisaig as a 'growing settlement', known for its tourism and marine-based enterprises. Arisaig lies on the border of the Moidart, Morar and Glen Shiel Scenic Landscape Area, and the Morar, Moidart and Ardnamurchan National Scenic Area, with the Larach Mor Designed Landscape lying east of the built settlement (Figure 1).

The main economic focus of the Arisaig Community is tourism. As Arisaig is located in close proximity to Mallaig (the ferry terminal for the Small Isles and Skye), areas of outstanding beauty (Silver Sands of Morar) and close to some of the best beaches on the West Coast.

Therefore, the economy is based around the typical tourist season in the North West of Scotland, and the Mallaig ferry timetable.

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7 https://www.highland.gov.uk/info/178/local_and_statutory_development_plans/582/west_highlands_and_islands_local_development_plan

The main source of employment in Arisaig is hospitality and tourism, with a few people working in agriculture, fishing and forestry. Other occupations are noted as property management, childcare, graphic design, and marriage ceremonies (2018 Housing Need Report). However, the 2018 Housing Need Report also highlighted that nearly 50% of people are economically inactive, possibly due to retirement. The high numbers of retired people coincide with the aging population in the area. Respondents of the survey highlighted that they would like more cafes, arts and crafts facilities and a seaweed farm as possible future businesses in the area.

Arisaig is also a hub for Scottish Heritage. There are regular ceilidhs, concerts & craft fairs at the community hall. Additionally, the Land Sea and Islands Centre (LSIC) is home to souvenirs, crofting artefacts, a rebuilt forge, wildlife exhibitions and war presentations.

The community has a resident population of approximately 300 with 34 pupils at Arisaig Primary School. The school children follow on to Mallaig High School for Secondary education. There are two classes at the primary school, P1 to P3 and P4 to P7. The school is also a source of employment for 12 members of staff including, teachers, classroom assistants, catering staff and cleaners[8].

The WestPlan lists several Placemaking Priorities for Arisaig. While none make direct reference to the development of renewable energy or energy efficiency measures, they nonetheless highlight the importance of promoting low-carbon activities whilst remaining sensitive to Arisaig's rich environmental and cultural heritage and value for seasonal tourism.

[8] http://www.highland.gov.uk/download/downloads/id/22237/arisaig_primary_school_handbook_21-22.pdf

Figure 1: Arisaig (circled red) lies within the Moidart, Morar and Glen Shiel Special Landscape Area.

2.3. LAND OWNERSHIP AND POTENTIAL DEVELOPMENT OPTION SITES

Two separate land types have been highlighted for potential renewable energy development: land which is already owned by the Arisaig Community Trust itself, and land for whom the landowners are willing to consider sale or lease for suitable projects. The ACT-owned land totals around 5,425m^2, between two areas along the shorefront.

The other land, available for lease/sale consideration, together totals around 26,000 m^2 and distributed among fields more to the north of the Arisaig centre.

2.4. LAND USE AND AMENITY

Given the rural and sparsely populated nature of the region, much of the land surrounding Arisaig town centre is used for sheep grazing, agriculture and forestry, or is preserved for natural and environmental heritage given the economic value of seasonal tourism.

2.5. PLANNING

A review of the Highland Council's planning applications portal[9] was conducted to understand and situate recent or upcoming developments which may impact the renewable energy options available for consideration and of benefit to ACT.

The review paid particular attention to any applications related to the installation of renewable energy assets, and those which were closely situated to the areas of land considered for development by ACT. The majority of applications related to the construction of new houses, housing extensions, and a number of camping or caravan sites - no directly relevant renewable energy proposals were found. (It should be noted that Permitted Development Rights apply to most rooftop solar installations, so these would not appear on a search of the planning portal).

However, the list below describes some applications which were still deemed relevant and useful for the appraisal process of this project.

1. **Erection of manager's house and smokehouse building with associated parking (Cnoc Fraoch Kinloid, Arisaig, PH39 4NS)**

The site boundary for this development begins around 60m north of the hill/mound on which a small wind turbine was considered by the Arisaig Community Trust during the first project meeting. This proximity may prevent such a development due to the noise and visual impacts of the turbine.

2. **Improvements to car park and footpaths, including installation of benches, tables, bin store and landscaping works (Arisaig Shorefront)**

The location of these proposed works lies within one of the areas marked for priority consideration of renewable energy development, along the Arisaig town shorefront.

3. **Erection of 6 semi-detached houses (Land 65M NW of Drumcannach Station Road Arisaig)**

The location for this development lies within one of the areas marked for secondary (non-priority) consideration for renewable energy options by ACT. The application has received a number of objections and complaints from neighbouring landowners and residents, one having experienced reduced water pressure, another having been told that their own property will suffer a loss in financial value, and another raising additional noise, traffic, and lighting concerns due to the new development.

[9] https://wam.highland.gov.uk/wam/

While not of direct relevance to this appraisal, the above concerns do provide an insight into the sensitivities of local people which should be kept in mind when considering any renewable energy development options and their impacts.

4. Formation of camp site (Land 740M SW of Rhue House Arisaig)

This proposed camping site is over 10km to the south of Arisaig town centre and does not represent a direct concern to any local renewable energy options. However, it has received complaints and objections from the John Muir Trust and the Scottish Wild Land Group - giving an insight into the natural heritage and environmental sensitivity of the Arisaig region. The John Muir Trust expressed concerns that the campsite development may threaten the site's existing wild qualities, while the Scottish Wild Land Group objected to the proposal on the similar grounds - that the site lies within the Special Landscape Area of Moidart, Morar and Glen Shiel (see Figure 1), and may threaten the wildness qualities of the area and coastline and subsequent appeal to tourists.

This review suggests visual impact on wild land and designated landscapes might raise objections were larger scale wind turbines be proposed.

2.6. CULTURAL HERITAGE

Databases and maps provided by Historic Environment Scotland[10] and NatureScot[11] were consulted to understand nearby cultural and heritage sites and risks relevant for consideration of future renewable energy developments within Arisaig.

2.6.1. LISTED BUILDINGS

There are 19 listed buildings within the Arisaig area of relevance to this renewable energy options appraisal. None are 'A' Listed; 14 are 'B' listed; and 5 are 'C' listed (see Figure 2)

Nine of the B listed buildings are situated on the B8008 road ('Lowlands') which runs through the village centre and along the Arisaig shoreline. About 150m to the south-west of these buildings is situated one of the ACT-owned sites for renewables consideration. Any developments at this site will have no effect on the nearby listed buildings.

There are 5 Listed buildings (2 B-Listed and 3 C-Listed) within the land of St Mary's Church, north-west of Arisaig town centre and listed below. These buildings are clustered amongst two areas highlighted for renewable energy development consideration for this project, not owned by ACT. However, these areas are not for priority development consideration.

2.6.2. CANMORE SITES

There are around 30 Canmore sites within the Arisaig area of relevance to this project. Many of these are the same sites as the B- and C-Listed buildings described above.

Of these 30 sites, only one lies directly within one of the areas of priority (ACT-owned) consideration for renewable energy development. This site is the Czechoslovakian Special Operations Executive Training Memorial (Canmore ID (318847)[12].

[10] https://hesportal.maps.arcgis.com/apps/Viewer/index.html?appid=18d2608ac1284066ba3927312710d16d

[11] https://sitelink.nature.scot/map

[12] https://canmore.org.uk/site/318847/arisaig-czechoslovakian-special-operations-executive-training-memorial

Figure 2: There is one Canmore site (green), and no listed buildings (yellow) which lie directly within one of the areas identified as within the control of ACT for consideration for renewable energy development in the original Invitation to Tender (red).

Figure 3: The Czechoslovakian Special Operations War Memorial, a Canmore site, sits directly within one of the sites in ACT control for consideration for renewable energy development, along Arisaig's shoreline.

2.6.3. SCHEDULED MONUMENTS

There are no scheduled monuments within the Arisaig community area relevant to this project.

Within the general surrounding area, there is one scheduled monument, ~950m to the south-east of Arisaig town centre - Loch na Eala (Historic Environment Scotland reference: SM3831)[13].

2.7. NATURAL HERITAGE

2.7.1. GARDENS AND DESIGNED LANDSCAPES

There are no Gardens and Designed Landscapes (GDL) within the Arisaig region of relevance to this project.

About 1km to the east of the town centre there is one GDL site – Larach Mor, a woodland garden containing exotic trees and shrubs of horticultural interest. (Historic Environment Scotland reference: GDL00254)[14].

2.7.2. SCOTTISH NATURAL HERITAGE

Arisaig lies on the border between the Moidart, Morar and Glen Shiel Scenic Landscape Area (SLA) and the Morar, Moidart and Ardnamurchan National Scenic Area (NSA) (see Figure 1).

The SLA is said to cover an extensive area of mountains, moorland and lochs which lies between Glen Shiel and Moidart. It also includes the coast of Arisaig from Mallaig to Loch nan Ceall, and the upper part of Loch Ailort. It is an area of 917km2 (91,700ha). The Area is highly valued for its mountain ranges, hidden lochs, and diverse wildlife[15].

The NSA is one of 40 such areas in Scotland, describing areas of exceptional scenery and to ensure their protection from inappropriate development by restricting certain forms of development. The Morar, Moidart and Ardnamurchan NSA covers 370km2 (36,956ha) in total.

2.8. DEVELOPMENT POTENTIAL – OPPORTUNITIES AND RISKS

Given the location's exposure to Scotland's west coast and the abundance of open land nearby, the installation of a wind turbine development could generate a significant amount of renewable energy to meet the community's energy needs, and also generate some income for community benefit through exporting any unused energy. A relatively small 100 kW turbine, for example, could generate an estimated 360 MWh of wind energy per year, meeting over 10% of the community's annual energy demand. However, the merits of this option are counterbalanced by the acute environmental sensitivity of the region, highly valued for its appeal to tourists, campers, and wildlife enthusiasts. The visual and noise impacts of even a modest wind development (e.g. 100kW, 23m hub height/35m height to tip) may be reasons to refuse planning permission.

Alternatively, the installation of a solar PV array may be a more feasible option given the significantly lower visual and noise impacts of such a development compared to a wind turbine. As an example, the existing ACT-owned rectangle of land to the east of the Arisaig shoreline measures around 2,000 m^2. A site of this size would be capable of hosting a solar array of up to 240kW installed capacity, meeting 5% of the community's annual energy demand. This particular location is a popular community playing field and is not appropriate for a solar PV development.

