CLEAN ENERGY FOR EU ISLANDS

Energy consumption & CO_2 emissions baseline

Off-grid Scottish Islands

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CLEAN ENERGY FOR EU ISLANDS

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Table of Contents

The Clean Energy for EU Islands Secretariat

Who we are

The launch of the Clean Energy for EU Islands Initiative in May 2017 underlines the European Union's intent to accelerate the clean energy transition on Europe's more than 1,400 inhabited islands. The initiative aims to reduce the dependency of European islands on energy imports by making better use of their own renewable energy sources and embracing modern and innovative energy systems. As a support to the launch of the initiative, the Clean Energy for EU Islands Secretariat was set up to act as a platform of exchange for island stakeholders and to provide dedicated capacity building and technical advisory services.

The Clean Energy for EU Islands Secretariat supports islands in their clean energy transition in the following ways:

• It provides technical and methodological support to islands to develop clean energy strategies and individual clean energy projects.

• It co-organises workshops and webinars to build capacity in island communities on financing, renewable technologies, community engagement, etc. to empower them in their transition process.

• It creates a network at a European level in which islands can share their stories, learn from each other, and build a European island movement.

The Clean Energy for EU Islands Secretariat provides a link between the clean energy transition stories of EU islands and the wider European community, in particular the European Commission.

1. Introduction: the off-grid Scottish Islands

The off-grid Scottish Islands consist of six islands; two to the north of Scotland: Fair Isle and Foula; and four to the west of Scotland: Canna, Rum, Eigg, and Muck. These islands are developing a joint clean energy transition agenda (CETA). In order to do so, they first need to analyse and understand their current energy system and its interdependencies. The Energy System Description section of the CETA acts as a baseline for the future and allows to determine priorities and key sectors that the clean energy transition should address. This report describes the energy system of each of the six Off-Grid-Scottish Islands. It was developed in collaboration with the islands that independently gathered large parts of information from relevant stakeholders.

Section two first explains the methodology; how the energy system description is structured and what estimates and assumptions were required. Section three elaborates on the energy system of each of the six Off-grid Scottish Islands, while Section four gives an overview of the six islands altogether.

2. Methodology

Following the recommendations of the Clean Energy for EU Islands Secretariat in the Islands Transition Handbook, the energy system description for each island includes four vectors; the electricity consumption, heating and cooling, transport on the island, and transport to and from the island. For each of these vectors, the method of gathering data, as well as the estimates and required assumptions are discussed in detail.

Electricity consumption

None of the Off-grid Scottish Islands have an electricity connection to the mainland, but instead produce all their electricity autonomously from renewable sources and fossil fuels.

Data on the total installed capacity per technology—such as wind turbines, diesel generators, etc.—is given by the Highlands and Islands Enterprise. This data is seen as the most up-to-date and best-quality data that was available at the time of writing. The yearly energy production per renewable technology is given for each island, except for Foula, Rum, and Eigg where the electricity production was based on the present installed capacity and yearly production of the other islands with known production. This means that one kW of installed PV is assumed to produce 1,000 kWh per year, and thus has a capacity factor of about 11%. This corresponds well—and is even a bit higher— than the average Scottish solar capacity factor of 9% (1). One kW of installed hydropower is assumed to produce 2,000 kWh per year, with a capacity factor of about 23%. This value is based on the peninsula Knoydart whose installed capacity and production is known; however, it should be noted that capacity factors for hydropower can vary greatly from 20% to 95%, depending on location and the design of the hydro-plant (2). A capacity factor of 23% is thus seen as feasible since it is within the possible interval and based on the peninsula Knoydart with known installed capacity and production. One kW of installed wind power is assumed to produce 3,000 kWh per year, with a capacity factor of about 34%. This corresponds well—and is even a bit higher—than the average Scottish wind capacity factor of 30.8% for off- and onshore wind (3).

For diesel generators, the annual fuel consumption in litres is also given by the Highlands and Islands Enterprise. The conversion from fuel consumption in litres to primary energy consumption in kWh of the electricity sector is calculated through the energy conversion factors in Table 1. The diesel generators are assumed to have an average efficiency of 40%, which allows to calculate electricity production from the primary energy consumption. For renewable energies such as solar photovoltaic or wind energy, there is no primary energy consumed. Additionally, the CO_2 emissions corresponding to each technology are calculated. Renewable technologies have no associated CO_2 emissions during production, while the emissions from diesel generators are calculated through the emission conversion factors in Table 2.

Electricity on the Off-grid Scottish Islands is assumed to be mostly used for residential purposes to power electrical appliances, for residential heating and hot water demand, although islands can also have a church, post office, telecom tower, etc. that use electricity. Electricity that is used for heating is, e.g. electric heaters, is allocated under electricity consumption and not heating to avoid counting the same consumption twice. The overview of the electricity consumption for each island shows the installed capacity, the yearly production, the primary energy consumption and the CO_2 emissions for each technology.

Heating and cooling

Heating on the island mainly happens during the winter and consists of fossil-based and/or electric, depending on the island. Electric heating is considered as part of electricity consumption, while fossil heating is considered in this section. Fossil-based heating on the Off-Grid Scottish Islands happens through a variety of sources such as heating oil, kerosene, gas, propane, coal, peat, and wood, depending on the island. The yearly usage of each fossil source is provided in litres by the Highlands and Islands Enterprise and converted to primary energy consumption in kWh through the energy conversion factors Table 1. Additionally, the CO_2 emissions corresponding to each fossil source are calculated through the emission conversion factors in Table 2. The overview of heating per island shows the yearly fuel usage, the primary energy consumption and the associated CO_2 emissions per fossil source.

Transport on the island

The analysis of energy consumption of land transport comprises all vehicles on the Off-grid Scottish Islands. This includes private vehicles, but also leisure vehicles, agricultural vehicles, and industrial vehicles if they are present. Two approaches were used to calculate the energy usage of land transport, based on the data provided by the islands.

The first approach is used when the total usage of vehicle fuel, broken down into e.g. petrol and diesel, was available. This is the case for Canna, Fair Isle, Foula, and Rum. Then, the total fuel usage in litres can be converted to energy consumption in kWh through the energy conversion factors in Table 1 and to associated CO_2 emissions through the emission conversion factors in Table 2.

The second approach is utilised if the total vehicle fuel usage is not known. This approach requires an index of all vehicles on the island, classified per vehicle type, given by the Highlands and Islands Enterprise. For each vehicle type, the number of vehicles on the island, fuel type, and estimated mileage per year were used as an input for this study. If the fuel type is not known, an even distribution of petrol and diesel is assumed. The fuel economy per vehicle type is then calculated, as explained in the following section. This allows to find a yearly energy consumption and corresponding CO_2 emissions per vehicle type, based on the conversion factors in Table 1 and Table 2.

A mixture of the two approaches is also possible if for some vehicle types, the total yearly fuel usage is known, while for others it is not. The overview of energy consumption for road transport shows the quantity, fuel type, mileage, fuel consumption, energy use and emissions per vehicle type, or simply the total vehicle fuel usage if this is known.

Fuel economy calculations

Conventional car

The fuel consumption of a car depends on several factors such as: the type of vehicle, the age, the driving conditions, etc. The UK department for transport statistics keeps data on the average fuel consumption of new cars from different years (4). Since the cars used on the island are rather old, the average fuel consumption of a UK car from 2010 was used. This corresponds to 6.3 l/100 km for petrol cars and 5.5 l/100 km for diesel cars. These numbers are obtained under laboratory settings. However, these reported values do not reflect the actual performance of the vehicles on the road and a difference of 30–40% between official values and real-world estimates was found by a research team of the European team of Energy (5).

Additionally, fuel consumption tends to get higher with age although this mainly depends on proper maintenance, so this effect is neglected. This results in a fuel consumption that is increased by an average of 35% to 8.5 l/100 km for petrol cars and 7.4 l/100 km for diesel cars, compared to the laboratory values. If no information is known on the share of diesel and petrol cars, they are assumed to be equal. Then the fuel consumption of a typical conventional car is estimated at 8 l/100 km. The energy content of the conventional car fuel is estimated at the average of petrol and diesel, which is 9.23 kWh/l. The emission factor of an average conventional car is also the average of the diesel and petrol emission factors, which is 2.515 kg CO_2/l.

4x4 vehicles

The fuel consumption of the 4x4 is based on the light goods vehicle (LGV) data from the UK department for transport statistics (4). The average fuel consumption for a LGV from 2012 was used and increased by 35% to account for the inaccurateness of laboratory testing (5), as explained above. This results in 8.9 l/100 km for a diesel 4x4.

Electric vehicles

The average real-world energy consumption of an electric car is 18.3 kWh/100 km, based on a database of 86 different electric vehicles (6). The electrical buggy is assumed to have a similar energy consumption as an electric car. The energy consumption of the electric quad is based on the 2WD 'Ecocharger' electric quad, which has a battery capacity of about 3.5 kWh and a mileage of 50 km per charge (7), which results in 7 kWh/100 km.

Hybrid vehicles

The fuel consumption is assumed to be 8 l/100 km for a conventional car and 18.3 kWh/100 km for an electric car, as explained above. The hybrid cars are assumed to drive on conventional fuel half of the time, and on electric power the other half. The fuel consumption of the hybrid car then equals the average of the conventional and the electric car. This equals 46 kWh/100 km. The emissions also equal the average but since electric cars have zero emissions during operation, this is simply half the emissions of a conventional vehicle. This results in 0.137 kg CO_2/kWh for hybrid vehicles.

Transport to and from the island

Transporting goods and people to and from the island happens through maritime transport (boats, ferries) and/or air transport. To show the full picture in terms of energy consumption and following the guidelines from the Clean Energy for EU Islands Secretariat, both trajectories (to and from the island) are taken into consideration. As for transport on the island, two approaches to calculate the yearly energy consumption exist.

The first approach is used when the total amount of fuel in litres for maritime and air transport is known. This can then be converted to energy consumption in kWh through the energy conversion factors in Table 1 and to associated CO_2 emissions through the emission conversion factors in Table 2. Additionally, Caledonian Maritime Assets ltd reviewed ferries of the Scottish Government (8) and calculated its yearly energy consumption and CO_2 emission. This serves as the primary source of information if no other data was available. This is the case for the ferry 'MV Lochnevis' ferry, operated by Caledonian Macbrayne, that travels from Mallaig to the off-Grid Scottish Islands: Eigg, Muck, Rum and Canna, and back. It's is a medium-sized ROPAX ferry that, according to the ferry review of the Scottish Government (8), travels 1,800 hours annually. During this time, it uses 810,000 litres of marine gas oil, which is equivalent to 9,031

MWh and accounts for 2,153 t of CO_2. The fuel consumption is particularly high, especially in comparison with the ferries of Foula and Fair Isle, which is a factor seven lower (see the respective calculation on page 26 and 30). However, unlike the ferry of Foula and Fair Isle, the MV Lochnevis sails every day and does more distance because it does a tour of all four islands. Although each island has a different distance from the mainland, each island is equally reliant on the ferry, so the energy usage is spread over all four islands equally. This results in 2,257,750 kWh and 538,250 kg CO_2 per year for maritime transport for Canna, Rum, Eigg, and Muck. If another source of data on maritime transport was available, the ferry review serves as a double-check to compare both results.

