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Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands

D 1.1 – Islands documentation and mapping reports

Lead partner: Energy Innovation

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Executive summary

Deliverable 1.1 of the ROBINSON project corresponds to Task 1.1 that is entitled "Baseline definition for all three islands." The objective here is to map the current situation at the demonstration island, Eigerøy, in Norway, and on the follower islands, Crete in Greece, and the Western Isles in Scotland. The outcome will be used as a baseline for all other technical work packages and tasks.

The report presents the following topics:

- Mapping of already installed infrastructure on the local energy system's production, distribution, and demand side.
- Mapping of the topography in terms of dimensions, accessible area, and potential constraints resulting from local regulations.
- Mapping of demand-side energy consumption including the currently available information and its energy consumption profile.
- Identification of the stakeholders, as well as their needs and interests.

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List of abbreviations

AC	Active current
CHP	Combined heat and power
EMS	Energy management system
HVDC	High-voltage direct current
IPTO	Independent Power Transmission Operator
LNG	Liquefied natural gas
MITS	Modular integrated transportable substation
RES	Renewable energy sources
WP	Work package

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1. Introduction

The ROBINSON project "smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands" aims at developing an integrated energy system to help decarbonise (industrialised) islands. The project will develop and deploy an integrated, smart and cost-efficient energy system that couples thermal, electrical and gas networks; hence optimizing the utilization of local renewable energy sources (RES).

As part of this project, work package 1 has a main objective to define boundary conditions (PHASE 1 – DEFINITION OF THE BOUNDARY CONDITIONS). Deliverable 1.1 is corresponding to Task 1.1 that is entitled as "Baseline definition for all 3 islands". The goal here is to map the current situation at the demonstration island (i.e. Eigerøy in Norway), as well as on the follower islands (i.e. Crete in Greece and Western Isles in Scotland). The outcome will be used as a baseline for all other technical work packages and tasks.

In connection to Task 1.1, it is worth noting that a preliminary analysis of the available renewable energy sources and their need on the island of Eigerøy has already been performed within the frame of a Norwegian national project funded by ENOVA SF[1]. The demonstration island's main goal is to build on this experience and cover additional energy needs (electrical and thermal) by innovative integration of the locally available RES. This provides the islands with multiple advantages including avoiding expensive capacity extensions of the already existing connections to the mainland to cover the new and future needs. In addition, use of fossil fuels is replaced by RES, or through recovery of otherwise wasted energy.

This report is organized as such to provide the following information in the future chapters:

- Chapter 2 presents a general description of both the demonstration island as well as the follower islands.
- Chapter 3 reports mapping of already installed infrastructure on the local energy system's production, distribution, and demand side.
- Chapter 4 presents the topographic conditions of the demonstration island in terms of dimensions, accessible area, and potential constraints resulting from local regulations.
- Chapter 5 provides more detailed information on the demand-side energy consumption including the currently available information and its energy consumption profile.
- Chapter 6 presents an overview of the identified stakeholders, as well as their needs and interests.
- Chapter 7 summarizes the outcomes of Task 1.1 and their connections and future uses in other work packages and activities.

[1] ENOVA SF is a Norwegian state-owned enterprise that is responsible for promotion of environmentally friendly production and consumption of energy

2. Description of the islands

The following Table 1 presents a general description of Eigerøy as the demonstration island and the follower islands, i.e., Western Isles and Crete.

Table 1: Basic information on the islands

Name	**Eigerøy**	**Western Isles (or the Outer Hebrides)**	**Crete**
Country	Norway	Scotland	Greece
Location	South west coast of Norway 58°26’37,608”N 5°57’11,581”Ø	A chain of islands off the west coast of Scotland	Approximately 160 km south of the Greek mainland
Size	20 km^2	3,059 km^2	8,336 km^2
Population	About 2.500 within about 800 households	More than 26.000 within about 12.500 households	About 635.000 in about 214.150 households
Climate	Influenced by the coast with relatively high temperatures in winter and low temperatures in summer, wind speeds are high	The climate is mild and oceanic. High wind speed.	The climate is mainly Mediterranean

2.1. Eigerøy

In Eigerøy, - or in Norway in general, there are no thermal power plants located close to the island. Almost 100 % of the electricity is provided through cables from the main land, and this power is generated mainly from hydropower (89,2 %), with 8,6 % onshore wind power with and 2,2 % Thermal power[1]. There are some few photovoltaic (PV) panels installed on household rooftops on Eigerøy, however, - additionally about 28 000 m2 is identified as being available on rooftops of industrial buildings. When fully developed, this large area could contribute to energy production with currently estimated 5 200 MWh/year. Thermal energy in households is 78 % based on electricity, 16,7 % via wood, coal, and coke, and 5,3 % with liquid fossil fuel. In the industrial sector at Eigerøy is electricity used as well as fossil fuel. Detailed data for the energy split is missing as electricity for heating in industries is not separately measured. Fossil fuel-based were about 6 950 MWh liquid fuel used (based on available 2017 number), and about 26 500 MWh/year are based on LNG9.

One of the particularities of Eigerøy is that new industries are to be established on the island in the coming years, specifically around the harbor area of Kaupanes. The industry in the harbor handles about 30 % of the turnover of all industrial fish processing in Norway (according to data from 2019). The new industries will increase the island’s energy demand and require an upgrade of the existing energy system. One of the new industries is a fish food producer, in operation since January 2019. In

[1] Retrieved 2021-03-24: https://www.nve.no/energiforsyning/kraftproduksjon/

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addition to electrical power, their production process requires a large amount of high-temperature steam, which is currently supplied by an LNG fired boiler. The process also generates low-temperature waste heat, which other local industries could use for heating (planned to be investigated in ROBINSON). Such integration has the potential to convert their current fossil-based heating systems to fossil-free, and thus achieve 100 % decarbonization. To make this happen, different profiles of demand and availability of energy will be balanced via the ROBINSON Energy Management System (EMS).

Further - there are ongoing plans for building of two new fish factories (including big freezers) in near future at the Kaupanes area with an additional need of up to 8 - 16 MW power capacity.

Level of interconnection: The electrical connection to the mainland is currently based on sea cables with a maximum power transfer of **20 - 30 MW**. Measured data for the cable for half a year indicate an average load of 7,9 MWh/hour, while peak demand rises to 18,5 MWh/hour. Additional local electrification (e.g., transport on land and sea) and additional local businesses are expected to result in a significant increase in electricity consumption by about a factor of two. An example is represented by the contract of the Egersund shore power and the trawler Ocean Star. While de-loading fish and being several days at the kay, it consumes about 48.000 kWh of energy. Electricity from shore is planned to replace the diesel-generated power produced on the ship, when in harbor.

Seasonality: Seasonal impact in energy consumption on the island results from the use of the traditional cabins (used for recreation) during weekends and vacation and, even more important from the seasonal business of the fish de-loading and processing businesses.

Island size in terms of peak load demand: The current average electrical energy demand at the site amounts to about 7 MWh/hour with peaks of up to **18 MWh/hour**. New businesses and industries are expected to require additional 1,6 MWh/hour as an average electrical energy demand but with peaks of up to **12MWh/hour**. In addition, a thermal process energy of 26 500 MWh/year (process steam at 180^{o}C) is required as well as a heating energy demand of about 6 950 MWh/year based on 2017 figures.

2.2. Western Isles

Comhairle nan Eilean Siar (Western Isles Council) is the local authority for the Western Isles (or Outer Hebrides) of Scotland and delivers a wide range of statutory and non-statutory services for the benefits of residents and communities in the islands. The Outer Hebrides are a chain of islands off the west coast of Scotland with a population of around 26,000. Most of the population are situated in and around the main town of Stornoway on the Island of Lewis.

The Outer Hebrides is a Follower Island in the ROBINSON Project and Comhairle nan Eilean Siar will develop a Replication Plan for implementation of the energy management system (EMS) in the islands, specifically focussing on a site at Creed Waste Management Facility on the outskirts of Stornoway. Comhairle nan Eilean Siar has a commitment to fully realising the renewable energy potential in our islands, both for economic benefit and to support our journey to achieving net zero greenhouse gas emissions. Our interest is in assessing whether EMS such as the one proposed through ROBINSON can be adapted to our energy system to address decarbonisation needs and levels of energy poverty.

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The Outer Hebrides are home to abundant renewable energy resources, particularly wind, wave, and tidal energy. To date, exploitation of these resources has been restricted due to low levels of indigenous demand and a constrained capacity for the export of electricity off the island network via interconnectors to the mainland. The drivers for exploiting these resources, not least in an attempt to address the energy supply challenges that impact the local economy and quality of life on the Western Isles, has gained significant traction among the island community.

Different energy challenges of Western Isles include:

- Exorbitant energy costs and associated high levels of fuel poverty: The Western Isles are reliant on imported liquid and gaseous fuels and pay high prices due to their position at the end of the supply chain.
- Extreme weather conditions and energy efficiency issues: The Western Isles experience extreme weather conditions particularly during the winter months. Coupled with poor energy efficiency standards in the private housing stock, these factors drive up the levels of consumption and therefore the total cost of energy.
- Exposure to supply interruptions: The Western Isles experience a higher frequency of grid supply interruptions than mainland areas, and poor weather conditions interrupt fuel imports.
- High energy consumption and emissions per capita: High use of liquid and solid fuels and inefficient appliances can result in high energy use and emissions on a per capita basis.
- Reducing carbon emissions: The Comhairle has published a new Corporate Strategy (2020), where we aim for the islands to achieve Net Zero by 2035.

2.3. Crete

Crete is the biggest island in Greece and the fifth in size in the Mediterranean basin, with regard to both its area (8.336 km^2) and population (634.930 inhabitants). Crete is located between the geographical longitudes from 23° 30΄E to 26° 22΄ E and latitudes from 34° 53΄ N to 35° 42΄ N. The Crete's length from the eastern to the western coast is approximately 260 km, while its width from the northern to the southern coast ranges from 12 km to 60 km. The island's coastline has a total length of approximately 1.000 km. Regarding the Cretan economy, tourism, commerce and agriculture correspond to the 46% of the overall economic activity in the island. The most emissive activities in the island with regard to the greenhouse gases are the electricity production, which is heavily based on imported fossil fuels, the transportations on the island and from and to the island.

