Fuinneamh Oileáin Árann
Aran Islands Energy

Energy Master Plan 2018

Árainn and Inis Meáin

5th November 2018

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Table of Contents

Figures

Tables

Acknowledgements

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1. Introduction

Renergia Ltd in conjunction with Plan Energy Consulting Ltd were commissioned by Comharchumann Fuinnimh Oileáin Árann Teoranta (CFOAT) in support of Energy Co-Ops to develop an Energy Master Plan (EMP) for Árainn (Inis Mór) and Inis Meáin that reviewed the energy import and consumption of the island, as well as reviewed past and future energy efficiency and renewable technology opportunities.

The key objectives of this Energy Master Plan are:

- Review the current energy baseline of energy imports to the Islands
- Review the energy usage by sectors
- Provide an over-arching energy strategy for the islands and identify discrete project opportunities
- Identify grant and funding mechanisms available to support project opportunities
- Establish an action plan to sustain and develop energy efficiency and renewable generation

This Energy Master Plan aims to future-proof planning and energy policy in light of the potential future impact of National and European legislation outlined in subsequent sections. A key objective of this initiative is to continue to develop a structure to allow all local stakeholders to make more informed policy decisions relating to energy provision and development in the area. It is also expected that the work will act as an exemplar for other local authorities to demonstrate the value of the energy master planning process, to encourage similar initiatives elsewhere, and the engagement of the community.

2. The Energy Master Plan

2.1. OBJECTIVES OF THE ENERGY MASTER PLAN

The goal of the Energy Master Plan is to provide a roadmap for efficient, practical, cost effective and robust energy systems for Árainn (Inis Mór) and Inis Meáin. This goal was further broken down into the following objectives:

- Review the current energy baseline of energy imports to the Islands
- Review the energy usage by sectors
- Provide an over-arching energy strategy for the islands and identify discrete project opportunities

2.2. METHODOLOGY OF THE STUDY

The approach to the plan is detailed in Figure 2-1.

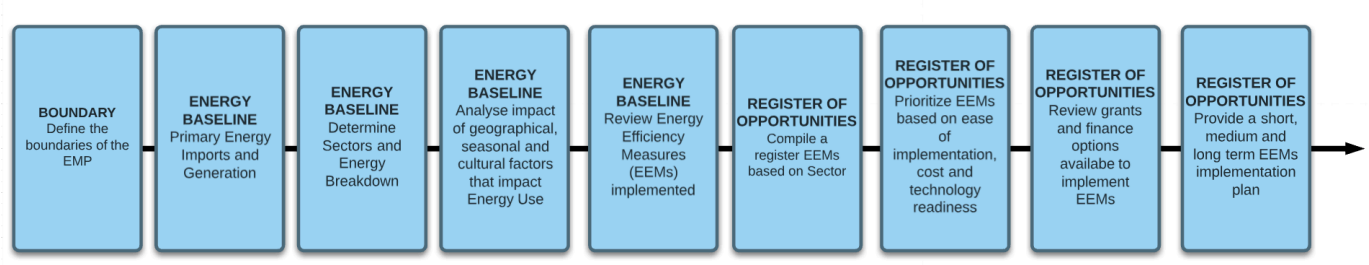

Figure 2-1 Energy Master Plan approach

The first step was defining the boundaries of the plan. Due to the geographical nature, fuels are imported to the island. However, certain fuels are not directly linked with the Islands' economic activity or are not directly utilised in situ, hence they were discounted. This particularly pertains to transportation fuel associated with large Fishery vessels. Boats are fuelled in Rossaveal, and the economic activity (fishing) takes place at a significant distance from the Island. Although these Fishery companies employ some Islanders, the activity is not directly associated with Árainn (Inis Mór) and Inis Meáin as the fish is sold in the mainland, the fishermen/fisherwomen do not moor the boats on the island, and they spend a significant time at sea.

The main Primary Energy Sources (PES) used on the Islands are; imported electricity, thermal fuels (solid fuel, gas and oil and non-road diesel), and transportation fuels. Transportation diesel used for ferries, and aviation fuel have also been included, despite refuelling taking place in the main land, as they are the two main sources of transportation to and from the Islands. The resulting boundary of the EMP is depicted in the figure below.

Figure 2-2 Energy Master Plan boundary

ESB networks provided electricity consumption data for a year's period (from 30 April 2017 - 29th April 2018) in the form of 30-minute interval data that was tallied and organised.

Lasta Mara, a Galway based fuel cargo company, provided records of solid fuels, gas and oil imported to the Islands. The Comharchumann Forbartha Árann Teo (CFTA) also provided fuel records for imported kerosene and gas oil. These records were tallied and organised.

Aviation fuel records were provided by Aer Aran Islands. Records of road diesel associated were only available for Árainn, which were provided by the CFTA. Ferry diesel consumption data was not made available by the companies providing the services, hence figures were estimated based on number of vessels, frequency of journeys and average usage of diesel per vessel.

Energy costs and emissions records were not readily available for all fuels, hence SEAI published documents on average cost of fuel and emissions were utilised[1].

The energy baseline was then further broken down into sectors that utilise the imported energy. This includes Residential, Commercial, Public Buildings and Utilities and Public Services, and Transport. Some data on the premises and vehicles associated with each sector were collected via site visit, telephone interview, online and direct surveying. However, the majority of the energy usage data was not available, hence it was estimated using CIBSE Guide F benchmarking data[2] for similar buildings Furthermore, by means of a literature review of, journals, reports and other work conducted by third parties on the islands and the 2016 census[3, 4] further information was gathered.

As part of the data collection process, energy efficiency projects completed on the two islands were reviewed. This included participation in SEAI Better Energy Community (BEC) projects, research projects or any other funded project. Details are further discussed in each section.

Having evaluated the energy usage and the sectors that utilise it, a register of opportunities for Energy Efficiency Measures (EEM) and Renewable Energy Technology (RET) projects was developed. The register was subdivided into sectors, and EEMs and RETs were prioritised based on ease of implementation, technology readiness, and costs. Furthermore, funding and grants available to support these projects, along with government and international programs that could support the initiatives of this plan were highlighted. This resulted in a plan for short, medium and long-term actions to achieve CFOAT's goals.

The outputs of this body of work include the compilation of this report detailing the action plan, development of the live Register of Opportunities, and the design of data gathering and analysis tools that will facilitate the on-going Energy Baseline review for the islands.

2.2.1. DATA ASSUMPTIONS AND POTENTIAL SOURCES OF ERRORS

Fuel data was gathered from various sources, and the authors of the report have carried out calculations on the assumptions that all these records are accurate. It is worth noting that:

- Thermal fuel records obtained were manually transcribed from shipping dockets into spreadsheets, which were then provided in the form of raw data.
- Thermal fuel records for 2012 were provided, however figures did not seem to be accurate in various instances, and corresponding dockets from which data was obtained were not readily available, hence this data was not utilized.
- For all fuels, the periods for analysis considered were the last 5 years (2013 to 2017); electricity data was available only for 2017, Thermal fuel data was available from 2012 to 2017 and Aviation fuel and Road Diesel figures were available from 2013 to 2017.

2.3. RELEVANT POLICY CONTEXT

Ireland has developed the National Energy Efficiency Action Plan (NEEAP), which presents the country's min policy targets to energy efficiency. The fourth published version of NEEAP was published in early 2017[5]. The policy outlines the plan to deliver 20% energy efficiency by target date of 2020, based on the European Union (EU) Energy Efficiency Directive. This represents €2.4 billion in energy cost and 7.7 million tons of carbon emissions reduction. To date, the country has achieved 12% of its national target.

The key points of the plan include:

- The Public Sector has been set an energy efficiency target of 33%. A comprehensive Action Plan for Energy Efficiency in the Public Sector has been deployed, and the most recent Annual report published (2015 figures) reported a 21% improve efficiency amounting to 2,422 GWh annual primary savings. SI 426 mandates that all public buildings with gross internal floor areas greater than 250m² have Display Energy Certificates in prominent places clearly visible to the public, and that all buildings with floor area greater than 500m² or an energy spend of greater than €35,000 must have an energy audit completed every 4-years by a Registered Energy Auditor.
- The EU Energy Performance in Buildings Directive (EPBD) legislation Article 9 requires all new buildings to be "nearly zero energy" by end of 2020. NEAP has set a target to achieve 70% energy efficiency in Residential buildings compared to 2005 standards, and 60% energy efficiency in Non-residential buildings compared to 2008 standards
- In the Commercial sector there is a target to reduce energy usage by 20%. It is primarily driven by the Energy Auditing Scheme which requires companies with more than 250 employees or a turnover greater than €50M to carry out an energy audit by a registered SEAI auditor.
- Improvements to Electricity and Natural gas transmission and distribution systems are a key priority to increase generation and distribution efficiency. To date 3,279 GWH PPE.
- In transportation, Ireland set an initial target of converting 10% of its passenger and light commercial vehicle stock to Electric Vehicles (EVs) by 2020

In terms of alterative technology, the EU's Renewable Energy Directive has been adapted in Ireland under the Nation Renewable Energy Action Plan (NREAP). The fourth version of the plan published in February 2018 continues to support the goals set of 40% electricity consumption from renewable energy sources (RES), 10% electric vehicles and 12% renewable heat by 2020. In the last 5 years in particular, Ireland has made big strides in accelerating renewable generation achieving 14.4% RES electricity in 2009 and has risen to 27.2% based on 2016 figures. RES in transport was 5%, and RES for heat was at 6.8% as of end of 2016[6].

The energy efficiency and renewable energy implementation targets align with the objectives of CFOAT to become fossil fuel free by 2022.

2.4. OVERVIEW OF COMHARCHUMANN FUINNIMH OILEÁIN ÁRANN TEORANTA

Comharchumann Fuinnimh Oileáin Árann Teoranta is a community owned energy cooperative on Árainn (Inis Mór). The aim is for every resident of the island to become a member. At the moment, there are 85 members. The intention of the organization is to steer the broad direction of sustainability goals and ambitions for the three Aran Islands, while securing the essential assets and resources for the community. CFOAT aims to make the Aran Islands self-sufficient in clean locally owned energy and build its economy on the related benefits that accrue from this. The key objectives of the group:

1. To secure the future energy needs of the three Aran Islands by gaining a controlling interest in the local sources of alternative energy production.
2. To reduce and gradually remove the dependency of the Aran Islands communities on fossil fuels by replacing them with alternative and more sustainable sources of energy.
3. To preserve the islands' unique language, heritage and culture by providing sustainable employment and a sustainable environment for people to live in.
4. To facilitate the conversion of homes and other buildings on the three islands to be more sustainable in their energy usage.
5. To provide low-cost energy to industry so as to create employment on the islands
6. To create, provide and encourage employment in projects of sustainable energy
7. To facilitate and at least part-own initiatives and projects in research and development into sustainable energy.
8. To provide education and training to both residents and non-residents in sustainable living.

To date CFOAT has promoted and carried out the following initiatives:

- **Electric Vehicles:** There was a 3-year pilot involving 10 electric vehicles (EVs) deployed in partnership with SEAI. The vehicles were removed after the culmination of

the pilot. There are currently 10 privately owned EVs in Árainn. There are also 8 electric bicycles for hire.

- **Residential and Commercial Sector Retrofitting:** With the support of SEAI's Better Energy Community scheme, Warmer Homes Scheme, and the Greener Homes Scheme approximately half of the Árainn residential and various commercial properties have undergone energy efficient retrofits including; building fabric upgrades, solar thermal installations, air source heat pumps and solar photovoltaic. Similar work has also been carried out in Inis Meáin at a smaller scale.

- **Renewable Energy Generation:** A feasibility study has been conducted for a 2.3 MW turbine that did not go ahead, as the location was not accepted by the island community. There is a proposal to install 3 x 900 kW Wind Turbines, and the organisation is working on procuring a commercial feasibility study.

- **Research and Development**: The organisation is participating in several research and development programs with universities in Ireland, including;
    - RESPOND (Horizon 2020) researching Demand-Response sensors and meters in buildings to improve efficiencies. Over 20 houses on Árainn will participate.
    - SEAFUEL (InterREg Atlantic area) researching the feasibility of generating hydrogen fuel from surplus wind and photovoltaic energy on Árainn
    - GEOFIT (Horizon 2020) researching larger geothermal heating systems that supply large buildings or a number of residential homes. 8 homes on Árainn will participate.
    - C-VVP (InterREg) researching a virtual power plant. Aran will participate by supplying micro-generated power and buy it back for residential usage.

3. Energy Baseline

3.1. THE ARAN ISLANDS

The Aran Islands are located approximately 20 kilometres from Rossaveal, Co Galway on Ireland's west coast, and are 5-12 nautical miles out in the Atlantic Ocean. The island group consists of Árainn (Inis Mór) Inis Meáin and Inis Oírr. This report will focus on the first two islands only.

Figure 3-1 The Aran Islands (Terraform, 2018)

3.1.1. ÁRAINN

Árainn (Inis Mór), meaning the big island, stretches over 31 km². It has the largest population of the Aran Islands with 712 regular residents [7]. Its inhabitants primarily speak Irish but are also fluent in English. The island is one of the most popular tourist destinations in Ireland due to its historical interest and its importance in modern Irish Culture. Annually circa 250,000 tourist visit the Aran Islands, with daily visitors ranging from 1,000 to 3,000 per day during summer months[8].

Most islanders make their income from tourism, and hence the season commencing in May and culminating in late September is vital in terms of sustainable living through the rest of the year.

Fishing industry is also a large employer of the island, however most of the activity is managed from Rossaveal, and fishing takes place in open waters mainly across the Atlantic as well as in the Irish Sea.

There are also small and medium enterprises (SMEs) established on the Island. These include a Goat Farms, and a Sea Weed processing plant. In addition there is a supermarket, clothes, souvenirs and crafts retail businesses, and a bank. There are also seven restaurants and cafes, as well as 14 B&Bs, a Glamping site and the Aran Islands hotel. There are also 20 minibuses servicing locals and tourist. There are approximately 20 pony and traps, and two bicycle hire shops with up to 1000 bicycles.

There are various public buildings including; churches, a Garda Station, a Fire Station, the Community Centre, a HSE medical building, Aras Rónáin, a community owned facility for the elderly which includes a HSE run nursing home and some sheltered social housing units, two primary schools and a secondary school, and the Post Office.

There is also a Recycling Centre that processes and manages waste for the islands. In terms of water treatment, there are public schemes set up to manage household and commercial sewage, as well as individual septic tanks located across the island. There is a water processing plant that provides water from 3 water sources, and distributes them across the island.

In terms of settlement, there are 14 villages across the island. The main settlement of Cill Ronaín contains all the main facilities and services for the island. Housing is located primarily along existing roads of the island. Based on the 2016 Census results, there are a total of 462 homes built on the island. Out of these, 297 are fulltime occupied households, 58 are holiday homes occupied only partly during the year, approximately 19% or 87 of them are vacant dwellings.

The great majority of family houses are connected to septic tanks, and commercial premises are connected to proprietary sewage treatment plants, most of them being in Cill Rónáin. A new public sewerage scheme is being designed to treat the effluent of the two principal villages on Árainn i.e. Cill Rónáin and Cill Éinne. There are public water schemes serving Árainn and Inis Oírr. Improvements to both schemes have been carried out in recent years [3, 8].

3.1.2. INIS MEÁIN

Inis Meáin is the second largest of the Islands, stretching over 9km². It has a population of 183 residents. 82% of the Islanders are Irish speaking. The island has maintained its distinctive traditional field pattern, giving it a unique visual character.