The second approach is used when fuel usage is not known, for example for smaller leisure boats. In this case, the time cruising on the water is estimated, which together with the fuel economy allows to calculate the yearly energy consumption. Several islands have small boats, such as outboard leisure boats or rigid inflatable boats. The motor sizes of boats can greatly vary in comparison to the motor size and fuel economy of road cars. However, after reviewing the function of the smaller boats, the estimate is that the average smaller boat on the Off-grid Scottish Islands has a 50-horsepower motor. These motors are multifunctional and can be used for cruising, fishing, etc. To estimate the fuel economy, a general rule of thumb of the boat sector is applied (9). This states that the motor horsepower should be multiplied by 0.10 for gas engines and by 0.06 for diesel engines to calculate the gallons per hour of that motor. Diesel motors the use approximately 3 gph, which is 11.3 l/h, and gasoline motors use 5 gph, which is 18.9 l/h. Subsequently, the time spent cruising on water is estimated. For the purposes of this study, leisure boats are estimated to spend approximately 3h/week on the water, while fishing boats spend significantly more time, estimated at 3h per working day or 15 h/week. These two types of boats are combined to arrive at an estimate of 6 hours per week on average, which adds up to 312 hours cruising on the water per year per boat. Smaller boats on the Off-grid Scottish island running on diesel then use about 3,526 l diesel per year on average, while boats un gasoline use about 5,897 l gasoline per year on average.

For one ferry - the MV Sheerwater- no data was available. This ferry offers islands and wildlife cruises to the islands of Eigg, Muck and Rum from April 1st until September 30th. The ferry departs from Arisaig harbour and does three trips per week in April and September, and seven trips per week in the months in between. However, data on the energy consumption was lacking at the time of writing, so it is not included in the current analysis. Nonetheless, it is strongly recommended to add this data once it becomes available in the future.

Conversion factors

This section gives an overview of the energy and emission conversion factors for each type of fuel mentioned in the document. Additionally, it also includes fuel densities of several fuel types, required for the calculations in the report.

Energy content

The energy content factors are given per litre or per kg for fuel types, as shown in Table 1.

Table 1 Energy conversion factors

Type	Amount and unit	Source
Petrol	8.76 kWh/l	(10)
Diesel	9.7 kWh/l	(11)
50% diesel - 50% petrol	9.23 kWh/l	
Marine Gas Oil	11.15 kWh/l	(12)

Heavy Fuel Oil	11.61 kWh/kg	(3)
Marine Diesel	11.86 kWh/kg	(13)
Kerosene	12.89 kWh/kg	(2)
Heating oil	13.12 kWh/l	(14)
Coal	8.61 kWh/kg	(15)
Peat[1]	2.778 kWh/kg	(16)
Natural gas	13.11 kWh/kg	(17)
Propane	13.97 kWh/kg	(17)
Wood pellets	4.75 kWh/kg	(18)
Wood air-dried	4.4 kWh/kg	(19)

Emissions

The CO_2 emission factors are given per kWh or litre for specific fuel types, as shown in Table 2. These are the standard emission factors and not the life cycle assessment emission factors.

Table 2 Emission conversion factors

Type	Amount and unit	Source
Petrol	2.64 kg CO_2/l	(20)
Diesel	2.39 kg CO_2/l	(20)
50% diesel - 50% petrol	2.515 kg CO_2/l	
Marine Gas Oil	652 g/kWh or 270 g/kWh	(21)
Heavy Fuel Oil	0.278 kg CO_2/kWh	(22)
Marine Diesel	0.270 kg CO_2/kWh	(21)
Kerosene	0.259 kg CO_2/kWh	(22)
Heating oil	0.264 kg CO_2/kWh	(23)
Coal	0.34 kg CO_2/kWh	(23)
Peat	0.38 kg CO_2/kWh	(23)
Natural gas	0.2 kg CO_2/kWh	(23)
Propane	0.22 kg CO_2/kWh	(24)
Wood	0.39 kg CO_2/kWh	(23)

Fuel densities

The fuel densities are given in Table 3.

Table 3 Fuel densities

Type	Amount and unit	Source
Diesel	0.885 kg/l	(25)
Heating oil	1.12 kg/l	(26)
Marine Gas Oil	0.86 kg/l	(27)
Marine Diesel	0.89 kg/l	(28)
Kerosene	0.820 kg/l	(29)

[1] The energy content of peat depends heavily on its moisture level, which can range from dry peat at 2% moisture to wet peat at 60%. The figure presented here is the average energy content of both as the islands indicated there was a big difference in peat moisture and quality.

3. Energy consumption baseline

Canna

Canna is located to the West of Scotland, as indicated in Figure 1. It has a population of 19 people, spread over 11 households. The island is 6.9 km long and 1.6 km wide, with only private roads.

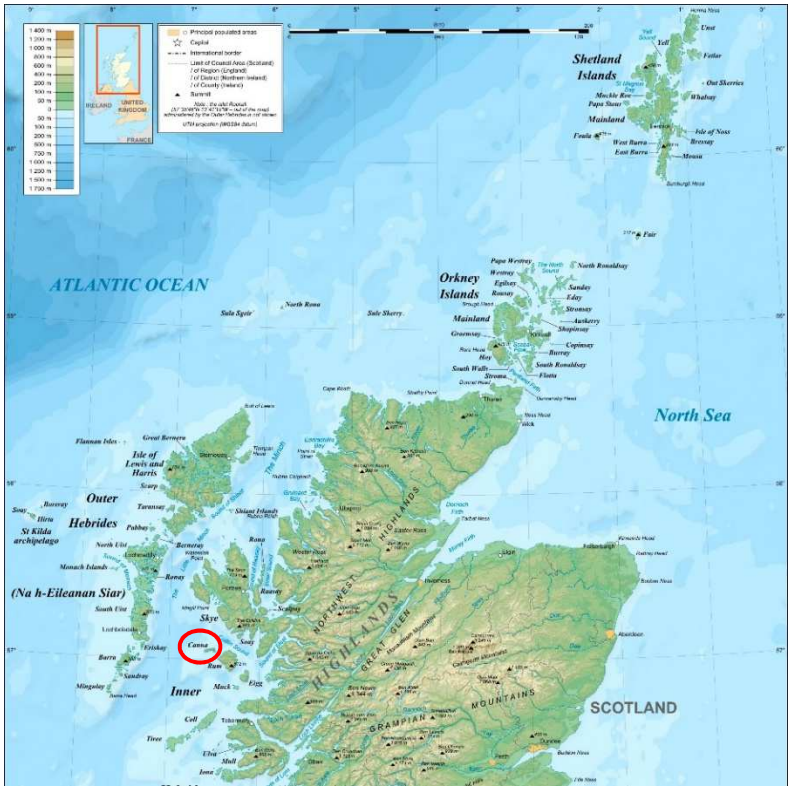

Figure 1 Location of Canna

Electricity

Canna has 30 kW of installed PV, 30kW of installed wind power, a lead-acid battery storage system and three diesel generators (two of 32kW, one of 60 kW), as shown in Table 4. Table 4 also shows the produced electricity per technology, as indicated by the Highlands and Islands Enterprise. Most of the produced electricity comes from wind turbines, while the diesel generators are used when renewable energy production is insufficient. The current electrical system is designed to accommodate the electrification of the existing households; however, no capacity exists for additional demand without having to expand the system.

Table 4 Electricity consumption overview of Canna

	Total Installed Capacity [kW]	**Total Energy Production [kWh/year]**	**Share of Total Production [%]**	**Primary Energy Consumption [kWh/year]**	**CO_2 Emissions [kg/year]**
Diesel generator	124	9,059	7	26,675	7,042
PV	30	26,323	19		
Wind	30	103,342	74		
TOTAL	**182**	**138,724**	**100**	**26,675**	**7,042**

Heating and cooling

Heating on Canna is done through a mixture of diesel and wood. Most people have boilers run on red diesel and either a wood burning stove with or without a backboiler, while others have open fires with a backboiler and red diesel boilers. However, data about the actual yearly fuel consumption was unavailable. Therefore, the yearly energy consumption for heating on Canna is based on the 2020 Small Islands Energy System Overview report, issued by Highlands and Islands Enterprise (30). They estimated that each household on Canna has a heating demand of 15.186 kWh per year, which adds up to 167,046 kWh for all 11 households per year. The assumption is made that half of the heating demand is met by diesel, while the other half is met by wood. This results in 55,306 kg CO_2, as indicated in Table 5.

Table 5 Heating overview of Canna

	Primary Energy Consumption [kWh/year]	**CO_2 Emissions [kg/year]**
Diesel	83,523	32,574
Wood	83,523	22,732
TOTAL	**167,046**	**55,306**

Transport on the island

The Highlands and Islands Enterprise found that the aggregated fuel consumption of all their vehicles is 950 l of red diesel per year (see Table 6). This results in 9,215 kWh of energy consumed, which brings the annual emissions of Canna due to road transport to 2,500 kg of CO_2.

Table 6 Energy consumption of road transport overview of Canna

Vehicle type	**Quantity**	**Fuel used**	**Aggregated fuel consumption [l]**	**Aggregated energy use [kWh]**	**Aggregated emissions CO_2 [kg]**
Pick-up	8	Red diesel	950	9,215	2,500
Quad bike	2				
Tractor	1				
Forklift	1				
Excavator	1				

Transport to and from the island

Transport to and from the island is facilitated by the 'MV Lochnevis' ferry, operated by Caledonian Macbrayne, that travels from Mallaig to the off-Grid Scottish Islands: Eigg, Muck, Rum and Canna, and back. As explained in the Section 2, this ferry consumes 2,257,750 kWh and emits 538,250 kg CO_2 per year for maritime transport on Canna, as shown in Table 7.

Additionally, the freight ship 'The Spanish John II' delivers supplies and can deliver a deck cargo of up to 40 t or a fuel cargo of up to 26,000 l. The freighter is assumed to consume 40 l of marine diesel per hour and to take 3 h to get to Canna. This adds up to 240 l per return trip. The island is supplied by the freighter once per month, which results in 2,880 l of fuel used per year. This is shown in Table 7, along with the corresponding energy consumption and emissions.

Table 7 Energy consumption of transport to and from the island overview on Canna

	Fuel type	Fuel usage [l/year]	Energy consumption [kWh/year]	CO_2 emissions [kg/year]
Ferry	Marine gas oil	202,500	2,257,750	538,250
Freighter	Marine diesel	2,880	304,000	82,080
TOTAL		205,380	**2,561,750**	**620,333**

Energy consumption overview Canna

The final and primary energy consumption and associated CO_2 emissions for electricity production, heating, transport on, and transport to and from the island are summarized in Table 8. Final energy consumption refers to the total energy used on the island, while primary energy consumption refers to the energy contained in all fossil fuels used for energy production.

