SEAFUEL

Pre-trial studies.
Examination of the existing transport in each of the special regions: Árainn, Tenerife and Madeira

Interreg
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This document is part of the WP 5 - H2 Deployment in Special Regions, Action 2 - Pre-trial studies. Examination of the existing transport in each of the special regions.

Acronyms and abbreviations

A.D.I.: Average Daily Intensity
DGT: Directorate General of Traffic (in Spanish Dirección General de Tráfico)
EV: Electric Vehicle
FCV: Fuel Cell Vehicle
GDP: Gross Domestic Product
H2: Hydrogen
INE: National Statistics Institute (in Spanish, Instituto Nacional de Estadística)
ISTAC: Canary Islands Statistics Institute (in Spanish Instituto Canario de Estadística)
LPG: Liquefied petroleum gas
OMR: Outermost Region
SEAFUEL: Sustainable integration of renewable fuels in local transportation
Toe: Tonne of oil equivalent
VAT: Value Added Tax
WP: Work package.

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Contens

1. Summary

This paper conducts a survey of three Islands in the European Union with a view to assessing their suitability for H2 deployment in the transport sector. We look at issues of geography, population and socio ecconomic in how the affect transport as well as the availability of renewable energy. We also examine the energy use of the islands focussing on that used in the transport sector to determine relevant drivers or obastacles to H2 deployment.

The three islands studied are Tenerife (Spain), Madeira (Portugal) and Árainn (Ireland). The research was conducted by partners in the SEAFUEL research project which is funded by the European Commission through INTERREG. Research on Tenerife was conduced by Instituto Tecnológico y de Energías Renovables, ITER, on Madeira by Agência Regional da Energia e Ambiente da Região Autónoma da Madeira, AREAM, and on Árainn by Comharchumann Fuinnimh Oileáin Árainn Teo, CFOAT.

This paper is the first of a series which will look at H2 in transport in these three island case study areas. Further research wil examine energy system requirements for H2 deployment as well as public acceptance assessments. We will also relate the direct experience of the deployment of H2 vehicles on Tenerife to the other islands.

The paper finds that H2 deployment is most likely to be determined by issues of geography and population where daily commute distances below 100km will not act as an incentive fro private car owners or vehicle fleet owners to choose Fuel Cell Vehicle (FCVs) over Electric Vehicles (EVs). The existanceof fleets of vehicles on larger islands will likely provide opportunites for FCV adoption.

Maritime and Air transport opportunties are discussed, but it felt that for each of these islands their open ocean Atlantic location will require a maturation of martime H2 technology. Similarly the authors recommend the comletion of studies examining H2 in small passenger air transport before comitting to aditional research into this sector.

2. Introduction

2.1. Transport Use Survey SEAFUEL: Árainn, Madeira and Tenerife – the goals of this paper

This paper was written as part of the background contextualisation of the INTERREG Seafuel project. It seeks to provide a pre-project survey of the transport environment and practices of three case study areas, the island communities of Árainn, CO Galway Ireland, Madeira, Portugal, and Tenerife, Canary Islands, Spain. We conducted these surveys as a means of preparing SEAFUEL's research as localised and matched to real-life conditions.

We divide the paper into seven key sections: Sections 4-6 will examine the each of the islands in detail identifying the specifics of their geography, economy an social environments as they impact on transport. Section 7 will bring these diverse experiences together both as a set of common practices but also specific opportunities for H2 roll-out in the transport sectors of each island.

3. Árainn

3.1. Geographical Overview

Árainn[1] is one of the three Aran Islands, an archipelago off the coast of Galway in the Republic of Ireland. It is the largest of the three islands and has the largest population.

The main port on Árainn (it's effectively the only one) is in Cill Rónáin. It is the location of Árainn's largest settlement in the east of the island, 21.6km by sea from the nearest mainland port in Ross a Mhíl. There are ferry services to Arainn from Doolin in Co Clare, but these are a secondary access by sea to the island and mainly serve the smaller islands of Inis Oírr and Inis Meáin.

[1] The area studied is in the Gaeltacht – that part of Ireland where Irish is the spoken language. The Gaeltacht has special status under successive governments' policies whereby in as far as possible the state encourages Irish as the medium of communication in business and social life. Place names in the Gaeltacht region are officially in Irish only (although English versions are also used). In this report, all Gaeltacht place names and company names are given in the official Irish language. Place names outside the Gaeltacht are given in the most widely used form. Árainn is the name of the largest of the 'Aran Islands', the other two being Inis Meáin ('Middle island') and Inis Oírr ('Eastern Island').

Figure 1. Arainn in Context.

Showing Árainn in relation to the mainland, the two other smaller Aran Islands and also the transport links.

Árainn is approximately 14km long on its North West to South East axis[2]. It is 3.5km at it's widest point.

The island is well known for its unusual geology: limestone pavement. This put is geologically more akin to the Burren in neighbouring Co. Clare than to the red granite of Connemara across Galway Bay.

The typical features of the limestone pavement are embodied in Árainn: sparse, low vegetation, ultra thin topsoil subject to erosion, the almost total absence of trees. Field sizes are generally very small and many fields are unsuited to agriculture at all. However, the unique environment in Árainn has become a significant heritage asset which helps support the thriving tourism sector which is the principal commercial and employment driver on the island. The physical environment has been given special status by the State.

Implications of Physical Geography for this study

The Western Coast of Ireland is exposed to the Atlantic Ocean. There is a very high wind resource on the island. The island is sparsely inhabited away from the central axis – which may permit wind generation of electricity.

There are no local traditional resources of energy (for example biomass) which would compete with renewably generated energy - 100% of fuel and energy is imported.

The cost of transport on the island is excessive. Islanders not only pay for excess transport of fuels, they are restricted in that only diesel is permitted. Transport costs are also subject to VAT. Island economics mean that benefits from supplier competitors are non-existent.

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[2] excluding two uninhabited off-shore islands in the NW: Inis Bhreathnach and Oiléan Iarach

The price of transport fuel is discussed in more detail below.

The significance of the island's geology for the tourism sector has implications for the scale and character of any developments.

The isolation of the island from secondary markets means that while the cost of imported fuels is high, so there are likely to be favourable economics for H2 in import cost avoidance, the cost of finding markets for excess production of any product is high (and H2 would need to meet this challenge).

Island economies always need to be very mindful of achieving a balance between their resources and their use.

3.2. Demographics

There is a small permanent resident population on Árainn; there are a total of 722 people resident on the island. This represents a decline on the population of 2011 (845)

There are 297 households on Árainn[3]. The total population is 722 normally resident. For census purposes the island is divided into four 'Small Areas' (SA) by the Irish Central Statistics Office the CSO. These are broadly corresponding to the areas around the following villages:

SA: 067110006: Cill Rónán; SA: 067110001/067110002: Cill Mhuirbhigh; SA: 067110004: Eochaill; SA 067110005: Cill Éinne.

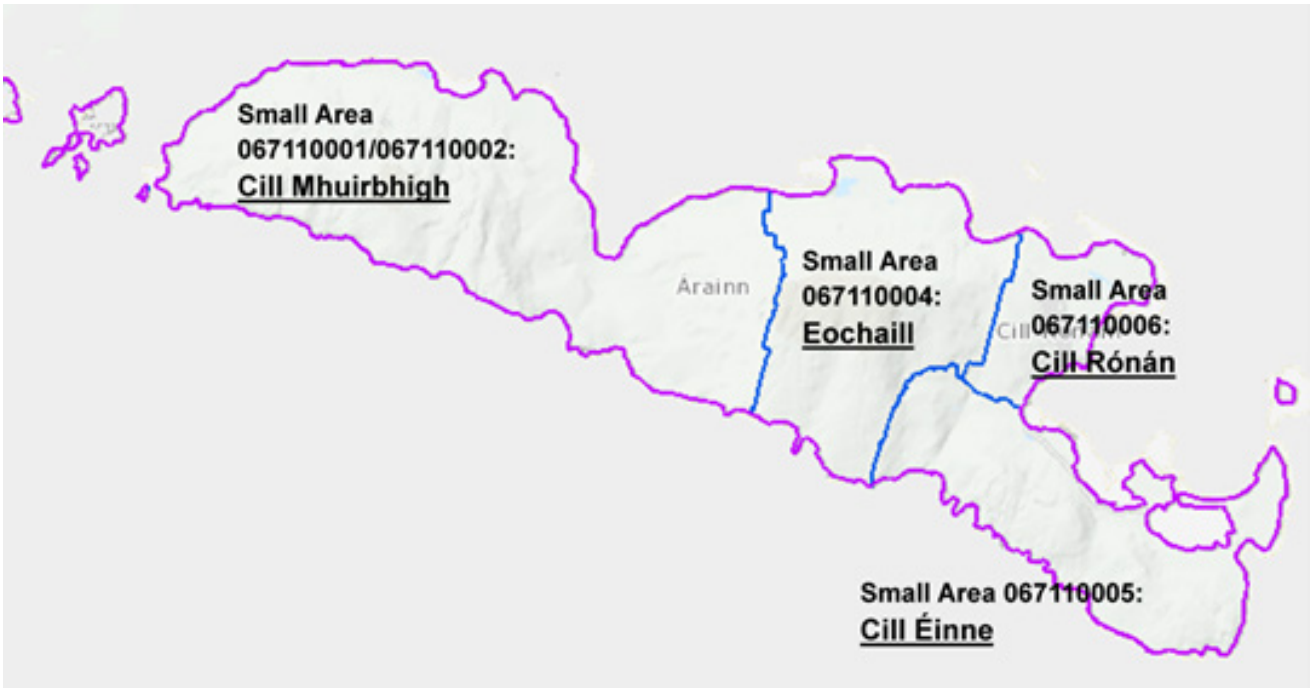

Figure 2. Map showing CSO Small Areas (SA) in Árainn

[3] This study uses data from the CSO's [2016] census (available at this link: https://www.cso.ie/en/census/census[2016]reports/census[2016]smallareapopulationstatistics/). The data is extremely robust and detailed.

	POPULATION	HOUSEHOLDS
Cill Ronan	207	89
Eochaill	146	52
Cill Éinne	170	69
Eoghanacht	202	87
TOTAL	722	297

Table 1 Population and number of households of Árainn by Small Area (CSO, 2016)

The population structure of Árainn is not typical of that nationally. By comparison, Árainn's permanently resident population has a considerably older age-profile than the national profile.

AGE RANGE	Árainn	Ireland
0-19	20.2%	27.5%
20-39	21.8%	27.8%
40-59	28.1%	26.3%
60-79	24.7%	15.3%
80+	5.2%	3.1%

Table 2a Age range Arainn v Ireland

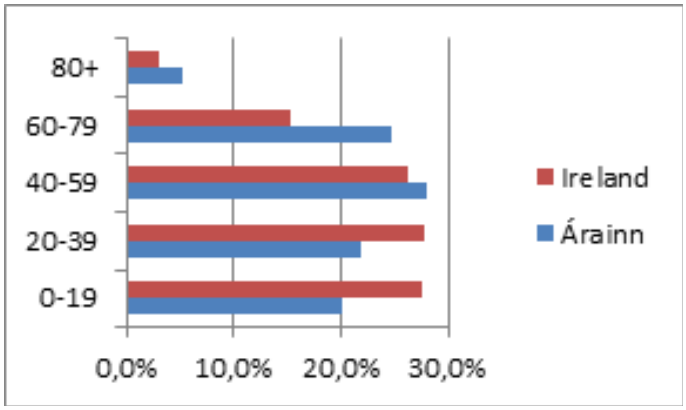

Table 2b Age Range Árainn v Ireland

Implications of demography on this study

The facts that the under 40's demographic cohorts are proportionally smaller than those in Ireland generally, and that the over 40's cohorts are greater, may influence the adoption of new technologies. Older cohorts are believed to be generally more technologically less inclined to innovations and more inclined to tradition. This may impact on their willingness to adopt hydrogen as a transport fuel. In particular because the technology is the least established replacement for carbon fuels. However, in the case of EV's this appears not to hold true: Plotz, et al (2014) found that in Germany, the most likely group of private EV buyers were middle-aged men with technical professions living in rural or suburban multi-person households[4]. The same may also hold true here.

In addition, there is anecdotal evidence for the existence of a culture of innovation on Árainn which is culturally a very outward-looking island. It has a large number of returned natives who have spent time abroad (in particular prior to family formation) but who have resettled on the island. There is also a large number of non-natives who have migrated to the island bringing with them a broad range of cultural experiences.

These two factors may have a unique influence on the generally older demographic in Arainn being open to innovation. The early establishment of a renewable energy co-operative on the island (the first such in Ireland) may bear witness to this. There are also 10 electric vehicles on the island (representing 3% of the transport stock) which is much higher than the national average of 0.21%[5]. Further investigation of public attitudes which will take place in Year 2 of SEAFUEL will provide a clearer picture of the potential influence of demographics on openness to innovation in transport fuel types.

3.3. Population Distribution

Human settlement ranges largely along the central axis of the island (An Bóthar Árd). There are very few houses and only one settlement (Gort na gCapaill) not on this central axis.

The population is small and is widely dispersed; however the households are aligned on the main road axis of the island in what is known as a *sráidbhaile*[6] settlement pattern of ribbon development that is typical in Western Ireland. Árainn is in an unusual situation of having a dispersed settlement pattern but a concentration of services. There is one supermarket on the island, and one post office. These are both in the port village Cill Ronán – thus residents from the eastern and western parts of the island make a journey regularly (daily) to Cill Ronán. A journey between 9km and 3km one way.

The CSO figures for 2016 show that there is variance across the SAs as to commuting to work or school patterns.

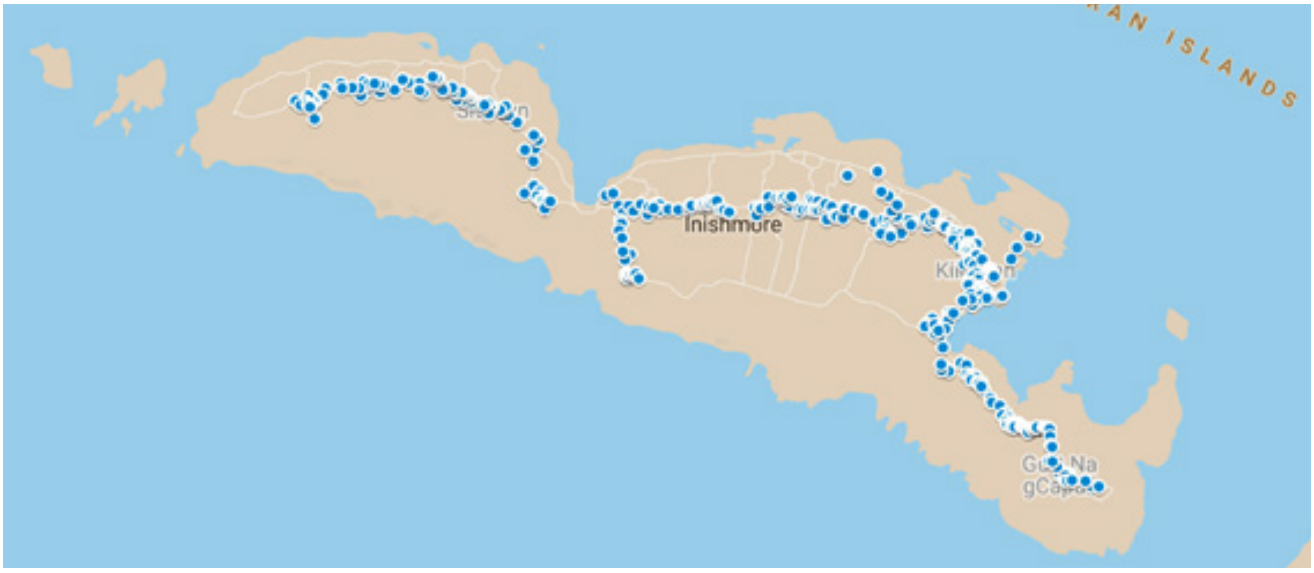

Figure 3 Map showing the distribution of houses in Árainn.

[4] Patrick Plötz, Uta Schneider, Joachim Globisch, Elisabeth Dütschke, 'Who will buy electric vehicles? Identifying early adopters in Germany', Transportation Research Part A: Policy and Practice, Volume 67, 2014, Pages 96-109.