Tourism is also a source of income; include the Inis Meáin Suites, and smaller B&Bs. The local business includes; a knitwear factory shop, a craft shop, a small supermarket, a bike hire shop, a pub, and restaurants.

There are various public buildings, including a Catholic Church, a primary and secondary school and a co- operative.

The island has approximately 135 houses with approximately 40 remaining vacant. Most houses are built in linear type development along the main routes of the Island. Inis Meáin is served by a group water scheme managed through a private contract by a third party[4, 8].

3.2. ENERGY BASELINE

To establish the energy baseline for the two islands fuel import data was gathered. As detailed in Section 2.2, there are three main fuel imports associated with the island daily life and economic activity; imported electricity, imported thermal fuels, and transportation fuel. Electricity import data was available from May 17 to April 18 for both Islands, as well as maximum load data made available for Árainn from 15 December 2013 to 10 October 2014 by a previous study conducted on the island[9]. Thermal fuels (solid, gas and oil) import data was available from 2012 to 2017, aviation fuel data was available from 2013 to 2017, and road diesel for Árainn was available from 2012 to 2017. Inis Meáin road diesel and ferry diesel data for both islands was not available, hence it was estimated. To establish a full picture of fuel imports, 2017 was selected as the year for which most data was available.

Table 3-1 summarizes the Total Primary Energy Requirement (TPER) and Total Final Consumption (TFC) per sector for 2017. TPER conversion, TFC emissions and TFC cost were based on SEAI conversion publications[10, 11]. Total Primary Energy Requirement (TPER), is the measure of all of the electricity consumed that accounts for the energy that is consumed and/or lost in transformation, transmission and distribution processes (e.g. electricity generation transmission and distribution). Total Final Consumption (TFC) is the electricity at point of use (the quantity of electricity directly used by the consumer) [11].

Data collection and calculations demonstrated that the two islands spent close to 3.2 million euro on energy, with Árainn accounting for 74% of the overall spend and Inis Meáin for 26%. Transportation fuel was by far the largest area of consumption, accounting for 69% of the overall energy consumption and 59% of the overall energy spend of the two islands.

Table 3-1 2017 Energy Summary for Árainn and Inis Mein

	Árainn (2017)				Inis Meáin (2017)			
	Total Primary Energy Requirement	Total Final Consumption (TFC)			Total Primary Energy Requirement	Total Final Consumption (TFC)		
	Usage (MWh)	Usage (MWh)	Emissions (tCO_2)	Cost (€)	Usage (MWh)	Usage (MWh)	Emissions (tCO_2)	Cost (€)
Transportation	13,412	12,193	3,215	€1,166,458	8,730	7,936	2,093	€712,447
Thermal Fuel	6,184	5,622	1,572	€930,039	1,295	1,178	305	€56,741
Imported Electricity	4,012	1,855	895	€259,461	870	402	194	€56,258
Total	**23,608**	**19,669**	**5,682**	**€2,355,958**	**10,895**	**9,516**	**2,592**	**€825,446**

Table 3-2 (next page) details the breakdown by sector of the TFC for each island for 2017. Data collected and calculations identified Maritime energy usage as the largest for both islands, accounting for 49% of Árainn's overall energy usage, and 81% of Inis Meáin's energy usage. Thermal fuel energy spend for the two islands was close to 1 million euro, while electricity was around 315,000 euro.

Table 3-2 Total primary consumption breakdown by sector

		Árainn (2017)			Inis Meáin (2017)		
	Sector	Total Final Consumption (TFC)			Total Primary Consumption (TPC)		
		Usage (MWh)	Emissions (tCO_2)	Cost (€)	Usage (MWh)	Emissions (tCO_2)	Cost (€)
Transportation Fuel	Maritime (Ferries only)	9,541	2,519	€801,441	7,678	2,026	€664,952
	Road Diesel	2,298	607	€278,093	128	34	€15,461
	Aviation	353	89	€86,925	130	33	€32,034
		12,193	**3,215**	**€1,166,458**	**7,936**	**2,093**	**€712,447**
Thermal Fuel	Residential	3,144	879	€520,103	584	151	€96,610
	Commercial	1,283	359	€212,296	266	74	€44,027
	Industrial	0	-	€-	110	31	€18,205
	Public Bldgs.	894	250	€147,846	214	60	€35,326
	Utilities	301	84	€49,794	4	1	€662
		5,622	**1,572**	**€930,039**	**1,178**	**305**	**€56,741**
Electricity	Residential	537	259	€75,126	88	42	€12,311
		– 38		– €54,	– 8		– €11,58
	Commercial	8	– 187	264	3	– 40	5
	Industrial	34	16	€4,704	47	22	€6,505
	Public Bldgs.	224	108	€31,285	46	22	€6,417
	Utilities	663	320	€92,689	139	67	€19,409
	Transport (EV)	10	5	€1,399	0	0	€0
		1,855	**895**	**€259,467**	**402**	**194**	**€56,228**

Figure 3-2 and Figure 3-3 further detail the energy balance for each island; from Total Primary Energy Requirement (TPEF) to Total Final Consumption (TFC) per sector.

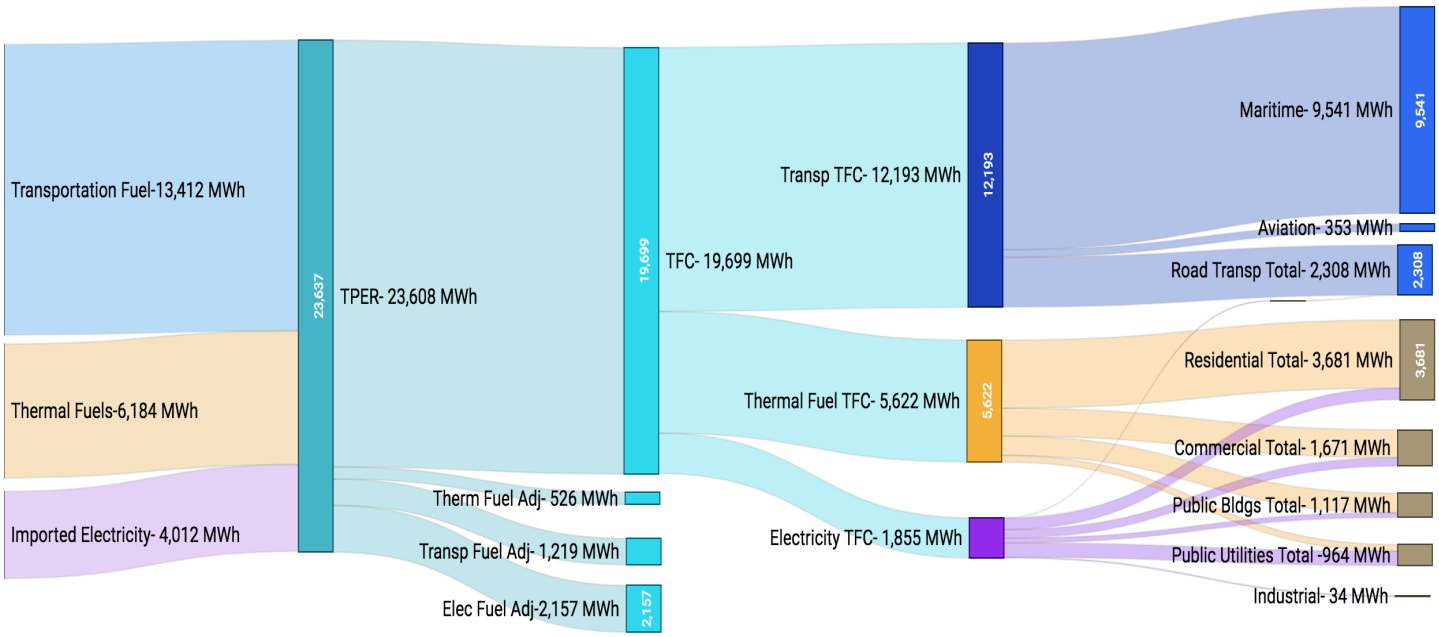

Figure 3-2 Árainn Energy Balance (2017)

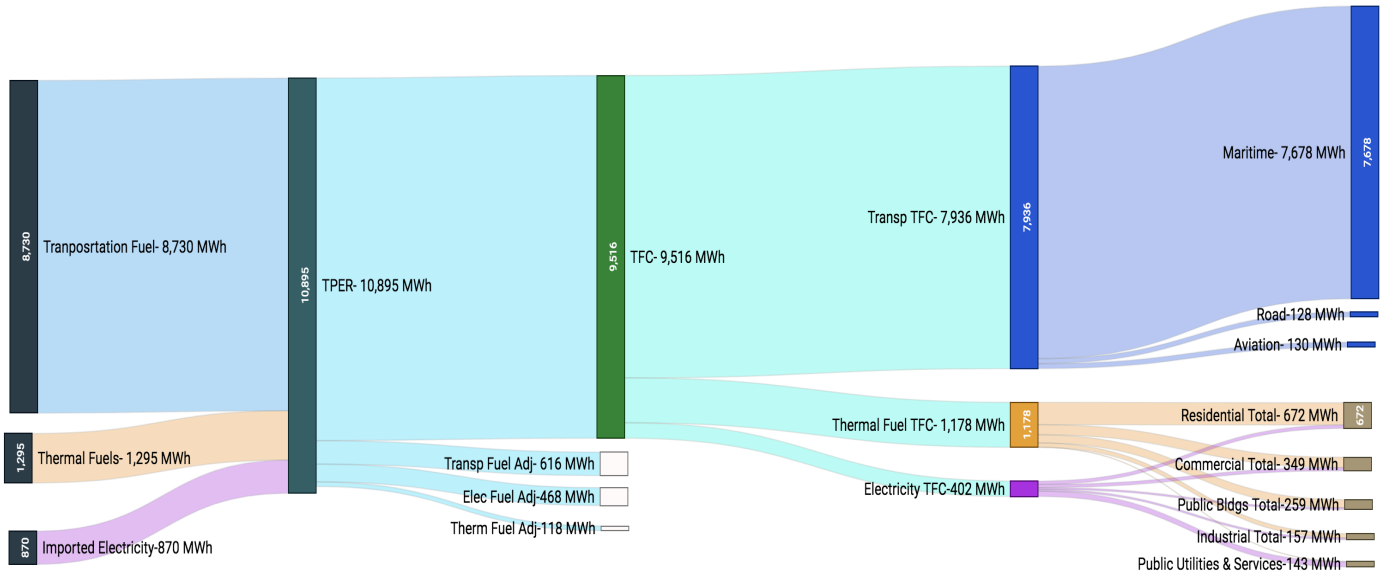

Figure 3-3 Inis Meáin Energy Balance (2017)

3.2.1. ELECTRICITY

Electricity is imported to the Islands via a 3 MW cable connection from Irish mainland into Árainn, and is then distributed to the other two islands as detailed in the figure below. There is a recloser located at Rossaveal and then one on each island. Data was available from each of the 4 reclosers.

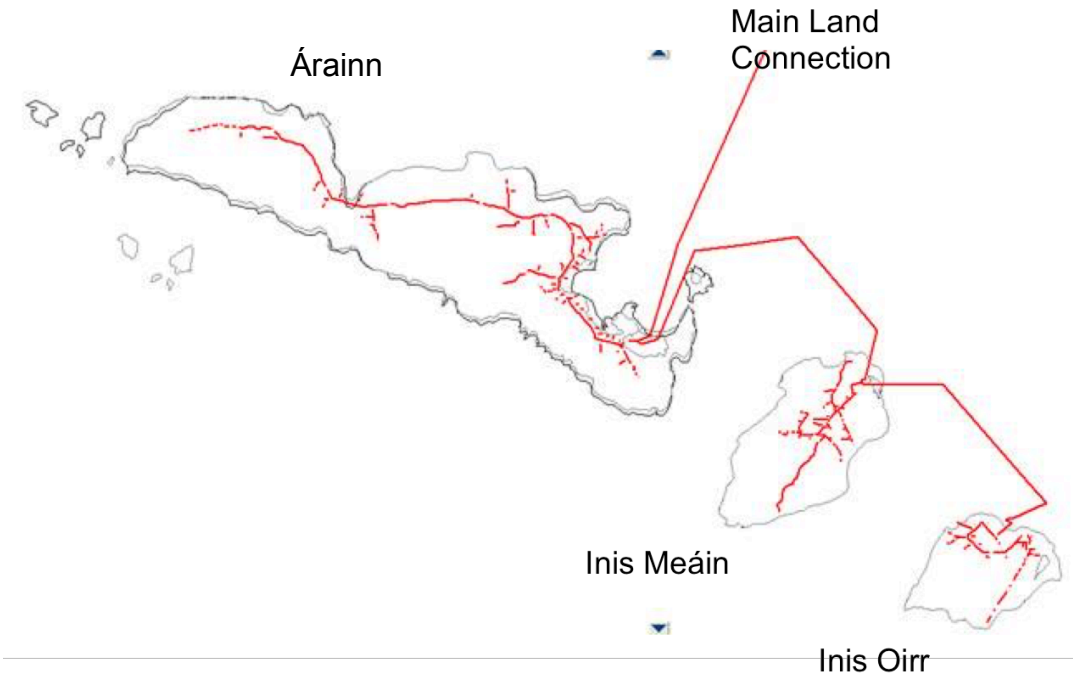

Figure 3-4 Electricity Import from Rossaveal to the Aran Islands

Data provided by ESB was analysed, and a consumption pattern for 2017 was established. It should be noted, that the original data set was supplied in amps readings for a year's period (May 17 to April 18), and it was assumed that the consumption from Jan to April 2018 was representative of Jan to April 2017, as the average load did not change significantly throughout the year.

These figures represent Total Final Consumption (TFC) or the electricity at point of use. Total Primary Energy Requirement (TPER) was calculated by applying SEAI published conversion factors as per Public Sector reporting requirements[11].

The mainland recloser recorded a total of 6,741 MWh of electricity consumption, however the sum of the 3 island reclosers totalled to 2, 993 MWh. This means that there was a total of 3,748 MWh of electricity difference between that recorded on the main land and that supplied to the islands. It would be important to review the nature of the difference is records (56% difference), as despite potential transmission losses from the mainland recloser to the islands, the value seems significantly high. It would be advisable to carry out an in depth study to further determine the unaccounted amount.

Figure 3-5 details the electricity analysis carried out for both islands quantifying TFC and TPER.

A total of 2,993 MWh of electricity was imported into the Aran Island reclosers. Árainn is the most energy intensive of the islands, accounting for 62% of the electricity imported to the three islands. It accounts for 62% of the total emissions and cost. The winter months were the most energy intensive, with March being the month with most consumption.

Inis Meáin accounts for 13% of the overall Electricity imported, 13% of electricity emissions and cost. Winter months are also the most energy intensive in Inis Meáin, with January having the largest recorded consumption.

Figure 3-5 2017 Electricity Analysis for Árainn and Inis Méain

The average load in Árainn during this period was 208 kVA, with a max load of 368 kVA. While Inis Méain had an average load on the island during this period was 45 kVA, with a max load of 95 kVA.