Energy consumption in the island is distinguished in the following basic final uses:

- heating and cooling of indoor space, covered with diesel oil, biomass and electricity
- hot water production, covered with solar collectors and electricity
- transportations on the island, based on imported fossil fuels (gasoline, diesel oil and LPG)
- transportations from and to the island, based also on imported fossil fuels (heavy fuel, diesel oil and kerosene).

Electricity production in Crete is based on three thermal power plants, equipped with steam turbines, diesel generators, gas turbines and a combined cycle. The power production system is integrated with wind parks, photovoltaic stations installed either in the countryside or on the buildings roofs, and a small hydro power plant. The total installed electrical power in Crete per different technology and the

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corresponding annual electricity productions in 2019 are summarized in Table 2. The annual CO_2 emissions from the thermal generators are also presented in this table. According to Table 2, the annual RES contribution on the electricity demand coverage was 21% in 2019. The steam turbines and the diesel generators consume heavy fuel, while the combined cycle and the gas turbines consume diesel oil.

Table 2: Analysis of the electrical system and the annual electricity production in Crete in 2019.

Units	Installed power (MW)	Annual electricity production		CO_2 emission (tn)
		(MWh)	(%)	
Steam turbines	204.3	936 645	30.5	2 686 392
Diesel generators	185.9	785 273	25.6	2 252 243
Gas turbines	320.8	204 490	6.7	586 497
Combined cycle	132.3	498 542	16.2	1 429 867
Hydro plant	0.6	737	0.0	0
Photovoltaics	107.4	135 964	4.4	0
Wind parks	200.3	510 275	16.6	0
Totals	**1 151.6**	**3 071 926**	**100.0**	**6 955 000**

From the above analysis it is derived that electricity production in Crete is based on the use of imported heavy fuel and diesel oil, and the exploitation of the available wind energy and solar radiation.

Currently there are three plans for the interconnection of Crete with the mainland grid. The two of them are planned by the Independent Power Transmission Operator (IPTO), the Greek mainland grid operator. The third one, the so-called "Euroasia Interconnector", is an international project between Greece, Cyprus and Israel, with their national grid utilities involved. The fundamental technical characteristics of these three interconnections are summarised in Table 3.

Table 3: Technical characteristics of the planned electrical interconnections of Crete with the mainland grids

Interconnection	IPTO 1	IPTO 2	Euroasia Interconnector
Route	Molaoi Cape, Lakonia, Southeastern Peloponnese – Kissamos Chania, Western Crete	Lavrio, Southern Attica Cape – Korakia, Heraklion, Central Crete	Crete - Cyprus – Israel
Nominal Voltage	150 kV AC	400 kV DC	500 kV DC
Nominal capacity	2 x 200 MW	1 000 MW	2 000 MW
Length	134 km	330 km	Israel-Cyprus: 310 km; Cyprus-Crete: 898 km Total: 1,208 km
Maximum depth	950 m	1 200 m	3 000 m

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Different energy challenges of Crete include:

- High dependency on the imported fossil fuels for different purposes: Crete is particularly depended on heavy fuel and diesel oil for electricity production and thermal energy production for residential, commercial, and industrial sectors.

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3. Installed infrastructure

This chapters presents the collected information on the already installed energy infrastructure including those for power production and distribution. It covers specifically technical characteristics and interfaces within the currently available energy system.

3.1. Eigerøy

Electrical energy on Eigerøy is currently generated on a very low and local level. There are only six residential buildings equipped with solar PV panels. While most of the generated power locally is used within the corresponding buildings, only a very small share is fed into the grid. Some cabins, which are used during vacation or at weekends are also equipped with solar panels. However, they are not considered within the ROBINSON project, as they are due to their remote location not connected to the grid. One main reason for the low number of installed PV panels is due to the relatively low electricity costs in Norway and feed-in tariffs, which are matching the electricity market price (Nordpool[1]).

The island itself is connected to the mainland via a sea cable with a peak capacity of 20 MWh. The map below Figure 1 indicates the connections and gives an impression on the transmitted electricity. The transmission lines are operated at 50 kV. One transformer station represents the connection to the distribution grid, which is operated at 15 kV.

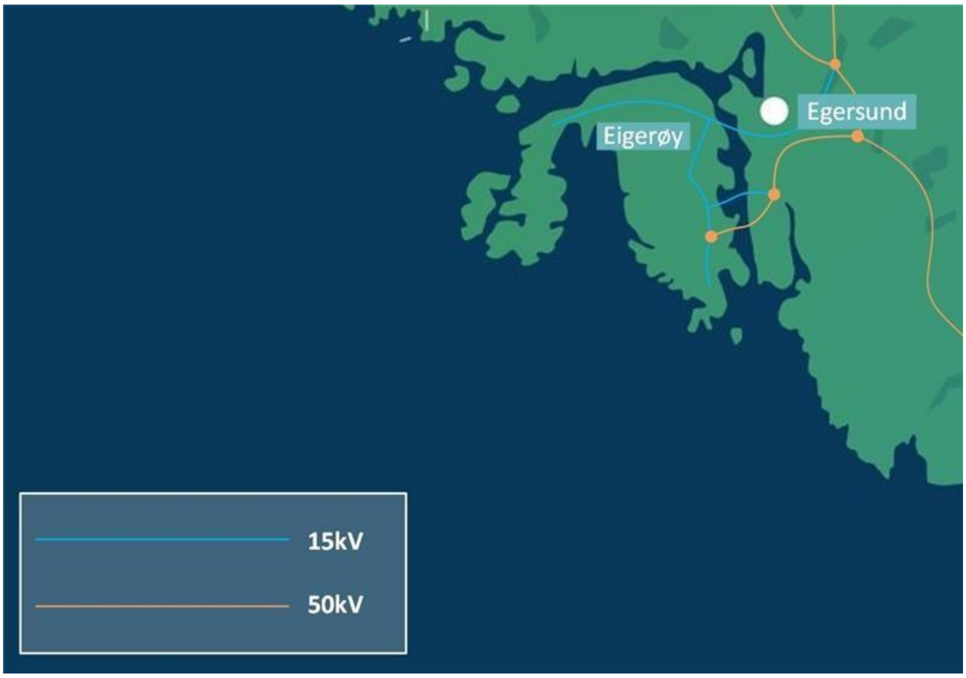

Figure 1: An overview of the transmission lines and electricity network in Eigerøy

In 2020, about 88 % of the electricity was consumed by local industry, mainly by appliances on the 400 V level. One industry converting fish waste into protein consumes considerable amounts of liquified natural gas (LNG) as an energy source to produce process steam.

[1] https://www.nordpoolgroup.com/Market-data1/#/nordic/chart

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3.2. Western Isles

The Western Isles is home to a rich resource of renewable energy. The exploitation of these resources to date has been limited relative to their absolute potential. Island wide domestic and non-domestic renewable energy schemes currently generate approximately 74 GWh through exploitation of these resources. However, installation of a proposed HVSC subsea interconnector would unlock delivery of a substantial capacity of recently consented wind farms and change this picture.

At present, electricity is supplied to the Western Isles by active current (AC) cable from a modular integrated transportable substation (MITS) substation at Fort Augustus. The cable runs through Skye to Ardmore where it divides into two subsea cables – one running to Stockinish in Harris and on to Stornoway and the other running to Lochcarnan in South Uist. Effectively, the islands receive two independent electricity supplies – one to Lewis and Harris (the North Island Group) and one to North Uist, Benbecula, South Uist and Barra (the South Island Group).

Peak electricity demand across the Western Isles is about 30 MW but the existing AC electricity supply is constrained to 22 MW in its subsea sections. Top-up generation in times of peak demand is supplied by on-island diesel generation at Stornoway and Lochcarnan (Uist).

34.3 MW of renewable generation is already connected to the Western Isles Distribution network, much of it on non-firm connection. This 30-year-old AC link, rated at 22 MW in its subsea section, was built to supply distribution electricity to the Western Isles and was never designed to accommodate exported generation.

Once the new high-voltage direct current (HVDC) link is in place, electricity supply for Lewis and Harris will come through the new HVDC link. All the 34.3 MW of heavily constrained generation currently connected to the AC link will be transferred to the new transmission link.

The Western Isles electricity supply suffers frequent interruptions due to poor weather conditions and spikes in demand. The supply exhibits a seasonal variation pattern as supply declines during the summer months and rises during the heating season. This is a result of variation in the lighting load and may also suggest there is a large presence of electric heating systems on the Western Isles.

The back-up power supply of the Western Isles is responsible for supplying approximately 5 GWh of electricity per annum. The demand for back-up power is concentrated, except for the month of July, during the four months between November to February. This may be caused from impact of poor weather conditions combined with the widespread use of electric heating systems.

3.3. Crete

Crete is heavily based on imported fossil fuels to cover its energy consumption. Particularly regarding electricity, Crete is depended on 78 % on heavy fuel and diesel oil, consumed in three centralised thermal power plants, located at the western, central, and eastern part of the island. The power production system is integrated with 200 MW of wind parks and 90 MW of photovoltaic stations, which contribute 22 % to the annual electricity demand coverage. A small hydro power plant of 600 kW nominal power is also available, despite it was constructed at the beginning of the previous century.

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Thermal energy production for domestic, commercial, and industrial use is based on diesel oil, electricity, solar radiation, LPG and a small contribution of biomass. Diesel oil is traditionally the main fuel for domestic indoor space heating. Electricity is mainly used in commercial buildings, for indoor space heating, and in industry for special uses. Solar radiation is exploited with many solar collectors' installation in residential buildings and in tourist facilities, mainly for hot water production. It is roughly estimated than more than 60 % of the residential buildings in Crete has at least one or two solar collectors installed on their roofs for hot water production. LPG is exclusively consumed in tourist facilities for cooling. Finally, small amounts of biomass, despite the huge available potential coming from agriculture and stock farming, is used in the form of solid biomass (woods or pellets) in traditional or hydraulic fireplaces and central heating burners, for indoor space heating in residential buildings.