[5] The co-operative has been front and centre in the adoption of EVs, but there has also been work done by the SEAI in this regard also which may also have influenced EV adoption.

[6] Collier, P. (2004). Ireland's Rurban Horizon: New Identities from Home Development Markets in Rural Ireland. Irish Journal of Sociology, 13(1), 88–108. https://doi.org/10.1177/079160350401300107

Population Distribution effects on transport

Thus, there are small but regular journeys taken by the residents daily (often multiple per day). The typical distances driven per inhabitant per day are 20 to 30 km. This journey pattern is very much within the ideal range of electric vehicles (EVs), even the cheapest and oldest models. This will have implications for an adoption of hydrogen vehicles (HVs) on the island. HVs have longer range as a significant selling point amongst non-carbon-fuelled cars. This would not represent and advantage over EVs on the island.

3.4. Socio Economic Context

Community Sector

Árainn has a thriving community sector. Comharchumann Forbatha is a services co-operative with X members. The co-operative which is supported by Údarás na Gaeltachta is a democratically structured organisation which supplies services to its members and promotes employment and business on the island. The co-operative is also contracted to run the community waste collection and recycling scheme. It is also a major fuel supplier of coal, 'green' agri-diesel[7]', and white road diesel. Formerly the Co-operative was the electricity supplier on the island, but with the installation of an interconnector with the mainland, this role has passed to the main network operator ESB. The co-operative is also responsible for the running and maintenance of the islands group water scheme.

CFOAT is a is a Community Energy Co-operative on the Aran Islands aiming to make the Islands Energy independent and Carbon Neutral by 2022. It is a non-profit with membership open to all residents on the three Aran Islands. It currently has 70 members. It is a key driver of public acceptance and behaviour change in the sustainable sector. It will play a key role in the engagement by the local community and businesses in hydrogen adoption.

Other community organisations include: the Catholic Parish, the GAA, and Coiste Áras Rónán. There is a local Credit Union (a local independently managed finance institution also structured as a co-operative).

There are two primary schools (SN Rónán, and SN Eoin Pól II) under the patronage of the Catholic Archdiocese of Tuam, and a Secondary School (Gairmscoil Éinne), under management of Galway and Roscommon Education and Training Board.

There are three churches on the island, a community centre, a GAA club, and a large elderly care facility. Each of these operate as a important community hubs.

- ***Potential Impact of community organisations on this study***

  These community organisations will have a significant impact on the public acceptance and information dissemination of SEAFUEL. In some case, for example the Comharchumann Forbatha, they may be potential adopters of hydrogen in transport both as a retailer and a user.

  In the case of CFOAT, there will be close involvement through renewable electricity supply to a future hydrogen electrolysis process. CFOAT can also be expected to be

[7] 'Green' diesel is a chemically marked diesel which is permitted to be used for agriculture or as a home heating fuel, but not as a fuel for road vehicles.

a key driver of technology acceptance serving as a conduit for group purchasing of vehicles. As has been noted, CFOAT is a key driver of EV adoption.

The close integration of island community life means that there could be a role for the both the Church and the schools as fora for information dissemination. The Comhar Creidmheasa Árainn Credit Union would also have a role in financing the purchase of new hydrogen-powered vehicles. Any provider of finance for a new technology would be expected to be very cautious and demand the highest level of information. Bearing in mind that Credit Unions are ethical, community organisations, they are very risk averse.

Business Sector

The remit of SEAFUEL is to investigate the replacement of carbon fuels with hydrogen in transport. Thus the commercial sector on Árainn is seen through the lens of transport.

Tourism is by far the largest industry on the island. A great many visitors come to the island annually (the majority on day trips). There are no published records of the exact numbers, but the Office of Public Works which manages Dún Aonghusa – the tourist highlight on the island recorded 132,233 visitors to the site in 2016[8]. This implies that up to 200,000 visitors come to the island annually[9]. Much of the commercial life of the island involves offering transport, accommodation and food and drink to these visitors.

There is one large hotel on the island, and 11 Bed and Breakfasts (B&Bs). There has recently been a proliferation of 'pod' style single room accommodation units with approximately 20 units for hire – all in Cill Rónán. The hotel and the majority of the B&Bs are also located in Cill Rónán.

There is a thriving bus-guided tours sector with 20 commercial tour buses operating for most of the year[10]. These buses operate hop-on-hop-off guided tours of the island concentrating on a route from Cill Ronán (the port and main settlement) to Eoghanacht (site of a 6th Century monastery) a distance of some 18km round trip.

There is at present no sustained public bus service on the island – transport by car or other vehicle is private.

There is an airstrip on the eastern end of the island from which a small Cessna 9-seater passenger craft operates flight from Indreabhán on the mainland in County Galway. The plane also services the other two islands. The service is currently supported by the Department of Transport, although there have been recent controversies surrounding its continuation. The air service is very significant for the islanders although in terms of passenger numbers, it carries far less than the ferries. It is not predicted that the air service will feature significantly in this study.

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[8] OPW, [2017], https://www.opw.ie/en/media/[2016]-visitor-numbers.pdf accessed [29.10.18]. Tourists are charged entry and have to purchase a ticket, so the numbers would be accurate.

[9] The site is not remote, but is accessed by a steep climb over broken ground – it would be fair to say that not only do not all day-trip tourists buy a ticket to visit the site, but returning tourists would not revisit the site on every visit.

[10] The high tourism season is considered to be from April [1]st until [1]st of October – the ferry operates additional sailings during this period.

The transport by ferry to Árainn is critical to the commercial life of the island. The details of the existing technologies and the possibility for replacement with hydrogen is discussed later in this paper and will also be dealt with extensively in the studies in Year 2 and Year 3. However, the significance of the tourism sector to the commercial life on Árainn and the role the ferries play in this is indicated by the numbers of visitors using the ferry to access the island.

Ferries to Árainn are direct from Ross a Mhíl in Galway or from Doolin in County Clare via Inis Oírr. There are two ferry companies operating to and from Árainn: O'Brien Shipping and Island Ferries. The fleet of these two companies is discussed in Section below. The participation of these ferry companies in the study would be very beneficial. However, owing to commercial sensitivities there is an understandable reluctance on the part if both companies to share information publicly. Stakeholder engagement with the two companies will be very important during the lifetime of SEAFUEL.

There is a small fishing fleet that while it is not based on the islands, is manned and owned by islanders. The main fishing port is also in Ross a Mhíl Galway.

Many people in Árainn own land and have connections to agriculture, while it is a major employer on the island[11] many farmers operate part time and have other employment. The limestone pavement geology has meant that there is continuous erosion of topsoil, and so the land is classified as poor with very low yields.

There are several farmers breeding store-cattle and one medium scale goat dairy farmer. Farming here is not intensive, rather it is grounded in conservation. This approach is supported by grants given to the farmers to maintain the unique habitats on the island such as Rural Environmental Protection Scheme (REPS).

There is agricultural machinery in use throughout the island however. This is not used for ploughing or harvesting, but rather for transportation (typically tractors) of materials and people involved in the work.

There are a few manufacturers on the islan

d. These are small scale food processors with minimal transport requirement- they do however have thermal energy demands.

- ***Impact of Commercial Sector on the study of Transport Fuel in SEAFUEL***

  There are three main factors that will affect the results of the SEAFUEL study on Árainn:

  - Significance of tourism
  - Ferry transport dominance of all transport fuel uses
  - Marginality of other commercial transport uses of carbon fuels.

[11] 88 people on Árainn said they were farmers in the 2016 census

It is to be expected that all developments on Árainn must be seen through the lens of the effect of the proposed development on tourism. Anything which had a potentially negative effect on tourism will not find traction in public acceptance. A development which augments the existing tourism sector will find greater public acceptance.

The ferries are very significant as a source of income through their dominance of access to the islands. The relationship between the ferry companies and the island community is one which must be approached with careful consideration.

There are few commercial uses of fossil fuels in transport. Those that exist are in a sense bound up in the ferry-tourist matrix. There is a small amount of agricultural work on the island that does require diesel. In that sense, it may be useful to consider the agricultural sector as a useful stepping stone for the adoption of hydrogen as a new fuel. Tractors are primarily used as on-farm transport but are used occasionally on the public road. They are almost equivalent to the light industrial vehicles being trialled by SEAFUEL in the Canaries. While there are complicating factors (see Section below). It is proposed that the study examine this avenue of technology change.

3.5. Transport Energy Use

This section is an analysis of the existing fuels and technologies in the transport sectors in Árainn. It provides a benchmark of energy use, carbon emissions and costs of existing fuels, practices and uses. This will provide the context for the examination of the opportunity of hydrogen adoption in transport here and using Árainn as an exemplar, the remainder of the Atlantic Region.

Private Cars

There are 297 private cars on Árainn. Of this number 10 are EVs.

The non-EV private cars on the island run exclusively on road diesel[12] – for safety reasons in 2007 transport of petrol on cargo ferries to the island was prohibited. There is one sole importer of road diesel to Árainn, namely Comharchuman Forbatha, and one sole distribution point. This means that there are excellent records of diesel use on the island, and these were made available to the authors.

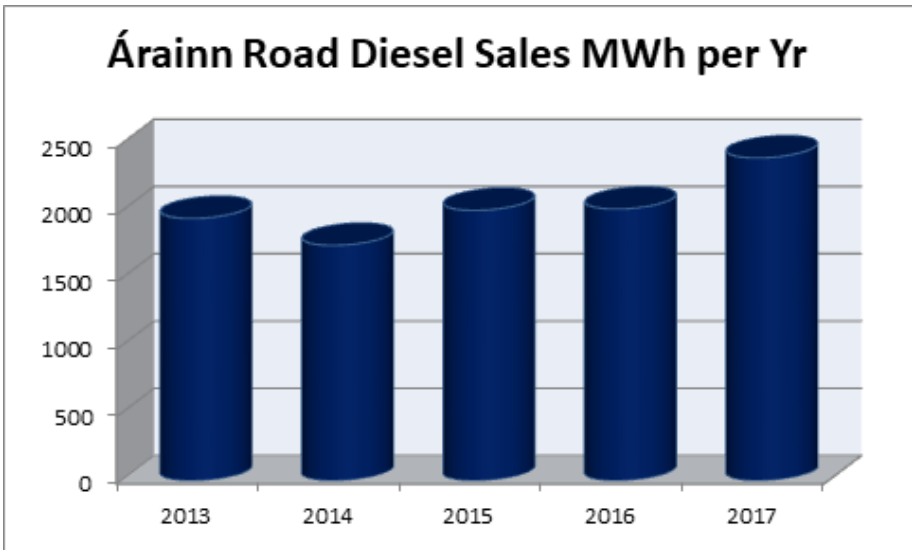

Figure 4 Road Diesel Sales

[12] This is a form of diesel that is liable for a higher tax rate than subsidised 'green diesel' which can be used in agricultural machinery and home heating.

The total amount of road diesel used on the island amounts to 2,298 MWh. Excluding the estimated road diesel use by private buses (below), the 287 diesel vehicles consume approximately 85% of the road diesel on the island – 1,953MWh. As Tables 1-4 Appendix 4 show a greater percentage of adult residents of Cill Rónán travel to work on foot (29%) than the average for the island (19%) whereas a smaller percentage do so in the SAs of Cill Éinne (6.8%) and Cill Mhuirbhigh (16.4%). The percentages driving to work vary accordingly with car journeys being taken to work by 32% of adult Cill Rónán residents 7.4% less than the island average, while 47% of Cill Muirbhigh residents and 52.5% of Cill Éinne residents drive by car to work. The means of transport to school also vary according to distance from Cill Rónán. There is a reported[13] wide variation across the island in the distance driven per year also, as nearly all of the traffic is to and from Cill Rónan where the sole supermarket on the island is. Thus, the 28.7% of the population who live in Cill Rónán report travelling very few km per day on average, while the 28% who live in Eoghanacht travel upwards of 32km daily[14].

Buses

The sales of Road diesel above encompass the use of diesel as a fuel in bus transport also. Drivers and owners of these private buses are for commercial reasons unwilling to publicly state their diesel use. To identify the level of diesel use for bus transport, it will be necessary to use averaging.

It is estimated[15] that the twenty buses travel on average 45km per day, 300 days per year, and thus use each approximately 2,200 litres diesel per year. In total buses consume 45,000 liters of diesel per year. This is a share of the total diesel sold at the filling station on the island. There is thus an estimated 450 MWh/a used in private bus transport.

Ferry

There are two ferry companies servicing the island: Island Ferries, based in Galway, and O'Brien Ferries, based in Doolin Co Clare. Aran Island ferries has a fleet of five ferries.[16]

The Ferries to the Island from Ross a Mhíl in Co. Galway and Doolin in Co. Clare represent by far in a way the greatest energy use on the island, for all sectors of activity, not just in transport. In a study sponsored by the Sustainable Energy Authority of Ireland, produced on behalf of CFOAT by Plan Energy Consultants, the energy use of the ferries to and from Árainn were calculated to be in excess of 9,541 MWh/y.

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[13] It is beyond the scope of this study to determine by survey the distance driven by residents: the population size is very small. Surveying a representative sample would be very hard to achieve as to achieve confidence of 5% would involve surveying over [50]% of the entire population. It may be possible to build in a question of distance driven per day into the attitudinal survey to be undertaken in M12-18 of the project that could determine this.

[14] A journey from the midpoint of Cill Muirbhigh SA to Cill Rónán is 8.1 km one way, Assuming two trips each way per day would be a distance of 32km per day.

[15] Calculation in appendix 2

[16] These are described on the company's website: http://www.aranislandferries.com/fleet.php (accessed 1/11/18) and listed in Appendix 2

Arainn 2018						
Total Final Consumption						
Sector	Usage (MWh)	As % of Absolute Total	Emissions (tCO2)	As % of Absolute Total	Cost €Euro	As % of Absolute Total
Maritime (Ferries only)	9,541	49%	2,519	44%	801,441	34%
Road Diesel	2,298	12%	607	11%	278,093	12%
Aviation	353	2%	89	2%	86,925	4%
Residential	3,144	16%	879	15%	520,103	22%
Commercial	1,283	7%	359	6%	212,296	9%
Industrial	0	0%	0	0%	0	0%
Public Buildings	894	5%	250	4%	147,846	6%
Utilites	301	2%	84	1%	49,794	2%
Residential	537	3%	259	5%	75,126	3%
Commercial	388	2%	187	3%	54,264	2%
Industrial	34	0%	16	0%	4,704	0%
Public Buildings	224	1%	108	2%	31,285	1%
Utilites	663	3%	320	6%	92,689	4%
Transport (EVs)	10	0%	5	0%	1,399	0%
Total	19,670	100%	5,682	100%	2,355,965	100%

Table 3 Energy Consumption Árainn across all sectors

This demonstrates that the ferries constitute the largest energy use across all sectors: 34% of all fuel spend in euro, 49% of all energy consumed in MWh, and 44% of Carbon all emitted. This could be particularly significant as there are very few decision makers determining the fuel use in the ferries.

Air Travel

There is a regular air service from the airstrip in Indreabhán on the Galway mainland. The plane is an 11-seater Cessna aircraft powered by kerosene. The fuel consumption for Aviation Gas for transport to Arainn by air is 35,300 litres per annum, or 353 MWh.

Agricultural Transport Energy Use

Tractors. The total number of tractors on the island is 26. These vary from small to large, but are still on the small scale of anything the farmers on the mainland might use. There is a mix of models, but mainly Zettor with several Ford tractors of various ages and states of repair and fuel efficiency. Tractors are used consistently, but usually on very short trips, mainly for farmers for drawing water or accessing areas that cannot be accessed by car. Irish farmers tend to live adjacent to their land, and this is even more the case in Árainn.

From reported usage by, an admittedly small and unscientific sample, we estimate the average fuel usage of each tractor to be 55 litres of agricultural diesel per month. Thus, the total agri-diesel use on the island is estimated to be 1,430 litres per year.

Commercial Sector

There is a fleet of privately-owned commercial light industrial machines engaged in building and earth moving. These are broken down here into two categories: diggers, and dumpers.