[13] http://portal.historicenvironment.scot/designation/SM3831

[14] http://portal.historicenvironment.scot/designation/GDL00254

[15] Page 145: https://www.gov.scot/binaries/content/documents/govscot/publications/factsheet/2018/06/highland-council-planning-authority-core-documents/documents/special-landscape-area-citation-pdf/special-landscape-area-citation-pdf/govscot%3Adocument/Special%2BLandscape%2BArea%2BCitation.pdf

However, it has been used to provide an illustration of the amount of energy, carbon savings, and revenue which could be generated by a site of this size. Further work would be needed to identify a suitable site for a solar array of this scale, which is beyond the scope of this particular options appraisal.

3. ENERGY AUDIT

3.1. INTRODUCTION

This chapter presents a high-level overview of the baseline energy characteristics for Arisaig. It considers total annual energy demand across the vectors of electricity, heating and transport, and provides an indicative demand profile and peak load for the existing situation, and considers the future demand profile and peak load for a net-zero Arisaig, where heating and transport have been electrified. This chapter also provides an overview of the existing grid supply, and infrastructure capacity.

3.2. DOMESTIC HEAT DEMAND

Five home archetypes were generated, each with differing sizes and energy consumption profiles. These archetypes were developed by a satellite overview of the home types in Arisaig combined with calculations based on 48 EPC reports[16] of homes within the community.

The five archetypes are outlined below with their respective values:

Archetype	Number of Homes	Median Floor Area (m^2)	Median Annual kWh Consumption
1 - Detached Residential	73	160	28377
2 - Semi-detached Residential	92	109	19422
3 - Bungalow Residential	74	84	14939
4 - Flat	16	61	10822
5 - Detached Holiday Home	65	160	14189

Table 1: Description of domestic archetypes in Arisaig and estimated annual energy consumption.

There are approximately 320 homes currently in Arisaig, with around 65 (18-22%) of the dwellings used as second/holiday homes. Average Airbnb occupancy rates are around 46.5% - possibly slightly less in Arisaig as travel will be seasonally dependent, with many tourists using Arisaig as a stopping point on their travels to or from Skye and the Small Isles. This rate was used in calculations to determine energy use of Archetype 5 (Detached Holiday Home) buildings.

The figures above were compared against UK averages to validate them. Typical household gas usage in the UK[17] is listed in the table below:

Consumption Rate	Usage (kWh)
Low	8,000
Medium	12,000
High	17,000

[16] https://www.scottishepcregister.org.uk/

[17] https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values

Table 2: Ofgem typical household gas usage

In addition, the Scotland heat map[18] indicated that the area of Arisaig has a total domestic heat demand of 4 GWh/year.

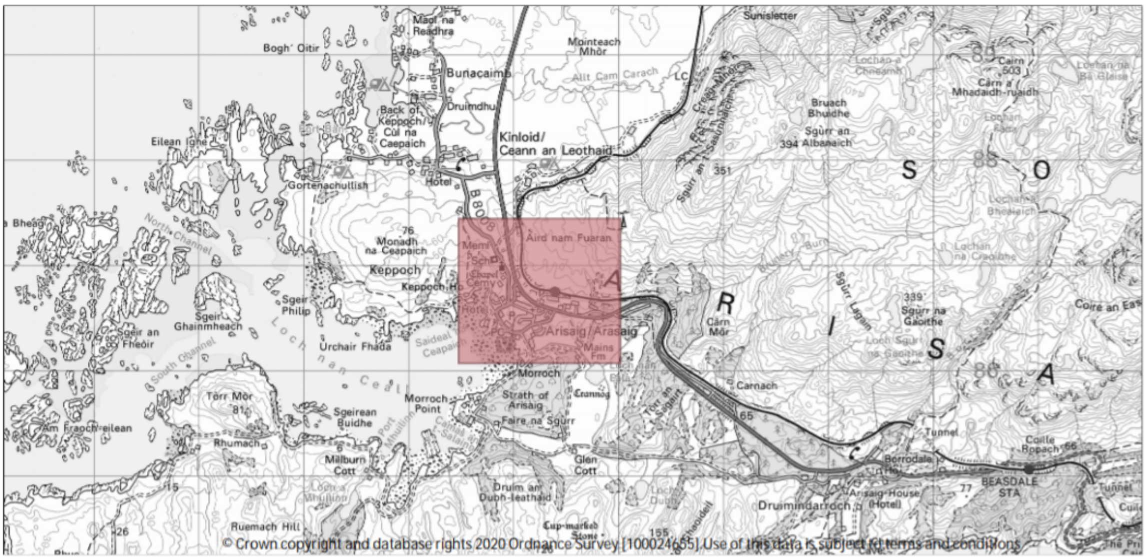


Figure 4: Highlighting the area of Arisaig on the Scotland Heat Map

However, due to the remote location, the size of the homes, the number of older dwellings and the aging community in the area, the EPC values and our calculations have highlighted that the heating consumption for the homes in the area may be slightly higher than the UK average. This is typical of remote rural Scotland and ties in with higher than average levels of fuel poverty.

The figure below shows the range of property sizes taken from a sample of surveys in 2018[19].

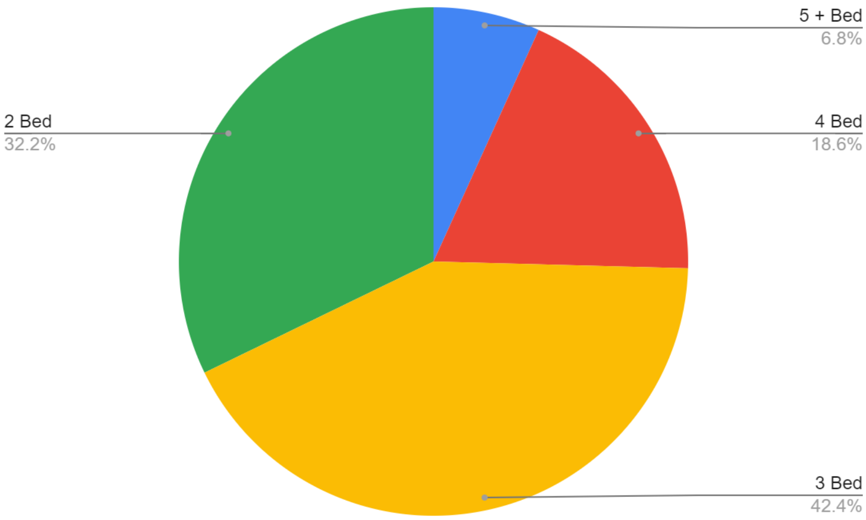


Figure 5: Property Size Distribution in Arisaig

[18] http://heatmap.scotland.gov.uk/

[19] Housing Need Report Final Report 2018.pdf

Further analysis was performed on the variety of heating systems used within the dwellings in the community. The table below demonstrates the assumed distribution of heating systems in Arisaig based on the available EPC certificates.

Heating System Type	Percentage of Homes (rounded up)	Number of Homes
Heat Pump	4	14
Oil	42	131
Electric / Storage Heaters	36	119
LPG	7	21
Coal	4	14
Wood & Mineral	7	21

Table 3: Heating system type distribution

For our calculations, the 2021 base case was developed with 60% of homes using fossil fuels, 36% using electric or storage heaters and the remaining 4% using heat pumps.

Energy surveys of 15 permanent members of the community have been undertaken by ACT. These surveys have detailed the diversity of people's homes and the fuel types they have used. A key piece of information gained from these surveys is an approximated amount of coal used by the community per year. An average of 6 x 50kg bags of coal were delivered to each household per year. Therefore, based on an estimated 80% of homes in Arisaig with a chimney or stove, and holiday homes not using any coal, there were 1,210 50kg bags (60,520 kg) of coal used by the community.

Thus, the total fossil fuel demand for heat consumption is approximately 4.2 GWh, and the total electrical demand for heat consumption is approximately 2.2 GWh. This is also assuming that storage heaters use an Economy 7 tariff, heat pumps have an average COP of 3 and typical holiday homes are used between March and October.

3.3. DOMESTIC ELECTRIC DEMAND

The electrical demand for each house archetype was based on typical domestic consumption values (Electricity Profile Class 1 – Domestic, unrestricted customers) [20] as there was no real consumption data available.

Consumption Rate	Usage (kWh)
Low	1,800
Medium	2,900
High	4,300

Table 4: Ofgem typical household electricity usage

The values below were calculated to assign the electrical demand to each archetype, to be scaled up to the full community.

[20] https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values

Archetype	No. Homes	Average Electricity per Archetype (kWh)
1 - Detached Residential	73	4,153
2 - Semi-detached Residential (or mid-terrace)	92	3,322
3 - Bungalow Residential	74	3,866
4 - Flat	16	2,829
5 - Detached Holiday Home	65	2,575

Table 5: Estimated annual electricity consumption per archetype.

Estimated electrical consumption based on approximately 320 residential properties is 1.1GWh, this does not include the added electrical demand used by homes with heat pumps or storage heaters.

The overall electrical consumption of the residential buildings including electrical heat demand is approximately 3.3 GWh.

Additional information gathered by ACT members refers to the energy suppliers for the town. We have not included delivery details in writing this report.