Transportations on the island are totally based on diesel oil, gasoline, and LPG. Currently there are no infrastructures for the transition to e-mobility and, consequently, no e-vehicles on the island.

The interconnection of Crete with the mainland grid is already under construction by the Independent Power Transmission Operator (IPTO), which is the mainland grid's Operator in Greece. The first 150 kV AC cable, with nominal capacity of 400 MW will be completed during 2021 (IPTO 1). The installation of the second 400 kV DC cable, with a nominal capacity of 1 GW will also start in the forthcoming couple of years (IPTO 2). The routes of the two interconnections are shown in Figure 2.

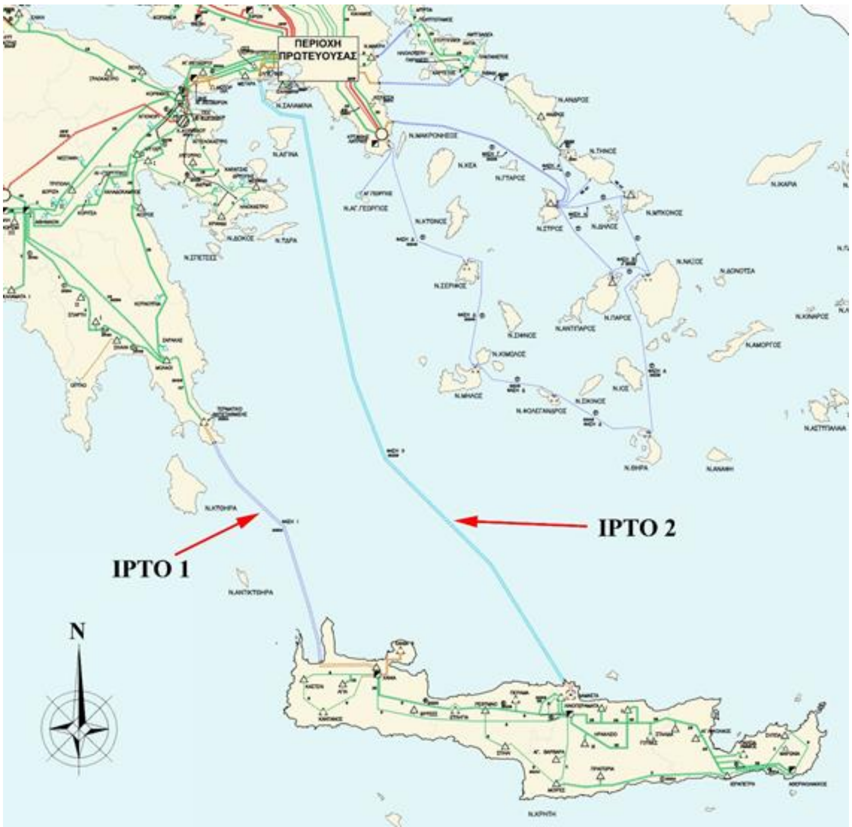

Figure 2: Power cable connections (under construction) to Crete

Currently, there are no other energy networks apart from the electrical grid, such as natural gas networks or decentralized CHP plants are installed in Crete.

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4. Topographic conditions

The topography in terms of dimensions, accessible area and potential constraints resulting from EHS regulations for the three different locations is summarized. Restriction on positioning of local power production, power to gas technology and energy storage units are considered (=> information to be provided to WP2 and WP3).

4.1. Eigerøy

As the largest share of energy on Eigerøy is consumed by industry located in the area of Kaupanes on the east coast of the island. It has long kai-lines and the regulation as an industrial area makes it an

Figure 3.The industrial area Kaupanes on Eigerøy and the location of Prima Protein

Figure 4:Locations of Prima Protein, waste wood storage and wind turbine relative to each other

ideal case for locating components for local power generation. The industrial area is indicated in Figure 3. Also indicated is the location of the project partner Prima Protein. As Prima Protein is the main consumer of LNG on the island, all equipment and components contributing to replace LNG will be located preferably on the site or close to the site of the factory. This ensures short connections for gas and heat transport pipes as well as transport related losses. Furthermore, the placement of equipment in the industrial area reduces potential hurdles which might result from applying for permits to place such equipment close to residential areas. The location of waste wood storage and the possible place for the wind turbine relative to Prima Protein is indicated in Figure 4. The first idea of placing the wind turbine on the area of Prima Protein was found as being a bad choice due to the expected influence of buildings on the local wind condition. Instead was an elevated place selected which still is not too distant from Prima Protein. The location of the other equipment, the AD-BES unit, the gasification, electrolyser and gas turbine CHP on the area of Prima

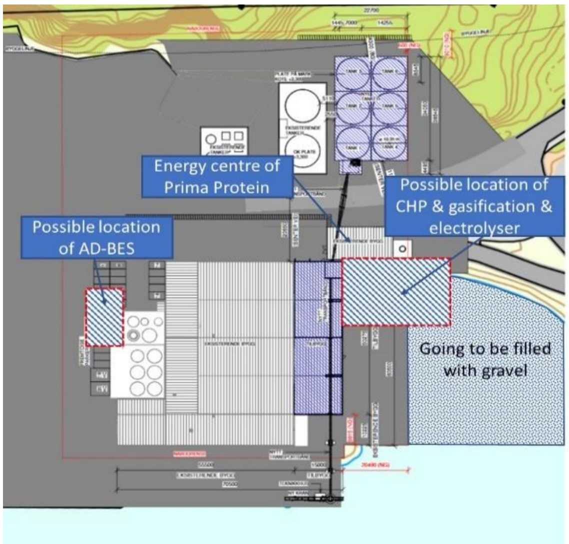

Figure 5: Location of equipment on the Prima Protein premises

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Protein is shown in Figure 5. The location of components is selected according well-suited place and short distances to other components with which it needs to be connected.

4.2. Western Isles

The area under consideration for the implementation of the replication study in the Western Isles is Creed Waste Management Facility. The facility is located on the outskirts of Stornoway, the main port of entry and administrative centre for the Western Isles.

Figure 6: Creed Waste Management Facility

It is classified in the Outer Hebrides Local Development Plan as an 'Outwith Settlement' area: "*These areas act as a separation between settlements which helps to retain distinctiveness. They have some local and strategic resource functions, supporting a diverse range of development activities and largely non-residential uses, which include agriculture, recreation activities, mineral extraction, energy development and storage/waste depots. Generally these areas have dispersed development in a more open landscape, encompassing various landscape character types with machair, moorland and some upland. Development proposals are likely to be mainly resource or tourism based. There may be capacity for a limited amount of development where siting and design are critical to mitigate impacts on landscape. 'Outwith Settlement' is not mapped but is defined as the area between settlement boundaries and mapped Remote Areas." (Outer Hebrides Local Development Plan, November 2018)*

The following aerial images and maps show the Waste Management Site, the site in relation to the Town of Stornoway, and the positioning of Stornoway in relation to the rest of the Outer Hebrides and Scotland.

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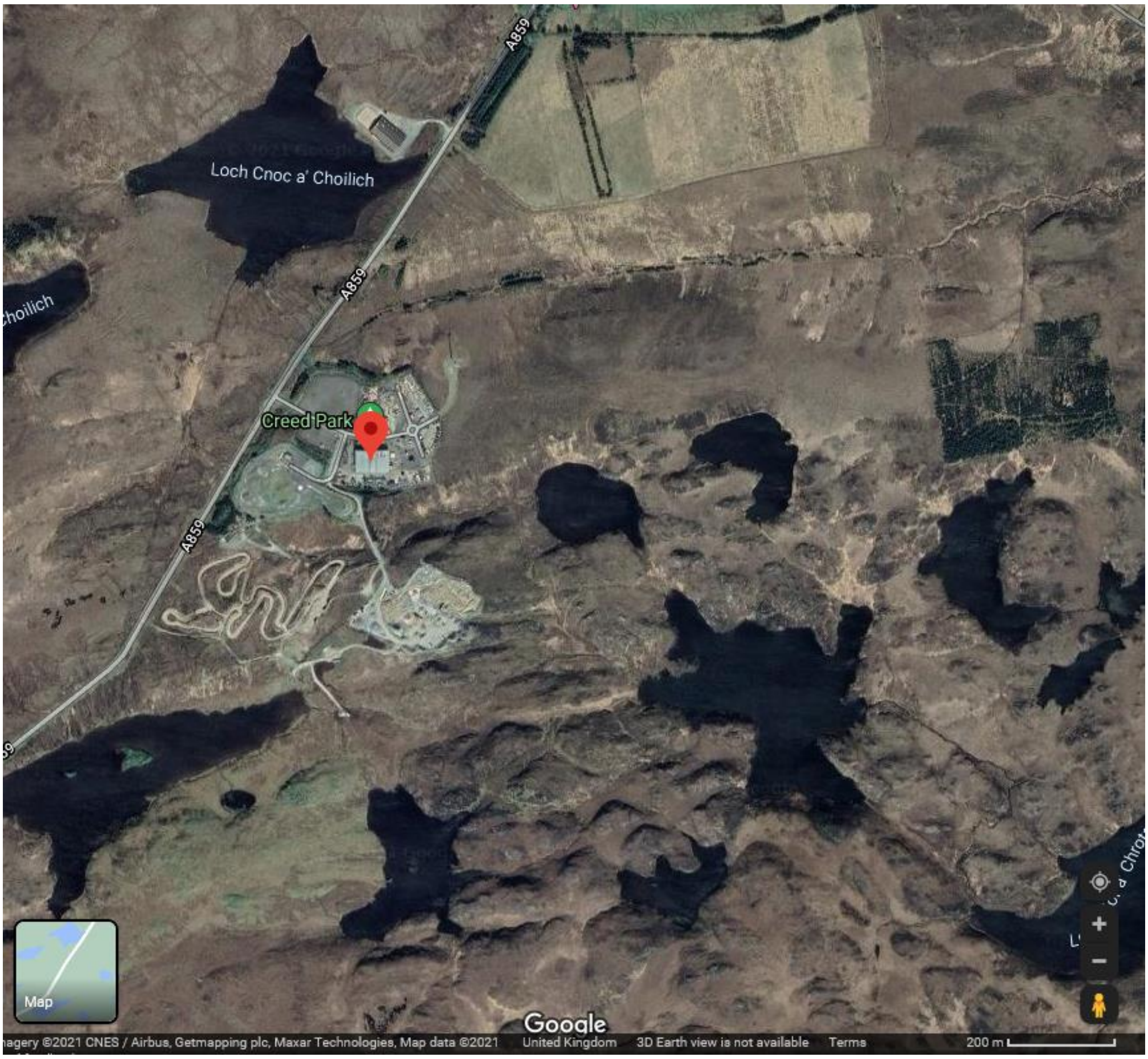