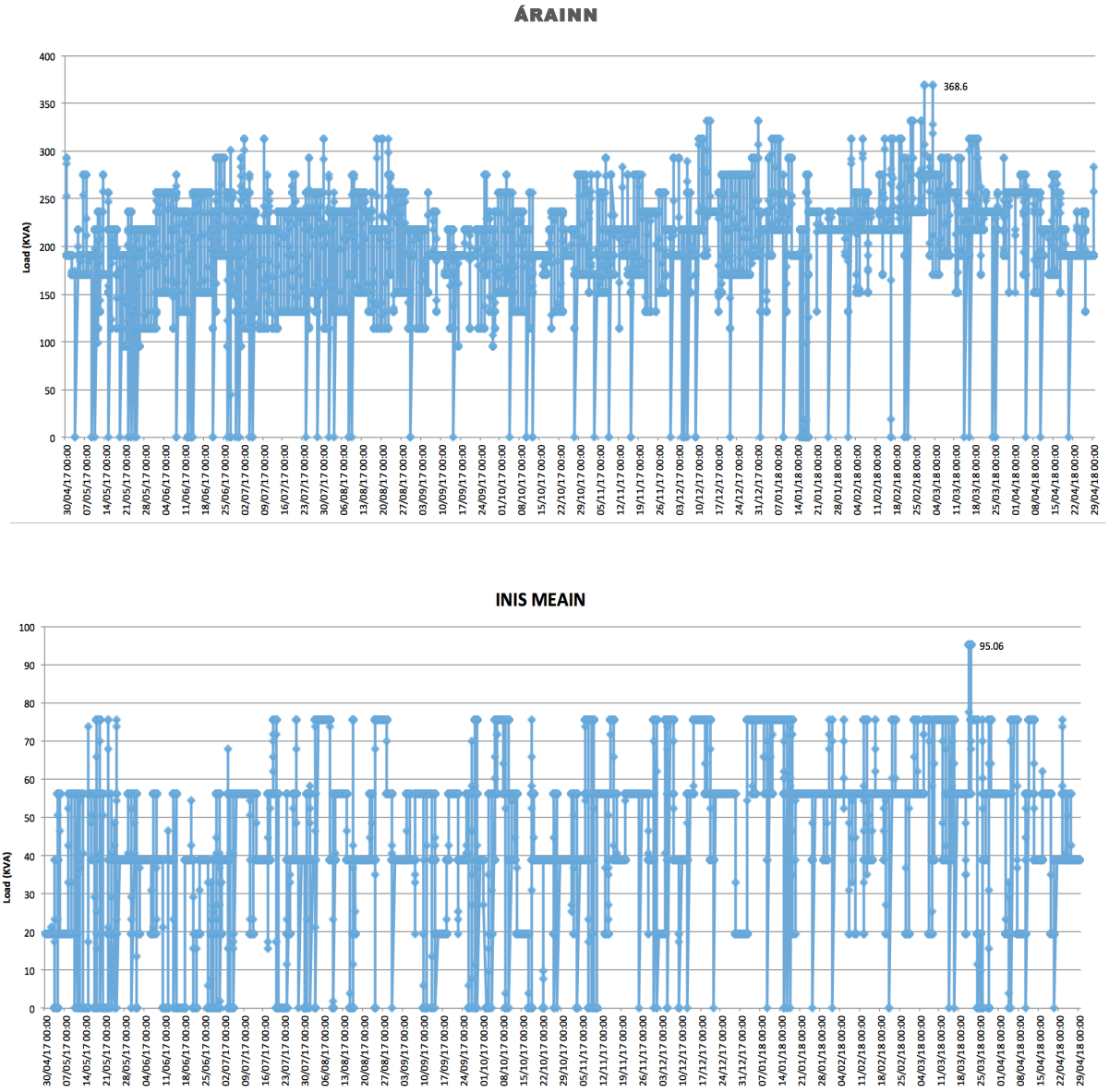

Figure 3-6 Árainn and Inis Meáin load profiles

3.2.2. THERMAL FUELS

The two islands import thermal fuels from the main land from Lasta Mara, and have recently (since mid 2016) also been importing kerosene and diesel from Sweeney Oils based in Clifden, Co Galway. Lasta Mara provided fuel import records for both islands, and the Comharchumann Forbartha Árann provided fuel import data for Árainn.

The import records were compiled for each fuel source, and aggregated monthly resulting in an annual thermal fuel baseline for each island. As with electricity, the TPER was also calculated for each fuel. The thermal element of the consumption was adjusted for degree days to account for weather-related variations in energy consumption, and the SEAI conversion factor was applied [11].

Records were analysed from 2013 to 2017 for each island. This section will discuss thermal fuel imports (based on records provided which correspond to the TFC) for each island, as well as provide an analysis for 2017 data set both for TPER and TFC.

Árainn

Árainn has had an average Thermal fuel TFC import of 6,500 MWh per annum, with 2015 representing the year with the highest annual import. The most predominant imports are coal, kerosene and gasoil.

Kerosene is the main import (average of 32%) followed by Gasoil (26%) and, Coal (25%). These fuels are predominantly used for heating both in the residential sectors and the commercial properties (hotels, B&B, amongst others). Diesel for non-transport purposes accounts for 10% of imports on average, and is used for heating and as principal fuel for generators. Wood and peat briquette are used for heating, and each accounts for an average of 2% of imports.

Butane and propane tanks are delivered in cylinder sizes (34 kg and 47 kg cylinder for propane, and 11.34 kg for butane), and are mainly used as residential and commercial cooking fuel. These represent a combined average import figure of 6%.

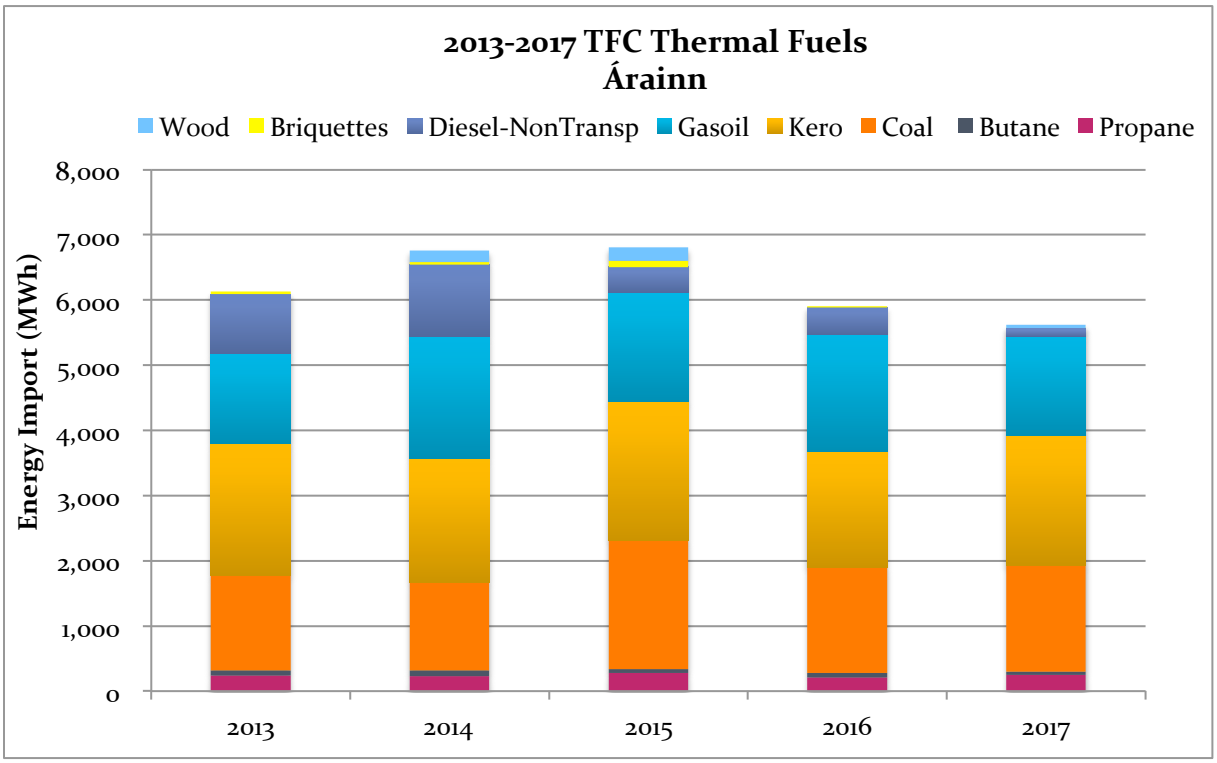

Figure 3-7 2013 to 2017 TFC Thermal fuel imports- Árainn

In terms of emissions from fuel imports, Kerosene, Coal and Gasoil are the main contributors, with average percentage contributions of 29%, 30%, and 25% respectively. Diesel for non-transportation purposes accounts for 10% of the emissions, and the other fuels account for the remaining 6%.

This highlights the very significant opportunity for the island in terms of alternative heating methods.

Inis Meáin

Inis Meáin had an average of 1,500 MWh of fossil fuel imports for heating per annum between 2013 and 2015, with 2015 representing the most imports at 2,135 MWh/annum. Diesel, coal and kerosene are the most predominant fuels imported.

Coal was the main fuel import during this period, representing approximately 58% of the overall imports. It is used mainly for residential heating. Kerosene represented on average 26% of the overall fuel imports during this period, and was mainly used as commercial and residential heating source. Diesel represented approximately 8% of thermal fuels, it is estimated that the majority was used for heating along with generators for electricity back up.

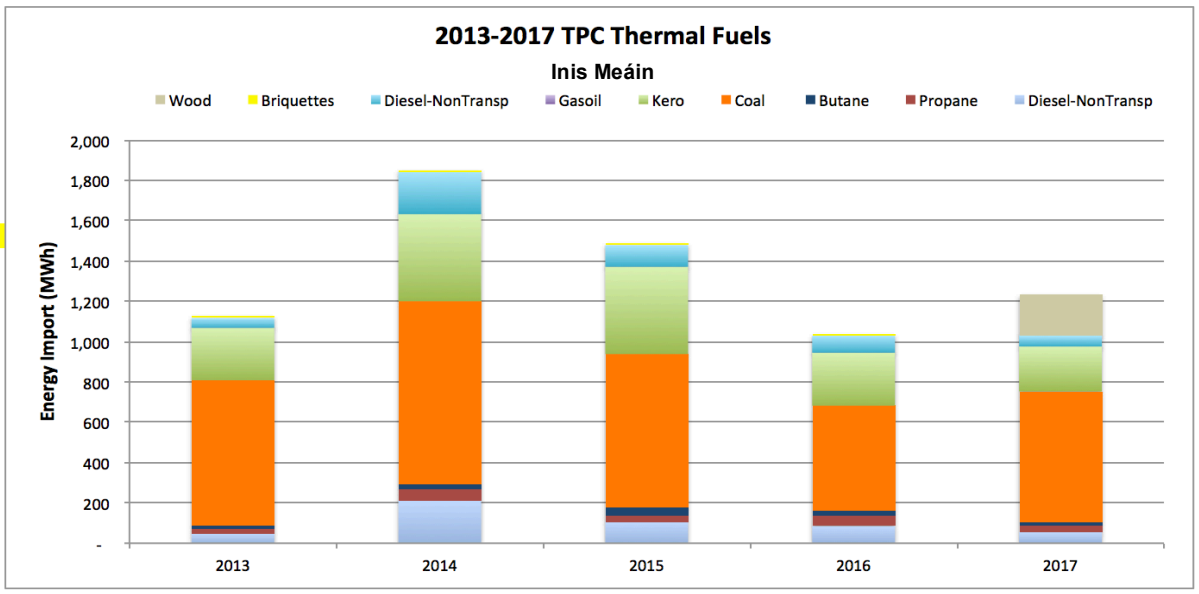

Figure 3-8 2013-2017 TFC Thermal Fuel Imports- Inis Meáin

Butane and propane each represent approximately 2 and 3 per cent, respectively, of the fuel imports between 2013 and 2015. Butane and propane are mainly used as cooking fuels. Peat briquettes represented on average 1% of the energy imports. Wood was not imported between 2013-2016, however in 2016 it represented 16% of fuel imports for that year.

In terms of emissions from fuel imports, Kerosene and Coal are the main contributors, with average percentages of 21% and 64%, respectively. Diesel for non-transportation purposes accounts for 7% of the emissions, and the other fuels account for the remaining 8%.

The patterns of imports significantly increased in 2014, and then decreased steadily until 2016. In 2017, a spike in wood imports took place that generated an overall increase in imports. There is a significant opportunity for the island in terms of alternative heating methods to reduce thermal fossil fuel imports, decrease emissions and increase security of supply.

The 2017 thermal fuel imports were analysed on the basis of TPER and TFC, similar to the analysis completed for electricity imports in section 3.2.1. The analysis is depicted in Figure 3-9.

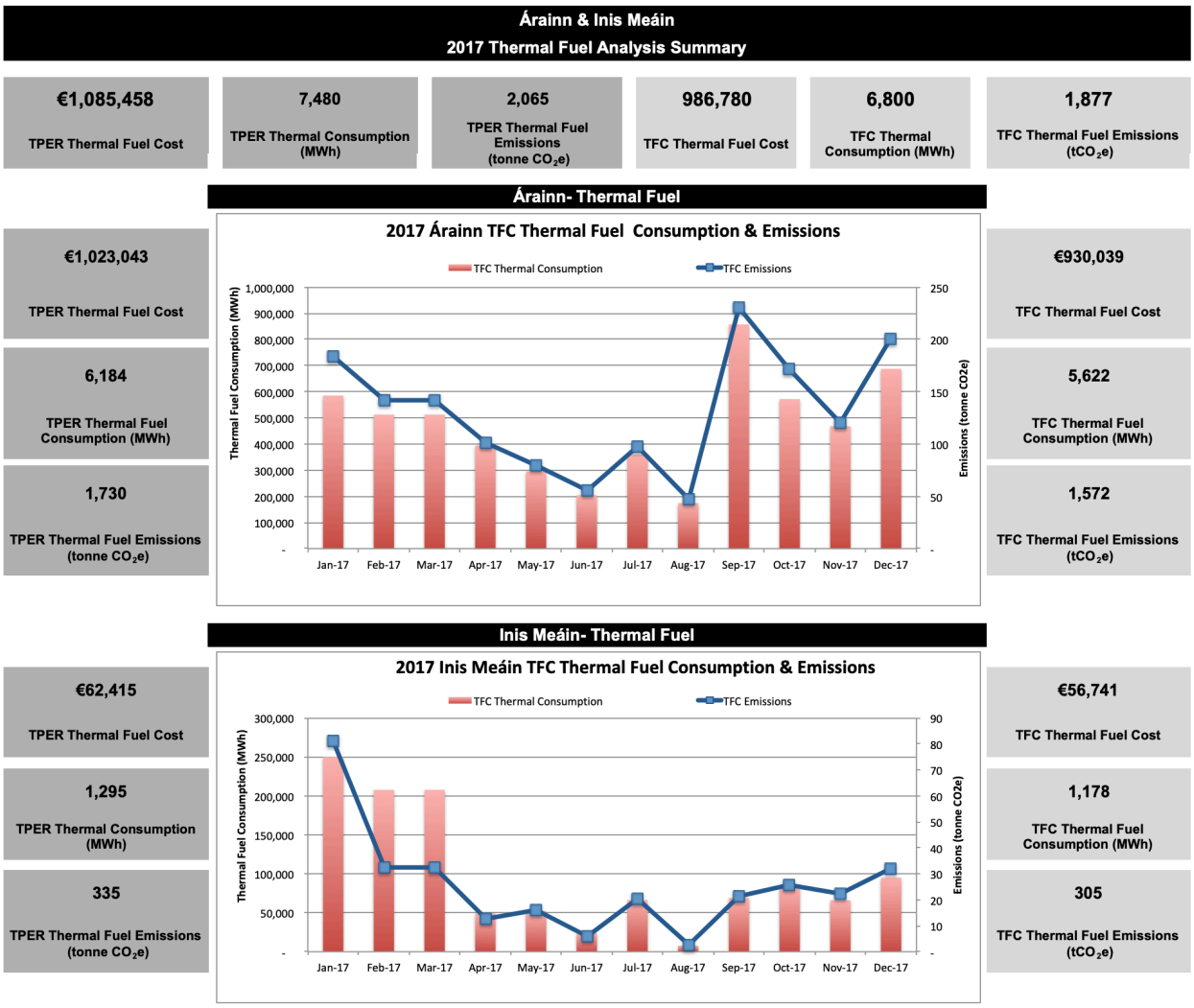

Figure 3-9 2017 Thermal Fuel Analysis for Árainn and Inis Meáin

During 2017, Árainn imports represented 83% of the combined imports to the two islands. The associated emissions corresponded to 84%, and costs summed to 94%. Inis Meáin was responsible for 17% of the imports, which accounted for 16% of the emissions and 6% of the total cost.

