Inishbofin Energy Transition Plan

-On behalf of the Inishbofin Development Company DLC

Delivery Date: 02/05/2022
Final Revision Date: 05/07/2022

Rialtas na hÉireann Government of Ireland
Tionscadal Éireann Project Ireland 2040
Ár dTodhchaí Tuaithe Our Rural Future
LEADER
The European Agricultural Fund for Rural Development: Europe investing in rural areas
FORUM

Funded by the Department of Rural & Community Development

Table of Contents

Figures

Tables

1 Executive Summary

Inishbofin, situated around 8km off the west coast of County Galway, Ireland, is a beautiful island community with around two hundred inhabitants, which caters to circa 50,000 tourists each year who enjoy the excellent nature, history, sports, culture and gastronomy the island has to offer.

Island communities such as Inishbofin are very important in the context of climate change: they are at the frontline of the effects of climate change, being vulnerable to the effects of severe storms, rising sea levels and droughts. At the same time islands offer stories of hope and optimism about humanities ability to transition away from a fossil-fuel based economy, regenerate our environments and mitigate the worst effects of the climate and biodiversity collapses which represent possibly the greatest to human existence in its history.

The Inishbofin Development Company Limited (IDCL), founded by islanders, engaged KRA Renewables in 2021 to undertake assessment of the island's energy usage at present, how that usage can be reduced through efficiency and how it can be generated using renewable energy sources. The key objectives of this "Energy Transition Plan" were:

- An Energy Audit of the Community Centre.
- A Register of Opportunities.
- A Road Map to Implementation.
- A Comprehensive Report on all of the above.

The energy audit of the community centre can be found in a separate document, presented to the IDCL on 09/07/2021. This document contains the other three deliverables, with the roadmap being represented by three transition pathways. A final, subjective opinion document will accompany this document, based on the experience of the authors but based on experience and situational understanding rather than data.

The analysis found that, at present, the island uses approximately 6675MWh of energy per year between all fuel types, including ferry transport and transport within the island, space heating and hot water in buildings, and electrical power for all uses. This usage is responsible for more than 1830 tonnes of CO_2 emissions per year.

The potential to reduce the energy and carbon emissions intensity of the island through the improvement of building fabrics, electrification of heating and the transition of transport energy from fossil fuels to electricity of renewable fuels has been found to be very significant, with a total reduction of approximately two thirds of all usage and emissions possible from these measures.

The potential for energy generation on the island from its natural resources has also been found to be strong, with strong technical potential for energy generation from building mounted or large-scale Solar PV ("solar panels"), small scale wind energy, and one of the most commercially viable wave generators.

The electrical infrastructure on the island is light, but the main connector to the mainland appears to be of sufficient capacity to import or export as much power as the island could conceivably need without major upgrades.

2 Methodology

KRA Renewables' methodology to undertake this project involved a multi-faceted approach, beginning with a site-inspection of the entire island over the course of a week, and proceeding to data collection from various sources for analysis.

To create a meaningful plan, a bespoke technoeconomic model was developed for the island. Data was fed in from several sources, which were collectively used to create an energy baseline. The impact of efficiency upgrade measures were analysed to adjust that baseline. For both the baseline and the adjustments that followed, the analysis was undertaken on a profile basis, rather than annual point measurements, to ensure that the final energy baseline could be investigated across a year, which allows a much greater accuracy of comparison with regards to generation methods.

Various generation technologies were researched as far as possible, including desktop research, discussions with suppliers and manufacturers, industry papers, atlases of resources etc. Each research technology was analysed on its annual energy output and the profile of its output on a monthly basis.

The predicted production and consumption profiles were compared, and combined with other flows that were tracked throughout the model (cost and emissions) to present the lifetime financial outcomes of each generation technology being used individually. Technical and financial KPIs were determined for each of the 6 technologies investigated in detail.

Three possible Transition Pathways (combinations of measures that could bring the island through a complete energy transition) were assembled and compared both qualitatively and quantitatively.

Battery storage options and other opportunities were investigated quantitively. Basic financial pathways were laid out.

A register of opportunities was created, ranking each opportunity qualitatively against a set of metrics (Impact, Capital Cost, Cost Effectiveness & Realisability) and given a score from Very High to Very Low across each metric.

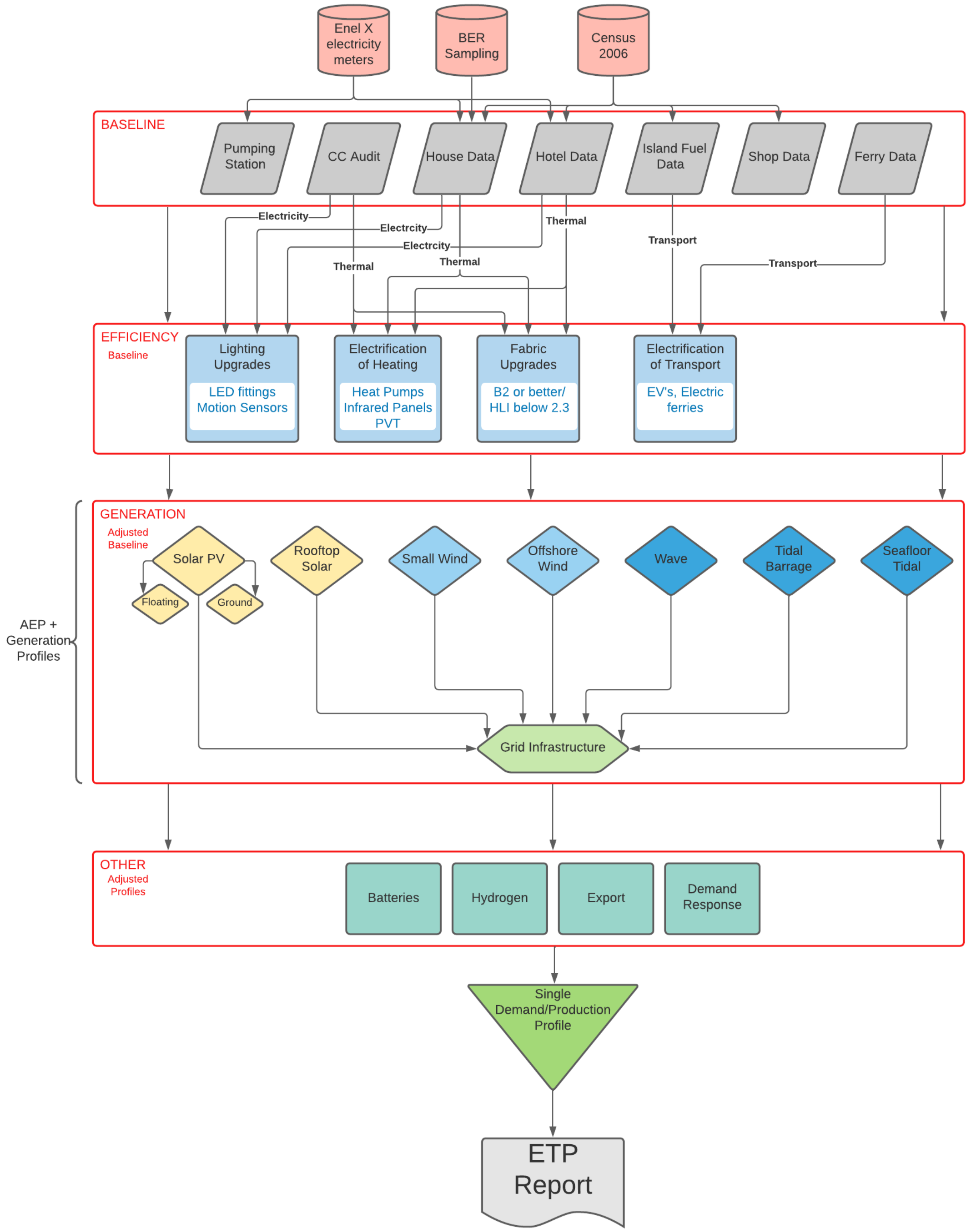

Figure 1: Flowchart of Methodology

2.1 Data Gathering and Collation

Data collection was a pivotal element of the project, and also represented a key challenge due to low data availability.

Table 1: Data Gathering Methods

Data Type	Collection Method	Challenges	Solutions
Island Geography	Geohive, GIS, Site Surveying	Remote location	Engineers time on site.
Electrical Loads + Costs	Metering, Bills Collection	No high-level metering available. No central information on bills	Installation of electrical meter by Enel X. Direct contact with business owners. IDCL surveying of householders.
Thermal Loads + Costs	BER Data, Business Thermal Bills	BER data very sparse (2 BERs available). No central information on bills	Direct BER surveying by KRA BER assessor. Direct contact with business owners. Use of climate data from weather stations.
Vehicular Usage + Costs	Request for information from diesel delivery.	Request not answered. Only very loose estimation provided.	Several methods of engineering analysis required to estimate usage, utilising survey of vehicles, estimation of driving distances and fuel efficiency of vehicles.
Ferry Usage + Costs	Request for information from Ferry Company	Long delay in information provision. Only partial information supplied.	Multiple engineering analysis approaches required (extrapolation and comparison with information on number of passengers and schedules).
Cost Data for Upgrades	Previous experience, discussion with suppliers	Wide variety of upgrade measures.	Combination of top-down and bottom-up approaches.

2.2 Partnerships and Collaborations

As the project progressed through its varying stages, partnerships with specific organisations were developed to obtain industry specific knowledge and guidance.

2.2.1 EnelX

EnelX, part of the Enel Group, offer optimisation software solutions to businesses, and facilitate a Demand Response Programme in Ireland. Enel X are interested in the potential for Demand Response for the island of Inishbofin, and installed meters on the main incoming cable coming into the island in order to determine the demand response potential present. This data was made available to the KRA team and was critical to the successful completion of this plan.

2.2.2 Energy Citizenship and Energy Communities (EC^2)

EC^2 (EC2, n.d.) are a European Union Horizon 2020 funded interdisciplinary organisation trying to determine the social, economic and legal conditions that will enable a shift in our energy model from a centralised to a decentralised one. They primarily work in law, economics and psychology. EC^2 are using the island as a case study, and will be running a survey in tandem with this study. The findings of the two studies will be combined to give the more informed set of choices which balance social, technical and economic elements.

2.2.3 New Energy Solutions Optimised for Islands (NESOI) & European Small Islands Federation (ESIN)

The IDCL obtained funding through NESOI and ESIN to further this study in one specific area, using the expertise of KRA Renewables (further involvement), Sinloc and CWP. The aim of the study is to take one element identified as highly feasible from this study, and progress the feasibility via the financial pathways that might be undertaken (Sinloc), and the grid upgrades required to do so (CWP).

3 Background

Measuring roughly 5.5km x 4.8km and with a permanent population of c. 180 people, Inishbofin island is located 11.2km off the coast of Galway. A lot of the island has been designated as a Special Area of Conservation, owing in part to the presence of seals and corncrakes. The island does not have any trees or forests, as historically and wood was cut down to be used as heating fuel and to make way for agriculture.

The name Inishbofin is derived from the Irish 'Inis Bó Finne' which translates to 'Island of the White Cow'. Legend has it that the name came about when a group of fishermen sheltering on the island came upon an old woman driving a white cow. Seeing them, the old woman struck the cow with a stick, turning it into a rock. In recent times the island's name was anglicised to 'Inishbofin' or simply 'Bofin' island.

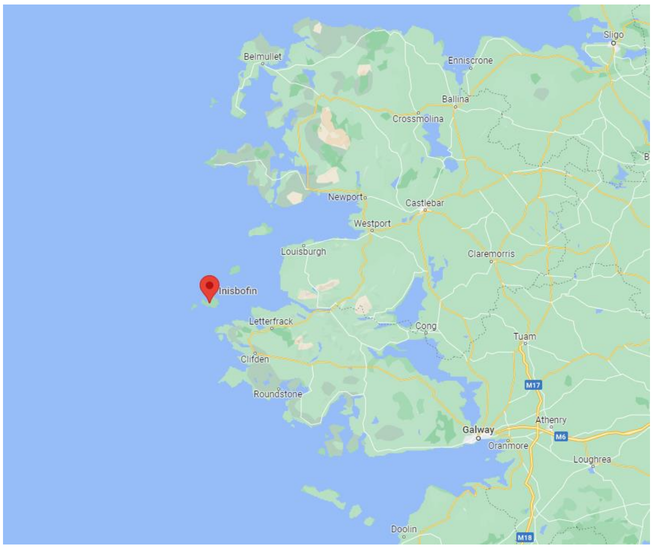

Figure 2: Island Location (Google Maps)

Figure 3: Island Map – GIS

3.1 Geographic situation

The island is circa 5.5km long on its longest axis, and 700m wide at its narrowest point (including the length of Lough Bofin).

The island is divided into 5 townlands; Westquarter, Fawnmore, Middlequarter, Loonamore and Knock, as shown in the Inishbofin Chart below.

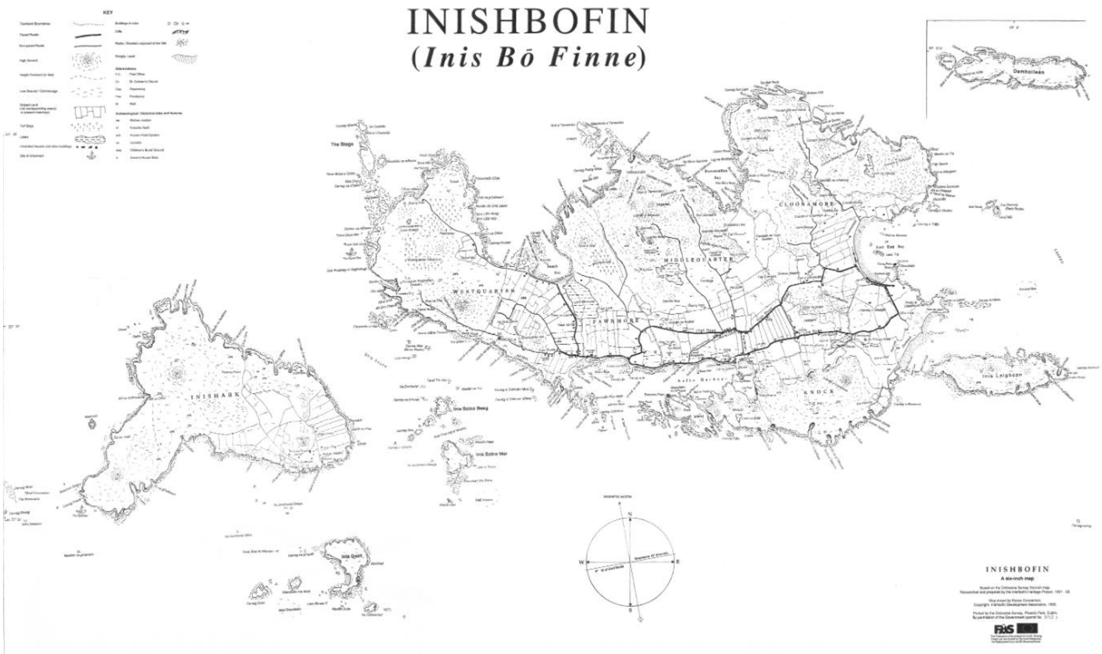

Figure 4: Inishbofin Chart

The highest point of the island is the summit of Westquarter Mountain which rises to 89 metres above sea level.

Figure 5: Map of island contours

Figure 6: Circumference and area

The island is approximately 10km^2, and has a rugged coastline. Correctly estimating the length of the coastline would depend entirely on the length of measurement used. This is known as the "coastline problem".

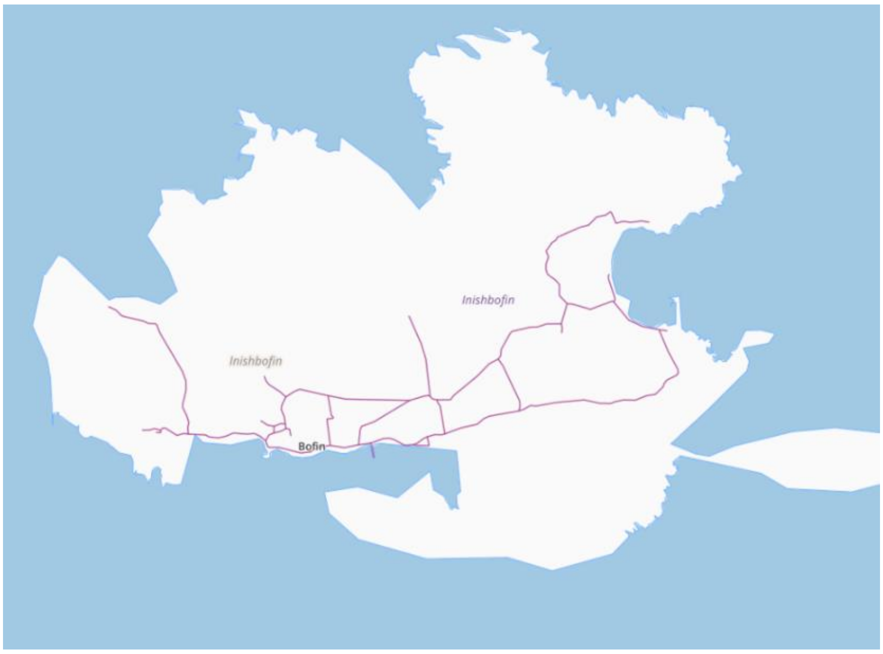

Figure 7: Road network on the island

The road network on the island connects all of the settlements, but does not extend far into the commonage. Dirt tracks are existent in some areas, while in others there are no tracks at all.

3.1.1 Average wind speed in Inishbofin

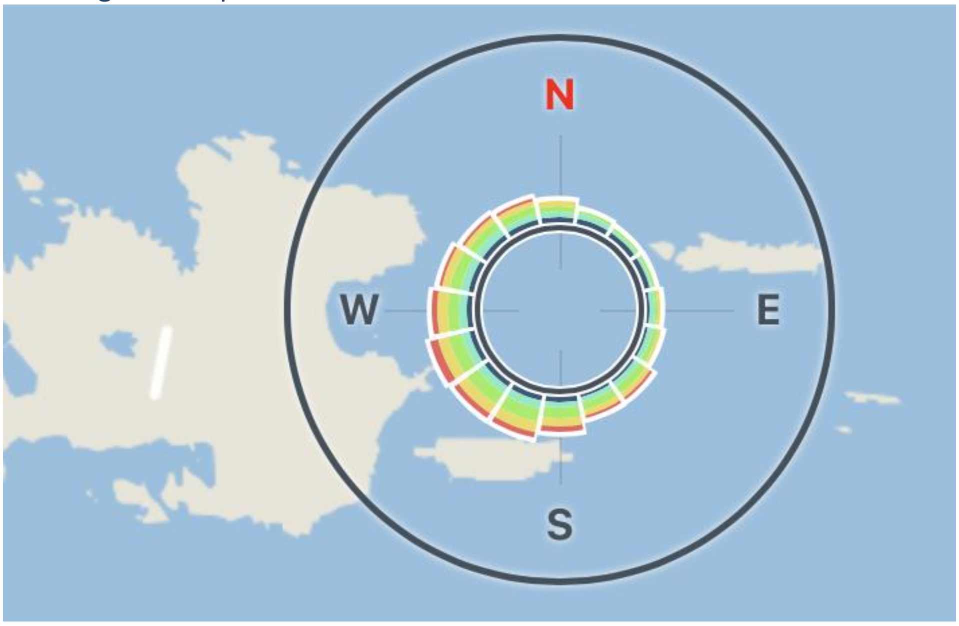

Figure 8: Average wind speed in Inishbofin - Source: https://windy.app/forecast2/spot/389091/Inishbofin/statistics

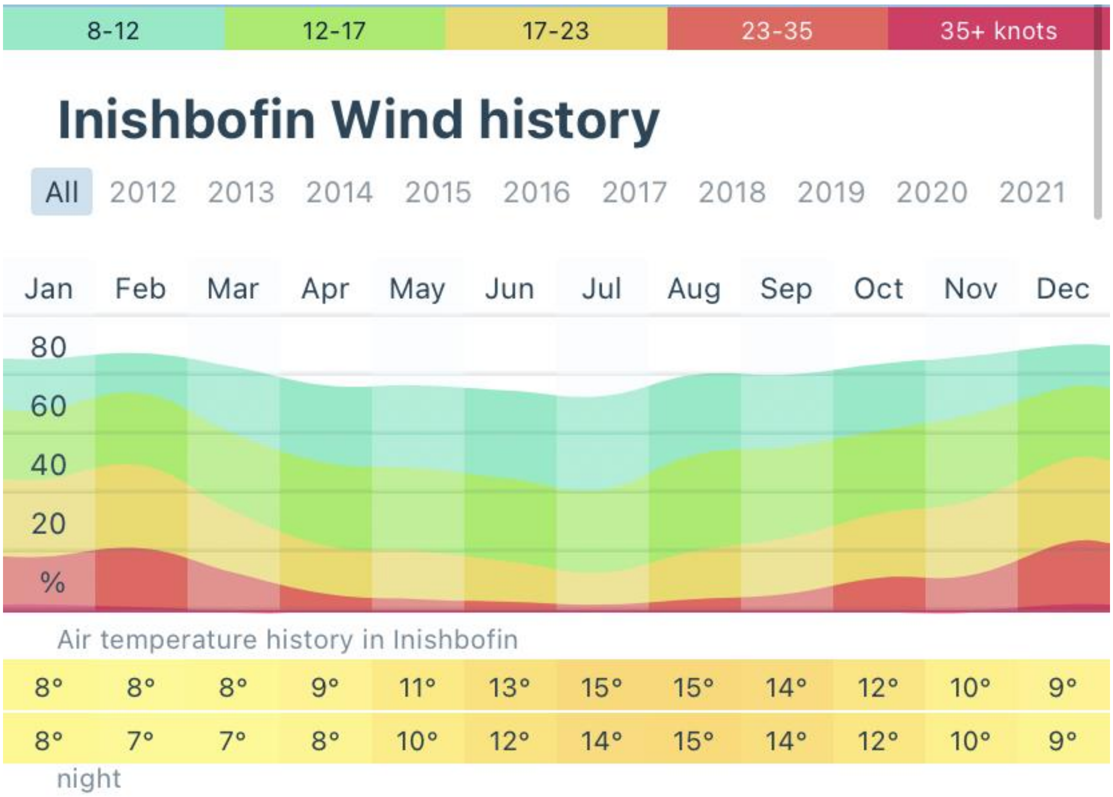

Figure 9: Inishbofin Wind History - Source: https://windy.app/forecast2/spot/389091/Inishbofin/statistics

Based on climate data from World Weather and Climate Information and Windy.app, we can summarise Inishbofin's wind history as follows:

- There is a relatively consistent wind pattern across the island;
- On average, the most wind is seen in December, January and February;
- On average, the least wind is seen in July;
- The island very rarely sees wind above 35 knots;
- The island rarely sees wind between 23-35 knots, with this wind occurring most frequently between December and February;
- The majority of wind on the island is between 8-23 knots, with slower windspeeds corresponding with summer months.

3.1.2 Wave Data on Inishbofin

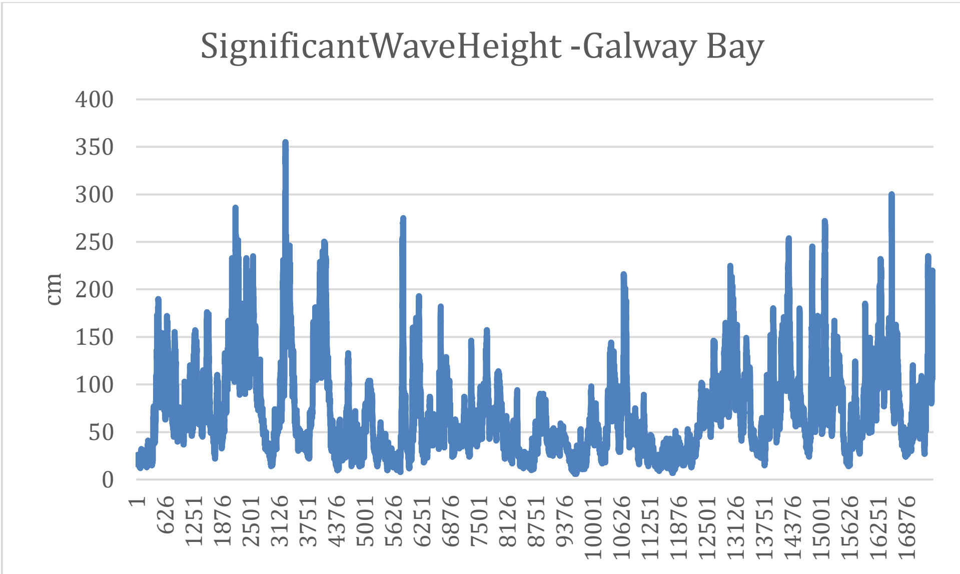

Figure 10: Significant Wave Height (Galway Bay)

No wave data was available for Inishbofin itself. Wave data from a buoy in Galway bay was investigated to give the above profile over one year, however it should be noted that Galway Bay is significantly more sheltered than any of the coastlines of Inishbofin.

3.1.3 Tide Data on Inishbofin

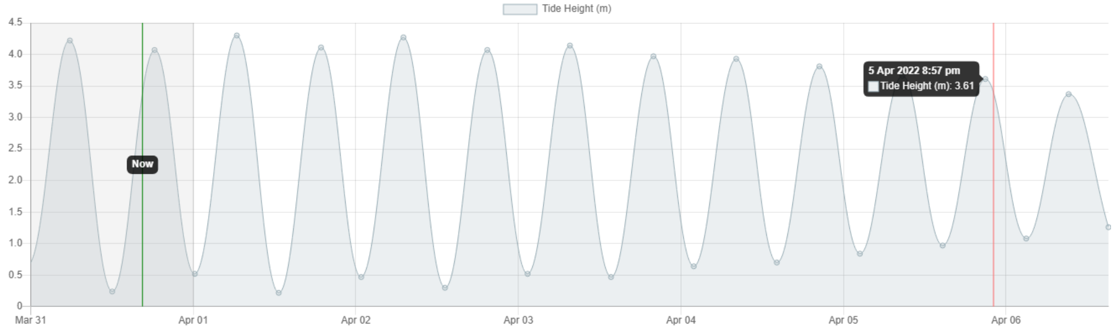

Figure 11: Tide Data on Inishbofin - Source: https://tides.today/en/c/ireland/county-galway/bofin-harbour

A sample tidal reading taken on Thursday 31 March 2022 at 4:42PM IST (GMT +0100); showing that the tide was at the time rising in Inishbofin.
As shown on the tide chart, the highest tide of 2.2m was at 5:57am and the lowest tide of 0.4m was at 12:10pm.

3.1.4 Solar Data on Inishbofin

Figure 12: Solar Data on Inishbofin - Source: https://trek.zone/en/ireland/places/25718/inishbofin/sunrise-and-sunset

According to data from Trek Zone, on Inishbofin the longest day of the year is 17 hr 4 min and takes place in June. The shortest day of the year lasts for 7 hr 27 min and takes place in December, meaning that the difference between the longest and shortest day of the year is 9 hr 36 min.

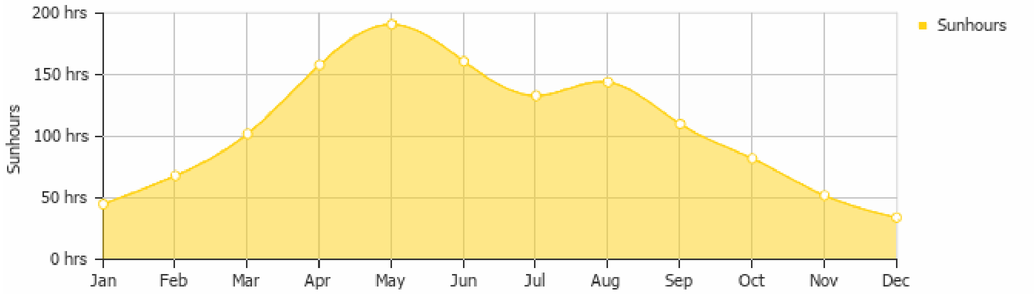

Figure 13: Shortest and Longest Day on Inishbofin - Source: https://weather-and-climate.com/average-monthly-hours-Sunshine,inishbofin-galway-county-ie,Ireland

On average, May is the most sunny month with 191 hours of sunshine, while December has on average the lowest amount of sunshine with 34 hours.