Figure 7: Creed Waste Management Site

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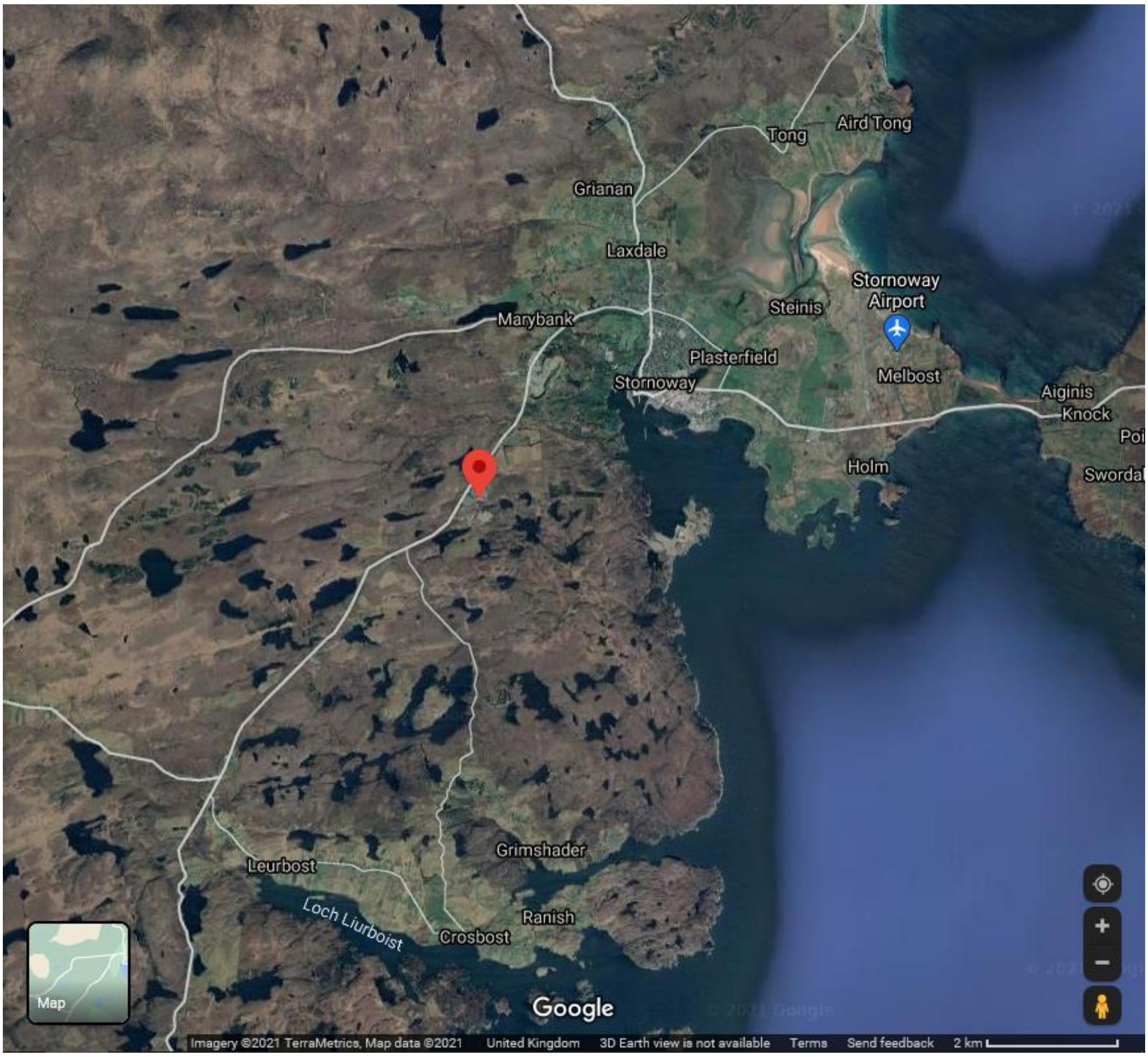

Figure 8: Creed Waste Management Facility in relation to the town of Stornoway

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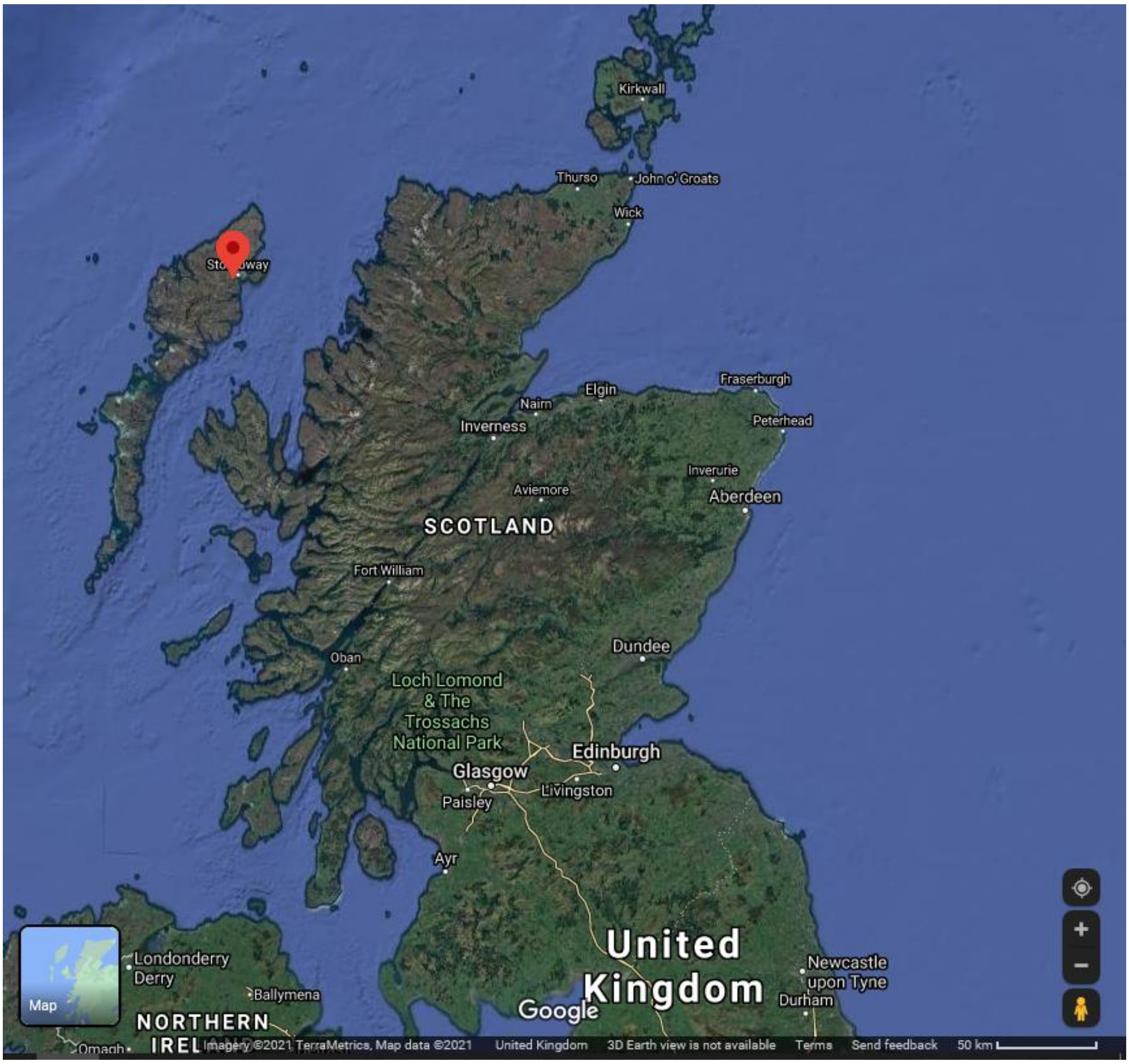

Figure 9: Location of the Western Isles relative to Scotland

Overview of the current installation at the Creed Park in the Western Isles is detailed in Figure 10 below.

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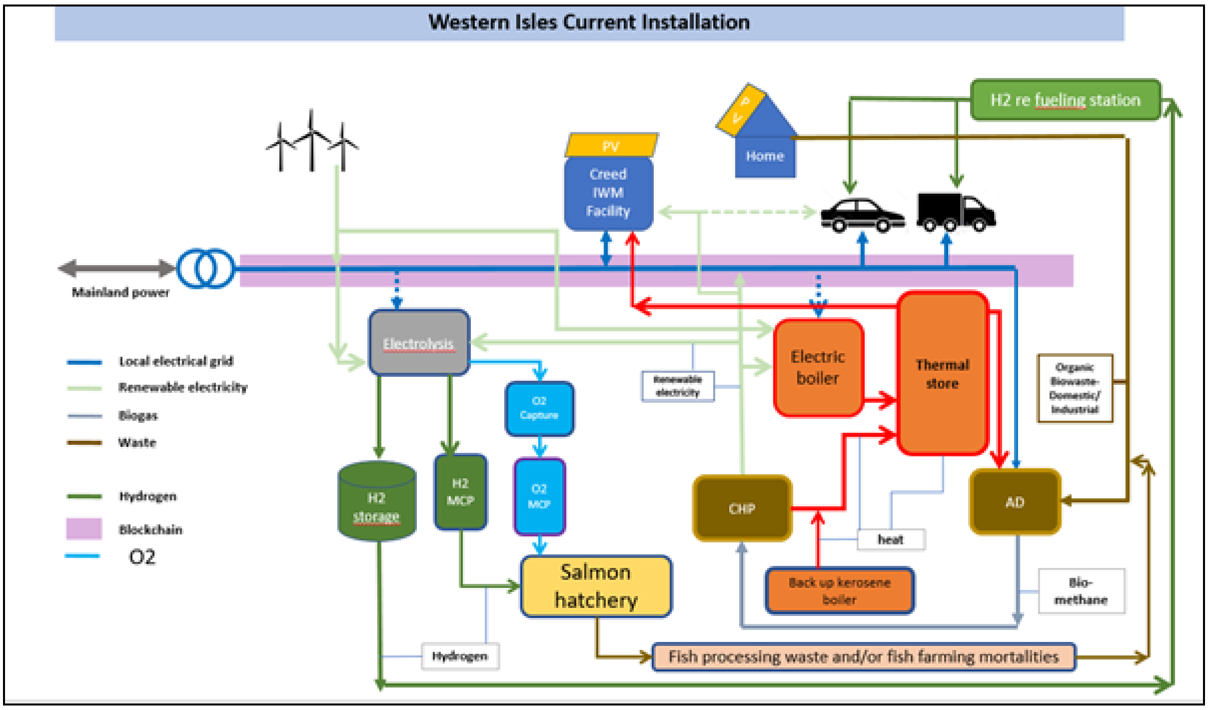

Figure 10: Schematics of the current installation at Creed Park

The facility has already been the site of the innovative Outer Hebrides Local Energy Hub (OHLEH) – an award-winning circular economy project which shows the scope offered by renewable energy technologies to bring about tangible business benefits around energy use and waste reduction.