Table 8: Final and primary energy consumption and CO_2 emissions for Canna

Data for year 2019	Energy consumption [kWh]	CO_2 emissions [kg]
Electricity		
Final electricity consumption	*138,724*	*7,042*
Primary energy consumption	*26,675*	*7,042*
Transport on the island		
Diesel	*9,215*	*2,500*
Transport to and from the island		
Maritime transport	*2,561,750*	*620,333*
Heating and cooling		
Diesel	83,523	32,574
Wood	83,523	22,732
TOTAL PRIMARY ENERGY CONSUMPTION	*2,764,686*	*686,181*
TOTAL FINAL ENERGY CONSUMPTION	*2,876,735*	*686,181*

Most of the energy consumption on Canna clearly goes to transport to and from the island (see Figure 2). Electricity and heating take up a minor part, while the energy consumption of transport on the island is almost negligible.

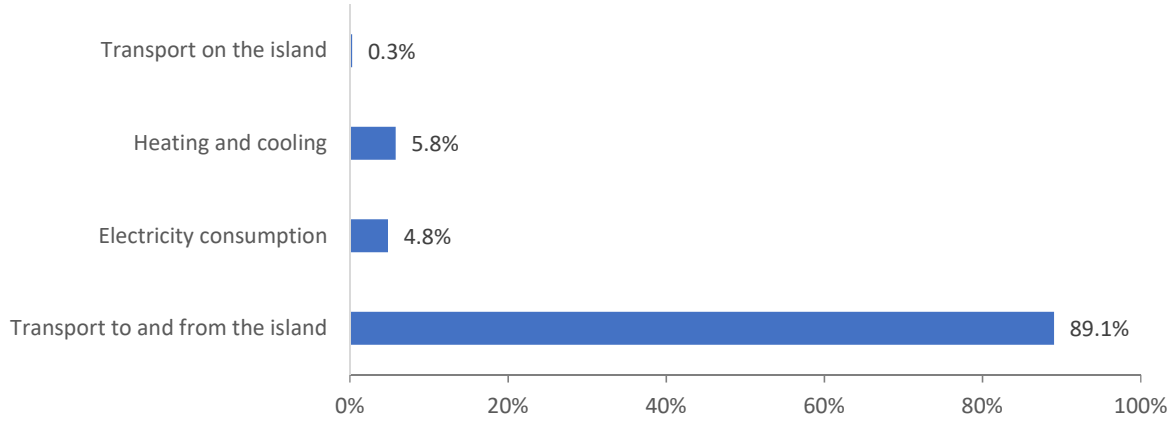

Figure 2 Final energy consumption breakdown for Canna

Rum

Rum is located to the West of Scotland, as indicated in Figure 3. It has a population of 38 people, spread over 19 households. The island itself is about 105 km^2 large.

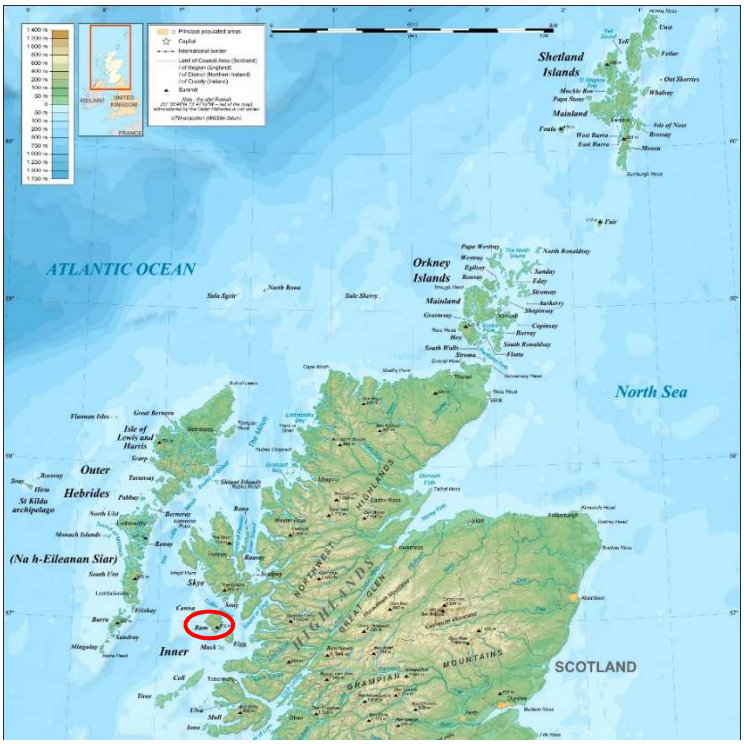

Figure 3 Location of Rum

Electricity

Rum has 24 kW of installed PV, 45kW of installed hydro power, a lead-acid battery storage system, and two back-up 48kW diesel generators, as seen in Table 9. No information was known about the amount of electricity produced from renewables, so electricity production was scaled according to the local installed capacity installed, and the yearly production of the other islands with known production, as explained in the methodology. The results are shown in Table 9. Most of the produced electricity comes from diesel generators, which operate approximately 30% of the time. The current system meets the electrical demand but does not have capacity to accommodate the electrification of heat nor the expansion of the demand. However, upgrading the existing system will allow the community to accommodate ten additional homes.

Table 9 Electricity consumption overview of Rum

	Total Installed Capacity [kW]	**Total Energy Production [kWh/year]**	**Share of Total Production [%]**	**Primary Energy Consumption [kWh/year]**	**CO_2 Emissions [kg/year]**
Diesel generator	98	155,200	58	388,000	95,600
PV	24	24,000	9		
Hydro	45	90,000	33		
TOTAL	**167**	**269,200**	**100**	388,000	95,600

Heating and cooling

The best and most accurate estimation of the fossil fuel used for heating on Rum stems from 2013 when an estimated 13,000 l of heating oil was used. This corresponds to 135,920 kWh and 35,883 kg CO_2 per year, as shown in Table 10.

Table 10 Heating overview of Rum

Type of fuel	Fuel used	Primary Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Heating oil	13,000 l	135,920	35,883

Transport on the island

The analysis of the energy consumption of land transport is based on the index of all vehicles on the island, categorized per vehicle type (see Table 11). The total fuel consumption of the Land Rover Defender is estimated at 550 l diesel per year, as received by the Highlands and Islands Enterprise, while the conventional quad's fuel consumption is estimated at 80 l petrol per year and its mileage at 2,170 km. The mileage for the electric quad and buggy were not given but are assumed to have the same estimated mileage as the conventional quad, since they're used for the same purpose.

Table 11 Energy consumption of road transport overview of Rum

Vehicle type	Quantity	Fuel used	Mileage per annum per car [km]	Fuel/energy consumption	Energy use [kWh]	Emissions CO_2 [kg]
Conventional car	17	Diesel – 50% Petrol – 50%	800	8 (l/100 km)	10,042	2,737
Land Rover Defender	1	Diesel	4000	550 (l)	5,335	1,452
Quad conventional	1	Petrol	2170	80 (l)	701	191
Quad electric	1	Electric	2170	7 (kWh/100 km)	152	0
Buggy Electric	1	Electric	2170	18.3 (kWh/100 km)	397	0
TOTAL					**16,627**	**4,380**

Transport to and from the island

Transport to and from the island is facilitated by the 'MV Lochnevis' ferry, operated by Caledonian Macbrayne, that travels from Mallaig to the off-Grid Scottish Islands: Eigg, Muck, Rum and Canna, and back. As explained in the Section 2, this ferry consumes 2,257,750 kWh and emits 538,250 kg CO_2 per year for maritime transport on Rum, as shown in Table 12.

Additionally, the freight ship 'The Spanish John II' delivers supplies can deliver a deck cargo of up to 40 t or a fuel cargo of up to 26,000 l. The freighter is assumed to consume 40 l of marine diesel per hour and to take two hours to get to Rum. Per return trip, this adds up to 160 l. The island is supplied by the freighter once per month, which results in 1,920 l of fuel used per year. This is shown in Table 12, along with the corresponding energy consumption and emissions.

Table 12 Energy consumption of transport to and from the island overview on Rum

	Fuel type	Fuel usage [l/year]	Energy consumption [kWh/year]	CO_2 emissions [kg/year]
Ferry	Marine gas oil	202,500	2,257,750	538,250
Freighter		1,920	202,667	54,720
TOTAL		204,420	**2,460,417**	**592,970**

Table does not include the ferry MV shearwater, since data was unavailable

Energy consumption overview Rum

The final and primary energy consumption and associated CO_2 emissions for electricity production, heating, transport on, and transport to and from the island are summarized in Table 13. Final energy consumption refers to the total energy used on the island, while primary energy consumption refers to the energy contained in all fossil fuels used for energy production.

Table 13 Final and primary energy consumption and CO_2 emissions for Rum

	Energy consumption [kWh]	CO_2 emissions [kg]
Electricity		
Final electricity consumption	269,200	
Primary energy consumption	388,000	95,600
Transport on the island		
Petrol	5,722	1,560
Diesel	10,350	2,821
Electric	549	0
Transport to and from the island		
Maritime transport	2,460,417	592,970
Heating and cooling		
Heating oil	*135,920*	*35.883*
TOTAL PRIMARY ENERGY CONSUMPTION	*3,000,958*	*728,833*
TOTAL FINAL ENERGY CONSUMPTION	*2,882,164*	*728,833*

Most of the energy consumption on Rum clearly goes to transport to and from the island (see Figure 4). Electricity and heating take up a minor part, while the energy consumption of transport on the island is almost negligible.

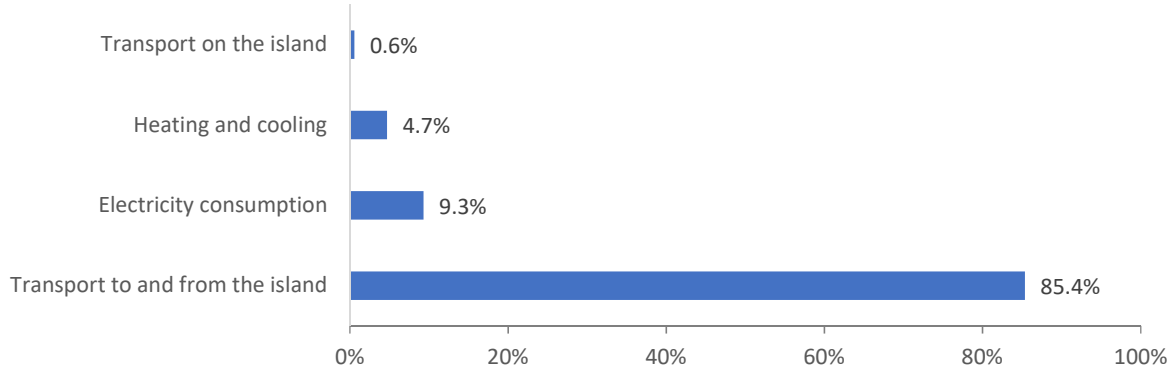

Figure 4 Final energy consumption breakdown for Rum

Eigg

Eigg is located to the West of Scotland, as indicated in Figure 5. It has a population of 83 people, spread over 67 households, which makes it the most populated of the four Western Off-grid Scottish Islands. The island itself is about 31 km^2 large.