Diggers:

There is a total of 10 machines total on the island. Fuel consumption based on full time work:

Class	*Number*	*Fuel Consumption (L/m)*	*Total Fuel Consumption L/yr*
3 tonnes	4	50	2,400
6 tonnes	5	50	3,000
12 tonnes	1	280	3,360
TOTAL			**8,760**

Diggers are used only occasionally and when needed. Our estimate is that they are in use on average 2 days per month.

Dumpers:

There is a total 15 on the island. Fuel consumption based on actual usage at time of study (August-October 2018).

Class	*Number*	*Fuel Consumption (L/m)*	*Total Fuel Consumption L/yr*
1 tonnes	5	15	900
6 tonnes	6	30	2,160
90 tonnes	4	55	2,640
TOTAL			**5,700**

Total fuel consumption for diggers and dumpers of all classes on the island is therefore approximately 14,460 litres per year.

3.6. Total Transport Fuel Use Árainn

Table 4.below shows the breakdown of all transport fuel consumption on the island

TYPE	*Litres per year*	*MWh per year*
Maritime	95,4100	9,541
Cars	17,0340	1,703
Buses	45,000	450
Commercial	14,460	146
Aviation	35,300	353
Agri-diesel	1,430	14
TOTAL	**1,220,630**	**12,207**

Table 4 Transport fuel consumption on the island

Thus, although each sector has very different characteristics vis-à-vis openness to adoption of Hydrogen as an alternative to diesel, this demonstrates a very large opportunity for fossil fuel reduction and replacement by a potentially locally and renewably generated fuel such as hydrogen. These opportunities are discussed below.

3.7. 1st stage assessment of H2 Opportunities in the Transport Sector on Arainn

Private Cars

As we saw in Section 5.1 there is a relatively modest amount of road diesel sold and consumed on the island. The vast majority, 85% is used in private cars. However, journey distances are short. Given that the chief advantages of hydrogen over electric vehicles in car transport is the potential for greater range (although EVs are fast catching up on hydrogen fuel cell vehicle [HFCV] range) and shorter refuelling times (6 minutes for an HFCV v 30 minutes for an EV), it is unlikely that there is a marked incentive for drivers to choose HFCVs over EVs on Aran.

Adopters of EVs on Aran report that an overnight charge on a 2013 Renault Fluence can last two to three days' driving on the Island – even for residents of the western part villages (see 5.1 for typical driving distances for each SA). There is quite likely to be a gradual move away from diesel vehicles to second hand EVs on Aran - in particular as the second-hand market in EVs develops. In general, because of the short-range driving and moderate to poor road infrastructure on the island, there is a tendency on the island to buy second hand vehicles in any case.

Many islanders do own second cars on the mainland, usually parked in the Ros a Mhíl Car Parks. It is this market which could be investigated for potential HFCV adoption. It would be useful to include this possible opportunity in attitudinal surveys of residents that are due to be conducted in Semesters 3 and 4 of the SEAFUEL research project. However, this would be seen as a non-island/mainland deployment of H2 in transport, and so outside of SEAFUEL's focus of study.

Buses

As with cars, journey distances on buses are short. However, the fleet is in general newer and is updated more frequently owing regulations for public service vehicles. Thus, those tour bus operators that are purchasing new buses might consider switching to new fuel/power technology such as EVs or HFCVs at that time. Again, the advantage at this time would appear to reside with EVs – as this is the low-zero emission transport technology that at present is preferred by policy makers in Ireland (see the Irish section of the SEAFUEL Work Package 6 report). An investigation of the attitudes of tour-bus drivers should however, be included as part of the SEAFUEL survey work in 2019.

Ferries

This may well represent area of greatest opportunity for hydrogen fuelled transport. The level of emissions generated by the ferry services far outweigh those of any other sector –even greater than all other sectors combined, Table 5.3.1. this creates a pressing case for pursuing the reduction of carbon emissions on the islands through exploring the option for conversion to hydrogen fuel cell technology. While this technology is still at the demonstration stage (BIG HIT, the Osterøy car ferry, Norway) it should be a priority for investigation in the Árainn component of the SEAFUEL research. As was noted above, the limited number of decision-makers involved could represent an opportunity. However, it is significant that the sustainable tourism reputation that Árainn has cultivated could be very valuable in leveraging not only public acceptance, but also positive public attitudes as a driver of technology switching. A close investigation of this public attitude element should be considered in the semester 3 and 4 work-streams of SEAFUEL that will focus on public perceptions of hydrogen technology.

Agricultural Energy Use

This is an area which could offer an environment for hydrogen adoption. Hydrogen tractors could well appeal to the innovative and early adopter characteristics of farmers. Farmers, particularly West of Ireland farmers, are an expert group to whom experimentation with new approaches and technologies can often appeal. A key here would be to demonstrate the cost efficiencies of the new technology. In this the competition with subsidised agricultural diesel process could be problematic. Synergies between the community/ locally owned renewable electricity generation as the source of the energy to produce hydrogen would also be a consideration in the decision process which cold represent a pull factor in experimenting with hydrogen farm transport. While the amount of carbon emission reduction would be small relative to other sectors, there are other considerations. H2 could be considered to be more viable than battery power in these deployments where greatewr power is needed in rough terrain. If the benefits of hydrogen fuel cell use in farm transport could demonstrated, this could represent a lever for technology change across the transport sector as a whole.

Commercial Sector

As with the agri-sector, there are potentially greater opportunities for innovations in the commercial sector. Indeed this is the sector where the demonstration component of SEAFUEL is taking place in the Canaries. However, it is not clear that there are excavators and dumper powered by hydrogen at the market ready stage (or event beyond the prototype stage). Thus beyond potential user survey, there may not be much more additional research that could be done as part of the SEAFUEL project.

Air Transport

We do not consider that there would be a great appetite in the aviation sector on Árainn for hydrogen technology adoption. While there are some research deployments being conducted fro example Zerovia's particpation in HyFlyeR[17], the technology is not at a developed enough stage, the sector is comparatively small in terms of energy used of carbon emitted, and the future of the air service is not secure enough to justify the necessary investment in new aircraft should it become available. We do not recommend expending scarce research resources on investigating this sector as part of SEAFUEL.

3.8. Conclusions Árainn

There are significant areas of opportunity for the potential adoption of hydrogen as a transport fuel on Árainn. Electric vehicles are the most likely zero emission technology to be adopted by private car owners over the medium term (5-10 years). Hydrogen aircraft are too novel to be considered a significant option at this time, and air transport on the island for social, policy and economic reasons is likely to be locked-in to the existing aviation fuel type to offer any opportunities for hydrogen innovation in the next 10 years. Agriculture transport, i.e. tractors could present an area where users are open to innovation and where market ready technology exists. It is a small contributor to carbon emissions however, and government subsidy of diesel may out hydrogen at a disadvantage from a cost competitiveness point of view: we do consider it an area where research into potential user attitudes would be useful. This is also true of the commercial transport sector: for example tour buses, where H2 adoption could provide adopters a commercial advantage. Converting marine transport, such as ferries, to H2 is possible, but adopters are likely to await developments in other less challenging coastal environments – there is of course the switching cost issues to be considered: many of the ferry companies have invested heavily in diesel vessels which have a >30 years service life.

[17] https://www.sciencedirect.com/science/article/pii/S1464285919304146

4. Madeira

4.1. Geographical Overview

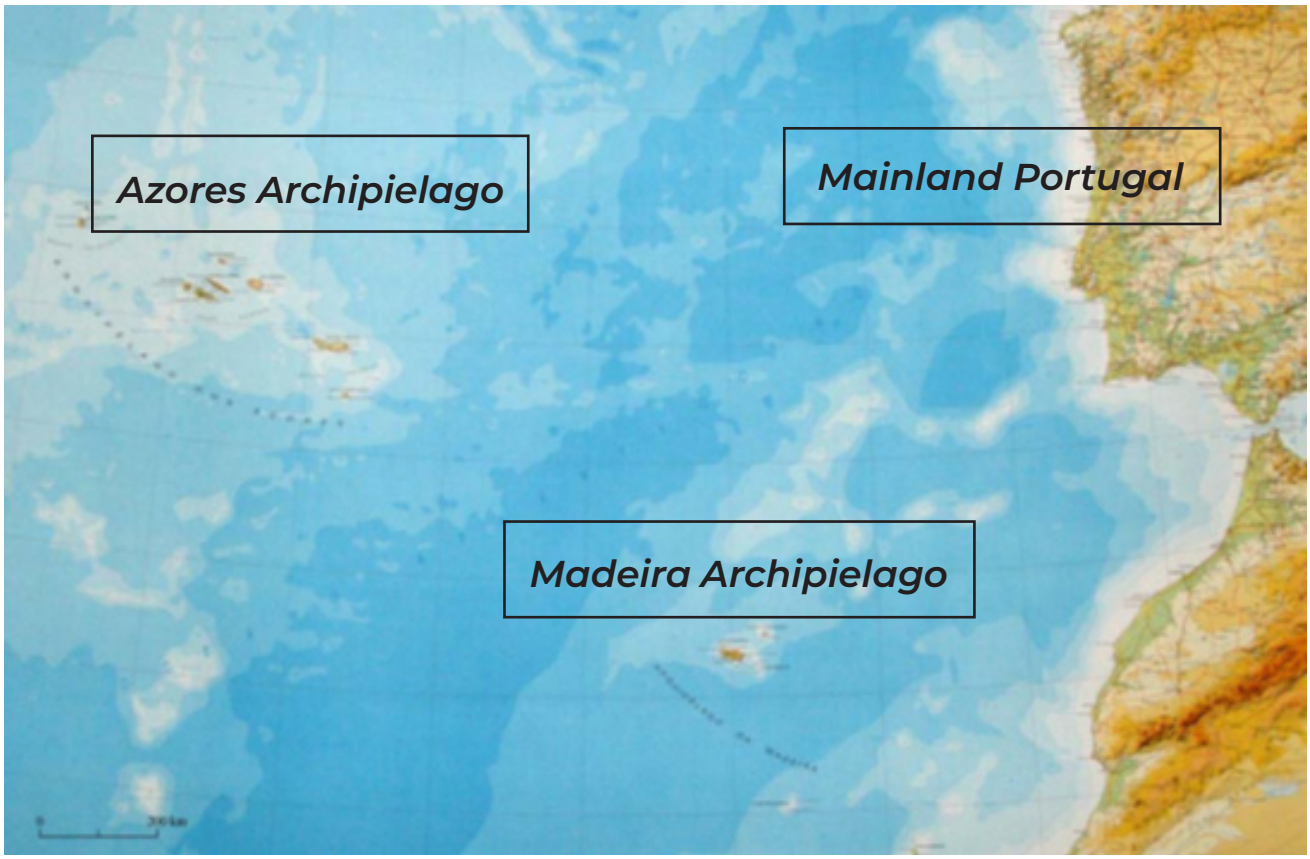

Figure 5. Map of Madeira Archipelago and the nearest territories[18]

Madeira Island

Madeira Island is the larger of the two inhabited islands of the Madeira archipelago, one of the seven outermost regions of the European Union, located in the North Atlantic Ocean, between the parallels of 30° 01' N and 33° 08' N latitude and between the meridians of 15° 51' W and 17° 16' W longitude.

Madeira Island lies approximately 880km from the Azores archipelago and from mainland Portugal (about 900 km from the capital, Lisbon) and 28 miles from Porto Santo Island, the smaller inhabited island of the Madeira archipelago. The nearest territories are the Canary Islands, with the island of Tenerife lying approximately 500 km from Madeira Island, and the Moroccan Africa coastline, about 680km east from Madeira Island.

[18] Chart of mainland Portugal and Autonomous Regions, IGP, 2003

The land area of Madeira Island is 736,75 km2, with a maximum length of 58 km from West to East and with a maximum width of 23km, from North to South. Madeira Island has a very rugged orography, Pico Ruivo its highest point peaks at 1 862m. The main mountain ridges are located in the central mountain range of the island, with several peaks towering over 1,600m and the Paul da Serra plateau between 1 400 and 1 600m.

Approximately one quarter of the island's land area (189,50 km2) is above 1,000 m. Most of the area has slopes greater than 25% (about 482 km2 exceed 25%) and 170 km2 have slopes between 25% and 16%.

The coastline, a total of 153km long, has steep cliffs, more evident on the North coast, but also on the South coast, being Cabo Girão the highest cliff at 580m above sea-level. The series of cliffs is interrupted in Funchal "amphitheatre" and in Machico bay and also in the remaining coast by river mouths.

In terms of land occupation, about two thirds of the island is occupied by the Madeira Natural Park, integrating areas with different protection statuses. Approximately 75% of Madeira Island's population lives on only 35% of the land, especially along the south coast where 94% of the population resides and where the majority of hotels are situated.

Porto Santo Island

Porto Santo Island is the smaller of the two inhabited islands of the Madeira archipelago, one of the seven outermost regions of the European Union, situated in the North Atlantic Ocean, between the parallels of 32° 59' 40" N and 33° 07' 35" N latitude and between the meridians of 16° 16' 35" W and 16° 24' 35" W longitude.

The land area of Porto Santo Island is 42,5 km2, with a maximum length of 11km from West to East and with a maximum width of 6km, from North to South. Porto Santo has a milder orography than Madeira Island, being its highest points, Pico do Facho (517m) and Pico Branco (450m) in the northeast sector and Ana Ferreira (283m) and Espigão (270m) in the southwest.

About 40% of the island's area is less than 50m of altitude and most of the area (54%) is between 50 m and 200 m of altitude, which corresponds approximately to 23 km2. The coastline is very rocky with jagged cliffs on the north side, being more exposed to the action of the sea and predominant winds from the North, and has a long, narrow sandy beach on the south side, sheltered from the wind and action of the sea.

About 10% of the land is used for agriculture, and 15% of the total area is occupied by exotic forest. The population is concentrated along the south coast where the beach occupies the coastline and where the majority of hotels is situated.

4.2. Political and administrative structures

The Autonomous Region of Madeira is a region of the Republic of Portugal, endowed with an Administrative-Political Statute and self-ruling governmental bodies. Its political, administrative, financial, economic and fiscal autonomy is exercised in the framework of the Portuguese Constitution and of the Political-Administrative Statute of the Autonomous Region of Madeira.

While a Portuguese territory, the Region falls under the Communities and Portuguese Legislation, in particular, regarding European Union commitments on energy and climate, being the legislation adapted to the regional legal regime, according to regional specificities, namely political-administrative.

For the purpose of defining legislative powers or legislative initiative for the Region, the Political-Administrative Statute of the Autonomous Region of Madeira defines the specific regional matters of interest, for example local energy production, on which the Region has the authority to define regional policies and to legislate.

4.3. Demography

According to preliminary data from the 2011 Census, the resident population of the Autonomous Region of Madeira is comprised of 267 785 inhabitants, of which, 262,302 live on Madeira Island, representing 98% of the archipelago's population, and 5,483 reside on Porto Santo.

Madeira Island is divided in 10 municipalities in which about 43% of Madeira Island's population is concentrated in the Funchal municipality, comprising 111,892 inhabitants. The population density of Madeira Island is 356 inhabitants/km2, but it is 1,472 inhabitants/km2 for Funchal, which shows the high population concentration in the island's capital. The population density of Porto Santo, with a sole municipality, is 129 inhabitants/km2.

In 2011, 94% of the total resident population of Madeira Island is concentrated along its southern coast. In Porto Santo, due to its peak tourism in summer, the non-resident population may increase three-fold.

	1981	1991	2001	2007	2009	2011
Calheta (South coast)	12 954	13 005	11 946	11 939	11 864	11 521
Câmara de Lobos (South coast)	31 035	31 476	34 614	35 969	36 279	35 666
Funchal (South coast)	112 746	115 403	103 961	99 214	97 793	111 892
Machico (South coast)	22 126	22 016	21 747	21 115	20 923	21 828
Ponta do Sol (South coast)	9 149	8 756	8 125	8 352	8 397	8 862
Porto Moniz (North coast)	3 963	3 432	2 927	2 679	2 616	2 711
Ribeira Brava (South coast)	13 480	13 170	12 494	12 599	12 583	13 375
Santa Cruz (South coast)	23 261	23 465	29 721	35 985	38 269	43 005
Santana (North coast)	11 253	10 302	8 804	8 326	8 198	7 719
São Vicente (North coast)	8 501	7 695	6 198	6 121	6 099	5 723
TOTAL	**248 468**	**248 720**	**240 537**	**240 299**	**243 021**	**262 302**

Table 5. Resident Population by Municipality in Madeira Island[19]

	1981	1991	2001	2011
Calheta (South coast)	4 376	4 706	4 474	5 483

Table 6. Resident Population in Porto Santo Island [20]

[19] INE (Statistics of Portugal) – 1991 Census, 2001 Census, 2011 Census (provisional results), DREM – Demographic Statistics of the Autonomous Region of Madeira – 2007 and 2009

[20] INE (Statistics of Portugal) – 1991 Census, 2001 Census, 2011 Census (provisional results).