The project incorporates two sites on the Isle of Lewis – the Creed Integrated Waste Management Facility (IWMF) just outside Stornoway, owned and operated by Comhairle nan Eilean Siar (the Local Authority for the Western Isles) and a salmon hatchery at Barvas, operated by The Scottish Salmon Company.

OHLEH integrates Scottish Salmon's fish waste with household and garden waste in an anaerobic digester at the Creed IWMF. The Biogas produced is used to fuel the on-site Combined Heat and Power (CHP) plant. The heat is used for the buildings at the Creed site, and electricity generated by an on-site wind turbine and by the CHP is used to produce hydrogen and oxygen.

Hydrogen is being used to fuel a dual-fuel refuse collection vehicle which, in turn, collects household and garden waste for the anaerobic digester. This hydrogen will also be used to power a hydrogen fuel cell at the salmon hatchery to provide power for lighting and feeding units for outdoor cages. Oxygen will be delivered to the hatchery to be used for oxygenation of the fish.

The project aims to address challenges faced by many island and rural locations – weak electricity grid, underutilised bio-waste resources, high on-island oxygen prices and an unreliable energy supply. Solutions provided by OHLEH include the diversion of fish waste from landfill, the integration of fish waste with domestic waste (which is believed to be a first), the production of hydrogen for power and transport, and the production of oxygen at lower-than-market price.

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4.3. Crete

The area under consideration for the implementation of the replication study in Crete is depicted in **Error! Reference source not found.**. It is found in the western part of the island, at the Prefecture of Chania, and it is focused on the production of biogas from the exploitation of the agricultural residues coming mainly from the greenhouse tomatoes crops located at the western coastline of the island, as shown in this figure. In total 800,000 m2 of tomatoes crops are found in the specific location. In the most favourable case regarding the agricultural production, 1 tn of tomatoes residues are produced for every 1,000 m2 of crops, while during years with extensive crops' diseases, the tomatoes residues can reach 4-5 tn for every 1,000 m2 of cultivated land. An average biogas specific production from tomatoes residues is given at the range of 150 – 240 L/kg of volatile solids in the relevant literature, revealing the huge potential for biogas production in the area.

Figure 11: Possible area of installation on Crete

The biogas produced from the tomatoes residues can be consumed in CHP plants for power and heating production to serve the needs of several nearby facilities, also depicted in Figure 11 Indicatively, in the nearby village of Platanos a bakery factory and an olive oil mill are found, with considerable electricity and heating needs.

In the coastal settlement of Kissamos, at the north coastline of the islands, a significant number of tourist facilities are found, mainly hotels of small sile (50 – 60 beds each) and seasonal operation, exhibiting also significant needs for both electricity and heating (mainly for hot water production). At the same settlement and oil processing unit is also found. The Kissamos settlement itself has a permanent population of 4,236 inhabitants, imposing significant residential electricity and heating needs too. Finally, close to the settlement Perivolakia, a cheese factory and a winery are found, which can be also considered as potential final users of the produced heat and power.

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5. Energy consumption

Mapping of demand side energy consumption in detail and beyond the currently available information and its profile, specific focus will be on the measured energy demand for process heat and heating (in this case fish food production industry), as this was based on estimation only (earlier project). The required energy demand level and profile will serve as input to all further steps for designing and optimising the ROBINSON concept.

5.1. Eigerøy

The analysis of the energy consumption on Eigerøy is based on data for 2020, thus updating information used for the proposal. On the right side visualizes Figure 12 consumed electricity on Eigerøy as well as the share of it consumed by local industry. The decreasing share in December as well as during July and March and April is resulting from vacation periods mainly. The other impact results from the seasonal variation of some of the industries on Eigerøy, mainly fish industry and the availability of caught fish. The electrical energy mix imported via cable connection to the mainland is predominantly based on hydro power. Figure 13 below shows the typical energy mix in Norway. Coal has a specific role, as it’s use is restricted to Spitzbergen only which has no landline connection to the Norwegian mainland, but it usually appears in the breakdown of energy. The electricity mix at Eigerøy is therefore mainly based on hydro power with a growing share of wind-based electricity as there has been a considerable growth especially in the region. Actually - most of the power supporting Eigerøy when it is blowing will come from local wind farms on the main land.

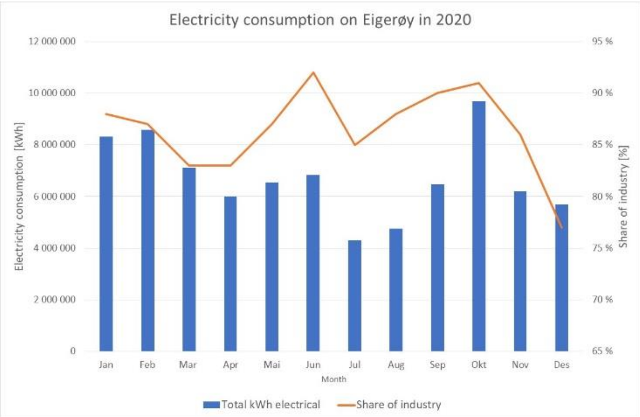

Figure 12: Electricity consumption on Eigerøy in 2020

An additional energy consumption is based on biomass. Biomass is solely used in residential houses for heating purposes. Logs are burned in wood ovens during winter. A statistic does not exist, but an estimation based on sample interviews indicates that it is mainly used during the period ranging from October to March. The consumption was estimated to be about 1,044 kWh thus being very small compared to energy based on other sources.

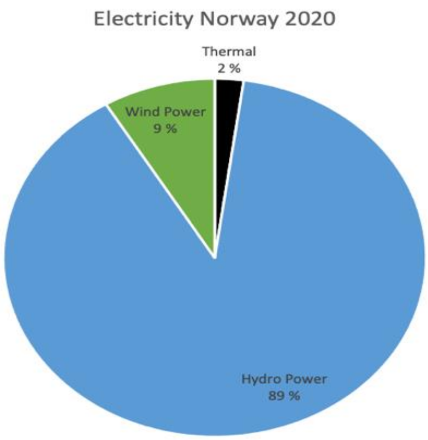

Figure 13: Energy mix in the Norwegian electricity grid

The seasonal variation of energy consumption of Prima Protein is visualized in Figure 14. The variation is a result of the availability of raw material for the process. While at most industries on Eigerøy electricity is the dominating energy input to cover thermal demand also uses Prima Protein LNG as an energy source to cover the demand of steam in their process. The thermal energy demand is by far the comminating one at that consumer (Figure 16).

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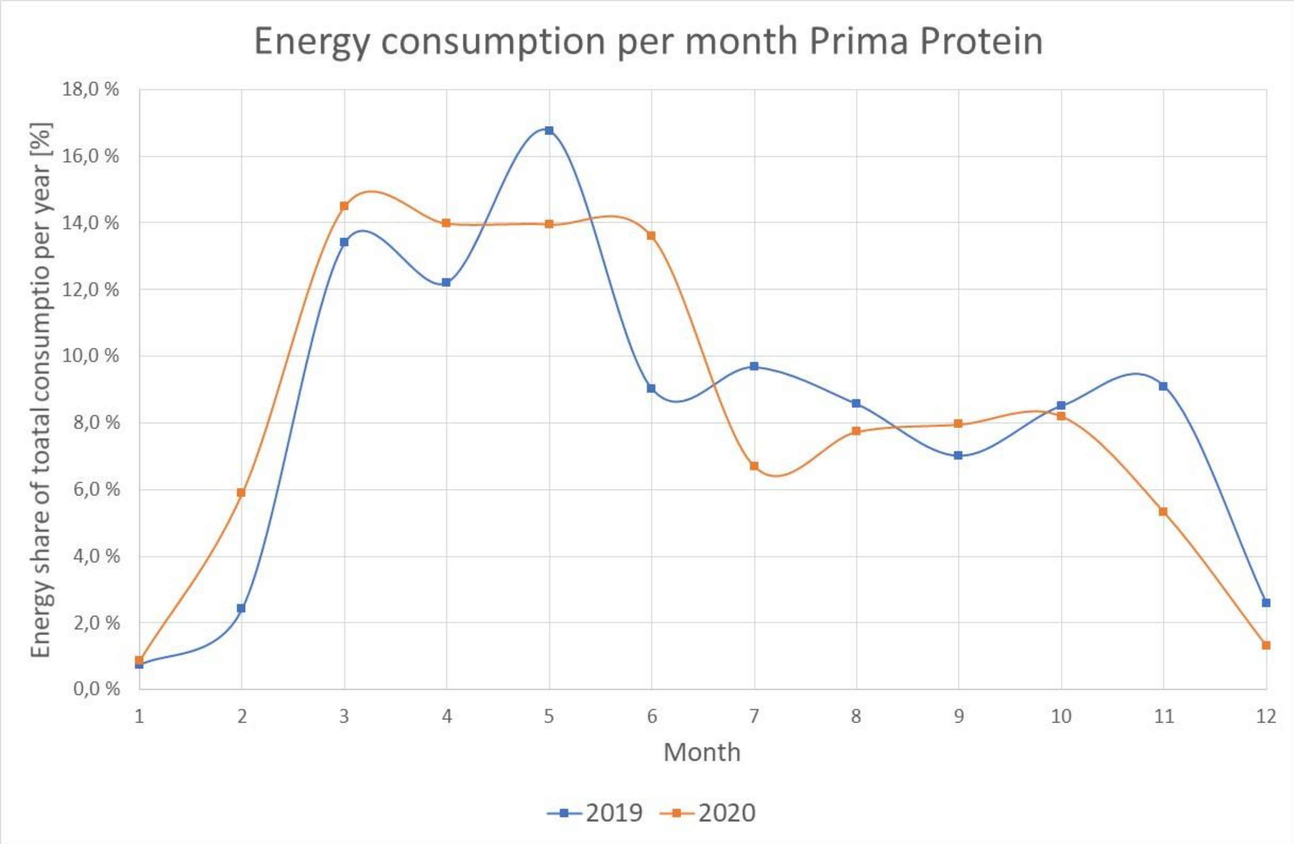