3.2 Demographic situation

According to the Central Statistics Office (CSO), which collects data via the census, the island has a diverse population in terms of age, background, family status, living situation, social class, education and occupation.

The 2016 census collected the following information (the date of the census was the 24th of April, which is outside of the peak of the tourist season, however tourists are likely to have been present, somewhat impacting the below figures).

3.2.1 Age Demographic

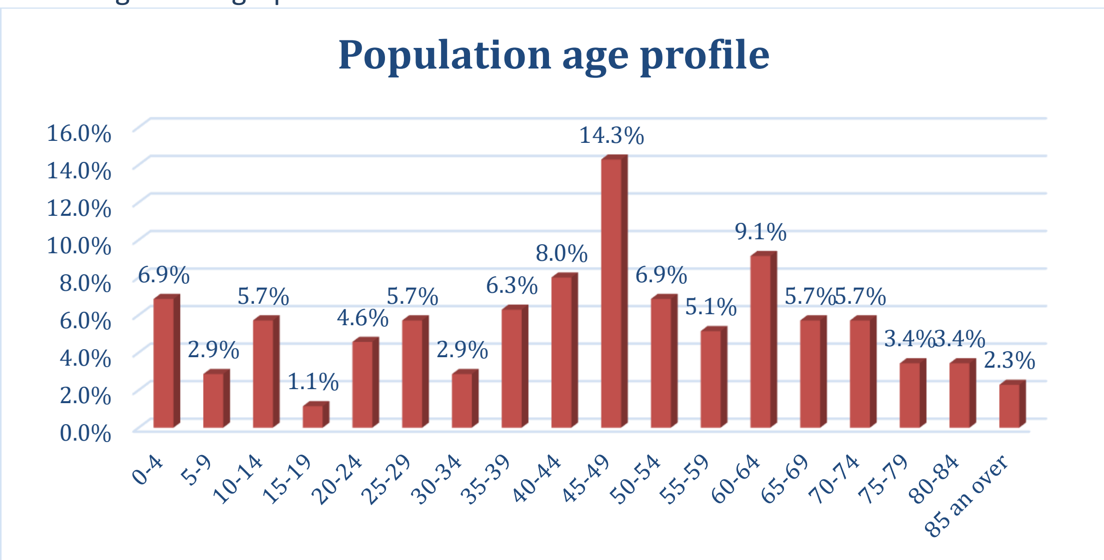

Figure 14: Population age profile as per 2016 Census

According to the 2016 census, the highest proportion of people living on the island (14.3%) fall between the ages of 45-49. The lowest proportion of people living on the island (1.1%) are in the range of 15-19 years old, possibly owing in part to the fact that many secondary school-aged children leave the island to attend school on the mainland. In any event, children and young adults aged between 0-20 make up a larger proportion (16.6%) than those aged over 70 (14.8%). Even though the population of the island has been statistically declining according to the census data, since 2019 eight new households of residents have moved to the island, including six children (situation in March 2022)[1].

3.2.2 Family Size

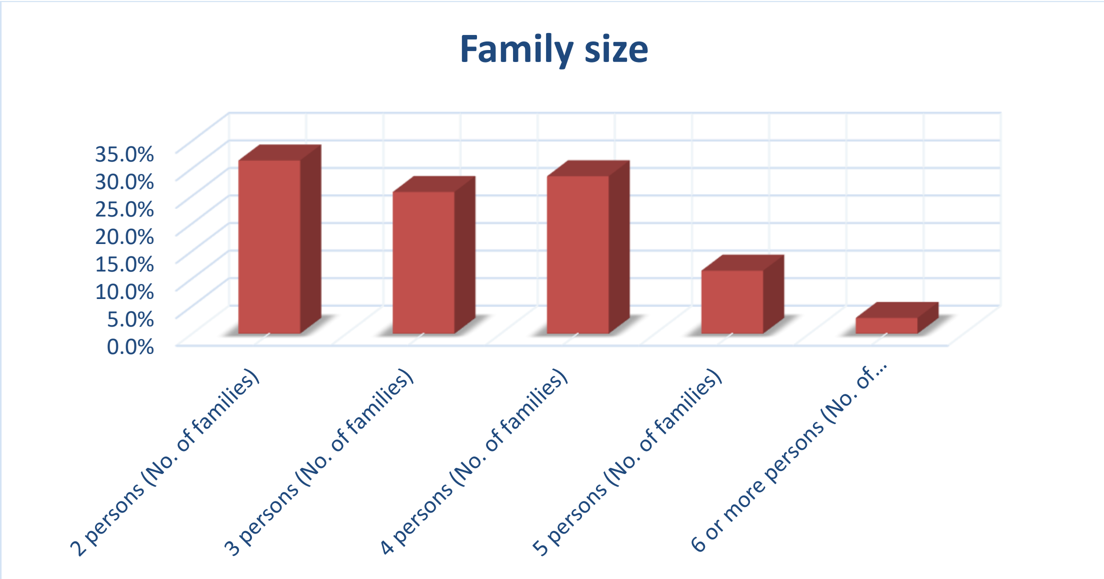

Figure 15: Family Size Profile as per 2016 Census

It is clear from the census data that the majority of families on the island live in 2-person households. The data on this is further broken down in section 3.2.3 below. It is however clear that 2-person, 3-person and 4-person families are far more common on the island than families with 5 or 6 people.

[1] Source: Inishbofin Development Company

3.2.3 Household Type

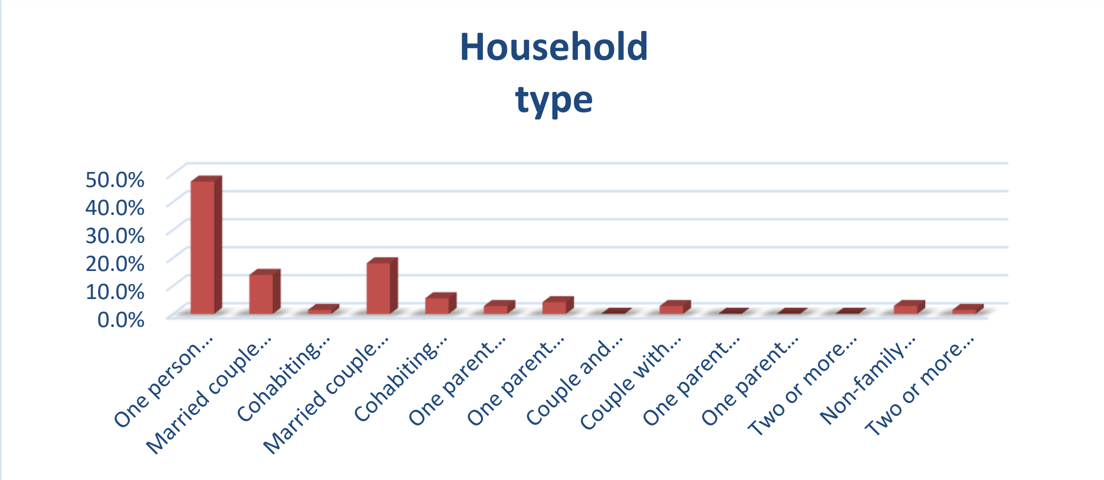

Figure 16: Household Type Profile as per 2016 Census

The Household Type figures go some way toward breaking down the Family Size figures shown in section 3.2.2. What is clear is that the most common household type (c.45%) on the island features an adult living alone. The next two most common household types both include married couples, although it is unclear from the available 2016 census data how many of these couples have dependents living with them.

3.2.4 Housing Age

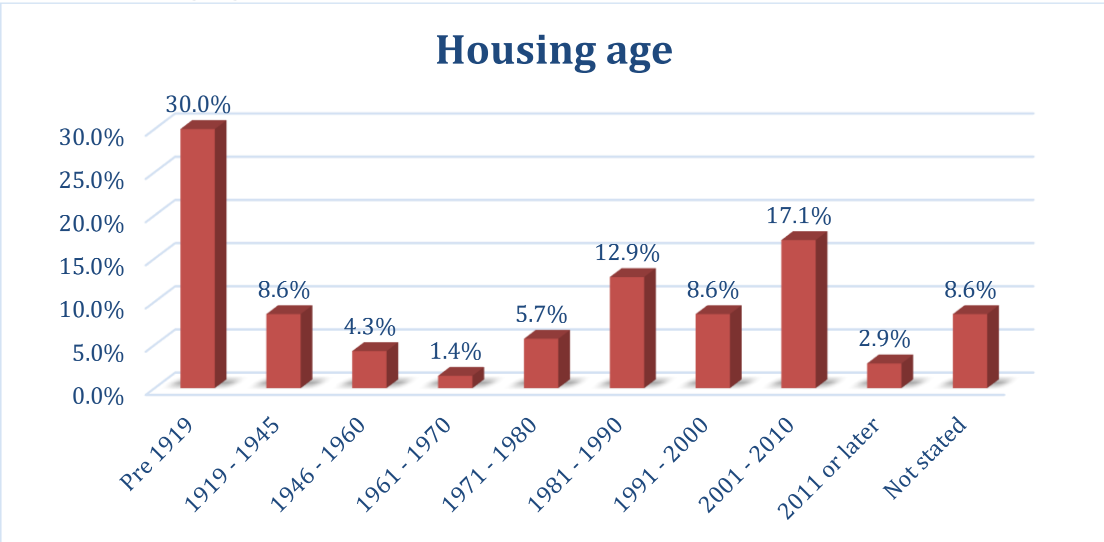

Figure 17: Housing Age Profile as per 2016 Census

We can see that the majority of housing on the island (60%) was built before 1990, with only 2.9% of the total housing stock built since 2011. The age of the housing stock on the island means that a large proportion of all dwellings will be of traditional, breathable construction (particularly those built pre-1940s). These dwellings represent a challenge to retrofit, as modern, vapour impermeable insulation materials may not be appropriate to their construction method, and passive ventilation rates will likely be high. The authors of this report recommend that readers consult the Energy Efficiency in Traditional Buildings guidance document, due to be released in 2022 by the Department of Housing, Local Government and Heritage for best practice in the energy retrofit of traditional buildings.

3.2.5 Principal Economic Status

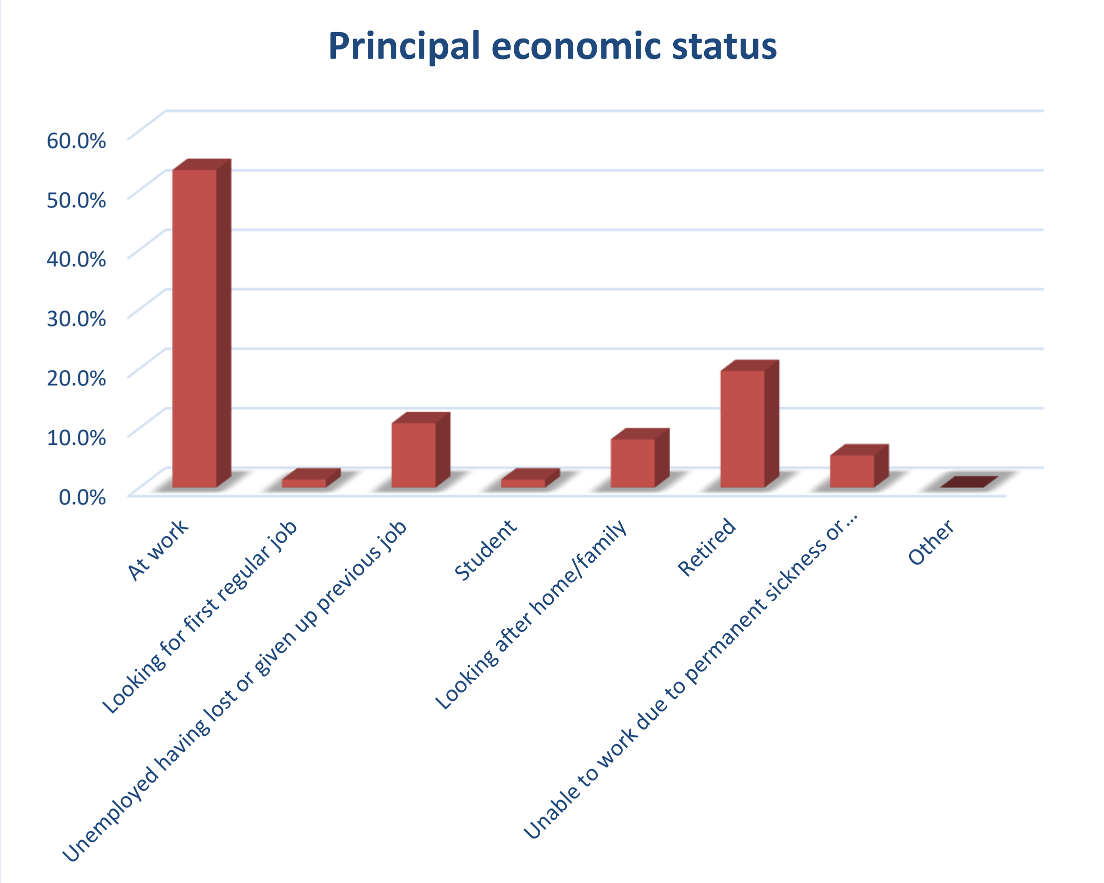

Figure 18: Principal Economic Status as per 2016 Census

The majority of island residents (c.52%) were identified in the 2016 census as being in employment, with another c.18% identified as being retired. Less than 10% were identified as being unemployed, with an even smaller number (c.4%) identified as being unfit or unable to work due to illness or injury. Only c.2% of residents were identified as being students, with a further c.1.5% identified as seeking their first regular employment. Island teenagers attending secondary school are required to live on the mainland during the week.

3.2.6 Social Class

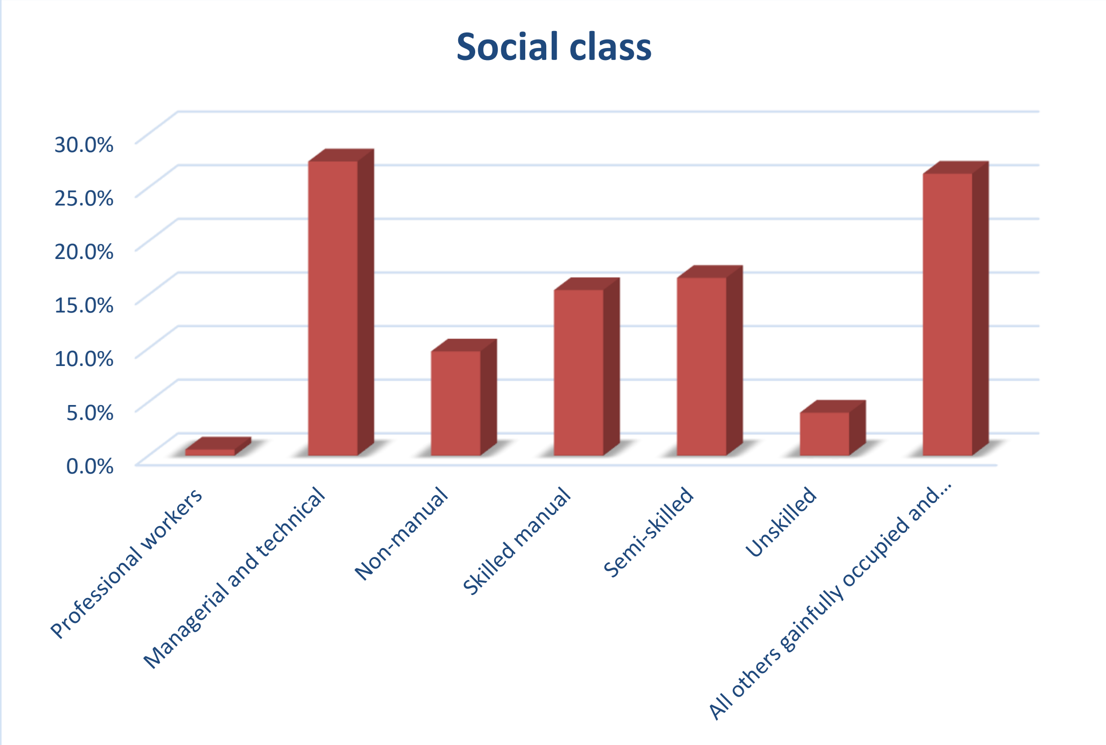

Figure 19: Social Class as per 2016 Census

The highest proportion of people identified in the 2016 census as being in employment, listed themselves as working in managerial and/or technical positions, with another c.8% identified as "non-manual". A further 25% are listed as "gainfully employed", but unfortunately this is not further broken down within the available data. C.16% of residents described themselves as being semi-skilled, while a further c.14% identified themselves as skilled manual workers. Just c.05% of respondents identified themselves as professional workers, while c.3% reported that they were "unskilled".

3.2.7 Highest Level of Education Completed

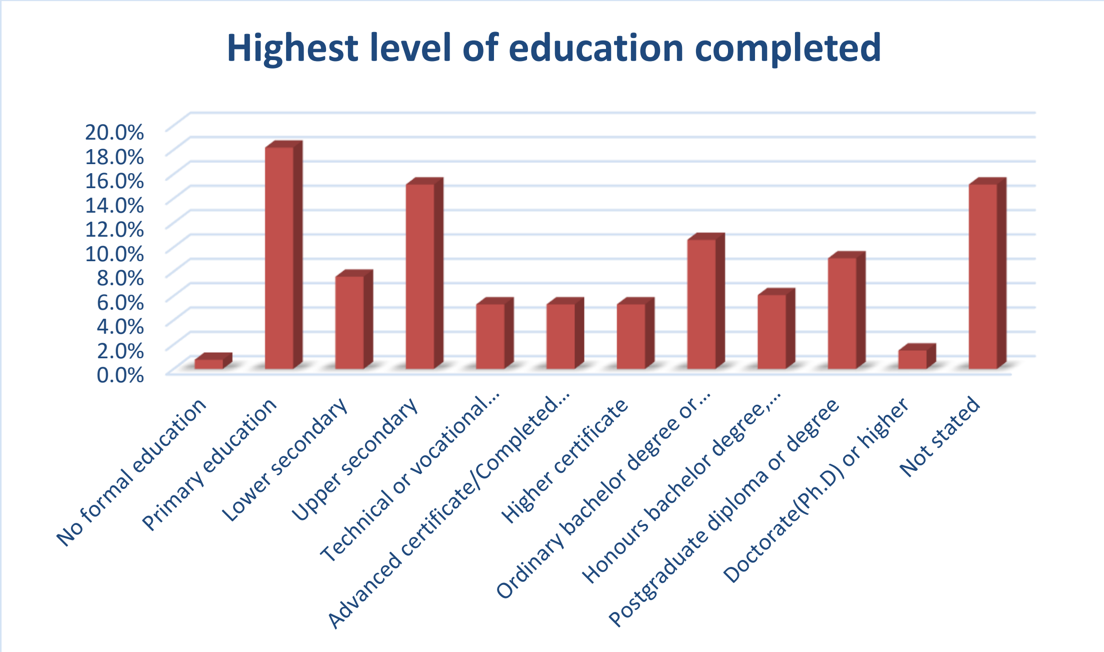

Figure 20: Highest Level of Education Completed as per 2016 Census

The 2016 census data shows us that only c.0.5% of the island's residents have no formal education. Although c. 16% of census participants chose not to disclose their education status, the majority of islanders who did choose to disclose their education status (50%) were educated from primary through to Honours Bachelor level. More people chose not to disclose their level of education (15.2%) than the national average (6.4%) and the number of people who had no formal education or only primary education was higher than the national average (18.9% vs 12.5%). There were no other significant differences from the national averages.

3.2.8 Commuting to Work

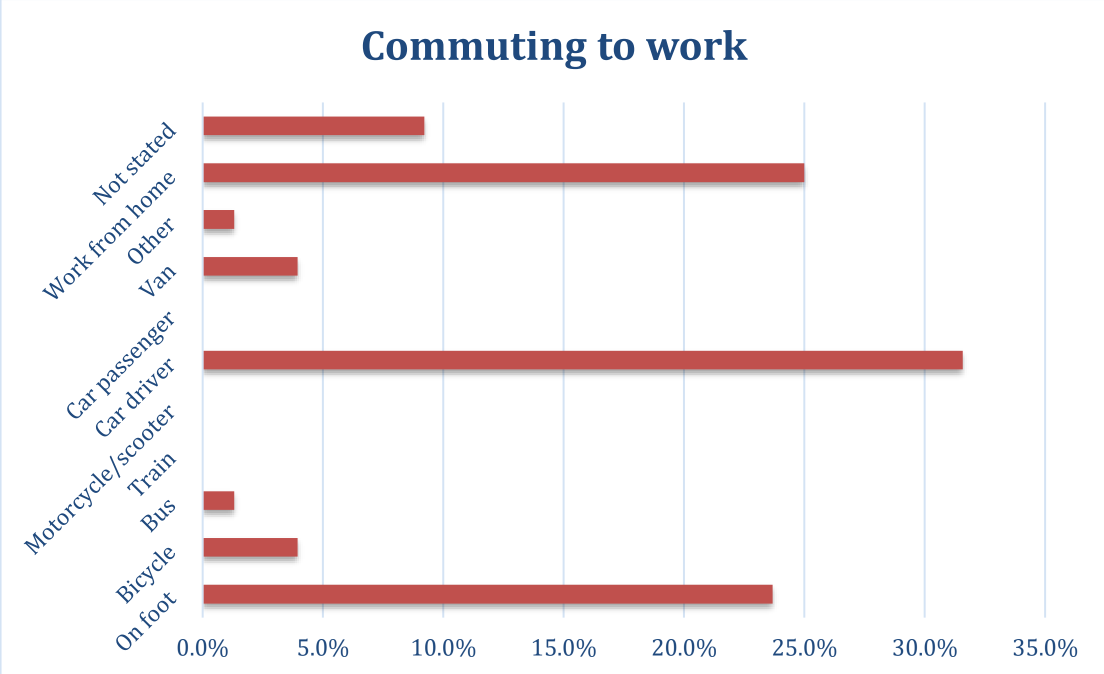

Figure 21: Commuting to Work as per 2016 Census

Interestingly, c. 32% of 2016 census respondents stated that they commuted to work by car. Unfortunately, the data does not break this down further, but we can assume these islanders commute within the island setting owing to the fact that the car ferry only runs twice per week. Another 25% of islanders reported that they work from home, with a further c.24% travelling to work on foot. A small number (c.10%) report using other methods of transportation to commute, including by van, bus and bicycle.

3.2.9 Persons at Work / Unemployed

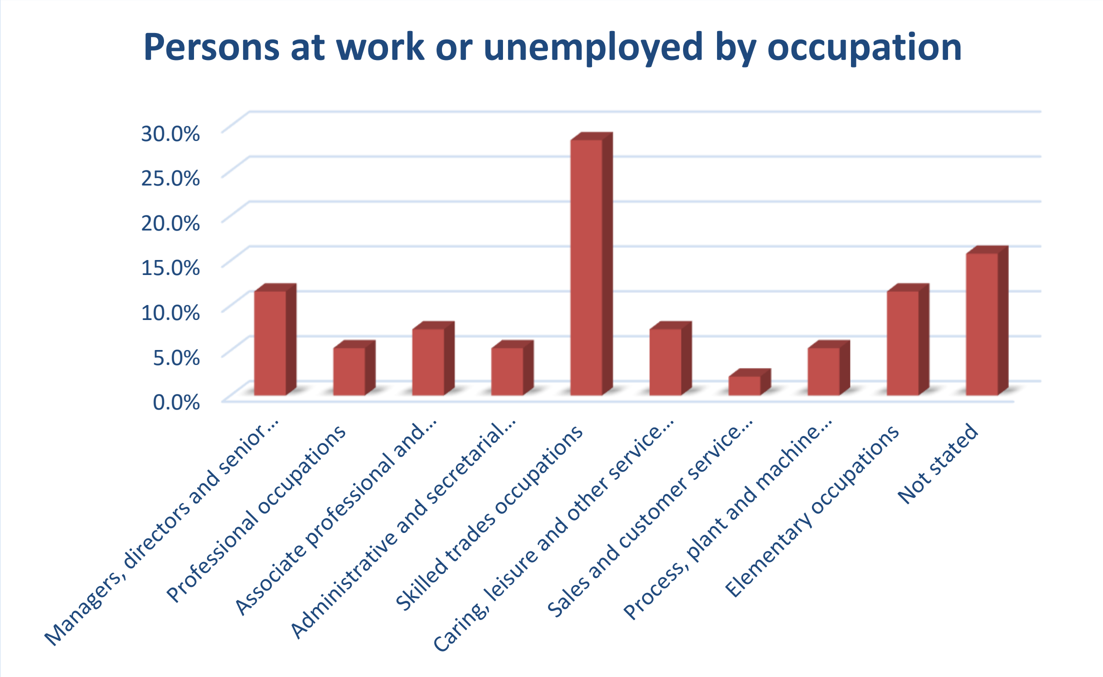

Figure 22: Persons at Work or Unemployed by Occupation as per 2016 Census

A large proportion of islanders (c.27%) identified themselves as "skilled trades operatives" in the 2016 census. 15% declined to state their occupation. C. 11% of respondents listed their occupations as falling within the "managers, directors and senior professionals" categories, while a further c.11% identified themselves as working in "elementary occupations". The remaining 27% fell into the categories of "professional", "associate", "administrative", "caring/leisure" and "sales and customer services".

3.2.10 Commuting Time

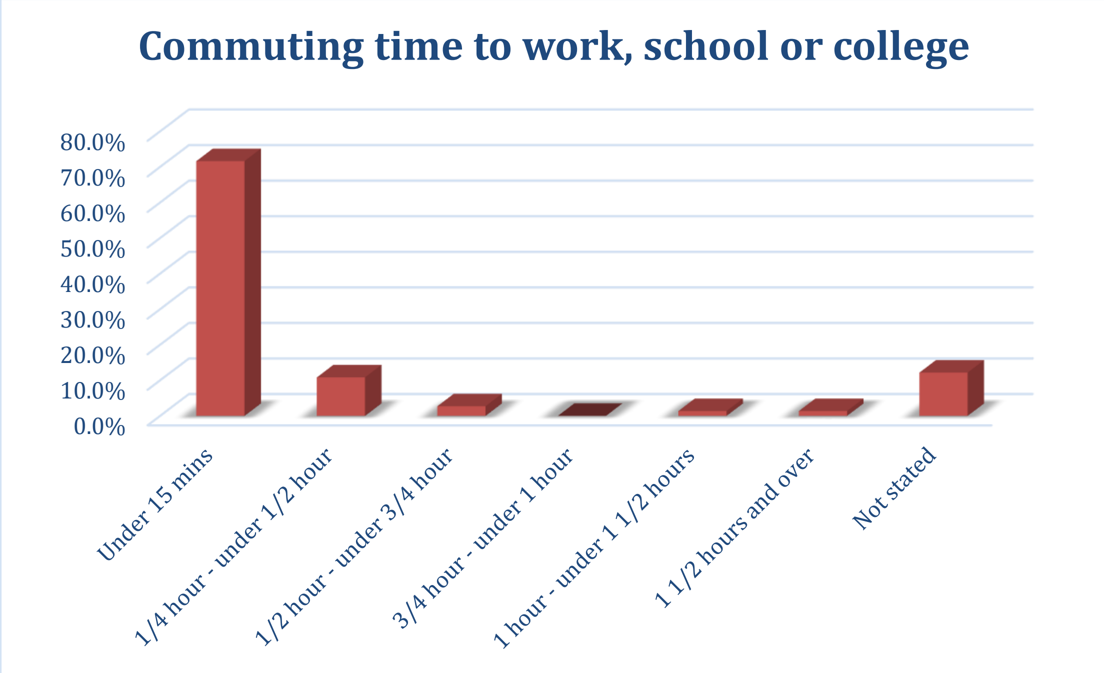

Figure 23: Commuting Time to Work, School or College as per 2016 Census

The vast majority of respondents (c.70%) to the 2016 census reported that the commute to work, school or college took no more than 15 minutes. Another c.9% stated that their commute time was between 15 – 30 minutes. Considering that the ferry takes 40 minutes to get to the mainland, this data shows that in 2016 at least 79% of islanders either worked or attended school on the island, while an additional 10% chose not to state their commute time. Of the remaining respondents, c.5% stated that their commute took between 30 minutes and 1.5 hours.