Fuel	Supplier	Applications
Electricity	SSE, EDF, Bulb	Heat pumps, electric heating, storage heaters, underfloor heating, cookers, small appliances, information technology, craft/ small manufacturing technology
Oil	Johnson Brothers (Mallaig), Scottish Fuels	Heating, cooking, vehicle fuel
Gas	Calor	Heating
Wood	N/A	Secondary heating source

Table 6: Community energy suppliers

3.4. TRANSPORT

3.4.1. EV CHARGING

The community of Arisaig has 5 EV chargers installed at the Land, Sea and Islands Centre (LSIC), with three different connection types[21]. The charges are owned by ChargePlace Scotland and are currently free to use, charger types are described below:

Number of Chargers	Charger Type
2	7kW 32A Type 2 Mennekes
1	22kW 32A Type 2 Mennekes
1	50kW 125A JEVS (CHAdeMO)
1	50kW 125A CCS (Combo)

Table 6: EV charger types at LSIC

[21] https://chargeplacescotland.org/live-map/chargepoint/51687/

Figure 7: Photo of the EV chargers located at the LSIC

Below is their projected usage for a normal year for low and high usage:

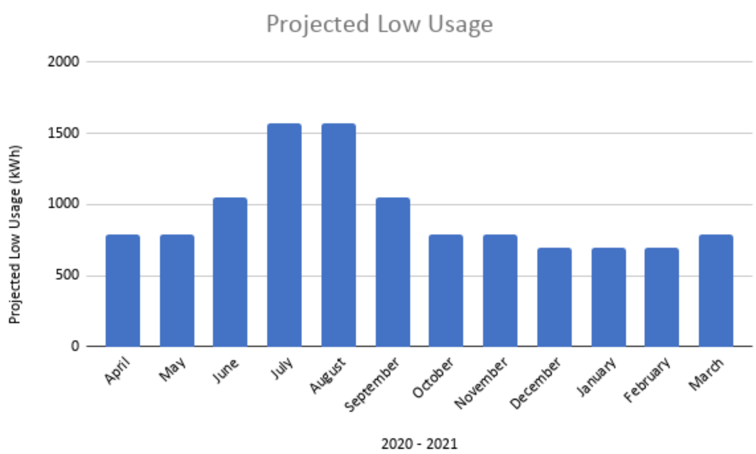


Figure 8: Projected low usage of EV chargers

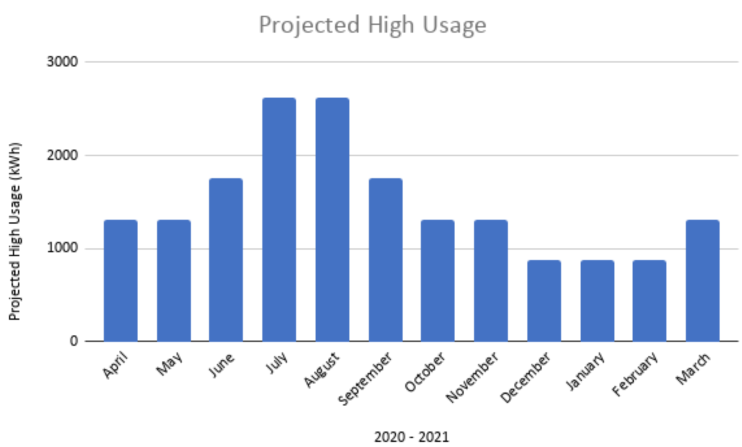


Figure 9: Projected high usage of EV chargers

Approximately, 11,288 kWh and 17,938 kWh of electricity is needed for the projected low and high use, respectively.

3.4.2. INDIVIDUALLY-OWNED EV CHARGERS

Within the town there is currently only one EV owned by a member of the community. The data gathered from this one EV can be seen below. The data can also be adjusted and scaled up for use in our model to assess the potential of more community members buying EVs and installing EV chargers in their own homes.

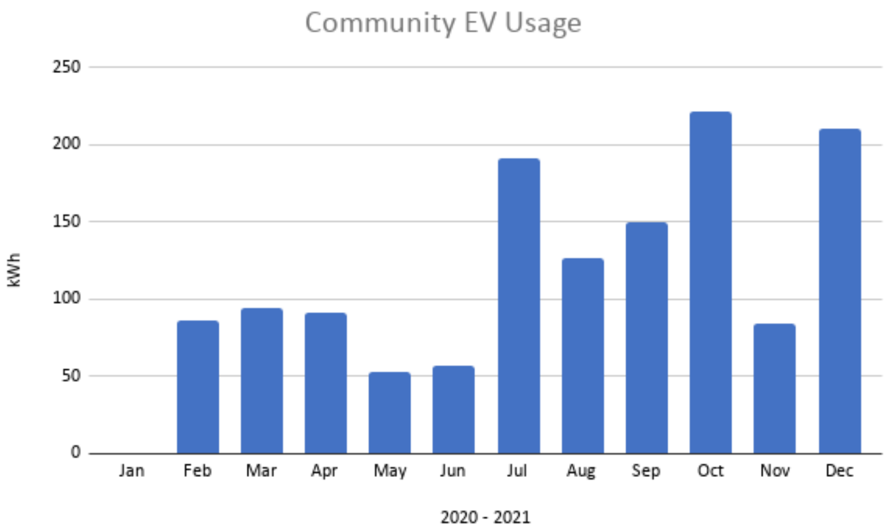


Figure 10: EV charging data from community member

3.5. NON-DOMESTIC ENERGY USE

Non-domestic electricity usage for the town was calculated to add estimates to our final model. Fossil fuel usage for heating demand for these buildings has not been calculated in this assessment as no relevant data was available.

Non-domestic electricity usage has been calculated for each building and business type. The process for these calculations was to use the floor area of each business and an electrical consumption benchmark from the CIBSE Energy Benchmarking Tool to calculate the total annual electrical demand for each sector[22]. This annual value was then extrapolated across the year to create an hourly demand profile that could be compared against potential renewable supply[23].

Table 7 below includes the LSIC, medical practice, hotel, bunkhouse, pub, Post Office, local shop, marine works (tearoom & gift shop), the church, primary school, and the two new developments (motorhome park amenity building and smokehouse).

The current total electricity demand for non-domestic buildings has been estimated to be 398 MWh annually.

Sector	kWh p.a. (rounded up)	Proportion of total consumption (%)
EV Charging Station	17,937	5
Hotel	121,120	30
Local Shops and Businesses	135,932	34
Amenity Building	9,549	2
New Smokehouse	94,335	23
Public Sector (Primary School and church)	19,387	5

Table 7: Non-domestic electricity usage by sector

3.6. EXISTING DEMAND PROFILE AND PEAK LOAD

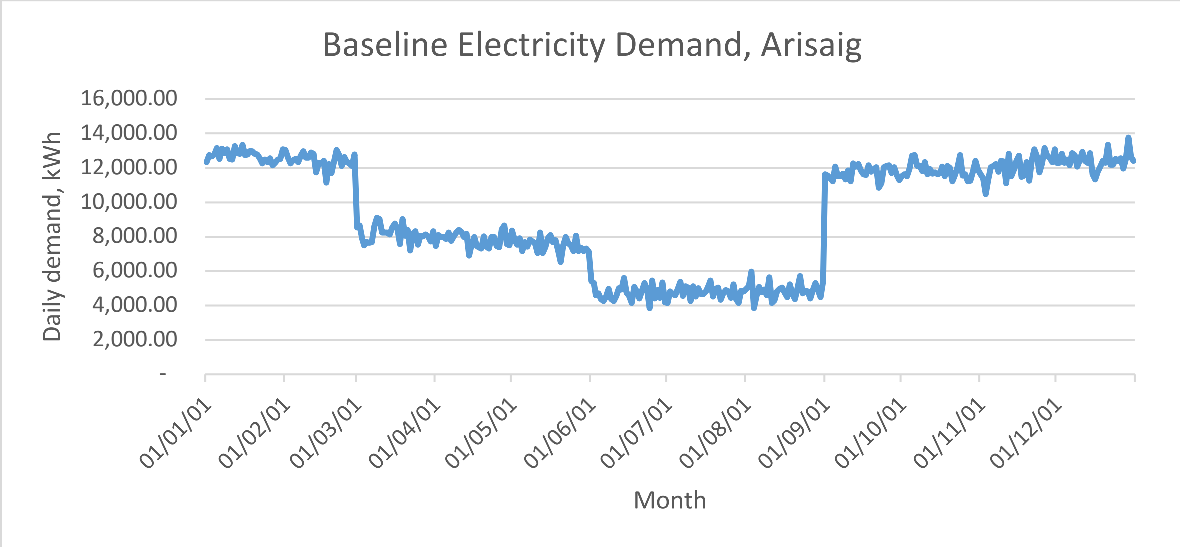
In order to model the feasibility of increased low carbon technologies in Arisaig, a demand profile of the town's buildings was first generated.

To create the existing demand profile and peak load across Arisaig we disaggregated loads of the town into individual building categories, or 'archetypes: residential homes, holiday homes, businesses and community buildings. The residential building loads were calculated by using our total annual energy loads from previous calculations and extrapolating across the year with generic house usage profiles. The local businesses and community buildings were generated using generic load profiles from *Ofgem* and *CIBSE Energy Benchmarking Tool* to approximate the annual electrical energy use for each building.

As the data is defined seasonally, rather than monthly or daily, in reality, the profile would be smoother.

[22] https://www.cibse.org/knowledge/benchmarking-registration

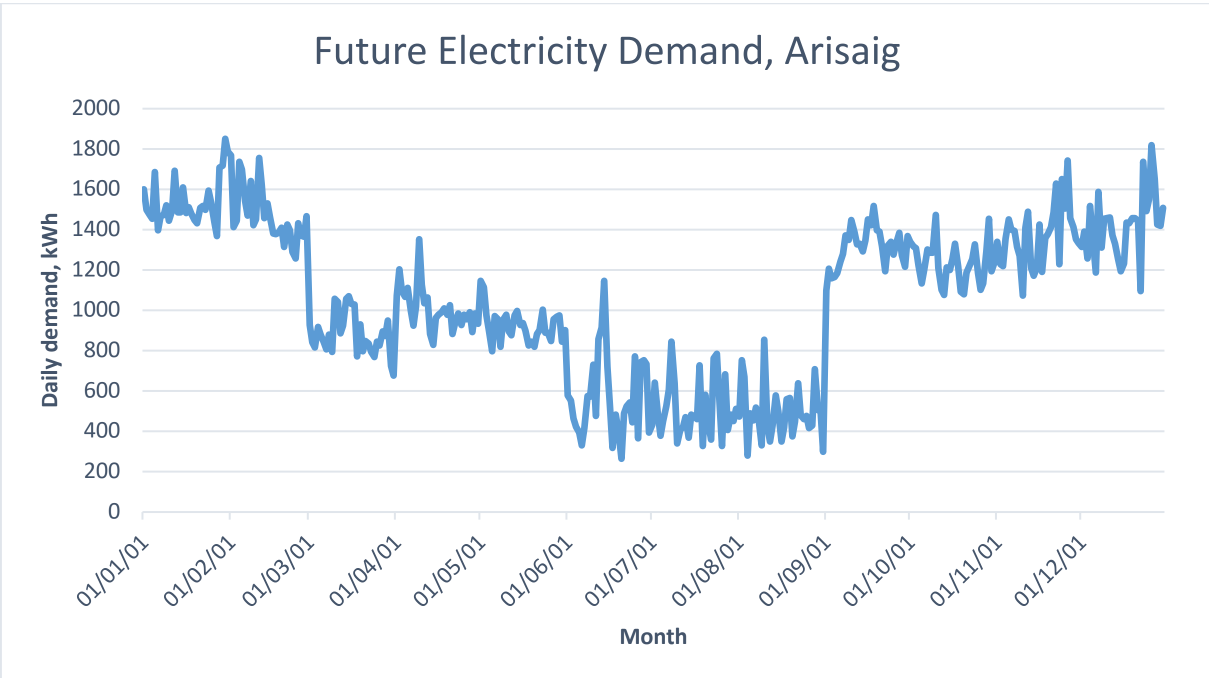
[23] https://www.ofgem.gov.uk/ofgem-publications/57017/electricit y-demand-profiles.xlsx



3.7. FUTURE DEMAND PROFILE AND PEAK LOAD

Future demand profiles were developed from the existing estimated electrical demand profile. Additional components were added to the current estimated electrical demand profile, including the new developments (6 new homes with heat pumps, smoke house and manager's house, and amenity block for the motorhome park).