Figure 14: Variation of the monthly energy consumption of Prima Protein in % of the consumption per year

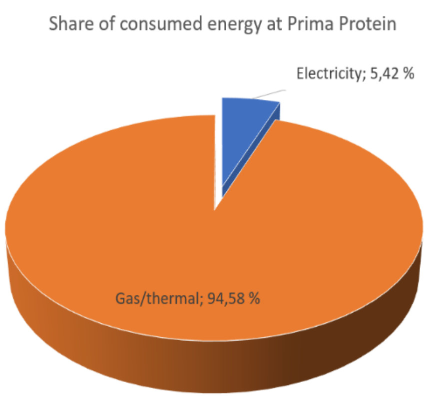

Figure 16: Energy demand split at Prima

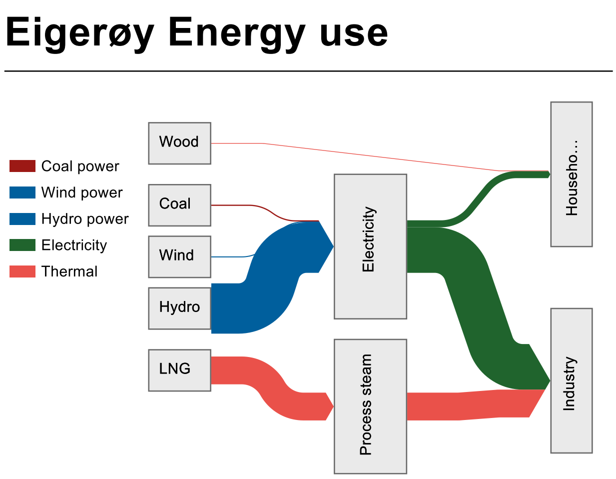

Figure 15: Sankey diagram of energy fluxes on Eigerøy

An overview over the energy fluxes on Eigerøy by 2020 is shown in Figure 15.

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5.2. Western Isles

Data has been extracted from the 'Western Isles Energy Audit', Element Energy (2014) and Total final energy consumption at regional and local authority level (2018).

Fossil fuels account for **75%** of the total energy consumed in 2013. Liquid fuel sources make up a significant proportion of energy supplied. The largest fuel source in energy terms is gas oil, which accounted for **25%** of the total supply in 2013. The total non-electric fuel supply to the Western Isles in 2013 was **583 GWh**.

Fossil fuels account for **74.1%** of the total energy consumed in 2018. Liquid petroleum fuel sources make up a significant **63.4%** proportion of energy supplied. The total non-electric fuel supply to the Western Isles in 2018 was **512.2 GWh**.

Other than a small gas network serving approximately 1,500 households in the Stornoway area, there is no access to natural gas. This is reflected in the above, with households heavily dependent on oil and electricity for heat.

The domestic sector is the largest consumer in energy terms at 43% in 2018 and residents on the Western Isles consume **25%** more energy per capita compared to the mainland.
The per capita carbon dioxide emissions of inhabitants on the Westerns Isles are 3% higher than those on the mainland.

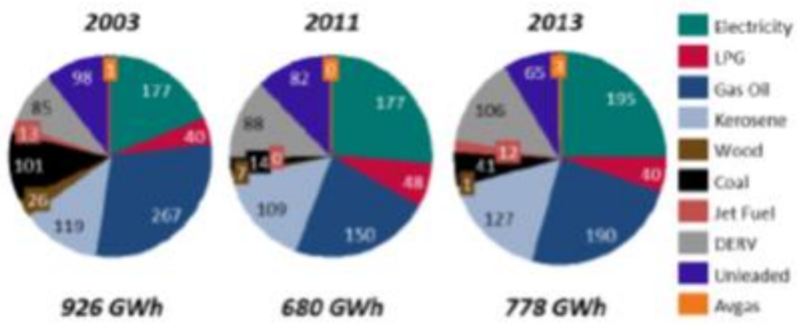

Figure 17:The primary fuel mix of the Western Iles as reported in 2013 and two earlier energy audits

The back-up power stations are fuelled with gas oil (Figure 18). We estimate that annual consumption for power generation is approximately 20 GWh which would suggest an overall efficiency of 25%.

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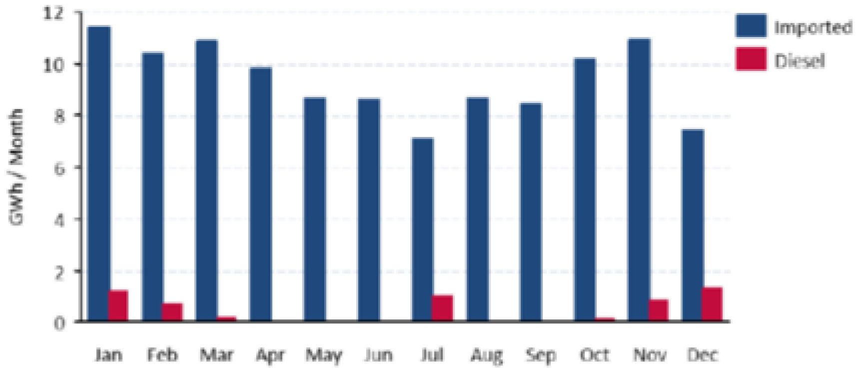

Figure 18: Monthly variation in imported electricity supply and generation from the Western Iles backup power stations (Diesel)

Presented in the figure below is an estimate of the load profile for the Western Isles electricity demand (based on information provided by SSE for both imported and locally generated electricity).

As expected demand for electricity increases during the late hours of the morning and peak demand is approximately at 4pm. Peak demand for electrical consumption is approximately 30MW on the peak day. The average daily peak demand during the winter and summer months are 24MW and 22MW respectively.

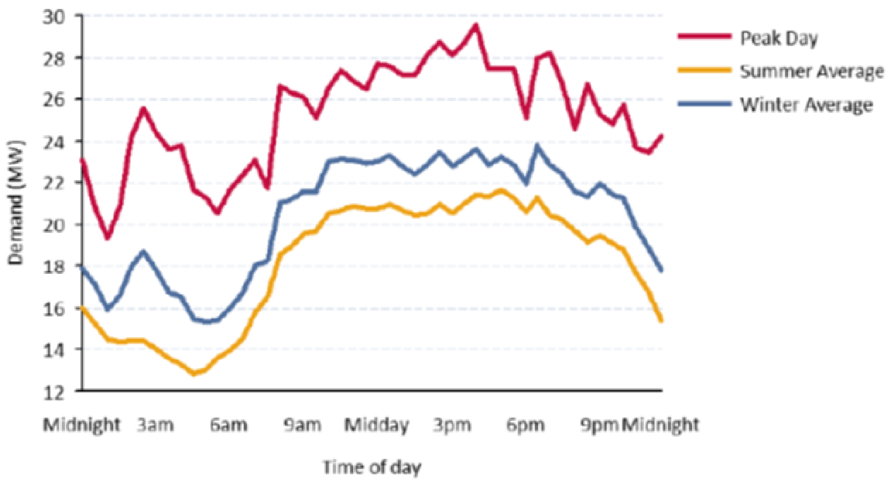

Figure 19: Energy consumption profiles for the Western lles.

There is a clear difference in how energy is consumed on the Western Isles compared to the rest of the UK. The domestic sector is the largest consumer of energy on the Western Isles, accounting for 37% of the total energy supply. The industrial and commercial sectors are comparable in percentage terms to the UK average, but transport consumption is considerably lower. The following sections of this report provide an analysis of each sector breaking down consumption by fuel type.

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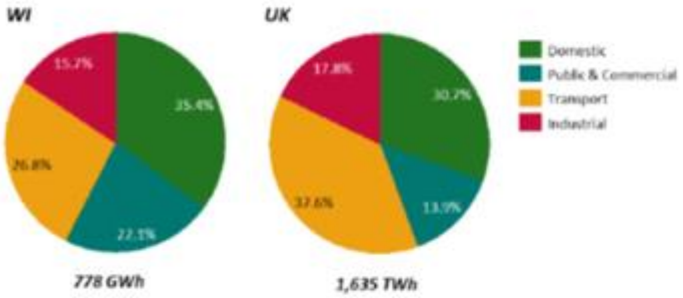

Figure 20:Split of energy consumption by sector for the Western Iles and for comparison in the UK

Presented in Table 4 below is a summary of each fuel source split by sector.

Table 4: The proportion of each fuel source supplied to Western Iles consumed by each sector

	Electric	LPG	Kerosene	Coal	Wood Peat	Gas Oil	Unleaded	DERV	JetA1	Avgas	Total
Domestic	94	32	107	42	1						275
Public and com.	42	8	20			64					134
Industrial	50	1				32					83
Transport - private							61	71			132
Transport - public						13		31	10	53	53
Transport – industrial						13	4	4		3	23
Power Generation						20					57
Agriculture	9					10					19
Total	195	41	127	42	1	189	65	106	10	3	778

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5.3. Crete

The annual final energy consumption in Crete is presented in Table 5. It is underlined that all energy amounts presented in Table 5 refer to final energy forms. All the final energy consumptions were found for the year 2019, apart from the liquid fossil fuels consumptions, which were available particularly for Crete for the years 2017 and 2018. In the same table, the corresponding annual CO_2 emissions are also presented.

