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D2.12 - IANOS Islands Decarbonisation Master Plan

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2.12.4	19/06/2023	Ameland	Revision 2
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Executive Summary

Under the IANOS - Integrated Solutions for Decarbonisation and Smartification of Islands project, a Decarbonisation Master Plan for the islands (Ameland, Terceira, Lampedusa, Nisyros and Bora-Bora) has been prepared.

This plan aims to provide information about the reality regarding GHG (greenhouse gas) emissions, its goals and the path defined for the decarbonisation of each of those islands. For that purpose, a characterisation is provided according to the available information and with the help of the various local project partners.

The elaboration of the document enabled the identification of the difficulties in the definition of clear strategies for the decarbonisation of the various islands so that often national targets are presented due to the difficulty in the establishment of more suitable values for the island reality.

There is a common pattern in the emission of GHG which is the predominance of the energy sector (which includes transports) with origin in the economic activity related to Tourism. Thus, the path to decarbonization can be done mainly through energy efficiency, and electrification of consumption (for example transport) supported by an optimisation of the production of renewable energy with storage.

Concerning the previous version of this document (D2.11), the main differences are the inclusion of information from D9.1 and D9.3, the correction of some errors and the updating of information. The contribution regarding the replicability and scalability plan does not yet present the necessary detail, and practical results on this are yet to be produced. Thus, in further deliverables throughout the project, this matter will be addressed.

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Abbreviations and Acronyms

AEC	Amelander Energie Coöperatie
BEI	Baseline Emissions Inventory
BESS	Battery Energy Storage System
CHP	Combined heat and power
DSO	Distribution System Operator
EDA	Electricidade dos Açores
EMI	Emissions Monitoring Inventory
ESD	Effort Sharing Decision
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicles
FEID	Fog-Enabled Intelligent Device
GHG	Greenhouse Gas
HEMS	Home Energy Management System
IEPT	Island Energy Planning and Transition
iVPP	Intelligent Virtual Power Plant
IPCC	Intergovernmental Panel on Climate Change
IRERPA	Regional Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants
KPI	Key Performance Indicator
LPG	Liquefied petroleum gas
LULUCF	Land Use, Land Use Change and Forestry
LV	Low Voltage
PAESC	Action Plan for Sustainable Energy and Climate
PMEA	Azores Electric Mobility Programme
PRAC	Regional Climate Change Programme
PV	Photovoltaic
RES	Renewable Energy Sources
RNC	Roadmap for carbon neutrality
TNO	Transmission Network Operator
UC	Use Case
V2G	Vehicle-to-Grid
WP	Work Package

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1.Introduction

1.1 Purpose and Scope of the Deliverable

IANOS project aims, amongst others, to decarbonise the energy systems of its Lighthouse Islands (Ameland and Terceira) and explore the possibility of replication in the Fellow Islands (Bora-Bora, Lampedusa, Nisyros).

This document is aimed to help in the definition of the different strategies of each of the islands for decarbonisation.

For this purpose, a Decarbonisation Master Plan will be developed, based on the available information/documentation, to form the stakeholders' consensus on the decarbonisation pathways. Therefore, a historical analysis of GHG emissions is made and then the main targets and policies defined by the government authorities are highlighted.

1.2 Kyoto Protocol and Paris Agreement

Kyoto Protocol

On 11 December 1997, the Kyoto Protocol was adopted in Kyoto (Japan) and entered into force on the 16th of February 2005. This Protocol had 2 commitments periods: the first started in 2008 and ended in 2012, and the second was the extension until 2020 (known as Doha Amendment).

This Protocol aimed to commit industrialised countries and economies in transition to limit and reduce greenhouse gases in accordance with agreed individual targets [1]. Also, this Protocol allows Annex I Parties to add to or subtract from their initial assigned amount, thus raising or lowering the level of their allowed emissions over the commitment period, by trading Kyoto units with other Parties. All participating countries emissions must be monitored in order to confirm that the objectives are being accomplished.

Paris Agreement

The Paris Agreement is a "*legally binding international treaty on climate change*" that was adopted by 196 Parties, on 12 December 2015 and entered into force on the 4th of November 2016 [2].

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The objective of this Agreement is to "*limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial (1990) levels*" [2]. Developed countries will provide financial resources to help the developing ones and a review of the funds and objectives will be carried out every 5 years. The European Union aims to **reduce its emissions by at least 55% by 2030** [3] and reach **Climate neutrality by 2050** [4]. The EU wants to transform Europe into the first carbon-neutral continent, investing around one third of the overall amount of the recovery plan, thus becoming a modern, efficient, and competitive economy.

EU Emissions Trading System

This System "*is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one*" [5]. And operates in all EU countries (plus Iceland, Liechtenstein, and Norway), limits the emissions from 10,000 installations of the power sector, manufacturing industry, and also the airlines operating in the previously mentioned countries. The EU ETS covers around 40% of Europe's GHG emissions.

Effort Sharing

This legislation "*establishes binding annual greenhouse gas emission targets for Member States for the periods 2013–2020 and 2021–2030. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as transport, buildings, agriculture, and waste*" [6]. The emissions covered by these sectors accounts for almost 60% of total domestic EU emissions.

Recovery and Resilience Facility

This temporary recovery instrument aims to "*mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient, and better prepared for the challenges and opportunities of the green and digital transitions*" [7].

It makes available €723.8 billion in loans (€385.8 billion) and grants (€338 billion) [7] that will help the EU to achieve carbon neutrality until 2050.

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All of these policies are important to transform Europe in a low-carbon economy, increase the energy security and achieve the carbon neutrality in 2050.

1.3 Structure of the Deliverable

Deliverable D2.11 is structured as follows:

- Chapter 2: Terceira Demonstrator GHG emissions distribution is characterised. This chapter contains a general characterisation of the emissions of GHG by sector (historical data, current status, major measures and forecast for 2025/2030/2050). Followed by a characterisation of the energy sector, in particular the electricity and transport subsectors of the island;
- Chapter 3: Ameland Demonstrator GHG emissions distribution is characterised. This chapter contains a general characterisation of the emissions of GHG by sector (historical data, current status, major measures and forecast for 2025/2030/2050). Followed by a characterisation of the energy sector, in particular the electricity and gas subsectors;
- Chapter 4: An overview of the GHG emissions distribution and the main policies will be presented for each Fellow Island (Lampedusa and Nisyros);
- Chapter 5: Conclusions and Next Steps.

For each island, a SWOT analysis is presented for the decarbonisation.

1.4 Relation to other deliverables/tasks

This deliverable is related to the others of the Requirements Engineering & Decarbonisation Roadmapping (WP2), as it will capitalize on the results of Tasks 2.1 (namely the D2.3 - "Report on Islands requirements engineering and UCs definitions") to T2.3 to understand the current and future requirements and barriers as well as the most important KPI's in island decarbonisation. Also, tasks 9.1 and 9.2 (Lighthouse / Fellow Islands Replication and Scalability Plan, respectively) are related to the decarbonisation plan since they aim to identify the replication and scalability potential of the various solutions on each one of the islands.

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2 Terceira Demonstrator

Terceira is the third largest island in the Azores archipelago, with an area of 402.2 km^2. Terceira is a volcanic island, located in the middle of the North Atlantic Ocean, 1,600 km West of Portugal, with a population of 55,300 inhabitants. Its economy is mostly based on livestock raising, production of dairy-based products and, as of recently, tourism. Between 2010 and 2018, tourism in Terceira has skyrocketed by 230%, welcoming around 137,920 tourists in 2018. Angra do Heroísmo, the historical capital of the archipelago and a part of Terceira, has been labelled a UNESCO World Heritage Site. Terceira has a subtropical climate, with mild annual oscillations.

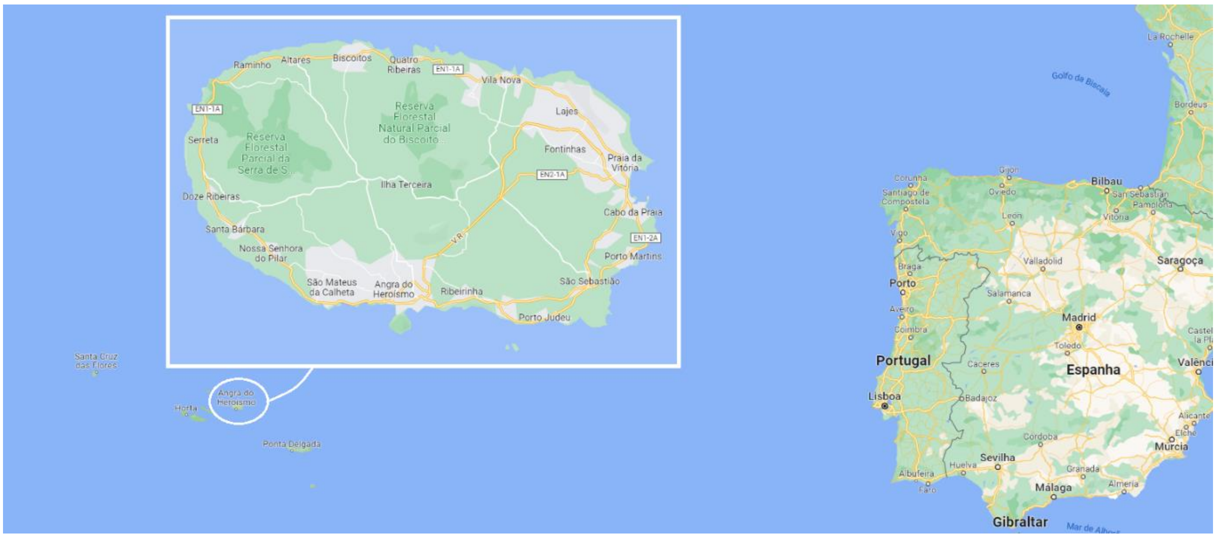

Figure 1 - Terceira Island location.

The Autonomous Region of the Azores has administrative and political autonomy and, as such, is endowed with a series of political, legislative, and administrative powers of its own. Thus, when it comes to matters such as Energy, Climate, or Mobility, the Region is responsible for developing its strategy and plans, taking into consideration the specificities of the Region itself. However, such plans must always be in line with the standard national and international targets and objectives, established both for renewable energy sources and for the reduction of GHG emissions.

As foreseen in the Carbon Neutrality Roadmap for 2050 (RNC 2050) [8], the GHG reduction target for Portugal by 2050 was set to between 85% and 90% compared to 2005, and the remaining percentage will be covered by Land

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Use, Land Use Change and Forestry (LULUCF), through carbon sequestration. The path to reducing emissions has been settled on somewhere between 45% and 55%, by 2030, and between 65% and 75% by 2040, compared to 2005. The decarbonisation targets defined by each sector, at a national level, cannot be easily transposed to the Azores, since their GHG emission profiles are very distinct. For example, and according to the figure below, unlike the mainland, in the Azores, there seems to be a more evident predominance in the agricultural sector, and a near absence in the industrial process and product use sector.

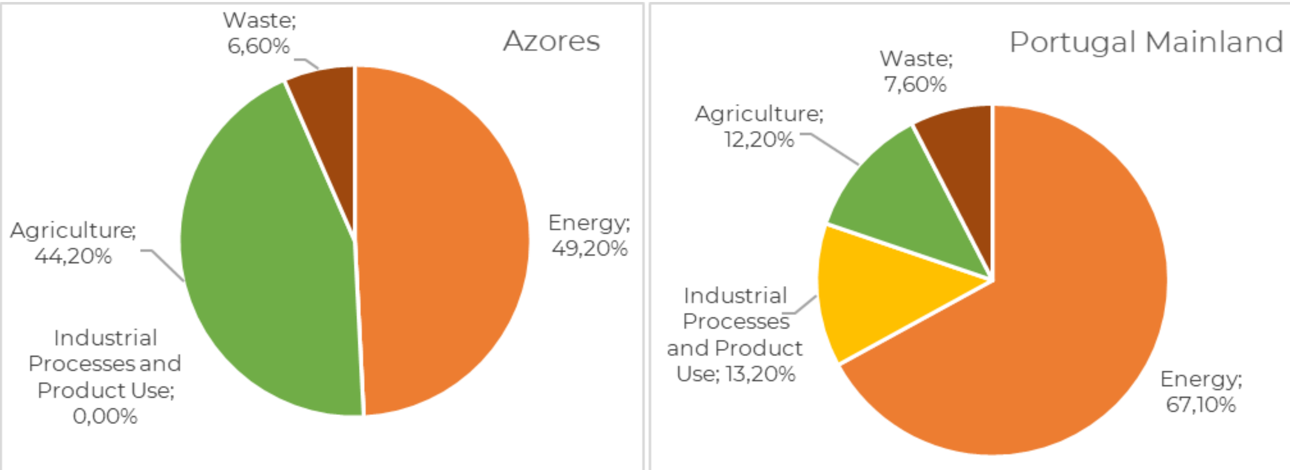

Figure 2 - Comparison between the Emissions Profile in the Azores and the National Total of 2020.