In the future demand profile, the current housing stock was also changed from being heated by predominantly (~60%) fossil fuels to being heated by heat pumps (64%). This removes all fossil fuel heated homes and increases the percentages of homes with heat pumps from 4% to 64%, and keeps the existing 36% of homes with electric or storage heaters. It was assumed that the heat pumps installed will have a coefficient of performance (COP) of 3[24].



[24] A COP of 3 would imply that for every 1 unit (kWh) of electricity consumed by the heat pump, 3 units (kWh) of useful heat would be generated.

3.8. GRID CAPACITY

The DNO for the Arisaig area is Scottish & Southern Electricity Networks (SSEN)[25], with local substation connecting to the nearest grid supply point in Fort William, approximately 47km to the east. Below is the detailed substation information for Arisaig.

The Generation Availability Heatmap from SSEN shows the Arisaig substation is currently 'Constrained'[26]. Scene has contacted SSEN for more details about this constraint, and the potential cost of upgrading the substation to integrate exported electricity from a hypothetical solar or wind energy generation asset belonging to ACT. The cost of this upgrade could vary widely, costing anywhere between a more nominal fee of £1-2,000 to a more prohibitive cost in the tens of thousands.

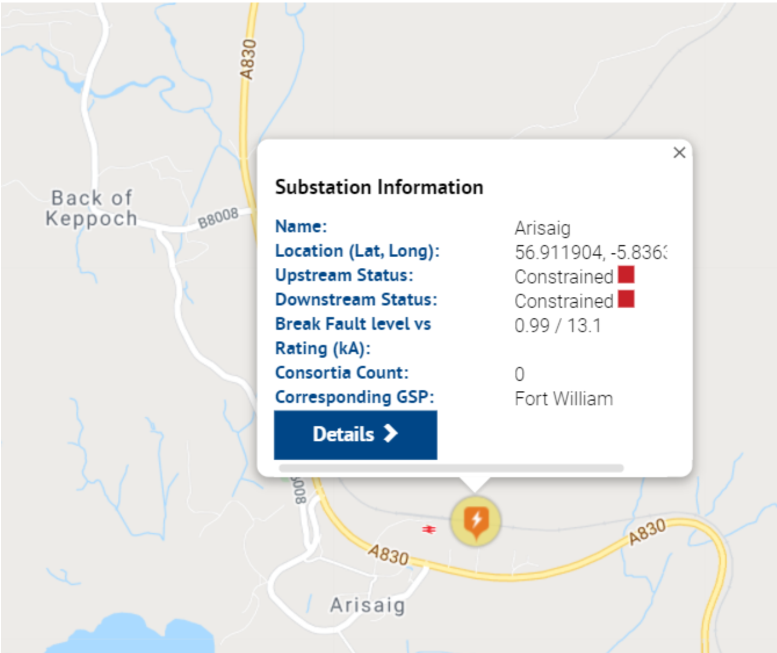


Figure 11: SSEN's Heatmap shows that Arisaig's local electricity substation is currently constrained and may need upgrading if ACT wish to export solar or wind electricity.

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[25] https://www.ssen.co.uk/ContractedDemand/

[26] https://www.ssen.co.uk/generationavailability/

4. NATURAL RESOURCES – GENERATION POTENTIAL

4.1. INTRODUCTION

This chapter presents the renewable energy generation potential from various natural resources within the area. It considers varying scales of development and the associated opportunities and risks, calculates CO2e emissions reductions, and provides a commentary on how the indicative generation profile corresponds with the demand profile in Arisaig.

4.2. WIND

A modest wind turbine development has been requested for consideration by ACT, for possible siting on a small mound to the north of Arisaig town centre (see Figure 18 on page 30). Scotland's west coast boasts significant wind energy generation potential. The wind station nearest to Arisaig is on the Isle of Tiree[27], according to which the average wind speed between the years 2000 and 2010 was around 3.3 m/s with maximum figures of 4.4 m/s in December (see Figure 12). However, Tiree's exposed location is likely to be windier than that on the mainland.

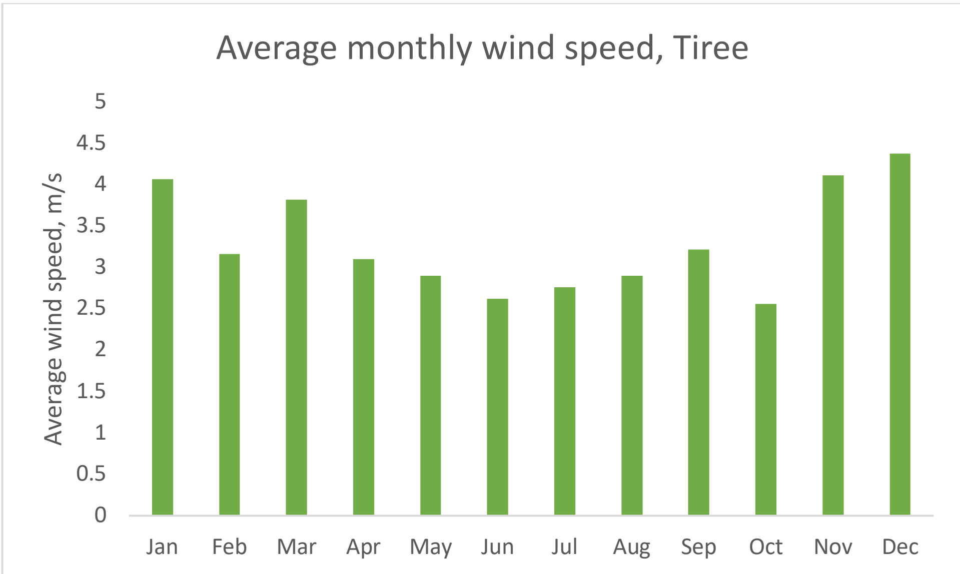

Figure 12: The average wind speed recorded at Tiree, the nearest wind station to Arisaig, was 3.3 m/s between 2000 and 2010.

A more precise geographical estimate of potential wind energy generation was also made using the online renewables.ninja tool. According to this, a 23m 'XANT M21 100' 100kW wind turbine would generate almost 360 MWh of energy each year, assuming 2019 wind data[28] (see Figure 13).

[27] https://www.rensmart.com/Maps#NOABL

[28] https://www.renewables.ninja/

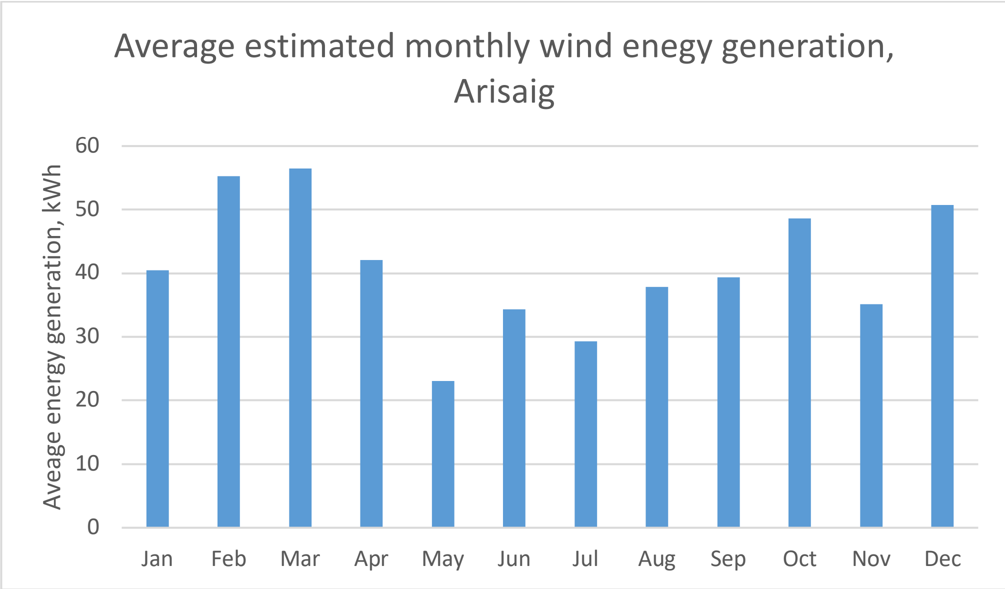

Figure 13: The renewables.ninja energy generation modelling tool estimates that a 100kW wind turbine in Arisaig could generate almost 360 MWh of energy each year for the community.

In addition to the generation potential of wind in Arisaig, another important factor for considering wind turbine installation are the geological and drift deposits of the location, for construction purposes. Drift and solid geological maps at 1:63,360 scale were obtained from the BGS website (Figures 14 and 15)[29]. Fortunately, for this project the location of the proposed wind turbine lies in an area of land with very low volumes surface drift deposits.

Figure 14: BGS Drift Map of Arisaig Area

The deposits are so low that the BGS map records the area to have bedrock at or near the surface. However, there are significant deposits of peat indicated to be within close proximity of the proposed wind turbine. Peat is a water

29 https://webapps.bgs.ac.uk/data/maps/maps.cfc?method=listResults&mapName=&series=S50k&scale=&getLatest=Y&pageSize=100&start=100

dense soil that can lead to unstable conditions and the release of natural gases. Therefore, suitable ground investigations would be necessary to prove the underlying conditions of the site prior to installation.