The resident population of the Madeira Archipelago has not always had a constant growth. In 2001, this indicator falls in relation to previous decades, but in 2011, returns practically to values not seen since the 1960s, due to the return of immigrants and to the rectification of the 2001 Census results.

4.4. Socio Economic context

Considering the official figures published from the Regional Accounts, the following table shows the progress of the Gross Value Added (GVA) of the Autonomous Region of Madeira, whic is not broken down between Madeira Island or Porto Santo.

The largest contribution to the GVA in the Autonomous Region of Madeira comes from tertiary sector activities (83% from GVA and 69% from employment in 2009), with a strong presence from activities connected to tourism and commerce.

Economic Activity	2000 [€m]	2005 [€m]	2008p [€m]	2009p [€m]	
Agriculture, livestock-breeding, hunting, forestry and fishing	59	75	79	81	2%
Extractive industry; manufacturing; production and distribution of electricity, gas, steam and air-conditioning; water supply, sewerage, waste management and remediation activities	207	270	322	320	7%
Construction	314	387	395	369	8%
Wholesale and retail trade; repair of motor vehicles and motorcycles; transport and storage; accommodation and food service activities	933	1 214	1 371	1 342	30%
Information and communication	55	83	98	96	2%
Financial and insurance activities	202	160	273	230	5%
Real estate activities	183	248	319	320	7%
Consulting, scientific and technical activities; administrative and support services	361	419	682	626	14%
Public administration and defence; compulsory social security; education, human health and social work activities	541	893	956	1 024	23%
Arts and entertainment activities; repair of household goods and other services	67	81	96	130	3%
TOTAL	**2 924**	**3 832**	**4 590**	**4 539**	**100%**

Table 7. Distribution of GVA per economic activity in Autonomous Region of Madeira[21]

The– "Employment Statistics of the Autonomous Region of Madeira – 1st Quarter of 2011" conducted by the Regional Directorate of Statistics, indicate an estimate of the Region's active population of 131,551 individuals for this quarter which represents 53.1% of the total population and confirms positive growth of the active population

[21] INE (Statistics of Portugal), Regional Accounts, base year 2006, 1995 – 2009p.

in relation to the 2001 Census.

In Madeira Island, regarding the distribution of the population by activity sectors, the primary sector recorded a substantial decrease since 1991, against the increase of the secondary sector and especially of the tertiary sector, which results from the dynamics of development in the island in recent years, especially in the tourism and services sector and from the gradual abandonment of agricultural activity.

4.5. Energy demand

Madeira Island energy demand

The final energy demand, per energy carrier and per sector, in Madeira Island, in 2009, is presented in the following table and figures.

Energy carriers		Residential [MWh]	Primary sector [MWh]	Secondary sector [MWh]	Tertiary sector [MWh]	Transports [MWh]	TOTAL [MWh]
Centralized energy services	Electricity	259,265	11,108	79,972	492,557	22	842,924
	Heat			11,192			11,192
	Subtotal	259,265	11,108	91,164	492,557	22	854,116
Fossil fuels	Fuel oil			23,121	12,097		35,218
	Diesel		17,488	10,335	9,832	1,151,345	1,189,000
	Gasoline				2,820	503,455	506,275
	LPG	202,603	3,438	8,232	125,918		340,191
	Subtotal	202,603	20,926	41,688	150,667	1,654,800	2,070,684
Renewable energy sources	Solar	24,683			2,303		26,986
	Biomass	55,191		5,058	1,686		61,935
	Subtotal	79,874		5,058	3,989		88,921
TOTAL		**541,742**	**32,034**	**137,910**	**647,213**	**1,654,822**	**3,013,722**

Table 8. Final energy demand in 2009 in Madeira Island

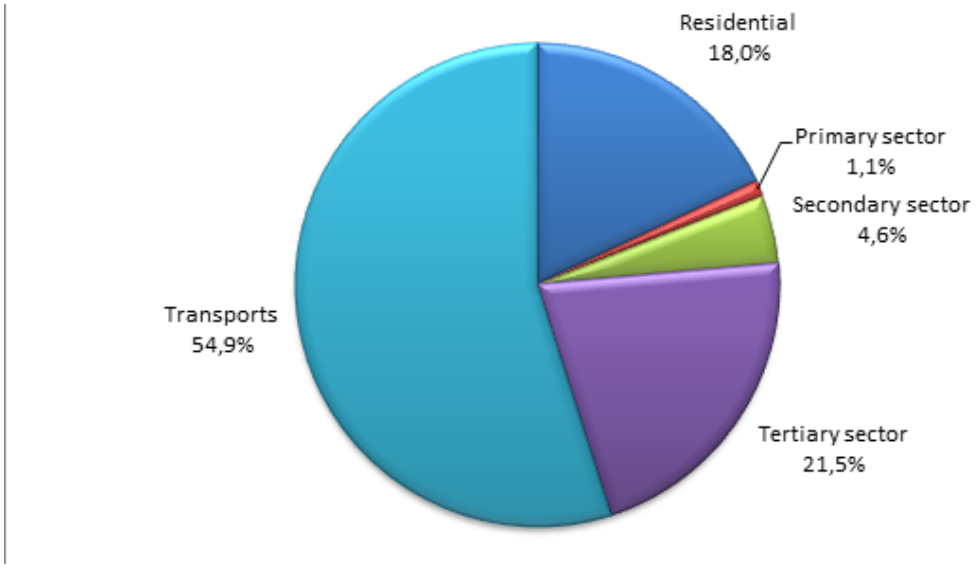

Figure 6. Final energy demand per sector in 2009 in Madeira Island

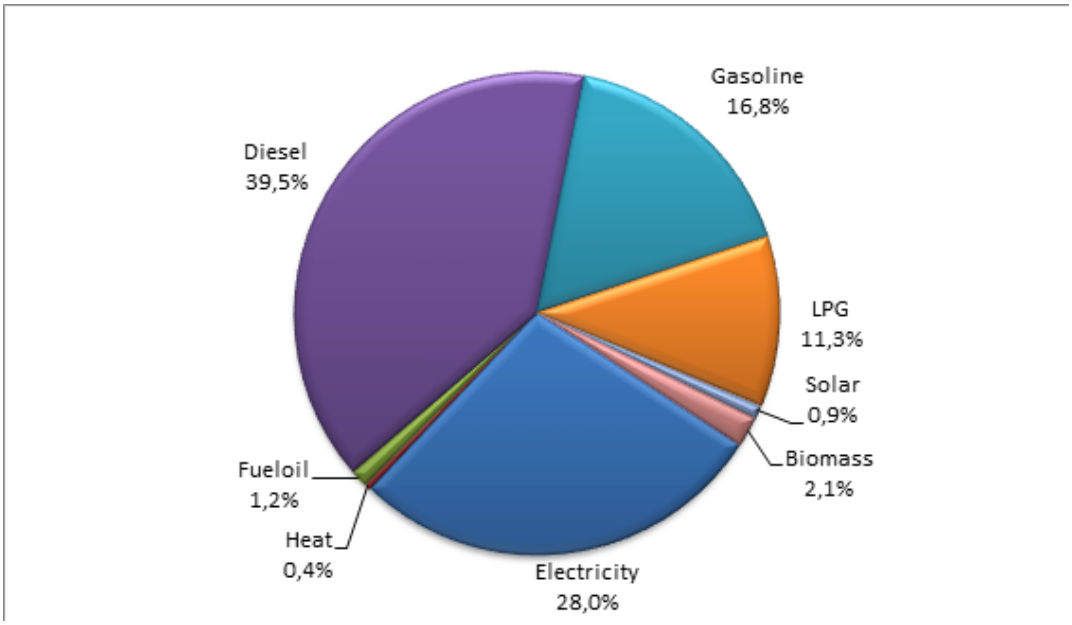

Figure 7. Final energy demand per energy carrier in 2009 in Madeira Island

From the analysis of the final energy demand, it's worthy to note the significant weight of the land transport sector in Madeira Island, with a 54,9% contribution.

Primary energy demand in Madeira Island

The primary energy demand is determined, through an energy balance, by the final energy demand and by the use of energy resources for energy conversion into heat and electricity.

Energy carriers		2005 [MWh]	2009 [MWh]
Fossil fuels	Fueloil	1 509 747	1 753 347
	Diesel	1 279 798	1 198 727
	Gasoline	561 338	506 275
	LPG	370 105	340 191
	Subtotal	3 720 988	3 798 540
Renewable energy sources	Hydro	86 550	139 639
	Wind	15 360	36 905
	Solar	20 360	27 275
	Biomass	96 592	61 935
	Urban waste	34 300	36 512
	Subtotal	253 162	302 266
TOTAL		**3 974 150**	**4 100 806**

Table 9. Primary energy demand in 2005 and 2009 in Madeira Island

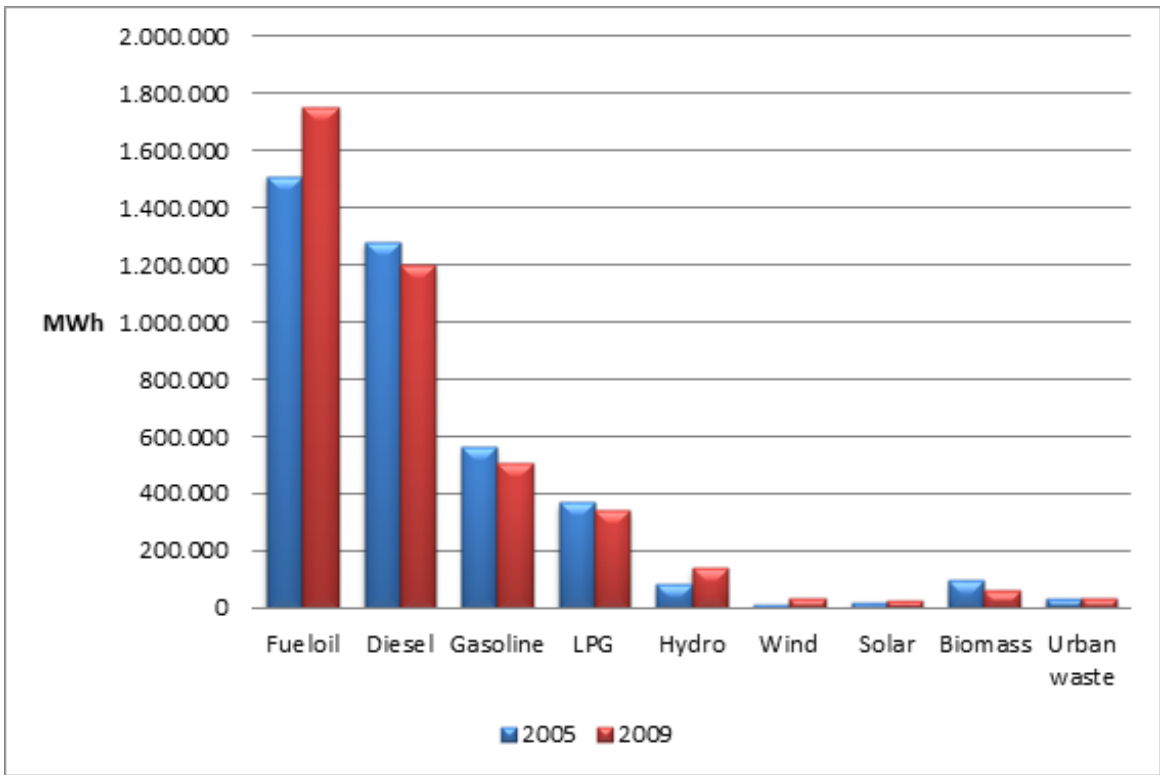

Figure 8. Primary energy demand in 2005 and 2009 in Madeira Island

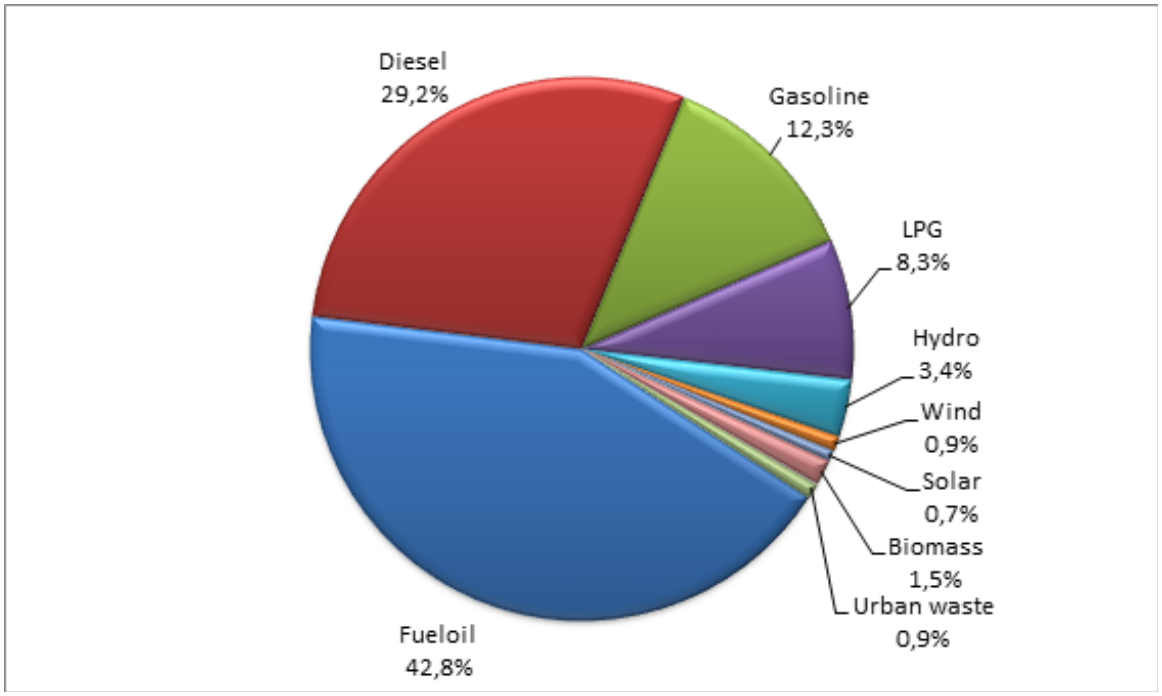

Figure 9. Primary energy demand in 2009 in Madeira Island

The share of renewable energy resources represented 6,4% of the total primary energy demand in 2005 and 7,4% in 2009.

Porto Santo Island energy demand

The final energy demand, per energy carrier and per sector, in Porto Santo Island, in 2009, is presented in the following table and figures.