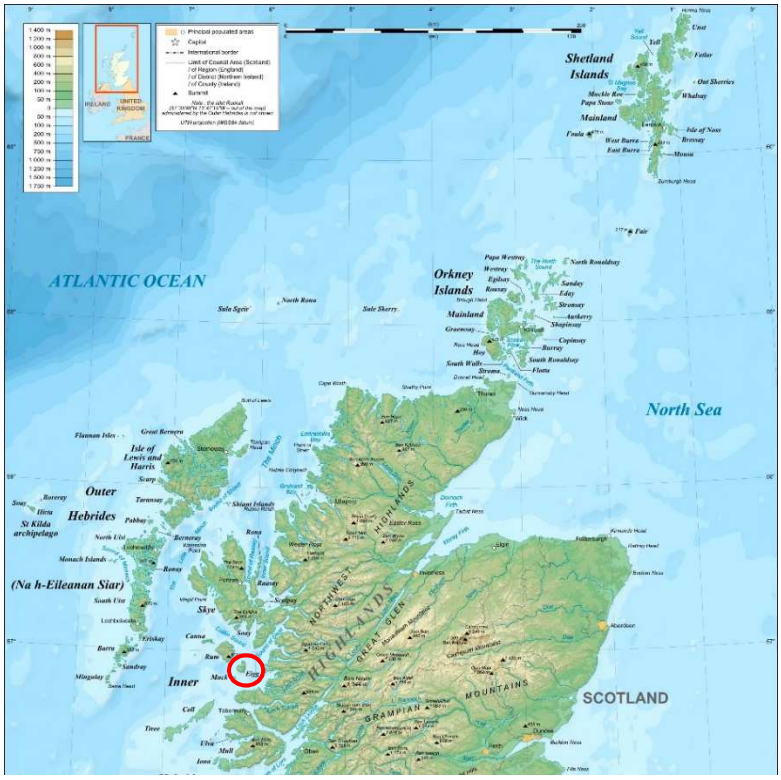

Figure 5 Location of Eigg

Electricity

Eigg has 50 kW of installed PV, 108 kW of installed hydro power, 24kW of installed wind, and a lead-acid battery storage system. Additionally, electricity is produced with diesel generators with a total installed capacity of 160 kW, as seen in Table 14. No information was known about the amount of electricity produced from renewables, so electricity production was scaled according to the local installed capacity installed, and the yearly production of the other islands with known production, as explained in the methodology. Most of the produced electricity comes from hydro power. The generators run about 10% of the time to meet electricity demand when renewables alone are not enough. The current system also needs to be upgraded in the future to cater for added demand.

Table 14 Electricity consumption overview of Eigg

	Total Installed Capacity [kW]	Total Energy Production [kWh/year]	Share of Total Production [%]	Primary Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Diesel generator	160	73,960	18	184,900	45,410
PV	50	50,000	12		
Wind	24	72,000	18		
Hydro	108	216,000	52		
TOTAL	**342**	**411,960**	**100**	**184,900**	**45,410**

Heating and cooling

Heating on Eigg is based on electric heating (allocated under electricity consumption), fossil fuels such as heating oil and coal, and renewables such as solar thermal heating and biomass. The amount of fuel used, the energy consumption and its associated CO_2 emissions are shown in Table 15. The energy consumption of biomass heating was not available but is based on an average yearly heating demand of 12,650 kWh for each of the nine households that use it.

Table 15 Heating overview of Eigg

	Fuel used	Primary Energy Consumption [kWh/year]	Share of Total Production [%]	CO_2 Emissions [kg/year]
Heating oil	20,400 l	213,307	35	56,313
Coal	17 t	118,150	20	40,171
Solar Thermal	167 m^3	160,320	26	0
Biomass	N.A.	113,850	19	0
TOTAL		**605,688**	**100**	**96,484**

Transport on the island

The analysis of the energy consumption of land transport is based on the index of all vehicles on the island, categorized per vehicle type (see Table 16). Since no estimate of mileage per vehicle type was given, these estimates are based on estimates used on Rum, which has comparable length of public roads. The yearly fuel consumption of the conventional quad is also based on the estimate of Rum at 80 l. The fuel usage of the tractor is based on data by Muck, where all five tractors combined were estimated to use 1,500 l of diesel. Transferring this to Eigg leads to an estimate of 300 l diesel used per tractor.

Table 16 Energy consumption of road transport overview of Eigg

Vehicle type	Quantity	Fuel used	Mileage per annum per car [km]	Fuel/Energy consumption	Total energy use [kWh]	Emissions CO_2 [kg]
Conventional car	39	Petrol & Diesel	800	8 l/100 km	23,038	6280
Hybrid car	3	Petrol & electric	800	46 kWh/100 km	1,104	242
Electric car	1	Electric	800	18.3 kWh/100 km	146	0
Quad conventional	5	Petrol	2,170	80 l	3,505	955
Buggy conventional	2	Petrol	2,170	8 l/100 km	3,041	831
Buggy electric	2	Electric	2,170	18.3 kWh/100 km	796	0
Tractor	6	Diesel	/	300 l/tractor	17,460	4,302
TOTAL					**49,166**	**12,610**

Transport to and from the island

Transport to and from the island is facilitated by the 'MV Lochnevis' ferry, operated by Caledonian Macbrayne, that travels from Mallaig to the off-Grid Scottish Islands: Eigg, Muck, Rum and Canna, and back. As explained in the Section 2, this ferry consumes 2,257,750 kWh and emits 538,250 kg CO_2 per year for maritime transport on Eigg, as shown in Table 17.

Eigg also has five local boats which, as indicated in the methodology, are estimated to use 3526 l diesel per boat per year. This is equivalent to 34,193 kWh and 8,425 kg of CO_2.

Additionally, the freight ship 'The Spanish John II' delivers supplies can deliver a deck cargo of up to 40 t or a fuel cargo of up to 26,000 l. The freighter is assumed to consume 40 l of marine diesel per hour and to take two hours to get to Eigg. Per return trip, this adds up to 160 l. The island is supplied by the freighter once per month, which results in 1,920 l of fuel used per year. This is shown in Table 17, along with the corresponding energy consumption and emissions.

Lastly, another ferry - the MV Sheerwater- offers islands and wildlife cruises to the islands of Eigg, Muck and Rum from April 1st until September 30th. The ferry departs from Arisaig harbour and does three trips per week in April and September, and seven trips per week in the months in between. However, data on the energy consumption was lacking at the time of writing, so it is not included in the current analysis. Nonetheless, it is strongly recommended to add this data once it becomes available in the future.

Table 17 Energy consumption of transport to and from the island overview of Eigg

Boat type	**Quantity**	**Fuel type**	**Fuel usage [l/year]**	**Energy consumption [kWh/year]**	**$CO_{2\,e}$missions [kg/year]**
Ferry MV Lochnevis	1	Marine gas oil	202,500	2,257,750	538,250
Ferry MV Sheerwater	1				
Freighter	1	Marine diesel	1,920	202,667	54,720
Local boats	5	Marine diesel	17,630	170,965	42,125
TOTAL			**222,050**	**2,631,382**	**635,095**

Table does not include the ferry MV shearwater, since data was unavailable

Energy consumption overview Eigg

The final and primary energy consumption and associated CO_2 emissions for electricity production, heating, transport on, and transport to and from the island are summarized in Table 18. Final energy consumption refers to the total energy used on the island, while primary energy consumption refers to the energy contained in all fossil fuels used for energy production.

Table 18: Final and primary energy consumption and CO2 emissions for Eigg

	Energy consumption [kWh]	CO_2 emissions [kg]
Electricity consumption		
Final electricity consumption	411,960	
Primary energy consumption	184,900	45,410

Transport on the island		
Conventional cars	23,038	6280
Hybrid cars	1,104	242
Electric cars	146	0
Conventional Quads	3,505	955
Conventional buggies	3,041	831
Electric buggies	796	0
Tractors	17,460	4,302
Transport to and from the island		
Maritime transport	2,631,382	635,095
Heating and cooling		
Heating oil	213,307	56,313
Coal	118,150	40,171
Solar Thermal	160,320	0
Biomass	113,850	0
TOTAL PRIMARY ENERGY CONSUMPTION	*3,471,136*	*789,599*
TOTAL FINAL ENERGY CONSUMPTION	*3,698,196*	*789,599*

Most of the energy consumption on Eigg clearly goes to transport to and from the island (see Figure 6). Electricity and heating take up a significant part as well, especially in comparison with other Off-Grid Scottish islands. This is because Eigg counts many more inhabitants, and thus electricity and heating requirements, while the transport to and from the island largely remains unchanged. As for the other islands, the energy consumption of transport on is almost negligible.

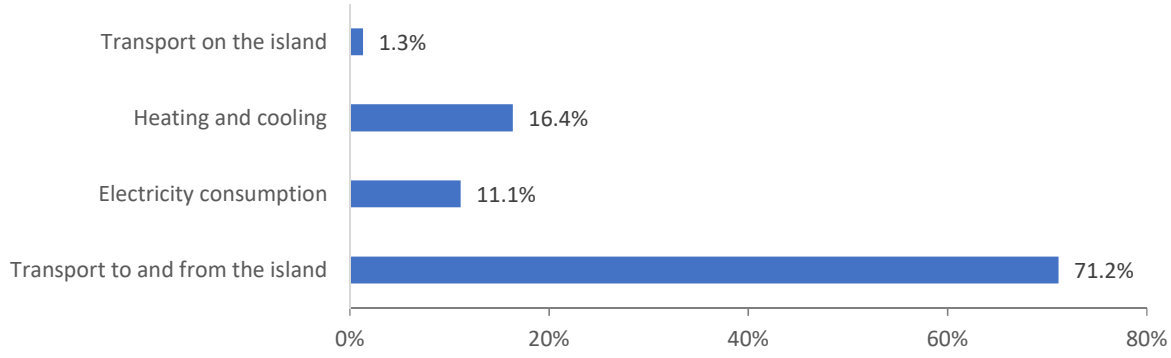

Figure 6 Final energy consumption breakdown for Eigg

Muck

Muck is located to the West of Scotland, as indicated in Figure 7. It has a population of 40 people, spread over 14 households. The island is about 5.59 km^2 large.