The monthly pattern of consumption for both islands during 2017 was not consistent throughout the year. It is worth noting that the monthly records correspond to deliveries rather than to actual consumption. Hence it is difficult to determine if outside temperatures (Heating Degree Days) are in fact the main drivers of energy consumption, although this would be expected.

3.2.3. TRANSPORTATION FUEL

The three main fuels associated with transportation are; Road diesel, Ferry diesel and Aviation Gasoline (AVGAS). Road diesel figures for Árainn were provided by Comharchumann Forbartha Árann, while Inis Meáin figures were estimated based on private vehicles reported by the 2016 Census and estimated mini buses based on the hotel and B&B. Cost and conversion figures were calculated using SEAI publications [3, 11].

The Doolin and Rossaveal ferry companies, and Aer Aran Airlines are the main providers of maritime and aviation transportation, respectively. They were contacted directly to obtain fuel consumption related data. Only Aer Aran Airlines provided data.

The ferry fuel consumption has been calculated based on vessel types and service timetables for 2017. While it is likely that Ferry diesel usage is relatively consistent for previous years, the calculations of consumption were only performed for 2017. It would be highly advisable to revise the calculations presented in this report with actual recoded figures from the ferry companies, to have the most accurate values associated with each form of transportation.

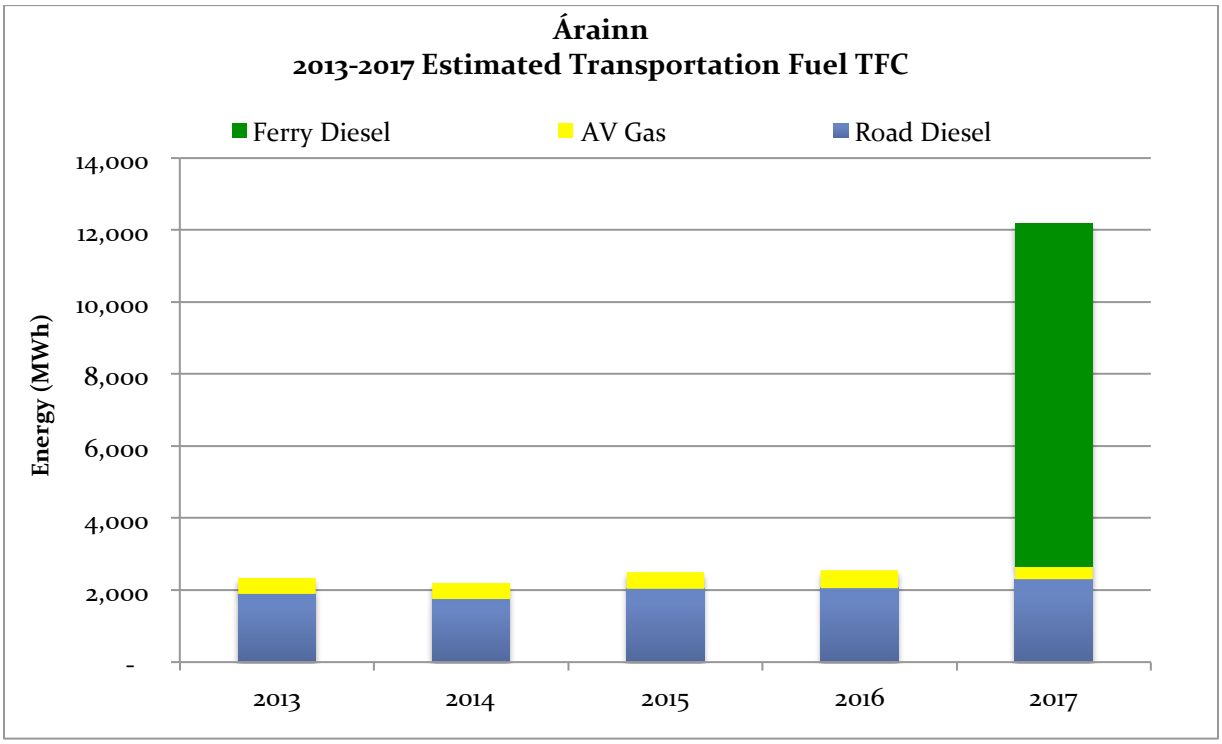

Figure 3-10 2013-2017 Árainn estimated transportation fuel TFC

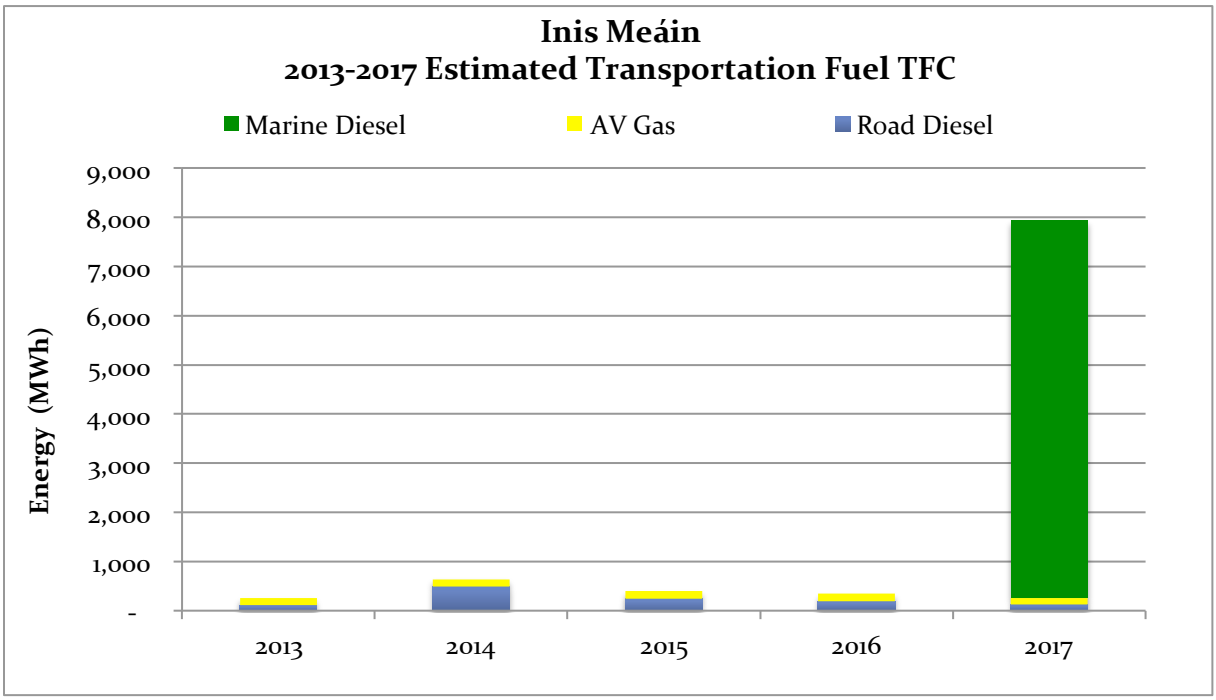

Figure 3-11 2013-2017 Inis Meáin estimated transportation fuel TFC

3.3. ENERGY BREAKDOWN BY SECTOR

This section will first discuss the sectors analysed during this study, and then detail the Electricity, Thermal and Transportation fuels breakdown by sector. It should be noted that a significant attempt was carried out to collect data from all sectors, however based on project constraints (schedule and budget) it was not possible to gather all desired data. Hence, reasonable assumptions were made based on literature and previous studies, and calculations and estimations based on these assumptions were carried out. It would be advisable to consider more thorough data collection from each sector, with the aim of further fine-tuning the data presented, and obtaining a more accurate sectorial breakdown.

3.3.1. RESIDENTIAL SECTOR

Residential sector data was collected for the two Islands by means of reviewing the 2016 Census for Árainn and Inis Meáin, and an online questionnaire distributed to Árainn inhabitants with support from CFOAT. The online questionnaire was not distributed in Inis Meáin, as contact details of the inhabitants were not made available at the time of the study.

Árainn

Based on the 2016 Census, there are 762 inhabitants in Árainn, and 297 fulltime occupied households on the island. A total of 19 respondents participated in the survey; hence the majority of the data was obtained from the Census.

From the 297 properties on the island, 94% of them are houses or bungalows, 3.4% are apartments and the remaining are caravans or mobile homes. The majority of the homes are one or two bedrooms (38% and 25%, respectively), with several three, four and five bedrooms and only 4% properties larger than five rooms.

The majority of the properties on the Island were constructed before 1980's (66%), 20% were built between 1981-2000, and 14% after 2001. In addition to these homes, the Census reported 87 vacant dwellings, 58 unoccupied holiday homes and 22 temporarily absent (during the time of the Census) premises. This would equate to a total of 462 residential properties on the island.

To establish an energy consumption for the residential sector, the average Irish household energy usage published by SEAI in there most recent report [12]was considered, along with number of occupied dwellings and their heating technologies detailed in the 2016 Census and information gathered from the survey respondents in relation to their billed consumption.

Inis Meáin

The 2016 Census indicated that the population of Inis Meáin is 183, and that there are a total of 78 occupied households, all of which are house or bungalows. The majority of the homes are one or two bedrooms (43% and 27%, respectively), 14% have 3 bedrooms and the remaining properties vary between four, five and seven bedrooms.

The majority of the properties on the Island were constructed before 1980's (59%), 29% were built between 1981-2000, and 14% after 2001.

The Census indicated that there were 11 unoccupied holiday homes, and 38 vacant dwellings, in addition to the 78 occupied homes.

3.3.2. COMMERCIAL SECTOR

The commercial sector is primarily divided into; hospitality, retail and small industries. Data was collected in Árainn by means of an online questionnaire, interviews with the CFAO main point of contact and some representatives of the main commercial and industrial premises. Data for Inis Meáin was collected via interview with the main contact person Chomhlacht Forbartha Inis Meáin.

In addition, information was obtained through literature review of previous studies and reports carried out in the islands, well as information available on individual businesses.

Árainn

The primary industry on the Islands is tourism with the average population doubling during the summer months. As a result, the number of guesthouse per capita is significantly higher on average on the Aran Islands than for the mainland. There is one main hotel, the Aran Islands hotel, and 14 bed and breakfast/guest houses, along with a Glamping site and rental holiday homes. There are 4 main restaurants, 4 pubs and ice cream shop that operate year round. The hotel is the main energy consumer of this sub-sector.

The retails sector includes a large Spar shop in Kilronan, 4 craft shops, and an art shop. There are also 5 knitwear and Aran Islands specialty-clothing shops, as well as a jewellery shop. There is a Bank of Ireland branch located in Kilronan, and a Credit Union. The largest energy consumer in this sub-sector is the Spar shop.

There are two main industrial companies on the island; Blath na Mara, a seaweed factory and Aran Islands Goats Cheese, a goat farm and shop,

Blath Na Mara specializes in hand harvesting wild seaweed with the purpose of bring seaweed from tide to table. Their main product is dried organic milled or whole seaweed, brought to market wholesale. They utilise a specialised drying process ensuring the harvested seaweed retains its nutrients. They operate at a 160m² building located in Onaght, on the north side of the island. Their main energy fuel is electricity. They utilise dehumidifiers and fans to carry out their process, as well as use electrical immersion and heaters for hot water and ambient heat. When surveyed in reference to their energy usage, they were not sure of what their annual energy consumption totalled to, however the indicated that they had carried out a series of energy efficiency projects including LED light change over and building fabric upgrades.

Aran Islands Goats Cheese, produce a variety of goat cheese that is distributed locally and in the Galway area. The 150m² premises consists of a goat farm with a herd of 93 adult goats and 70 kids, and a dairy processing plant equipped with a 1,000-litre vat pasteurizer, press and moulds. They produce approximately 1000ltrs of milk a week, yielding approximately 100 kg of cheese. The site utilises electricity mainly for pasteurising, milk cooling and for cold-room storage. Based on survey responses from the owner of the company, the site consumes around 16,000 kWh of electricity per annum. Their most recent energy efficiency upgrade was the installation of air to water heat pump to heat process water.

Inis Meáin

Inis Meáin has a 5-star boutique hotel, Inis Meáin Suites that operates year round, and 5 bed & breakfasts that operate during 6 months of the year (April to September). There is one pub

that operates year round and several restaurants. The hotel is the main energy consumer of this sub-sector.

The retail sector includes a shop that operates year round, a souvenir shop and a craft shop. The Inis Meáin Knitting Co. is the main industrial company on the island. It was founded in 1976 and supplies knitwear to stores around the world. It is the main employer on the island. It stretches over 775 m^2, which include both the factory building and a shop.

3.3.3. PUBLIC SECTOR AND UTILITIES

Árainn has a mix of community and office service buildings, education, health and public services, and spiritual and cultural centres.

There is a Community Development and Office services, the Co-Op Offices and a general office building. There is a Village hall, sport pavilion and a public library. In terms of education and child services, there is a crèche, two primary schools and a secondary school.

There is a general practitioners office and a nurse station, as well as a nursing home. There is Garda station that serves all three islands, a fire station and coast guard station. There is also a post office. There are three churches, a tourist office and a heritage centre.

The main public buildings on Inis Meáin include; a community building, a primary school and a secondary school. It also has a health centre and a fire station. There is a post office located in the convenience store.

The main utilities reviewed on both islands include; recycling plant, water treatment plants, public lighting, the harbour, and telecommunication infrastructure. Data was gathered mainly from published reports and as well as during the site visit.

Athchúrsáil Árann Teoranta, the recycling plant set up by Comharchumann Forbartha Árann and Galway County Council processes waste for Árainn and Inis Meáin. All of the food waste, paper and cardboard and glass are fully recycled and re-used on the island, reducing the amount of energy required to transport waste to the mainland. Only around 20% of the islands waste ends in landfill. The site also serves as the main diesel pump station for Árainn.

Árainn is served by three water treatment plants; Kilcarna, Oghill and Cregacareen. The first two plants share the same source (Kilcarna rainwater spring source supplemented by boreholes), while Cregacareen is served by a separate rainwater spring source. The treatment processes at each plant involves pressure filtration, UV disinfection and chlorination[13]. The plant is operated and maintained by Irish Water.

Inis Meáin has its own water treatment plant. A third party has a Design Build and Operate (DBO) contract for the plant. Details on the plant were not readily available at the time of this study. It was assumed that it consist of a rainwater spring source and boreholes, and a treatment process similar to that of Árainn. Based on review of publications, there are plans to upgrade the current scheme to ensure security and quality of supply[14].