3.2.11 Persons at Work by Industry

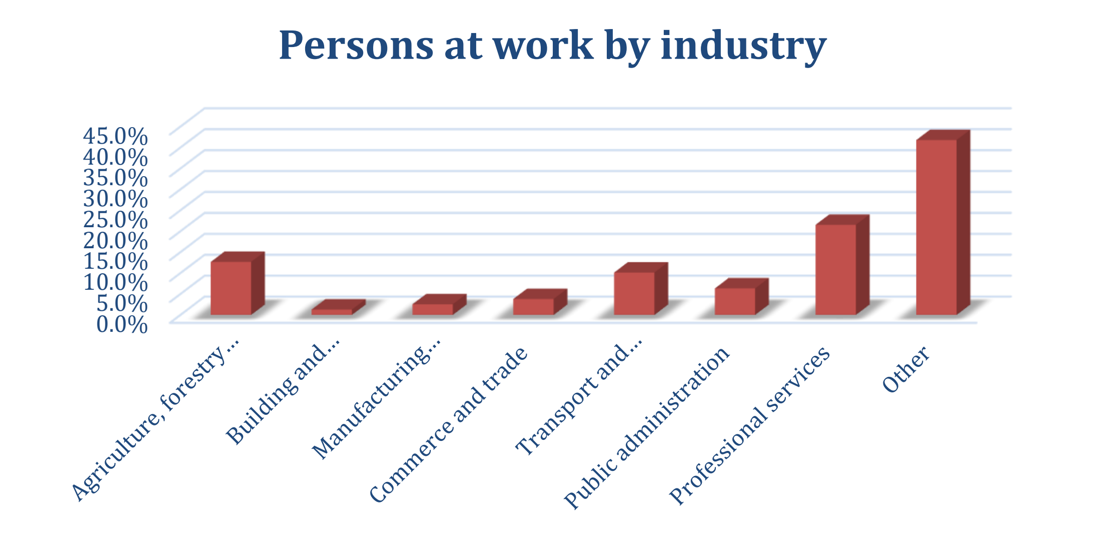

Figure 24: Persons at Work by Industry as per 2016 Census

According to census 2016 data, the majority of islanders worked in fields not identified by the census. A further 20% stated that they worked in "professional services" (very likely tourism), with another c.11% stating that they worked in the "agriculture and forestry" industry. Of the respondents, C.8% stated that they worked in "transport", while c.5.5% stated that they worked in the "public administration" arena. "Building", "manufacturing" and "trade" made up a further c.5% of the total.

3.2.12 Homes with Cars

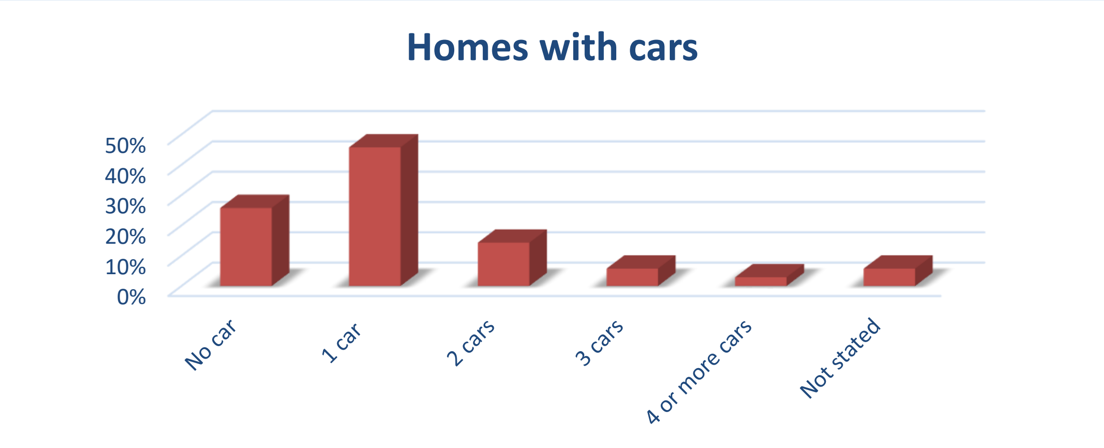

Figure 25: Homes with Cars as per 2016 Census

Interestingly, c. 22% of respondents to the 2016 census stated that they do not own a car, while c.41% stated that they own 1 car. A smaller number (c.10%) stated that they own 2 cars, while a small number of people (c.5%) stated that they own more than 2 cars.

3.3 Ecological situation

The Inishbofin Community Nature Plan 2016-2021 (Inishbofin Community Nature Plan 2016-2021, n.d.) identifies important Biodiversity considerations and actions on the island.

The plan identifies several wet and dry **habitats** on the commonage of the island, the patches of bog and marsh that mat be found, the beaches which contain excellent quality water, sea cliffs, sand dunes which were part of a previous conservation project and the brackish lagoon which is Lough Bofin.

Regarding **flora**, the plan notes the existence of a range of grasses and wildflowers, as well as species of grasses and herbs. It also notes Foxtail Stone Wort and two species of Tassleweed which all dwell in the lagoon and are not particularly common.

The island is home to some important **fauna.** Most notable are the birds, which includes the Corn Crake (which is on the Irish Red List of Birds of Conservation Concern). **The island is designated as a Special Protection Area under the EU Birds Directive for the Corncrake**. There are a wide range of other bird species which make their home on the island.

The ocean around the island is home to a wide range of fish and marine mammals, including dolphins, which are known to follow the ferry to and from the island at times, seals, and even whale species.

The island is a Special Area of Conservation under the EU Habitats Directive.

The rare bird species and rich marine life are of primary consideration for this study, which will qualitatively examine the possible impact on these species from the use of renewable energy technologies, particularly turbines.

4 Similar Island Projects

4.1 Inis Mor

Figure 26: House with PV Solar in Inis Mor Island - Image Source: Galway Beo

CASE STUDY	
Summary	In 2012, the Aran Islands Energy Cooperative was founded by a group of residents concerned about the island's reliance on fossil fuels. On their website www.aranislandsenergycoop.ie, the group describes itself as follows: "community owned energy cooperative" in which the island inhabitants are "working towards becoming self-sufficient in locally-generated renewable energy and free from dependence on oil, coal and gas by 2022." In addition to this, in 2020 Inis Mór was one of three islands chosen to participate in the 4-year REACT research project, the objective of which is to achieve island energy independence through renewable energy generation and storage, a demand response platform, and promoting user engagement in a local energy community. The aim of the project is to ensure that this island community achieves energy autonomy, as well as reducing energy-related greenhouse gas emissions.
About The Island	Inishmore is the largest of the three Aran Islands, and is

	located in Galway Bay, off the West coast of Ireland. Island residents speak the Irish language in the particular dialect of Connemara Irish. Steeped in culture and rich with the collective history of the Aran Islands, the earliest evidence of human habitation on Inis Mór dates back to 3,000BC, with examples of stone age and megalithic monuments found throughout the island. Today the island supports a permanent population of approximately 1,100, but the island can draw up to 3,000 tourists per day over the summer months.
Action taken	The Aran Islands Energy Cooperative has identified three key focus areas; heating, transport and energy generation. So far, the group have achieved the following: 1. Heating: Retrofit works have begun, with the aim of upgrading all 500 homes and other miscellaneous buildings on the island. Retrofit works include external wall insulation, heat pumps and solar PV. 2. Transport: The island now boasts a range of electric vehicles, having been chosen to participate in SEAI's 3-year Electric Vehicle pilot project in 2011. In addition to this, the island is home to over 1000 bicycles, of which a large proportion are electric. 3. Energy Generation: • Installation of heat pumps and solar PV panels to 250 houses. • 10 houses have installed ground-source heat pumps. • 100 houses have installed solar thermal panels. • Several homes and other miscellaneous buildings have installed battery storage.
Next Steps	• Early feasibility studies are underway to investigate the opportunities for wind-generation on Inis Mór. • There are currently two research projects underway (SEAFUEL and HUGE), which aim to investigate hydrogen production on the island and the potential to integrate this into the carbon reduction strategy of the island. • Investigating hydrogen-powered ferries to further reduce the islands reliance on fossil fuels.

4.2 Orkney

Figure 27: Wind Energy Farm Onshore in Orkney Island (Scotland) - Image Source: The Guardian

CASE STUDY	
Summary	In 2009 the Orkney Partnership, in collaboration with Orkney Islands Council, Orkney Renewable Energy Forum, Community Energy Scotland and the Highlands and Islands Enterprise, developed a Sustainable Energy Strategy for Orkney. This strategy has now been revised for the 2017 – 2025 period, with many initiatives now complete and still more in planning and development. Once utterly reliant on power from the Scottish mainland, Orkney now produces on average 120% of its electrical requirement per annum, thanks to their investment in renewable energy sources.
About The Island	Orkney lies 16km north of Scotland and is comprised of c. 50 islands, of which 20 are inhabited. The islands have been inhabited for the past 8,500 years, and the local people (known as Orcadians) speak the distinctive Scots language as well as Scots English. Orkney is a UNESCO World Heritage Site, having been granted the recognition in 1999 on foot of its most famous neolithic archaeological sites; Skara Brae, the Ring of Brodgar, the Standing Stones of Stenness and the Maeshowe chambered tomb. With a rich and varied history, Orkney was heavily influenced by Norse culture, serving as a strategic trading location for the Scandinavian kingdom

	from the 8th century until 1468, when the islands were taken over by the Scottish Crown. Today, Orkney has a population of 22,000, most of whom reside on the largest island (Mainland).
Action taken	The Sustainable Energy Strategy for Orkney (2009) identified three key focus areas: • To ensure Orkney uses energy as efficiently as possible, and has a secure and affordable energy supply to meet its future needs • To add value to Orkney's renewable energy resources, for the benefit of the local economy and local communities, whilst minimising damage to the environment • To reduce Orkney's carbon footprint The following progress has been made since the introduction of the Sustainable Energy Strategy for Orkney, as outlined in the updated Sustainable Energy Strategy 2017 - 2025: • Achieved an incredible uptake in EV ownership, giving Orkney the highest per-capita proportion of EV ownership in the UK. Orkney was also the first place on the UK to use wind turbines to charge EVs for domestic consumers. • The installation of 20 EV chargers in 2016, with more planned as demand grows. • The installation of 8 community-owned large-scale commercial wind turbines. • In 2016 Orkney produced 120.5% of its total electricity needs, and local production looks set to rise further with the installation of solar PV etc. • Orkney saw the installation of the first smart grid, enabling the island to facilitate Active Network Management. • Partnering with key stakeholders to investigate projects that will reduce carbon, such as Building Innovative Green Hydrogen in Isolated Territories (BIGHIT) Hydrogen. • The Council has reduced its carbon emissions by 18% over the last 10 years, after partnering with the Carbon Trust to initiate a carbon-reduction programme. • An increase in public awareness of environmental issues had led to a 42% increase in public bus usage in Orkney, with figures continuing to rise.

	• The installation of a sea-source heat pump at Stromness Library.
Next Steps	The Strategic Action Framework outlined in the Sustainable Energy Strategy 2017 – 2025 sets out specific actions to be taken in the following areas: 1. Maximum Local Value and Efficiency 2. Smart, Low Carbon Transport and Heat 3. Secure Transition to Renewable and Low Carbon Energy Systems 4. Smart Supportive Energy Investment 5. Develop and influence policy: delivering access to energy markets In addition to this, investigations are currently underway into the production and distribution of green hydrogen, with the Orkney island of Flotta having been identified as a potential location. The proposed development, Flotta Hydrogen Hub, aims to transform the existing crude oil processing station Flotta Terminal into a diversified energy hub. Here, green hydrogen will be produced both for local use, as a fuel for a new generation of ferries serving the island, as well as to facilitate the storage and transport of Orkney's abundant renewable energy resources to the mainland.

4.3 Samsø

Figure 28: Wind Energy Farm in Samsø Island (Denmark) - Image Source: Nordregio

CASE STUDY	
Summary	The Danish island of Samsø has transitioned entirely away from fossil fuels and now operates on 100% renewable energy, cementing its' status as the world's first renewable energy island. The island's key achievements to date are: • Achieving carbon negativity; • All renewable energy investments are in local ownership; • Numerous socio-economic benefits including mental health improvements. The Samsø community recognised that other communities around the world would benefit from learning about the measures implemented on Samsø, specifically how to kick-start and implement such an ambitious project. In order to implement this sharing of information, the island community established the Samsø Energy Academy, which aims to educate and resource energy development projects with an emphasis on international cooperation. In addition, the Samsø Energy Academy also organises and participates in knowledge exchange programmes; providing advice on sustainable community development and. They also organise study visits to Samsø, as well as running workshops and leadership programmes.
About The Island	Samsø is an island off the coast of Denmark, located 15km off the Jutland Peninsula. The island is 114km^2 in area and has a permanent population of c. 3,700 inhabitants. The island is steeped in history, with examples of monuments and archaeologically significant sites dating as far back as the palaeolithic period. In 1997 Samsø won a national competition and became Denmark's Renewable Energy Island. The challenge: To be 100% energy self-sufficient within 10 years. The island succeeded and by 2007 the island was self-sufficient due to the installation of wind turbines, biomass district heating plants and improvements to transportation and energy conservation.
Action taken	In 1997 Samsø become Denmark's first renewable energy island, giving the project an anticipated 10-year timeframe. At the time, the island's electricity was supplied by mainland Denmark's grid via an undersea cable, and the majority of the power was produced by coal. Oil shipped from the mainland was the primary energy source for heating Samsø's homes and businesses, as well as fueling the majority of transportation on the island. The masterplan outlined the following key objectives:

	• Installing both on-shore and off-shore wind turbines; • Replacing the existing oil-fired heating systems with biomass and electric alternatives; • The installation and commissioning of new district heating plants; • The opportunity to install solar PV; • Investing in energy efficiency measures; • Encouraging and incentivising EV ownership. 10 years after the masterplan was implemented, Samsø succeeded in reducing its annually CO2 emissions to almost zero. This effective carbon neutrality was achieved through strategic investments in the following areas: • Installing a total of 11 on-shore and 10 off-shore wind turbines; • Commissioning 4 biomass-fueled district-heating plants to serve the local community; • The widespread installation of solar panels and incentivisation of electric vehicles, enabling Samsø to become fully energy self-sufficient. Interestingly, 70% of the total DDK 468,000,000 invested in the project came from local investors, and community engagement has been identified as having played a pivotal role in the success of the project overall.
Next Steps	Samsø has not stopped at energy self-sufficiency. They have now turned their focus toward carbon emissions, and have resolved to become completely carbon-free by 2030. The group aims to meet all of the island's energy needs with renewable energy, meaning that no fossil fuels will be imported or used on he island. In order to achieve this, the island community will electrify their heating and transportation systems, as well as replacing any marine-oil based fuel with a renewable alternative such as biofuel.

5 Relevant Policies & Stakeholders

5.1 The Climate Action Plan 2021

The 2021 Climate Action Plan (Department of the Environmnet, n.d.) details Ireland's strategy to unachieved a 51% reduction in overall greenhouse gas emissions by 2030, with a pathway to zero emissions being established by 2050. Gov.ie notes:

"It will put Ireland on a more sustainable path; cut emissions; create a cleaner, greener economy and society; and protect us from the devastating consequences of climate change. It is a huge opportunity to create new jobs and grow businesses in areas like offshore wind; cutting-edge agriculture; and retrofitting, making our homes warmer and safer."

Key deliverables of the plan relevant to this document include:

5.1.1 Electricity

- Increasing renewable electricity up to 80% by 2030.
- Reduction in electricity emissions by 62-81%.
- The introduction of support schemes for homeowners, farmers, business and communities to generate electricity and sell it to the grid.

5.1.2 Enterprise:

- IDA, Enterprise Ireland and SEAI to promote investment and employment in decarbonisation.
- Introduce new obligation to ensure a proportion of energy for heat comes from renewable sources.

5.1.3 Homes and Buildings

- Drive demand with the new National Retrofit Plan
- Blend low-cost loans with SEAI grants to make retrofit affordable.
- Open three training centres for retrofit upskilling.
- Promote use of electric heat pump or other low carbon technology in new and existing residential and commercial buildings.

5.1.4 Transport

- Increase the use of biofuels in transport
- Increase the number of EVs to circa 1 million by 2030

5.1.5 Agriculture

- Produce 1.6TWh of indigenous, sustainably produced biomethane per year.

5.1.6 Just Transition

- Establish a Just Transition Commission to integrate just transition principles into climate policy.

5.1.7 Citizen Engagement and Community Leadership

- Empower everyone to help deliver on our goal of a climate neutral economy by 2050.

- Promote active engagement at local level- provide financial support for innovations, host climate conversations, support capacity buildings, empower local communities to transition to carbon neutrality in a way that is meaningful to them.
- Increase the number of Sustainable Energy Communities to 1,500 by 2030.

5.1.8 Carbon Pricing & Cross-Cutting Policies

- Develop green hydrogen supply and demand
- Promote the digital transformation, sustainable remote working practices and the roll-out of the National Broadband Plan.
- Support research, development and innovation in climate action.

There are many other important deliverables that are relevant to sustainability on the island, but not specific to this plan.

5.2 Community Engagement

The community is the most important stakeholder in any energy transition project, and good community engagement means the difference between a highly successful, impactful project that hugely reduces emissions and overhauls the local economy, and a project which divides communities, creates tension and is unnecessarily costly. To ensure effective community engagement, Thomas Neilsen was engaged to undertake a direct mini-study into community engagement for island energy projects.

This study has been reproduced in full in the appendix, and the conclusion is presented here:

5.2.1 Community Engagement Acceptability Study

Conclusion

Community engagement is an essential part of an island energy project. It can lead to more acceptable outcomes but only when it is done in the right way. To foster acceptability and avoid public resistance against the energy project on Inishbofin, responsible actors should consider gaining the trust, including the priorities, and respecting areas of significance to the island's residents. Earlier island energy projects teach us that a project may affect people's financial outlook. The project on Inishbofin should be designed to avoid that people's main form of income is affected and instead reactivate them in the planning and maintenance of the new energy system. Certain areas that hold significance may also be affected by the presence of renewable energy. Therefore, responsible actors should consult residents on how best to implement energy systems in line with the meaning people prescribe to such areas. Lastly, the priorities that people find most important in life should be included in planning a project. If people feel like their major concerns are reflected in the project, they will be more likely to accept solutions for making Inishbofin self-sustained on renewable energy.

5.2.2 Inishbofin Community Engagement Strategy

Noting the importance of Community Engagement as highlighted by the mini-study in the subsection above, a specific strategy was developed by the IDCL, KRA Renewables and Thomas Neilsen to engage effectively with the Inishbofin community. This strategy can be summarised as follows:

1. Ensure the highest level of accuracy possible in all evaluation and analysis work, to minimise any potential mis-portrayal during the study.
2. Engage with "EC^2 Energy Citizenship and Energy Communities for a Clean-Energy Transition" which is gathering insights in the fields of law, economics and psychology to answer questions on citizenship and community engagement.
3. Present the preliminary findings of the technical and financial elements of the study to the community on the island in a presentation event, including a Q&A.
4. Distribute a survey to the community members to collect empirical data regarding community acceptance of various aspect of the energy transition plan, and the initiatives which surround it.
5. Incorporate the findings of the community survey along with the technical and economic aspect in a techno-socio-economic scoring methodology to the solutions examined within the plan.

6 Island-level Energy Baseline

The following graph shows the division of energy usage between electricity, thermal energy and transport energy (incl. ferries) on the island. In total, the island is estimated to use 6.67GWh of energy annually.

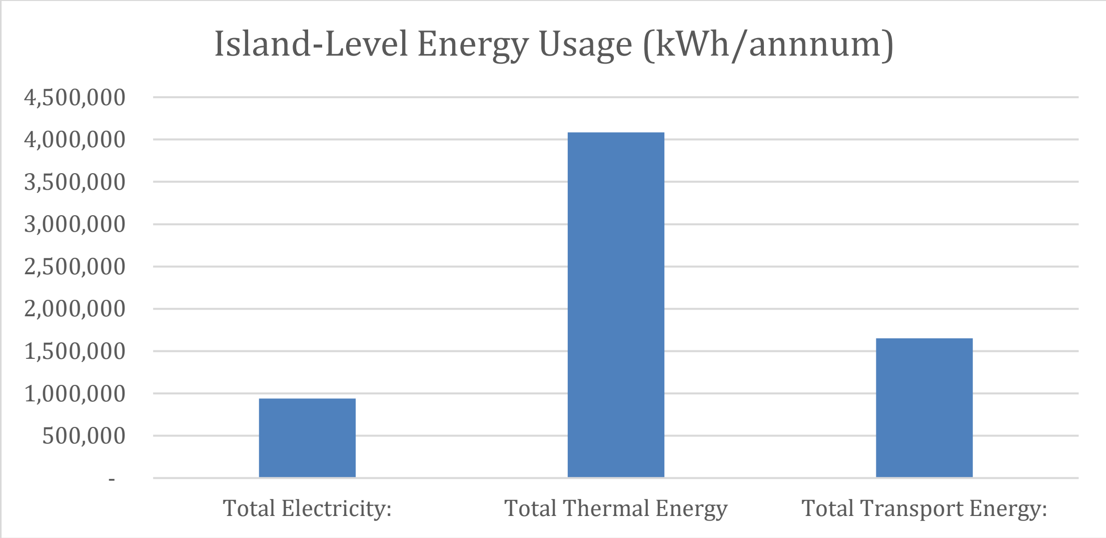

Figure 29: Energy Usage by Sector

By fuel type, this equates to the following usage:

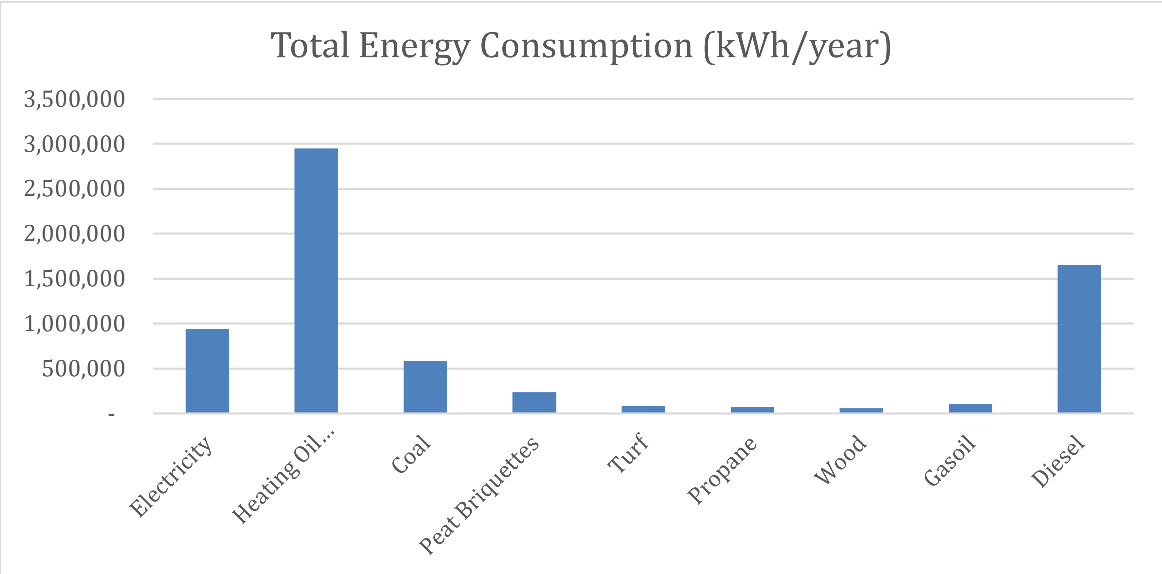

Figure 30: Energy Usage by Fuel Type

This energy usage results in the following annual CO2 emissions:

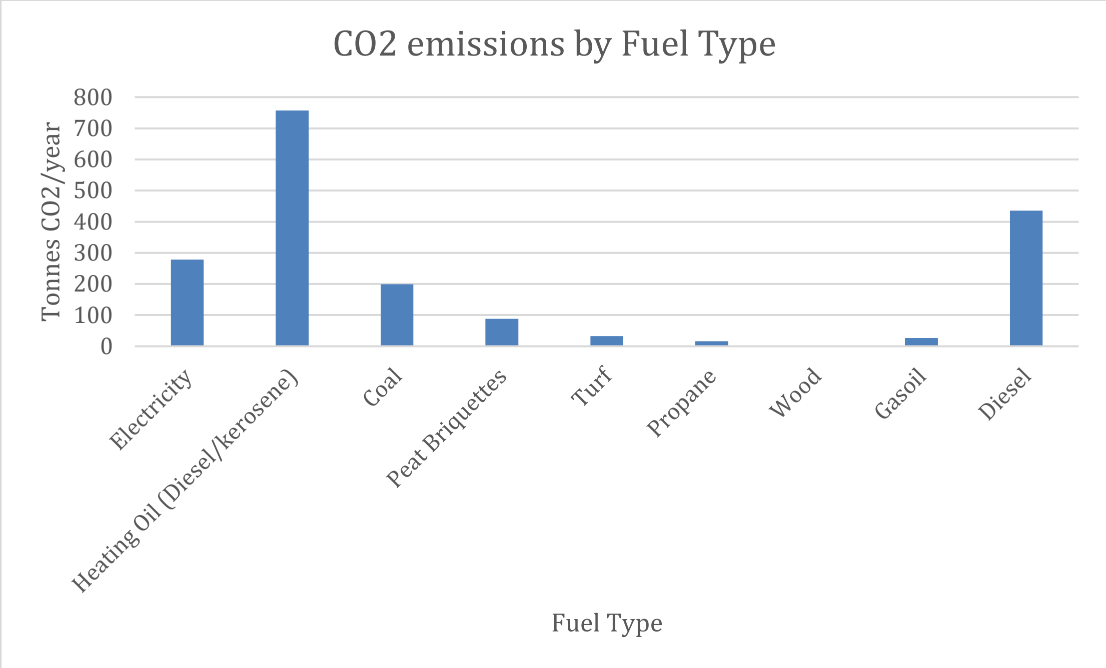

Figure 31: CO2 Emissions by Fuel Type

In total, over **1,800 tonnes** of CO_2 are emitted across all sectors of the island per year.