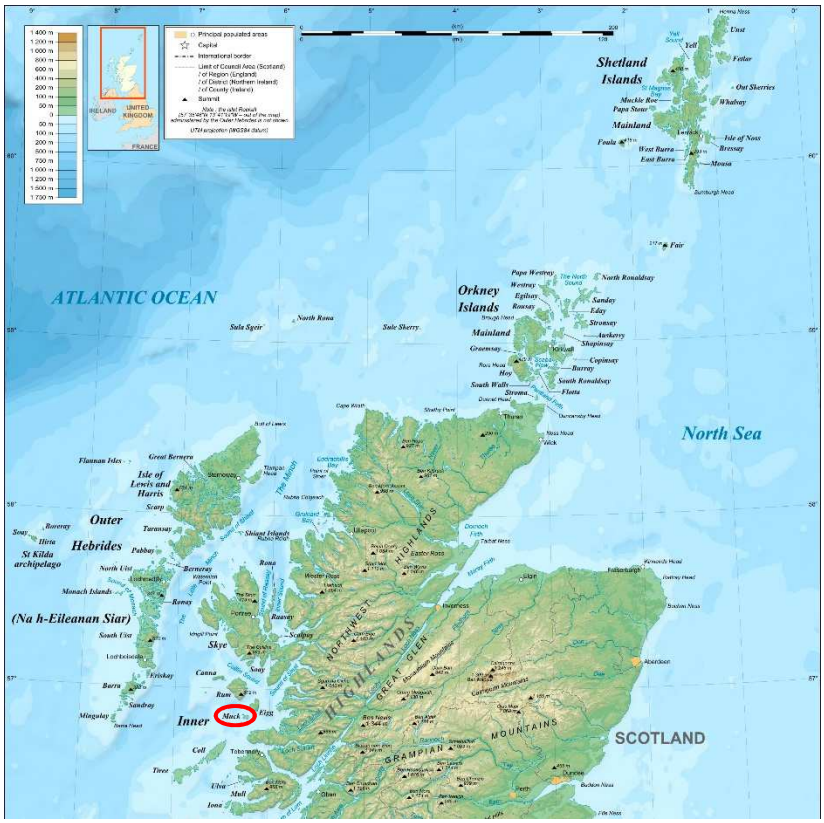

Figure 7 Location of Muck

Electricity

Muck has 36 kW of installed PV, 30 kW of installed wind, a lead-acid battery storage system, and diesel generators with a nominal capacity of 36 kW, as illustrated in Table 19. Additionally, Table 19 shows the produced electricity per technology, as indicated by the Highlands and Islands Enterprise. Most of the produced electricity comes from wind turbines and the PV system. The generators only produce about 7% of all electricity, when renewable production is not enough. The current system works relatively well but needs to expand if heating is to be electrified.

Table 19 Electricity consumption overview of Muck

	Total Installed Capacity [kW]	Total Energy Production [kWh/year]	Share of Total Production [%]	Primary Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Diesel generator	36	9,407	9	23,518	5,128
PV	36	26,800	26	0	0
Wind	30	68,200	65	0	0
TOTAL	**102**	**104,407**	**100**	**23,518**	**5,128**

Heating and cooling

Heating and cooking on Muck is based on fossil fuels such as kerosene, coal, split log, wood pellets and propane. The amount used per year, indicated by the Highlands and Islands Enterprise is shown in Table 20, as well as the corresponding energy consumption and associated CO_2 emissions. 12,000 l of kerosene is used for the properties associated with the fish farm, while the remaining kerosene is used for the oil boilers in the newer houses. The wood pellets are used for heating the hotel, while the split log is used by domestic households for cooking and heating. The propane is solely used for cooking.

Table 20 Heating overview of Muck

	Fuel used	**Primary Energy Consumption [kWh/year]**	**Share of Total Production [%]**	**CO_2 Emissions [kg/year]**
Kerosene	33,000 l	348,803	66	90,340
Coal	9 t	77,490	15	26,347
Split log	10 t	44,000	8	17,160
Wood pellets	9 t	42,750	8	16,673
Propane	1.14 t	15,926	3	3,504
TOTAL		**528,969**	**100**	**154,024**

Transport on the island

The analysis of energy consumption of land transport comprises all vehicles on the island. This includes 14 cars, five quads, as well as two excavators and five tractors, as summarized by the Highlands and Islands Enterprise. Furthermore, they estimated that the total annual diesel usage on road transport is 3,000 l, of which 50% is for agricultural and farm use (see Table 21). This allows to find the total energy usage and emissions, based on conversion factors explained in the methodology section.

Table 21 Energy consumption of road transport overview of Muck

Fuel type	**Quantity (l)**	**Total energy use (kWh)**	**Emissions CO_2 (kg)**
Diesel	3,000	29,100	7,170

Transport to and from the island

Transport to and from the island is facilitated by the 'MV Lochnevis' ferry, operated by Caledonian Macbrayne, that travels from Mallaig to the off-Grid Scottish Islands: Eigg, Muck, Rum and Canna, and back. As explained in the Section 2, this ferry consumes 2,257,750 kWh and emits 538,250 kg CO_2 per year for maritime transport on Muck, as shown in Table 22.

Additionally, the freight ship 'The Spanish John II' delivers supplies can deliver a deck cargo of up to 40 t or a fuel cargo of up to 26,000 l. The freighter is assumed to consume 40 l of marine diesel per hour and to take two and a half hours to get to Muck. Per return trip, this adds up to 200 l. The island is supplied by the freighter four times per year, which results in 800 l of fuel used per year. This is shown in Table 22, along with the corresponding energy consumption and emissions.

Table 22 Energy consumption of transport to and from the island overview of Muck

Boat type	Quantity	Fuel type	Fuel usage [l/year]	Energy consumption [kWh/year]	$CO_{2\,e}$ emissions [kg/year]
Ferry	1	Marine gas oil	202,500	2,257,750	538,250
Freighter	1	Marine diesel	800	84,445	22,800
Local boats	3	Marine diesel	10,578	102,607	25,281
TOTAL			**213,878**	**2,444,802**	**586,411**

Table does not include the ferry MV shearwater, since data was unavailable

Energy consumption overview Muck

The final and primary energy consumption and associated CO_2 emissions for electricity production, heating, transport on, and transport to and from the island are summarized in Table 23. Final energy consumption refers to the total energy used on the island, while primary energy consumption refers to the energy contained in all fossil fuels used for energy production.

Table 23: Final and primary energy consumption and CO_2 emissions on Muck

	Energy consumption [kWh]	CO_2 emissions [kg]
Electricity		
Final electricity consumption	104,407	
Primary electricity consumption	23,518	5,128
Transport on the island		
Diesel	29,100	7,170
Transport to and from the island		
Maritime transport	*2,257,750*	*538,250*
Heating and cooling		
Kerosene	348,803	90,340
Coal	77,490	26,347
Split log	44,000	17,160
Wood pellets	42,750	16,673
Propane	15,926	3,504
TOTAL PRIMARY ENERGY CONSUMPTION	3,026,389	752,733
TOTAL FINAL ENERGY CONSUMPTION	3,107,278	752,733

Most of the energy consumption on Muck clearly goes to transport to and from the island (see Figure 8). A significant part goes to heating as well, while electricity and energy consumption of transport on the island is almost negligible.

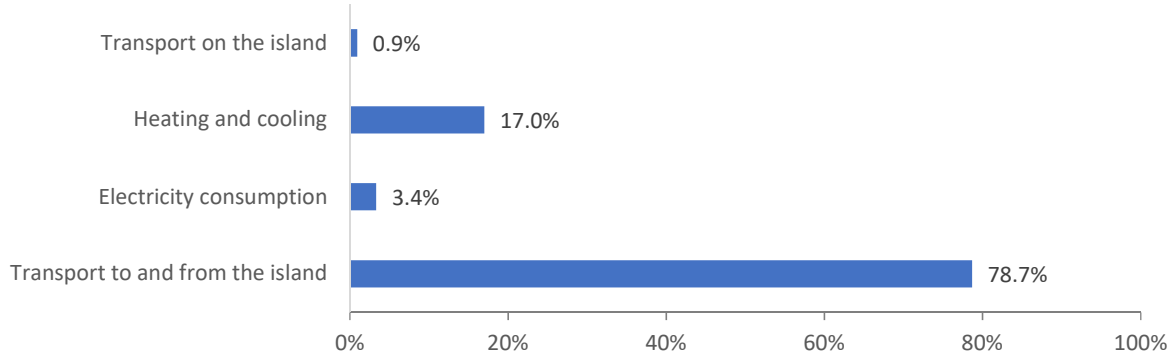

Figure 8 Final energy consumption breakdown for Muck

Foula

Foula is located to the North of Scotland, as indicated in Figure 9. It has a population of 38 people, spread over 24 households. The island is about 12.65 km^2 large.

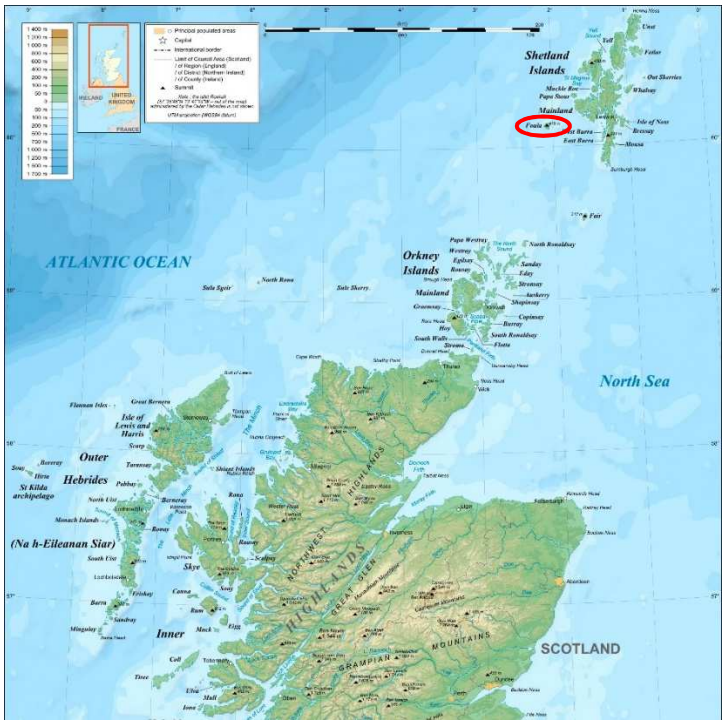

Figure 9 Location of Foula

Electricity

Foula has 25 kW of PV, 20kW of hydro power, 30 kW of wind power, a lead-acid battery storage system, and a diesel generator, as seen in Table 24. No information was known about the amount of electricity produced from renewables, so electricity production was scaled according to the local installed capacity installed, and the yearly production of the other islands with known production. Most of the produced electricity comes from the diesel generator, which runs approximately 16 hours per day. The current electricity mix consists of about 40% renewables and 60% diesel, but plans are made to change this to 60% renewables and 40% diesel. There is still potential for 30 kW expansion, which will then likely accommodate electrification of heat and transport.