There are no wastewater treatment plants currently in operation at either island although one is proposed for the two main Árainn villages Wastewater is generally managed via septic tank systems.

Public lighting is located across the main roads of both islands, and in the harbour areas. Most of the lighting is either Low or High Pressure Sodium (SOX or SON) or Metal Halide. In Árainn harbour, some lamps have been upgraded to Light Emitting Diodes (LEDs).

There is a main harbour at each island, utilised for passenger and goods fleet management. Árainn has a secondary harbour that is currently only used by small fishing or recreational boats.

The islands each have a telecom mast installed that allow for the telecommunication infrastructure. Data was not available on their configuration or management.

3.3.4. FISHERIES

The majority of the Fishery vessels are based and fuelled in Rossaveal. Although these companies employ some islanders, the economic activity (fishing) takes place at a significant distance from the Island. There are few local fishermen that have small boats that carry out fishing close to the Islands' shores. They were surveyed on the energy consumption associated with their activity, however none provided responses.

It is estimated that there are 7-8 regular fishing boats in Árainn, and 5-6 regular fishing boats year round in Inis Meáin. Information was not available on the size or type of boats utilised, nor was there detail on the daily activity. .

3.3.5. TRANSPORT

There are two sources of transport to the islands; ferry crossings and flights. On the main land, public transportation is available via mini buses and bikes. Furthermore, there are also private vehicles owned by those residing in the island. This section will discuss each form of transportation further. Aviation was evaluated from 2013 to 2017 for the two islands, road diesel imports for Árainn, and discusses an overall transportation import breakdown based on 2017 figures calculated.

3.3.6. ELECTRICITY BREAKDOWN BY SECTOR

Figure 3-12 details the electricity TFC breakdown per sector for Árainn. The most energy intensive sectors were Utilities and Public Services, followed by Residential and Commercial Buildings, and Public Sector.

When compared to national energy usage [15], the residential sector electricity TFC is very similar (30.8% for Ireland and 29% for Árainn). The commercial and public sectors (public utilities and buildings) are reported together at national level, and represent 27.2% of the electricity TFC, while for Árainn, the same sector represents 68.7% of the total electricity TFC. At a national level, industry is the most energy intensive sector, at 39.7% of the total electricity TFC, while for Árainn, the industrial sector accounts for 1.8% of the total electricity TFC. In terms of transport, electricity corresponds to 0.2% at a national level, while it represents 0.5% for Árainn.

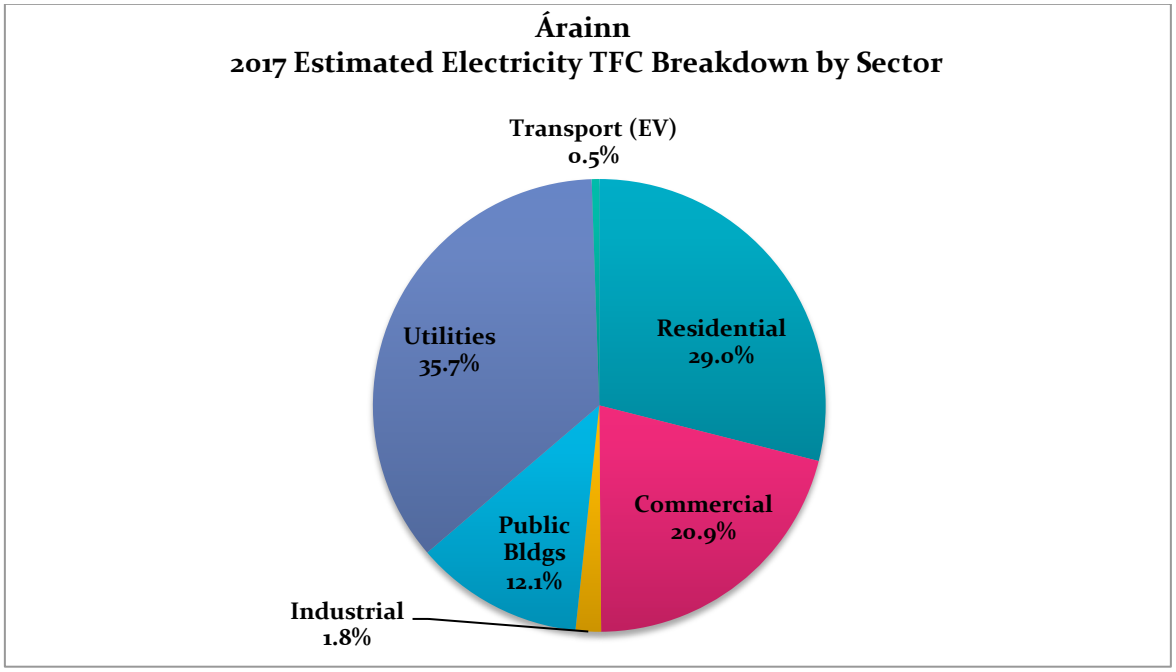

Figure 3-12 Árainn estimated Electricity TFC breakdown by sector (2017)

Figure 3-13 details the electricity TFC by sector for Inis Meáin. The most energy intensive sector was Utilities and Public services, Residential and Commercial Buildings. When compared to national energy usage [15], the residential sector electricity TFC is slightly less (30.8% for Ireland and 22.9% for Inis Meáin). The commercial and public sectors (public utilities and buildings) represent 27.2% of the national electricity TFC, while for Inis Meáin, the same sector represented66.5% of the total electricity TFC. At a national level, industry was the most energy intensive sector, with 39.7% of the total electricity TFC, while for Inis Meáin, the industrial sector accounts for 11.6% of the total electricity TFC. In terms of transport, electricity corresponds to 0.2% at a national level, while it represents 0% for Inis Meáin.

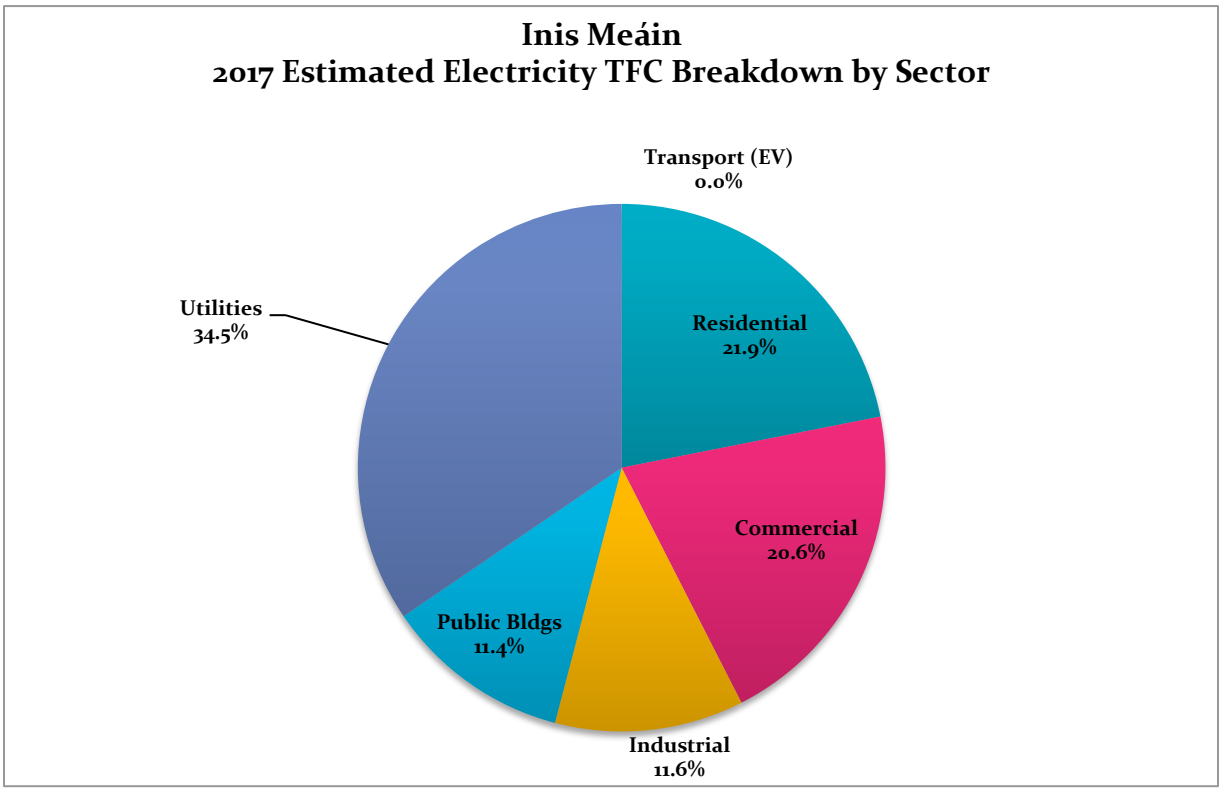

Figure 3-13 Inis Meáin estimated Electricity emission breakdown by sector

These results indicate that energy efficiency measures and alternative energy generation should be particularly focused in the Utilities and Public services, Public Buildings, Residential sector and Commercial buildings.

3.3.7. THERMAL FUELS BREAKDOWN BY SECTOR

Figure 3-14 details the breakdown for Thermal fuel TFC by sectors. The residential and public and commercial buildings are the most energy intensive sectors. Compared to national final energy use [15] the breakdown was significantly different. For Árainn, 55.9% of its thermal TFC was residential, while Ireland thermal energy TFC was 23% for the same sector.

Árainn's thermal TFC for the Public and Commercial building sector corresponded to 39%, while the national average is 11.5%. The national final thermal energy consumption in the Industry sector was 42%, while in Árainn there was no thermal energy usage in this sector.

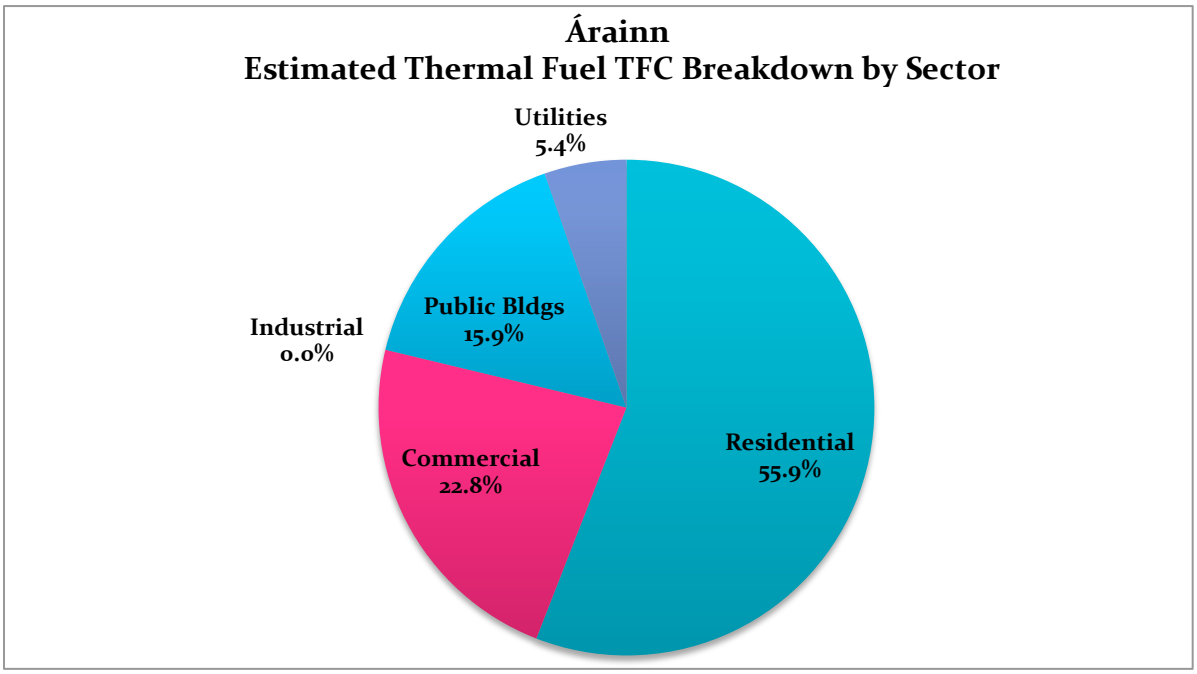

Figure 3-14 Árainn estimated Thermal Fuels TFC breakdown by sector (2017)

Figure 3-15 details the thermal fuel TFC breakdown by sector for Inis Meáin. The Residential, and Public and Commercial sectors were the two most energy intensive sectors.

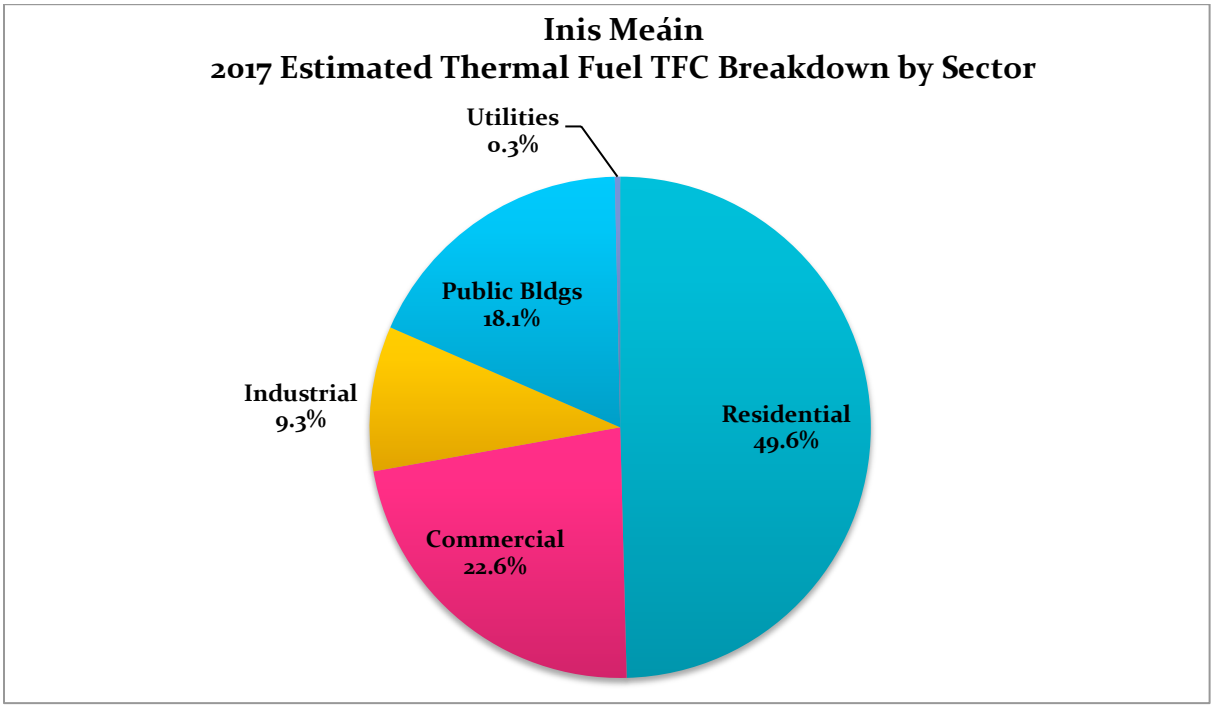

Figure 3-15 Inis Meáin Estimated Thermal Fuels TFC breakdown by sector (2017)

The Public and Commercial building sector Inis Meáin thermal fuel TFC consumption was 40.7%, while the national average for the same sector corresponded to 11.5%. The national final thermal energy consumption in the Industry sector was 42%, while in Inis Meáin the thermal energy TFC was 9.3%.