2.1 GHG emissions per sector (historical data, current status, major measures and forecast for 2025/2030/2050)

The Regional Inventory of Emissions by Sources and Removals by Sinks of Air Pollutants [9] (IRERPA) is one of the main elements of the Azorean Regional Climate Change Programme, approved by the Regional Legislative Decree No. 30/2019/A, 28 November 2019. This document enables the Azorean government to better understand the reality of the regional greenhouse gas emissions. Furthermore, it also allows the Region to systematize and organise the regional information to submit and contribute to the improvement of the Portuguese National Inventory of Emissions by Sources and Removals by

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Sinks of Air Pollutants. The most recent IRERPA was published in September 2022, with results from 2020 [9].

IRERPA considers the emissions of the Region as a whole, meaning that there is no desegregated data for each of the 9 islands on the archipelago, something that poses a limitation. Given this limitation, and the fact that the current document is exclusively for Terceira Island, as it is a lighthouse island of the IANOS project, an estimate of the greenhouse gas emissions of that particular island was required. It was assumed the ratio of 0.2337, the correlation between the electricity consumed in the year 2020, in Terceira Island, vs the energy consumed in the Azores. This ratio was chosen because the consumption of electricity has been correlated to economic growth since the industrial revolution. However, '*The effect of energy consumption on economic growth decreases as the income level of the country increases*' [10]. Considering the context of the Region, applying this ratio to the distribution of emissions registered at a regional level is, in any manner, a solid approximation.

Furthermore, this ratio has also been validated by the 2007 Regional Strategy for Climate Action [11], a document published by the Azorean Regional Government, in which Terceira is mentioned as responsible for 23% of total emissions, thus corroborating the ratio previously stated.

Recently adopted by the Autonomous Region of the Azores is the Azorean Strategy for Energy 2030 (EAE2030), aligned with regional, national and international commitments. One of its three objectives is the 'reduction of GHG emissions, as well as the minimisation of other environmental impacts'.

2.1.1 Total

The GHG emissions in Terceira amounted to a total of 401.318 kt CO_{2eq}, according to IRERPA 2022 [9] (results obtained from 2020, and with the assumption mentioned previously). Given that the Land Use and Forestry sector is responsible for a net sequestration of 33.927 kt CO_{2eq}, the net balance emissions stand at 367.4 kt CO_{2eq}.

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The total emissions of GHG have decreased by 5.5% in relation to the previous year, due to a decrease in the energy sector but have seen a 54.4% rise in relation to the values registered in 1990.

As for the emissions profile by sector (figure 3), the values remain stable, with the energy sector representing 49% of emissions, followed by the agricultural sector, with 44% (increasing when compared to the 36% registered in 1990), and the waste sector with 7%, (decreasing when compared to the 11% in 1990). The Industrial Process and Product Use sector is neglectable in the Azores and only represents about 0.1% of total GHG emissions.

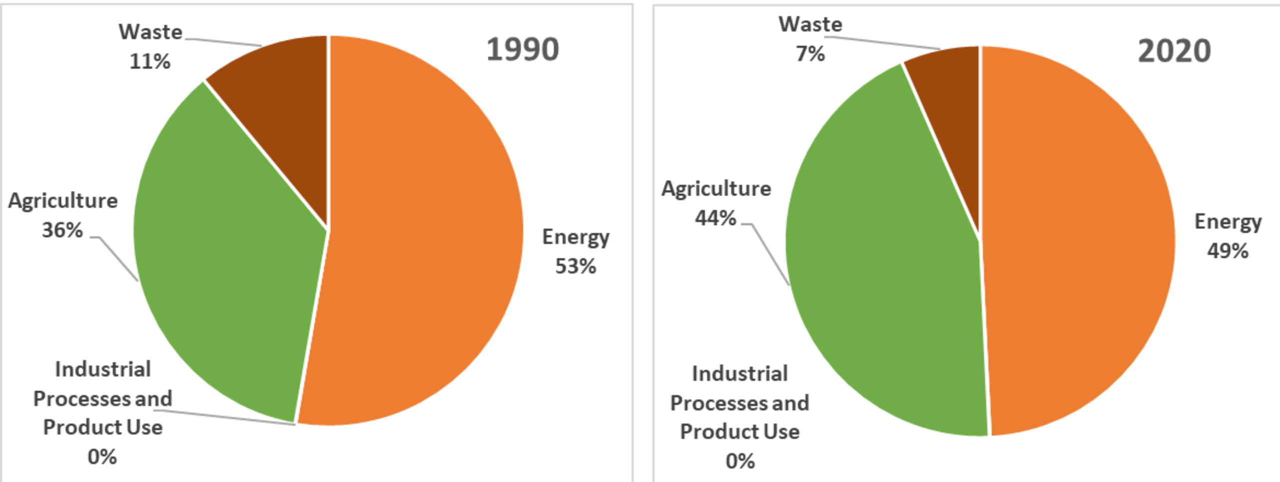

Figure 3- Azores GHG Emissions Profile by sector in 1990 and 2020.

According to figure 4, from 1990 to 2009, there occurred some growth in GHG emissions, seemingly due to the development of this ultra-peripheral region. From 2010 until 2014, there was a decline in emissions, largely due to the great global economic crisis that has hit the Portuguese economy. It should also be noted that the sink capacity of the (LULUCF sector) is reported as constant over the years, from 1990 until 2014, in part due to a lack of sufficient data from the Azorean government. The values above the LULUCF line represent the net balance emissions.

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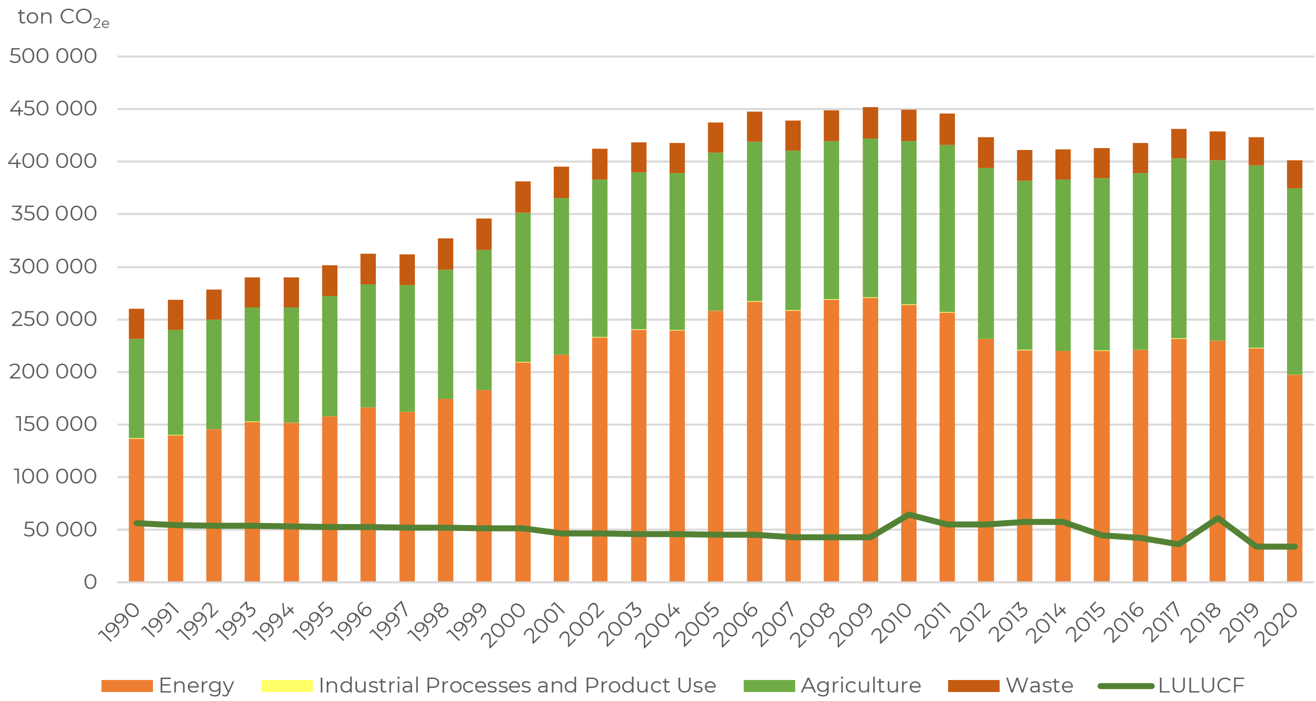

Figure 4 - Total GHG Emissions (1990-2020).

2.1.2 Agriculture

In the Azores, agricultural activity is highly focused on livestock farming and similar activities. Within this sector, there is a great significance and specialisation in cattle, particularly the dairy industry and meat market. It should also be mentioned that the number of cattle in the Azores surpasses the number of inhabitants.

This sector currently represents 44% of the emissions in Terceira Island and covers the emissions resulting from: livestock production; the application of fertilisers and correctives in agricultural soils and pastures; and the intentional burning of agricultural waste.

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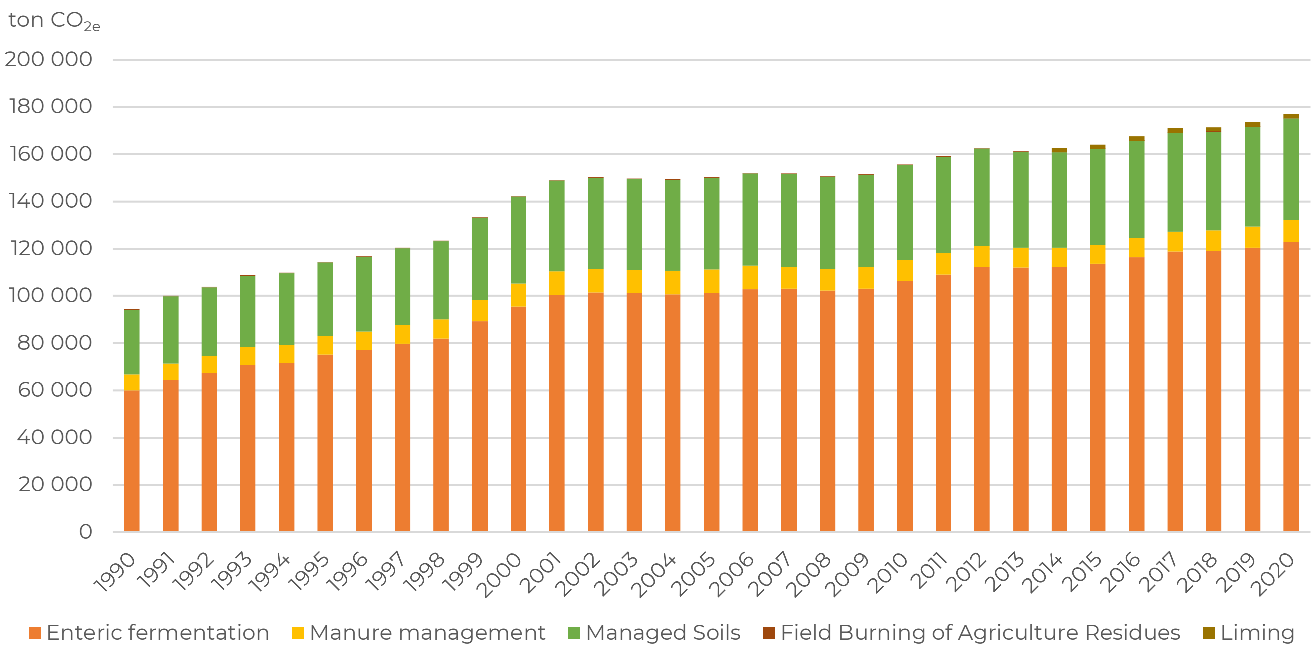

Figure 5 - Agriculture Sector GHG Emissions (1990-2020).

The subsector with the highest weight in emissions is enteric fermentation, resulting from the digestive process in ruminant animals, and responsible for methane (CH_4) emissions.