Energy carriers		Residential [MWh]	Primary sector [MWh]	Secondary sector [MWh]	Tertiary sector [MWh]	Transports [MWh]	TOTAL [MWh]
Centralized energy services	Electricity	7 439	137	8 097	19 279		34 953
Fossil fuels	Diesel		103		2 173	20 123	22 399
	Gasoline					11 688	11 688
	LPG	4 275			652		4 927
	Subtotal	4 275	103		2 825	31 811	39 014
Renewable energy sources	Solar	102			14		116
	Biomass	111					111
	Subtotal	213			14		227
TOTAL		**11 927**	**240**	**8 097**	**22 118**	**31 811**	**74 194**

Table 10. Final energy demand in 2009 in Porto Santo

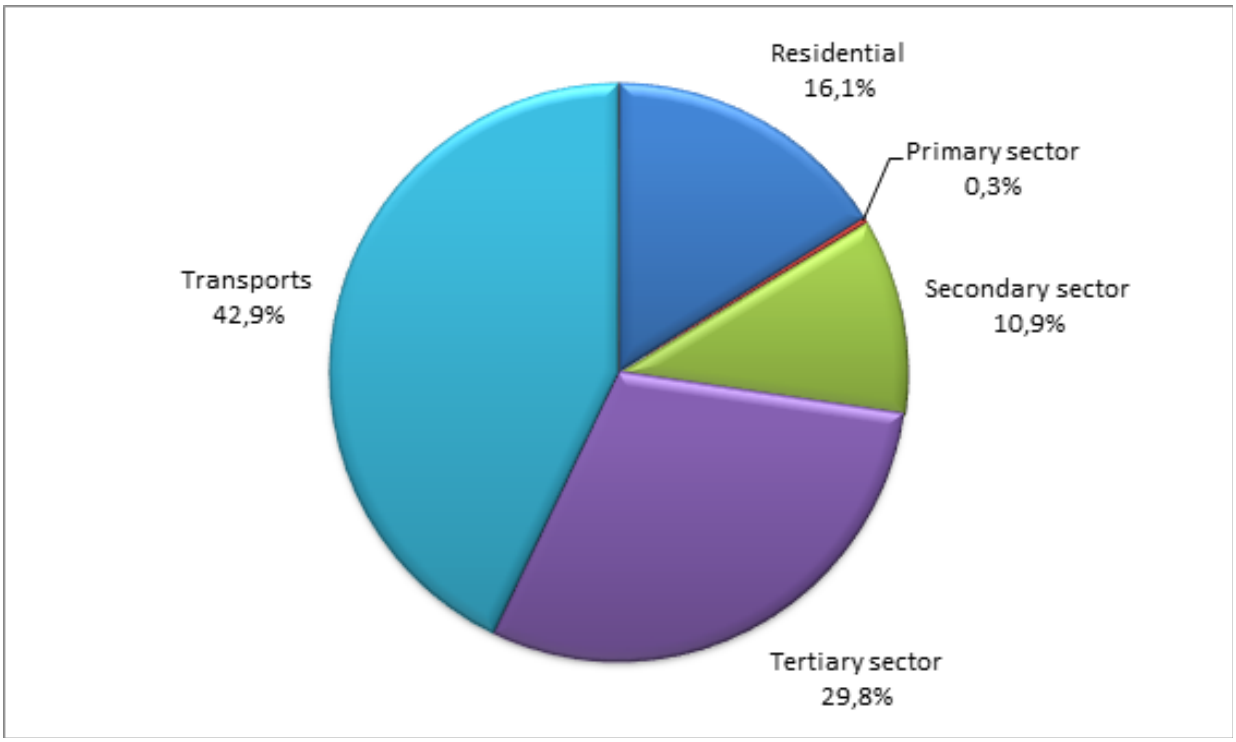

Figure 10. Final energy demand per sector in 2009 (Porto Santo Island)

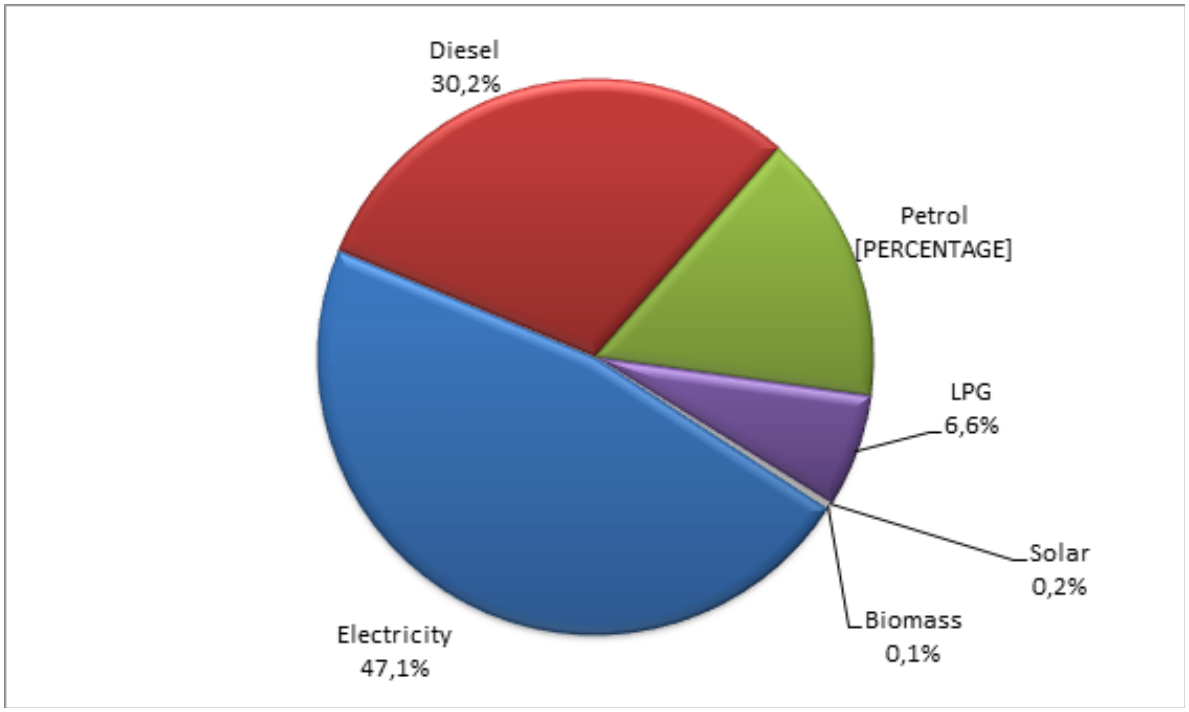

Figure 11. Final energy demand per energy carrier in 2009 (Porto Santo Island)

From the analysis of the final energy demand, it's worthy to note the significant weight of the land transport sector of Porto Santo Island, with a 42,9% contribution.

Primary Energy Demand in Porto Santo Island

The primary energy demand is determined, through an energy balance, by the final energy demand and by the use of energy resources for energy conversion into electricity.

Energy carriers		2005 [MWh]	2009 [MWh]
Fossil fuels	Fueloil	89 800	93 127
	Diesel	30 272	28 354
	Gasoline	13 022	11 688
	LPG	5 360	4 927
	Subtotal	138 454	138 096
Renewable energy sources	Wind	1 900	1 821
	Solar	82	122
	Biomass	173	111
	Subtotal	2 155	2 054
TOTAL		**140 609**	**140 150**

Table 11. Primary energy demand in 2005 and 2009 (Porto Santo Island)

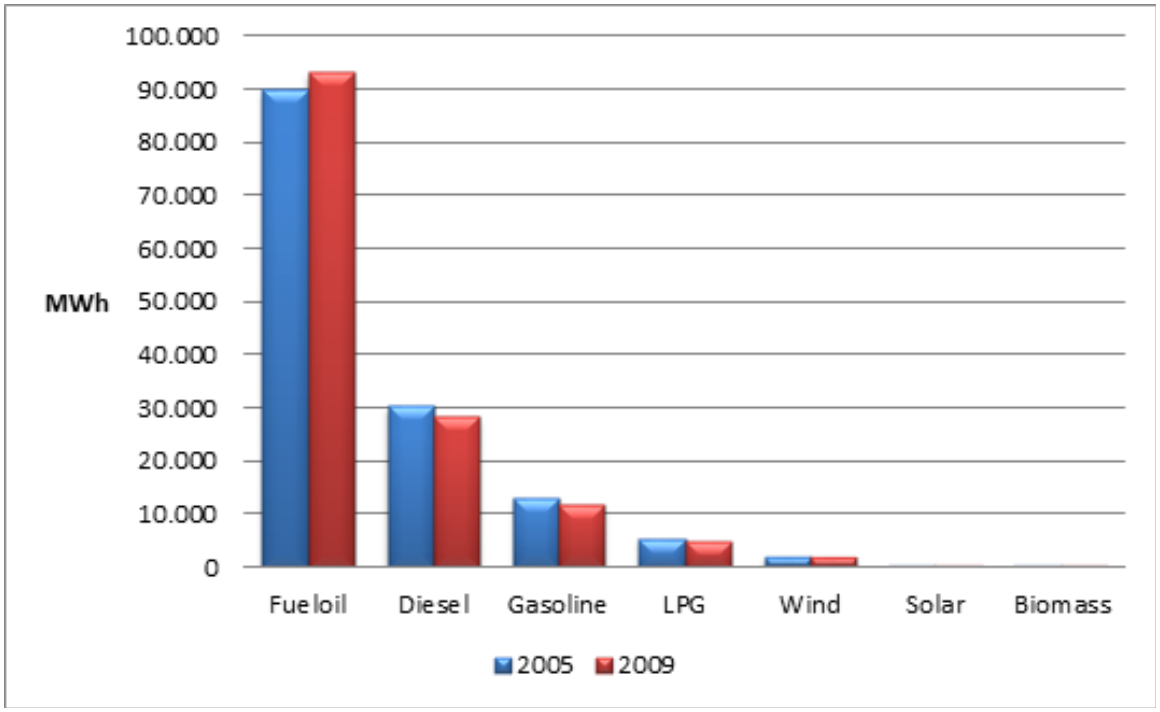

Figure 12. Primary energy demand in 2005 and 2009 (Porto Santo Island)

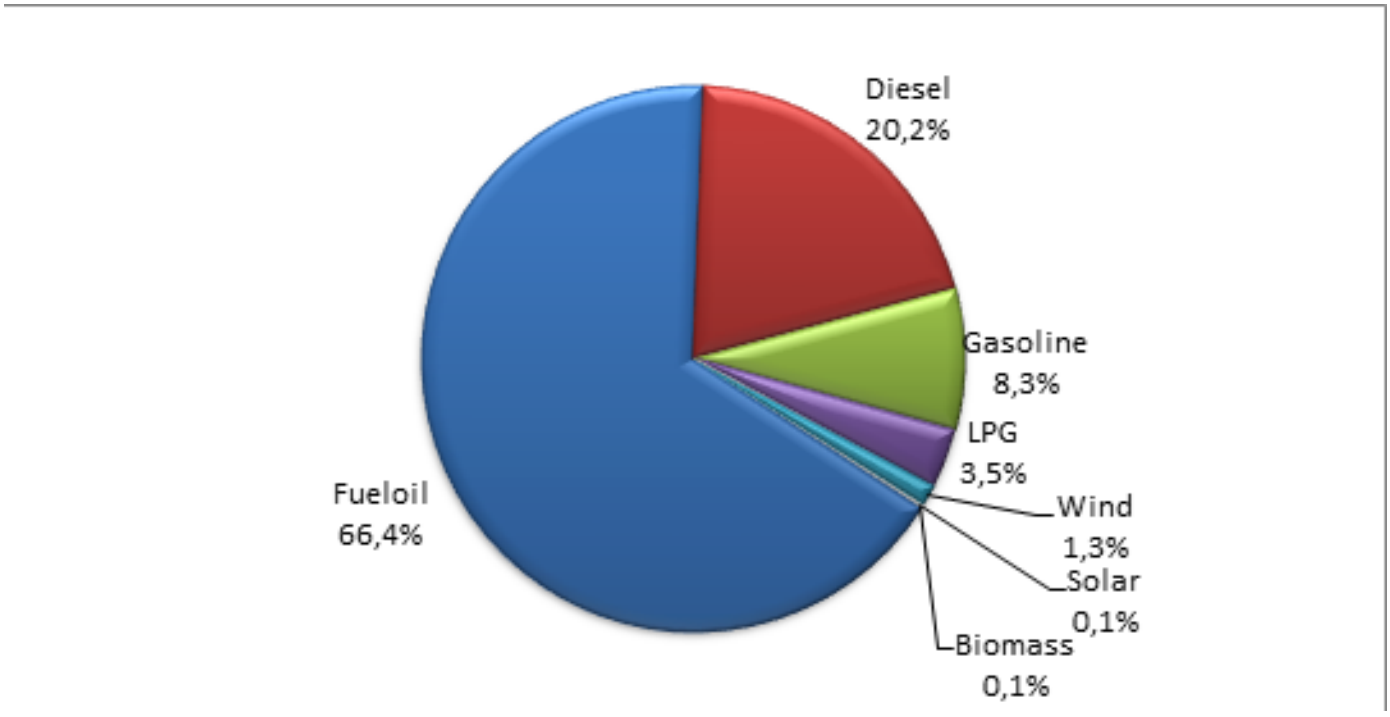

Figure 13. Primary energy demand in 2009 (Porto Santo Island)

The share of renewable energy resources represented 1,5% of the total primary energy demand in 2005 and in 2009.

4.6. Transport energy Use Madeira

Existing Transport

- #### *Private transport of passengers and goods*

  In 2017, the total of private vehicles for passengers and goods on Madeira Island and Porto Santo Island was 148,443, diesel, petrol and electric vehicles. The consumption related is approximately 714,416 MWh, which represents a consumption of 69,578,762 litres of diesel and 37,235,426 litres of petrol. At this moment there is approximately 250 electric vehicles on the islands.

- #### *Public transport*

  In the Autonomous Region of Madeira, there are six public operators: five on Madeira Island and one on Porto Santo Island. From the six, only one is considered urban public operator.

  The fleets of all public operators are all diesel buses and the consumption of diesel was 12,489,530 litres in 2017.

- #### *Ferry*

  There is a ferry that make a daily trip between Madeira Island and Porto Santo Island (leaving Madeira Island in the morning and returning at the end of the day). The company "Porto Santo Line" owns a single RO-RO passengers vessel, with the capacity for 1,150 passengers and 145 vehicles. The ship runs on diesel with engines of 8,000 kW power and speed of 21 knots at full power. There are no published figures available for energy consumption.

- #### *Air Transport*

  In the Autonomous Region of Madeira, there are two international airports, one on Madeira Island and one on Porto Santo Island. According to Direção Regional de Estatística da Madeira (Regional Directorate of Statistics of Madeira), in 2016 the number passenger traffic in both airports was 2,954,269 for a total of flights 27,338, which represented an increase of 12% compared to the previous year.

- #### *Maritime transport*

  Currently there is no maritime passenger transport between the Autonomous Region of Madeira and the mainland of Portugal. In relation to commercial vessels, there were registered 2,442 movements of vessels in the regional ports.

4.7. 1st stage assessment of H2 Opportunities in the transport Sector of Madeira and Porto Santo

Hydrogen has significant potential for use in the Autonomous Region of Madeira, as opposed to obtaining fossil energy from abroad to satisfy the energy needs of the islands, including transport use. The opportunity available for the hydrogen fuel in the transport sector is essential to increase energy independence and to contribute to the reduction of CO2 emissions with the use of a clean energy vector.

With the great potential of renewable energy production in the Autonomous Region of Madeira, through photovoltaic (PV) and wind electricity generation, the production of hydrogen associated with these energy sources, as principal in SEAFUL project, is viable and with great potential for use in transport.

As a result of the geographical character of the island significant opportunities exist for the introduction of hydrogen be used in particular in fleets of commercial vehicles, public passenger transport as well as the ferry, as a good practice for the introduction to general population.

With a considerable number of commercial fleets operating on the island, such as the postal service, the municipalities and some local producers and manufacturers, there is the opportunity to associate some of the fleet as a demonstration of the use of hydrogen and reduce the dependency of fossil fuels, which have a very high vulnerability of price variation, in particular as all fuel uis imported from the Portugese mainland. The same principle can be applied to the public transportation sector, which presents an opportunity to the public operators to reduce their consumptions and emissions.

It must be noted that characteristics of FCVs such as shorter refuelling times, as well as the demanding terrain on the islands are significant. Although there is less dannger in Madeira of range anxiety affecting the uptake of EVs, it is present in a way that is not true of Árainn above.

For the ferry working between the two islands, the change from diesel to hydrogen could represent a significant opportunity to reduce the emissions and become a clean and ecological transportation, working as an example to be replicated in other regions. Furthermore, it is possible to have a marine accessible hydrogen production station equipped with renewable sources in Madeira Island or in Porto Santo Island. The distances covered in supply chain of fossil fuels improves H2 viability. It must be noted however that the issues of ocean going H2 powered transport's novelty are as true in Madeira and Porto Santo as the are in Arainn. Thus marine transport could be seen as a medium to long term opportunity.