Table 24 Electricity consumption overview of Foula

	Total Installed Capacity [kW]	Total Energy Production [kWh/year]	Share of Total Production [%]	Primary Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Diesel generator	96	183,101	53	457,752	113,424
PV	25	25,000	7		
Wind	30	100,000	29		
Hydro	20	40,000	11		
TOTAL	**171**	**348,101**	**100**	**457,752**	**113,424**

Heating and cooling

Heating on Foula is based on fossil fuels such as coal, peat, and heating oil. Coal and peat are used to heat people's homes, while heating oil is used for heating the school and three tourist properties. Additionally, natural gas is used for cooking on the island. The amount of these fossil fuels used per year, indicated by the Highlands and Islands Enterprise, is shown in Table 25, as well as the corresponding energy consumption and associated CO_2 emissions. Important to note is that the amount of peat is very hard to estimate as there is no place where they are formally weighed. Furthermore, there are also big variations in the dryness of peat, and therefore its energy content. To compensate, an average conversion factor between moist and dry peat is used, as explained in section 2.

Table 25 Heating overview of Foula

	Fuel used [t]	Primary Energy Consumption [kWh/year]	Share of Total Production [%]	CO_2 Emissions [kg/year]
Coal	12	103,320	29	35,129
Peat	29	80,562	22	49,917
Heating oil	13	152,230	42	30,614
Natural gas	2	26,222	7	5,244
TOTAL	**56**	**362,334**	**100**	**120,904**

Transport on the island

The analysis of energy consumption of land transport comprises all vehicles on the island. This includes 13 private vehicles, 7 4x4's, 3 vans, 2 tractors, 2 excavators and 1 fire truck, as summarized by the Highlands and Islands Enterprise. Furthermore, they estimated the total annual fuel usage on road transport, categorized in petrol and diesel (see Table 26). This allows to find the total energy usage and emissions, based on conversion factors explained in the methodology section.

Table 26 Energy consumption of road transport overview of Foula

Fuel type	Quantity (l)	Total energy use (kWh)	Emissions CO_2 (kg)
Diesel	8,184	79,385	21,606
Petrol	2,728	23,897	6,525
TOTAL	**10,912**	**103,282**	**28,131**

Transport to and from the island

Marine Transport

Marine transport to and from Foula happens through the ferry, the New Advance, operated by the Shetland Island Council. It does a return journey to Walls on Shetland mainland, three days per week. Annually, it uses 8 t of kerosene and 9 t of heavy fuel oil, as mentioned by Highlands and Islands Enterprise. The corresponding energy consumption and emissions are shown in Table 27.

A review by Caledonian Maritime Assets of Scottish ferries for the Scottish Government found that the New Advance travels around 500 hours a year and uses 22,500 l of marine gas oil (8). The corresponding energy consumption and emissions are shown in Table 27, and closely resemble the values found from estimates provided as an input for this study.

Air Transport

Air transport to and from Foula happens through 'Islander', a twin-engine aircraft by Briten-Norman. The aircraft uses 9,800 l of kerosene per year, with the corresponding energy consumption and emissions due to air transport to and from Foula also shown in Table 27.

Table 27 Energy consumption of transport to and from the island overview of Foula

	Fuel type	Fuel used per year	Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Marine transport - Ferry	Kerosene	8 t	103,120	26,700
	Heavy fuel oil	9 t	104,490	29,000
	Total		***207,610***	***55,700***
Review by Caledonian Maritime Assets[2]	*Marine gas oil*	*22,500 l*	*229,491*	*60,000*
Air transport	Kerosene	9,800 l	103,597	26,830
TOTAL			**311,207**	**82,530**

Energy consumption overview Foula

The final and primary energy consumption and associated CO_2 emissions for electricity production, heating, transport on, and transport to and from the island are summarized in Table 28. Final energy consumption refers to the total energy used on the island, while primary energy consumption refers to the energy contained in all fossil fuels used for energy production.

[2] This figure only serves as check for the data given by the Highlands and Islands Enterprise. It is not included in the calculation of the total energy consumption nor the total CO_2 emissions

Table 28: Final and primary energy consumption and CO_2 emissions on Foula

	Energy consumption [kWh]	CO_2 emissions [kg]
Electricity		
Final electricity consumption	348,101	
Primary energy consumption	457,752	113,424
Transport on the island		
Diesel	79,385	21,606
Petrol	23,897	6,525
Transport to and from the island		
Maritime transport	207,610	55,700
Aviation	103,597	26,830
Heating and cooling		
Coal	103,320	35,129
Peat	80,562	49,917
Heating oil	152,230	30,614
Natural gas	26,222	5,244
TOTAL PRIMARY ENERGY CONSUMPTION	1,234,575	344,989
TOTAL FINAL ENERGY CONSUMPTION	1,124,924	344,989

The energy consumption on Foula is spread quite evenly over heating, electricity consumption, and transport to and from the island (see Figure 10). Especially striking is the significantly lower share of transport to and from the island in comparison to its share on Canna, Rum, Eigg, and Muck. This is the case because the ferry on these latter four islands, the MV Lochnevis, has a very high energy consumption because it travels to those islands every day, while the New Advance on Foula has a significantly lower energy consumption. Still, as with the other islands, the energy consumption of transport on the island is minimal.

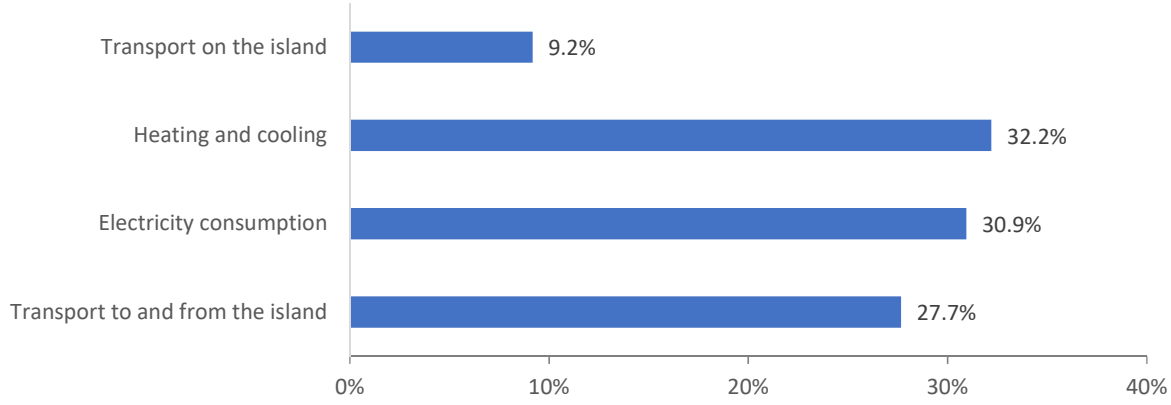

Figure 10 Final energy consumption breakdown for Foula

Fair Isle

Fair Isle is an island in Shetland, in northern Scotland, as indicated in Figure 11. It has a population of 55 people, spread over 26 households. The island is about 7.68 km^2 large.

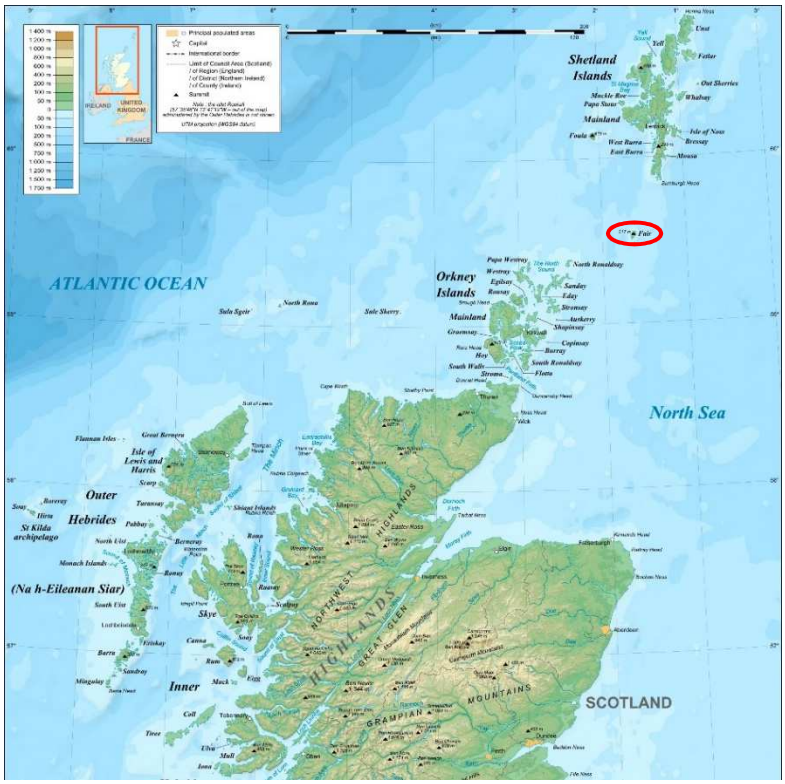

Figure 11 Location of Fair Isle

Electricity

Fair Isle has 50 kW of installed PV, 120 kW of installed wind power, a lead-acid battery storage system, and diesel generation with a nominal capacity of 280 kW, as seen in Table 29. Additionally, Table 29 shows the produced electricity per technology, as indicated by the Highlands and Islands Enterprise. Most of the produced electricity comes from wind turbines, while the diesel generators are used when renewable energy production is insufficient, which is only around 4% of the year. Furthermore, the electricity system needs to be operating at full capacity in order to even consider charging EVs. Additionally, British Telecommunications (BT) services are also operated from the island and use a significant amount of diesel fuel.

Table 29 Electricity consumption overview of Fair Isle

	Installed Capacity [kW]	Purpose	Total Energy Production [kWh/year]	Share of Production [%]	Primary Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Diesel generator	280	Electricity network	23.700	4	75,757	17,163
		BT services	194,000	37	485,000	119,500
PV	50	Electricity network	40,500	8		
Wind	120	Electricity network	273,197	51		
TOTAL	**450**		**531,397**	**100**	**560,757**	**136,663**

Heating and cooling

Heating on Fair Isle is based on fossil fuels such as coal, wood, kerosene, and propane. Most of the houses are not well insulated and are also occupied by elderly people, which implies that they need to be heated more. Additionally, there is a large school building and a nurse surgery, with neither being properly insulated. The amount of these fossil fuels used per year is shown in Table 30, as well as the corresponding energy consumption and associated CO_2 emissions. The figures were taken from 'Good Shepherd IV' freight log. The year the figures were taken from was also the same year as the turbines failed so these figures might be exceptionally high compared to previous years. Moreover, there used to be a Bird Observatory that used kerosene for 12 months straight for heating and hot water, irrespective of guests or not. Now, however, it has burned down. These two factors, the failing of the turbines and continuous kerosene consumption of the Bird observatory, help to explain the significantly larger primary energy consumption on heating per year compared to other Off-Grid Scottish Islands. It's clear the data from this year is an outlier, therefore the author recommends the Highlands and Islands Enterprise to either find a reasonable estimate of which part of the heating consumption is excessive based on conversations with relevant island representatives, or to gather data from another year.