Finally, the costs of energy can be divided as follows:

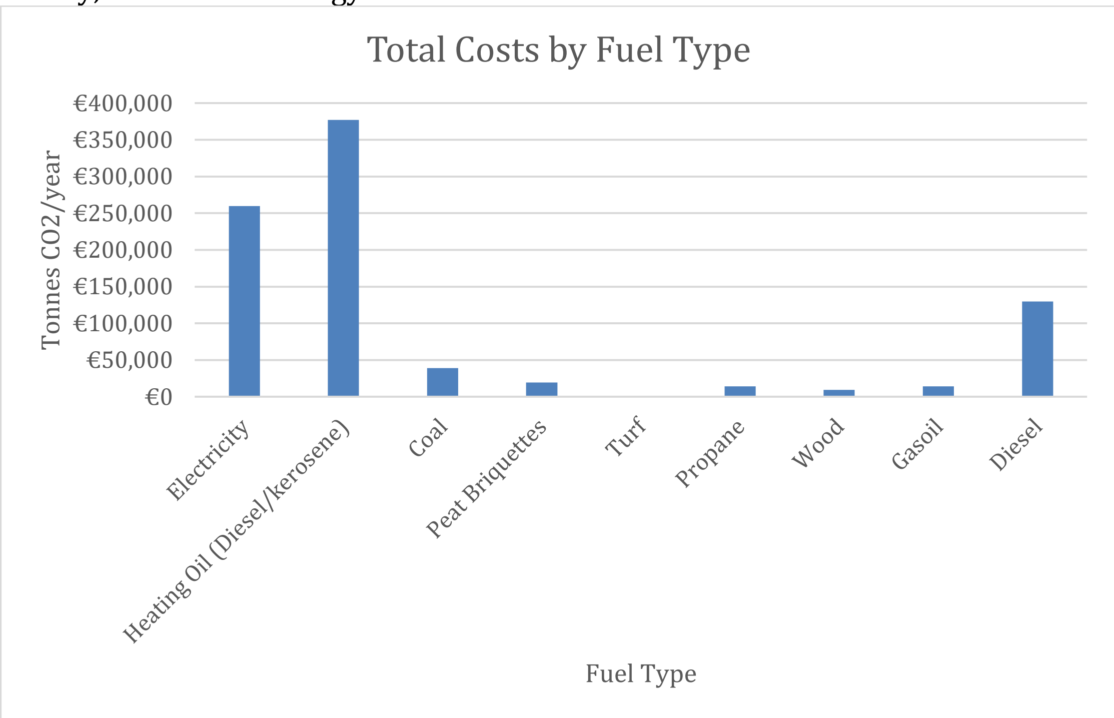

Figure 32: Energy Cost by Fuel Type

5 Sectors of energy use were identified; Domestic, Community Centre, Commercial, Land Transport and Sea Transport.

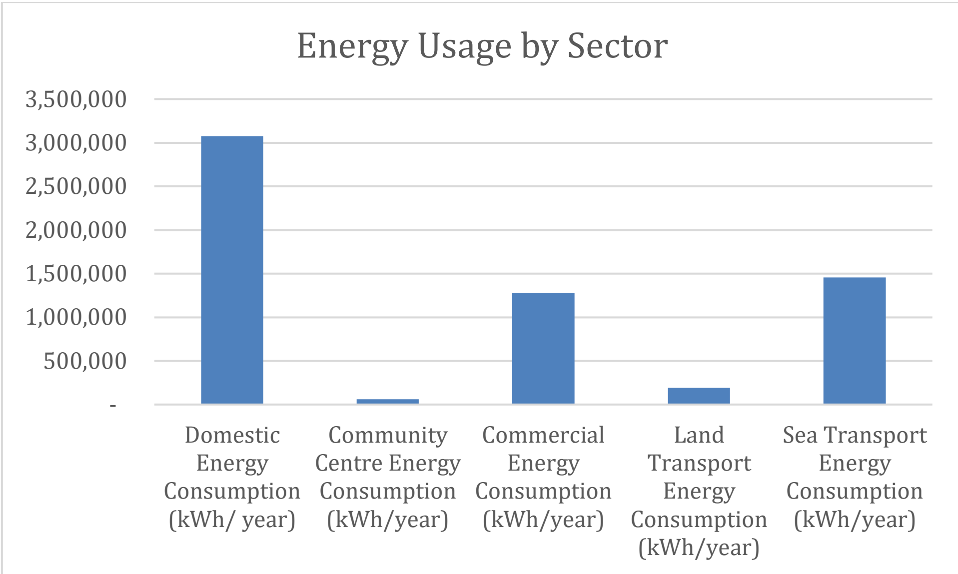

Figure 33: Energy Usage by Sector

One of the most important elements when considering the efficiency, and especially generation, options later in this report is not only total usage but an estimation of the *profile* of usage across an average year. To that aim, the following profiles were estimated for every fuel type:

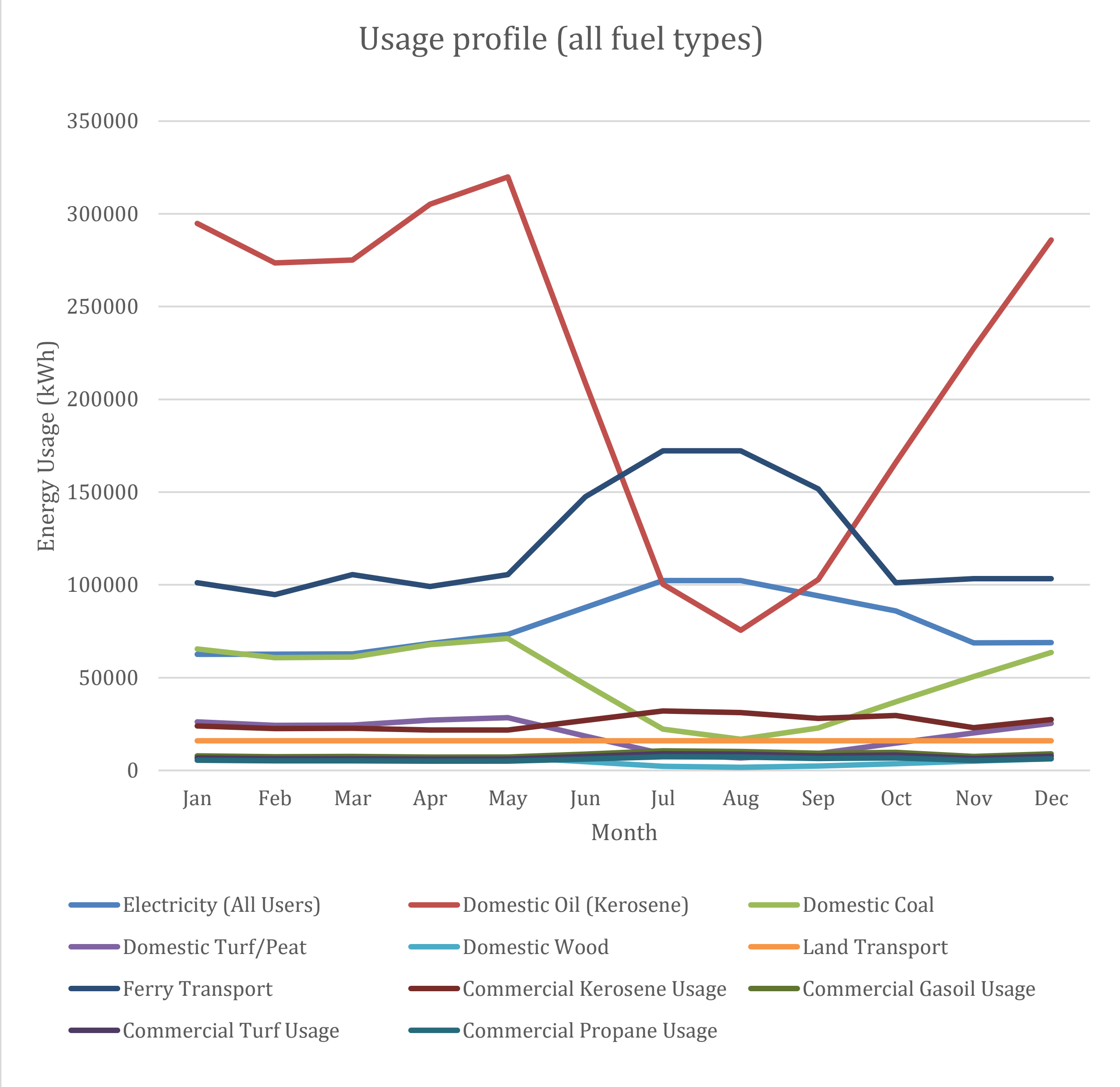

Figure 34: Profiles of Thermal Usage across all fuel types

6.1 Thermal Usage

Thermal usage for the Domestic, Community Centre and Commercial sectors are outlined below:

6.1.1 Domestic Thermal Usage

The 2021 survey indicated that there are 215 total houses on the island, of which 38 are ruins and 7 are permanently vacant, leaving a total of 170 properties which contribute to overall domestic energy usage.

Figure 35: Breakdown of housing on the island

Of these 170 properties;

- 68 are full-time owner occupied, and will contribute the largest share of thermal energy usage.
- 59 are holiday homes. These will contribute the smallest share, as the primary tourist season is the summer time, when thermal demand is lowest.
- 43 are rental properties.
  - 11 of the rental properties are long-term rentals, and will be assumed to have an occupation profile comparable to full-time owner occupied homes.
  - 32 are seasonal rental properties, which will be assumed to have an occupation and thermal demand profile comparable to holiday homes.
- Overall, that leads to 79 properties with a year-round energy usage profile, and 70 properties with a summer energy usage profile.

6.1.1.1 Energy Efficiency of Homes

There are very few published BERs (Building Energy Ratings) for homes on the island, with only 2 in the BER database. This makes establishing the energy usage of homes deeply challenging.

KRA undertook "preliminary" BER surveys of 2 homes on the island, to have a slightly larger sample to work with. These four BERs can be used as a **very rough** approximation of domestic energy use on the island, and are summarised here:

Table 2: Known Domestic BERs on island

Database/KRA	Energy Usage (kWh/M2/year)	Rating	Area (m2)	Total Energy Usage (kWh/year)	Heating Method	Location
Database	147.3	B3	131*	19346		Unknown
Database	1030.9	G	131*	135393		Unknown
KRA	654.16	G	155.6	101787	Open Fire w/ Back Boiler	Fawnmore
KRA	385.9	F	107.07	41318	Oil Boiler	Middlequarter
Average	554.565			71553		

The BER system assumes that homes are occupied year-round. Applying the known total usage figure to the year-round dwellings gives an estimated total energy usage figure of 5,652MWh of energy across these homes yearly (thermal and electrical).
As the two houses surveyed by KRA were vacant at the time, it was assumed that this estimation of performance was overly pessimistic. Taking an **assumed** BER rating of E (320kWh/m2/year) for the average house on the island, this led to a usage of circa 3,002MWh/year for permanent residences, and 629MWh/year for homes occupied primarily over the summer tourist season (assumed to be 150 days, mid-April to mid-September).

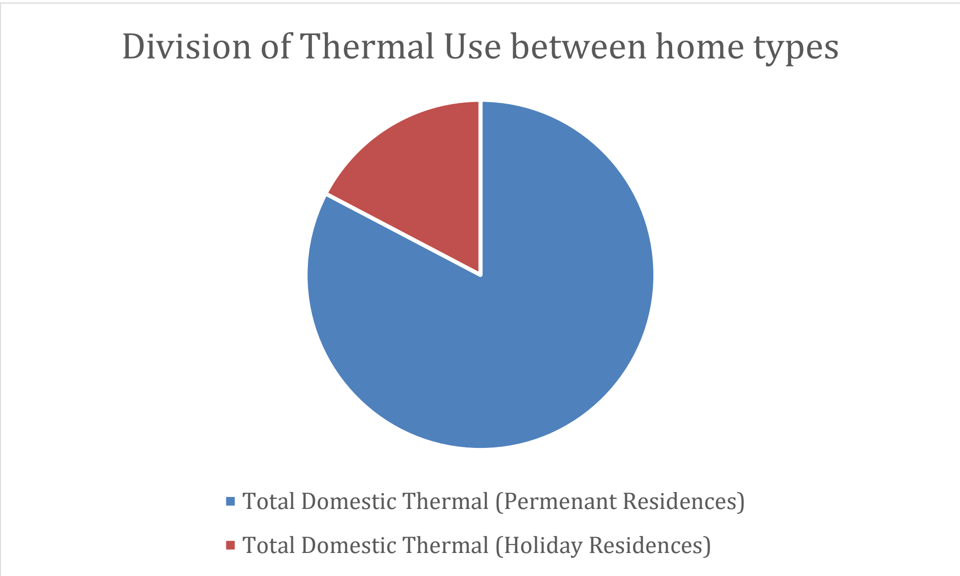

Figure 36: Division of thermal usage between home types

Permanent homes obviously dominate thermal usage, as they are occupied during the colder months.

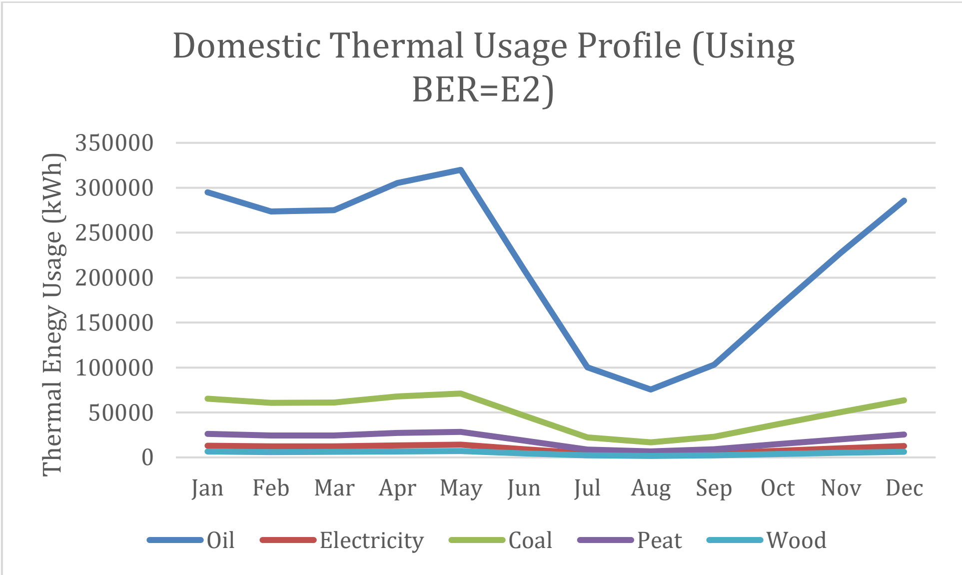

Figure 37: Domestic Thermal Energy Use by Fuel Type

It can be seen from the figure above that usage of thermal energy is seen to drop significantly over the summer months, despite the increased presence on the island from tourists.

6.1.2 Community Centre Thermal Usage

Usage for the community centre is outlined in depth in the Community Centre Audit section. It uses a very small share (<1%) of total energy usage on the island.

6.1.3 Commercial Thermal Usage

There are 3 hotels on the island (with seasonal restaurants);

- The Dolphin Hotel- 8 Rooms
- Doonmore Hotel- 22 rooms
- Inishbofin House Hotel- 35 rooms

There are 7 B&Bs offering accommodation on the island:

- The Beach Bar – 4 rooms (contains only year-round restaurant).
- St Ellen's – 3 rooms
- Lapwing House- 2 rooms

- Culu- 3 rooms
- The Galley – 4 rooms (contains seasonal restaurant)
- Emerald Cottage – 2 rooms
- The Hostel – 5 rooms.

It is estimated that between hotels and B&Bs, there are 49,650[2] overnight stays on the island each year, plus around 30,000 day-trippers.

There is only one shop (the Pier Shop), which has only an electrical demand and does not contribute to the thermal consumption.

To estimate the thermal usage of the commercial entities on the island, thermal usage information was collected for one hotel (Inishbofin House Hotel) and one B&B (The Beach Bar) and extrapolated across the other hotels and B&Bs proportionally to their size (in estimated overnight stays per season). As there was no coherent monthly division of usage, total usage was divided over the year by combining two methods: the Heating Degree Days for each month of the year, and following the electrical usage profile for commercial entities (which was known at monthly granularity).

6.2 Transportation Fuel

Transport overall is a very large energy user for the island, with the vast proportion of transport energy being transportation to and from the island by ferry. Transport is responsible for over 435 tonnes of CO_2 emissions (circa 24% of total) per annum, and costs circa **€130,000.**

[2] Taking a season length of 150 days, and using the relative capacity of each room in each property, not listed here.

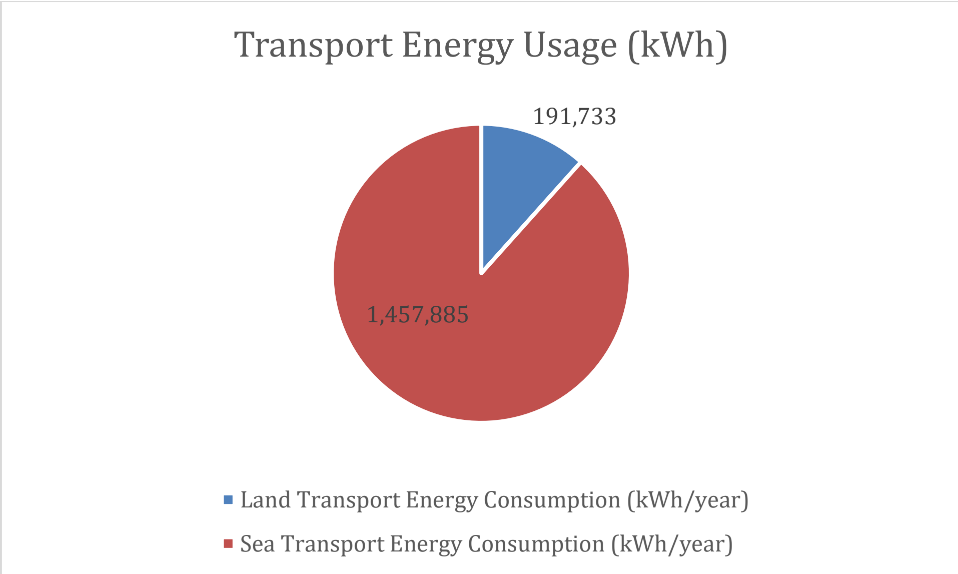

Figure 38: Division of Transport Energy between Land and Ferry

6.2.1.1 Transport to and from the islands

Almost all transportation to and from the island is conducted by the Inishbofin Ferry (Inishbofin Ferry Website, n.d.), which operates from Cleggan Harbour to Inishbofin Harbour. There is both a passenger ferry and a cargo ferry.

The main passenger ferry (the "Island Adventure") typically operates two return journeys per day, subject to weather conditions. More journeys operate in summer to cater for the tourist season. In total, 1,700 single journeys per year are estimated for the ferry.

The older passenger ferry (the "Island Discovery") only operates in the summer season when capacity of the main ferry is insufficient. It operates an estimated 184 journeys per year.

The cargo ferry (the "Rassay") typically operates two return journeys per week, subject to weather conditions. All vehicles, livestock and construction materials are transported to the island by cargo ferry. It operates an estimated 412 journeys per year.

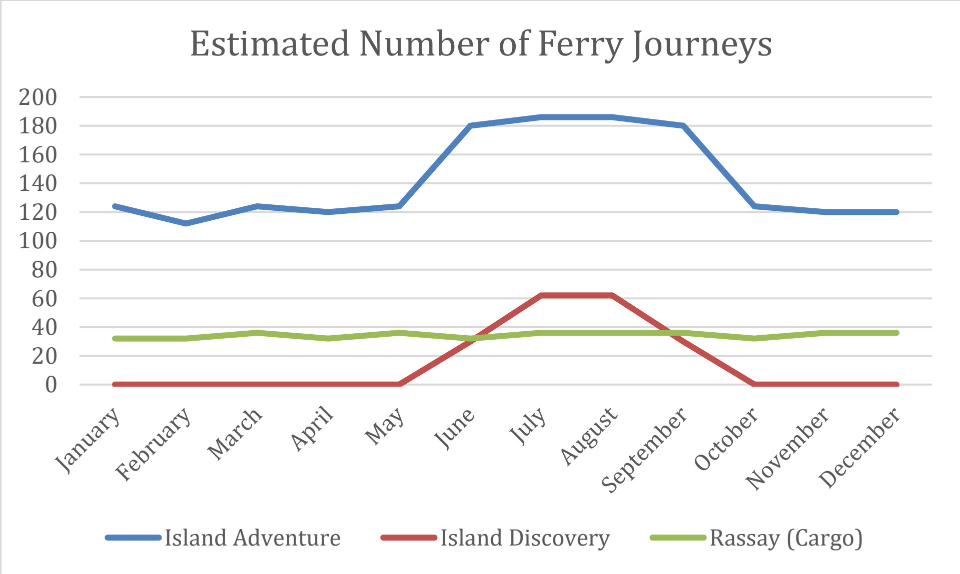

Figure 39: Estimated Number of Ferry Journeys

Taking an average usage of 7,500L of diesel fuel per month for the Island Adventure (approximate figure supplied by the Inishbofin Ferry Company), and assuming that each ferry has approximately equal fuel economy, the total energy usage of each ferry has been calculated as follows:

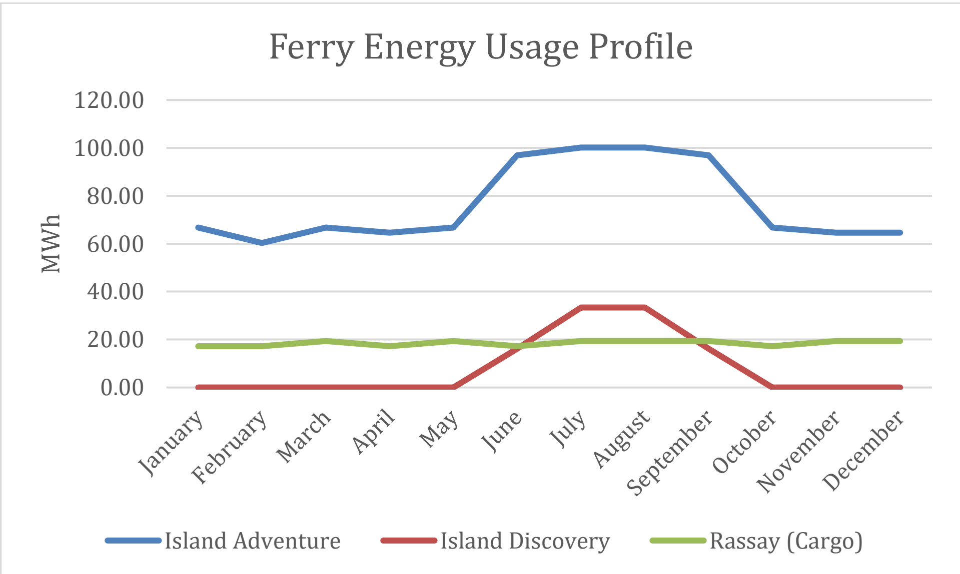

Figure 40: Ferry Energy Usage Profile

The total annual usage is estimated at over **1,450MWh** of diesel fuel, responsible for **over 380 tonnes** of carbon emissions, and at a cost of circa **€115,000/annum**[3]

6.2.1.2 Transport on the island

There is no public transport on the island. Given the relatively small distances involved, many islanders travel by foot (24%[4]), and some travel by bicycle. The predominant mode of transport on the island is nevertheless cars. The second largest mode of transport is boats.
A survey of vehicles on the island estimated that there are a total of 123 operational cars on the island (23 in West Quarter, 17 in Fawnmore, 43 in Middlequarter, and 40 in Cloonamore). There are 23 boats, 3 trucks, 5 quads and 9 motorbikes.
There are 4 tractors on the island.
There are also 6 dumpers, 3 diggers and 1 teleporter, assumedly all for construction.

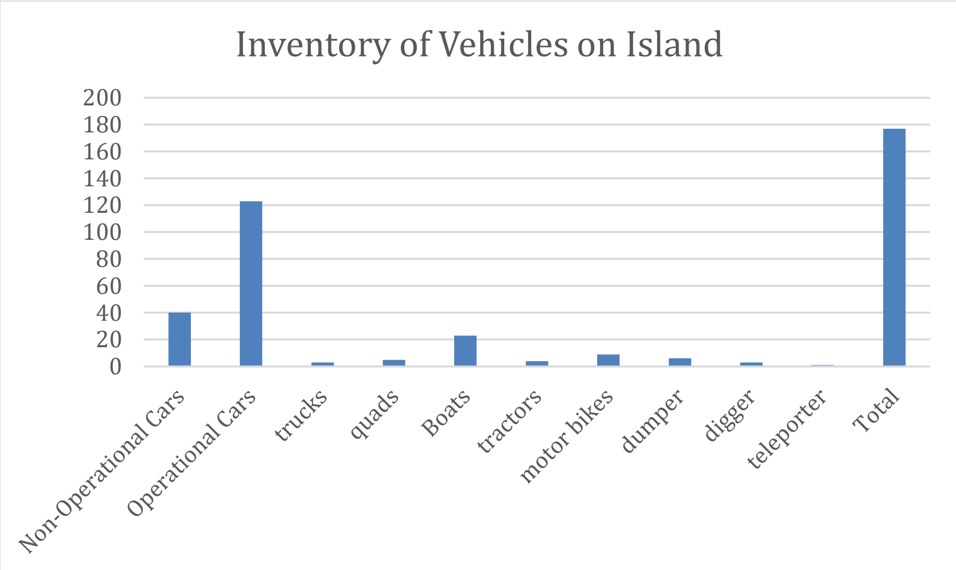

Figure 41: Inventory of Vehicles on Island

An estimation of fuel usage for land vehicles is highly challenging. Several approaches were undertaken, and compared with each other.

For the first approach, it was assumed that:

- All vehicles use diesel, for simplicity.

[3] Taking a current fuel cost of €0.8/L of diesel, as no cost information was made available.
[4] CSO data 2016 Census

- Diesel costs €0.8/L.
- The average fuel economy of a car on the island is 9L/100km.
- The average car undertakes 10 journeys per week, each half the length of the island (25km/week)
- The average car uses the same amount of fuel as every other vehicle (this assumption is certainly incorrect, but it is thought that vehicles that use less fuel (e.g. motorbikes and quads) will balance out those that use more fuel (e.g. tractors and diggers).

This led to an estimate of circa 20,00L of diesel used per year (210,500kWh), emitting 56 tonnes of CO2 and costing €16,500 per year.

To verify this estimate, another method was taken. In this second method, the total diesel & kerosene delivered to the island together was used. No exact figures were available for analysis, but an overall estimated combined figure of 40,000-45,000L of combined diesel and kerosene were taken.

It was then assumed (arbitrarily) that 60% of the fuel was for heating and 40% was for transport. This leads to a figure of 17,000L of diesel (173,000kWh), emitting circa 46 tonnes of CO_2 and costing €13,600 per year.

Taking a centre-point of these two estimates gives an annual land-transport usage figure of circa **192,000kWh**, or 16,000kWh/month, emitting **50 tonnes of CO_2** and costing circa **€15,000 per year**.

6.3 Electricity

Electricity usage on the island currently makes up an estimated 14% of total energy usage and is responsible for 15% of total carbon emissions and 27.5% of total costs. Electrification is a critical step for the decarbonisation of heating and transport on the island, and understanding the electrical infrastructure and current usage is an important step in the overall understanding of energy usage on the island now and in the future.

6.3.1 Electrical Infrastructure

Electrical infrastructure on the island is entirely above-ground and pole-mounted. The island is fed by a main incomer which comes from the 38kV substation in Clifden and lands at a substation on the southern side of the island.

The total capacity of the incoming cable was determined to be 11.4MVA, during an analysis carried out by the NESOI partners in the island study.

Before the beginning of this project, this main incomer was an **unmetered cable**, with no island-wide usage data being available at any time interval.

Utilising the ESB Heatmap, and assuming an island level power factor of 0.95, the following table of transformers was constructed:

Table 3: Pole-Mounted Transformer Characteristics

ESB pole substation id	Installed Capacity (kVA)	Capacity used (kVA)	Capacity used -MIC (kW)	Generation Capacity
252594X	50	31	29.45	50
252624X	50	39	37.05	60
252605X	50	50	47.5	60
252604X	200	58	55.1	200
252609X	50	31	29.45	50
252599X	50	17	16.15	50
Total	450	226	214.7	470

There are 6 pole-mounted substations, with 5 rated at 50kVA and 1 rated at 200kVA. The locations of the transformers are shown below, with the 200kVA transformer being the one located close to the old harbour (the right amber marker).

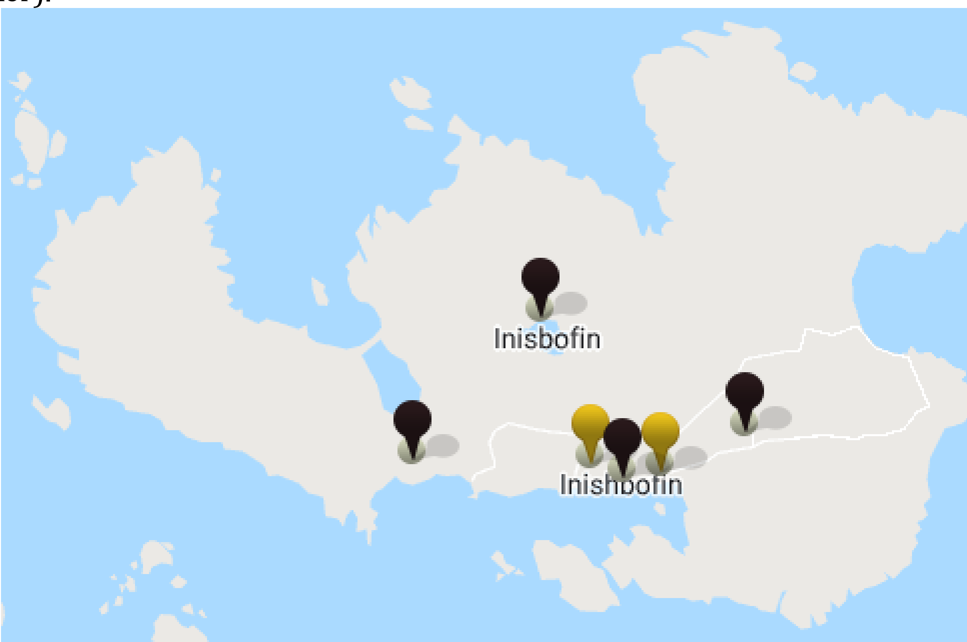

Figure 42: Transformer Locations (Source Pending)

Noting that the ESB Heatmap cannot guarantee the accuracy of the usage figures, we can draw the following tentative conclusions:

1. The maximum island wide electrical **power**[5] demand before major upgrades to the electrical system is 450kVA (circa 427kW estimated).
2. The estimated maximum power demand at any one time (which will be taken to be the island's Maximum Import Capacity (MIC) is 214kW under current utilisation.
3. The maximum generation (renewable energy on the island) that can be accepted on to the network before major upgrades is 470kVA.
4. The maximum yearly electrical use on the island before major upgrades is 3,745MWh.[6]
5. The maximum yearly electrical usage from current ESB estimated of utilisation (point 2 in this list) is 1,880MWh. Maximum usage in any given month is 160MWh. These figures represent a sensible cap to yearly estimates of usage.
6. The cable itself is sufficiently large to accept as much power as the island could ever want to import or export without replacement, though upgrades may be required to the power processing equipment (switchgear, transformers etc.)