Efforts have been taking place over the last five years to carry out energy efficiency improvements in the residential sector with the implementation of several Better Energy Communities projects for heating and building fabric upgrades.

The results show that there are still opportunities for further improvement both in the residential, and that the public and commercial buildings sectors should be actively engaged to introduce energy efficiency measures as they are the second largest consumer of thermal fuels on the islands.

3.3.8. TRANSPORTATION ENERGY BREAKDOWN

Figure 3-16 and Figure 3-17 depict the transportation TFC breakdown for Árainn and Inis Meáin, respectively. For both islands, maritime transportation fuel used for ferries is the most significant energy user. Each fuel usage will be further discussed in subsequent sections in more detail.

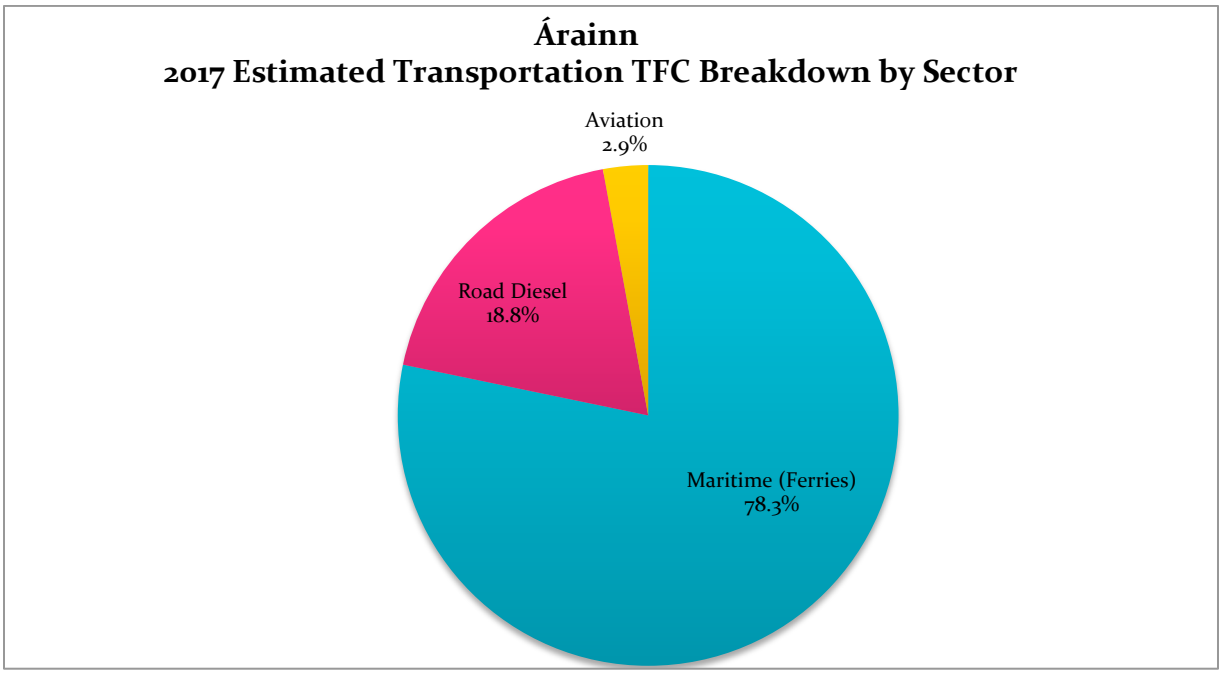

Figure 3-16 Estimated transportation fuel breakdown for Árainn (2017)

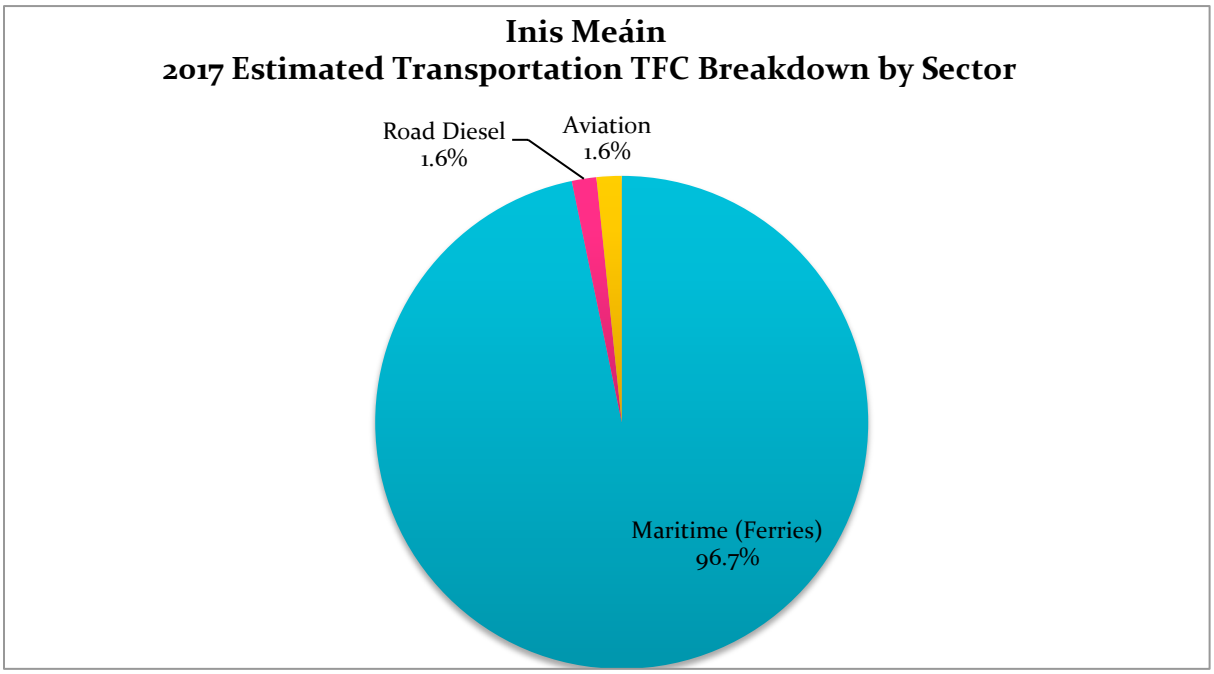

Figure 3-17 Estimated transportation fuel breakdown for Inis Meáin (2017)

Aviation Gasoline

There are two airports on the Aran Islands; one located in Árainn and one in Ins Meáin. The flight patterns to the island vary seasonally, with frequency of 2-3 return flights daily to each island November to February, and as many as 8 daily return flights during June to August.

An annual average consumption of 585,000 kWh of AVGAS was used for flights to and from Árainn and Inis Meáin between 2013 and2017. There is an average of 2,300 flights per annum to Árainn and an average of 928 flights per annum to Inis Meáin. There is an average of 193 kWh of AVGAS per flight to/from Árainn, and an average of 155 kWh of AVGAS consumption per flight to Inis Meáin. The figures below detail the fuel consumption and CO_2 emissions for the period of 2013 to 2017.

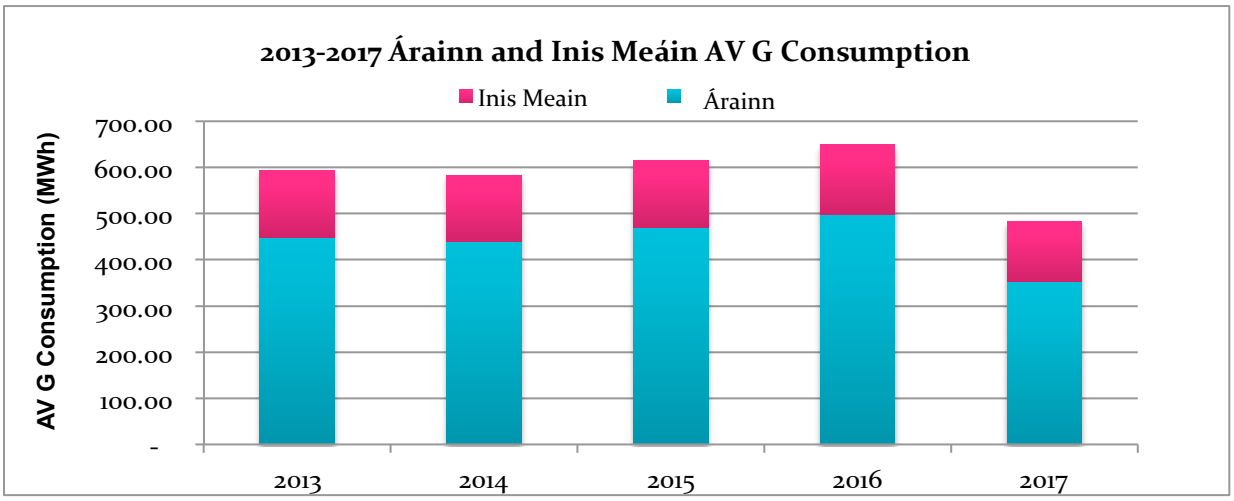

Figure 3-18 2013-2017 Árainn and Inis Meáin AV G consumption

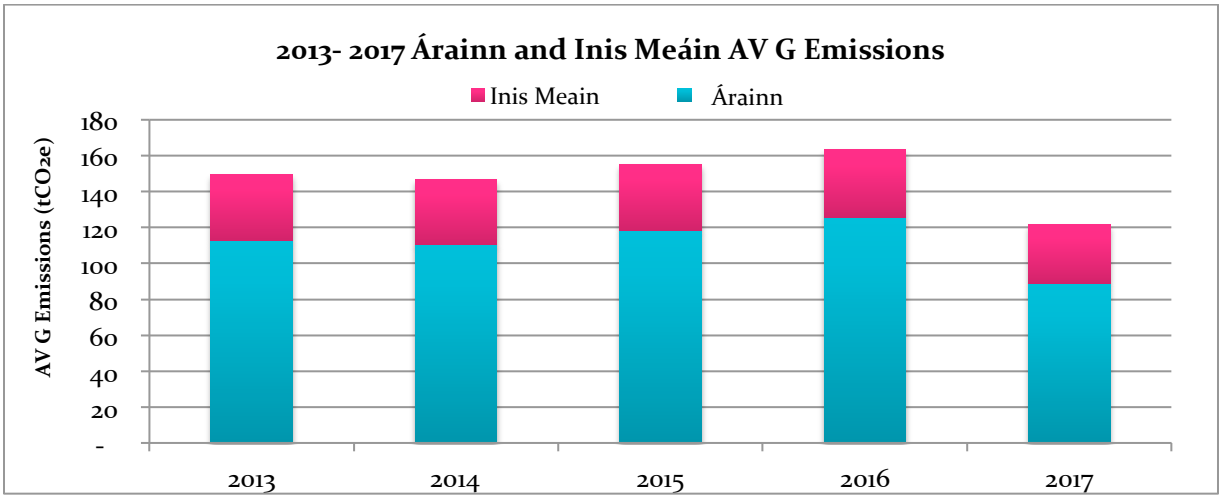

Figure 3-19 2013-2017 Árainn and Inis Meáin Av G emissions

Road Diesel

In Árainn, the main form of public transportation is mini buses run by small companies that provide transportation to the different areas around the islands. These are typically 10-12 passenger capacity vans that operate on diesel. The 2016 Census reported that there were approximately 297 private vehicles and 20 mini buses used for road transportation. Currently there are 10 electric vehicles in operation on the island; seven cars, two vans, and one 6-seater minibus. Information was not available at the time of the study of the most recent number of vehicles on the Island.

Figure3-20 details the road diesel fuel imports to the island. On average, the Árainn imported 2,000 MWh per year of road diesel during the period of 2013-2017. Contrary to thermal imports, road diesel imports have increased since 2014 to 2017. This could be driven by an increase in tourism volume.

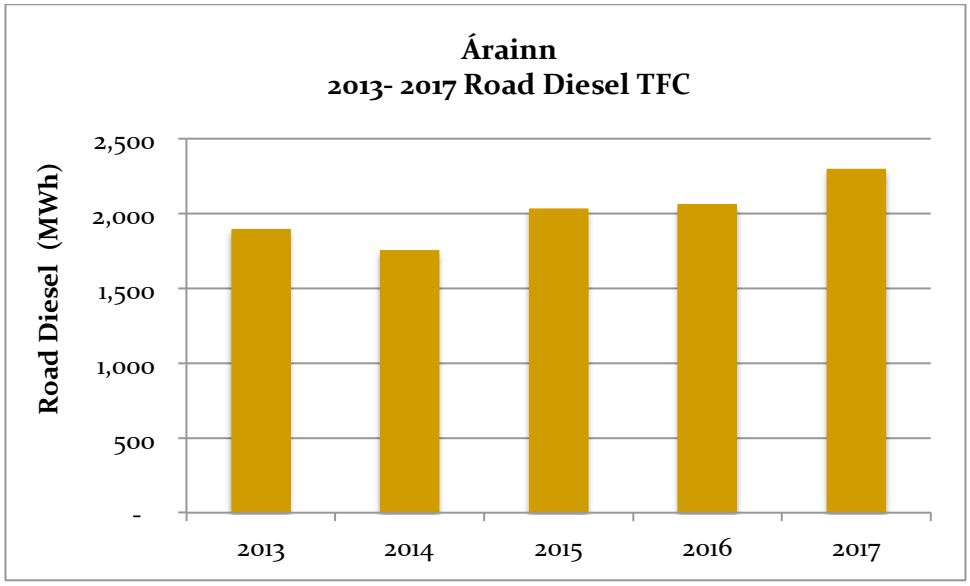

Figure3-20 2013-2017 Árainn Road Diesel TFC

In Inis Meáin, there are small mini buses operated by the hotel and some of the B&Bs. The main source of transportation of the locals is private vehicles. Road diesel figures were not available for Inis Meáin, however, overall diesel import figures were. Hence, based on the 62 vehicles accounted for by the 2016 Census and an estimate of 6 Mini buses in operation for tourism, it was estimated that on average, 230 MWh per year of road diesel was imported to the island between 2013 and 2017.

Maritime- Ferry Diesel Only

Ferries are accessed from the main land from Rossaveal, Co Galway and Doolin, Co Kerry. Aran Islands Ferry operates from Rossaveal, while Doolin Ferries and O'Brien Lines operate from Doolin. Aran Island's Ferries operate two daily services to the Island (morning and afternoon), and third service operates during June, July and August from Rossaveal to Árainn only. Doolin ferries offer two daily services to Árainn and Inis Meáin, and provide inter island transfer.

The service providers did not make ferry diesel consumption data available. All ferries are fuelled in the mainland, however this fuel has been treated as an import, since it is one of two ways to access the islands from the main land, and to move between islands. Information on the make and model of the ferries used by the companies, and the frequency of services

throughout the year was available on their respective websites. From vessel manufacturer's specification, average fuel consumption per nautical mile was obtained. Furthermore, nautical distance from main land to each island was obtained from Google maps. Hence energy usage associated with ferry usage was calculated using first principles.

Based on 2017 time schedule, it was calculated that the Rossaveal to Árainn ferries utilize a total of 7,769 MWh of diesel during a year. The Rossaveal to Inis Meáin ferries utilize a total of 5, 906 MWh of diesel per year.