Table 30 Heating overview of Fair Isle

	Fuel used	Primary Energy Consumption [kWh/year]	Share of Total Production [%]	CO_2 Emissions [kg/year]
Coal	12 t	103,320	14	35,129
Wood	7 t	33,250	5	12,967
Kerosene	53,900 l	569,712	75	147,555
Propane	3.5 t	48,895	6	10,757
TOTAL		**755,177**	**100**	**206,408**

Transport on the island

The analysis of energy consumption of land transport comprises all vehicles on the island. This includes 39 diesel cars of mixed make and model, six tractors, two quads, two lorries, two excavators and one fire truck, as indexed by Highlands and Islands Enterprise. Furthermore, the total annual diesel usage of all these vehicles was also given, as seen in Table 31. This allows to find the total energy usage and emissions, based on conversion factors explained in the methodology section.

Table 31 Energy consumption of road transport overview of Fair Isle

Fuel type	Quantity [l]	Total energy use [kWh]	Emissions CO_2 [kg]
Diesel	5,400	52,380	12,906

Transport to and from the island

Marine Transport

Marine transport to and from Fair Isle happens through the ferry, the Good Shephard IV, operated by the Shetland Island Council. It does a return journey to Grutness Pier on Shetland mainland, three days per week in Summer and one day per week in Winter (some occasional extra runs weather permitting). Furthermore, it does a return journey to Lerwick, the capital of Shetland, every second Thursday. Annually, it uses on average 30,000 l of marine diesel, as mentioned by the Highlands and Islands Enterprise. The corresponding energy consumption and emissions are shown in Table 32.

A review by Caledonian Maritime Assets of Scottish ferries for the Scottish Government found that the Good shepherd IV travels around 600 hours a year and uses 27,000 l of marine gas oil (8). The corresponding energy consumption and emissions are shown in Table 32, and while they are around 10% lower than the values found from estimates provided as an input for this study, they're still close enough to have trust in the data given by the Highlands and Islands Enterprise.

Fair isle also has five local boats which, as indicated in the methodology, are estimated to use 3526 l diesel per boat per year. This is equivalent to 34,193 kWh and 8425 kg of CO_2 per boat. The corresponding energy consumption and emissions of all five local boats are shown in Table 32.

Air Transport

Air transport to and from Fair isle happens through 'Islander', a twin-engine aircraft by Briten-Norman. The aircraft uses 28.12 t of kerosene per year, with the corresponding energy consumption and emissions due to air transport to and from Fair Isle also shown in Table 32.

Table 32 Energy consumption of transport to and from the island overview of Fair Isle

	Quantity	Fuel type	Fuel used per year	Energy Consumption [kWh/year]	CO_2 Emissions [kg/year]
Marine transport					
Ferry	1	Marine diesel	30,000 l	355,800	85,500
Review by Caledonian Maritime Assets[3]	*1*	*Marine gas oil*	*27,000 l*	*301,050*	*72,000*
Local boats	5	Marine diesel	17,630 l	170,965	42,125
Marine Total				**526,765**	**127,625**
Air transport					
Plane	1	Kerosene	28.12 t	362,467	93,880
TOTAL				**889,232**	**221,505**

[3] This figure only serves as check for the data given by the Highlands and Islands Enterprise. It is not included in the calculation of the total energy consumption nor the total CO_2 emissions

Energy consumption overview Fair Isle

The final and primary energy consumption and associated CO_2 emissions for electricity production, heating, transport on, and transport to and from the island are summarized in Table 33. Final energy consumption refers to the total energy used on the island, while primary energy consumption refers to the energy contained in all fossil fuels used for energy production.

Table 33: Final and primary energy consumption and CO_2 emissions on Fair Isle

	Energy consumption [kWh]	CO2 emissions [kg]
Electricity consumption		
Final electricity consumption	531,397	
Residential	337,397	
BT services	194,000	
Primary energy consumption	560,757	136,663
Residential	75,757	17,163
BT services	485,000	119,500
Transport on the island		
Diesel	52,380	12,906
Transport to and from the island		
Maritime transport	526,765	127,625
Aviation	362,467	93,880
Heating and cooling		
Coal	103,320	35,129
Wood	33,250	12,967
Kerosene	569,712	147,555
Propane	48,895	10,757
TOTAL PRIMARY ENERGY CONSUMPTION	*2,257,546*	*577,482*
TOTAL FINAL ENERGY CONSUMPTION	*2,228,186*	*577,482*

Most of the energy consumption on Fair Isle is spread quite evenly over heating requirements and transport to and from the island (see Figure 12). Only a smaller fraction is used on electricity consumption, while the energy consumption of transport on the island is, as with all Off-grid Scottish Islands, almost negligible.

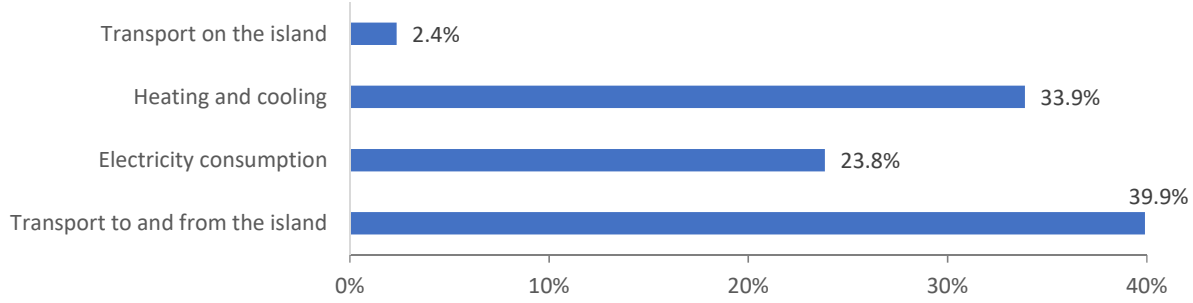

Figure 12 Final energy consumption breakdown for fair Isle

Island comparison

In previous sections, the baseline energy consumption for the six off-grid Scottish Islands was presented. This section compares the energy consumption and CO_2 emissions of all six Off-grid Scottish islands, highlights the most important differences and aims to clarify them.

The energy consumption of the four islands to the West of the mainland (Canna, Rum, Eigg, and Muck) is significantly higher than the energy consumption of the two islands to the North (Foula and Fair Isle), as seen in Figure 13. This is because the share of transport to and from the island is very high – around 90% - for these first four islands due to the large energy consumption from the 'MV Lochnevis' ferry, which travels between these four islands every day.

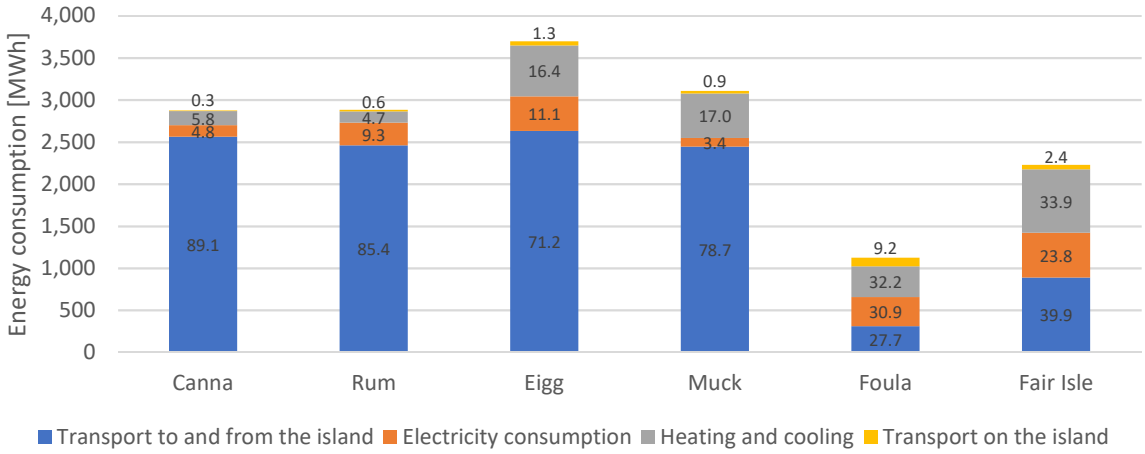

Figure 13 Total energy consumption of all six Scottish Off-Grid Islands.

Looking at the energy consumption without transport to and from the island gives a different image though. Now the energy consumption of Eigg and Fair isle is highest, as illustrated in Figure 14. This is expected since their respective number of inhabitants are the highest as well. Still, Fair Isle has a disproportionately higher energy consumption than the other four islands when taking into account the population. This is partly explained by the fact that Fair Isle hosts the BT services, which use a significant amount of electricity from diesel generators (see Figure 18). The share of the energy consumption of transport on the island remains minimal for all the islands, probably due to their small size.

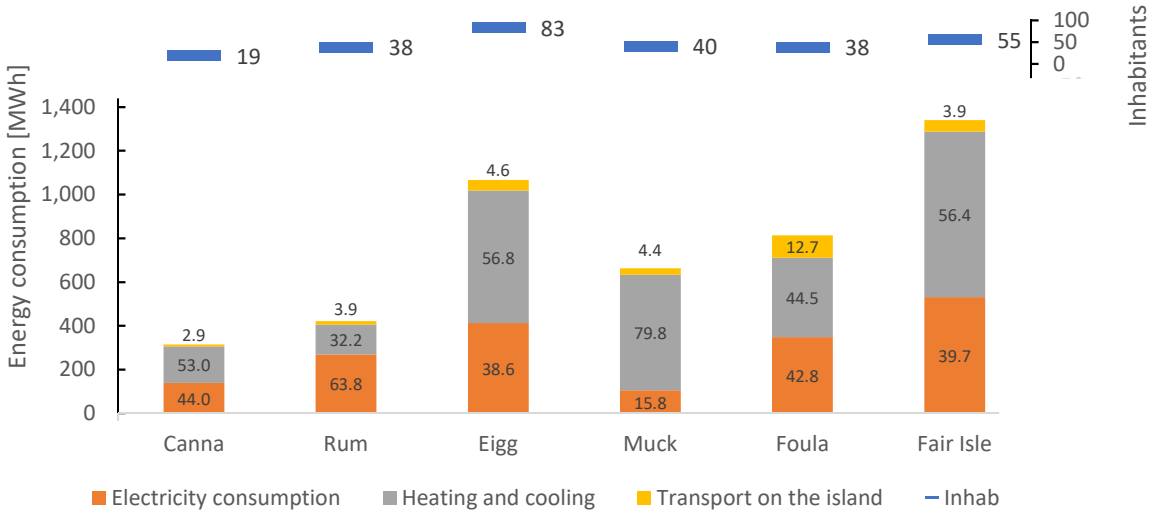

Figure 14 Energy consumption without transport to and from the island

When looking at the CO_2 emissions, it is clear that transport to and from the island has a significant impact on the results (see Figure 15). This is once again due to the ferry, MV Lochnevis, and its corresponding high usage of marine diesel.