In addition, the solid rock geological map indicated that the rock beneath the proposed location is ‘dominantly psammite with subordinate bands of semi-pelite and pelite’ dipping steeply in a westerly direction. There are also significant dykes in the area following a north-west south-east trend, composed of dolerite, basalt or tholeiite.

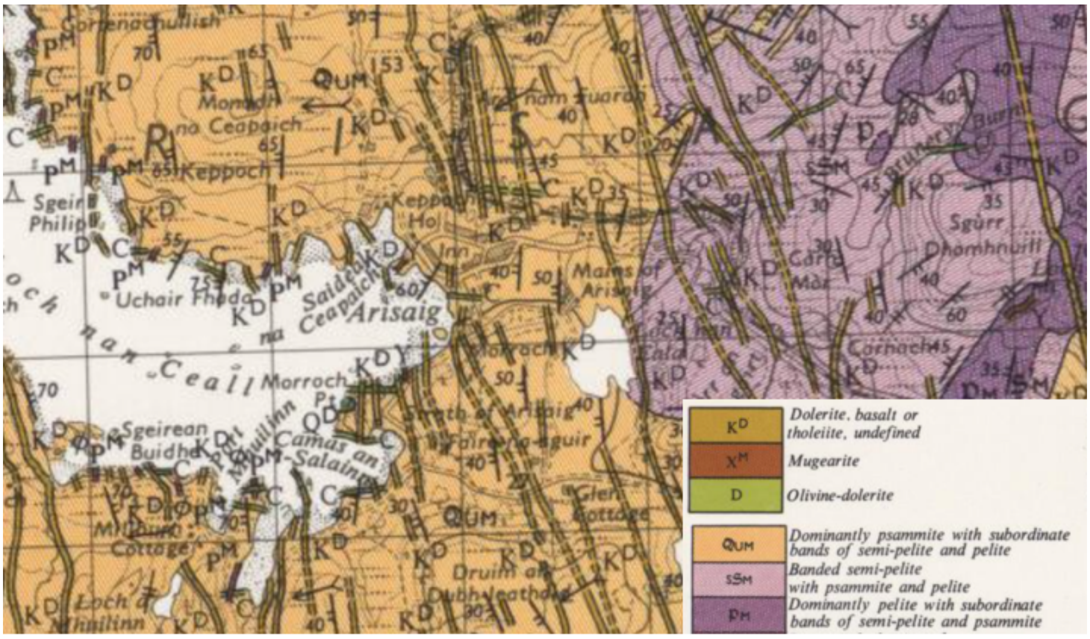

Figure 15: BGS Solid Map of Arisaig

4.3. SOLAR PV

One of the areas marked for priority development consideration, owned by ACT, comprises a rectangle of around 2,000m^2, and is situated near to the Arisaig shoreline 200m to the east of the SPAR village supermarket.

This land could host a solar PV array of up to 240 kW in capacity, generating up to 170 kWh of solar energy each year[30]. For comparison, the Hotel in Arisaig consumes around 120 kWh of electricity per year.

Rooftop solar PV could also be considered, and there are already 8 houses in Arisaig with rooftop solar to our knowledge.

4.4. HEAT PUMPS

Heat pumps are devices that can absorb heat energy from a cold source (outside) and transfer it to a warmer one (inside). Heat pumps are powered by an electrical source and tend to be very efficient in terms of energy use. In our model we have assumed that the heat pumps currently installed, and the projected ones have a coefficient of performance (COP) of 3. A COP of 3 means that for every 1 kWh of energy supplied by electricity 3kWh of energy is delivered to the home as heat. This can also be seen as 300% efficiency, whereas a typical gas boiler would have an efficiency of 80-90%.

[30] Assumes an energy density of 0.12127 kW/m2, used for previous projects and recommended by solar installation company Absolute Solar.

However, there are many factors that can increase the efficiency of a heat pump. These include; sizing, local climate, fluctuating temperatures, auxiliary equipment and technology.

From the available EPC reports and the community energy surveys, it was estimated that currently approximately 4% of homes in Arisaig have a heat pump installed. This equals 14 homes, with an estimated total energy use of 68,493 kWh and 8,449 kWh for residential and holiday homes, respectively.

4.5. DISTRICT HEATING SCHEME

The Thermos web-based tool[31] was used to map the heating systems within the local area. The tool is designed to help public authorities develop or upgrade thermal networks. In this instance, it was used to approximate the costs and cabling needed to upgrade the existing thermal network to a community district heating scheme.

The tool shows that to install a new heat supply point and distribute to the local area, 10.22km of cable would be needed, with associated approximate costs of £6.28 million. The costs represent the variable pipe and dig costs and estimated heat losses to the environment. This tool also estimates the heat peak of Arisaig as 2.95MWp, and a required total capacity of 1.89MW. Additionally, the diameter of cable needed would be 125mm and the estimated losses would be 9.65 W/m.

Across an estimated 320 homes, this is equivalent to an average cost of £20,000 per home, which is comparative to the costs of a standalone Ground-Source Heat Pump, but significantly higher than an Air Source Heat Pump. Further, if every home does not connect, the proportionate cost per house will increase. For example, excluding houses which already have ASHP and holiday homes, average costs increase to £26,000. Due to the low heat densities, a networked solution for the whole village is not considered the best approach, but the potential for a network within the village centre, connecting domestic and non-domestic buildings, may merit further investigation.

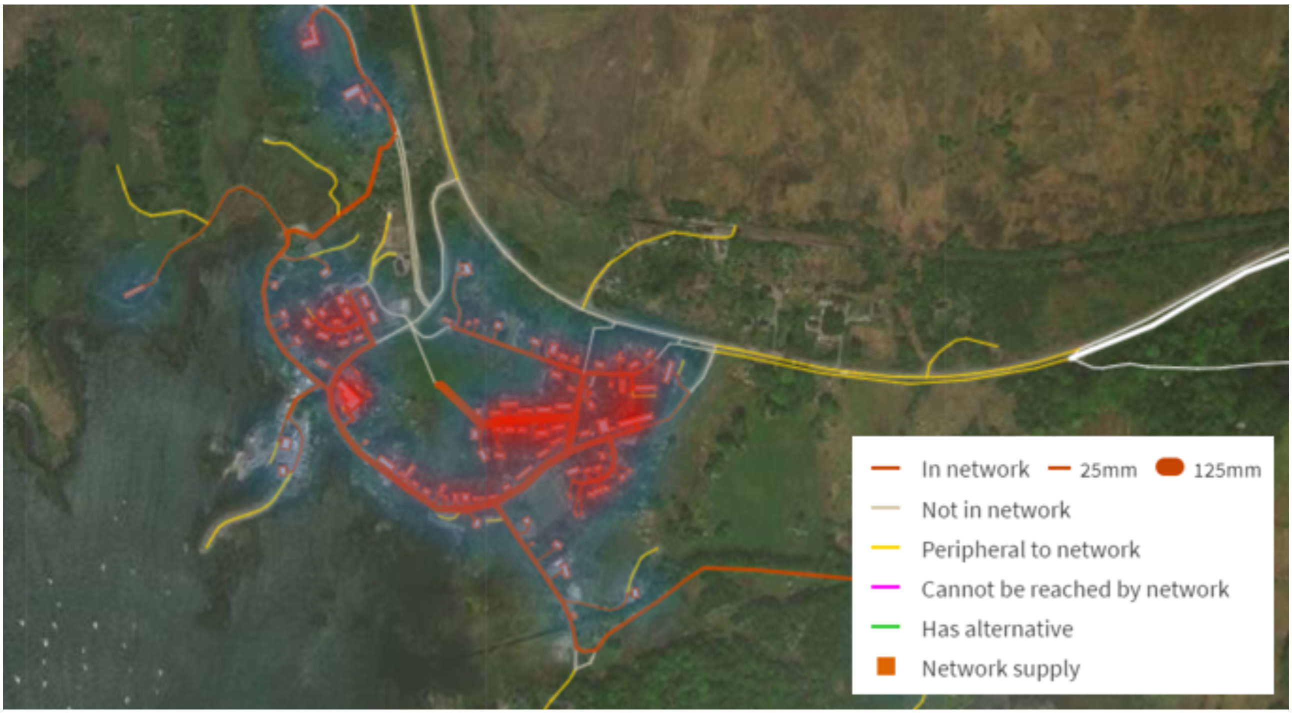

Figure 16: Thermos tool map of Arisaig

[31] https://www.thermos-project.eu/thermos-tool/thermos-tool/

4.6. ELECTRICAL STORAGE

Storage heaters are electric heaters that store heat energy, by heating up bricks within the device during the night and slowly releasing the thermal energy during the day. These devices work best when users utilise a specific time of use tariff, such as Economy 7. This means that a cheaper off-peak rate of electricity is given for 7 hours during the night when the rest of consumers aren't using electricity. Storage heaters tend to be used more when there is no mains gas connection.

From the available EPC reports and the community energy surveys, it was estimated that currently approximately 36% of homes in Arisaig have electric storage heaters installed. This equals 119 homes, with an estimated total energy use of 1,849,314 kWh and 29,354 kWh for residential and holiday homes, respectively.

4.7. NON-VIABLE OPTIONS

4.7.1. HYDRO

Hydro power is a type of renewable energy that uses gravity and falling water to turn a turbine. This turbine then turns a metal shaft in an electric generator and produces electricity. There are many advantages of hydropower, however, in Arisaig the cons outweigh the pros.

Due to the large upfront costs of turbines, the effects of hydro turbines on the local environment, and the lack of suitable locations it was ruled out for this feasibility study.

4.7.2. WAVE AND TIDAL

Similarly, to hydro power, the harnessing of wave and/or tidal power is not included in this study. Wave energy and tidal energy can also be damaging to the local marine environment, disruptive of the marine and local economy, are dependent on suitable locations, and as the technology is in its' infancy tends to be very costly.

5. ENERGY SYSTEM SCENARIOS

5.1. INTRODUCTION

This chapter presents and appraises several energy system scenarios with regards to their technical, economic, and environmental impacts.