We predict that with the demonstration of the use of hydrogen for commercial purpose such as commercial fleets, the use of hydrogen for the private transportation will become more accepted by the general population. Any residual safety concerns will be allayed, and there will be a purpose built infrastructure which can be made acessible to the general public. We propose that Madeira offers a strong opportunity for future FCV distribution.

5. Tenerife

5.1. Geographical overview

The Canary Islands are an archipelago of Spain located in the Atlantic Ocean, south-west of mainland Spain and north-west of Africa. The nearest territories are Morocco, about 100 kilometres west at the closest point, and Madeira Archipelago, lying approximately 500 kilometres north. The minimum distance to mainland Spain is approximately 1,000 kilometres.

Figure 14. Location of Canary Archipelago[22]

The archipelago has an area of 7,493 km2 and includes seven main islands (from largest to smallest in area: Tenerife, Fuerteventura, Gran Canaria, Lanzarote, La Palma, La Gomera and El Hierro) and much smaller islands and islets (La Graciosa, Alegranza, Isla de Lobos, Montaña Clara, Roque del Este and Roque del Oeste). Like its neighbours the Azores, Cape Verde and Madeira, also including the Savage Islands, the Canary Islands belong to Macaronesia, the modern collective name for these groups of islands and home to various endemic species of flora whose origins lie in the Tertiary Period.

[22] Wikimedia Commons, [En línea]. [Último acceso: December 2018].

The islands have a subtropical climate, with long hot summers and moderately warm winters. The precipitation levels vary depending on location and elevation. Green areas as well as desert exist on the archipelago.

Tenerife is the largest of the seven Canary Islands and the Macaronesia region, with an area of 2,034 km2. It is situated at the geographical heart of the archipelago, 200 miles off the west coast of Africa at 28°16'7'' latitude north and 16°36'20'' longitude west. The shape of the island is triangular and has a road perimeter of about 358 kilometres.

Like all the islands that form this archipelago, Tenerife is of volcanic origin and is made up of complex network of cones and calderas. The island is dominated by Mount Teide, the volcano that stands at 3,718 meters, being the highest peak of the Spanish and also a World Heritage Site. The volcano is visible from most parts of the island today, and the crater is 17 kilometres long at some points.

The landscape is rugged, and the rocky volcanic coastline is dotted with cliffs, especially at the far north-western (Teno Massif) and north-eastern (Anaga Massif or Point) ends of the island. The south-eastern coastline is lower and gentler scattered with beaches and coves of volcanic origin, with their characteristic fine black sand.

Thus there are areas in Tenerife which can be considered very mountainous. This will feature in the study as it provides an advantage to FCVs over EVs in certain conditions.

5.2. Socio Politico Context

The Canary Islands are one of the 17 Autonomous Communities of Spain, endowed with an Administrative-Political Statute and self-ruling governmental bodies. It comprises the provinces of Las Palmas (includes Gran Canaria, Lanzarote and Fuerteventura) and Santa Cruz de Tenerife (embraces Tenerife, La Palma, La Gomera and El Hierro). Canary islands political organization does not involve a provincial government body, but instead each of the major islands is ruled by an island council called the Cabildo Insular. The capital of the Autonomous Community is shared by the cities of Santa Cruz de Tenerife and Las Palmas de Gran Canaria. The Canary Islands are also one of the eight regions with special consideration of historical nationality recognized as such by the Spanish Government.

The Canaries are one of the nine Outermost Regions (OMR) of the European Union, being the most populated and economically strongest territory of all them. They have a special tax system, being outside the EU VAT Area.

Figure 15. Map of Canary Islands [1]

The island of Tenerife is divided administratively into 31 municipalities, which can be seen in Figure 3. The largest municipality with an area of 207.31 kilometres is La Orotava, which covers much of the Teide National Park.

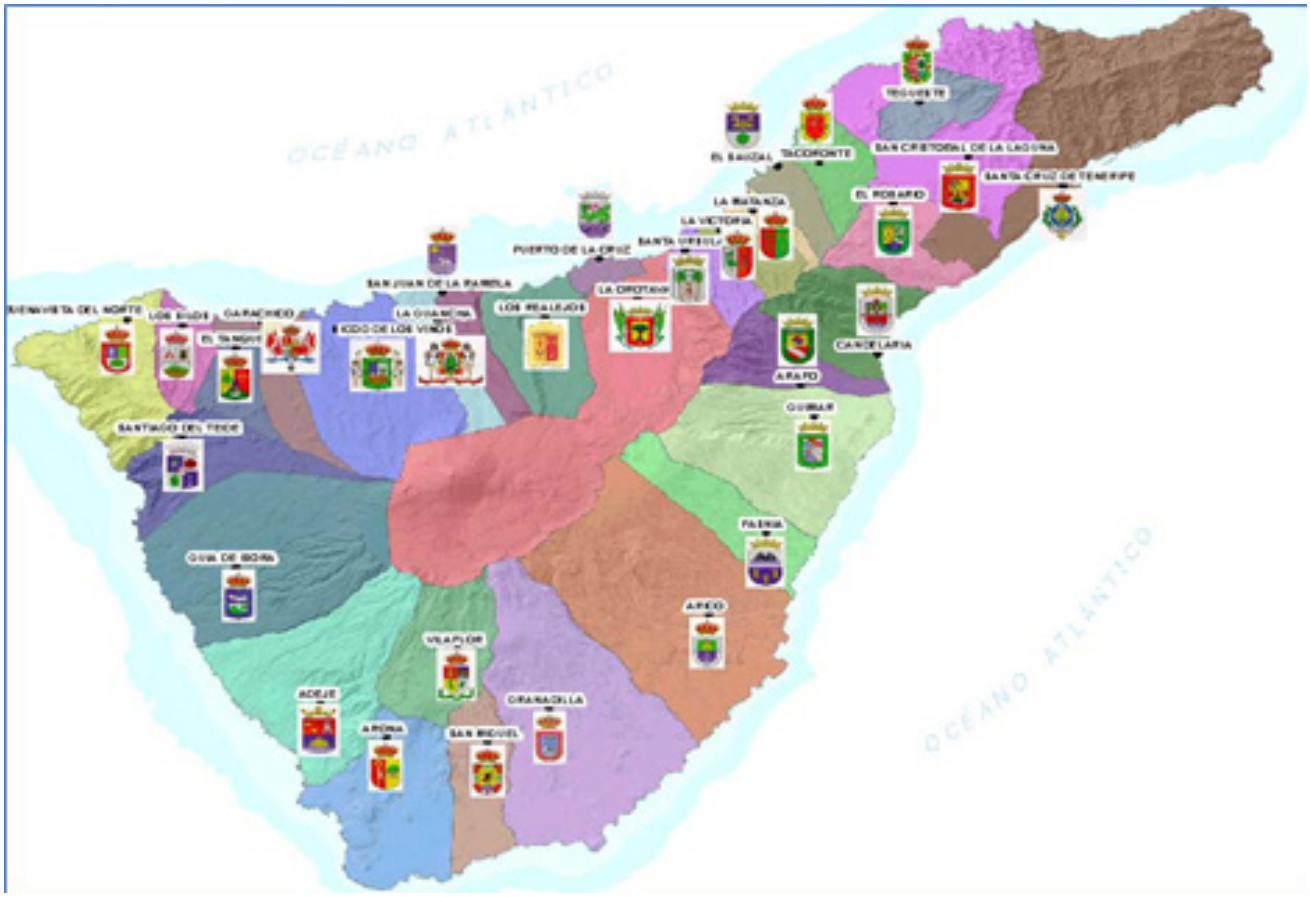

Figure 16. Municipalities on Tenerife [23]

5.3. Demographics

According to data from the National Statistics Institute (INE), the Canary Islands is the eighth most populated Autonomous Community of Spain, with a resident population of 2,108,121 inhabitants year-end 2017, as can be noted in Table A.1 in the Annex. Just as in Spain, the Canary Islands population decreased slightly between 2010 and 2017. This percentage represents the 4.53% of the Spanish total population. The population density of the Canary Islands is 281 inhabitants per km2, much higher than the population density of Spain as a whole (92 inhabitants per km2) and most of the rest of the Autonomous Communities of the country.

Besides being the largest of the seven Canary Islands, Tenerife is also the most populated Island, not only of the Canary Islands but also of Spain. As can be seen in Table 1, its population was 894,636 inhabitants year-end 2017, comprising more than 42.4% of the total population of the Canary Islands. Gran Canaria population represents 40.0%, Lanzarote 7.0%, Fuerteventura 5.2%, La Palma 3.9%, La Gomera 1.0% and El Hierro 0.5%. The number of inhabitants in Tenerife has decreased by 1.3 % between the years 2010 and 2017, just like in the rest of the islands in the archipelago, except Lanzarote and Fuerteventura.

[23] Atlas digital de Tenerife, [En línea]. Available: http://web.archive.org/web/20100917020543/http://atlastenerife.es/TeIDE2/FotoSubCategoria.do?cat=5&sub=33&numero=1. [Último acceso: December 2018].

		2010	2017	Surface (km²)	Change 2010-2017
CANARY ISLANDS	Population	2,118,519	2,108,121	7,493	-0.5%
	Population density	283	281		
TENERIFE	Population	906,854	894,636	2,034	-1.3%
	Population density	446	440		
GRAN CANARIA	Population	845,676	843,158	1,560	-0.3%
	Population density	542	540		
LANZAROTE	Population	141,437	147,023	846	3.9%
	Population density	167	174		
FUERTEVENTURA	Population	103,492	110,299	1,660	6.6%
	Population density	62	66		
LA PALMA	Population	87,324	81,350	708	-6.8%
	Population density	123	115		
LA GOMERA	Population	22,776	20,976	370	-7.9%
	Population density	62	57		
EL HIERRO	Population	10,960	10,679	269	-2.6%
	Population density	41	40		

Table 11. Canary Islands population, population density (inhabitant/km2) and surface in the Canary Islands by islands in 2017 and 2010.[24]

In the year 2017 its population density was 440 inhabitants per km2, second only to the other capital island of Gran Canaria (540 inhabitants per km2). As shown in the table, this value is much higher than the average of the Canary Islands (281 inhabitants per km2).

5.4. Socio-economic context

In 2017, the Canary Islands Gross domestic product (GDP) figure was €44,206m, ranking 8th economy in Spain[25]. Tenerife is the island with the highest GDP in the Canary Islands. Its economy is highly specialized in the tertiary sector, mostly tourism, the economic driver in the island, accounting for 78.98% of its annual GDP. The second most important sector is the construction which contributes 11.29%, followed by the industrial sector which shares in 5.80% and the energy sector with 2.85% of the total production. The primary sector only represents 1.98%[26] .

[24] ISTAC, [En línea]. Available: http://www.gobiernodecanarias.org/istac/temas_estadisticos/.

[25] Expansion, [En línea]. Available: https://datosmacro.expansion.com/pib/espana-comunidades-autonomas/canarias. [Último acceso: December 2018].

[26] Tenerife Guía Turistica, [En línea]. Available: http://www.tenerifeguiaturistica.com/datos/economia.php. [Último acceso: December 2018].

5.5. Energy demand

The two principal energy indicator, primary energy demand and final energy demand in the Canary Islands between the years 2011 and 2016, are presented in Table 2. The primary energy demand has been calculated as the sum of domestic production and stock variation, deducting net exports (exports-imports) and supplies to international maritime navigation (bunkers).

	PRIMARY ENERGY DEMAND (Toe)	Domestic production (Toe)	Net Exports (Toe)	Bunkers (Toe)	Stock variation (Toe)	FINAL ENERGY DEMAND (Toe)
2011	4,873,515	57,914	-7,235,924	2,538,437	118,114	3,410,486
2012	4,831,116	60,785	-6,982,391	2,416,715	204,654	3,349,622
2013	4,831,059	63,959	-7,070,635	2,354,418	50,882	3,341,420
2014	4,562,073	66,397	-6,395,707	1,977,770	77,740	3,366,465
2015	4,509,232	67,372	-7,080,974	2,372,032	-267,082	3,303,792
2016	4,728,936	68,189	-7,015,082	2,452,172	97,837	3,504,302

Table 12. Primary and final energy demand between 2011 and 2016 in Canary Islands. Source[27]

It is observed that the domestic production represents a very small fraction of the primary energy, being this figure the joint contribution of all renewable energies in the Canary Islands: wind, photovoltaic, solar thermal, hydroelectric, mini-hydraulic and biogas from waste. Its percentage distribution in 2016 is showed in Figure 4.

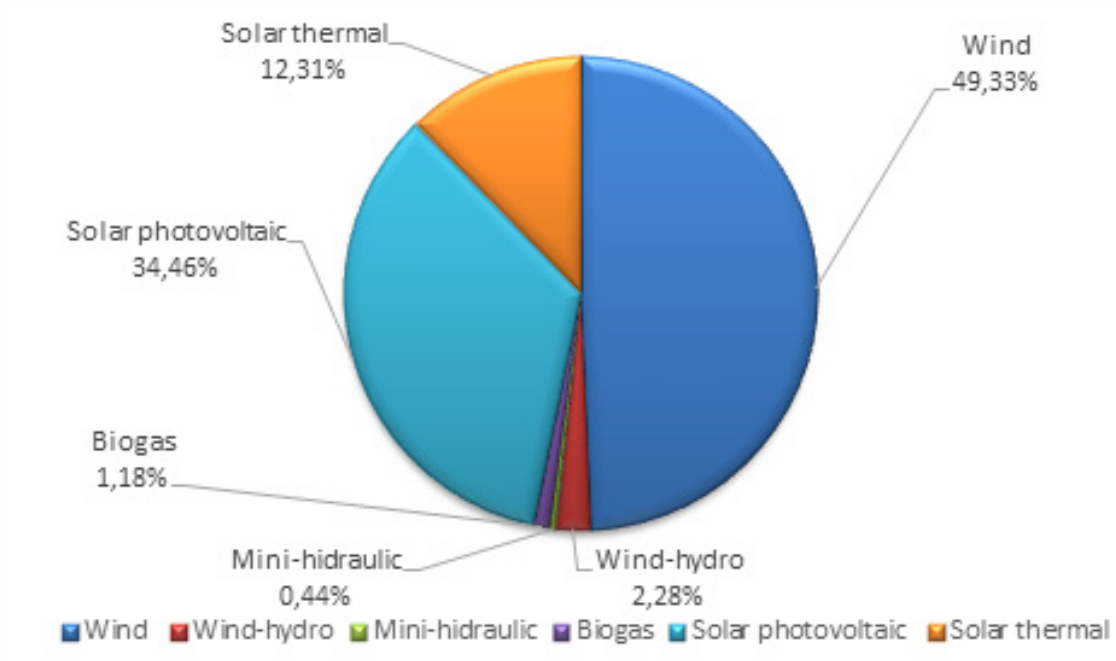

Figure 17. Percentage distribution of domestic production in [2016] (Canary Islands). Source: Own elaboration[28]

[27] Government of the Canary islands, «Anuario Energético de Canarias 2016,» December 2017. [En línea]. Available: http://www.gobiernodecanarias.org/ceic/energia/doc/Publicaciones/AnuarioEnergeticoCanarias/ANUARIO-ENERGETICO-CANARIAS-2016.pdf. [Último acceso: December 2018].

[28] ibid

The final energy demand, per energy carrier and per sector in the Canary Islands in 2016 is presented in the 6.5b and Figure 6.5c.