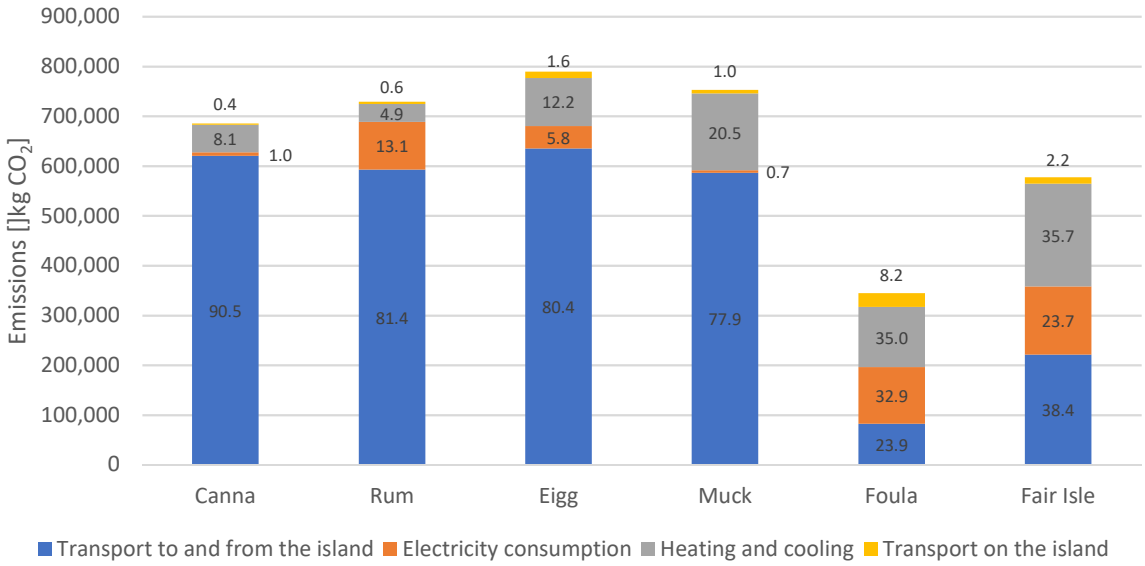

Figure 15 Total CO_2 emissions of all six Scottish Off-Grid Islands

When looking at the figures without transport to and from the island, another picture becomes clear. Now, Foula and Fair Isle clearly emit more CO_2 emissions in total, as indicated in Figure 16. However, one also must take into account the difference in population size per island.

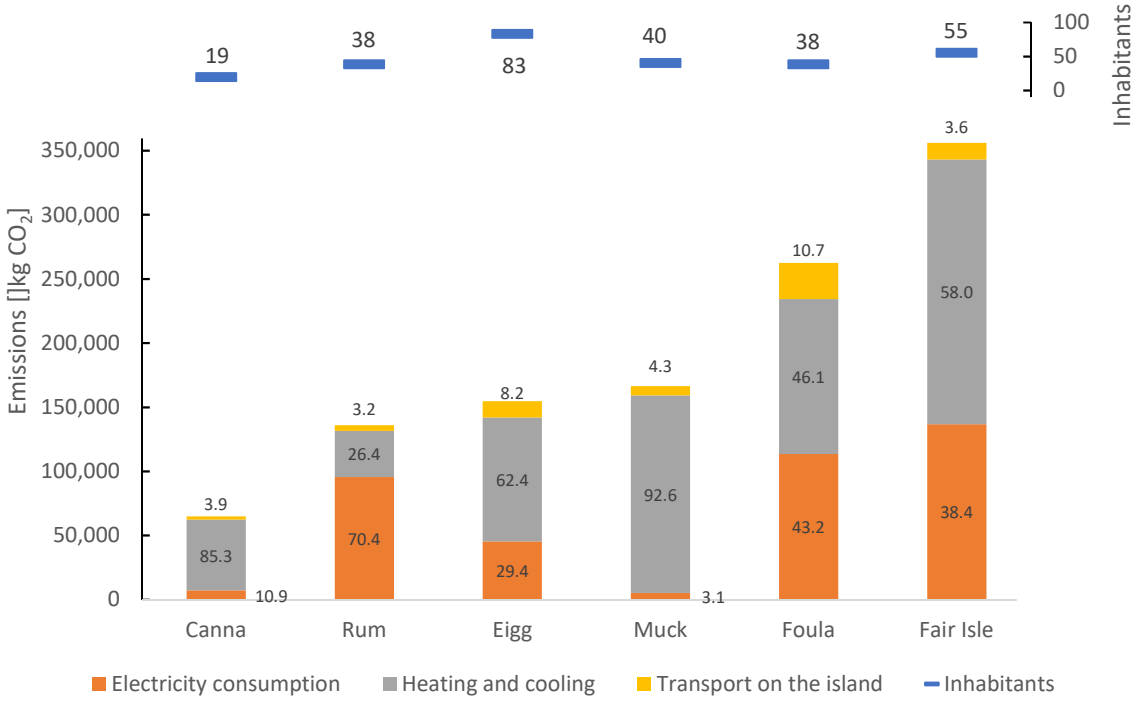

Figure 16 CO_2 emissions without transport to and from the island

The CO_2 emissions per inhabitant, excluding transport to and from the island, are still highest in Foula and Fair Isle (see Figure 17). However, the gap with the other islands has considerably diminished, compared to Figure 16. Eigg has the lowest emissions, because its electricity production is nearly fully renewable (see Figure 18), and its heating demand is largely met by this renewable electricity.

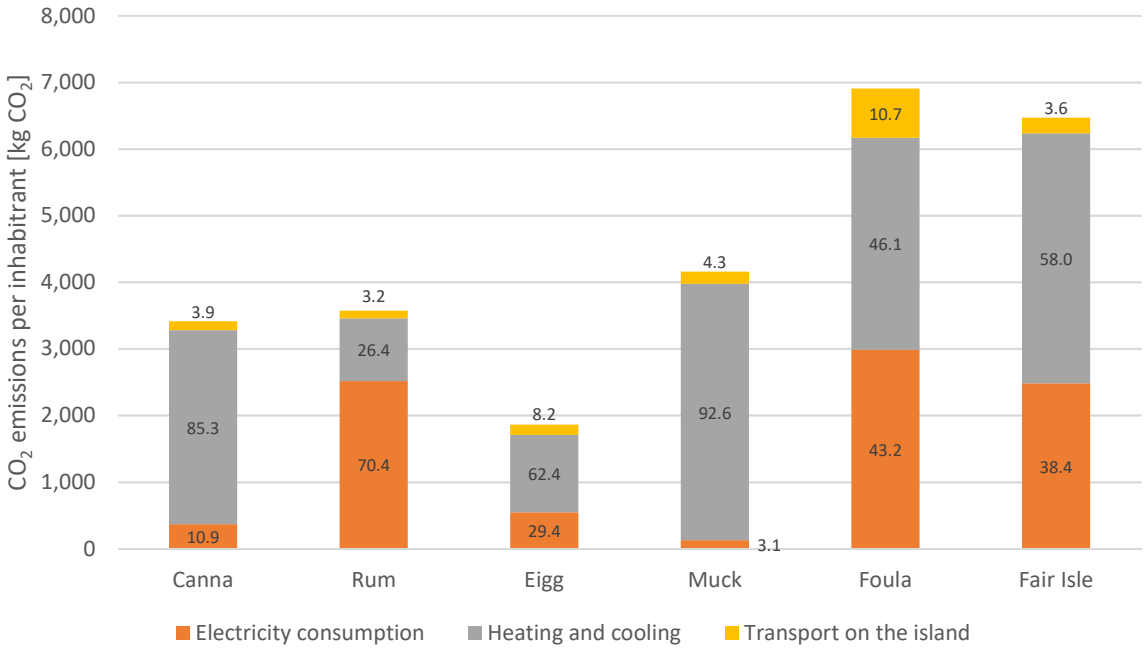

Figure 17 CO2 emissions per inhabitant, excluding transport to and from the island

Four of the six Off-Grid Scottish Islands meet their electricity needs almost completely with renewables. Rum and Foula still use diesel generators for about half of their generation. Fair Isle is a special case in the sense that its electricity is almost completely renewable for its own use, but a significant amount of diesel is used for the BT services.

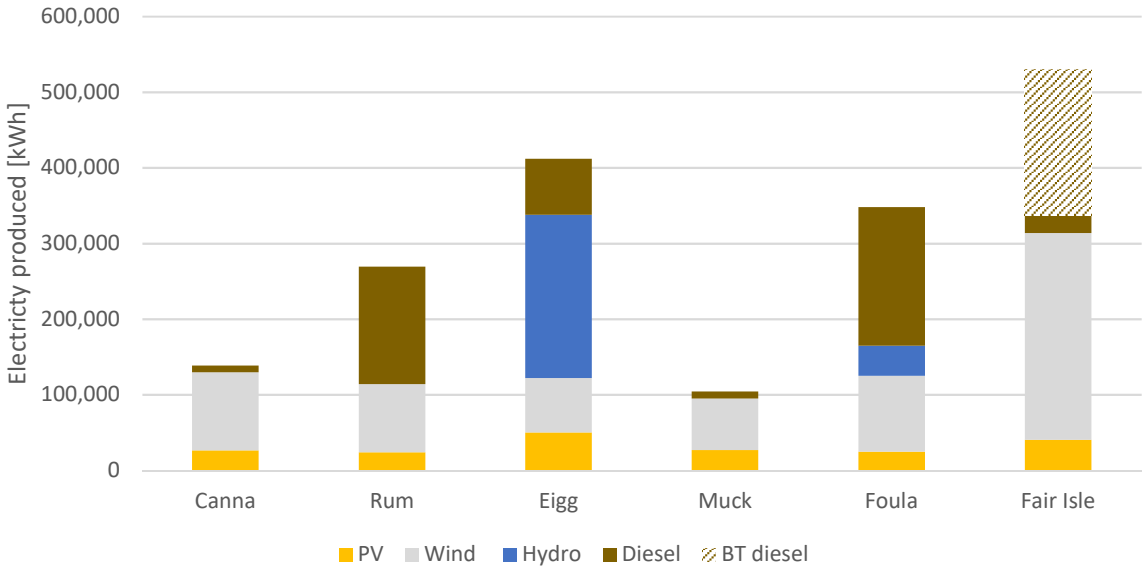

Figure 18 Electricity production on the Off-Grid Scottish Islands

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