Enel X installation engineers installed a meter on the main incomer to the island, which logs electrical usage in half-hourly intervals. The data from this meter is accessible through an online portal, and was made available to the IDCL. Data begins on the 18th of Feb 2022 and should exist in perpetuity.

6.3.2 Electricity Usage

As outlined in the methodology, capturing the electrical usage of the island was both very important and deeply challenging.

6.3.2.1 Island Usage March 2022

Figure X below shows the actual power demand of the island for a 1-month period from 21st of Feb-22nd Mar. This is taken directly from the Enel X portal for the meter on-site.

It can be seen that power demand is relatively predictable, with the maximum average power for any half-hourly period in that time being 159kW, and the

[5] Instantaneous energy usage, measured in kW or kVA rather than kWh or MWh.
[6] 450kVA* 0.95*8760/1000, where 0.95 is the assumed power factor, 8760 is the hours in a year and 1000 is the conversion factor from kWh to MWh.

minimum being 54kW. Average usage was 90.6kW. This is significantly below the MIC of 214kW.

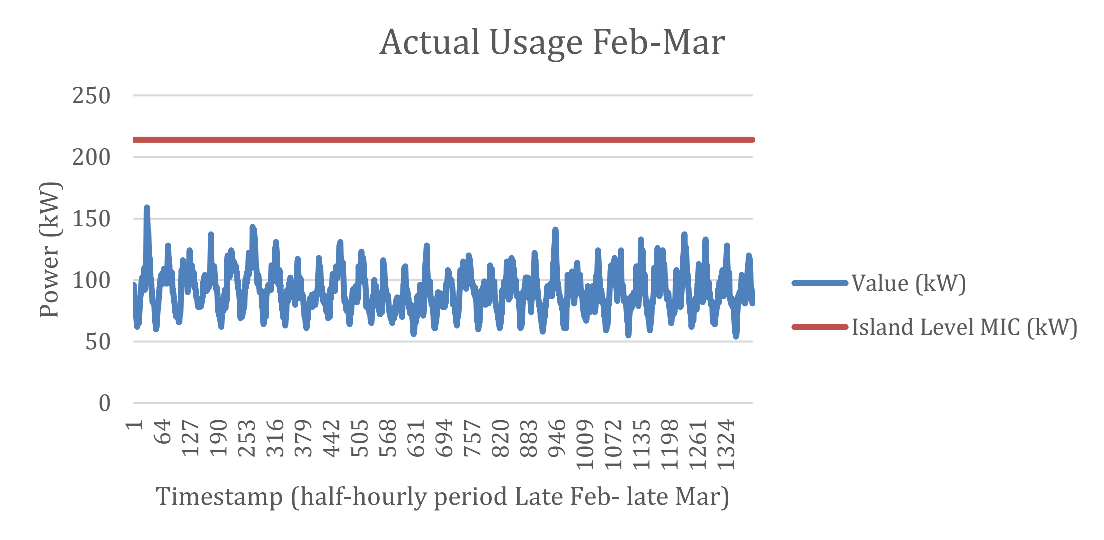

Figure 43: Real Island-Wide Usage Data 21st Feb-22nd Mar

The demand profile for 3 days chosen at random (24th of Feb, 5th Mar and 18th Mar, a Thursday, Saturday and Friday respectively) are shown below. Midnight usage begins around 90kW, dropping slightly towards 5:00 to circa 65kW, with a morning peak around 11:00-13:00, and a larger evening peak of 110-140kW between 18:00 and 20:00.

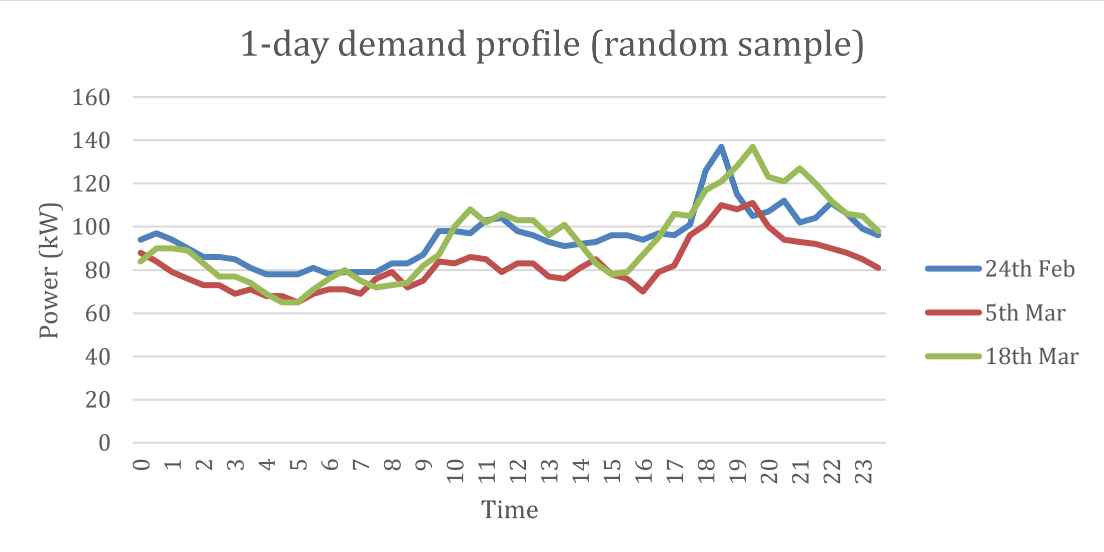

Figure 44: Demand profile for day chosen at random

A linear extrapolation of this usage across the entire year would amount to a **total yearly consumption of circa 753,000kWh**, however this metering period is outside of the tourist season, and so billing data must be examined to establish a broader usage profile. This figure broadly sets a lower-limit on sensible consideration of usage across the year.

6.3.2.2 Loads with Significant Seasonal Variation

Electricity bills were gathered for 4 of the major loads on the island that vary with the tourist season: the Community Centre, the Pier Shop, The Beach B&B, and Inishbofin House Hotel. These were examined as outlined in the description, to yield the below demand profile:

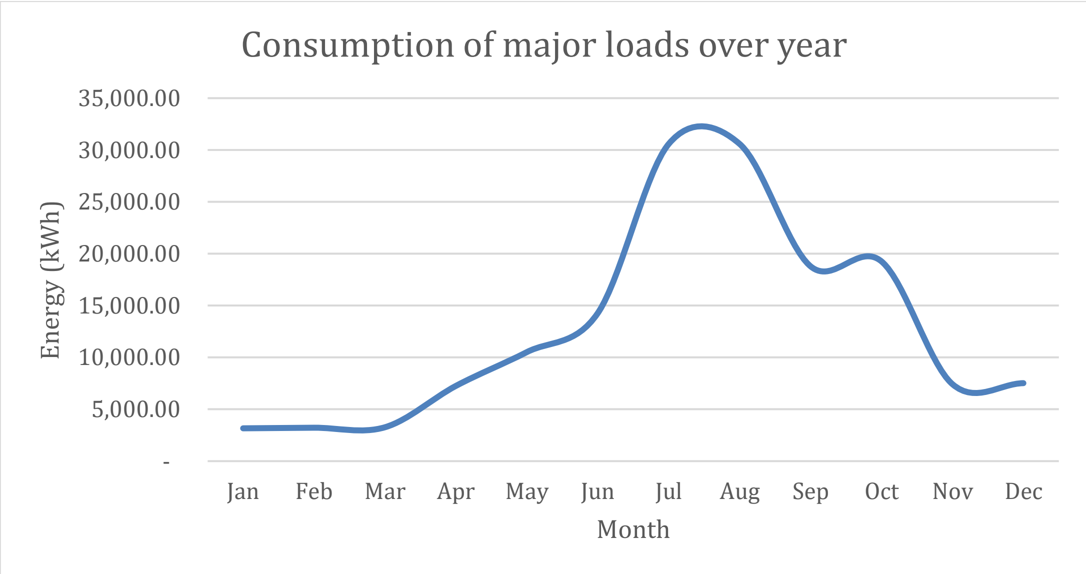

Figure 45: Electrical Consumption Profile of 4 Major Loads on Island

Total usage across the four properties for a year amounts to circa 155,000kWh. In March, total usage billed was 3,270kWh. Assuming that usage for March was typical for both the year of bill collection and 2022 (the metering period), this equates to 5.2% of total demand for the island over this time period.

It is important to note the profile of usage, which is expected to be typical of businesses on the island which cater to the tourist season, with low winter usage and high summer usage. This effect is very pronounced for these properties, with summer electricity usage nearly 10 times higher than winter usage.

Other loads which are anticipated to have a similar usage profile include the 3 hotels (one of which is represented above), 7 B&Bs (1 represented), 51 self-catering properties and the water pumping station. All of these will be significantly affected by the tourist season.

6.3.2.3 Estimation of Island-Level Annual Electrical Profile

To establish an overall electricity consumption profile for the year the following assumptions were made:

1. The daily and weekly profile shapes remained relatively unchanged.
2. The baseline around which the electricity usage varied increased in the summer months due to more presence on the island.
3. There was no major increase in winter electricity, as at present very little heating is electrical. There will be an increase from lighting, but this will be very minimal compared to summer increases.
4. The general shape of the profile followed that of the profile seen across the 4 major commercial loads, but with a less pronounced summer peak due to loads which do not increase in summer (e.g. year-round domestic loads).

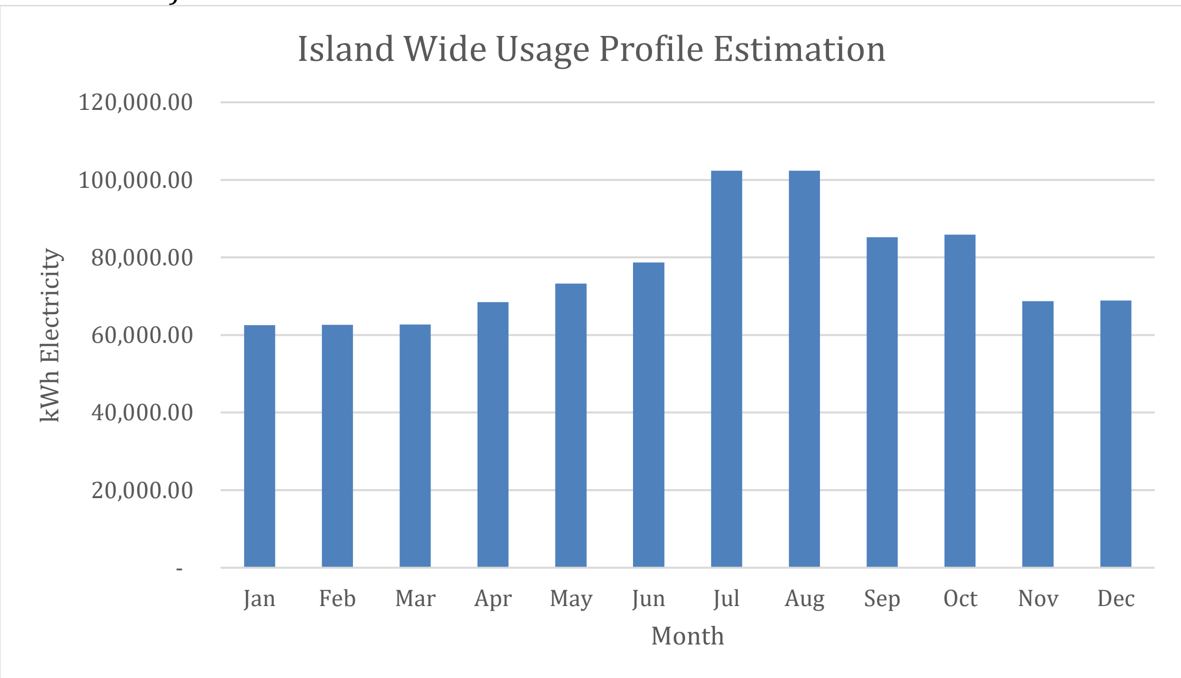

Figure 46: Estimated Annual Electrical Consumption Profile for Island

This methodology yielded an estimated yearly consumption of circa 939MWh/annum of electricity, island-wide.

6.3.2.4 Verification of Electricity Yearly Usage

A second estimation method was used to check the accuracy of the first method. In this a “bottom-up” approach was taken, using sampling and estimation across the different user types.

6.3.2.4.1 Domestic Estimation

To estimate Domestic Electricity Usage, a sample (N=12) of domestic electricity usage (shown in appendix) was taken from data supplied for 2019-2021, along with the number of occupants. The total usage was then divided by the occupants to get an estimated domestic electricity usage per person of 952kWh/person/annum. This was then multiplied by the total number of residents to find a figure of circa 169MWh/annum of domestic electricity usage.

6.3.2.4.2 Community Centre, Pier Shop and Pumping Station

Actual bills were utilised for the Community Centre and Pier Shop for 2019 (pre-pandemic). For the water pumping station, the total usage since system upgrades (204,000kWh) was divided by the years of operation (6) to achieve an approximate yearly usage of 34MWh.

6.3.2.4.3 Hotel and Hostel Estimation

Billing data was gathered for one of the 3 hotels, and one of the 7 B&Bs for the island. This was then assumed to be proportional to the number of tourists catered to annual, and extrapolated to the assumed number of tourists for every hotel and B&B on the island[7].

This methodology resulting in the below estimated division of current electricity usage on the island.

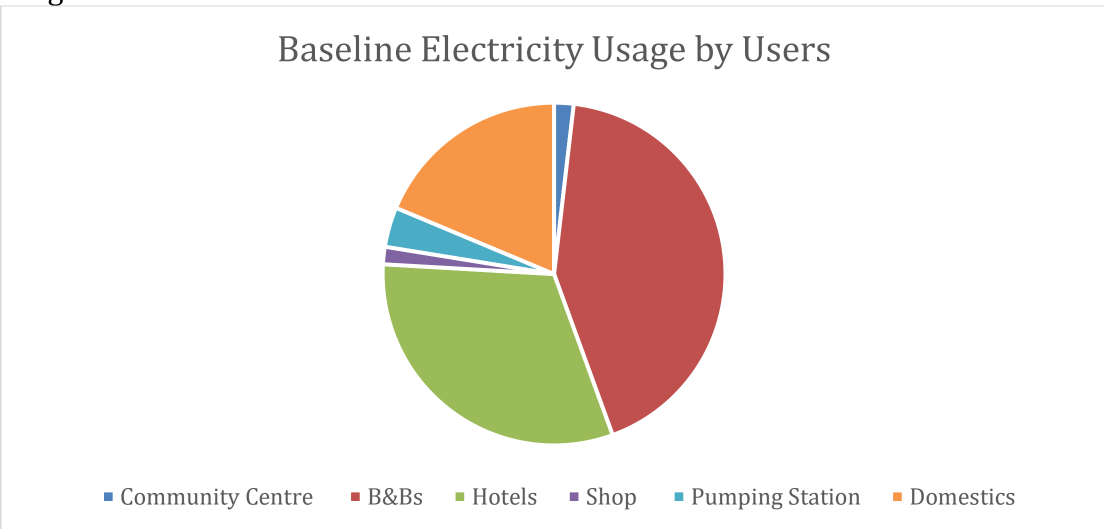

Figure 47: Electricity Usage by Sector on the Island

The total annual estimated usage from this method is circa 907MWh. This agrees to within 4% with the first method (using metered March data). This does not definitively indicate accuracy (the proportion of usage for B&Bs seems, intuitively, to be high), but supports the presumption that electricity usage at present on the island is broadly between 850-1000MWh/annum.

6.3.3 Electricity Costs

KRA were informed that all domestic users on the island pay the same rate for energy, which is high at circa €0.396/kWh, accounting for all taxed and charges.

[7] This yielded figures of circa 500MWh for B&Bs, and 386MWh for hotels

The rates paid by commercial users are lower and more variable, but averaged circa €0.25/kWh. In the present volatile electricity market, these prices are likely to change frequently in the coming years.

Total annual electricity costs for the island are estimated at €260,000

6.3.4 Electricity Emissions

The Irish electricity grid is slowly decarbonising, but the most recent SEAI figures for the emissions intensity of the grid are 295.8gCO_2/kWh. This means that electricity usage on the island, at present, is responsible for nearly **280 tonnes** of CO_2 emissions annually.

7 Energy Efficiency Measures

The Climate Action Plan, and general good practice in energy reduction is "efficiency first", as the best financial and emissions gains come from using less energy.

7.1.1 Overview of Potential Measures

The main efficiency measures available to the island are the upgrade of building fabric, upgrade of lighting, upgrade of heating systems and cooking appliances to those which use electricity (which can be decarbonised) or renewable fuels, and electrification of transport or change to renewable fuels for transport.

Each of these are outlined below:

7.1.1.1 Upgrading thermal performance of building fabric elements

As the thermal performance of the building stock on the island is very poorly understood (see Energy Baseline), it is very difficult to accurately quantify the impact and cost of fabric upgrades to the thermal usage of the island, however it has been assumed that every home must be brought from its current assumed BER of E2 to a BER of B2 as per the general retrofit standard (a change form 320 to 100kWh/m^2/year). This same proportional change was assumed for commercial buldings, and for the community centre the uplift was taken directly form the Energy Audit.

Costs were estimated at circa €69,000/home, €352,000/commercial property and €600,000 for the community centre (given the repair works required there in conjunction with the energy upgrades). SEAI figures were used for these estimations, along with an anticipated uplift for the additional cost of works on the island, of 50%.

It was found that these upgrades would cost a total of circa **€15.7M** across the entire buldings stock, **reduce total energy consumption** for the island by **nearly 42%**, and reduce emissions by nearly the same amount. This measure would be **the single most impactful measure to the island's energy system**, when considered as a whole.

The sub-measures making this up are outlined below:

7.1.1.1.1 Roof Insulation

Figure 48: Fibreglass Insulation - (Source: Green Oak Energy)

On average, a dwelling loses 20-30% of its heat through its roof. Attic/Rafter insulation is generally the most cost effective of any energy efficiency upgrade made to a house, considering the potential cost savings that can be achieved on the monthly heating bills (Sustainable Energy Authority of Ireland, n.d.).

There are two types of roof insulation which may be considered; ceiling-level insulation, where insulation is installed between the joists in the attic to insulate the rooms below; and rafter insulation, where the insulation is applied between the rafters of the roof to insulate the entire attic space.

7.1.1.1.2 Wall Insulation

Figure 49: Cavity Fill Insulation - (Source: Insulation Masters)

There are three main types of insulation which may be considered in a retrofit project; cavity fill insulation, internal insulation and external insulation. All methods aim to reduce heat loss from the dwelling, and the method should always be carefully detailed by a professional to eliminate the risk of creating a "cold bridge" from the exterior to the interior.

Cavity fill insulation involves pumping insulation between the external cavity walls of the property, filling the cavity and in turn reducing heat loss. Internal insulation involves fitting an insulated board to the internal walls of the dwelling, to eliminate heat loss from individual rooms. External insulation acts like a wrap for the outside of the dwelling, encasing the entire exterior in an insulated board which is then finished as required (usually in a render finish).

7.1.1.1.3 Airtightness and Ventilation

Figure50: Airtightness Measures - (Source: Prodomo Ireland)

Achieving a low airtightness test score is imperative when it comes to retrofitting, as this means that the house is leaking air slowly, therefore retaining heat. The preferred airtightness measure is an airtight tape, which is installed around windows and doors, as well as between insulation boards when relevant.

Ventilation is an important consideration when specifying insulation and airtightness measures, as ensuring optimal ventilation is of the utmost importance in a retrofit project. Adequate ventilation is essential to maintain excellent air quality in a highly insulated dwelling, and an experienced professional should always be consulted prior to the specification of airtightness and ventilation systems. Typical ventilation options include passive ventilation (very poor from an energy perspective) including trickle vents, demand controlled ventilation controlled by a switch, timer or sensor, single room heat recovery ventilation, and whole house heat recovery ventilation. Heat recovery ventilation is by far the most energy efficient ventilation.

7.1.1.1.4 Floor Insulation

Figure 51: Floor Insulation - (Source: CSE)

It is estimated that on average a dwelling will lose 10% of its heat through the floor although for older homes, or those without an insulated foundation, this figure will be far higher.

Floor insulation can be costly, as it requires the removal and reinstallation of the entire floor area, but the results are excellent, particularly when paired with an underfloor heating system (which is ideal for use with a heat pump).

7.1.1.1.5 Double/Triple Glazing

Figure 52: Window Glazing - (Source: Adwalton Windows)

A typical house loses 10% of its heat via the windows, and a property's thermal efficiency can be greatly enhanced by investing in windows that can combat this heat loss. Single glazed windows have only one pane of glass between the inside and outside air, allowing heat loss to easily occur. The average U-value for a single glazed window is 5. Double glazed windows have two panes of glass, with a layer of insulated air between the panes.

The average U-value for a double glazed window is 3. A triple glazed window is the most thermally efficient type of window, with three panes of glass separated by two layers of insulated air. The average U-value for a triple glazed window is 0.8 – 1.6. It is estimated that by installing triple glazed windows a homeowner can reduce their energy bills by approximately 50%.

7.1.1.2 Changing heating systems from fossil-fuel fired systems

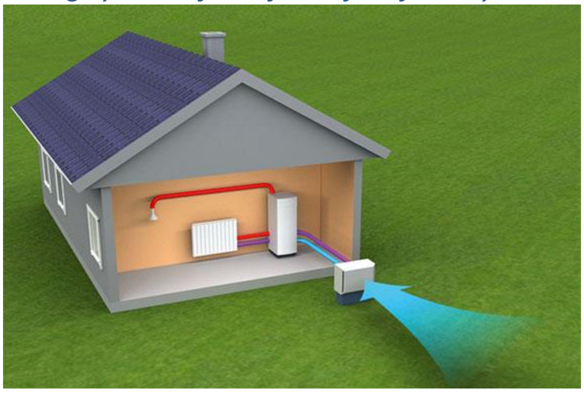

Figure 4953: Heat Pump Illustration - (Source: Heat Pumps Ireland)

An electrified heat supply is viewed as one of the most efficient and cleanest ways to heat our homes, schools and businesses.
One such solution is heat pump technology which has been in existence for a number of years and is a popular form of heating in many countries, particularly in Scandinavia. Heat pumps take heat from outside your home and convert it into useful heat and hot water. **Heat pumps are the preferred solution of the Irish and European retrofit approach, due to their very high effiency, comfortable indoor environment and compatibility with renewable electricity.**

Not all homes can be made heat-pump appropriate. Some of those of traditional construction may not be able to reach the required Heat Loss Indicator (HLI) which is needed for good heat pump performance. In those cases alternative heating systems which either use a renewable fuel source or are also electrical (and can therefore be decarbonised with renewable electricity) must be considered.

High-efficiency modern biomass (wood pellet or wood chip) burning stoves are an alternative to heat pumps that also have net-zero emissions (the emissions from burning are absorbed during a tree's growth phase) and can be a replacement for older, less efficient stoves. These stoves have an efficiency comparable to a modern condensing boiler (high efficiency but still much less than a heat pump) and are an alternative which may satisfy the needs to retain an existing distribution system or the "ambiance" of a stove.

Figure 54: Modern Wood-Burning Stove – (Source www.modernstoves.co.uk)

Direct electric heaters also use electricity (like heat pumps) but run at approximately one quarter of the efficiency. It is therefore important that they are used to the greatest effect possible, for example using storage heaters when there is an excess of nighttime electricity, or using radiant panels to heat areas with a high ventilation rate (entrance hallways etc.).

Figure 55: Domestic Radiant Heating Panel (Source ik.warmlyyours.com)

7.1.1.3 Changing from Propane Gas cooking to Induction

Electric induction hobs are much more efficient than their propane gas counterparts, using much less energy for the same amount of cooking. They are also compatible with renewable electricity, and so offer a pathway to renewable cooking on the island. An estimated 1% of all energy used on the island is propane (more than the total usage of the community centre) so this element should not be overlooked.

7.1.1.4 Upgrading lighting to LEDs

Figure 56: Domestic Lighting - (Source: Brightman LED)

The light emitting diode (LED) is the most energy efficient lighting technology. High quality LED bulbs are more durable and offer comparable or better light quality than traditional types of lighting such as fluorescent, incandescent or halogen.
In addition, LED bulbs last longer (up to 100,000 hours) and use approximately 90% less energy than regular incandescent or halogen light bulbs.

7.1.1.5 Installing rooftop solar PV or solar thermal systems.

Figure 5157: Domestic Solar PV - (Source: Irish News)

Domestic-scale solar refers to the installation of a solar panel array in a domestic setting. Domestic-scale solar arrays are generally mounted onto the rooftop of the dwelling, and provides electricity to an individual dwelling only.

Solar PV has become increasingly popular in recent years, quickly overtaking solar thermal panels as the system of choice for the homeowner.

Roof-mounted solar PV has not been considered in-depth in the modelling of this project as an efficiency measure for three main reasons:

- It is more expensive to install lots of small arrays than one large array.
- Not all houses are suitable for solar PV, and the combined output profile of many small arrays is much harder to predict than one large array.
- You cannot, at present, share power from one rooftop solar PV system to a neighbour's house, meaning that there is a lot of wasted power when it is being produced and not used in a given house.

7.1.2 Community Centre Measures

Refer to section 6 on Community Centre Audit.

7.1.3 Transport Measures

In order to provide a plan that moves the island to 100% sustainable energy, transport must be tackled. Broadly, this can be done by either electrifying transport (either directly or through a hydrogen fuel cell), or supplying a sustainable alternative to current fossil fuels.

7.1.3.1 Conversion (or replacement) of combustion engine vehicles to electric vehicles

Specialist contractors are often required for the conversion work, but for cars the industry is dominated by hobbyists, and there is a growing grassroots movement of amateur EV conversions. New Electric Ireland offer this training course, and have put a proposal forth for a weekend-long course on the island if there is specific interest. This could give rise to a new industry on the island, for both island cars and those from the mainland.

7.1.3.1.1 Electric Cars (Conversion or Replacement)

Figure 5258: Nissan Leaf – EV - (Source: Nissan Ireland)

Electric cars (EVs) have been steadily growing in popularity over the past decade, to the point that in Ireland the supply of new EVs is not currently sufficiently able to keep up with the demand. There are many reasons for this, one of which being that EVs have exceptionally low running costs owing to the fact that they have approximately 99% fewer moving parts to maintain than a typical ICEV (internal combustion engine vehicle).

They are also more environmentally friendly as they do not burn fossil fuels, leading to a reduction in air pollution in the areas in which they are being driven. A 2015 study researching the comparative LCA (life cycle analysis) of an EV and ICEV found the following; "The total life cycle air emissions externalities are 12.1 €/1000 km for the EV, 21.3 €/1000 km for the gasoline vehicle, and 24.3 €/1000 km for the diesel vehicle", showing that EVs perform better in terms of whole-life carbon emissions than their ICEV counterparts. (Girardi, 2019)

The main challenge with Electric Vehicles, especially those converted from ICEs (Internal Combustion Engines) is one of range; batteries are expensive, and big batteries that can bring hundreds of kilometres of range can be prohibitably costly and come with high embodied emissions. For this reason the island is better placed than most for EV conversions, or purchasing second-hand EVs whose battery capacities have dropped, making them unsuitable for the mainland.

7.1.3.1.2 Electric Ferries

Figure 5359: Electric Ferry - (Source: Inside EVs)

Electric ferries are a relatively new phenomenon, but we are now seeing the rapid adoption of this technology worldwide. Ferries can be an excellent starting point for the electrification of cargo transport, as they run to a regular schedule and make the same journeys over and over, which makes planning for range and charging relatively simple.

Recent figures reported by Norwegian ferry operator Norled suggest that an electric ferry can cut emissions by 95% and running costs by 80%. In addition to this, electric ferries can provide a more comfortable experience to passengers, owing to the reduction in noise levels and elimination of diesel fumes.