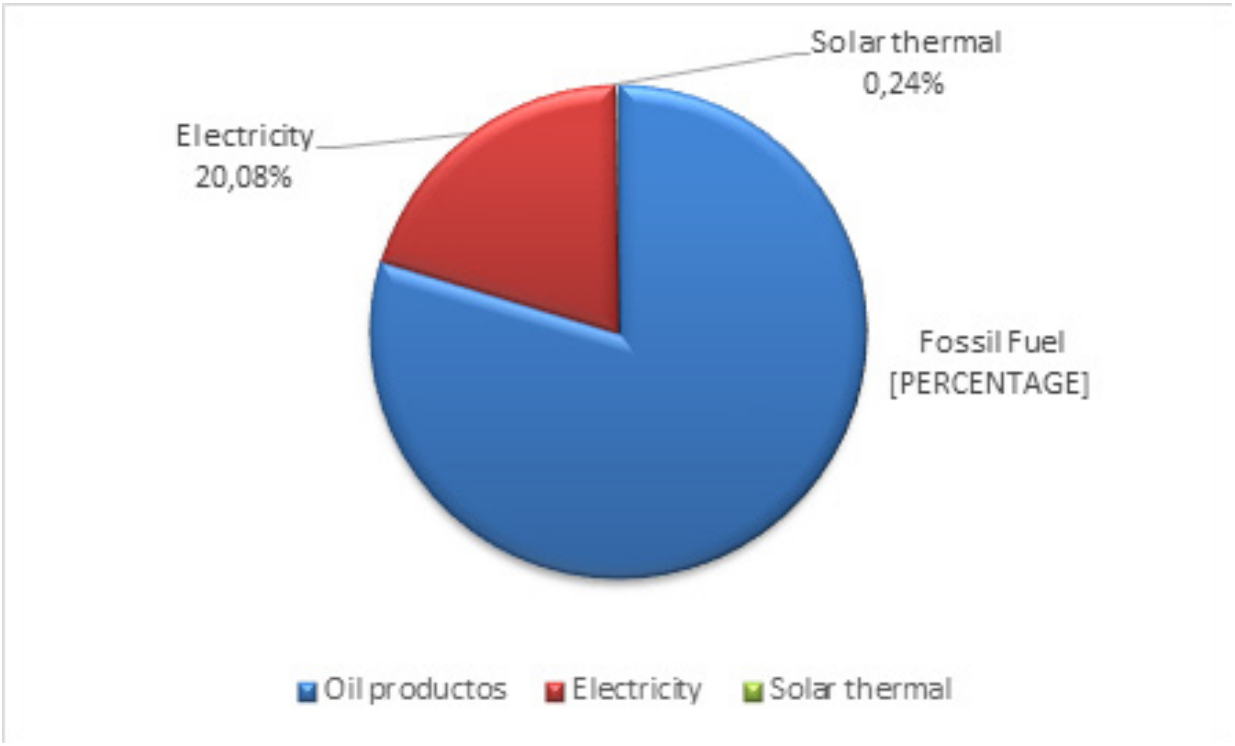

Figure 18. Percentage distribution of final energy demand by type of energy carrier in 2016 (Canary Islands).[29]

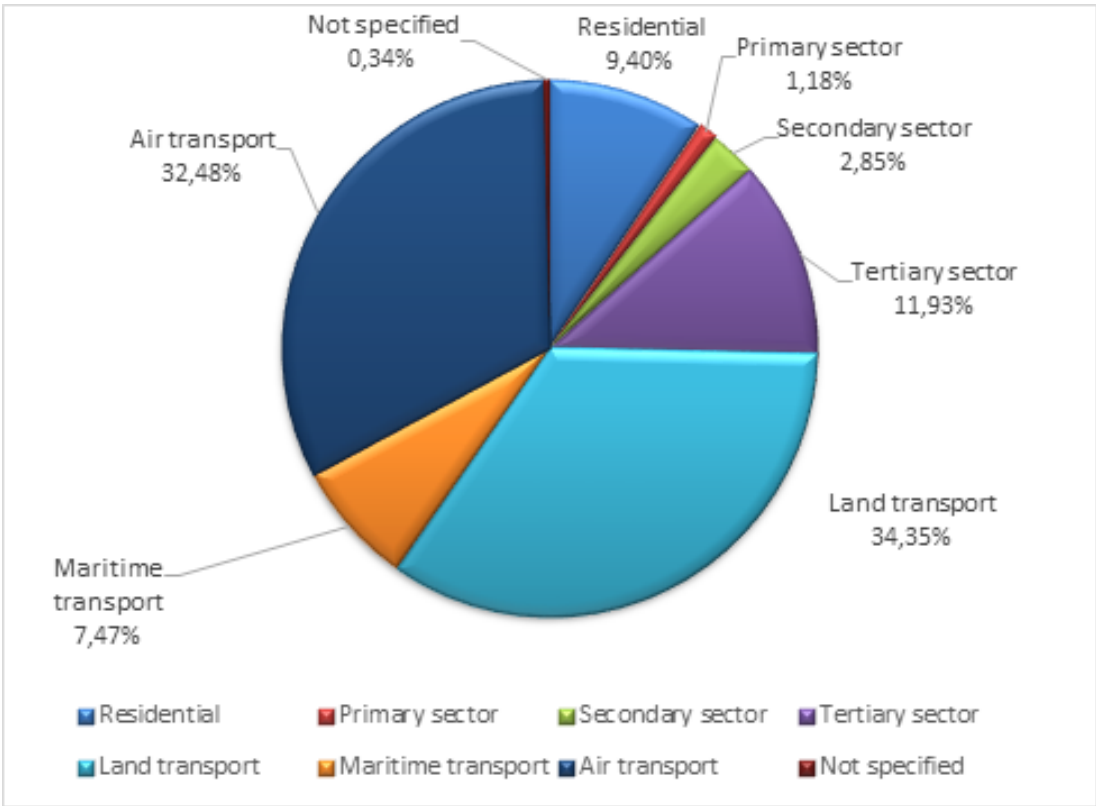

Figure 19. Percentage distribution of final energy demand by sector in 2016 (Canary Islands).[30]

[29] ibid

[30] ibid

5.6. Vehicles fleet

As pointed out in Section 6.3, the population in Spain decreased in the year 2017 in relation to 2010, in line with the whole of the Canary Islands and each of its islands, except Lanzarote and Fuerteventura. However, as can be seen in Table 3, the number of vehicles in the same period has increased both in Spain and in each of the Canary Islands.

		2010	2017	Change 2010-2017
SPAIN	Vehicles vehicles per inhabitant	31,086,035 0.66	34,165,913 0.73	9.9%
CANARY ISLANDS	Vehicles Vehicles per inhabitant	1,479,834 0.70	1,642,975 0.78	11.0%
TENERIFE	Vehicles Vehicles per inhabitant	649,978 0.72	710,869 0.79	9.4%
GRAN CANARIA	Vehicles Vehicles per inhabitant	563,927 0.67	628,259 0.75	11.4%
LANZAROTE	Vehicles Vehicles per inhabitant	108,001 0.76	125,137 0.85	15.9%
FUERTEVENTURA	Vehicles Vehicles per inhabitant	68,976 0.67	85,485 0.78	23.9%
LA PALMA	Vehicles Vehicles per inhabitant	66,798 0.76	69,652 0.86	4.3%
LA GOMERA	Vehicles Vehicles per inhabitant	14,128 0.62	14,984 0.71	6.1%
EL HIERRO	Vehicles Vehicles per inhabitant	7,886 0.72	8,451 0.79	7.2%

Table 13. Number of vehicles and vehicles per inhabitant in the Canary Islands by islands between 2010 and 2017. Source: Own elaboration from [31]

The number of vehicles on the island of Tenerife in 2017 reached 710,869 units, increasing by 9.4% since 2010. This amount represents an overall of 2% of the vehicles in Spain and 43% of the vehicles in the Canary Islands.

Tenerife is the island of the Canary Islands with the greatest number of vehicles, which is quite natural considering that it is also the island with the largest population. It is the fourth island having the largest increase in number of vehicles between 2010 and 2017, with 9.4%, after Fuerteventura (23.9%), Lanzarote (15.9%) and Gran Canaria (11.4%).

Ratio of vehicles per inhabitant in Tenerife was 0.79 in 2017, exceeding both the Spanish and the Canarian averages, of 0.73 and 0.78 respectively in that same year, but being overcome by La Palma and Lanzarote and equalled by El Hierro.

Regarding the vehicles fleet features, a classification based on type of vehicle and fuel in September 2018 is shown in Table 6.6.

[31] Directorate-General of Traffic, [Online]. Available: www.dgt.es. [Accessed November 2018].

	Fuel/ Type of vehicle	Diesel	Petrol	LPG	Electric	H2	Other fuels*	TOTAL
SPAIN	**TOTAL**	**18,689,449**	**16,379,796**	**29,011**	**55,750**	**28**	**500,473**	**35,654,507**
	Lorries under 3,500 kg	2,166,218	79,651	723	1,53	-	696	**2,248,819**
	Lorries over 3,500 kg	336,118	3,379	33	87	-	1,897	**341,514**
	Buses	62,013	239	96	241	7	2,489	**65,085**
	Vans	1,982,341	407,997	2,821	3,465	-	1,034	**2,397,658**
	Passanger cars	13,553,365	10,466,874	25,074	21,143	19	8,601	
	Motorcycles	63,678	5,297,864	65	19,918	-	515	**5,382,040**
	Industrial tractors	224,737	-	-	-	-	-	**224,737**
	Trailers	-	-	-	-	-	196,678	**196,678**
	Semi- trailers	-	-	-	-	-	275,628	**275,628**
	Others	300,979	123,792	199	9,365	2	12,935	**447,272**
CANARY ISLANDS	**TOTAL**	565,900	1,159,142	1,279	1,668	-	14,182	**1,742,171**
	Lorries under 3,500 kg	183,545	24,880	7	41	-	5	**208,478**
	Lorries over 3,500 kg	17,894	211	5	-	-	2	**18,112**
	Buses	5,878	50	2	4	-	-	**5,934**
	Vans	107,179	34,527	72	92	-	2	**141,872**
	Passanger cars	228,015	912,012	1,188	743	-	46	**1,142,004**
	Motorcycles	2,813	182,552	2	517	-	5	**185,889**
	Industrial tractors	4,647	-	-	-	-	-	**4,647**
	Trailers	-	-	-	-	-	5,111	**5,111**
	Semi- trailers	-	-	-	-	-	8,796	**8,796**
	Others	15,929	4,910	3	271	-	215	**21,328**
TENERIFE ISLAND	**TOTAL**	236,052	509,516	439	553	-	4,987	**751,547**
	Lorries under 3,500 kg	75,087	75,087	5	5	-	4	**85,466**
	Lorries over 3,500 kg	7,132	88	3	-	-	1	**7,224**
	Buses	2,509	21	1	1	-	-	**2,532**
	Vans	46,409	15,674	26	30	-	2	**62,141**
	Passanger cars	96,362	402,253	403	269	-	22	**499,309**
	Motorcycles	821	79,082	1	183	-	3	**80,090**
	Industrial tractors	1,808	-	-	-	-	-	**1,808**
	Trailers	-	-	-	-	-	1,696	**1,696**
	Semi- trailers	-	-	-	-	-	3,177	**3,177**
	Others	5,924	2,033	-	65	-	82	**8,104**

Table 14. Number of vehicles in Spain, the Canary Islands and Tenerife Island by type of vehicle and type of fuel in September 2018.

*In the Category "Other fuels" are included vehicles powered by butane, ethanol, biodiesel, compressed natural gas (CNG) or liquefied natural gas (LNG) and those encompassed in the category "Others" and "Without specifying" by DGT. Directorate-General of Traffic, [Online]. Available: www.dgt.es. [Accessed November 2018].

Overall, it can be said than vehicles fleet of Tenerife is similar to that of the Canary Islands as a whole, but that is slightly different from that of Spain. In all three cases, the bulk of the vehicles are passenger cars, which account for more than 65% of the total. Lorries under 3500 kg are the second most prevalent in the Canary Islands and Tenerife, with percentages higher than 11%. This type of vehicles is in fourth position in the whole of Spain with a percentage of 6.31%, exceeded by motorcycles and vans. The number of buses in the Canary Islands and Tenerife accounts for 0.34% of the total in both cases, almost twice than in the whole of Spain, with a 0.18%.

Most vehicles are powered by diesel or petrol with percentages over 98% in all three cases. Vehicles of the Canary Islands and Tenerife are mainly powered by petrol with percentages of 66.53% and 67.80%, respectively. In contrast, this category accounts for 45.94% of the total in Spain, where vehicles are in general diesel, with a percentage of 52.42% versus 32.48% in the Canary Islands and 31.41% in Tenerife. The number of electric vehicles is still low in the all three cases, especially in Tenerife where the 553 electric vehicles represent just 0.07% of the total vehicles in the island. In September 2018, there were no hydrogen vehicles on either the Canary Islands nor Tenerife.

5.7. Transport and communications infrastructure

Roads

The main means of transportation in Tenerife is by motorways and, as mentioned in Section 4, a large proportion of the traffic on these roads is from private passenger cars.

According to national regulation, roads can be categorized in motorways or dual carriageways; first level autonomic highways; and third level autonomic highways. Table 5 indicates the total amount of roads in Tenerife and their distance, without considering municipal roads.

	Number	Distance (km)
Motorways and dual carriage	5	176.82
First level autonomic highways	18	465.87
Third level autonomic highways	106	553.47

Table 14. Number and total distance of highways in Tenerife[32].

The total distance of these roads is 1,196.16 km. The most important of them, as much for the number of kilometres as for the associated traffic volumes, are the 3 motorways: TF-1, TF-2 and TF-5. Table 6 shows their main characteristics.

[32] Wikipedia, La enciclopedia libre, [En línea]. Available: https://es.wikipedia.org/w/index.php?title=Anexo:Red_de_carreteras_de_Tenerife&oldid=112522040

	Type	Distance (km)	Maximum Speed (km/h)	Maximum A.D.I.*
TF-1	Motorway	103	120	99,300
TF-2	Motorway	5.24	90	79,265
TF-5	Motorway	61.7	120	112,801

Table 15. Main characteristics of motorways in Tenerife[33].

*Average Daily Intensity (A.D.I.) is the number of vehicles that run daily for a determined stretch of road

TF-1 and TF-5 run from the metropolitan zone to the north and south, respectively. These two motorways are connected by means of the TF-2 in the outskirts of the metropolitan zone. Considering the maximum A.D.I. indicated in the table and the previous data about the vehicles fleet in the island, it seems clear that a serious problem of traffic congestion exists on the island.

5.8. Public transport

Public transport on the Canary Islands is effectively bus transport. In the case of Tenerife there are two companies owning the public bus transport (TITSA and Transportes de La Esperanza.) but there is also a tram managed by Metropolitano de Tenerife.

Buses

Transportes de La Esperanza has only four bus lines which connect different areas of the municipalities of La Esperanza and San Cristóbal de La Laguna. By contrast, TITSA owns 523 buses covering 176 different itineraries, which represents 98 % of the bus lines in the island. 53 out of these bus lines are urban, whereas the rest connect different municipalities. In 2017, TITSA fulfilled 1,612,109 trips in Tenerife, which meant a total of 33,118,848 kilometres travelled, carrying 35,655,555 users and consuming 15,675,946 litres of fuel[34].

Figure 6.8.1 shows the infrastructure related to public buses in Tenerife. The two most important transport exchangers are in the metropolitan area (San Cristóbal de La Laguna and in Santa Cruz de Tenerife) and there are some bus statio ns spread over the rest of the island.