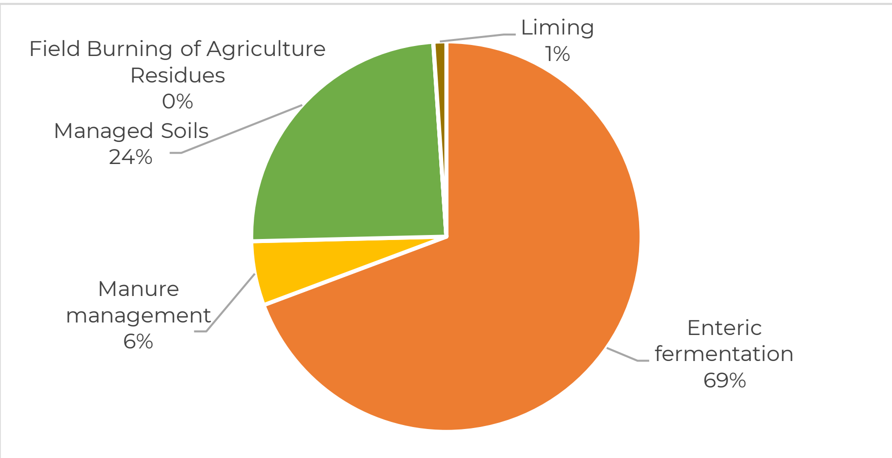

Figure 6- Distribution of Agriculture sub-sectors (2020).

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2.1.3 Energy

The Energy sector currently represents 49% of GHG emissions. Although this contribution has decreased as a percentage when compared to 1990 (53%), the absolute value has increased by 44%. This sector has undergone an evolution similar to the economy — that is, between 2009 and 2014, the trend dropped to downward (recession period), while, in the remaining periods, the trend of emissions increased.

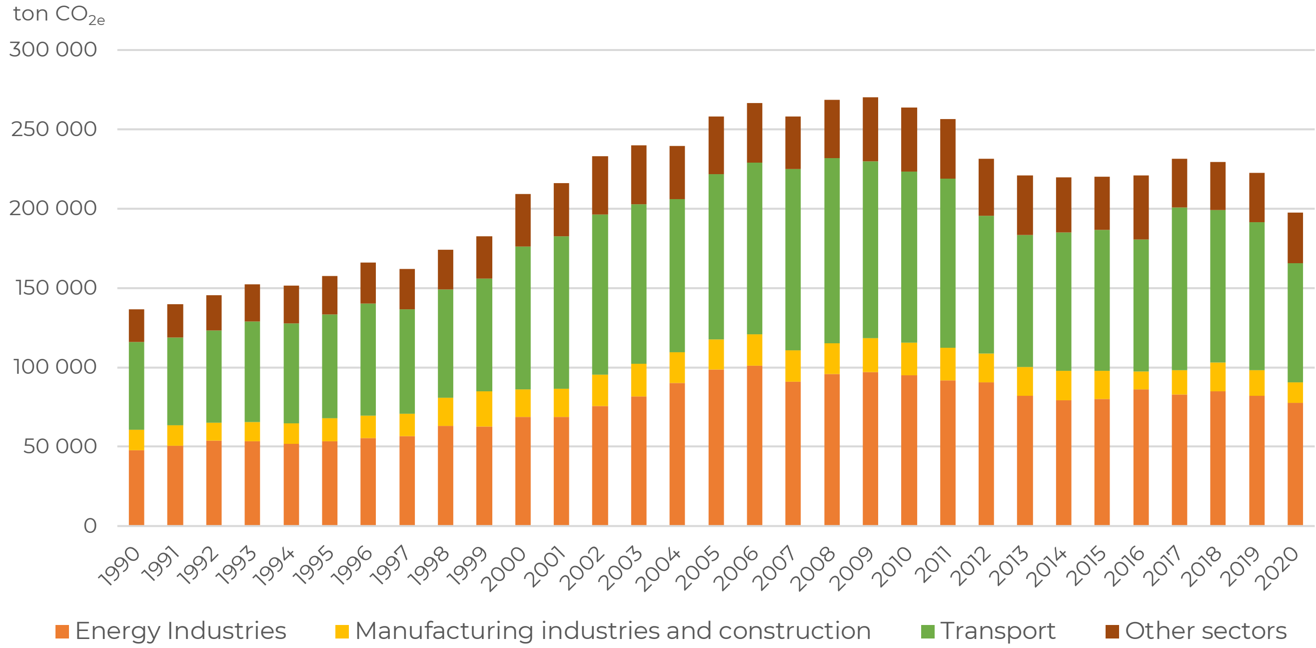

Figure 7 - Energy Sector GHG Emissions (1990-2020).

According to figure 8, the Energy Industries and Transport subsectors are the main contributors for GHG emissions, at 39% and 38%.

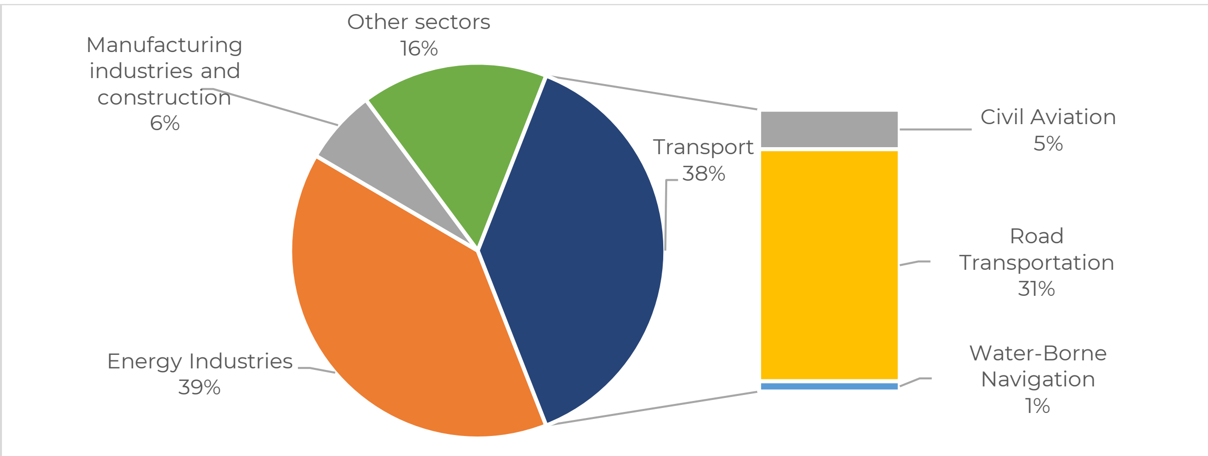

Figure 8 - Distribution of Energy sub-sectors (2020).

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About 82% of emissions of the transport subsector originate from road transportation. This reality will be difficult to change, since public transport on the islands is limited, as routes are not always direct, resulting in more stops, and schedules are sometimes not followed, leading the population to preferring their own personal vehicle.

In order to change this situation, an Electric Mobility Plan for the Azores was elaborated, which targets a reduction of emissions in the order of 1,200 tons of CO_2 through electric mobility [12].

Electricity production (this subsector will be described in Electricity Subsector) was responsible for 39% of the energy sector emissions, in 2020.

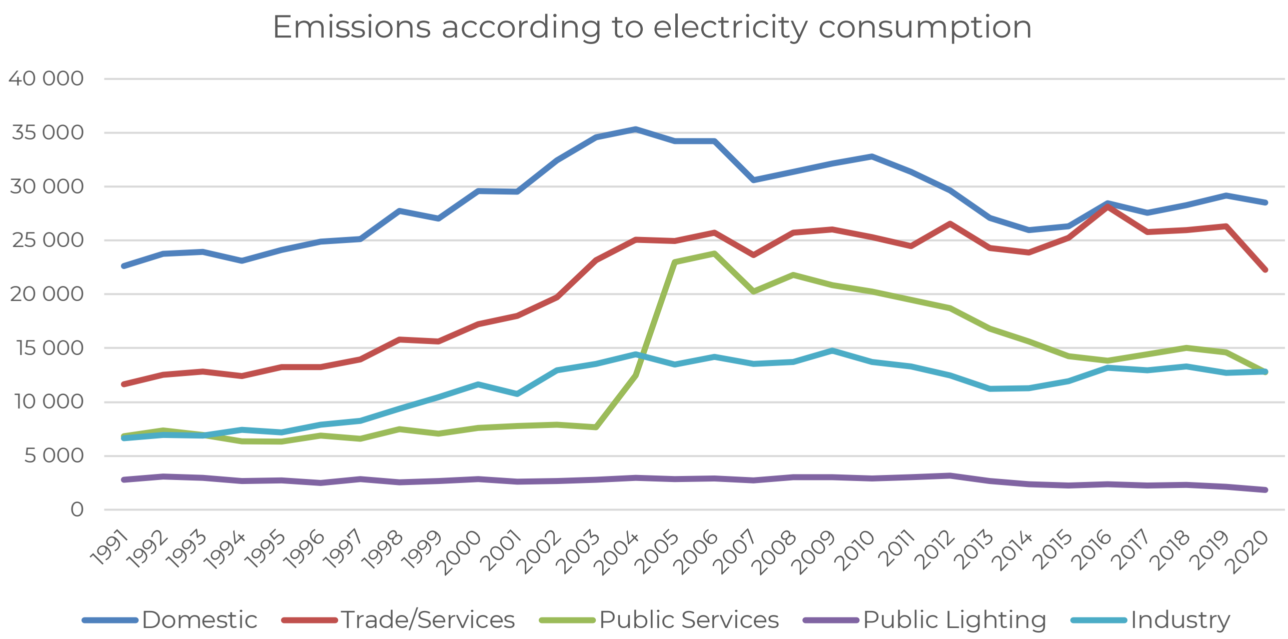

Figure 9 - Emissions according to electricity consumption (ton CO_2).

Given the emissions related to electricity production and the distribution of consumption by sector, we obtained the figure presented above.

The Domestic sector is the sector with the highest consumption, and, consequently, the highest CO_{2eq} emissions. However, in recent years, the Trade/Services sector has presented similar consumption patterns.

In addition, within the scope of EAE2030, one of the targets for 2030 is the reduction of GHG emissions by 40% for the energy sector, in relation to 2010 (1072 ktCO_2eq. in 2010 to 676 ktCO_2eq. in 2030).

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2.1.4 Industrial Process and Product Use

The Industrial Process and Use of Product sector represent merely 0.1% of the emissions of Terceira Island. There is a lack of diversity of industries in the Azorean Island and Terceira only contributes with the use of lubricants for this sector.

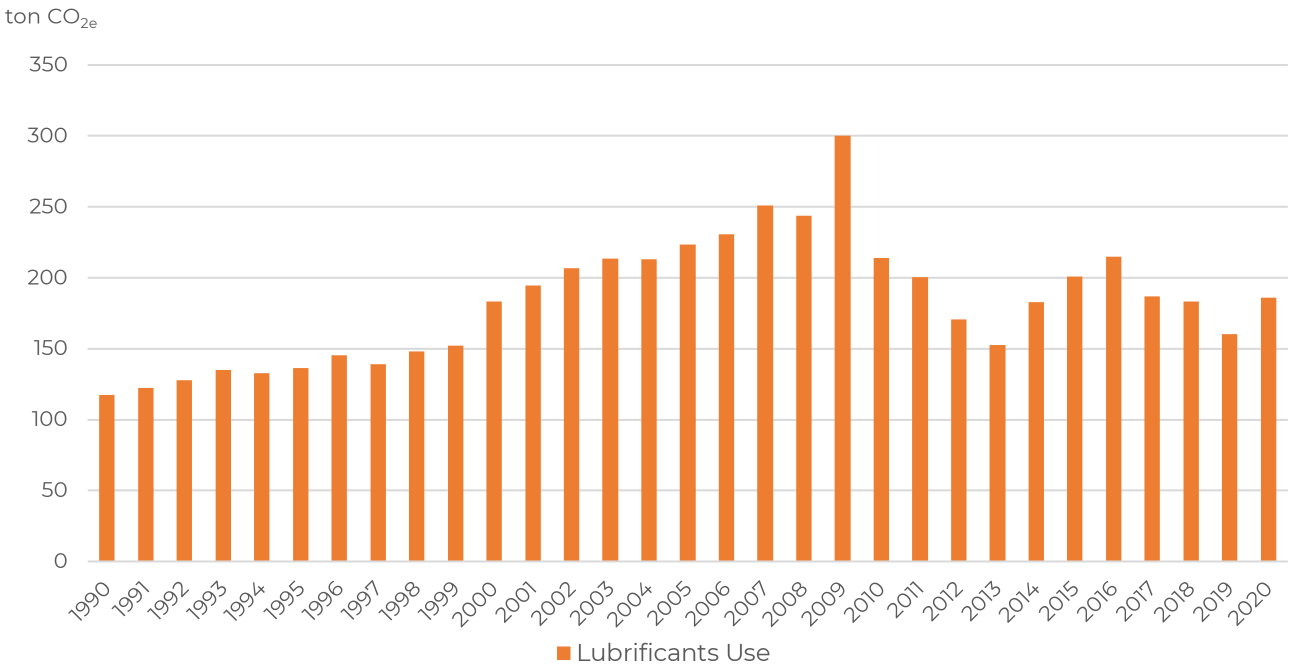

Figure 10 - Industrial Processes and Product Use Sector GHG Emissions (1990-2020).