The modelling was conducted using *Microsoft Excel*. The model allows the user to turn on/off the integration of solar and wind energy, adjust the scale of these renewable assets, and integrate or remove the electricity demand of particular buildings within Arisaig from the model. The model also compares the effects of upgrading the residences with non-electric heating to a low-carbon heating pump, or remaining at their existing state (estimated from EPC reports at 36% with storage heaters, and 4% with heat pumps).

Inputs				
Generation assets				
Solar	1		>	Choosing 0 will deactivate the generation asset within the model, and 1 will activate it.
Wind	1			
Scale of renewable energy generation				
Solar capacity to model (kW)	240		>	Adjusting these figures will change the solar/wind outputs presented in the respective worksheet.
Wind capacity to model (kW)	100			
Electricity demand				
		Electricity demand		
Residential	1	940,141 kWh	>	Choosing '1' from the dropdown list will integrate the electricity demand of this building class into the model, to compare against simulated renewables generation. Choosing '0' will ignore it.
Holiday homes	1	101,605 kWh		
New flats	1	17,008 kWh		
Businesses	1	135,932 kWh		
Church	1	4,380 kWh		
School	1	15,007 kWh		
Hotel	1	121,120 kWh		
Caravan Amenities Block	1	9,549 kWh		
Smokehouse	1	94,335 kWh		
EV charging station	1	17,938 kWh		
Heating scenarios	0		>	Baseline scenario - 36% of homes use storage heaters, 4% use heat pumps, and 60% use coal, oil, wood etc for heating.

Figure 17: The energy and financial model allows the user to adjust the amount of renewable energy generation and electricity demand of the building types in question, compared to the basline situation.

The model also allows the user to adjust the price of electricity of exported renewable energy to the grid, in addition to the carbon emission intensity of the existing UK electricity grid. A base price of £0.15/kWh for electricity was assumed, alongside a 'Base' and 'Optimistic' Smart Export Guarantee (SEG) rate of £0.04/kWh and £0.055/kWh, respectively. The optimistic price is based on that currently offered by Octopus, but there is some uncertainty as to whether the energy supplier would offer this SEG rate in the Arisaig region[32].

[32] https://octopus.energy/outgoing/

It was decided to integrate all known buildings of Arisaig into a single model in order to give a community-wide perspective on the impact of renewable generation and low-carbon heating upgrades. Additional models can also be generated from this overall data to present the impact of low-carbon developments on individual buildings and building types within Arisaig, or on specific groupings of buildings.

Table 9 below describes in more details the assumptions made for each different building archetype included within the model[33]:

Building category	Description of electricity demand and profile assumptions made
Residential	Demand aggregated across an estimated 320 year-round domestic residences.
Holiday homes	Demand aggregated across an estimated 65 seasonal holiday properties.
New homes	Demand aggregated across 6 low-usage homes each containing heat pumps and corresponding electricity loads.
Businesses	Aggregated across, and estimated demand and profiles made for: ● Land Sea & Islands Centre (LSIC), ● Old Library Lodge and Restaurant, ● SPAR Arisaig, ● Post Office, ● NHS Arisaig Medical Practice, ● Café Rhu, ● Arisaig Marine Ltd.
Arisaig Church of Scotland	Demand based on floor area and building-type kWh usage per m^2.
Arisaig Primary School	Demand based on floor area and building-type kWh usage per m^2.
Arisaig Hotel & Bunkhouse	Demand based on floor area and building-type kWh usage per m^2.
Motorhome Park Amenities Block	Demand data provided by ACT and extrapolated over a year to give an estimated annual hour-by-hour profile.
EV Charging Facilities	EV charging demand data provided by ACT and extrapolated over a year to give estimated annual hour-by-hour profile.
New Smokehouse	Demand based on floor area and building-type kWh usage per m^2.

Table 9: The energy and financial model integrated the electricity demand and profiles of 10 separate building archetypes.

[33] Note that that caravan park was not included within the model since the motorhomes are expected to supply their own electricity and heating.

5.2. SCENARIO 1: BASELINE DEMAND WITH RENEWABLES GENERATION

The first scenario assessed how the existing 'business-as-usual' electricity demand of all buildings in Arisaig would be impacted by the introduction of new renewable energy generation assets.

The assets integrated into the model were a 240 kW solar array and a 100 kW wind turbine, both of which were deemed reasonable scales for the context. Within the model, all Building Types were toggled 'on', and the Heating Scenario specified was '0' corresponding to the existing baseline (see Figure 17 above).

Figure 18: Scenario 1 assumed the installation of a 240kW solar array (yellow) and 100kW wind turbine (red) within Arisaig. The location of the solar array is for scale only and does not indicate any serious proposals to develop here.

<table>
<tr><th>Key Performance Metrics assessed by model</th><th colspan="2">Outcomes</th></tr>
<tr><td>Annual baseline electricity demand across Arisaig</td><td colspan="2">3,374,821 kWh</td></tr>
<tr><td>Annual carbon emissions associated with baseline electricity demand</td><td colspan="2">787 tonnes CO_2e</td></tr>
<tr><td rowspan="2">Annual renewable energy generated</td><td>Solar PV: 174,029 kWh</td><td>Wind: 358,988 kWh</td></tr>
<tr><td colspan="2">Total: 533,016 kWh</td></tr>
<tr><td>Annual electricity demand met by renewables</td><td colspan="2">504,405 kWh</td></tr>
<tr><td>Annual proportion of demand met by renewables</td><td colspan="2">14.9 %</td></tr>
<tr><td>Annual electricity cost savings made through renewables</td><td colspan="2">£75,661</td></tr>
<tr><td rowspan="2">Annual income from renewables exports</td><td colspan="2">Base SEG: £1,144</td></tr>
<tr><td colspan="2">Optimistic SEG: £1,574</td></tr>
<tr><td>Annual carbon emissions offset by renewable generation</td><td colspan="2">118 tonnes CO_2e</td></tr>
</table>

Table 10: In Scenario 1, the model assessed the economic and environmental impacts of meeting Arisaig's entire electricity demand through the installation of a 240kW solar array and a 100kW wind turbine.

5.3. SCENARIO 2: HEAT PUMP UPGRADES AND NO RENEWABLES GENERATION

The second scenario modelled the impact of upgrading Arisaig's residential heating supply to low-carbon heat pumps, for those houses currently using fossil fuels for heating. Heating upgrades for businesses, schools, churches etc., were not modelled since information regarding their current heating supply was not available.

The scenario was built on the assumption that 42% of Arisaig residences currently use oil; 36% use electric storage heaters; 4% have heat pumps; and the remaining 18% use a combination of oil, LPG gas, coal, and wood for their heating.

Notably, the financial case for upgrading to heat pumps is not positive, despite the significant reduction in carbon emissions. This is due to the fact that grid electricity is relatively more expensive (~£0.15/kWh) than the fossil fuels which they are currently using (~£0.05-0.07/kWh for coal, wood, LPG gas and oil[34]). A financially positive case can be made if the electricity would cost around £0.11/kWh.

Key Performance Metrics assessed by model	Outcomes
Estimated number of residences to upgrade to heat pumps	188 homes
Additional annual electricity demand due to heat-pump upgrades	+ 1,027,396.64 kWh
	+ 30 %
Annual carbon emissions savings by upgrading all eligible residences to low-carbon heat pumps	481 tonnes CO_2e
	- 52%
Annual cost savings by replacing fossil fuel heating by electric heat pumps (without RHI)	-£ 71,480
Annual cost savings by replacing fossil fuel heating by electric heat pumps (over seven years with RHI)[35]	£1,599,420

Table 11: Scenario 2 assessed the impacts of upgrading residences to low-carbon heat pumps, for those homes currently using fossil fuels instead.

While we have modelled the effect with RHI, due to lead times to develop and deliver such projects prior to the scheme closing (although an individual may be able to mobilise fast enough to be able to do so) we do not consider it viable to deliver a co-ordinated community project in this timescale. However, individual homes would be able to progress this fast enough to secure the current ASHP subsidy of 10.85p/kWh which provides cost savings for the 7 years it is possible to claim RHI.

Whether the costs would become net negative after that is difficult to predict: currently part of the reason between the unfavourable cost differential between electricity and fossil fuel heating is the carbon levies imposed on electricity: BEIS and Ofgem have recognised this is hindering the net zero transition and penalises electricity supply for having reduced its carbon intensity. There are discussions taking place now about these either being shared across all energy types rather than just electricity, or being moved to general taxation, to allow heat pumps to reach cost-parity or better without subsidy with other forms of heating. The second factor to bear in mind is the impending ban on fossil fuel boilers, which may have a positive effect on capital costs for heat pumps (for subsequent replacement scenarios).

[34] https://nottenergy.com/resources/energy-cost-comparison/

[35] https://www.ofgem.gov.uk/publications-and-updates/domestic-rhi-tariff-table

5.4. SCENARIO 3: SELLING ELECTRICITY TO EV CUSTOMERS

Currently, the community owns 5 EV chargers at the Land Sea and Islands Centre (LSIC) and there is one privately owned domestic EV charger. The total rated capacity of the 6 chargers is 93 kW, assuming the privately owned charger is rated at a typical domestic power of 7kW.

According to EV charging data provided by ACT, the total annual demand of the 5 community-owned EV chargers is estimated at around 11,288 kWh and 17,938 kWh for low and high usage, respectively. The annual demand of the privately-owned domestic EV charger is approximately 1,366 kWh.

The 5 EV charging stations outside the LSIC are currently free to use. However, ACT could consider generating community revenue through introducing a reasonable charging cost. A tariff of £0.25/kWh would be in line with other existing EV charging fees in the Highlands, although other tariff options could also be considered, such as minimum, standing, and long-stay charges[36]. An assumed grid electricity cost of £0.17/kWh was also used.

Key Performance Metrics assessed by model	Outcomes
Annual demand of EV chargers (high-use scenario)	17,938 kWh
Annual grid-electricity costs to meet demand	£ 3,050
Net revenue from selling grid electricity to EV customers	£ 1,435
Net revenue from selling solar electricity direct to EV customers (without storage)	£ 2,912
Annual carbon emissions associated with grid electricity use	4.18 tonnes CO_2e

Table 12: Annual EV charging station costs and revenue, assuming purchase of grid electricity

Table 12 displays the estimated annual electricity demand, costs, net revenue, and carbon emissions associated with a paid EV charging scheme at a reasonable tariff of £0.25/kWh. If the EV electricity demand were met by direct solar PV supply instead, the scheme would gain an additional £1,500 compared to selling grid electricity. Note that this income from selling solar electricity does not include the associated CAPEX and OPEX costs, and the revenue figures do not include the additional revenue that could be generated from further plug-in costs, minimum charges and long stay charges.