The ferries from Doolin stop at all three islands; hence the energy associated with both islands was calculated together. It is estimated that both companies operating from Doolin to Árainn and Inis Meáin services utilize a total of 3,540 MWh of diesel a year, equal parts were apportioned to each island.

This resulted in a total of 9,541 MWh of ferry fuel for Árainn and 7,678 MWh of ferry fuel for Inis Meáin. The total diesel import for the two islands equates to 17,219 MWh for all services.

4. The Register of Opportunities

To successfully achieve carbon neutrality by 2022 on the Aran Islands, there is a requirement to develop a structured implementation plan. The Energy Master Plan details the sources, quantity, carbon intensity and cost of energy currently being used on the island. The plan also details how efficiently each of the sectors in the community is using energy.

The register of opportunities (RoO) uses this information to set an overall target for the energy efficiency measures and the energy technology that will be required to offset the community's reliance on imports from the mainland. This information can also assist the community to quantify upgrade work required to ensure buildings and services on the island are consuming energy as efficiently as possible.

The process is designed to manage multiple projects over a long-term plan. As projects are identified they are recorded in the RoO and reviewed using a set scoring system. This evaluation process assists the committee in identifying which projects should be prioritised based on a cost vs. effectiveness principal.

Once the register is populated, it will assist the CFOAT in developing a detailed plan to manage projects and resource to achieve the islands carbon neutral ambitions.

4.1. METHODOLOGY

The register of opportunities is a process used to prioritise projects and highlight key metrics that will be important elements for any future grant application or decision-making process. This approach assists with resourcing, planning and budgeting for projects over a multi annual plan.

The tool looks at the boundary of the Aran Islands from a strategic perspective, with the aim of building a structured plan to reduce the islands dependence on fossil fuels.

1. Measuring the baseline:

The Energy Master Plan gives a detailed breakdown of the islands current usage of imported electricity, thermal and transportation fuels. This provides an overall indication of fuel sources dependency. In turn, this simplifies the process to target changes that could generate most impact in reducing such dependency.

It is advisable that this baseline be reviewed every 3 years, with the aim to benchmark performance, and review the scope of projects planed for the next phase.

2. Generating Project Ideas:

The Energy Master Plan energy breakdown will serve as a means of scoping project to substitute or reduce the imported energy currently used on the islands.

An example of this approach would be:

If the majority of diesel fuel being used on the island is for private vehicles, efforts should focus on replacing or reducing the private diesel vehicles on the island. This might be achieved by:

- Replacing private diesel vehicles with electric vehicles
- Investing in electric or hydrogen powered busses to encourage less people to drive
- Promote cycling on the island

3. Evaluating Project Ideas:

Once a list of project ideas has been generated, the solutions need to be evaluated. To do this the Register of Opportunities encourages understanding the key variables that impact the development of the project:

- Cost
- Potential Energy Savings (kWh)
- Payback periods/ Return on Investment
- Project Risk

The project can be assessed and scored, hence determining the benefit of undertaking the project, and when it should be executed. This list will assist focusing on the projects with the least risk and most potential.

4. Delivering Projects:

The Register of Opportunities will gather all the key information that will be required to start the early stages of building a project plan. This information will be important for any business plan or grant application to quantify the cost, energy and CO_2 savings associated with the works.

5. Monitoring Performance and Lessons Learned:

Once a project is delivered it is important for the SEC to keep a record of the experience that has been gained and how the project has performed. This information will help future projects to make more informed decisions during the early project stages.

4.2. RECOMMENDATIONS BY SECTOR

This section will discuss potential project opportunities for energy efficiency measures and renewable energy technology for each sector. It should be noted that all figures presented are estimated based on top-level desktop calculations, and do not represent definite project costs or energy savings or emissions. All opportunities would require further evaluation under feasibility studies to verify savings.

4.2.1. RESIDENTIAL SECTOR

Technical Measures

Since 2012 the residential sectors on both islands have made energy reductions through SEAI's Better Energy Community Schemes. As detailed in section 3.3.1, more than 75% of the households in both islands utilise fossil fuels (gas oil, coal and peat) as heating sources. The CFOAT's long-term strategy is to convert these homes to heat pumps or other renewable energy heating source to eliminate the dependancy on imported fossil fuels. In order to facilitate this change in technology the building facric will also need to be upgraded.

The combined thermal energy used for space heating and power for these dwellings is forecasted to reduce by 2,857 MWh based on upgrading the fabric of the homes and converting the heating systems to heat pumps on both islands.

To achieve a change of this scale, the CFOAT will need to aim to convert up to 15 homes per quarter for a period of 5 years. If the islands managed to generate an appetite among the community for this level of change, it would make the project more attractive to a wider range of grant funds and reduce the overall project costs due to efficiencies of scale.

The current average price of retrofitting a home is approximately €20,000. To bring the payback period down to 5 years a minimum of 80% is required to be grant funded.

Record Keeping

The information that was used to initiate the Energy Master Plan and Register of Opportunities for the residential premises on the island has been taken from the 2016 census data and fuel import records collected from third party organisations.

It is recommended that the group should request the CFOAT members on the islands for more information to help generate a clearer representation of the dwelling stock on the islands. Futhermore, details on works completed related to building upgrades, new technology implementation, amongst others was not cleary recorded. The CFOAT should maintain detailed records of the works that are undertaken through SEAI's grant schemes as well as pre and post work BER certifications, in order to accurately map and track a long term strategy to improve the home energy performance on the island.

Community Engagment and Education:

Engagement is a critical factor to this conversion plan. To achieve the targets set, the majority of the community will need to understand the benfits of engaging with the CFOAT to include their homes in the plan.

To start the transition, individuals will need to agree to review the current energy consumption in their homes. This process will give the opportunity to educate and outline how energy efficiency and costs could be improved. This will in turn provide a more accurate register of home electrical and thermal fuel consumption.

4.2.2. COMMERCIAL SECTOR

The commercial sector is estimated to use 1,927 MWh per annum for electricity and heat. To reduce the energy consumption and dependency on imported fuel sources it is recommended for businesses to follow the below approach.

Energy Assessments

1. Measuring Consumption:

During the project it was observed that many of the buildings in the commercial sector have not undergone energy audits or have established any energy efficiency plan. It would be beneficial for businesses to coordinate a survey of the commercial properties on the island to review their current energy performance in each of the buildings.

2. Identifying Projects:

The recommendations from these energy assessments can be inputted into the register of opportunities to evaluate which of the projects should be prioritised.

3. Deliver Projects:

Once the project details have been reviewed the total costs, energy savings and next steps should be clear for the beneficiary to invest in the upgrades. The project plan should be developed enough at this stage to outline the final costs and payback periods.

4. Knowledge Sharing:

Once businesses have undertaken works it is important that the upgrades are celebrated to encourage others to participate in future projects.

Lighting

The hospitality and retail sectors on the island should be encouraged to undertake low energy lighting replacements. Simple reviews can be used to quantify the payback and subsequent annual savings by upgrading to lower energy lighting solutions. These upgrades have short payback periods and are a relatively simple upgrades to undertake.

Engagement

It can be difficult for the commercial sector to find capacity to undertake energy auditing and efficiency projects when they are focused on their core business activities. This report was initiated during the start of the tourist season on the island. It would be recommended for the CFOAT to plan engagements with businesses after the summer season when the number of visitors to the island reduces and there is more time to dedicate to long term planning and upgrades.

Energy Management Training

SEAI offer courses for SME's and for the Public Sector to coach leaders to save money by managing energy more effectively. It would be highly recommended for the CFOAT to encourage business leaders and local authority leaders to avail of these training opportunities to improve their energy management knowledge and skillsets.

4.2.3. PUBLIC SECTOR AND UTILITIES

The Public-Sector Efficiency Strategy was set in place by government in 2009 to improve energy efficiency by 33% in 2020.Each of the public-sector buildings should have obtained a display energy certificate (DEC) and implement an internal process continually reduce their overall energy performance. Furthermore, there is a requirement to carry out an energy audit on all buildings with areas greater than 500m² or an energy spend of greater than €35,000. Energy audits for public buildings were not readily available at the time of the study.

Energy Assessments

Energy audits should be completed for all public buildings on both islands in order to clearly identify energy efficiency measures, and to ensure compliance with SI 426. The RoO should be updated with any proposed projects, and the CFOAT should work closely with Galway County Council and other key public sector stakeholders to establish a pipeline of projects that can be implemented over the next five years.

Public Lighting

Several local authorities have initiated projects to upgraded public lighting from traditional SOX or SON or Metal Halide lamps to LED fittings. The CFOAT should work alongside Galway County Council to ensure that both islands' Public Lighting is upgraded under the proposed National Public Lighting retrofit programme.

Based on similar projects completed across the country, a reduction of 45% TPER associated with Public lighting could be expected.

Water Treatment

Water treatment represents a significant amount of electricity imports to both islands. CFOAT should work closely with Irish Water in establishing clear energy efficiency projects related to pump efficiency, water treatment plant management, lighting and time of use, amongst others.

Engagement

Many of the building occupiers did not reply to the survey within the time frame of this study. In some instances, public sector may not have engaged with the energy performance strategy. It is recommended that the CFOAT encourage each of the buildings to engage in this exercise and included the outcomes from the energy surveys within the energy master plan and register of opportunities records and plans.

Education

SEAI offer schools support to monitor and report their energy consumption. Training is also made available to assist staff with these processes. SEAI also has an energy curriculum that can be thought to schoolchildren of all ages. Engaging children in the community is a very effective way to engage families in the community to get involved in energy efficiency projects.

4.2.4. TRANSPORT

The 2016 census has recorded 297 private vehicles on Árainn and 62 on Inis Meáin. Since 2012 the CFOAT has persuaded approximately 3% of car owners on Árainn to switch to electric vehicles. This report would recommend that this process be continued with an aim to reduce the number of vehicles on the islands as well as convert them to cleaner technology.

Second Hand Vehicle Market

Due to the contained size of the islands, the required range on vehicles is very low in comparison to main land driving. The average annual usage was estimated to be around 8,000 km/year. This creates a unique opportunity for residents to buy older first generation electric vehicles with a lower range to use on the island.

Private Bus Services

There are multiple independent diesel mini busses operating on the island to facilitate tourists. Multiple establishments and individuals around the island own these. Consideration for utilisation of electric vehicles to replace existing conventional fuel vehicles should be evaluated.

Bicycles

Upon arrival on the island one of the first businesses that is encountered is a bike rental shop. This facility is supplemented by a solar PV array and battery store and provides the best transport solution for most tourists visiting the island.

To continue to assist tourists to make the right transport decisions, this report would recommend that further measures could be taken around the island to make cycling more accessible:

- Signage on the pier that suggests cycling is the most sustainable means to visit the island by outlining how many trips have been undertaken by bicycle and the corresponding CO_2 savings.
- Shelters/refuge points along the route that tourists can seek cover from wind and rain during their exploration of the island
- Additional services offered near the point of rental such as wet gear rentals or bag lockers to further encourage people to cycle in changeable weather.

4.3. RECOMMENDATIONS FOR RENEWABLE ENERGY TECHNOLOGIES IMPLEMENTATION

4.3.1. RENEWABLE ELECTRICITY

The island is currently dependent on a 20-kVA electricity cable from the mainland that supplies Árainn, Inis Meáin and Inis Oírr. If the measures outlined in the Register of Opportunities are pursued in whole or in part the amount of electricity imported to the island would be expected to change. This could result in an increase in electricity used by electric vehicles and/or a reduction in electricity used as a result of building energy efficiency.

In order to meet electricity demand on Árainn and Inis Meáin there are multiple renewable electricity generation options. A number of feasibility studies and reports have been prepared in the past by others and have been reviewed for this Energy Master Plan. Relevant renewable energy resource databases have been reviewed. Relevant local development plans, spatial strategies and statutory regulations have been assessed in the context of renewable energy project development at this location[9, 16, 17]

A summary of the main sources of renewable electricity, the degree to which they could satisfy the likely demand of the islands and the potential for realisation is presented in Table 4-1 below. For purpose of this analysis we have used a notional annual demand 2,256 MWh of electricity. The review has focused on the near term likely prospects.

CFOAT have been undertaking initial feasibility studies and stakeholder engagement for the proposal for wind turbines to be installed on the island. This consultation work is on-going within the committee, residents and Galway County Council.

Table 4-1 Summary of Renewable Electricity proposals

Source & scale	% Demand	Realisation	Notes	Ref
0.75 – 1 MW onshore wind (one or more turbines)	100	Medium potential	Extremely high quality wind resource available. Some risk of community & planning refusal subject to consultation effort. High initial cost, long lead-time to project delivery. Difficult project construction environment given project scale. Robust technology and suited to climate. Some operating cost and complexity.	1. Wind Turbine Feasibility Report, Tipperary Energy Agency, September 2014. 2. Galway County Development Plan 2015-2021 3. County Galway Wind Energy Strategy 2011 - 2016
3MW solar farm	100%	High potential	Relatively low planning risk, likely high community acceptance. Moderate solar irradiance levels, similar to Dublin/Wicklow. Robust and low cost technology, low construction risk. Low operating cost and complexity.	1. Best Practice Guide Photovoltaic, SEAI 2. Galway County Development Plan 2015-2021
Wave Energy	0%	Low potential	Early stage technology, unproven at scale. Extremely high deployment costs.	Offshore Renewable Energy Development Plan, DCCAE, 2014
Tidal Energy	0%	Low	Tidal energy resource in Ireland is concentrated on the northern and eastern coasts. While some limited resource may be available at this location the exploitation cost would be expected to be high.	Offshore Renewable Energy Development Plan, DCCAE, 2014

4.3.2. RENEWABLE HEAT

The scale of heat use on the two islands is 6,764 MWh per annum. The residential sector accounts for 55% and the non-residential sector accounts for 45%. At national level there remains a very substantial gap to meeting legally binding 12% by 2020 target on replacing fossil fuel heat with renewable heat technologies across all sectors.

The Irish Government has outlined a Support Scheme for Renewable Heat expected to begin in late 2018 or early 2019. This applies only to the non-residential sector. The technology types benefiting from this support include biomass, anaerobic digestion biogas and heat pumps.

While each individual non-residential situation will require a bespoke technological solution this report has provided some high level calculations. A summary of the sources of renewable heat, the degree to which they could satisfy the likely demand of the islands and the potential for realisation is presented in the table below.

Table 4-2 Summary of Renewable Heat Proposals

Source & scale	% Demand	Realisation	Notes	Ref
Non-Residential Biomass Boilers	100%	Low	While the technology is robust and could be widely deployed this measure would require the import of biomass fuel to the island to burn in the biomass boilers. Biomass fuel is typically more bulky than the fossil fuel alternatives it is replacing. Although this measure would help transition the islands from fossil fuel to renewable fuel sources the move would be contrary to the ambition of energy independence.	Support Scheme for Renewable Heat. DCCAE, 2014
Residential biomass boilers	100%	Low		
Anaerobic Digestion **Non-residential and residential**	0%	Low	AD is a complex biochemical process that "digests" biological matter in the absence of oxygen to deliver a gas, similar to natural gas. The process typically occurs in large custom-built concrete or	Teagasc, Energy Fact Sheet No 2 – August 2016. www.teagasc.ie www.ifa.ie/cross-

			steel vessels connected to waste processing or intensive agriculture sites. The wide adoption of heat from biogas would require a fundamental overhaul of infrastructure of the islands including the development of a gas or heat network. This is not considered a suitable technology in the near to medium term.	sectors/renewables /anaerobic-digestion-ad/
Heat pumps Non-Residential	90%+	High	Heat pumps use electricity to pump a refrigerant around a circuit, transferring heat in the process. Heat pumps are available for residential and non-residential situations although Government supports differ for each sector. When matched with insulation measures this technology can provide a clean, cheap alternative to fossil fuel use. Very wide scale deployment in Ireland is expected in the coming years.	Support Scheme for Renewable Heat. DCCAE, 2014. Up to 30% capital grant available.
Heat pumps Residential	90%+	Medium		SEAI grants available up to €3500 plus €200 grant for technical pre-assessment of the home. A Homeowner's Guide To Heat Pump Systems, SEAI, 2018

4.3.3. RENEWABLE TRANSPORT

Transport fuels in use include road diesel, ferry diesel and Aviation Gasoline (AVGAS). There are a number of electric vehicles in use on Árainn. Table 4-3 details top level proposals for alternative technology uses for transportation fuels.