Table 5: Final energy consumption analysis in Crete in 2019.

Energy consumption sector	Final energy consumption (MWh)	Percentage share (%)	CO2 emissions (tn)
Electricity consumption			
Public buildings	237 519	7,7	537 754
Residential buildings	1 064 217	34,6	2 409 441
Primary sector	199 400	6,5	451 453
Industry	220 757	7,2	499 805
Tertiary sector	1 295 020	42,2	2 931 991
Public lighting	55 015	1,8	124 556
Total	**3 071 926**	**100,0**	**6 954 999**
Transportations on the island			
LPG	51 959	1,3	12 985
Diesel	2 006 359	50,3	582 647
Gasoline	1 929 588	48,4	530 637
Total	**3 987 906**	**100,0**	**1 126 268**
Transportations from and to the island			
Maritime transportations (heavy fuel)	2 605 827	36,7	917 251
Maritime transportations (diesel)	119 429	1,7	34 682
Air transportations (kerosene)	4 374 194	61,6	1 093 111
Total	7 099 450	100,0	2 045 044
Heating and other uses in buildings			
Oil burners for indoor space heating	350 687	41,6	101 840
Wood / solid biomass for indoor space heating	60 000	7,1	0
LPG for cooking	272 783	32,3	68 168
Solar collectors for hot water production	160 178	18,9	0
Total	**843 648**	**100,0**	**170 108**
Total	**15 002 930**		**10 296 320**

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Particularly, electricity demand in Crete exhibits intensive seasonal fluctuations due to the considerable increase of the population in the island and the corresponding activities during the tourist period (from April to October).

Figure 21 presents the annual variation for three consecutive years (2017 – 2019) of the peak daily power demand in the electrical system of Crete. In this figure it is observed that the electrical power demand in Crete is maximised during summer, obviously due to tourism and the need for cooling, while there is also a slight increase during winter, due to the gradual transfer of the heating demand coverage from diesel oil to heat pumps.

Particularly, electricity demand in Crete exhibits intensive seasonal fluctuations due to the considerable increase of the population in the island and the corresponding activities during the tourist period (from April to October).

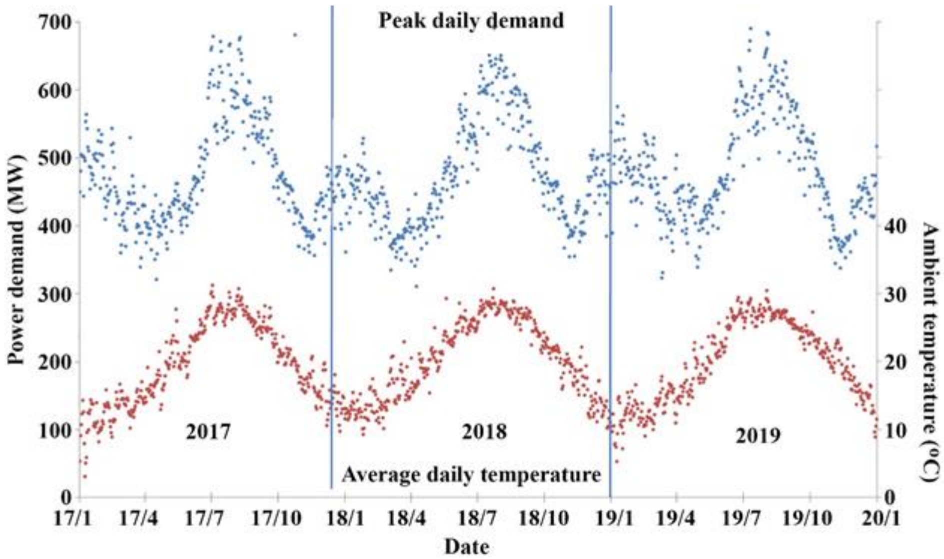

Figure 21: Daily peak power demand on Crete for 2017 - 2019

The evolution of the annual share of the primary energy resources involved in the electricity production in Crete since 1995 is depicted in Figure 22. In this figure it is seen that the exploitation of RES in Crete started in 1998, with the installation of the first wind parks. The installation of the first photovoltaics started more than ten years later, in 2010.

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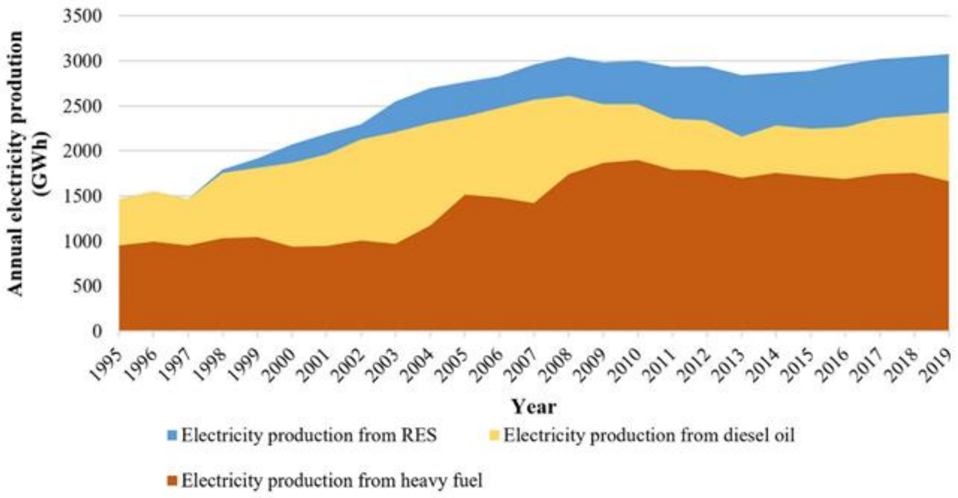

Figure 22: Evolution of the annual electricity demand coverage in Crete from the involved primary energy resources

The exploitation of the renewable energy sources in Crete is mainly restricted for the electricity production from wind parks and photovoltaics and for hot water production from solar collectors. Limited thermal energy needs are also covered by biomass and geothermal potential too. The percentage contributions of the involved energy resources for each discrete final energy form coverage are summarized in Figure 23. Specifically, Figure 23 refers to all final energy needs in Crete, including transportations from and to the island, while Figure 24**Error! Reference source not found.** refers exclusively only on the final energy uses onshore.

As seen in Figure 24, the renewables' annual contribution on the onshore final energy needs coverage exceeds 12%. The same feature calculated for the overall energy consumptions is configured at 5%. Energy transition in Crete aims to increase these percentages gradually at 100%. In the following sections, potential paths and pylons towards this target for the onshore energy needs are examined and proposed.

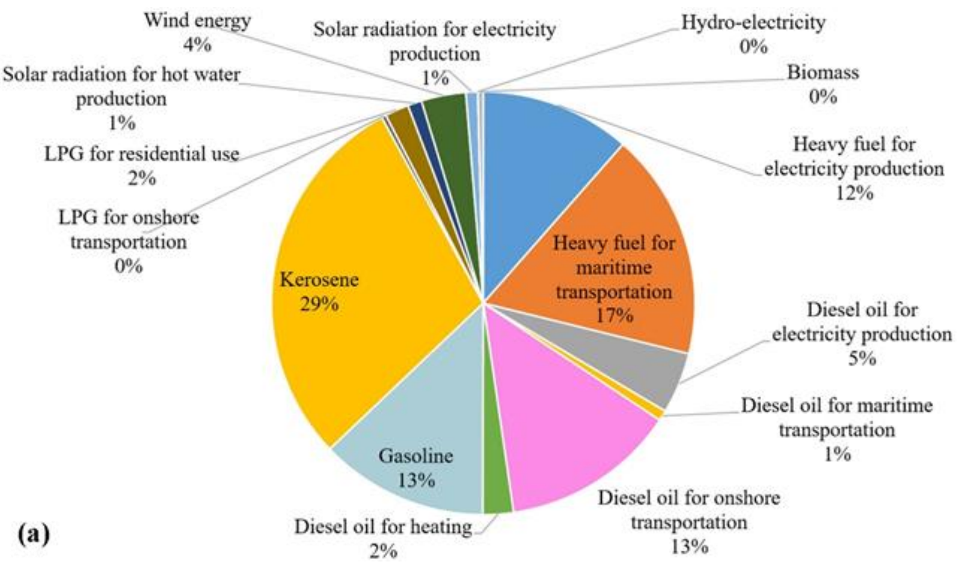

Figure 23: Share of energy sources in energy consumption on Crete

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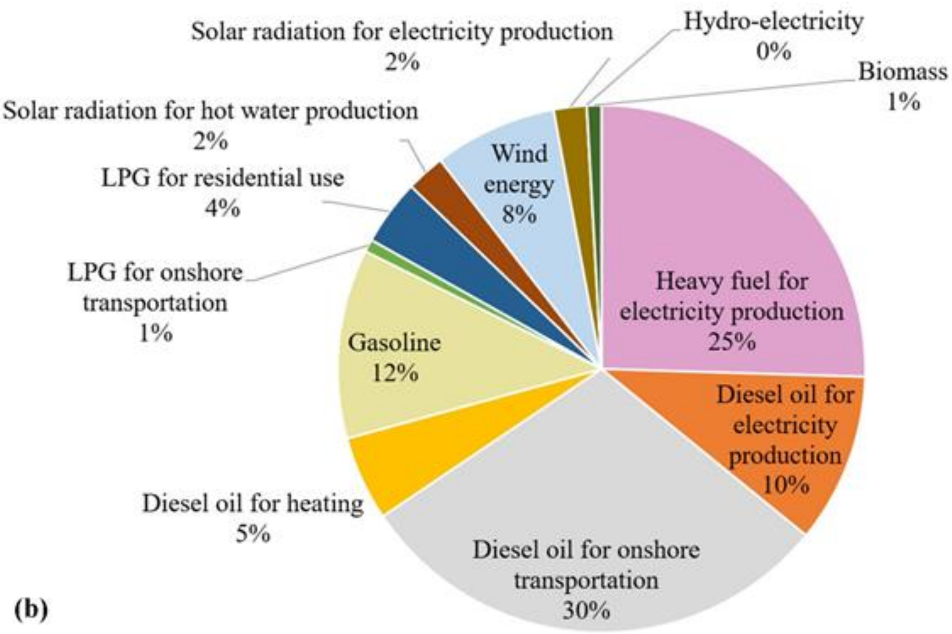

Figure 24: Share of energy sources in onshore energy consumption on Crete

6. Stakeholders' requirements

Mapping of stakeholder needs and interests and the scope for their engagement and empowerment. This is going to form the base for business cases and economical evaluation as well as social acceptance studies (WP5 and WP6). This task will also feed the task 6.4 related to the replication plans.