[36] https://chargeplacescotland.org/live-map/

Alternatively, ACT could consider directly supplying the existing EV charging station with energy from a 240 kW community-owned solar array. This would offset the carbon emissions currently associated with the chargers' grid electricity supply, offset the need to purchase this electricity, and would represent an additional source of revenue through exporting any excess electricity to the grid.

Key Performance Metrics assessed by model	Outcomes
Annual demand of EV chargers (high-use scenario)	17,938 kWh
Annual demand of EV chargers met through solar energy	11,646 kWh
Proportion of EV charging demand met through solar	65 %
Annual carbon emissions savings through solar supply (compared to baseline)	1.47 tonnes CO_2e
	- 35 %
Annual electricity cost savings through solar supply	£ 1,747
Annual solar electricity generated	174,029 kWh
Annual income from exported solar electricity	Base SEG: £ 6,495
	Optimistic SEG: £8,931
Or	
Annual savings if electricity was stored rather than exported	Base SEG: £ 17,862
	Optimistic SEG: £15,426

Table 13: Scenario 3 modelled the effect of supplying directly the existing EV charging station with solar energy from a nearby 240 kW solar array.

The results of this model indicate that a combined solar PV and battery storage system would be of high financial and environmental value to ACT (see Table 13). Without storage, over 90% of the solar generation is currently exported to the grid. If stored (estimated storage capacity requirement of 30kWh), this energy could instead be used to supply the EV charging station directly, offsetting the need to import electricity (at a simulated cost of £0.15/kWh). Over an average year of high-use EV charging, this equates to an annual electricity saving of almost £18,000 for the EV charging station supplier, assuming the 'Base SEG' rate. The savings from energy storage would be reduced if the higher optimistic SEG rate were used, since the value of exports would be relatively higher.

Note - this represents on-going savings only, and it does not account for the capital and operating costs involved in installing and connecting a battery storage system.

5.5. LOW-CARBON HOME RETROFITS

From the available EPC reports of dwellings within the Arisaig boundary the average EPC rating was E. The Scottish Government have outlined a roadmap for the decarbonisation of heat, and have stated that their goal is for the average EPC rating of a Scottish home to be C by 2040[37]. In line with this, energy efficiency measures will be needed to reduce the average rating in Arisaig.

As every home is different, a more thorough investigation would be needed to identify individual recommendations for the homes in Arisaig. However, below is a list of potential upgrades that could be implemented:

[37] https://www.gov.scot/policies/energy-efficiency/energy-efficiency-in-homes/

- Loft insulation
- Insulating hot water cylinders
- Upgrading single glazing to Low-E double glazing windows
- Upgrading heating system
- Solid and cavity wall insulation
- Underfloor insulation
- Draught proofing
- Installing low energy lighting fixtures
- Throating open chimneys
- Adding a solar PV array

In addition to this, it is good practice to keep thorough documentation of all energy efficiency measures installed.

5.6. AVAILABLE GRANTS AND FUNDS

Renewable Heat Incentive (RHI): This scheme will be open for domestic applicants until March 2022[38], and non-domestic applicants until April 2021 (i.e. it is too late to qualify for the non-domestic RHI). The RHI pays a tariff to consumers to compensate their initial installation costs of installing a renewable system to their property. The incentive financially supports the consumer for 7 years. In addition, the RHI is preferential to homes that are located off the gas grid.

The Clean Heat Grant Scheme: This scheme is not set to open until April 2022[39], and all details have not been confirmed yet. It is said to be the replacement of the RHI. However, the government plans to offer grants up to £4,000 to install renewable heating systems. This will be for home and business owners. The grant will be capped quarterly, to stop the funds depleting too quickly. It is assumed that heat pumps and biomass boilers will be included in this scheme.

The Energy Saving Trust is administering the **Home Energy Scotland Loan**[40], which is a loan facility with up to 40% cashback for some eligible energy efficiency measures, and 75% for certain renewable heating systems), on behalf of the Scottish Government, to cover the upfront capital costs. This is currently available on a first-come, first served basis.

5.7. EV CHARGING POSSIBILITIES

ACT is the Charge Point Host for the EV charging hub at the LSIC, Arisaig. The Charge Point Host is responsible for setting its own tariffs for the chargers they own on the ChargePlace Scotland network[41]. It is normal for hosts to apply charges to cover energy and maintenance costs they face. ChargePlace Scotland is removed from the pricing process and is only used for communication purposes, such as updating the live map and informing community members.

Liaising with ChargePlace Scotland will allow the host to configure charge points and begin generating revenue. The revenue would be collected by ChargePlace Scotland on the host's behalf, and the host is allowed to set the visibility, tariff and access rights of the charging points.

[38] https://www.greenerscotland.org/home-energy/advice-and-grants/renewable-heat-incentive

[39] https://www.homeheatingguide.co.uk/grants-schemes/clean-heat-grants

[40] https://www.homeenergyscotland.org/find-funding-grants-and-loans/interest-free-loans/

[41] https://chargeplacescotland.org/helpcentre/accounts-and-payments/

There are a wide range of tariffs and structures available, including:

- Unit charges (e.g. £0.25 / kWh)
- Minimum charges (e.g. £1.00)
- Connection fees (e.g. £1.50)
- Overstay fees (e.g. £10.00 after 12 hours)

These fees are decided at the hosts (i.e. ACT) discretion and often the charges range widely across Scotland. Currently, the next closest charging station to Arisaig is located in Mallaig. The charging station at Mallaig is currently free to use, however this is expected to change within a year or two, in line with other Councils across Scotland which have begun introducing fees for EV charging.

Further information is available on the ChargePoint Scotland website allowing hosts to calculate their Return on Investment (ROI) based on existing usage data, and status and energy consumption reports[42].

5.8. WIND ENERGY – DIRECT SUPPLY AND EXPORT

The transmission and distribution of electricity are both licensed via Ofgem, the UK's independent energy system regulator. In Arisaig, SSEN is responsible for the running and safety of the electricity distribution network. Connecting to the public electricity supply is subject to the conditions determined by the network operator. Where there is limited or no spare network capacity, the principle followed is that grid reinforcements are paid for by the first developer that requires the reinforcement. It is already known that the connection is in a constrained network area (Fort William Grid Supply Point (GSP) with the upstream and downstream status as constrained).

It is highly unlikely the turbine developer could secure a 'firm connection' (i.e. the ability to export 100% of the power generated at all times) without network upgrades at a prohibitive cost. One alternative is to secure a 'constrained connection', subject to 'Active Network Management' where the amount of export would vary. Depending on the constraint, firstly this is difficult to model (it is subject to multiple variables) and therefore difficult to secure financing, and secondly it can reduce operating revenues.

One way of avoiding contributions to network upgrades, constraining output, and charges for TNUOS (Transmission Network Use of System) and DUOS (Distribution Use of System) is to avoid exports to the public electricity system (PES) altogether, and supply electricity directly over a private wire system (PWS).

Private wire systems are micro-grids, usually small, privately owned and operated grids which are permanently connected to the main grid. They are similar but distinguishable from 'island' systems and 'true micro-grids' in that island systems are never connected to the main grid and true micro-grids can operate in both modes (in isolation and connected with the main grid).

Private wire systems in Scotland vary in size and in supply of energy to consumers. Many are part of private estates where it is more cost effective to run a private wire system than have the local DNO extend its system. Others, such as those in Orkney, connect assets in single ownership, such as that at Kirkwall Harbour and private wires linking micro-wind turbines to Council schools on several islands.

The ownership boundary between the PWS and the PES is highlighted by some form of metering at the Point of Common Coupling (PCC) with the licensed distribution network necessitating a licensed supplier to manage the

[42] https://chargeplacescotland.org/charge-point-hosts/

financial transactions associated with supply and demand of electricity to and from the main grid. The private wire system is typically not set up to operate in 'island mode' and therefore cannot provide power independently (such as in the event of a power cut on the main grid).

5.8.1. OPPORTUNITIES

Private wire systems can circumvent main grid constraints on generation export by using electricity locally and privately, thereby allowing the connection and use of renewable generation beyond the levels currently integrated by the mains electricity grid. Since private wire systems are permanently connected to the main grid, the technical challenges and costs involving the control systems needed to engage and disengage with the main grid are smaller than if installing 'true' microgrids.

An additional opportunity is that of trading the locally-generated energy at prices lower than from licensed suppliers the UK electricity market. As Arisaig is natural resource-rich but also fuel poor, enabling renewable energy for alternative uses, such as reducing costs for fuel, electricity, heating, and transport can offer multiple socio-economic solutions to persisting problems.

Other advantages include the reduction of greenhouse gas emissions, the promotion of renewable energy, the trial of innovative energy storage technologies, the support for greater electric vehicles uptake, the reduction of transmission/distribution losses on the main grid, local job creation and long-term community economic empowerment, may also be relevant to a private wire approach, to greater or lesser degrees.

5.8.2. CHALLENGES

The cost of the private wire and direct supply process, design, development, operation and management, and decommissioning, need to be weighed against alternatives. The decision also needs to consider questions such as the timeline for addressing the main grid constraint, and incentives such as feed-in-tariffs, consumer rights and appropriate licensing in mind. There is a need to look past short-term horizons and plan for potential future opportunities as well as risks.

5.8.3. SUPPLY MODEL

A direct supply business model allows an electricity generator to bypass a separate supplier organisation and provide electricity directly to multiple customers. The most common form of direct supply is within a private wire system which removes some or all dependence on the national grid and allows the generator to supply electricity without an electricity supply licence. However, private wire installations are limited primarily by location and the distance between generators and demand centres due to the high costs involved in developing the necessary infrastructure.

A direct supply business model can often offer the greatest potential in terms of social, environmental and economic returns, but it also assumes the greatest risk.