Table 4-3 Renewable Energy Proposals for Transportation

Source & scale	% Demand	Realisation	Notes	Ref
Electrification of personal transport	100%	High	Because the islands have limited road networks they are well suited to the use of electric vehicles at private and light commercial levels. Analysis of the transport energy demand, the impact on the existing electricity system and the development of a medium term work programme is required. It is considered that the availability of funding for a medium term capital plan for EVs, charging stations and electricity generation is good.	SEAI guidance on electric vehicles; www.seai.ie/ sustainable-solutions/ electric-vehicles
Hydrogen Fuel Cells or Electrification of the ferry services	50%	Medium	Maritime transport currently accounts for a large percentage of the islands energy consumption. There are several developing technologies in the maritime sector that could operate as potential alternatives to diesel engines. We believe that it would be a useful research project to commission for a review of the potential technologies and required secondary infrastructure to facilitate a low emission ferry service. This research would need to account for the deliverability, cost, reliability and timescales of a transition to an alternative fuel source.	Electrification of Norway's Ferry Fleet PBES, 2015

Hydrogen generation for fuel	Unknown	Low	SEAFUEL is a conceptual design project aiming to demonstrate the feasibility to power local transportation networks using fuels produced by renewable energies and seawater, with no net carbon footprint. The project will commence its Phase 1 work in Tenerife with the aim of further testing a prototype in the Aran Islands as part of a second or third phase of the project.	Interview with Dr Pau Farràs, PI, SEAFUEL, NUI Galway

4.3.4. ENERGY STORAGE OPTIONS AND ELECTRICITY NETWORK

INTERREG

There is an INTERREG research project being undertaken by NUIG to evaluate a hydrogen production facility on the island. The principals of this technology is that when renewable generators such as wind or solar are producing more power than the required demand, the plant produces Hydrogen and Oxygen. This allows the hydrogen to either be exported or used as an energy storage mechanism for when there is a greater demand than the generators can manage on the island.

Microgrid Options with Battery Storage

Microgrid assumes micro sources less than 100 kW that operated as a single controllable system to provide electricity and heat to a local area. This concept provides a new paradigm for defining the operation of distributed generation. When balancing the concept of micro-grids with battery storage, the system can be designed to meet specific needs; such as, enhance local reliability, reduce feeder losses, support local voltages, provide increased efficiency through use waste heat, or provide uninterruptible power supply functions[18, 19]. The concept of Microgrid could be further explored for the 3 islands considering there is an existing interconnection between them.

Furthermore, a balanced system like this can be married with demand side management programs such as the DS3, in which the islands become standby generator for the national grid providing renewable generation when required[20].

Network Stability

There will be a need to engage closely with ESB Networks with plans for reducing dependence on the mainland's electrical in feed. The network across all three islands will need to be managed and studied to ensure that there is security of supply at all times for all three islands.

4.4. AWARENESS, DISSEMINATION AND SECONDARY BENEFITS

Data Management

The Energy Master Plan and Register of Opportunity outlines a structured approach for CFOAT to process and manage energy data. Recording this data consistently will give the islands clear indicators of the current energy consumption and the most effective projects for the islands to undertake.

A methodology for data gathering has been presented in this document, and a tool has been developed to facilitate data gathering. It would be highly advisable to engage with the organisations that collect the raw data (i.e. Lasta Mara, Árainn Coop) to establish a clear process of data transfer and gathering that facilitates data aggregation.

SEC Collaboration

The CFOAT is a registered SEC. Comhar Caomhán Teo, the Inis Oírr Community Development Cooperative, is a registered SEC and represents Inis Oírr, while the Inis Meáin Energy Coop operates independently in Inis Meáin. It would be recommended that the groups maintain similar processes to manage their RoO and Energy Master Plans so that they can benefit from each other's knowledge experience and combined purchasing power.

It is recommended for the groups to maintain quarterly meetings to share best practice and their current progress.

It was noted that resources are very tight across all SECs. Hence, technology such as video conferencing, online project management software etc. should be utilised as much as possible to assist communication between the communities.

Skilled Local Employment

The works identified in this study will generate a demand for skilled labour on the islands. Local workers should be encouraged to up skill in energy efficiency and renewable energy technologies to build and maintain a skilled workforce on the island. This will generate jobs to

keep younger generations living locally. Building a specialised local work force will also diversify the local economy to provide employment outside of the tourist season.

The island is also involved with some long-term research projects. Another potential opportunity for the island is to establish a research centre of excellence. Academics working on these research projects could work from the islands. This would encourage more young people on the island to get involved in research and novel projects as well as attract researchers from other institutions to visit the Aran Islands to contribute to the over goals of the SEC.

4.5. MECHANISM OF SUPPORT

SEAI and other national and international funders have multiple funding schemes that can assist with the development and capital costs for low energy projects. For example, since 2012 the island have been upgrading homes through the SEAI Better Energy Community Scheme, Warmer Homes Scheme, the Greener Homes Scheme. Furthemore, since mid 2018 a dedicated capital grant has been available through the SEAI Sustainable Energy Communities (SEC) scheme under the Better Enegy Communities programme.

Key to gaining funding support is to have a strong pipeline of well condiered project ideas. The RoO can assist in creating this pipleine. Features of a good project include buy in from stakeholders, a well understood technology, reputable installers and a robust set of energy and cost saving calculations.

It is advised that the SEC utilise the register of opportunities to maintain a record of the homes that have been upgraded and those that are interested in furture improvements. This will assist with monitoring the overall progress of the upgrading homes on the island and with the application process for the BEC scheme.

The SEC should begin to develop a database of project funding options starting with the known local funders such as Galway County Council, LEADER, SEAI's various programmes, Western Development Commission and others. SEAI maintans a database of energy funders and this should form the basis of the CFOAT database.

5. Conclusions and Recommendations

This document presents an Energy Master Plan (EMP) for Árainn and Inis Meáin that reviewed the energy import and consumption of the island, as well as reviewed past and future energy efficiency and renewable technology opportunities. Furthermore, it aims to provide an over-arching energy strategy for the islands and identify discrete project opportunities, as well as grant and funding mechanisms available to support project opportunities and establish an action plan to sustain and develop energy efficiency and renewable generation.

The key recommendations from the study are detailed in Table 5-1.

Table 5-1 Energy Master Plan key recommendations

Category	Description	Action	Timeline	Cost	Complexity	Critical Stakeholder
Energy Efficiency	Energy Assets Review and establish a clear energy management plan	Conduct Energy Assessments of Commercial, Industrial and Public Assets to establish a consistent data based of assets on the Island.	Short Term	Low Cost	Medium	CFOAT committee, Local Authorities, Commercial and Industrial Sector representatives, Ferry Companies
Renewable Technology	Carry out preparation work for RES project implementation	a. Closely monitor electricity and heat demand, to design around auto-consumption and avoiding energy export; b. Monitor development control rules to establish which projects are most likely to succeed in consenting or licensing processes; c. Continue to engage wider community on acceptability of large capital projects, and work closely with Local Authorities and Utilities provider from project inception.	Short Term	Low Cost	Low	CFOAT committee, Local Authorities, Commercial and Industrial Sector representatives, Ferry Companies, SEAI
Organisational/ Behavioural	Prioritize projects for Short to Long terms, based on Cost, Resources and Ease of Implementation	CFOAT should get familiarized with the Reg of Opportunities tool provided from the EMP, with the goal of establishing a project prioritization list.	Short term	No/Low Cost	Low	CFOAT committee
Organisational/ Behavioural	Knowledge Sharing of energy consumption and costs, energy efficiency projects, clean technology implementation	Establish best practice groups for the different sectors in the Islands (i.e. Hospitality, Retail, Residential, etc.), and a record of energy consumption, building types, potential project opportunities	Short term	No/Low Cost	Low	CFOAT committee, Local Authorities, Commercial and Industrial Sector representatives, Ferry Companies

Category	Description	Action	Timeline	Cost	Complexity	Critical Stakeholder
Organisational/ Behavioural	Establish strong engagement with Local Authority and Utilities Companies (i.e Irish Water, ESB)	Establish clear channels of communication and engagement with LA/Utilities companies in order to avail of supports, discuss project planning and potential integration with existing planned projects by these organisations.	Short term	No/Low Cost	Low/ Medium	CFOAT committee, Local Authorities, Utilities Companies
Organisational/ Behavioural	Build consistent records of the residential, commercial, public and industrial assets on the islands. This will help to focus the committee's long-term efforts.	Establish a consistent method of data reporting with the different stakeholders based on tools provided with the EMP	Medium Term	No/ Low Cost	Medium	CFOAT committee, Local Authorities, Commercial and Industrial Sector representatives, Ferry Companies
Energy Efficiency	Building Upgrades	Carry out building fabric upgrades and energy efficiency measures on domestic and smaller commercial properties	Medium Term	Medium Cost	Low/ Medium	CFOAT committee, Local Authorities, Commercial representatives, SEAI
Renewable Technology	Electrification of Heat	Electrification of domestic and smaller commercial properties through the use of Heat Pumps	Medium Term	Medium Cost	Low/ Medium	CFOAT committee, Local Authorities, Island residents, Commercial Representatives, Utilities Companies, SEAI
Renewable Technology	Electrification of Personal Transport	Wide spread the use of electric vehicles at private and light commercial levels. Analysis of the transport energy demand, the impact on the existing electricity system and the development of a medium term work programme is required.	Medium Term	Medium Cost	Low/ Medium	CFOAT committee, Island residents, Local Authorities, Utilities Companies, SEAI
Energy Efficiency	Public Utilities Energy Upgrades	Engage with Irish Water in the efficiency projects related to water treatment and pumping across the islands. Engage with the Local Authority in Public Lighting upgrades in roads and ports.	Medium/ Long Term	High Cost	Medium	CFOAT committee, Local Authorities, Utility Companies.
Organisational/ Behavioural	Training and Employment- Create skilled local employment by establishing a centre of excellence for electric vehicle refurbishment	Long term project to create a business case and train individuals to undertake works.	Long Term	Medium	Medium/ High	CFOAT committee, Education and Training Board (ETBI), SEAI

Category	Description	Action	Timeline	Cost	Complexity	Critical Stakeholder
Renewable Technology	0.75 - 1MW onshore wind (one or more turbines)	Guarantee community, Local Authority and Utilities engagement to the project. Review techno-economic feasibility with Local Authority & Utilities companies.	Long Term	High Cost	High	CFOAT committee members, Local Authorities, Utilities Companies, SEAI
Renewable Technology	3 MW Solar	Guarantee community, Local Authority and Utilities engagement to the project. Review techno-economic feasibility with Local Authority & Utilities companies.	Long Term	High Cost	High	CFOAT committee, Local Authorities, Utilities Companies, SEAI
Renewable Technology	Hydrogen Fuel Cells or Electrification of the ferry services	Engage with local ferry companies, Minister of Transportation and Local Authorities to establish a strategic conversion to RES maritime transport. Engage with EU groups such as Hydrogen EU for the establishment of projects, funding and support mechanisms	Long Term	High Cost	High	CFOAT committee, Local Authorities, Commercial and Industrial Sector representatives, Ferry Companies, SEAI

The information presented and recommendations provided as part of the Energy Master Plan aim to future-proof planning and energy policy in light of the potential future impact of National and European legislation.

The most critical objective of this initiative is to continue to develop a structure to allow all local stakeholders to make more informed policy decisions relating to energy provision and development in the area.

It is also expected that the work will act as an exemplar for other local authorities to demonstrate the value of the energy master planning process, to encourage similar initiatives elsewhere, and the engagement of the community.

Comharchumann Fuinnimh Oileáin Árann Teoranta's collaborative approach throughout the Energy Master Plan process has been a critical factor the development of this report. The authors are confident that the committee will have continued success as an exemplar SEC both Nationally and Internally and would like to wish them the best with their future decarbonisation ambitions.

6. Bibliography

[1] SEAI. *Energy Efficiency Obligation Scheme*. Available: font: 11.5px Arial}Available: http://www.seai.ie/eeos/

[2] *CIBSE Guide F- Energy Efficiency in Buildings*, 2014.

[3] CSO, "2016 Census- Inis Mor Small Area Data," Central Statistics Office2017.

[4] CSO, "2016 Census-Inis Meáin Small Area Data," Central Statistics Office2017.

[5] DCENR, "National Energy Efficiency Action Plan," Department of Communications Energy and Natural Resources2014, Available: font: 11.5px Arial}Available: https://www.dccae.gov.ie/documents/NEEAP 4.pdf.

[6] DCENR, "National Renewable Energy Action Plan," Department of Communications, Energy and Natural Resources2018, vol. 4 Available: https://www.dccae.gov.ie/documents/The National Renewable Energy Action Plan (PDF).pdf.

[7] CSO, "2016 Census Results," Central Statistics Office of Ireland2017.

[8] "Oileain Arann-Community Development Framework Guidance," Galway County Council2017.

[9] A. Hamilton and P. Kenny, "Comharchumann

Fuinneamh Oileain Arann Teoranta (Aran Islands Energy Co-op) Wind Turbine Feasibility Report " in *Final Report: Feasibility Study for an*

Auto-Generation Wind Turbine for the Aran Islands Energy Co-op, ed, 2014.

[10] SEAI, "Conversion Factors," 2017, Available: https://www.seai.ie/resources/seai-statistics/conversion-factors/.

[11] SEAI, "Public Sector Energy Monitoring & Reporting System," 2017, Available: https://www.seai.ie/energy-in-business/monitoring-and-reporting/FAQs.

[12] SEAI, "Energy in the Residential Sector," 2018, Available: https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf.

[13] p. p. m. p. p. p. 0.0px *et al.*, "Inis Mor Public Water Supplies," in "Drinking Water Audit Report," EPA2015.

[14] I. Water, "Galway County Water Conservation Works Stage 3 - Phase 2," ed, 2018.

[15] SEAI, "Energy In Ireland," 2017, Available: https://www.seai.ie/resources/publications/Energy-in-Ireland-1990-2016-Full-report.pdf.

[16] E. Denny and A. Keane, "A Smart Integrated Network for an Offshore Island," *Proceedings of the IEEE,* vol. 101, no. 4, pp. 942-955, 2013.

[17] C. Pleijel, "Energy Audit on the Aran Islands," European Small Islands Federation2015.

[18] R. Lasseter, "Microgrids," *2002 IEEE Power Engineering Society Winter Meeting. Conference Proceedings,* 2017.

[19] S. Singh, D. Gao, and J. Giraldez, "Cost analysis of renewable energy-based microgrids," *2017 North American Power Symposium (NAPS) , Morgantown, WV,* 2017.

[20] EirGrid, "The DS3 Program," 2018, Available: http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/.