7.1.3.2 Conversion (or replacement) of combustion engine vehicles to Hydrogen Fuel Cell Engines

Hydrogen is a molecular energy carrier (gas) that can be produced renewably when using renewable electricity to run an electrolyser. This renewable gas can be stored, and run through a "hydrogen fuel cell" to turn back into electricity, which can power electric motors in cars and ferries. The only emissions from this process are water vapour.

The advantages of this are the need for smaller batteries, and the ability to have an integrated system with seasonal storage of energy (hydrogen can be stored in bulk much more easily than electricity). The disadvantages are conversion losses when created and regenerating hydrogen, increased system costs, more plant and equipment (electrolysers and storage) on the island and increased complex planning.

With the current level of data on the island energy system, it is premature to determine whether hydrogen vehicles would be beneficial to the overall energy system.

7.1.3.3 Running combustion vehicles on biofuels

Biofuel is produced by converting biomass into liquid fuels, and can be used to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel, both of which represent the first generation of biofuel technology. (Office of Energy Efficiency and Renewable Energy, n.d.)

Bioethanol is classed as carbon-neutral, as any carbon dioxide released during production is removed from the atmosphere by the crops themselves. (RAC, 2018) Biodiesel recycles otherwise unusable waste products, such as animal fats and cooking oil. (RAC, 2018)
When used, biofuels produce significantly fewer pollutant emissions and toxins than fossil fuels. Bioenergy Australia estimates that biodiesel could cut emissions by over 85% compared to diesel, while bioethanol could reduce emissions by around 50%.

For the island, there is little likelihood of producing biofuels directly; there is a relatively low volume of agricultural waste and that is not collected in one place, there is relatively low cooking waste volumes, and there is no capacity to grow energy crow or to construct the large plant (a bioreactor or biorefinery) required to convert biomass to biofuels.

All biofuels would therefore need to be imported from the mainland, in much the same way that diesel is currently imported, but at a significantly higher cost. Availability for the product is also very low in Ireland at the time of writing.

7.1.4 Post-efficiency energy baseline:

The post-efficiency energy baseline highlights the impact of different upgrade measures on total energy consumption, cost & CO_2 emissions. Impact of each upgrade measure on the energy consumption across different sectors was quantified in the Energy model.

7.1.4.1 Impact of Thermal Upgrade

- Thermal upgrade measures (including fabric upgrades and insulation) are recommended in line with BER standards of community centre, domestic and commercial properties.
- These measures could lead to an overall 41.8% reduction in total energy consumption and CO_2 emissions and 40% reduction in total running cost (more than €375,000 reduction)
- The cost of upgrades can be of magnitude of €15M with an estimated basic payback period of 42yrs.
- **As stated previously, fabric upgrades are the most impactful measure that can be undertaken on the island.**

Table 4: Impact of Thermal Upgrades

Summary	
% reduction in Total Energy Consumption	41.89%
% reduction in Total CO2 emissions	41.83%
% reduction in Operational Cost	40.01%
Total Operational Cost Reduction	€376,605
Cost of Upgrades	€15,745,062
Basic Payback	41.8

Fabric upgrades are usually undertaken with grant support. The same table is reproduced below assuming all capital costs are grant supported to 40% (a higher value than this may be possible due to the special grant aid for islands).

Table 5: Impact of Thermal Upgrades (with 40% grant support)

Summary	
% reduction in Total Energy Consumption	41.89%
% reduction in Total CO2 emissions	41.83%
% reduction in Operational Cost	40.01%
Total Operational Cost Reduction	€376,605
Cost of Upgrades	€9,447,037
Basic Payback	25.1

7.1.4.2 Impact of Lighting Upgrade

- A further reduction in total energy consumption, CO_2 emissions and cost would be 2.4%, 2.6% and 4.4% respectively from the new baseline after fabric upgrades (1.4%, 1.5% and 2.7% reduction from the total current energy usage on the island).
- This will lead to a total operational cost reduction of more than €25,000, while the total cost of upgrades is estimated at around €200,000. A payback of around 8 years would be achieved. KRA estimated the costs of this upgrade on the high side to account for the added costs of installation on the island. Lighting projects typically pay back in under 5 years.

Table 6: Impact of Lighting Upgrade

Summary	
% reduction in Total Energy Consumption	2.38%
% reduction in Total CO2 emissions	2.56%
% reduction in Total Cost	4.43%
Total Operation Cost Reduction	€25,022.15
Total cost of upgrades	€208,200.00

7.1.4.3 Impact of Heating System Upgrade

The change of heating systems (and cooking systems) to electrical systems or those using renewable fuels would have variable impacts, depending on the types of systems chosen.

It was assumed that the following mix of heating solutions was used:

Table 7: Proportions of new heating systems assumed

Proportion of Domestic Heating Systems replaced with Heat Pumps	50%
Proportion of Domestic Heating Systems replaced with Direct Electric Systems	15%
Proportion of Domestic Heating Systems replaced with Biomass Boilers/Stoves	35%
Proportion of Community Centre Heating Systems replaced with Heat Pumps	100%
Proportion of Community Centre Heating Systems replaced with Direct Electric Systems	0%

Proportion of Community Centre Heating Systems replaced with Biomass Boilers/Stoves	0%
Proportion of Commercial Heating Systems replaced with Heat Pumps	50%
Proportion of Commercial Heating Systems replaced with Direct Electric Systems	15%
Proportion of Commercial Heating Systems replaced with Biomass Boilers/Stoves	35%

These assumptions result in a further (relative 18% reduction in energy usage and a very significant 27% reduction in CO2 emissions), however the financial cost is high, and the energy cost reduction is relatively small. This is due to the current very high

Table 8: Impact of Heating System Upgrade

Summary	
% reduction in Total Energy Consumption	17.88%
% reduction in Total CO2 Emissions	26.91%
% reduction in Total Cost	3.89%
Total Cost of Upgrades	€4,046,837.50
Year 1 Cost Saving	€21,020.68
Basic Payback Period	193

It can be seen that the payback period is very long, however this is almost entirely due to the very low cost currently paid for oil (€0.7/L was taken for this analysis[8]), and the very high cost paid for electricity. To compare this in the context of the changes to the island's energy system, the table has been reproduced below with the cost of electricity changed to €0.1/kWh (easily achievable with renewable energy on a lifecycle basis). It is clear that the payback is still long, but very achievable with financial support.

Table 9: Impact of Heating System is Supplied by Renewable Electricity

Summary	
% reduction in Total Energy Consumption	17.88%
% reduction in Total CO2 Emissions	26.91%
% reduction in Total Cost	44.36%
Total Cost of Upgrades	€4,011,087.50
Year 1 Cost Saving	€239,425.52

[8] Source: The Inishbofin Development Company

Basic Payback Period	17

7.1.4.4 Impact of EV Chargers

As the total usage of road transport is not highly significant, the impact of converting to EVs is not highly impactful, achieving a notable but not deeply significant further reduction of 4.3% (1.8% of current total use, similar to lighting upgrades). Assuming that 60% of cars are converted, 30% are replaced, and 10% are taken off the road, this would result in poor economic return. This is not the most urgent measure in terms of impact for use on the island, but is more significant when cars are taken to the mainland for longer trips.

Table 10: Impact of EV Charges

Summary	
% reduction in Total Energy Consumption	3.95%
% reduction in Total CO2 emissions	3.97%
% reduction in Total Cost	-2.36%
Total Reduction in Running Costs	-€12,249.80
Upgrade Costs	€1,143,900
Basic Payback Period	-93.38

7.1.4.5 Impact of Electrification of ferries

Converting the ferries to electric engines would save a further 26% of remaining energy usage (11% of current total energy usage) and reduce running costs very significantly. The cost of this upgrade is deeply uncertain at present, as few companies are involved in this field. A broad estimation has been made below, but **this is subject to high uncertainty.**

Table 11: Impact of Electrification of Ferries

Summary	
% reduction in Total Energy Consumption	24.41%
% reduction in Total CO2 emissions	23.18%
% reduction in Total Cost	21.60%

Total Reduction in Running Costs	€114,691.76
Upgrade Costs	€2,000,000
Basic Payback Period	17.44

All renewable energy technologies have been considered for both the case when ferries are electrified, and for when they are not.

When considered cumulatively, the efficiency measures could save up to two thirds of total current energy usage on the island energy system!

8 Renewable Energy Generation

Energy efficiency is always the first thing that should be considered, but cannot bring a community to complete energy independence or allow for energy export. Renewable energy allows communities to bridge that gap, produce power to meet their remaining energy needs, protect against future increased energy prices and participate in the National Energy System. Any renewable energy generation project on the island will be helped hugely by the existence of the current 20kW electrical line serving the island, as connection costs can make-or-break renewable energy projects.

8.1 Potential Technologies

6 technologies have been considered for the generation of renewable energy on the island, each of which utilises a different one of the island's natural renewable energy resources.

8.1.1 Large Scale Solar PV

Utility-scale solar refers to the installation of one or more large-scale arrays of solar panels, which are generally ground-mounted. Utility-scale solar generally feeds directly into the grid, and goes on to power a vast number of buildings. The Irish Planning Authority has adopted the US National Renewable Energy Laboratory's definition of utility-scale solar to be upwards of 5 megawatts.

Two possible locations have been identifies for possible large-scale solar energy projects on the island.

Inishbofin Airstrip (Ground Mounted):
The first, which is considered in most depth, is Inishbofin Airstrip. The airstrip is large, flat, open and unshaded, which are the perfect conditions for solar energy. It's geometric shape is also ideal for a large solar array, the size of which could be scaled down modularly from the maximum size designs presented below.

Figure 60: Inishbofin Airstrip

Figure 61: Utility Scale Solar PV – (Source - KRA Design for Inishbofin Airstrip)

8.1.1.1 South facing design

Design specification

System Size: 3.05MW (8,256 x 370W panels)
Approximate Annual production: 2.7 GWh
Shading loss: 2.2%

Summary: South orientated system produces most of its energy around midday. It generally produces 15% more total energy as compared to east-west design. Shading loss is high due to single orientation of all the panels.

Figure 62: Aerial screenshot Utility Scale Solar PV – (Source - KRA Design for Inishbofin Airstrip)

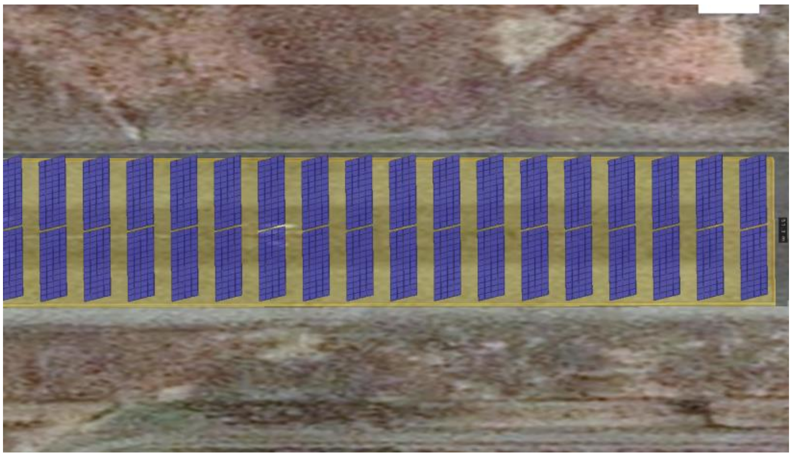

Figure 63: Close-in screenshot

8.1.1.2 East west design

Design specification
System size: 3.40 MW (9,180 x 370W panels)
Approximate Annual production: 2.6 GWh
Shading loss: 0.4%

Summary: An east-west orientated system (with some modules facing east and some west) provides a flatter profile of production throughout a day, with low shading losses. In this system design, there is significant row spacing for access path (required for maintenance and cleaning of panels) and thermal expansion of panels.

Figure 58: Aerial screenshot

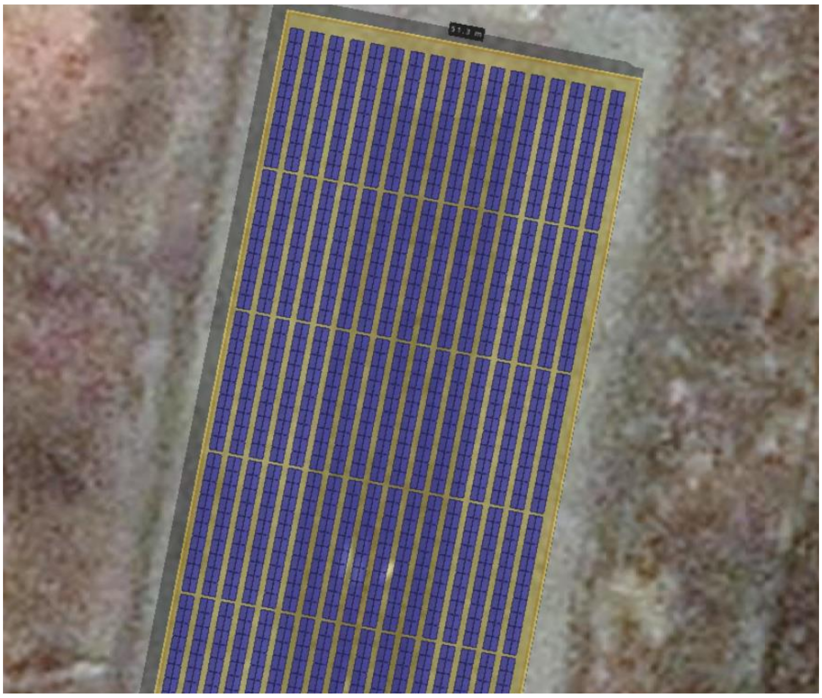

Figure 64: Close-inl Screenshot

8.1.1.3 East west design (Minimum row spacing)

Design specification
System size: 4.97 MW (13,440 x 370W panels)
Approximate Annual production: 3.8 GWh
Shading loss: 1.7%

Summary: Compared to the previous design, this east-west design has less row spacing and hence more PV panels. This would lead to higher percentage of shading loss yet better annual production.

Figure 65: Aerial screenshot

Lough Fawna (Floating Solar):

While the Airstrip offers the best location for a large-scale solar PV system, it may also be possible to install a floating solar system on the surface of Lough Fawna. This system would have the benefit of also reducing evaporation from the reservoir, but would come at a significantly higher cost, and require greater design, planning and coordination as this technology is less readily available in Ireland (but practiced more and more in other countries).

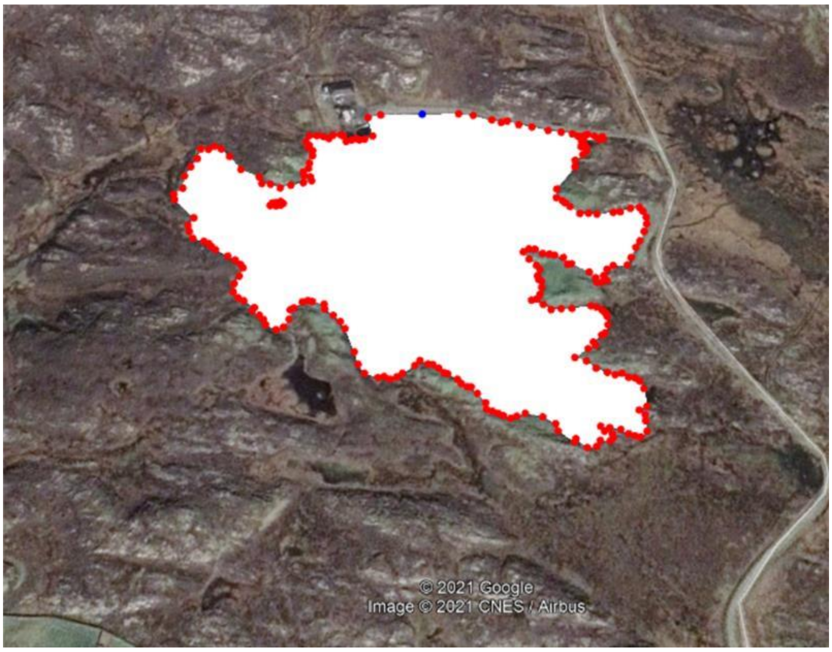

Figure 66: Close-in screenshot

8.1.1.4 Financial Performance (Large Scale Solar PV- Inishbofin Airstrip)

This option represents one of the lowest cost ways to make power on the island, with a 10-year payback and strong lifetime financials. Large-scale solar is viable on the island without grant support, but would require a funding structure of some kind.

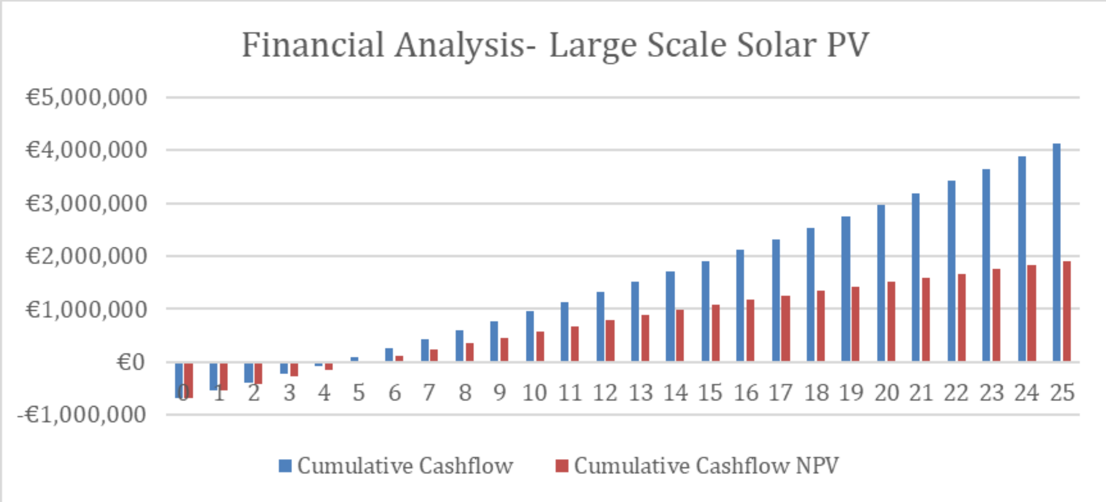

Figure 67: Financial Performance of Large Scale Solar PV (GS1)

- Payback year 5
- NPV payback year 6
- Total Lifetime Cashflow €4.1M
- Total Lifetime NPV €1.9M

The financial payback of solar is strongly influenced by the scale at which it is deployed. For this report, a capital cost of €1,100/kW has been assumed. This accounts for the high cost of installation on the island and will remain accurate only at large scale (> circa 500kW). A larger system will have a lower capital cost (€/kW) but at some point will become less cost effective as energy is produced and not consumed. There is a financially optimum size, which can be found when the input (profile) data is sufficiently well known.

The above financial report is based on a system size of 1500kW (as per Transition Pathway 3, later in the report).

8.1.2 Wave Energy Generators

Figure 68: Wello "Penguin" Wave Energy Device (Source: Wello)

Wave Energy generators work by translating the turbulent, almost random energy of the waver into renewable electricity, through the use of a vessel like the one shown above.
The array of wave energy generators can be designed to meet the energy demands of the island, or to include for energy export to the mainland.

Many wave energy generators have high energy yields but also very high lifetime costs because of their high failure rates in the hostile ocean environment, and initial high capital costs.
After some research, the authors of this report believe that one generator "the Penguin" may be sufficiently durable and at the appropriate price point to be effectively deployed to either the north or the south side of the island.

The device is, in essence, like a purposefully unstable ship which moves under the force of the waves, allowing a generator inside it to turn under the force of gravity.

8.1.2.1 Financial Performance (Wave Energy Generators)

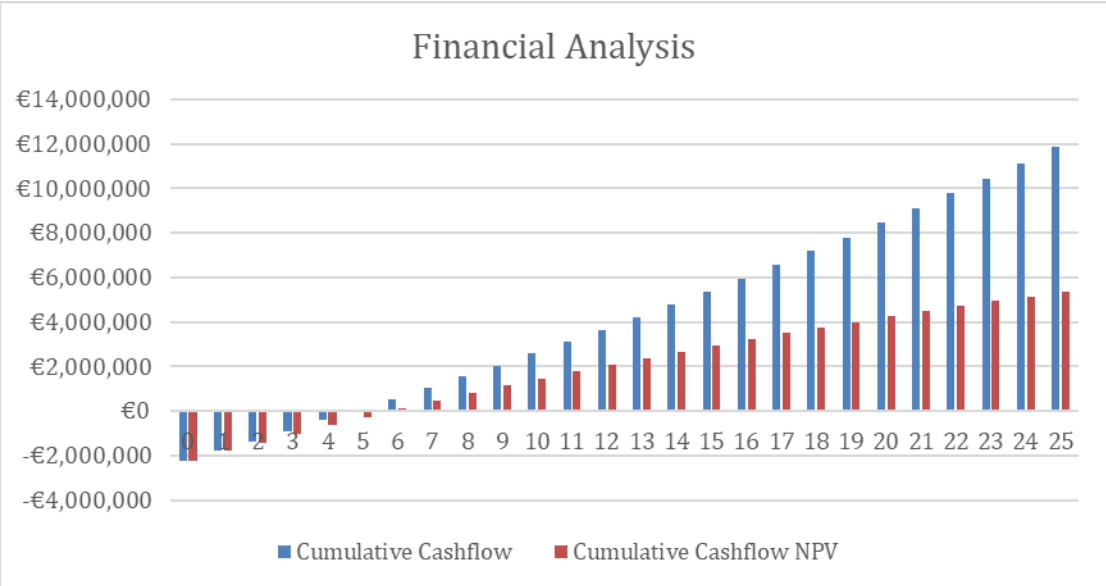

Figure 69: Financial Performance of Wave Energy Generator (GS2)

- Payback year 5
- NPV payback year 6
- Total Lifetime Cashflow €11.8M
- Total Lifetime NPV €5.3M

The figure here represents the financials for a single wave energy generator, under the assumptions of our model (as per Transition Pathway 3, later in the report).

The financial performance of the technology is based on a less solid body of knowledge than those for other, more developed technologies, and so should be taken with caution.

8.1.3 Small Wind

Figure 6670: 25kW Small Wind Turbine - (Source: Anlesey Today)

Small wind turbines function similarly to large turbines, which use a generator to convert the kinetic energy of moving blades to electricity. They fundamentally differ in two ways; their small size means decreased noise, complexity and footprint, however since wind turbines are most effective at large scale they are also less economical at small sizes per unit of power produced.

Small wind turbines would usually only ever be designed for self-consumption; that is, at a max to serve the energy needs of the island on a net basis.

As their capacity is smaller than large models, a wind farm of small turbines can be sized in a more modular way (in increments of 25kW).

The high windspeeds on Inishbofin make it ideal for wind production (while technically onshore, the wind profile is strong enough to achieve very high capacity factors, estimated at 46%), but the frequent stormy conditions mean that a highly durable, class 3 turbine and a proper Operation and Maintenance agreement is required to ensure that the machines last for their anticipated lifetime.

8.1.3.1 Financial Performance (Small Wind)

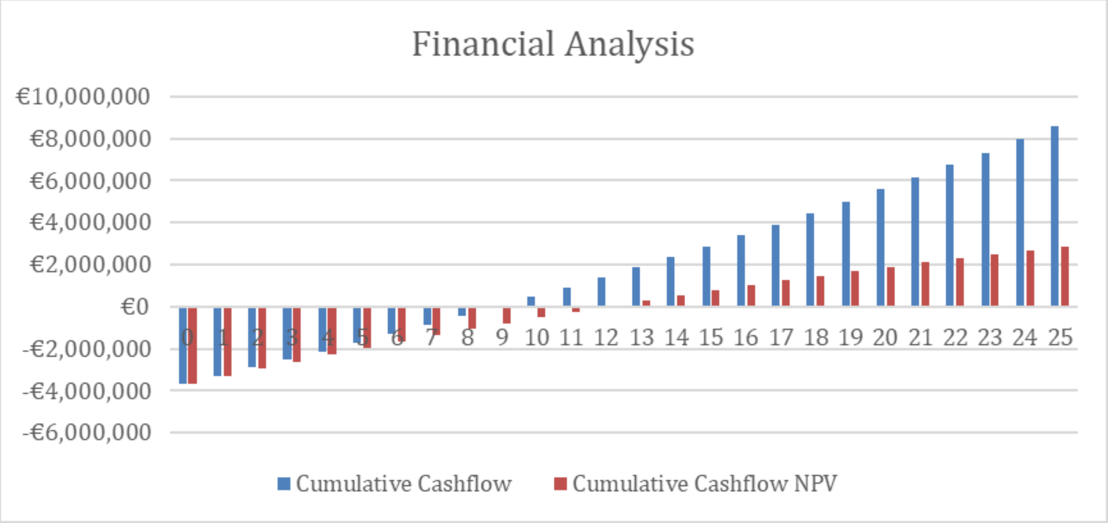

Figure 71: Financial Performance for Small Wind (GS3)

- Payback year 9
- NPV payback year 11
- Total Lifetime Cashflow €3.9M
- Total Lifetime NPV €1.4M
-

This financial model was created for the case of 5 turbines (as per Transition Pathway 3, later in the report).

8.1.4 Wind Energy (Offshore)

Figure 6872: Wind Farm Offshore - (Source: https://www.nationalgrid.com/stories/energy-explained/what-offshore-wind-power)

Offshore wind power or offshore wind energy is the energy taken from the force of the winds out at sea, transformed into electricity and supplied into the electricity network onshore.
Offshore wind power is a constantly renewable and infinite energy source, and the conversion of wind into power creates no harmful greenhouse gas emissions. As we work to tackle climate change and reduce greenhouse gases, offshore wind power will play an essential role in our future electricity generation.

Unlike small wind power, an Offshore Wind Farm project could not be undertaken by the islanders, no matter the support level, as it would involve thousands of people and the costs would like run into the hundreds of millions of euros.

However, the offshore wind industry is due for very rapid expansion of the coming years, and developers will looks for sites that fit several parameters (e.g. good wind conditions, and proximity to deep-water ports), one of which will be local communities which are friendly to the projects and to the industry. Those communities stand to gain in several ways:

- Catering year-round to construction and operations and maintenance staff working on the deployment and upkeep of the windfarms.
- Hosting wind-farm tourism (e.g. boat tours of wind farms, educational information etc.)
- Low price electricity from the wind farms in some cases.

8.1.4.1 Financial Performance (Offshore)

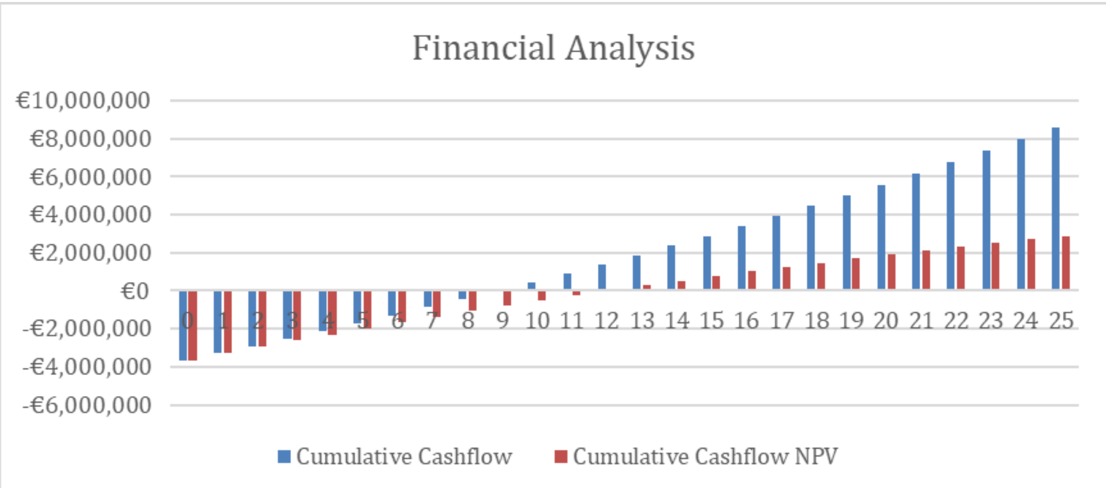

Figure 73: Financial Performance for Wind Energy (GS4)

- Payback year 11
- NPV payback year 20
- Total Lifetime Cashflow €465M
- Total Lifetime NPV €63M

Financials for this project are presented for ten 14MW turbines, as though the island were the developer, though in reality this would be highly unlikely.