5.8.4. ENERGY MANAGEMENT SYSTEMS

Innovations and development in the matching of demand, generation, and storage technologies require sufficient investigation to provide an accurate assessment of the opportunities and challenges of developing private wire systems. At the building level, these systems are becoming more common, where merchant generation (such as from rooftop solar or a wind turbine) is linked with demand in real time to maximise direct usage and minimise grid import and the need for expensive storage. Demand-side response provides flexibility with the timing and intensity of energy consumption, with energy storage (both thermal and electrical) providing further flexibility if required.

There are currently systems developed for wider grid balancing, providing generation and demand matching from renewables, and standalone control systems which might provide suitable levels of control. The control system will also have to ensure that the power quality of the distribution in terms of power factor and harmonics is not adversely affected due to the integration of generating and storage equipment.

5.9. SWITCHING ENERGY SUPPLY

N.B. Suppliers regularly change their tariffs and this section is therefore accurate only at time of writing (March 2021) and subject to change: all information should be checked prior to acting. Scene is not a financial adviser, and the information is provided for interest only and Scene cannot be held liable for any costs arising.

The incumbent electricity supplier for Northern Scotland and the Highlands is SSE and British Gas is the incumbent gas supplier for the whole of Scotland[43]. Scottish residents living in more remote areas of Northern Scotland and the Highlands are more likely to pay higher energy bills than those elsewhere. This is largely attributable to the high proportion of these users either not on the gas grid, or on older models of restricted energy meters unable to easily switch to cheaper 'dual fuel' tariffs. They instead have to use inefficient electric heaters, or import other fuels such as coal, oil, and wood logs for heating. These regions are also often out of reach of the main gas grid networks, which is one of the cheapest heating fuels (in part, due to the way in which environmental levies have been imposed on electricity but not on other fuel sources).

Exploring cheaper and lower emissions-intensive energy tariffs is therefore of high priority for many residents in the Highlands and Islands region of Scotland, including those in Arisaig.

5.9.1. COMPARING GREEN ENERGY TARIFFS

The energy market in the UK is increasingly competitive and dynamic, making it easier to find and switch to a cheaper and lower carbon energy supply. The market was dominated by the 'Big Six' suppliers - British Gas, EDF, E.ON, NPOWER, Scottish Power, and SSE – but increasingly this includes competition from the "new" suppliers, including Ovo energy (which acquired 3.5m SSE customers in 2019), Shell Energy (previously First Utility), Octopus Energy and Bulb Energy, along with many other smaller suppliers, or green suppliers.

A basic energy tariff comparison was conducted to explore the possible options available for a standard residence in Arisaig to switch to a cheaper and greener energy supply.

Assumptions made in comparison of energy tariffs[44]:

1. **Post code**: PH39 4NN, Arisaig village centre
2. **Existing Electricity supplier**: SSE Scottish Hydro (regional incumbent)
3. **Existing average electricity consumption**: 7200kWh (p.a) / 600kWh (p.m)[45]
4. **Existing average electricity costs**: £1466 (p.a) / £122.18 (p.m)
5. **Tariffs of interest**: Fixed rate, 100% renewable electricity supply.

[43] https://www.ukpower.co.uk/regional_energy_prices/7-Scotland

[44] Enquiry processed with: https://www.comparethemarket.com/

[45] Average from surveys of 444 kWh/m, adjusted to account for anomalous lower inputs (e.g. 87.5 kWh/month)

Recommended tariffs:

Supplier	Tariff name	Monthly cost, est	Unit rate (p/kWh)	Standing charge (p/day)	Annual saving, est.
Scottish Power	Greener Future March 2022 B1	£ 99.89	15.287	25.85	£ 267
People's Energy	Fixed Tariff February 21 v4	£ 104.09	16.154	23.55	£ 217
Together Energy	25 February 23	£ 104.53	15.969	28.65	£ 212
E-ON	Fix Online Exclusive v63	£ 106.18	16.654	20.58	£ 192
Octopus	Exclusive 12M Fixed February 2021 v2	£ 106.39	16.481	24.68	£ 189

5.8.2. REGOS AND SUPPLIERS' RENEWABLE GENERATION CLAIMS.

The Renewable Energy Guarantees of Origin (REGO) scheme is administered by the UK Government's energy network regulator Ofgem to provide transparency to consumers about the origin of their electricity supply, and the proportion generated from renewable sources[46].

Ofgem issues a single REGO certificate when suppliers generate 1 Mega-Watt hour (MWh) of electricity from renewable sources. These REGO certificates are then used to calculate energy suppliers' fuel supply mix. This is often used to show customers wishing to know the source of their energy supply. The scheme is ultimately intended to encourage greater renewable energy installation and generation, by making greener suppliers more popular with customers.

However, the structure of the REGO scheme has been criticised for allowing energy suppliers to 'green-wash' their public image. Suppliers can buy and sell REGO certificates between themselves, and so the value of a certificate reflects this supply-demand dynamic rather than being pegged to actual new renewable energy generation in the UK. Since there is enough renewable energy generated in the UK to meet present demand, the price of a REGO is actually lower than the wholesale cost of electricity. This means that suppliers can display renewable energy credentials without often actually having to invest in or produce it[47]. Much of this renewable generation has also already been subsidised, paid for by consumers through their taxes and energy bills. The REGO scheme has therefore been criticised as being ineffective in encouraging energy suppliers to install the much needed new and unsubsidised renewable energy generation assets to meet the UK's net-zero carbon targets.

While this doesn't mean that all energy suppliers' renewable generation claims are necessarily dishonest, it does raise some important caveats to be aware of when considering a switch to a new energy supplier. In comparison, using energy from a locally-installed and locally-owned renewable generation asset would provide consumers with more certainty around the source of their energy. Suppliers which own their own generating assets and use these to supply customers will always be 'greener' than those relying on REGOs to meet their renewable electricity obligations.

[46] https://www.ofgem.gov.uk/environmental-programmes/rego/about-rego-scheme

[47] https://www.current-news.co.uk/blogs/how-do-you-solve-a-problem-like-regos-why-a-new-origin-certificate-is-needed

6. CONCLUSIONS

A high-level energy options appraisal was conducted by Scene Connect on behalf of the Arisaig Community Trust. The objective of the appraisal, and this report, was to explore ways for the community to reduce their carbon footprint and generate additional income from renewable energy generation or supply.

The appraisal was conducted using a combination of desk-based research, GIS mapping, data analysis from inputs from ACT representatives, and a process of technical, financial, and carbon modelling using Scene's bespoke energy modelling in *Microsoft Excel* software. Three separate scenarios were considered, each of which considered renewable generation, low carbon heating, and EV charging, respectively.

6.1. SUMMARY

A highly positive financial and environmental case can be made for a version of **Scenario 3**. This would comprise an energy system of a 240kW solar PV array, battery storage system (e.g. 30kWh in size), and the existing EV charging stations near the shoreline. Doing so would allow the community to reduce their annual carbon footprint by 35% compared to baseline, generate an income of around £5,200 per year (by meeting all EV demand by renewable energy at a cost of £0.29p/kWh), save over £1,700 per year on electricity costs (by generating its own electricity supply), and save an additional £18,000 per year if excess solar generation were stored rather than exported. The financial case could be strengthened further if additional EV chargers were installed (subject to demand and grid connection capacity), increasing the ability for the community to generate more revenue.

The first scenario – comprising 240kW solar and 100kW wind renewable generation assets only – would also be a positive financial and environmental option for the community, savings over £75,000 in annual electricity costs by meeting their demand directly, while offsetting 118 tonnes of carbon emissions in doing so. Wind generation, while twice as productive as solar PV in terms of energy generation, may be more challenging to install due to the likely visual and noise-related planning constraint.

The upgrading of low-carbon heating for the homes currently using fossil fuels would yield significant carbon emissions reductions (481 tonnes CO_2 equivalent). However, in order to generate financial benefits, the cost of electricity for the heat pumps would need to be reduced to around £0.11/kWh. At the current standard electricity tariff of £0.15/kWh, this scenario would represent a financial loss of over £71,000 per year for the community. This is not including the additional up-front costs of the heat pump installations themselves, after which the financial case would appear prohibitive without generous financial support. Individuals who pursue the opportunity of installing a heat pump promptly may still be able to secure subsidy from the domestic Renewable Heat Incentive, which closes to new entrants in March 2022. Additionally, the Energy Saving Trust is administering the Home Energy Scotland Loan, which is a loan facility with cashback, on behalf of the Scottish Government, to cover the upfront capital costs. This is currently available on a first-come, first served basis.

It should be noted that the financial outcomes of the scenarios quoted above represent the on-going costs and benefits of each scheme only. They do not account for the capital or operating costs of any of the low-carbon installations or assets mentioned (heat pumps, batteries, wind turbines, solar PV arrays). For example, a 240kW solar array and 30kWh battery storage system as illustrated in Scenario 3, can be expected to cost over £300,000, including all design, project management, construction, but excluding VAT.

6.2. NEXT STEPS

We recommend that ACT can secure the simplest and quickest wins in the first instance by switching their EV chargers from a free to paid-for system. This will unlock a new stream of revenue for the community. ACT can liaise with *ChargePlace Scotland* to enquire into the details of this switching process. ACT are also recommended to decide on the particular tariff(s) they would like to charger their customers (e.g. unit costs, standing charge, minimum charge, overstay charge)[48]. A unit tariff of £0.25/kWh used in this model was illustrative only, a rough average from among the paid charging stations throughout Scotland. ACT can get a better insight into other EV charging tariffs by visiting the *ChargePlace Live Map,* selecting the filter icon in the top right corner, and choosing to view only Paid stations[49].

Secondly, we recommend ACT research and apply for an Enablement Grant from CARES[50] to explore in more detail the renewable generation and low-carbon heating development options in Scenarios 1 and 2, if these are of interest. This same grant could also, or alternatively, be used to develop the energy system approach for Scenario 3, including e.g. identifying an appropriate site and agreeing Heads of Terms with the landowner, then preparing designs and cable routing, detailed energy modelling based on a specific site layout, and engaging with the planning authority. This grant awards successful applicants with up to £25,000 of funding to conduct non-capital feasibility studies and engagement works. ACT can contact their CARES Local Development Officer to explore next steps.[51]

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[48] https://chargeplacescotland.org/contact/

[49] https://chargeplacescotland.org/live-map/

[50] https://www.localenergy.scot/funding/cares-enablement-grant/

[51] https://www.localenergy.scot/who-we-are/local-contacts/