[33] ibid

[34] TITSA, «Informe Estadístico 2017,» [En línea]. Available: https://titsa.com/images/documentos/Informe_Estadistico_2017.pdf. [Último acceso: November 2018]

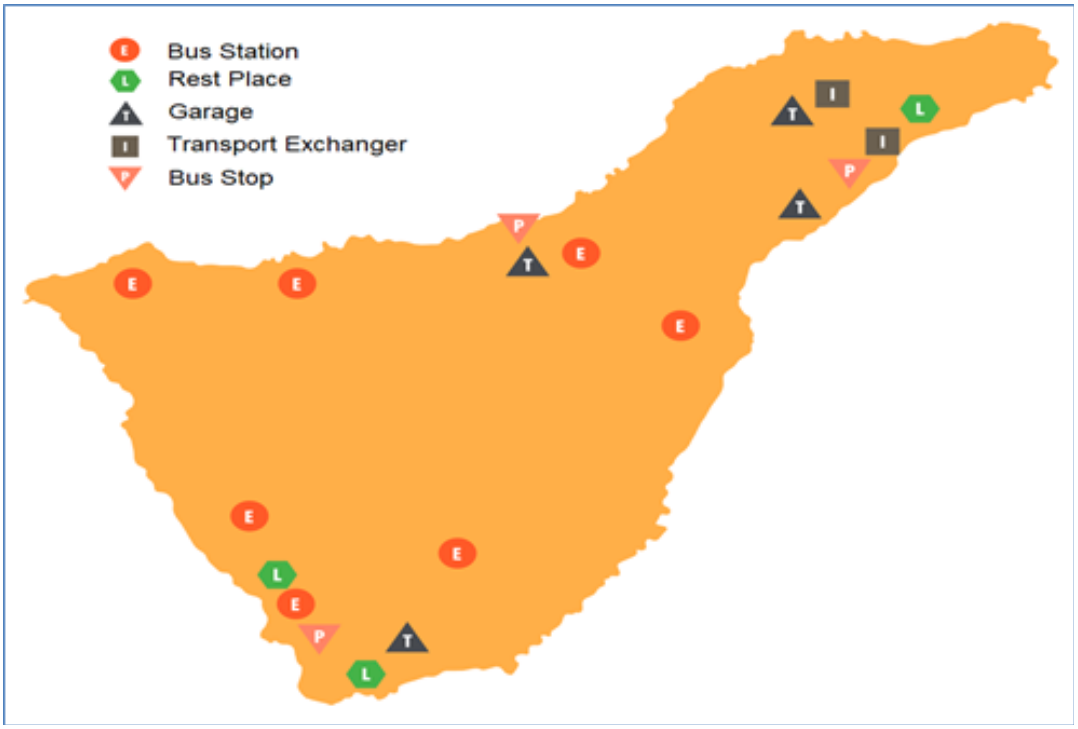

Figure 20. Public bus infrastructure in Tenerife[35]

Trams

The tram on Tenerife began operation in 2007. Currently there are two tram lines in the island and both operate within the metropolitan area of the island. These lines and their stops can be seen in Figure 6.8.2.

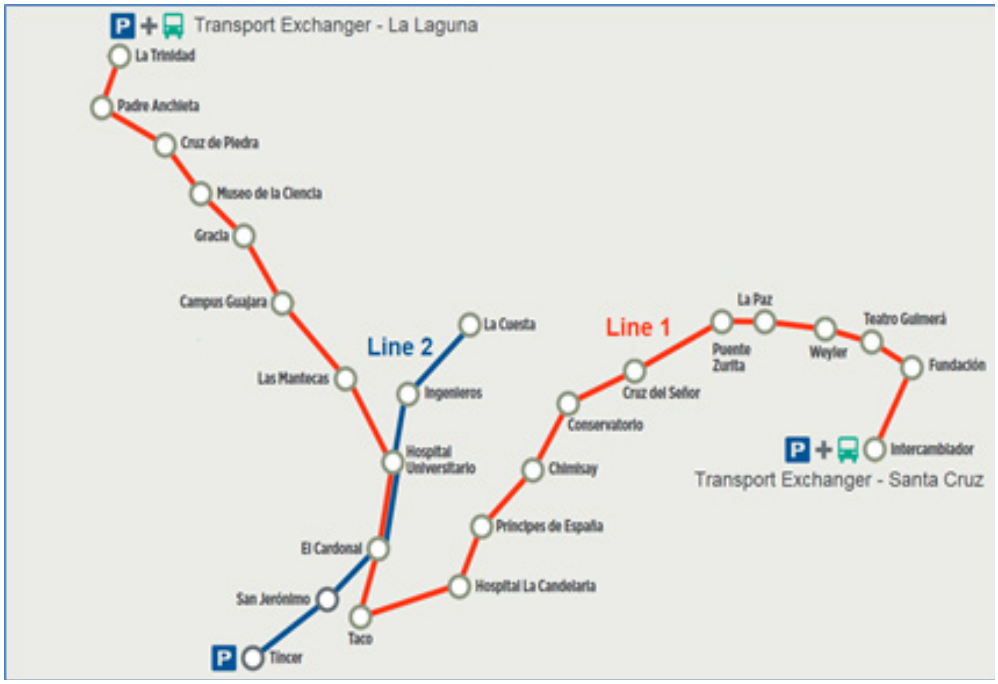

Figure 21. Tram lines and stops in Tenerife[36]

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[35] TITSA, «Corporative Presentation 2017,» [En línea]. Available: https://titsa.com/images/documentos/Presentaci%C3%B3n_Corporativa_2017.pdf. [Último acceso: November 2018].

[36] Wikimedia Commons, [En línea]. [Último acceso: December 2018].

Line 1 connects the two main cities of the island, La Laguna and Santa Cruz. It has 20 stops and covers a distance of 12.5 kilometres in around 40 minutes. Line 2 connects the areas of Tincer and La Cuesta, intersecting with Line 1 at the Hospital Universitario.

5.9. Airports

There are two airports in Tenerife, one in the South (Reina Sofía Airport) and other one in the north (Los Rodeos Airport), near the capital. During the last 2017, both airports together accounted for the highest passenger numbers in the Islands with nearly 16 million passengers (11,249,327 in Reina Sofía Airport and 4,704,863 in Los Rodeos Airport)[37]

5.10. Ports

Tenerife has two principal maritime ports: the Port of Santa Cruz de Tenerife (Puerto de Santa Cruz), which serves the various capitals of the Canary Islands, especially those in the west; and the Port of Los Cristianos (Puerto de Los Cristianos), which serves the various island capitals of the province of Santa Cruz de Tenerife. The first port also has passenger services, which connect with the mainland port of Cádiz (and vice versa). In 2017, a large port was opened in the south of the island, the Port of Granadilla.

5.11. Refuelling stations

Table 6.11 displays the number of conventional refuelling stations (diesel and petrol) and the ratio refuelling station per inhabitants, in the Canary Islands by island in the year 2016.

	Number	Refuelling station/ inhabitants
CANARY ISLANDS	433	0.21
Tenerife	191	0.21
Gran Canaria	145	0.17
Lanzarote	42	0.29
Fuerteventura	24	0.22
La Palma	21	0.26
La Gomera	7	0.33
El Hierro	3	0.28

Table 16. Number of refuelling stations and refuelling station per inhabitant in the Canary Islands by island in 2016[38]

[37] AENA, [En línea]. Available: http://www.aena.es/es/corporativa/aeropuertos-canarios-logran-record-historico-superar-44---millones-pasajeros-en-2017.html?p=1237548067436. [Último acceso: December 2018].

[38] Government of the Canary islands, «Anuario Energético de Canarias 2016,» December 2017. [En línea]. Available: http://www.gobiernodecanarias.org/ceic/energia/doc/Publicaciones/AnuarioEnergeticoCanarias/ANUARIO-ENERGETICO-CANARIAS-2016.pdf. [Último acceso: December 2018].

As one would expect, the greatest number of refuelling stations is concentrated in Tenerife (191) followed by Gran Canaria (145), the two most populated and largest islands of the archipelago. However, when attending to the ratio of refuelling station per inhabitant, Tenerife is the second island with lowest ratio with 0.21 refuelling stations per inhabitant.

The geographic distribution of these refuelling stations by municipality in each one of the Canary Islands can be noted in Figure 9. Regarding to Tenerife, the majority of refuelling stations are located in the municipalities of San Cristóbal de La Laguna and Santa Cruz de Tenerife, the most densely populated on the island.

Figure 22. Refuelling stations per municipality in the Canary Islands[39]

The number of alternative refuelling stations in the Canary Islands is scarce. The only alternative fuel commercialized in is liquefied petroleum gas (LPG), being around 6 refuelling points in Tenerife. Regarding electric charging points, their number has increased in the past few years and 200 electric charging points are estimated in Tenerife.[40]

This suggests that on Tenerife there is a large scale refuelling sector which can both serve as an opportunity for H2 fueling station rollout and also accommodate a gradual shift from fossil to H2 fuel. This sector also exists on Madeira, but is lacking on Árainn where it is not likely there would be the market for a bespoke H2 fueling station.

5.12. 1st stage assessment of H2 opportunities in the transport sector

Tenerife and the Canary Islands in general, are highly dependent on fossil fuels, which need to be entirely imported from abroad and account for some 80 percent of the final energy demand on the Islands. Moreover, much of this final energy demand stems from

[39] ibid

[40] GEOPORTAL, [En línea]. Available: https://geoportalgasolineras.es/#/Inicio . [Último acceso: November 2018]. And See also CANARIAS TE RECARGA, [En línea]. Available: http://canariasterecarga.com/es/inicio/. [Último acceso: November 2018].

transport: by land, sea and air. Thus, the deployment of hydrogen in the transport sector could be seen as a valuable way both to reduce external energy dependency and also greenhouse gas emissions related to transport.

The main objective of SEAFUEL project is the production of hydrogen through renewable energy to use in transport applications. And both the Canary Islands and Tenerife in particular have excellent potential for renewable energy production, from both sun and wind, making green hydrogen production for use in transport an achievable goal.

We consider that the hydrogen technology for air and maritime transport sector here is not mature enough yet. By contrast, land transport do present opportunities for hydrogen adoption.

Tenerife has a high ratio of vehicles per inhabitant, above that of Spain and the other Canary Islands, and most of these vehicles are fuelled by diesel and petrol. Substitution of these vehicles by hydrogen vehicles would drastically decrease greenhouse gas emissions. However, needless to say that there are still hurdles to overcome. Regarding to passenger cars, several challenges were addressed by ITER SEAFUEL Team during the conduct of the WP4, mainly in relation to the vehicle purchase on the Canary Islands. Detailed information can be seen in SEAFUEL WP4 Report.

Buying a hydrogen vehicle in the Canary Islands as a private user can still be complicated, so in this sense, identified opportunities are based in keeping public institution participation in demonstration projects to enable hydrogen infrastructure development.

6. Conclusions

It is clear that the gepgraphical and demographic contexts for the individual islands involved in the special regions case studies are key to determining both the scope and character of the opportunities for deployment of H2 vehicles in island conditions.

The threee islands have in common issues of fuel importation for transport which creates an added impetus for locally sourced fuels, in that there are greater cost avoidence dividends which, pending further economic analysis (currently underway in the SEAFUEL project), could give futher H2 opportunites over petrol and diesel.

However, the size of the island and thus the distnaces travelled by both tourists and inhabitants is a significant factor: EVs posses an advantage at present over H2 in that the costly infrastructural upgrades required by fast charging EV stations is offset by the opportunity for users to use slow feed home-chargers overnight. This helps remove some of the grid refurbishment difficulties which a widespread fast charge network creates.

It is for this reason that vehicles that are parked up at the owners home and are used for shoter ranges (<100km per day) may suit EV deployment. This is found to bethe case in Arainn and in fact we have seen where there has already been some movement towards EV adoption there.

However, on Madeira and Tenerife, the distances travelled are greater than on Árainn and this means that issues of range anxiety and refuelling time come into play on the larger islands. The rexistance of a car-driving (thus renting) tourist secotor is also a significant difference. Tourists renting cars do not have the facility of home-charging and thus are affected by fast-charge issues. It is for this reason that the specifics of each island's geography and tourist product are significant when considering H2 deployments. This will be examined in greater detail in other studies SEAFUEL is conducting.

There are further opportunities on Madeira and Tenerife which do not present themselves on Arainn. The large islands have fleets of various vehicles: delivery and works vans as well as rental cars that present economies of scale for the adotpion of H2. Fuelling stations are costly to install. When this cost can be spread across a range of vehicles. The switching costs can be spread and reduced. This then represents a very viable first stage towards adoption.

In relation to other transport uses of H2 on the three islands it was felt that we are not at a point where in depth study is required. Overall the exposure to Atlantic Ocean conditions means that H2 use in ferries on these three islands is some way off.

In effect the study has shown that H2 adoption on islands is lilely to be very susceptible to geography (distances travelled) and population (economies of scale)

We will be looking at further constraints and opportunities presented by the islands in terms of availablity of water (SEAFUEL's demonstration of the viability for using desalinated water will be very relevant in the Southern European Islands), available renewable energy (either installed or planned), and grid constraints. It is hoped that by looking at the transport sectors on these three islands in this paper we have determined key considerations that are applicable to the islands of Europe in general, and which will be used in our further research to identify the key characteristics required for to determine an island's suitability for H2 adoption.

7. Annex I

		2010	2011	2012	2013	2014	2015	2016	2017	Surface (km²)	Change 2010-2017
SPAIN	Population	47,021,031	47,190,493	47,265,321	47,129,783	46,771,341	46,624,382	46,557,008	46,572,132	505,990	-1.0%
	Population density	93	93	93	93	92	92	92	92		
Andalucía	Population	8,370,975	8,424,102	8,449,985	8,440,300	8,402,305	8,399,043	8,388,107	8,379,820	87,599	0.1%
	Population density	96	96	96	96	96	96	96	96		
Aragón	Population	1,347,095	1,346,293	1,349,467	1,347,150	1,325,385	1,317,847	1,308,563	1,308,750	47,720	-2.8%
	Population density	28	28	28	28	28	28	27	27		
Asturias	Population	1,084,341	1,081,487	1,077,360	1,068,165	1,061,756	1,051,229	1,042,608	1,034,960	10,604	-4.6%
	Population density	102	102	102	101	100	99	98	98		
Baleares	Population	1,106,049	1,113,114	1,119,439	1,111,674	1,103,442	1,104,479	1,107,220	1,115,999	4,992	0.9%
	Population density	222	223	224	223	221	221	222	224		
Canarias	Population	2,118,519	2,126,769	2,118,344	2,118,679	2,104,815	2,100,306	2,101,924	2,108,121	7,493	-0.5%
	Population density	283	284	283	283	281	280	281	281		
Cantabria	Population	592,250	593,121	593,861	591,888	588,656	585,179	582,206	580,295	5,321	-2.0%
	Population density	111	111	112	111	111	110	109	109		
Castilla y León	Population	2,559,515	2,558,463	2,546,078	2,519,875	2,494,790	2,472,052	2,447,519	2,425,801	94,224	-5.2%
	Population density	27	27	27	27	26	26	26	26		
Castilla-La Mancha	Population	2,098,373	2,115,334	2,121,888	2,100,998	2,078,611	2,059,191	2,041,631	2,031,479	79,461	-3.2%
	Population density	26	27	27	26	26	26	26	26		
Cataluña	Population	7,512,381	7,539,618	7,570,908	7,553,650	7,518,903	7,508,106	7,522,596	7,555,830	32,113	0.6%
	Population density	234	235	236	235	234	234	234	235		
Comunidad Valenciana	Population	5,111,706	5,117,190	5,129,266	5,113,815	5,004,844	4,980,689	4,959,968	4,941,509	23,255	-3.3%
	Population density	220	220	221	220	215	214	213	212		
Extremadura	Population	1,107,220	1,109,367	1,108,130	1,104,004	1,099,632	1,092,997	1,087,778	1,079,920	41,634	-2.5%
	Population density	27	27	27	27	26	26	26	26		
Galicia	Population	2,797,653	2,795,422	2,781,498	2,765,940	2,748,695	2,732,347	2,718,525	2,708,339	29,575	-3.2%
	Population density	95	95	94	94	93	92	92	92		
La Rioja	Population	322,415	322,955	323,609	322,027	319,002	317,053	315,794	315,381	5,045	-2.2%
	Population density	64	64	64	64	63	63	63	63		
Madrid	Population	6,458,684	6,489,680	6,498,560	6,495,551	6,454,440	6,436,996	6,466,996	6,507,184	8,028	0.8%
	Population density	805	808	809	809	804	802	806	811		
Murcia	Population	1,461,979	1,470,069	1,474,449	1,472,049	1,466,818	1,467,288	1,464,847	1,470,273	11,314	0.6%
	Population density	129	130	130	130	130	130	129	130		
Navarra	Population	636,924	642,051	644,566	644,477	640,790	640,476	640,647	643,234	10,391	1.0%
	Population density	61	62	62	62	62	62	62	62		
País Vasco	Population	2,178,339	2,184,606	2,193,093	2,191,682	2,188,985	2,189,257	2,189,534	2,194,158	7,234	0.7%
	Population density	301	302	303	303	303	303	303	303		
Ceuta	Population	80,579	82,376	84,018	84,180	84,963	84,263	84,519	84,959	20	5.4%
	Population density	4,029	4,119	4,201	4,209	4,248	4,213	4,226	4,248		
Melilla	Population	76,034	78,476	80,802	83,679	84,509	85,584	86,026	86,120	12	13.3%
	Population density	6,336	6,540	6,734	6,973	7,042	7,132	7,169	7,177		