6.1. Eigerøy

The stakeholder analysis has three sections: The Identification, Analysis, and Action Plan of stakeholders. The identification and analysis sections help map the importance and influence of stakeholders, and the action plan describes information activities requirements.

The identification section, Table 6, describes stakeholders' names, types of stakeholders, and relationships to the project. There are eight stakeholders identified from the island of Eigerøy. Five of the stakeholders are directly or indirectly partners in the project; local newspapers, neighbors, and politicians are considered spectators. However, Politicians are considered both spectators and premise providers to the project.

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Table 6: Identification of main stakeholders

Identification		
Name and Role	Main Category (type of Stakeholder)	Affiliation / relation to the project
The municipality	Premise providers	Partner, spectator and premise provider
Politicians	Premise providers	Spectator and premise provider
Replicate Islands	User	Partner
Suppliers	Supplier	Direct and indirect partner
Local Newspaper	Other stakeholder	Spectator

The analysis section then describes expectations and attitudes, interest and willingness to cooperate, influence/power/willingness to influence. Table 7 shows that almost all the stakeholders have positive expectations, high willingness to cooperate, and have high influence and power to the project except neighbors and surrounding industries. Neighbors have neutral expectations and attitudes to the project but minor desire to cooperate with the project. However, the neighbors also have little influence and a minor desire to influence the project. Surrounding industries are neutral throughout the analysis section.

Table 7: Interest analysis of stakeholders

Identification	Analysis		
Name and Role	Expectations and attitudes to the project	Interest and willingness / ability to cooperate	Influence and power / willingness to influence
Neighbours	Neutral	Minor	Minor
Partners	Positive	High	High
Surrounding industries	Neutral Positive	Medium	Medium
The municipality	Positive	High	High
Politicians	Positive	High	Medium
Replicate islands	Positive	High	High
Suppliers	Positive	High	High
Local Newspaper	Positive	High	High

The action plan describes the level of involvement of stakeholders needed in the project. Partners and suppliers have a high demand for information and participation, and Local newspapers, industries, and the municipality have a medium need for information and involvement. However, Politicians and neighbors have a low requirement for information and participation.

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Table 8: Interest analysis of stakeholders

Identification	Measures		
Name and Role	Stakeholder information requirement	Main measures	Status of use a separate tab for action plans
Neighbours	Low requirement of information and involvement	Provide info in local newspaper and on social media	No issues
Partners	High requirement of information and involvement	Information meetings and updating project files	No issues
Surrounding industries	Medium requirement of information and involvement	Information and sporadic update	No issues
The municipality	Medium requirement of information and involvement	Information meetings	No issues
Politicians	Low requirement of information and involvement	Provide continuous project updates	No issues
Replicate islands	High requirement of information and involvement	Information meetings and updating project files	No issues
Suppliers	High requirement of information and involvement	Information meetings and updating project files	No issues
Local Newspaper	Medium requirement of information and involvement	Provide continuous project updates	No issues

6.2. Western Isles

As in the Eigeroy example, we have undertaken Identification, Analysis, and an Action Plan of stakeholders. The identification and analysis sections help map the importance and influence of stakeholders, and the action plan describes information activities requirements.

The identification section, *Table 9* describes stakeholders' names, types of stakeholders, and relationships to the project. There are six stakeholders identified. The identification of stakeholders has focused specifically on the Creed Site where the EMS system will seek to be replicated

Table 9: Stakeholder identification

Name and role	**Main Category** (type of stakeholder)	**Affiliation / relation to the project**
Users of the facility	User	Spectators and indirect partner.
Surrounding industries on the site	Other stakeholders	Spectators and indirect partner.
Comhairle nan Eilean Siar - Staff	Premise providers	Partner, spectator and premise provider

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Comhairle nan Eilean Siar - Politicians	Premise providers	Partner, spectator and premise provider
Wider community	User	Spectator
Suppliers	Supplier	Direct and indirect partner

The analysis section then describes expectations and attitudes, interest and willingness to cooperate, influence/power/willingness to influence. Figure () shows that stakeholders have either positive or neutral expectations. Neutral expectations being due to a lack of knowledge and information at this stage. It is anticipated that Comhairle staff and politicians would be positive around any new proposals for Creed and would be willing to cooperate with the application of the EMS. These are also the stakeholder with the greatest influence.

Table 10: Analysis of stakeholder expectation

Name and role	Expectations and attitudes to the project	Interest and willingness / ability to cooperate	Influence and power / willingness to influence
Users of the facility	Neutral	Medium	Medium
Surrounding industries on the site	Neutral positive	Medium	Medium
Comhairle nan Eilean Siar - Staff	Positive	High	High
Comhairle nan Eilean Siar - Politicians	Positive	High	High
Wider community	Neutral	Medium	Medium
Suppliers	Positive	High	High

The action plan describes the level of involvement of stakeholders needed in the project. The highest level of information and involvement is Comhairle staff on the site, and politicians within the Comhairle, whose support is essential.

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Table 11: Action plan

Name and role	Stakeholder information requirement	Main measures
Users of the facility	Medium requirement of information and involvement	Provide info in local newspaper, internet and on social media
Surrounding industries on the site	Medium requirement of information and involvement	Information meetings and sporadic updates
Comhairle nan Eilean Siar - Staff	High requirement of information and involvement	Information meetings and regular updated.
Comhairle nan Eilean Siar - Politicians	High requirement of information and involvement	Regular updates through Committee or briefing notes.
Wider community	Medium requirement of information and involvement	Provide info in local newspaper, internet and on social media
Suppliers	Low requirement of information and involvement	Sporadic updates as required.

6.3. Crete

Following the analysis and the presented information in the "topographic conditions" sections, the potentially involved final beneficiaries in the replication study in Crete can be:

- The owners of the tomatoes crops' greenhouses and the beneficiaries which have the commercial rights on them. Some of them are: Agrifal, Platanos Cooperative, Iakovos farm, Producers group from Falasarna, Tsatsaronakis Vasilis, Nikolakakis general partnership, Spiliotis.
- The owner of the bakery factory in Platanos village, "To manna Tsatsaronakis", with 931 MWh annual electricity consumption and considerable diesel oil consumption, not available at this current moment.
- The olive oil cooperative in Platanos, with 1,000 tn oline oil production per year and 5.5 – 6.0% mass residues (olive oil kernel, liquid wastes etc).
- The owners of the hotels in Kissamos, with the largest of them: Molos bay hotel, Aphrodite beach hotel, Elena beach hotel, Nautilus, Crystal bay hotel, Maria beach hotel, with typical annual electricity consumption at 200 – 300 MWh.
- The olive oil processing unit Renieris in Kissamos.
- The cheese factory Papagiannakis and the winery Martsakis at the Perivolakia village.
- Additionally, in the replication study the following stakeholders will be protentially involved:

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- The Technical University of Crete, which will have the scientific responsibility for the implementation of the study.
- The Region of Crete, which will supervise and will have the role of the results dissemination.
- The Minoan Energy Community, the first and largest energy community in Crete, for technology and methodology transfer and a potential replication of the study in the other regions in the island.

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7. Summary

This report summarizes the current energy situation on the three Islands Eigerøy in Norway (demonstration Island), Western Isles in UK and Crete in Greece (follower Islands). The results will be used as a baseline for other technical work packages and tasks.

Main content:

- General descriptions of both the demonstration island and the follower islands;
- Mapping of installed infrastructure on local energy system's production, distribution and demand side;
- Topographic conditions of the demonstration island;
- Detailed information on the demand-side energy consumption including the currently available information and its energy consumption profile;
- Overview of the identified stakeholders, as well as their needs and interests;
- Summary of outcome.

Overview Energy Systems:

Eigerøy - demonstration island: Almost 100% of the electricity is provided through cables from the mainland, and this power is generated mainly from hydropower (89,2%), with 8,6% onshore wind power with and 2,2% Thermal power. 88% of the electricity consumption is from industry. However, in the industrial sector on Eigerøy there are a considerable amount of fossil-fuel based thermal energy used especially in the fish industry (26 500 MWh/year), and there are also planning for more factories elevating both the need for more thermal energy and more electricity. The current energy system is not able to handle the upcoming demand, and the approach in the ROBINSON project is to find the best way of solving the demand side when it comes to sustainability and convert existing fossil-fuel based energy with renewables without providing a costly new grid connection to the mainland which also include considerable environmental impact.

Western Isles: The Isles are reliant on imported liquid and gaseous fuels. The electricity supply to the isles is mainly based on two subsea cables providing 22 MW. However - the peak consumption is 30 MW, and the mismatch is covered by on-island diesel generators. On the positive side The Western Isles is home to a rich resource of renewable energy, especially wind, wave and tidal which could be harvested. And there is a plan for new HVDC-link to the mainland that will unlock the potential of import of considerable amounts of renewable power.

Crete: The energy supply is mostly based on fossil-fuels including electricity produced from thermal power plants, whereas the Renewable share is 21% (16,6% wind, 4,4% PV). It is roughly estimated than more than 60% of the residential buildings in Crete has at least one or two solar collectors installed on their roofs for hot water production. Transportation is based on imported fossil fuels. A new interconnection with the main land grid is under construction, with the first cable providing 400 MW capacity.

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