2.1.5 Land Use, Land Use Change and Forestry

Unlike other sectors, the LULUCF sector is responsible for both greenhouse gas emissions (conversion to urban areas) and carbon dioxide sinks (Forestry and Pastures). This sector allows a net reduction of emissions corresponding to -8.5% of total emissions.

This sector represents the sink capacity, that is, the amount of CO_2 from the atmosphere that can be captured and stored permanently.

The value shown was estimated based on the forest area of Terceira Island, according to the forest inventory [13]. Terceira Island has a forest area that corresponds to 13.24% of the Azorean Forest.

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According to IRERPA, the regional LULUCF suffered a significant reduction in 2014 and 2020. This can be explained by the conversion of abandoned lands into vineyards. Nevertheless, according to information gathered from the Regional Directorate of Forest Resources, it served no impact on Terceira Island and, therefore, a constant value was assumed between 2014 and 2017, and, for 2020, the value for 2019 was assumed. Moreover, according to the Occupation of Land Use Map [14], 61.53% of the island is occupied by Agriculture, predominantly pastures, which occupy 57.53%, while the Forest occupies 27.23%.

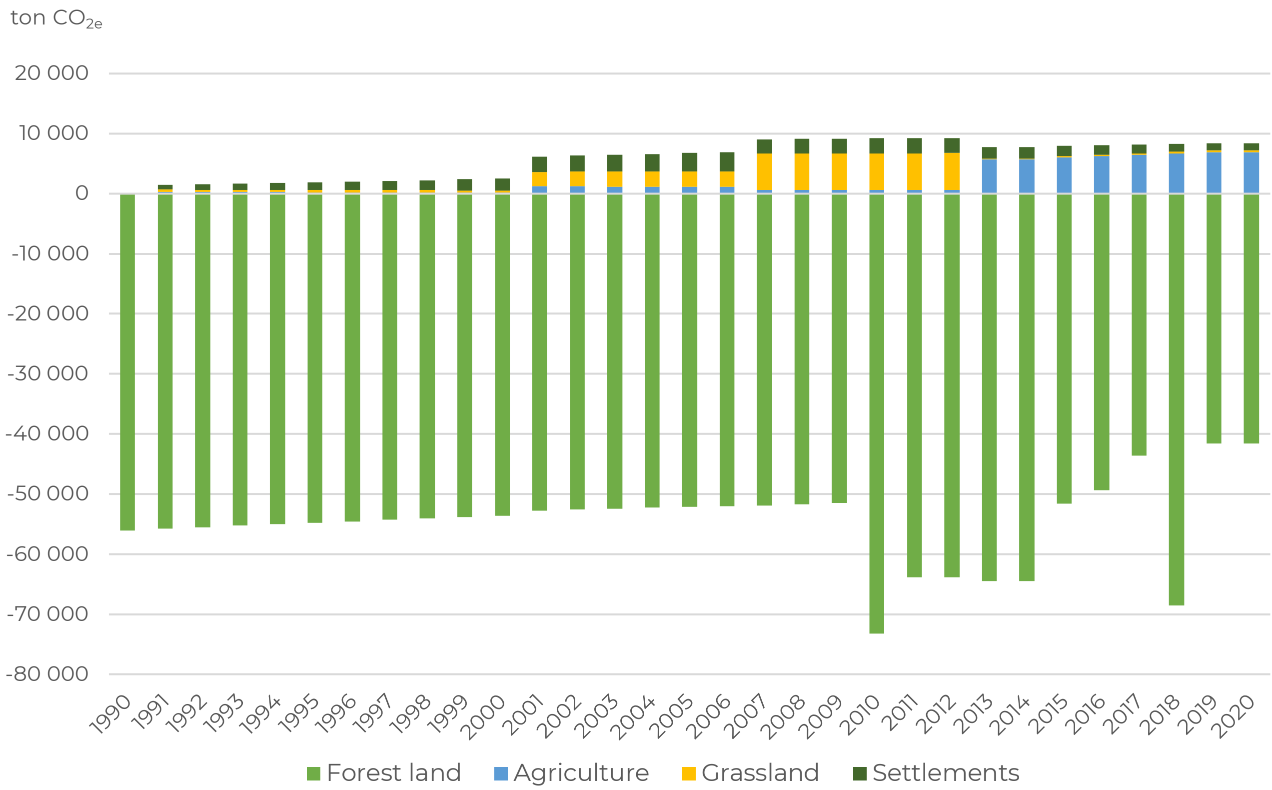

Figure 11 - Land Use, Land-Use Change and Forestry Sector GHG Emissions (1990-2020).

This capacity to offset emissions is, today, around 8.5%, a value lower than it was in 1990 (42.3%), due to the increase of emissions in the remaining sectors. The net sink capacity of the Land Use, Land Use Change and Forestry sector has decreased, compared to 2018. These values are an estimate, as there is no disaggregated data per island — there is an uncertainty regarding these values.

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2.1.6 Waste

The waste sector is currently responsible for 7% of total emissions in the Azores, which represents a decrease in its weight of 11% in 1990.

This weight reduction in the contribution to the total emissions in the archipelago is due to its maintenance over the years, versus a high increase in the other sectors.

This sector covers emissions from the disposal of solid waste, the biological treatment of waste, the incineration and open burning of waste, and the treatment and discharge of wastewater. Emissions from incineration for electricity generation were included in the energy sector.

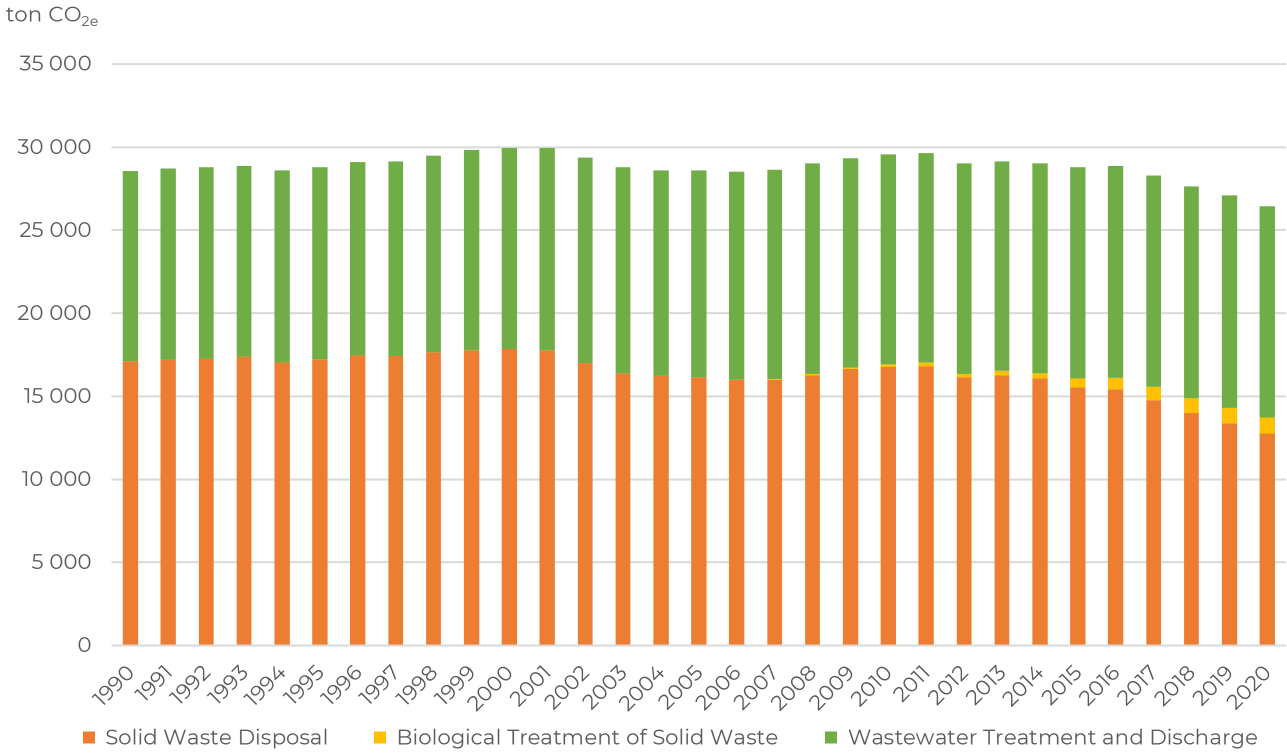

Figure 12 - Waste Sector GHG Emissions (1990-2020).

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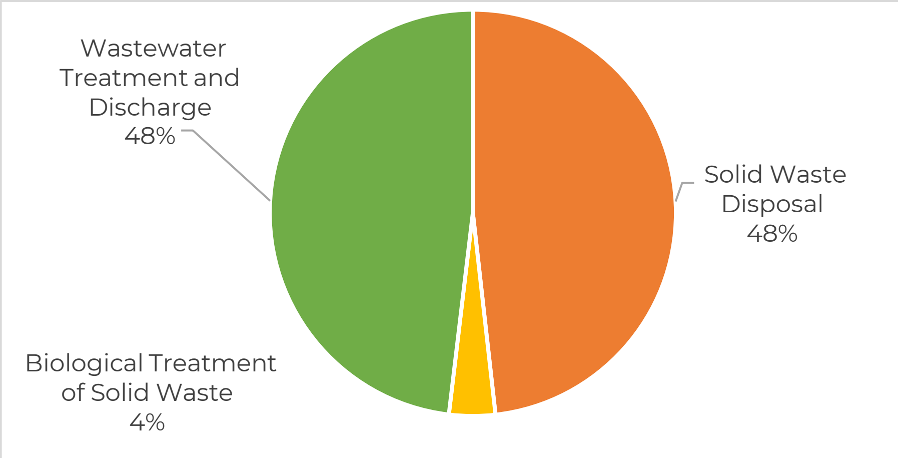

Figure 13 - Distribution of Waste sub-sectors (2020).

According to the data on the treatment of waste on Terceira Island [15] presented in the figure below, the amount of waste deposited in landfills has dropped, as a result of the incinerator coming into operation. It should also be noted that the amount of waste produced has been decreasing in recent years.

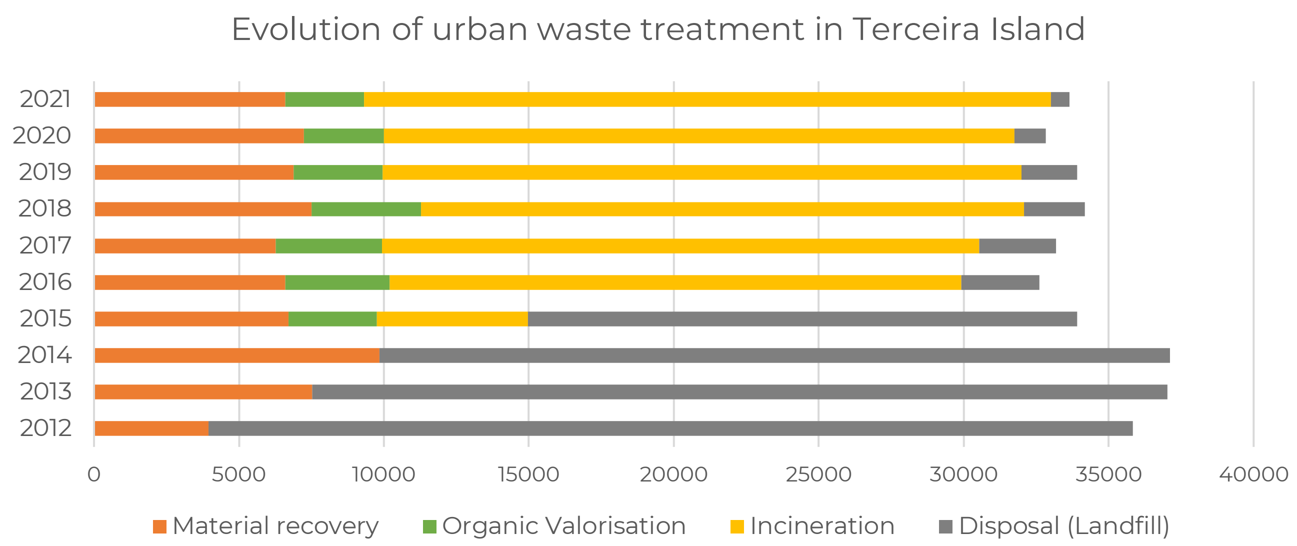

Figure 14 - Evolution of urban waste treatment in Terceira Island (ton/year).