8.1.5 Tidal Barrage

Figure 74: Tidal Barrage - LaRance Tidal Power Plant, France. (Source: WEAMEC Marine Energy)

A tidal barrage uses the flow of water to drive turbines and create electricity. Tidal barrages are rare in the world, with only 8 (of widely varying sizes) in operation, as the conditions for their success are rarely met.
At Inishbofin, it was noted that the island already has a brackish closed-off tidal lagoon, which could potentially be utilised for a tidal barrage system.

8.1.5.1 Financial Performance (Tidal Barrage)

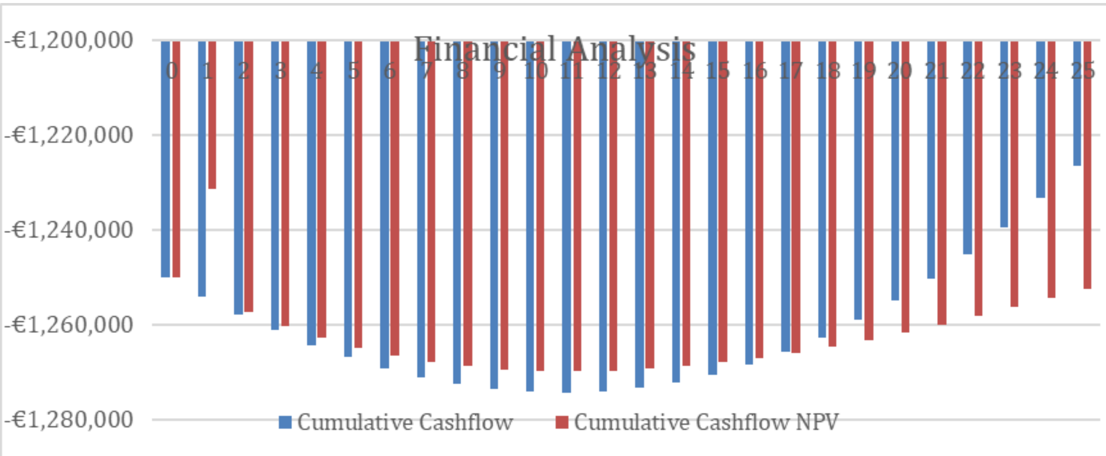

Figure 7175: Financial Performance for Tidal Barrage (GS5)

- Payback year – Does not pay back within 25 year period
- NPV payback year - Does not pay back within 25 year period
- Total Lifetime Cashflow -€1,226,404.30M
- Total Lifetime NPV -€1,252,417.54M

It can be seen that the tidal barrage system as modelled here does not represent a good solution for the island.

8.1.6 Seafloor Tidal Energy

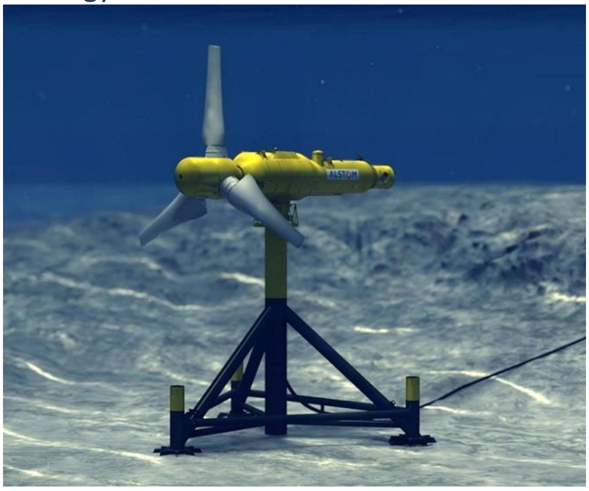

Figure 7276: Seafloor Tidal Energy - (Source: Nunatsiaq)

Seafloor Tidal Energy can be harnessed by installing an array of underwater turbines in the stream of a tidal current off the coast of the island, turning to generate renewable electricity much like a wind turbine. These turbines are in their infancy, but can be effective when the current velocity in the tidal stream is high (circa 2m/s). Investigations into the currents around Inishbofin indicate that they are about 0.2m/s, or one tenth of the desired speed. As tidal power is proportionate to the current velocity cubed, that means that a turbine placed in a flow moving at 0.2m/s would produce only 1/1000th of the power of the same turbine in a flow of 2m/s.

8.1.6.1 Financial Performance (Seafloor Tidal Energy)

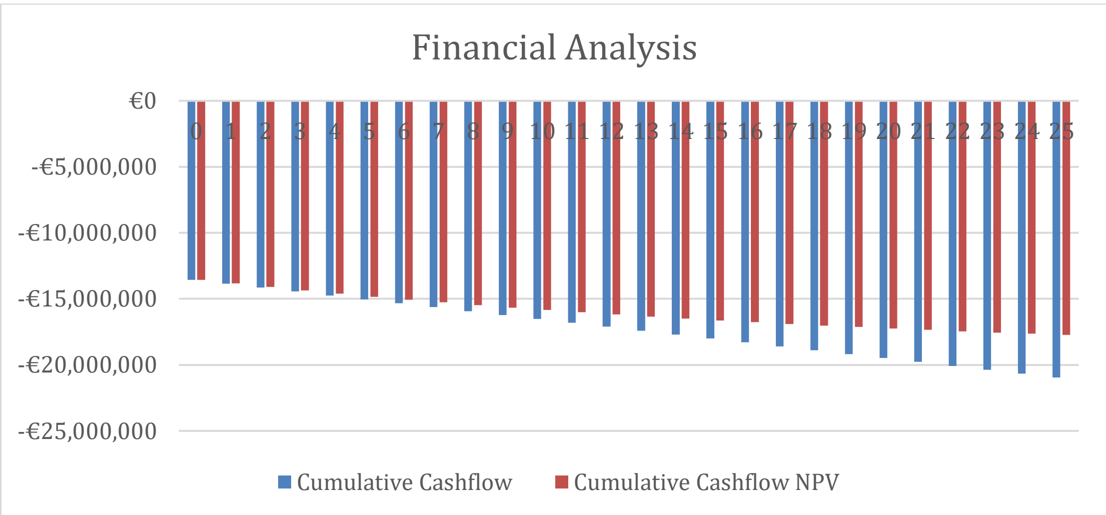

Figure 7377: Financial Performance for Seafloor Energy (GS6)

- Payback year – Does not pay back within 25 year period
- NPV payback year - Does not pay back within 25 year period
- Total Lifetime Cashflow -€20M
- Total Lifetime NPV -€17M

The financials demonstrate that this technology is not suitable for this environment.

8.2 KPIs of Investigated Technologies

The Key Performance Indicators (KPIs) for the 6 technologies investigated in depth are presented for both the cash for which the ferry runs ultimately on a biofuel, and the case where the ferry is electrified.

The two tables which follow demonstrate that Solar Energy, Wave Energy and Small Wind Energy could all be commercially and technically viable on the island, while Large Offshore Wind offers a significant commercial opportunity to become involved in a huge industry, and Tidal Barrage and Seafloor tidal are not effective technologies.

The LCOE's presented here represent the sum of lifetime costs, divided by the sum of lifetime energy output from each technology.

8.2.1 Ferry not electrified (biofuel ferry):

Table 12: Generation Scenario KPIs (Ferry not electrified)

Inishbofin Generation Scenario KPIs	Utility Scale Solar PV	Wave Energy	Decentralised (Small-Wind)	Wind Energy (Offshore)	Tidal Barrage	Seafloor Tidal Energy
LCOE (€/kWh)	€0.083	€0.114	€0.147	€0.030	€1.373	€93.933
EBOP/Plant Footprint (m2)	11000	1352	1440	44000	64	216
NPV	€1,894,969	€4,182,928	€1,429,983	€63,879,908	-€1,252,418	-€17,727,632
Total Annual Energy Export (MWh)	0	182.74	11453	18886133	0	182
Lifetime Cashflows (M€)	4.13	9.65	3.90	465.63	-1.23	-20.96
Energy Density (kWh/year/m2)	36	712	320	17281	719	34
Yield (kWh/kW)	704	963	3,689	5,431	184	5
Annual Energy Produced per Unit capital Cost (kWh/€)	0.44	0.43	0.33	1.91	0.03	0.001
Total Electricity Coverage	34%	83%	40%	>100%	4%	1%
Lifetime Carbon Offset (Tonnes)	1,500	3,699	1,770	2,918,411	176.8	28
Payback Year	5	6	9	11	Does not pay back within 25 year period	Does not pay back within 25 year period

Ferry Electrified:

Table 13: Generation Scenario KPIs (Ferries Electrified)

Inishbofin Generation Scenario KPIs	Utility Scale Solar PV	Wave Energy	Decentralised (Small-Wind)	Wind Energy (Offshore)	Tidal Barrage	Seafloor Tidal Energy
LCOE (€/kWh)	€0.083	€0.097	€0.147	€0.030	€1.373	€93.933
EBOP/Plant Footprint (m2)	11000	1352	1440	44000	64	216
NPV	€1,894,969	€5,364,733	€1,429,983	€63,879,908	-€1,252,418	-€17,727,632
Total Annual Energy Export (MWh)	0	11.58	11,453	18,886,133	0	182
Lifetime Cashflows (M€)	4.13	11.85	3.90	465.63	-1.23	-20.96
Energy Density (kWh/year/m2)	36	839	320	17,281	719	34
Yield (kWh/kW)	704	1,134	3,689	5,431	184	5
Annual Energy Produced per Unit capital Cost (kWh/€)	0.44	0.51	0.33	1.91	0.03	0.001
Total Electricity Coverage	21%	60%	24%	>100%	2%	0%
Lifetime Carbon Offset (Tonnes)	1,500	4,356	1,770	2,918,411	176.8	28
Payback Year	5	5	9	11	Does not pay back within 25 year period	Does not pay back within 25 year period

8.3 Exotic Energy Generation Options

During the research into possible generation technologies, two wind energy technologies were discovered which may not represent a strong opportunity right now, but might be a developing area which the island could help to pioneer in the coming years.

These two technologies are Airborne Wind, and Energy Ships. Both of these technologies use the power of the wind in novel ways to generate energy.

An energy ship follows the strong wind around, maximising the time it can generate energy. It uses this energy to charge batteries which before sailing back to port to discharge, and repeat the process over again.

Figure 78: Energy Ship- (Source: Farwind)

An airbourne wind generator is essentially a big kite that pulls a generator around in circles, causing it to create power.

Figure 79: Airbourne Wind Generator (Source- Airbourne Wind Europe)

Both of these technologies have strong long-term potential (possibly in niche areas) though the current technology readiness level is low. Inishbofin could serve as a research/ innovation/demonstration hub for technologies like these.

9 Energy Storage Options and Demand Response

When considering energy generation in the above scenarios, the level of energy self-consumed was calculated using monthly profiles (matching data availability from the island).

Once efficiency measures have been undertaken and renewable energy generators have been installed, it will become clearer how much energy storage is required to smooth out the peaks and troughs of daily generation and consumption (it is not practical to store enough energy to match seasonal mismatches in production and consumption).

Storage is always expensive, and should be minimised where possible.

Two methods have been qualitatively identified for Inishbofin (other methods, such as pumped hydro, have been discounted due to the geography):

9.1.1 Battery Storage:

Batteries are the way in which most people think of storing power, but in fact they make up only a small amount of global energy storage. Batteries may be centrally located, near a renewable energy generator or a load centre, or may be distributed, make up of many small battery banks. Batteries may also be, ultimately located in the body of electric vehicles, so that the island's cars are its energy storage devices, which interact actively with the grid.

Batteries are very fast to respond, and can help to protect grids from rapid fluctuations, but are expensive and have low energy density.

9.1.2 Hydrogen:

Hydrogen is a colourless, odourless gas with a low molecular density that burns very cleanly and very hot. It has a very broad range of uses, from combustion, to energy transport and storage, to the building blocks of chemical products. Most hydrogen in the world is produced from Steam Methane Reformation (Grey Hydrogen) but when is it produced using an electrolyser powered by green electricity it is considered a renewable fuel.

Has huge advantages in flexibility, but currently suffers from high cost and low conversion efficiencies.

9.1.3 Demand Response:

Demand Response is, simply, the concept of having devices that can automatically switch off in response to a grid signal that power on the grid is too low "an event". These outages can last from second to hours, depending on the severity of the event, the type of equipment and the demand response programme enrolled in.

Demand response is typically coordinated by a commercial entity (such as Enel X, who collaborated on this project) who install the necessary equipment and pay the entity (or community) for the ability to be able to switch their power partially off when the grid requires it. Events typically number less than a dozen per year, and entities can opt out for certain times of the year (e.g. when Inishbofin is in mid-tourist season).

The programme likely represents a win-win for Inishbofin, as it could help to stability their power grid as it grows greener, generate revenues for the community and raise the profile of the island by making a first for a community in Ireland. It could also represent the way to solve the immediate current problem of island blackouts- installing battery capacity to meet demand during blackouts, and using it for frequency response to cover its costs.

Demand response has been carried out on other islands (e.g. Eigg) by limiting the energy available to any household at one time. Demand response in this fashion can be carried out by local agreement, but would still require sensor and control technology to facilitate its usage.

Finally, many kinds of demand response with smart system integration are possible, which send signals to turn on devices (such as car chargers, heat pumps and immersion coils) in response to too much power on the grid (when supply outstrips demand). The validity of these systems is highly dependant on the final mix of electricity-using devices and electricity generating systems on the island.

10 Transition Pathways

While there are many, many possible combinations of measures that could bring about an energy transition on the island, three sample pathways have been presented below. These were chosen to take three strong stances. In the first, the island aims to be an energy exporter, exporting as much energy as is currently imported. In the second, electrification is strongly depended upon, and the island aims to match supply to demand as closely as possible. In the third, the island aims to diversify its energy supply technologies as far as possible.

These pathways were chosen as they represent different philosophical approaches to the energy transition:

- In the first pathway, the island would seek to not only reduce their energy usage, but also be a net positive force for the energy transition on the mainland. The key word here is external **impact.**
- In the second pathway, the island would try to undertake the transition in a lean and simple manner, with one fuel type being produces and used for all purposes. The key word here is **simplicity.**
- In the last pathway, the island would try to diversify its energy production, lowering the chances of any period of lengthy underproduction in the case of a fault, outage or downtime due to planned of unplanned maintenance. The key word here is **durability.**

The ferry electrification represents a significant electrical load. The choice to include this or not follows the logic of the scenario. In the first, if energy is not used for the ferry, there is more to potentially export. In the second, full electrification means everything is electric, including the ferry. In the last, the ferry should be electrified, as depending on shipments of fuel in the future (e.g. biofuel) has inherent risk as highlighted by the current energy crisis caused by the invasion of Ukraine.

The real future of the island is likely some blend of these pathways.

10.1.1 Transition pathway 1 – Export Focused

In this pathway, the island would utilise efficiency upgrades, would run the ferry, on biodiesel, and would maximise their cost-efficient renewable energy resources (Solar PV, Wave and Small Scale Wind) to export energy to the mainland.

Table 14: Transition Pathway 1

Measure	Energy Saving (GWh)	Energy Generation (GWh)	Fossil & Grid Energy Reduction	Emissions Reduction (Tonnes)	Cost (M€)

			(incl. export)		
Thermal Upgrades to Buildings	2.80	0	2.80	767	15.7
Lighting Upgrades to Buildings	0.09	0	0.09	27	0.03
Heating System Upgrades to Buildings	0.71	0	0.71	290	4.28
Conversion of Cars to EVs	0.12	0	0.12	30	1.14
Ferry Energy Change	0.00	0	0.00	0	0
Solar PV	0	2.2	2.15	261.45	3.44
Wave	0	5.7	5.73	302.32	11.68
Small Wind	0	2.8	2.77	302.17	3.75
Total	3.72	10.65	14.37	1980.08	40.06

In this scenario, the island would be exporting more energy than it is currently importing (though it would still be importing Biodiesel for ferries and Biomass for heating)

Table 15: Import and Export Results from Transition Pathway 1

Import and Export of Energy		
	Energy (GWh)	**Value (M€)**
Electricity Exported	9.52	0.67
Electricity Imported	0.00	0.00
Imported Biodiesel	1.46	0.29
Imported Biomass	0.36	0.06

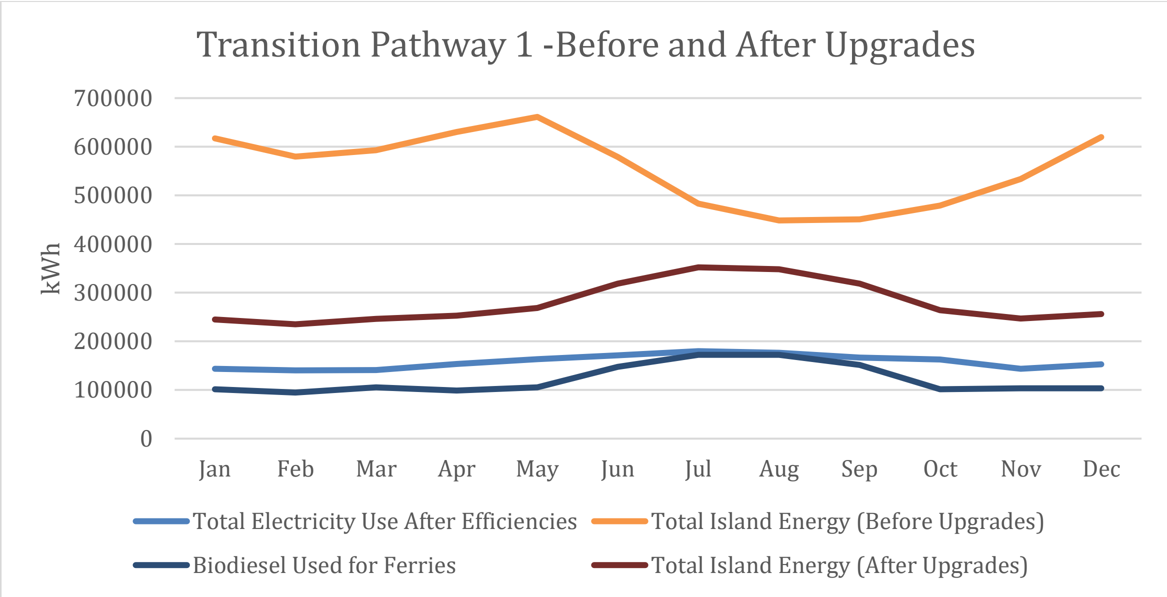

Figure 80: Pathway 1 Efficiency Impact (Profiles)

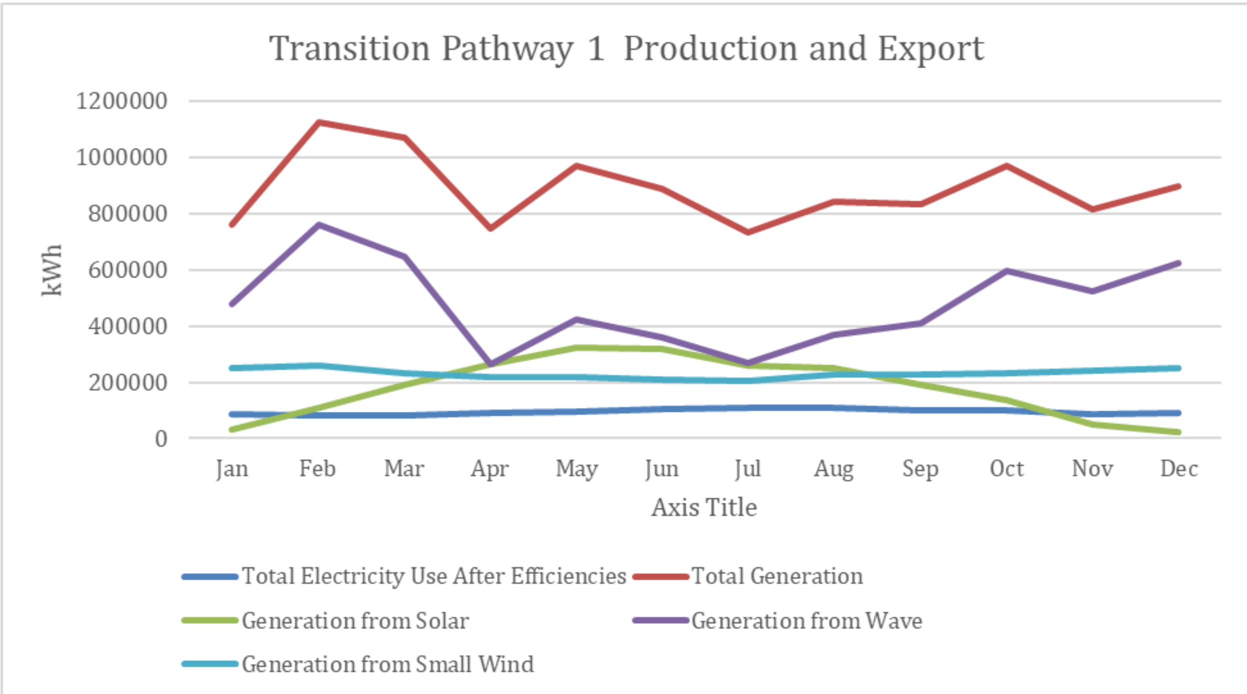

Figure 81: Output profiles of each technology (TP1)

10.1.2 Transition pathway 2 – All Electrified, No Export

In this pathway, the island would fully electrify its entire energy system (incl. all heating and transport) and size its renewable energy generators such that there was minimal import and export.

Table 16: Transition Pathway 2

Measure	Energy Saving (GWh)	Energy Generation (GWh)	Fossil & Grid Energy Reduction (incl. Export)	Emissions Reduction (Tonnes)	Cost (M€)
Thermal Upgrades to Buildings	2.80	0	2.80	767	15.7
Lighting Upgrades to Buildings	0.09	0	0.09	27	0.03
Heating System Upgrades to Buildings	0.96	0	0.96	257	5.83
Conversion of Cars to EVs	0.12	0	0.12	30	1.14
Electrification of Ferry	0.73	0	0.73	169	2
Solar PV	0	0.5	0.52	139.08	1.17
Wave	0	0.0	0.00	0.00	0.08
Small Wind	0	1.6	1.57	418.34	2.125
Total	4.70	2.09	6.79	1807.87	28.11

This pathway results in significantly lower capital costs, but involves no energy exported to the grid. A significant battery (or hydrogen) storage system would likely be required to balance production and demand this closely, the costs of which are not included here as there is insufficient data to analyse at that level at this stage.

Table 17: Import and Export Results from Transition Pathway 2

Other Results		
	Energy (GWh)	Value (M€)
Electricity Exported	0.14	0.01
Electricity Imported	0.03	0.01

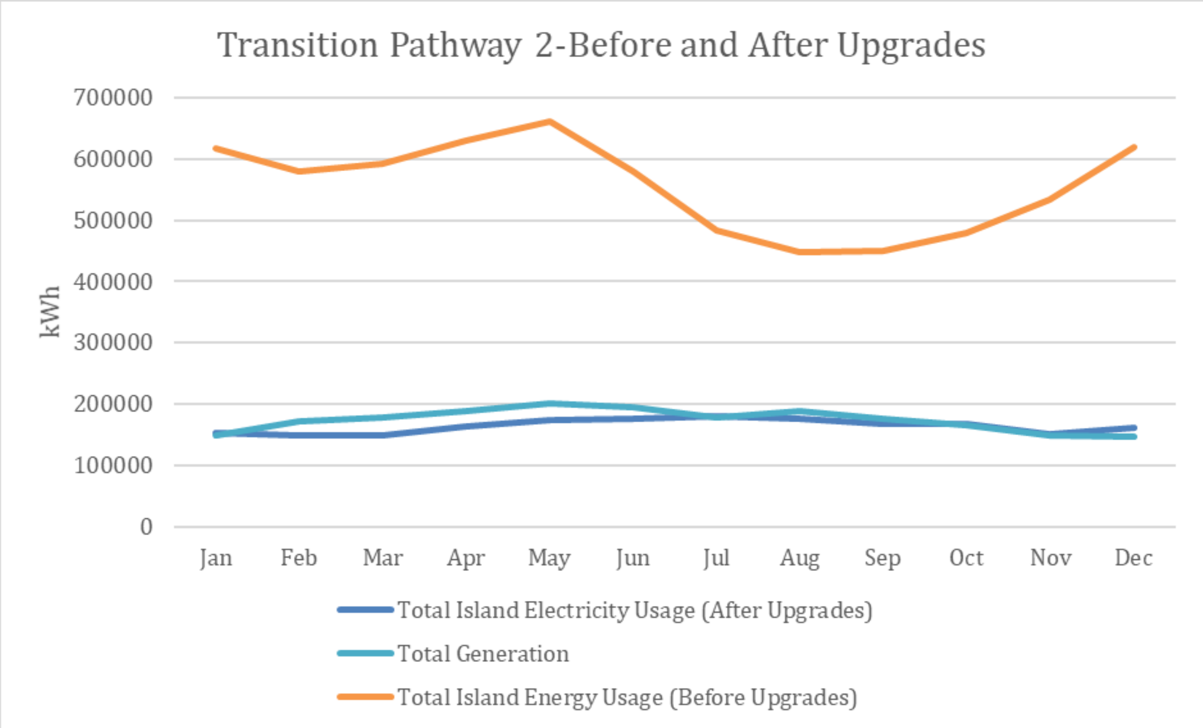

Figure 82: Pathway 2 Efficiency Impact (Profiles)

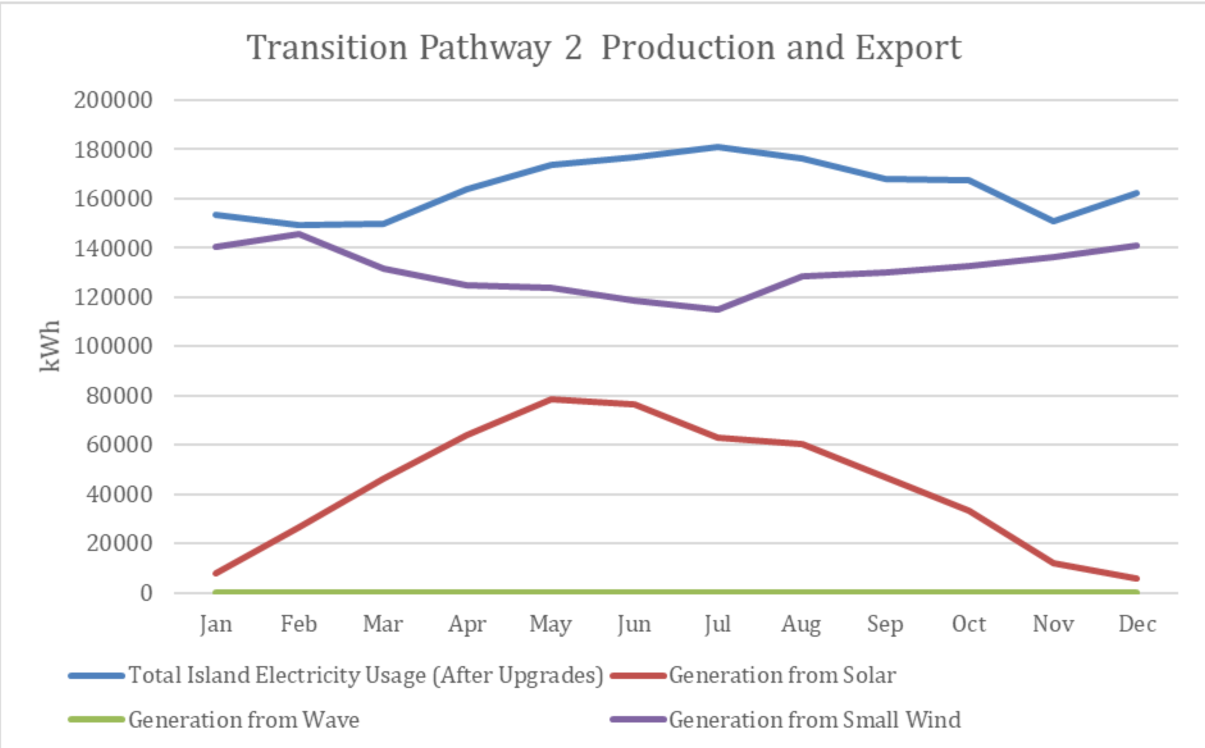

Figure 83: Output profiles of each technology (TP2)

10.1.3 Transition pathway 3 -Balanced Generation, Net Zero

In this transition pathway, ferries are electrified, and an attempt is made to balance the output of different sources (solar, wave and wind) as far as possible. Rather than true energy independence the scenario relies on the grid for "storage", importing and exporting when required and achieving only Net Zero.