Considering the methodology used to estimate values for Terceira Island from the total values of the Region (the only available information), the effect of the start of operation of the waste-to-energy plant is not easily identifiable in figure 14.

2.1.7 Forecast for 2025 and 2030

The Regional Programme for Climate Change in the Azores (PRAC) [16], published in December 2017 and referencing data from 2014, aims to operationalise the implementation of the Regional Strategy for Climate Change, with the following main strategic objectives:

a) Establish climate scenarios and projections for the Azores (2030).
b) To estimate regional greenhouse gas emissions.
c) To define and programme measures and actions, of sectorial application, for the reduction of greenhouse gas emissions, estimating its reduction potential.
d) To define and programme measures for the mitigation and adaptation to climate change for the various strategic sectors.
e) To define a programme for the monitoring and control of its implementation.

Two different scenarios were defined for the 2030 horizon, one of which hypothesising an increase and the other a decrease in GHG emissions. Given the current policy applied by the EU, the scenario envisaging a decrease in GHG emissions was the one chosen for this study.

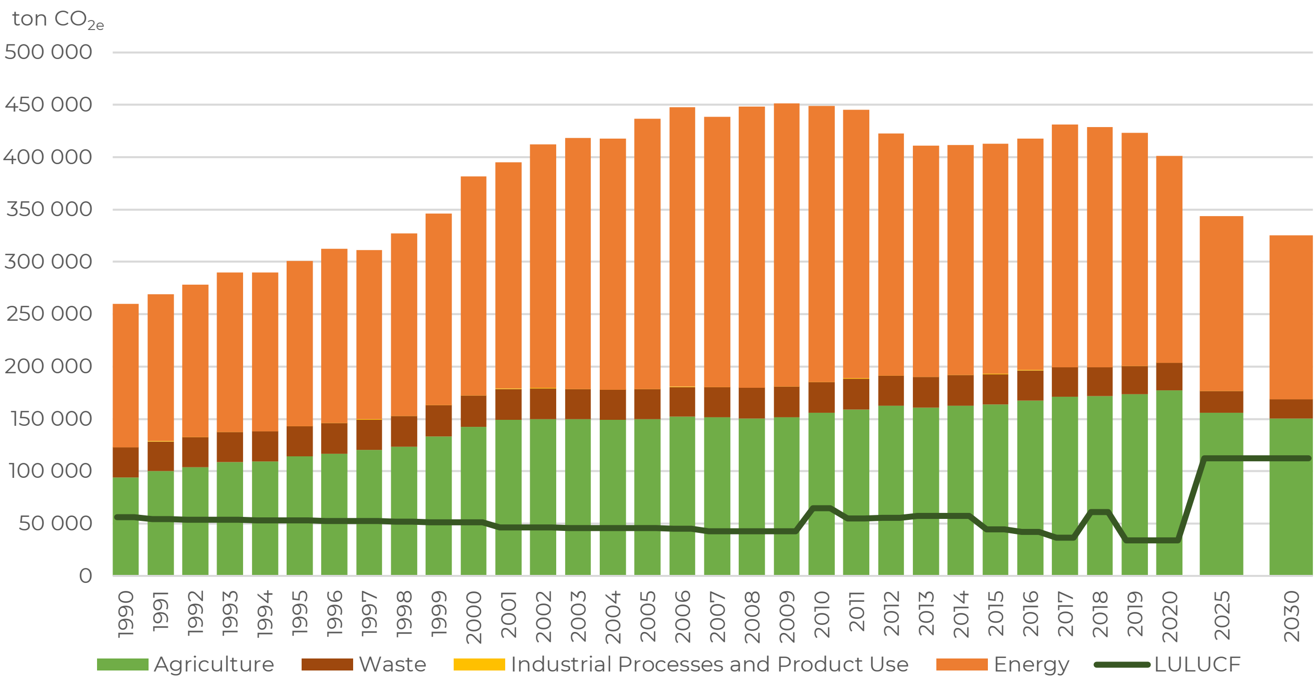

Figure 15 - GHG Emissions (1990-2020) and the forecast for 2025 and 2030.

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Considering that the document of the Autonomous Region of the Azores (PRAC) was drawn 2 years before the publication of the RNC2050, it has been verified that the 2025/2030 goals are not aligned between both. Thus, the regional authorities are expected to proceed with an update to the targets of their document.

Even though the EU targets defined in the various protocols and agreements point to 1990 as the value of reference, in Portugal, the year used as a base for the predictions was 2005, as it stands as the maximum value of yearly GHG emissions.

Table 1 - Comparison of the values for 1990, 2005, 2020 versus 2030.

Sectors	1990	2005	2020
Energy	14%	-39%	-21%
Industrial Processes and Product Use	56%	-18%	-1%
Agriculture	59%	0%	-15%
LULUCF	2%	2%	231%
Waste	-34%	-34%	-29%
Total with LULUCF	42%	-35%	-47%
Total without LULUCF	25%	-25%	-19%

By analysing the table above, we can see that the sectors that will prove most preponderant in the reduction of GHG emissions are: Energy; Agriculture; and Waste. This reduction, however, must be complemented with an increase of the sink capacity (LULUCF).

The energy sector is a fundamental pillar to the promotion of a low carbon economy and the mitigation of climate change. Therefore, the Region is developing strategies and plans that allow, along with the reduction of GHG emissions and respective environmental advantages, an increased RES production, the promotion of energy efficiency, and the increase of and appropriate use of electric vehicles. The Azorean Region has approved the Azorean Energy Strategy for 2030 (EAE2030) by the Government Council Resolution no. 6/2023, 31 January 2023 [17], a guidance document that incorporates the specificities preponderant to its archipelagic and outermost reality, exploring the potential of its natural and endogenous resources, as well as the new technologies currently available, in a constant search for balance between the energy demand and supply.

The EAE2030 sets relevant targets for 2030, aligned with the guiding principles of energy efficiency, electrification, and decarbonisation:

1. Reduction of 50% in the use of butane gas, through the electrification of consumption, compared to 2010, including its elimination on islands with smaller populations.
2. Energy Efficiency of 25% in land transport due to the 25% reduction in final energy consumption in road transport, compared to 2010.
3. Energy Efficiency of 28% in buildings, by reducing final energy consumption in the residential sector and in the trade and services sector by 28% compared to 2010.
4. Energy Efficiency of 40% in enterprises by reducing final energy consumption in the industry, construction, agriculture, and fishing sectors by 40%, compared to 2010.
5. 70% renewable electricity by increasing the ratio of electricity production from renewable energy sources.
6. Energy Efficiency of 33%, due to the reduction of primary energy consumption by 33%, compared to 2010.
7. Reduction of greenhouse gas emissions by 40% for the energy sector, compared to 2010.

The IANOS project solutions (at their scale) will help to reduce GHG emissions. These solutions will reach a limited number of residences; however, its aim is to demonstrate the benefits and encourage their replicability.

The development of a virtual power plant, with the aggregation of small distributed systems, associated smart meters, bidirectional chargers, hybrid transformer, and flywheel, will allow their users to provide grid flexibility for the DSOs. These technologies will optimise energy consumption, resulting in savings for its users.

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2.2 Characterisation of the Energy Sector (Current status and forecast for 2025/2030/2050)

The energy sector significantly contributes to the emission of GHG. Such is the reason why the subsectors of electricity production and road transport will be studied in more detail.

The road to decarbonisation in this sector was defined by the Azorean Energy Strategy 2030 [17], which consists of the following objectives:

- the improvement of security of supply.
- the decrease of energy costs.
- the reduction of greenhouse gas emissions, as well as the minimisation of other environmental impacts.

2.2.1 Energy Industries (Electricity) Subsector

The electricity subsector of the energy sector is one of the sectors that will be scrutinised the most, with significant changes that set a high bar for the increase of the consumption electrification, abandoning LPG use for space and water heating, and walking one step further towards decarbonisation as a result. Therefore, increasing the production of energy from renewable/endogenous origins is necessary.

Given the depth of the oceanic floor and the severity of the Azorean Ocean tides, there is no power interconnection between the islands. Therefore, each island of the Azorean archipelago has its own electricity production system, with a strong dependence on fossil-based production. In the case of Terceira Island, in 2021, about 68.95% of production was of fossil fuel origin and the remaining 25.88% was from renewable sources (wind at 14.96% and geothermal at 9.99%, predominantly), and waste-to-energy (5.17%).

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Table 2 - Electricity Production (2022) [18].

Type of Production	Installed Capacity (kW)	Energy Produced (kWh)	Energy Produced (%)
Thermal	58 116	134 874 088	68.95%
Fuel Oil	49 000	133 591 167	68.30%
Diesel Fuel	9 116	1 282 921	0.66%
Hydro	1 432	1 707 948	0.87%
Geothermal	4 675	19 544 958	9.99%
Wind	12 600	29 255 832	14.96%
Mini / Microgeneration	-	113 441	0.06%
Waste-to-energy	2 720	10 112 340	5.17%
Total		195 608 607	100.00%

Currently, conventional thermoelectric power (diesel/fuel oil) is used as a regulator of the quality of electric power in the grid (voltage and frequency). As a result, during off-peak periods, when thermoelectric power plants are operating at their technical minimum, RES must be rejected from the grid to avoid the shut-down of conventional power plants (Curtailment), which would reduce the capacity of response to increases in electricity demand and may compromise stability. To minimise this problem, EDA has developed a Battery Energy Storage System (BESS) with a power of 15 MW and a capacity of 10.5 MWh (End-of-Life) to increase the integration of renewables. It's also worth mentioning that the installed capacity of the geothermal power plant will increase to 10 MW, depending on the availability of the resource.

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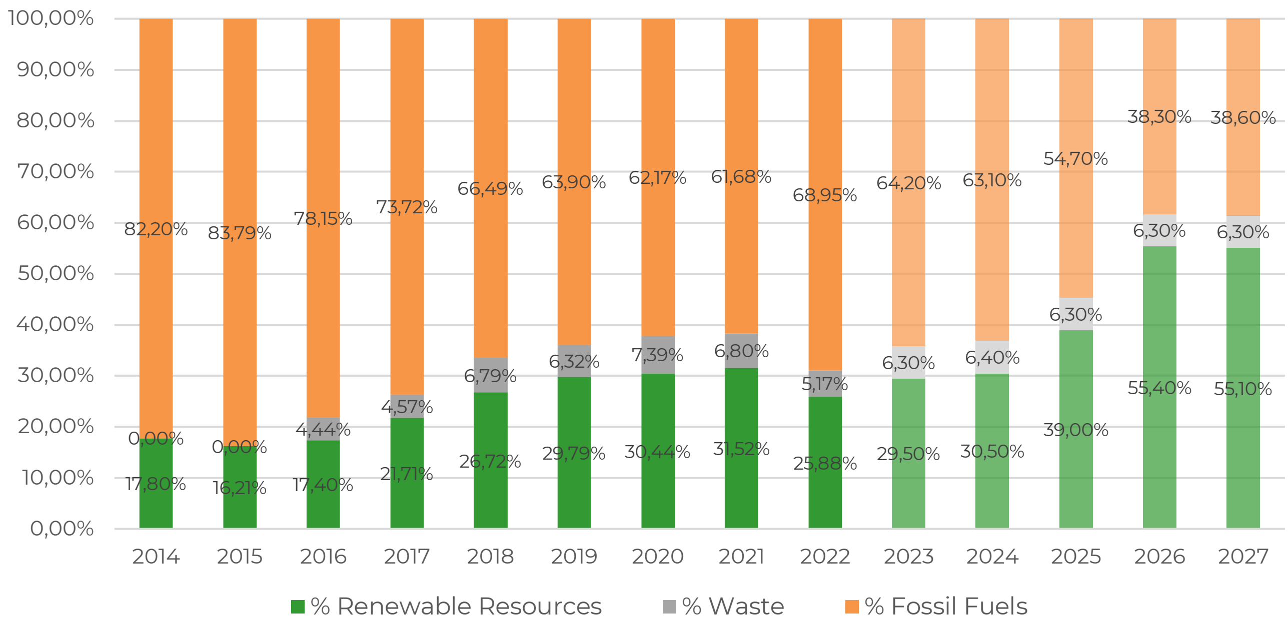

Figure 16 - Evolution of the percentage of renewable/endogenous and waste-to-energy electricity production vs fossil fuels.

According to the figure above, production from renewable sources will increase, due to the BESS, and, in 2026, the percentage will increase significantly due to the increase in the installed capacity of the geothermal power plant to 10 MW.

The contribution from RES is expected to reach more than 60% by the end of 2026. This is a delay when compared with other versions of this document—it can, however, be explained by a setback suffered by the new projects.

The Azorean Energy Strategy 2030 [17] sets the target of **70%** in 2030. In addition, Portugal has recently redefined the target to achieving carbon neutrality, currently set for 2045.

The increase in installed capacity from renewable sources is accompanied by an energy efficiency policy, through PROENERGIA [19]- a system of incentives for the production and storage of energy from renewable sources, which is available to stimulate the production and storage of electricity and heat, essentially for self-consumption. This campaign has several actions, such as, for instance:

- A refund of up to 25% (maximum of €4,000) on the purchase and installation of electricity and heat production equipment.

- A refund of up to 35% (maximum of €4,000) on the purchase and installation of domestic hot water production equipment.

In addition, bonuses are foreseeable for several Azorean islands: 12% for Graciosa, São Jorge, Flores and Corvo; 10% for Santa Maria; and 5% for Pico and Faial.

Another system of incentives has recently become available for the acquisition of photovoltaic solar systems for the production of electricity for self-consumption: SOLENERGE [20]. This system supports 100% of eligible expenses, up to a maximum of €1,500 per installed kW. It aims to increase the PV installed capacity by 12.6 MW.

This program is funded by the Recovery and Resilience Plan.

2.2.2 Transport Subsector

The transport subsector includes, besides Road Transportation, Civil Aviation and Water-Borne Navigation. Due to the emission profile of this subsector, we will focus on road transport in this section since it represents 78% of the GHG emissions.

Given that public transportation only accounts for 16.4% of the population [21], private transportation is the main transportation mode in the Azores, resorted to by about 65.1% of the population [22]. Therefore, the decarbonisation of this subsector involves, mainly, the electrification of vehicles, and an increase in the use of public transport.

The Plan for Electric Mobility in the Azores (PMEA) [12] was developed in response to the regional government's strategic focus on electric mobility. Road transport represents 32% of emissions caused by the energy sector, almost as much as those originating from the energy industry (38%), which is why the electrification of the vehicle fleet could significantly contribute to decarbonisation. Electric mobility in an insular context holds even more importance, since the autonomy of vehicles is sufficient for most of routes, and, if charging is coordinated, the efficiency of the electric system could increase.

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To encourage a shift into electric mobility, the Regional Government provides incentives that can reach €4,550 for the purchase of electric vehicles and €500 for the purchase of the charger [23]. It is worth mentioning that the regional incentives for electric mobility are cumulative with national incentives funded by the Environmental Fund.

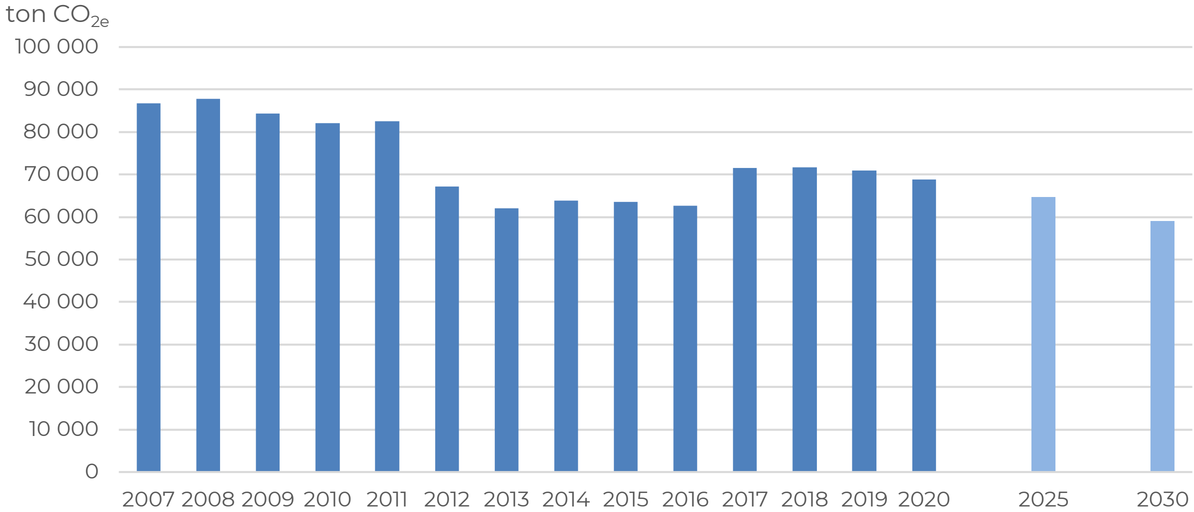

Figure 17 - Road Transportation Emissions.

According to the figure above, there occurred a reduction in emissions up until 2016, countered by an increase in 2017, explained by the growth in tourism rates as a result of the liberalisation of airspace.

2.3 IANOS Project

The IANOS project will focus on the Terra Chã neighbourhood, where solar panels, electrochemical or thermal batteries, and respective control/optimization systems (HEMS or FEID-PLUS) will be installed. Furthermore, the hybrid transformer will feed the neighbourhood, contributing to the improvement of the quality of service through the dynamic regulation of the voltage value per phase.

The flywheel will be installed in a dairy factory, more specifically, in the milk ultra-high-temperature pasteurisation unit, in order to protect the installation from voltage dips, and, thus, improving the quality of the electric power supply to said industrial unit.

Finally, 5 electric water heaters and 2 Smart Energy Routers will be installed, which will replace conventional inverters, adapting production to consumption, sharing information with the virtual power plant.
Although we mention the investments in the Solar Farm, the Geothermal power plant, and the BESS, these are not in the scope of this project, but will help to achieve the defined targets/KPI, and so a short description of them will be made.

Terceira LH Island aims to implement energy efficiency, grid flexibility and e-mobility measures in the context of the island's decarbonisation. According to D9.1, a Master Use Case was defined and will consider the set of UCs 1, 3, 4 and 5 to investigate their replication potential and feasibility, based on the foreseen decarbonisation scenarios [24]. The UCs consider the following equipment's.

2.3.1 Equipment and system specification

2.3.1.1 iVPP – Intelligent Virtual Power Plant

This solution developed by CERTH will control and optimise the consumption of behind-the-meter assets in the user's premises, while considering the comfort of the users.

2.3.1.2 PV panels with microinverter

These solar kits will be developed by BeOn Energy and their main innovative feature is the incorporation of a microinverter, reason being they can be connected to any electric power socket. The nominal power for each installation will be 1.5 kWp (5x300Wp) and requires 10m^2 (around 2m^2 per panel).

2.3.1.3 Electrochemical batteries

These batteries will be standard, with no innovation feature associated, and were installed with sixteen distributed electrochemical batteries with a capacity of 3.3 kWh.

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2.3.1.4 Heat Batteries

Twenty-four heat batteries developed by SUNAMP (Thermino 70 e) will enable the production of domestic hot water heating by using grid electricity and surplus PV energy. These batteries allow a maximisation of thermal power by incorporating a powerful heat exchanger into the Phase Change Material used as storage medium. The heat storage capacity is 3.5 kWh and the volume of hot water available at 40°C is 85 L.

2.3.1.5 Electric Water heaters

The solution developed by UNINOVA allows the non-intrusive characterisation and use of energy flexibility provided by (existing) electric water heaters. It comprises a set of sensors coupled and installed in a non-intrusive manner (there is no need to change or modify a classic water heater) to individual water heaters and the iVPP will provide high level instructions on the grid's flexibility. For purposes of the project, UNINOVA will supply 5 electric water heaters (capacity: 150L) with the sensors already installed.

2.3.1.6 V2G chargers

V2G chargers are bidirectional chargers that, apart from providing energy to electric vehicles, also have the capability of providing ancillary services and grid support. For this project, two V2G chargers (with a rated power of 10 kVA) will be developed by EFACEC MOBILITY and installed in Terceira - one in the EDA headquarters and the other in the Geothermal facility of Pico Alto.

2.3.1.7 Flywheel

The Flywheel developed by Teraloop will provide fast frequency regulation support and power quality, meeting the demands of unpredictable charge/discharge conditions and presenting an inertial load for the iVPP.
The maximum power rating is 100kW, max. energy rating is 3kWh and possesses an efficiency of 95%.

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The function of this equipment is to mitigate the voltage dips in the ultra-pasteurisation of the milk unit, avoiding faults in this process and the consequent economic losses.

2.3.1.8 Smart Energy Router

The Smart Energy Router, developed by UNINOVA, is a power electronic device that manages the energy transfer from/to different sources (distribution grid, RES-based distributed generators), loads and electricity storage systems. In the IANOS project, the intended location for the Smart Energy Router will be at building level (behind the meter). The Energy Router collects data from various energy assets, like PVs (generation profile) and batteries (charge state) and will receive higher-level instructions from the iVPP to control individual assets accordingly. It thus acts as an intermediary between the iVPP and individual assets at building level.

For Terceira Island, there will be 2 smart energy routers, with a battery of 5 kWh (per unit), deployed in existing PV installations.

2.3.1.9 Hybrid Transformer

The hybrid transformer, developed by EFACEC ENERGIA, incorporates two technologies, electrical and electronic, operating simultaneously. These combined technologies will allow a stepless, phase-by-phase, voltage regulation at the LV side, with power factor control and monitoring.

The rated power is 400kVA and rated voltage is 15kV ± 2 x 2,5%/420 V/242 V ± 12%.

2.3.1.10 FEID-PLUS

The FEID-Plus, developed by CERTH, is a fog-enabled computing device equipped with special functions to control I/O, phase width modulation and analog signals. It employs enough processing capacity for applying distributed computing, such as information capturing and storing, algorithm execution, and control over the installation. Additionally, it also has the capacity

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to interface with several field elements, such as controllable building loads, storage, and EV charging stations, through appropriate protocols.

This equipment will gather data and manage local devices by controlling the set-points from the iVPP for the flexibility devices. There will be 20 FEID-PLUS installed in residential buildings of Terra Chã.

2.3.1.11 HEMS

The HEMS, developed by Cleanwatts, will provide real time data to the iVPP, such as energy consumption, generation, charging state of batteries and others, and manage the technological solutions installed in the client's premises. The system is composed by hardware (Smart Meters, Sensors, and Actuators), Data Management (Communication, Data Processing, and other modules) and User Interfaces. There will be 20 HEMS installed in residential buildings of Terra Chã.

2.3.1.12 Solar Farm

A Solar Farm of 2 MWp was installed in Praia da Vitória, but there are some delays and during this year, it is expected to start the operation.

2.3.1.13 Geothermal Power Plant

EDA will invest up to a total of €26 M in the geothermal resource, through the execution of 3 wells and, if they are viable, such decision will allow us to saturate the installed capacity (3.5 MW), as well as increase it up to a total of 10 MW. This is expected to be completed by September 2025.

2.3.1.14 Battery Energy Storage System

This system has a rated power of 15 MW, and the End-Of-Life capacity is 10.5 MWh. This means that the capacity of the BESS in 10 years will be 10.5 MWh. The cost of this system is approximately €14 M [25]and its main applications are:

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- **Static Reserve** and **Grid Forming capacity**, replacing the spinning reserve, and the system will be able to replace a large thermal unit for 50 minutes (start-up time).
- **Primary frequency regulation**, compensating the imbalances caused by the intermittency of renewables.
- **Increase the integration of renewables**, by reducing the number of operating hours of thermal units due to the static reserve and adjusting the load profiles to the availability of renewables.

The project involves 3 different areas: the storage system (BESS); the energy management system of Terceira Island that integrates all of the generating centres; and the secondary control system for the thermal power plant of Belo Jardim, with the integration of all the thermal groups.

The introduction of this system, with the expansion of the geothermal power plant to an installed capacity of 10 MW, could result in the achievement of 60.9% for electricity production based on renewable/endogenous sources.