Table 18: Transition Pathway 3

Measure	**Energy Saving (GWh)**	**Energy Generation (GWh)**	**Fossil & Grid Energy Reducton (incl export)**	**Emissions Reduction (Tonnes)**	**Cost (M€)**
Thermal Upgrades to Buildings	2.80	0	2.80	767	15.7
Lighting Upgrades to Buildings	0.09	0	0.09	27	0.03
Heating System Upgrades to Buildings	0.70	0	0.70	280	4.05
Conversion of Cars to EVs	0.12	0	0.12	30	1.14
Electrification of Ferry	0.73	0	0.73	169	2
Solar PV	0	0.4	0.39	104.31	0.89
Wave	0	1.1	1.15	302.84	2.24
Small Wind	0	0.5	0.46	123.04	0.63
Total	4.44	2.00	6.43	1803.60	26.71

This Transition Pathway is slightly less costly than the full electrification pathway, but results in greater ongoing import of electricity and biomass. The slightly more balanced mix of technologies will likely result in a lower requirement for energy storage from this site, but this has not been quantified.

Table 19: Import and Export Results from Transition Pathway 3

Imports and Exports		
	Energy (GWh)	**Value (M€)**
Electricity Exported	0.20	0.01
Electricity Imported	0.10	0.04
Imported Biomass	0.34	0.06

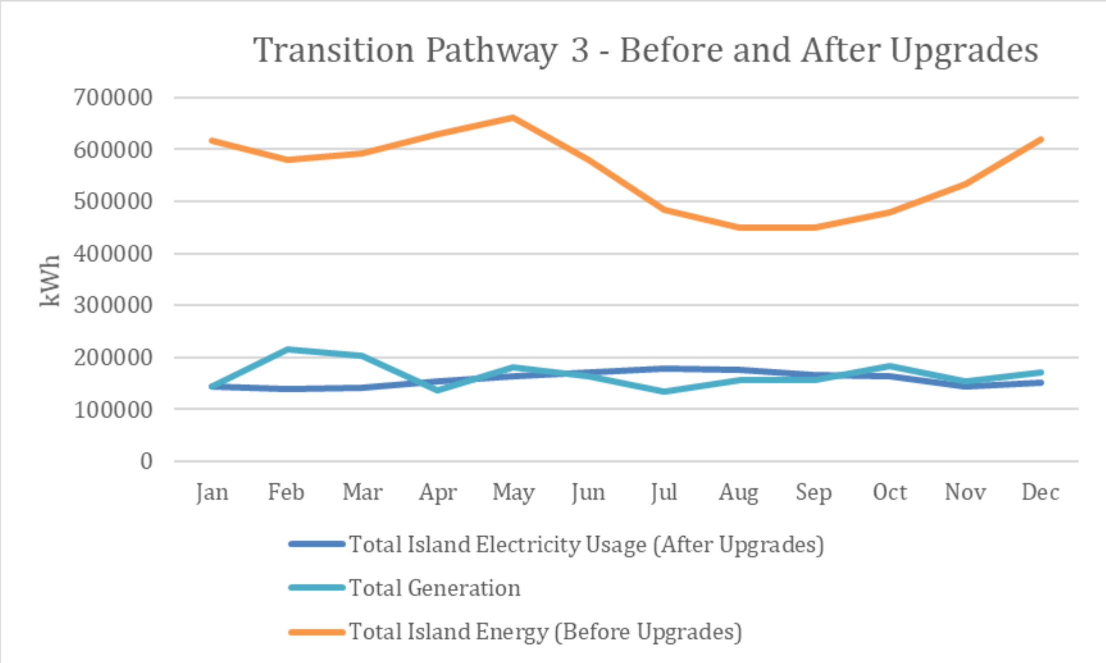

Figure 84: Energy Transition Pathway 3

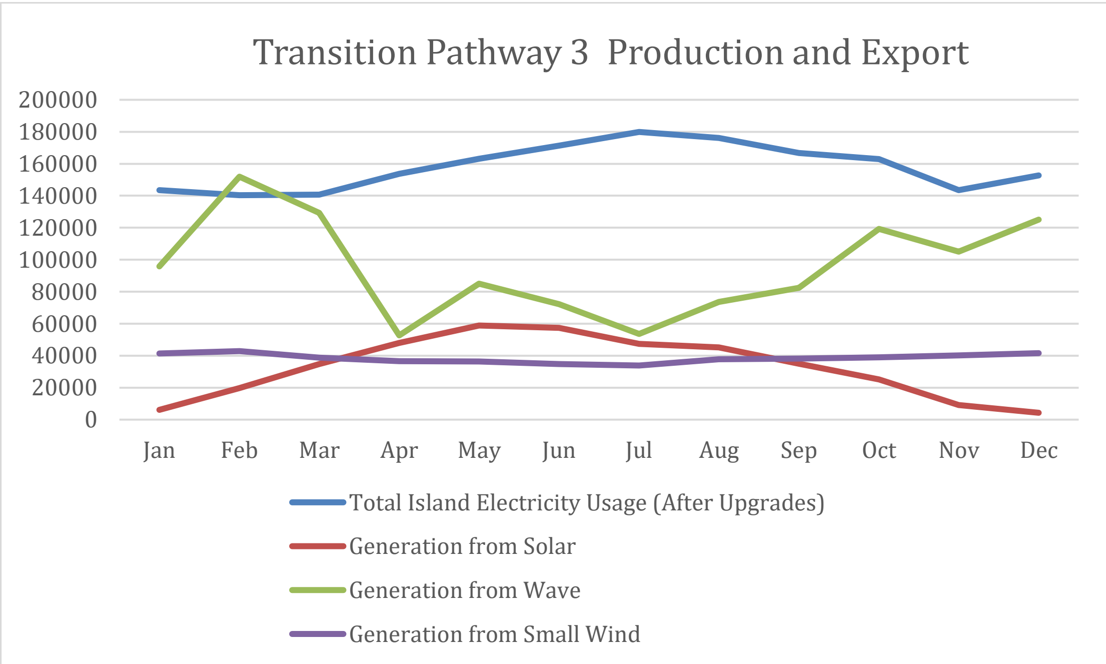

Figure 85: Output profiles of each technology (TP3)

11 Impact on Biodiversity

Because of the potential for impact on ecology (sensitive plants and protected animal species as identified in the ecology section), **KRA would recommend a dedicated ecological study for each of the generation measures identifies**, with the possible exception of large-scale solar at the airstrip, which is unlikely to negatively impact the local biodiversity, and may in fact have positive benefits for it.

The efficiency measures are unlikely to have any negative impact on ecology, with the possible exception of stoves, which should be examined before being adopted en-masse for their potential emission of particulates, which can be harmful to the environment and human health.

12 Financial Pathways

There are a range of possible financial options to proceed with projects, which all have pros and cons and various levels of suitability to a community project.

These have been divided into funding sources and delivery models:

12.1 Funding Sources:

12.1.1 SEAI

The Sustainable Energy Authority of Ireland (SEAI) have a range of supports available for energy upgrade projects, from the Communities Energy Grant, which offers communities support towards almost all kinds of buildings upgrades, through the National Housing Retrofit Scheme targeted directly at houses, to the RD&D grant, which offers support for projects bringing new knowledge, to the Support Scheme for Renewable Heat (SSRH) which offers financial support to entities adopting low carbon heating technologies.

12.1.2 EU

There are a wide range of grants at an EU level for decarbonisation works. Many of these are focused on the planning and research side, but some support with implementation.

12.1.3 Not-For-Profit Community Finance

Low cost finance for communities is available from several sources, including but not limited to:

12.1.3.1 Community Finance Ireland

A charity established in 1999 which aims to “create a world-class community finance system that works tirelessly towards ensuring that positive social impact is felt”.

12.1.3.2 Clan Credo

A registered charity established in 1996 which aims to "help organisations achieve their social, economic and financial potential on terms and conditions that may not be available to them commercially."

12.1.4 Private Equity

Private investors might be encouraged to fund project, partially or wholly, in exchange for partial or whole ownership of renewable energy assets.

12.2 Delivery Models:

There are several means/models by which energy efficiency measures and renewable energy assets can be deployed. For models not relating to energy efficiency measures of individual homes, significant additional work is required to answer a range of questions (who owns the assets, who buys and sells the power, etc.)

Models include:

12.2.1 Individual Action:

For upgrade works, particularly to domestic buildings, grant funding will cover part of the cost, but the remainder is usually covered by the homeowner, who ultimately benefits from the works. Bridge funding or partial loans can be used to cover funding gaps in some cases.

12.2.2 Energy as a service

For entities undertaking large upgrade works at the same time, some companies offer to fund the works, and in exchange are paid from the energy savings that were made by undertaking the measures. This is appropriate for a coherent approach in which many upgrade measures are undertaken together and there is a clear indication of what the savings will be from undertaking the works.

12.2.3 Power Purchasing Agreements

A Power Purchasing Agreement (or PPA) is like an Energy as a Service model, except that it is for a specific asset (e.g. a solar plant) which is owner by another entity from whom the island buy their power at a low price (but the entity takes a margin).

12.2.4 Full community ownership

If the community were sufficiently united, they could collectively invest in certain elements of the project that have a clear benefit for all parties (likely generation assets) and share the profits between the owners.

This model requires specific legal structures to be put in place, but might also allow energy export to the mainland (such as in Transition Pathway 1) for the financial benefit of the island.

The International Renewable Energy Agency (IRENA) identifies the following forms of community ownership for renewable energy assets:

- Co-operatives
- Community Trusts
- Non-Profit Organisations
- Partnerships
- Housing Associations

Though Cooperative and Partnerships are the most common.

T: 01 2819182
E: info@kra.ie
W: www.kra.ie
E11A Network Enterprise Park
Kilcoole
Co. Wicklow

Register of Opportunities

Table 20: Register of Opportunities

Opportunity	Impact	Capital Cost	Cost Effectiveness	Realisability	Quantified in Study (Y/N)
Thermal Upgrades to Buildings	High	High	Medium	High	Y
Lighting Upgrades to Buildings	Low	Low	Migh	High	Y
Heating System Upgrades to Buildings	High	Medium	Medium	High	Y
Electrification of Cars	Low	High	Low	Medium	Y
Electrification of Ferry	High	High	Medium	Medium	Y
Large Scale Solar on Airport	High	High	High	High	Y
Large Scale Floating Solar	High	High	Medium	Medium	N
Widespread Rooftop Solar	Medium	High	Medium	Medium	N
Wave Energy	High	High	High	Medium	Y
Small Scale Wind	High	High	Medium	Medium	Y
Large Scale Offshore Wind	Very High	Very High	High	Medium	Y
Tidal Barrage	Low	Medium	Low	Low	Y
Seafloor Tidal	Low	High	Very Low	Low	Y
Biofuels in Cars	Low	Low	Low	High	N
Biofuels in Ferry	High	Low	Low	Medium	N
Hydrogen Car Conversion	Low	High	Low	Low	N
Hydrogen Ferry Conversion	High	High	Low	Medium	N
Wind Ship	Medium	High	Low	Medium	N
Wind Kite	Medium	High	Low	Low	N
Battery Storage	Medium	High	Low	Medium	N
Hydrogen Production and Storage	Medium	High	Low	Medium	N
Demand Response	Medium	Low	High	High	N

13 Conclusion and Recommendations

Inishbofin island is home to a fantastic, vibrant community of independent, enterprising and practical people. It also hosts many thousands of tourists every year.

The island is currently very energy intensive, and responsible for a large amount of CO_2 emissions annually.

Transitioning to a zero carbon community would have enormous benefits for the environment, for the tourism industry on the island, for the direct employment in a new industry, for education and awareness, and for synergies with other development projects being undertaken on the island.

The authors of this report recommend that further information is gathered to supplement the findings of this report, namely:

- Further information on the energy performance of the buildings stock, through domestic BER assessments (ideally for every house) and energy audits (ideally for every business).
- Research requirements for upskilling of local contractors to undertake energy retrofit work, especially in the context of traditional buildings of breathable construction.
- The attitude of residents towards the measures herein suggested, especially through the collaboration with EC^2 and the study they are undertaking in tandem with this study.
- Information on the current state of the grid, which is somewhat lacking at present, and on the upgrades that would be required to facilitate an overhaul of the electrical system. Specifically through the collaboration with the European Small Islands Initiative.
- Location specific tidal current slow rates, to confirm the findings of this report that rule out that technology.
- Better siting information for wind turbines that balances the wind resource, grid requirements, use of land, and islander feeling.
- Better siting information for wave energy generators that balance costs, grid requirements, use of water, and islander feeling.
- Further develop the financial pathways for various upgrade measures, matching the relevant funding or financing options to the appropriate technological approaches in an optimal fashion.
- Further research on appropriate ownership/management models for delivery of energy efficiency measures and ultimate management of renewable generators.
- Further research on the short-term deployment of batteries to immediately tackle the challenge of blackouts on the island.

- Determine the plans for the development of offshore wind farms in the locality of Inishbofin to determine the role the island might play in the industry in future.

The authors of this report believe that Inishbofin could be a leader in the field of island energy, and a model for communities across Ireland who wish to be empowered and actively work towards mitigating the worst affects of the climate and biodiversity collapse; the greatest challenge of our times.

This study was undertaken using a wide range of scientific and industrial sources, as well as collaborations with the study partners as listed, and the judgement and experience of the authors. Great effort was made to ensure that all information in this report is objective and accurate. Any inaccuracies were the result of unintentional error.

Appendix

13.1 Appendix A: Community Centre Acceptance Study

Acceptability towards energy projects

Acceptance of renewable energy projects is highly related to the opportunities for engagement offered to a community[9]. *Community engagement* is the process by which responsible actors deliberately engage people in the planning, developing, and implementing environmentally relevant projects or policies that regard people's local surroundings[10]. Moreover, responsible actors must ensure that the information presented during engagement processes is entirely understandable to the public and that the public is encouraged to engage in the project's early stages. Different types of community engagement vary in the influence that the public is given over major decisions. These types of engagement range from informing the community about a project without giving it any decision-making power to letting the community have as much influence

[9] Bidwell, D. (2016). Thinking through participation in renewable energy decisions. In *Nature Energy*. https://doi.org/10.1038/nenergy.2016.51; Woolley, O. (2010). Trouble on the horizon? Addressing place-based values in planning for offshore wind energy. *Journal of Environmental Law*. https://doi.org/10.1093/jel/eqq009
[10] Dietz, T., & Stern, P. C. (2008). Public participation in environmental assessment and decision making. In *Public Participation in Environmental Assessment and Decision Making.* Page 12. https://doi.org/10.17226/12434

over decisions as the project developers have. Some researchers argue that the more decision-making power offered to the public, the more likely they are to accept a project in their vicinity[11]. However, other research suggests that the public's preferences for participation depend on a project's proximity to people's neighbourhoods[12]. Therefore, more extensive engagement processes may foster more acceptable outcomes when projects are physically closer to the locals. The physical closeness of a renewable energy project often means that the project has significant visual impacts on an area's landscape. The visual effects of, for example, wind farms are some of the biggest threats to its public acceptability[13]. The visual impact is significant to areas that people feel strongly connected and attached to. This phenomenon is called *place-attachment*. If an energy project is seen as intrusive to sites that carry significance to people, it can foster resistance[14]. However, a strong place-attachment can also promote acceptability if people perceive the project to be in line with what people find important about an area[15]. A project can influence an array of aspects that are important to people's everyday lives. For simplicity, these important aspects are categorised into two major topics: Societally relevant influences (environment, nature, community, pro-social) and personally relevant influences (resources, status, comfort, safety)[16]. Everyone prioritises all of these aspects to a certain extent. Addressing how a renewable energy project will influence societal and personal aspects of people's lives will be crucial for gaining the public's

[11] Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Planning Association*. https://doi.org/10.1080/01944366908977225
[12] Perlaviciute, Goda, & Squintani, L. (2020). Public Participation in Climate Policy Making: Toward Reconciling Public Preferences and Legal Frameworks. *One Earth*. https://doi.org/10.1016/j.oneear.2020.03.009
[13] Bidwell, D. (2013). The role of values in public beliefs and attitudes towards commercial wind energy. *Energy Policy*, *58*, 189-199. https://doi-org.proxy-ub.rug.nl/10.1016/j.enpol.2013.03.010
[14] Vorkinn, M., & Riese, H. (2001). Environmental concern in a local context: The significance of place attachment. *Environment and behavior*, *33*(2), 249-263. https://doi-org.proxy-ub.rug.nl/10.1177/00139160121972972
[15] Devine-Wright, P. (2011). Place attachment and public acceptance of renewable energy: A tidal energy case study. *Journal of Environmental Psychology*, *31*(4), 336-343. https://doi.org/10.1016/j.jenvp.2011.07.001
[16] Schwartz, S. H. (1992). Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. *Advances in Experimental Social Psychology*. https://doi.org/10.1016/S0065-2601(08)60281-6

acceptability. Furthermore, research has shown that the order in which these aspects are presented is important[17]. In the early stages of energy projects, people tend to indicate the importance of its societal aspects. Later in the project's planning, personal aspects become more important such as the safety, costs, and sensory disturbances. Therefore, presenting people with a project's societal aspects in the initial planning stage of the project followed by the personally relevant aspects in the later stages may foster higher acceptability. For the public to believe that their priorities are taken into consideration in an energy project, they have to trust that the responsible actors are competent enough to do so. *Trust* has been defined as the intention to accept vulnerability based on the perceived competence of responsible actors[18]. Trust on its own, and in combination with community engagement, has been found to lead to more acceptability towards renewable energy projects[19]. In order for responsible actors to gain the trust of members of a community, the actors must, therefore, be able to convince people of their competence in the field of renewable energy and engage them in the decision-making process. Trust is not merely gained through credentials or titles but should be gained through visible actions where responsible actors take the public's priorities into consideration.

Cases of island energy projects

Past island energy projects have succeeded and failed in taking the public's place-attachment, priorities, and trust into account when engaging the community in the planning, development, and implementation phases. The outcomes of such engagement procedures have been crucial for the outcomes of

[17] Stefanelli, A., Seidl, R., & Siegrist, M. (2017). The discursive politics of nuclear waste: Rethinking participatory approaches and public perceptions over nuclear waste storage repositories in Switzerland. *Energy research & social science*, *34*, 72-81. https://doi.org/10.1016/j.erss.2017.05.042

[18] Rousseau, D. M., Sitkin, S. B., Burt, R. S., & Camerer, C. (1998). Not so different after all: A cross-discipline view of trust. *Academy of management review*, *23*(3), 393-404. https://doi-org.proxy-ub.rug.nl/10.5465/amr.1998.926617

[19] Liu, L., Bouman, T., Perlaviciute, G., & Steg, L. (2019). Effects of trust and public participation on acceptability of renewable energy projects in the Netherlands and China. *Energy Research & Social Science*, *53*, 137-144. https://doi.org/10.1016/j.erss.2019.03.006

the energy projects and have influenced the community spirit on the islands. Following are two examples of engagement strategies:

King Island, Australia

A large-scale wind farm was proposed on King Island by an external contractor. However, this project was ultimately cancelled due to resistance from the island residents, leaving scars in the trust between community members and the local government[20]. This was the result of insufficient information about the project's early stages, limited or discriminatory engagement strategies, and dismissal of local circumstances. First of all, as already stated above, engagement processes should be concerned with all stages of an energy project, including the planning process. On King Island, however, the responsible actors only chose to enlighten the residents on the details of the project when the major decisions were already made in cooperation with the local government. This left the residents feeling powerless to practice any influence over the project. The lack of information also threatened the public's trust in the local government to be transparent with its residents. The project's proposal occurred around the time of the closure of the island's largest source of income: its abattoir. Hence, the financial situation was insecure, to begin with, and the project's financial benefits were not obvious to the residents. With a unique landscape and wildlife, and a growing tourist industry on King Island, the presence of a visually imposing wind farm seemed threatening to the island's natural beauty, being important for attracting tourists and protecting its ecology. In sum, the responsible actors failed to organise community engagement procedures that gained the trust of the community, failed to address the financial, pro-social, and ecological benefits of the project, and failed to take the residents' connection to the landscape into account. This inevitably led to the cancellation of the project.

[20] Colvin, R. M., Witt, G. B., & Lacey, J. (2016). How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia. *Energy Policy*, *98*, 483-494. https://doi.org/10.1016/j.enpol.2016.09.022

Samsø, Denmark

The island of Samsø took a different approach to develop renewable energy. Its project was developed by the island's own community. It also took steps to engage as many residents as possible in the decision-making[21]. External parties were consulted for technical assistance, but all the decisions were made on the island. This was true for major as well as minor decisions. For example, a group of residents opposed the placement of wind turbines on a field facing their houses due to the visual impact the turbines would cause on the area. In cooperation with these residents, the responsible actors took the concerns into consideration and found a less controversial location for the turbines. Thereby, the places that had importance to people were kept in their original state to avoid resistance. Similar to King Island, the project was organised in a period of financial insecurity for the island. Population decrease and the closure of the island's slaughterhouse had threatened its financial future. The renewable energy project was seen as a solution to their financial struggles, but some industries on the island, specialising in repairing fossil-fuelled boilers, also saw themselves threatened by the new heat pumps that were planned to be installed. To counter the island's financial concerns, excess electricity from its wind turbines, biogas, and solar fields were sold to the mainland. Furthermore, the employees of the threatened boiler industries were reactivated in implementing and servicing the new heat pumps. As such, the financial concerns and concerns of professional obsoleteness were taken into consideration. Lastly, since the implementation of the project on Samsø, the island has received wide international recognition for its innovation and community-centred approach to renewable energy development. Thereby, does the project not only appeal to people's priorities of the project's environmental benefits; it also appeals to the

[21] Sperling, K. (2016). *How does a pioneer community energy project succeed in practice? The case of the Samsø Renewable Energy Island*. https://doi.org/10.1016/j.rser.2016.12.116

priority of the heightened status and recognition of Samsø as an energy frontrunner.

Community engagement on Inishbofin

The responsible actors of Inishbofin's renewable energy project have laid an advantageous groundwork for gaining the public's acceptability of its energy project. By being based on the island and, thereby, being in contact with the island's other residents is a major advantage since people will be more trusting towards people they consider part of their own group. However, the responsible actors must be cautious of sufficiently taking people's priorities and significant areas into consideration when developing renewable energy.

Address all priorities

During community engagement events, responsible actors should make sure to address how a project affects all the priorities that residents find most important in life, both societally and personally relevant ones. Suppose people's most important priorities are left out of the engagement process. In that case, people may feel that their concerns are being overlooked, and this may negatively affect how they perceive a project. Below is given examples of how the responsible actors may address peoples different priorities:

Societally relevant priorities

- Nature and environment: People should be made aware of the emissions savings that can be achieved by installing renewable energy and how this influences the environment. It should also be addressed how the wind turbines, solar fields and tidal energy systems may influence the local flora and fauna.
    - *The emissions from past and future energy systems could be compared.*
    - *Are migrating birds in danger of the turbines?*

- *How does it affect people's personal carbon footprint?*
- *Do aquatic flora and fauna suffer or benefit from installing tidal systems?*

- Community and pro-sociality: People should be made aware of how the energy project may influence the community spirit and sense of togetherness on the island. It should also be addressed how the project may influence people that are less financially or socially fortunate.
  - *Will residents become more or less interconnected as a result of a new energy system?*
  - *Are there less fortunate island residents that will suffer or benefit from the project?*
  - *Does the project create new opportunities to arrange community gatherings?*

Personally relevant priorities

- Resources and status: People should be made aware of the financial costs and gains that the energy project presents. Furthermore, the heightened status of Inishbofin as an energy island and their status as self-sufficient energy producers and consumers should also be addressed.
  - *What is the financial incentive of installing solar, wind and tidal energy?*
  - *How do people personally benefit from being part of an island-wide energy system?*
  - *How will the project affect Inishbofin and its residents in terms of reputation?*
  - *How could a heightened reputation bring more business opportunities to the island?*

- Comfort, pleasure, and safety: People should be made aware of the energy project's influence on their daily comfort. Furthermore, the responsible actors should address if the project presents potential safety hazards or if safety hazards are eliminated as a result of discontinuing fossil fuel energies.
    - *How does the project affect people's ability to use energy when they desire, like taking long showers, turning up the heat, or driving wherever, whenever?*
    - *Are there potential dangers of installing heat pumps in the houses?*
    - *Will there be annoying glare from solar panels or flutter and shadows from wind turbines?*

As mentioned earlier, everyone prioritises finances, the environment, their community and their comfort and safety to a certain degree. This is also the case for residents of Inishbofin. For example, residents prioritising the project's benefits for the environment may resist the project if the energy from the technologies will be much more expensive than it was in the past. Vice versa, residents prioritising a heightened status as a result of the energy project may still resist it if other less fortunate residents will occasionally be without heating given that they cannot afford a heat pump. During community engagement events on Inishbofin, the responsible actors should, therefore, address all the aspects of the energy project, both societally and personally relevant ones. Even aspects that may seem obvious to the planners may not be obvious to the layperson. Furthermore, the project should attempt to comply with these priorities as best as possible.

Significant areas on Inishbofin

The responsible actors on Inishbofin should take into consideration how the landscape of the island will change with the implementation of renewable energy systems. It is crucial for the project to consider how such changes may affect the emotional and instrumental connection that people may have to the landscape. For example, the connection or attachment to an area may be formed by certain hobbies or events practised in areas that wind turbines or solar panels will change. It may also be the therapeutic qualities of areas near water that the presence of tidal energy will alter. Further implications that energy systems may have on the landscape are areas of historical significance. During the engagement of the Inishbofin residents, the responsible actors should thoroughly consult people about the areas that are deemed fit for implementing energy systems. Suppose conflicts arise in areas that carry significance to people. In that case, the responsible actors should consult residents about developing the energy systems in harmony with the meaning that people prescribe to the area. For example, one could dedicate a solar field to historically significant figures from the island or design wind turbines from more aesthetically fitting materials to a natural area, such as wood. The latter example worked for limiting resistance against wind turbines in the northern part of the Netherlands. There, smaller scale turbines were built to fit the agrarian landscape[22].

Before and during community engagement, responsible actors should take the following steps to respect the importance of significant areas on Inishbofin:

1. *Identify areas of high emotional, instrumental, or historical importance to the residents of Inishbofin, and avoid altering these areas altogether.*
2. *Identify the potential attachment that people may have to areas that are well-fitted to implement renewable energy.*
3. *Consult people that may be attached or have a connection to the area.*
4. *If people resist altering a well-fitted landscape, consult with them about how the energy systems could be implemented in line with the meaning they prescribe the area.*

Conclusion

[22] van der Waal, E. C., van der Windt, H. J., Botma, R., & van Oost, E. C. (2020). Being a Better Neighbor: A Value-Based Perspective on Negotiating Acceptability of Locally-Owned Wind Projects. *Sustainability*, *12*(21), 8767. https://doi.org/10.3390/su12218767

Community engagement is an essential part of an island energy project. It can lead to more acceptable outcomes but only when it is done in the right way. To foster acceptability and avoid public resistance against the energy project on Inishbofin, responsible actors should consider gaining the trust, including the priorities, and respecting areas of significance to the island's residents. Earlier island energy projects teach us that a project may affect people's financial outlook. The project on Inishbofin should be designed to avoid that people's main form of income is affected and instead reactivate them in the planning and maintenance of the new energy system. Certain areas that hold significance may also be affected by the presence of renewable energy. Therefore, responsible actors should consult residents on how best to implement energy systems in line with the meaning people prescribe to such areas. Lastly, the priorities that people find most important in life should be included in planning a project. If people feel like their major concerns are reflected in the project, they will be more likely to accept solutions for making Inishbofin self-sustained on renewable energy.

13.2 Appendix B: Domestic Energy Usage Sampling

Table 21: Domestic Electricity Usage Sampling

Household No.	2019	2020	2021	Electricity consumption per person
2 adults, 3 children	2601	4382	3541	876.4
1 adult	1153	2307	1846	461.4
3 adults, 1 child	2300	4615	3692	923
2 adults	5769	11538	9320	2307.6
3 adults	3173	6346	5077	1269.2
1 adult	1551	3103	2483	620.6
1 adult	1557	3115	2492	623
1 adult	1442	2884	2307	576.8

1 adult	1488	2976	2380	595.2
2 adults	1846	3692	2954	738.4
2 adults, 1 child	3210	6420	5136	1284
2 adults, 1 child	2873	5746	4597	1149.2