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2.4 SWOT Analysis per sector

A SWOT analysis identifies strengths, weaknesses, opportunities, and threats, conformed to the decarbonisation of the sectors with the most significant contribution of GHG emissions: Agriculture (Enteric Fermentation); and Energy (Energy Industry and Transport). The LULUCF (Forestry) sector is also mentioned, due to its carbon sequestration function.

The absence of a unique document with a clear and defining strategy of decarbonisation targets, with the different sectors of activity in the Region under cross-alignment, hinders the possibility of a more rigorous SWOT analysis. However, it has managed to highlight different items, such as the main aspects to be taken into account in the scope of identifying a path towards decarbonisation in the islands.

The Agro-Food industry sector is the sector that consumes the most electric energy, and it is connected to the agricultural sector. Therefore, the decarbonisation of the electric and agricultural sector will, expectedly, impact the economic activity of the islands.

In the energy sector, while the dimension of the islands facilitates electric mobility and the reduction of emissions in road transport, their dispersion and the unfeasibility of interconnections are an obstacle to a deeper integration of RES.

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Table 3- SWOT analysis per sector (Terceira).

Sector	Strengths	Weaknesses	Opportunities	Threats
Agriculture	• Reduction of the number and size of agricultural and stock farms (reduction of livestock numbers); • Improved productivity through animal genetics; • Improvement of animal nutrition; • Substitution of mineral fertilization by organic compost; • Growing demand for organic products.	• Activity sector with high relevance in the Region's economic and social structure.	• Diversification of the Region's economic structure.	• Low social acceptance; • Possible increase in the cost of food products.
Energy	• Potential for use of RES; • Islands where the dimensions of car routes facilitate electric mobility.	• High geographic dispersion between islands; • Islands with isolated micro-grids (unfeasible interconnection); • High cost of electric vehicles.	• Higher RES utilization contributes to greater energy autonomy; • Emergence of new economic activities alternative to agriculture; • Increase energy efficiency.	• The islands' scale factor hinders the economic viability of investments.
Forestry (LULUCF)	• Increase in CO_2 sequestration capacity.	• Land use for agricultural production.	• - Economic alternative to traditional agricultural activity.	• Agriculture and farming.

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3 Ameland Demonstrator

Ameland is one of the 5 inhabited Waddeneilanden (Wadden sea islands). The islands total size is 58.83 km^2 and consists mostly of sand dunes. It is the third major island of the West Frisians. Ameland is connected to the mainland electrical grid and to the mainland natural gas grid. There are four villages in Ameland: Hollum, Ballum, Nes and Buren with a total population of 3,673.

Figure 18- Ameland Island location.

The total energy usage in Ameland is approximately 490 TJ per year, excluding the NAM-platform (NAM is a joint venture between Shell and Exxon Mobil, responsible for the exploration and extraction of natural gas and oil from Dutch soil). The NAM-platform now uses the gas it produces for gas compression which amounts up to 410 TJ/year. In 2022 the compressor will be replaced by an electrical compressor which increases the energy flow to the island with approximately 180 TJ/year.

Ameland is a frontrunner in addressing the climate challenges with an integrated approach targeting consumers, tourists, and local companies, as well as realizing more distributed renewable energy sources and adjusting grids (heating, gas, and electricity) to accommodate these new energy sources.

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3.1 GHG emissions per sector (historical data, current status, major measures and forecast for 2025/2030/2050)

The Dutch Climate Policy [26] states that in 2050 the total CO_2 emissions have to be 0. In 2019, the municipality of Ameland adopted a policy program indicating that Ameland wants to achieve the goals set for climate policy by 2035 – 15 years ahead of the National Policy. In addition to this ambitious objective, Ameland has formulated a number of more qualitative goals: to meet its own energy needs as much as possible, to actively involve the population in the transition process and to share knowledge about Sustainable Ameland projects [27].

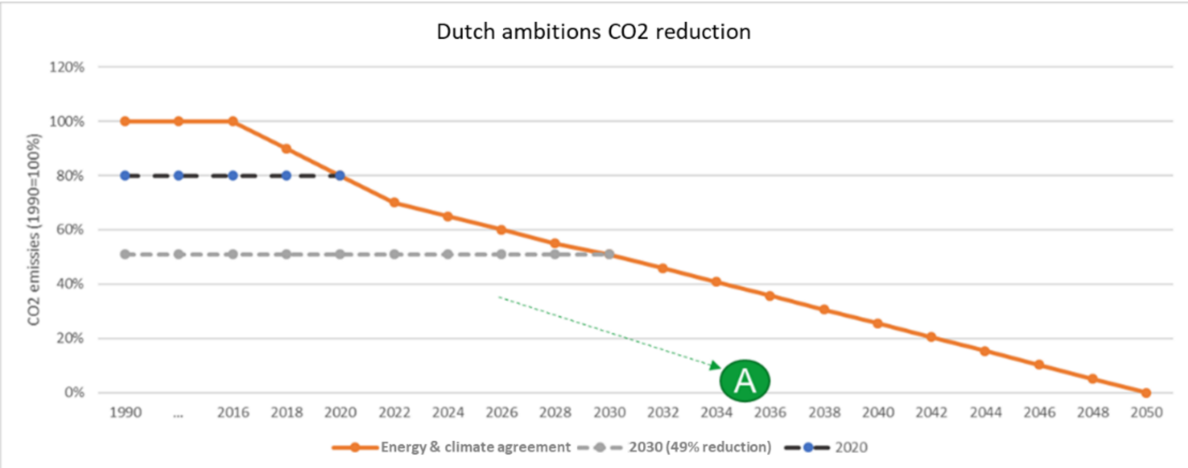

Figure 19- GHG emissions reduction goals for Ameland.

In this policy the municipality acts as a partner in larger projects, as owner of grounds and buildings (including the municipal housing company), and as a facilitator of new projects.

In the coalition agreement - the policy agreements in the college of mayor and aldermen, the Municipal Executive has stated that all possible projects to contribute to sustainable Ameland will be carried out, provided they are financially responsible. Financially responsible projects are projects for which a positive business case is expected, or projects where the contribution from the municipality fits within the budget.

The website Climate Monitor (Klimaatmonitor [28]), a site of the Dutch government, keeps track of all climate related data per municipality. All data used in this chapter is obtained from Klimaatmonitor, including the figures. This website itself does not enrich information but uses existing information, such as statistics, subsidy schemes, sector reports and data from individual institutions and companies. This information is fragmented across all these sources and is therefore not easily found or presented in an accessible manner. The Klimaatmonitor bundles, combines, and integrates this data and presents it in a uniform and accessible way.

3.1.1 Total

The GHG emissions on Ameland totalled 34 kt CO_{2eq} in 2018. The emissions have gradually increased (Figure 20) mostly because of increased emissions by the transport sector (see Traffic and Transport).

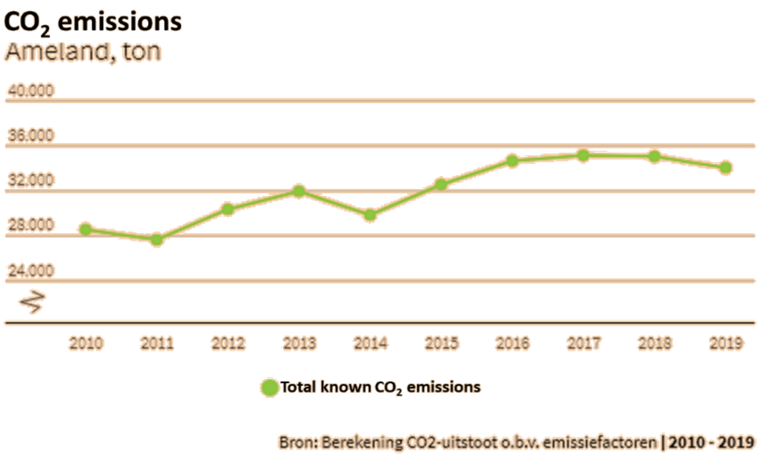

Figure 20- Total GHG emissions per year.

Ameland's energy demand can be divided into the following sectors and subsectors (Figure 21). A different demand profile and CO_2 emissions profile applies per sector and sub-sector, which means that measures to reduce this demand also differ:

1. Built environment: households; holiday homes and hotels; other buildings;
2. Traffic and Transport: public and private transport (including ferry);
3. Industry, Energy, Waste and Water;
4. Agriculture, forestry and fishing.

Tourism - an important sector on Ameland - is (now) divided as a subsector of built environment, and traffic and transport (1st sector).

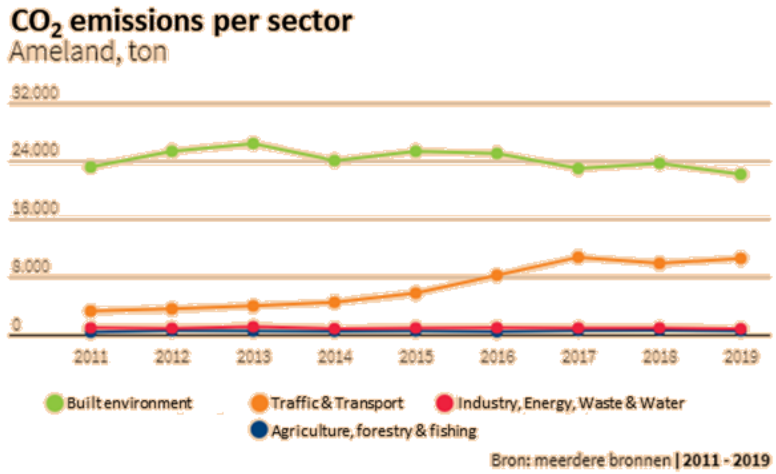

Figure 21- GHG Emissions by sector.

In these graphs the emissions from the NAM-platform are excluded. The platform will be fitted with new equipment in the period 2021-2023 which will reduce these emissions by 51 kt CO_{2eq}. After decommissioning the platform, expected in 2035 another 30 kt CO_{2eq}. will be saved.

According to TNO calculations, the projects already implemented have led to an estimated decrease in CO_2 emissions of 7 ktonnes per year.

3.1.2 Built Environment

The main sector Built Environment is responsible for 22 kt CO_{2eq}. per year. The sector is divided in three subsectors, namely Houses, Commercial Buildings

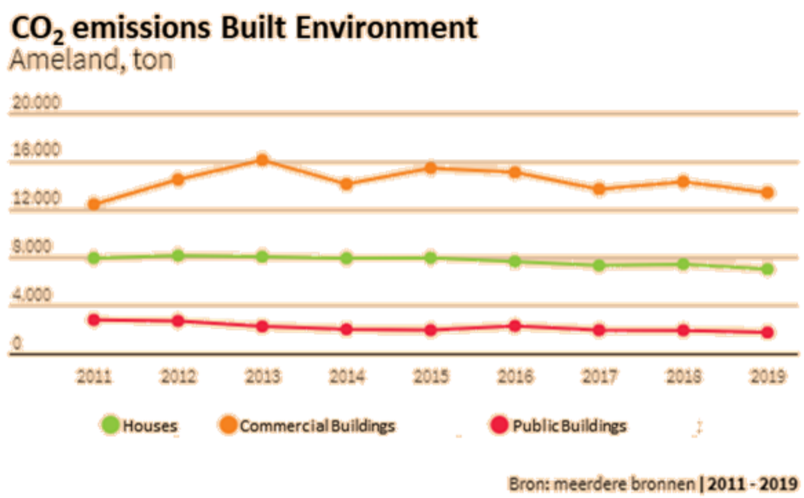

Figure 22- GHG emissions per subsector of Built Environment.

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and Public Buildings. Figure 23 below shows the part of the GHG emissions these subsectors are responsible for.

It is noticeable that the Commercial Buildings are responsible for the majority of the GHG emissions (Figure 23) and most buildings in this subsector are recreational buildings for hotels, bars, restaurant, etc. A lot can be gained by this subsector.

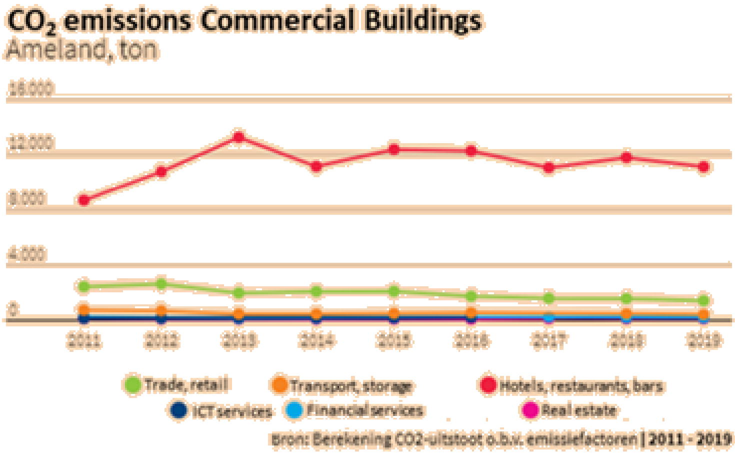

Figure 23- GHG emissions commercial buildings.

3.1.3 Traffic and Transport

The Traffic and Transport sector on Ameland emits 10.5 kt CO_{2eq}. per year in 2019. The emissions of this sector are at 275% of the level of 2005.

All subsectors increased their emissions in the past years, but the graph below clearly shows the large increase of the emissions by the subsector Shipping and Fishing. From 2015 onwards the fairway is being dredged with first 1 ship, later on expanding to 2 ships in 2016 and 3 in 2017.

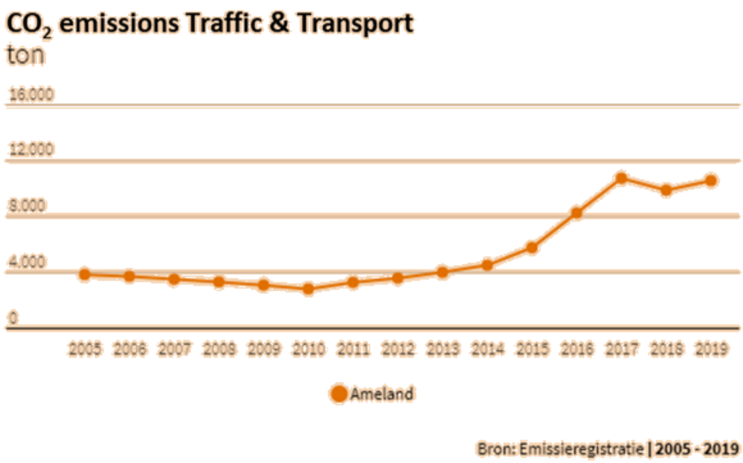

Figure 24-Total emissions of the sector Traffic and Transport.

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The subsector Road Traffic has also increased in the past 10 years with almost 90% because of more tourists and more tourists bringing their cars to the island.

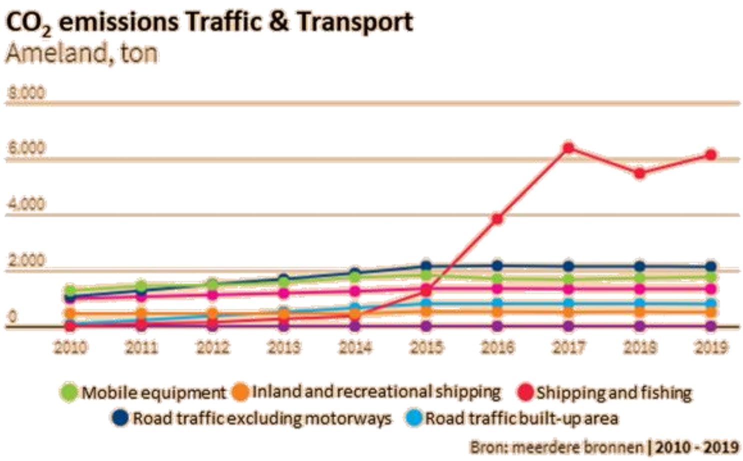

Figure 25- Emissions of subsectors Traffic and Transport.

3.1.4 Industry

The Industry sector is very small on Ameland. In 2019 the sector in total produced 801 tCO_2 in GHG emissions. The subsectors construction industry and industry each produce 219 tons of CO_2 and the water treatment plant produces 360 tCO_2. Other subsectors are negligible.

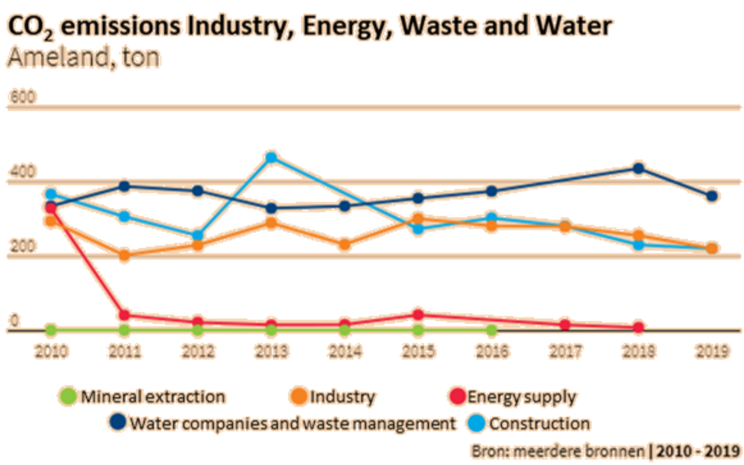

Figure 26- GHG emissions of the sectors Industry, Energy, Waste and Water.

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3.1.5 Agriculture

The Agricultural sector of Ameland produces 518 tCO_2 per year. This is – compared to the total of emissions – a small number.

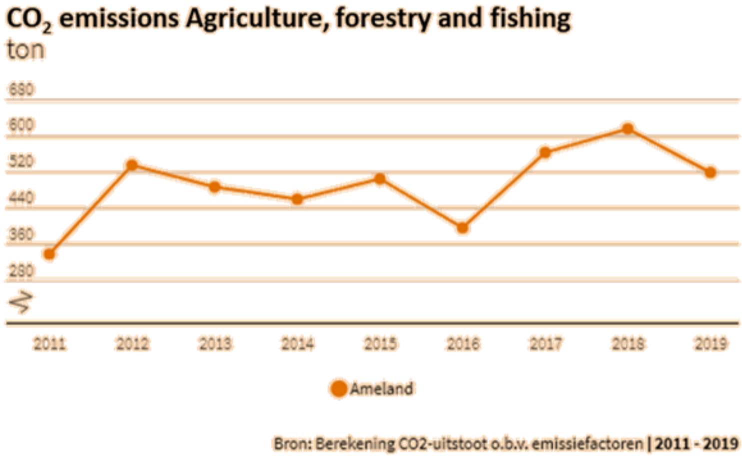

Figure 27- GHG emissions of the sector Agriculture, Forestry and Fishing.

3.2 Characterisation of the Energy Sector (Current status and forecast for 2025/2030/2050)

The Energy sector on Ameland consists of one solar farm operated by the Amelander Energie Coöperatie (AEC), Eneco and the Municipality of Ameland. Besides that, a number of solar panels are installed on residential housing. All other energy is imported from the mainland by cable, pipe or tank trucks.

A lot of effort on Ameland is set to produce (renewable) energy locally. Besides the continuous effort of AEC to help companies, farmers and residents

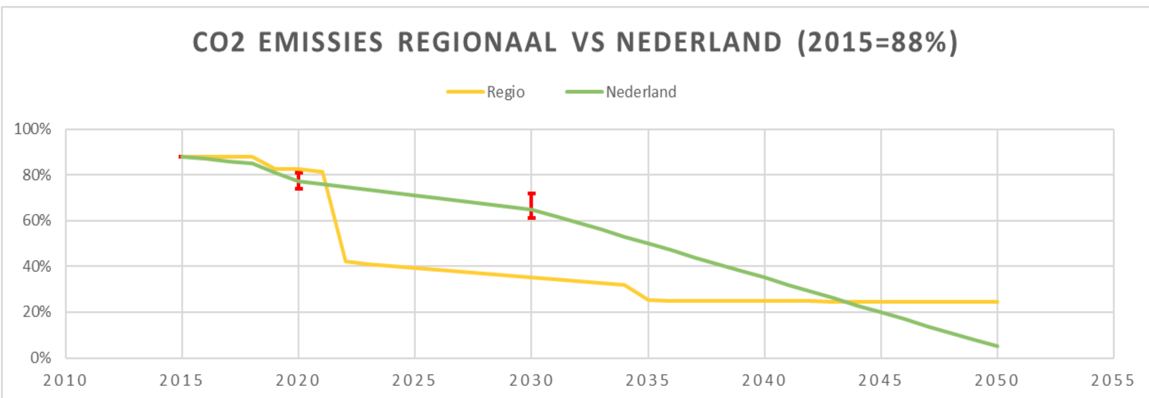

Figure 28- Planned CO_2 emissions on Ameland.

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to install solar panels, a number of larger projects are underway, planned or envisioned.

These projects will reduce the CO_2 emissions from 88% to 22% of the level of 1990. A large part of that is done within the IANOS project. Several projects make more efficient use of energy, i.e., reducing the demand-side. A number of projects increase the supply of renewable energy, such as a solar farm and tidal kite, i.e., increase the supply-side with low or no carbon emissions.

The policy program of the municipality of Ameland sets the goals for a further reduction of CO_2 emissions and adopting more renewable resources in the energy mix. In general, the goal is to meet its own energy needs as much as possible while working on this together with inhabitants and tourists.

3.2.1 Electricity

The municipal policy to meet its own energy needs is especially applicable to the electricity demand. Ameland installed the first large solar park in the Netherlands in 2015 and will continue to install as much renewable energy sources as possible.

Within the IANOS project period there are plans for a new solar park (Zonnepark Ballumerbocht) and plans for a trial of the tidal kite. During the project new plans will be formed for more solar energy, tidal energy, and wind energy.

Electricity will not be the end-product in all cases. When necessary, the electricity can be converted to hydrogen for alternative energy use.

3.2.2 Gas

Because of the fine-meshed gas network in the Netherlands, most of the households and companies are connected to this grid. In the past years a number of programs were in effect to insulate houses with support of the national and local government, to reduce the demand for natural gas. At this moment there are more plans to install a national insulation program.

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3.3 IANOS Project

Since a lot of factors influence GHG emissions reduction and energy efficiency, the IANOS project will not focus on a single system or region but the integration of multiple RES in a smart grid, combined with the reduction of energy usage of residents and tourists. The proposed RES systems are a Tidal Kite, a new solar farm with a storage facility, and more residential solar panels. The integration of the RES systems will not only make efficient use of the energy which is produced locally but will also ensure that no (or less) investments in the electricity or gas grid are necessary.

According to D9.1, the entire set of IANOS UCs that will be implemented by the LH Island of Ameland, focusing both on energy efficiency and decarbonisation aspects, will be examined also in terms of replication and upscaling potential. The Master Use Case will consider the aggregation of all interventions included in the UCs in order to investigate their replication potential and feasibility, based on the defined decarbonisation scenarios [24].

3.3.1 Equipment and system specification

3.3.1.1 Residential solar panels

There are several consumers which have solar panels installed on their roofs. However, it is not known which panels or inverters are installed.

3.3.1.2 Solar farm

In February 2016, the 6 MWp solar park started operation. In the last 5 years this solar park produced 6,600 MWh per year on an average basis. This Park has 3 owners: the municipality of Ameland, Eneco and the Amelander Energy Cooperative. This was the first ground based solar park in the Netherlands. There are 23,000 REC 260PE solar panels installed together with 165 ABB TRIO 27.6 TL OUTD inverters. The electricity is transformed to 10KV by three

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transformers and runs from the solar park in Ballum to the distribution in Nes by a 6 km cable and distributed to the households in Ameland.
Another Solar Park is planned in the Ballumerbocht the specifications of this park will be defined in 2021.

3.3.1.3 Micro-CHP

Three houses equipped with a battery pack (3.5 kWh), solar panels (1 kWe) and micro-CHP (5.5 kWth) were located at multiple locations in Ameland, because of higher gas-prices in the past, only one full installation is left.

3.3.1.4 Private Methane Fuel Cells

Thirty-five privately owned Methane Fuel Cells (2 kWe), fed by the methane district grid, on 35 individual homes are already in operation and funded by the National Project Slimme Stroom Ameland.

3.3.1.5 Fuel Cell

On the largest recreational park of the island, a 200 kWe Fuel Cell will be installed. This Fuel Cell will work as an innovative CHP where the heat produced by the Fuel Cell will be fed into an already existing local heat net. The capacity and location of this fuel cell are still to be defined.

3.3.1.6 Hybrid Heat Pumps

One hundred and thirty-five hybrid heat pumps are already installed in residential houses in Ameland. These hybrid heat pumps are fitted with a 20 kWth boiler and a 1.1 kWe/5 kWth heat pump. The units can switch between natural gas and electricity independently depending on weather conditions. These hybrid heat pumps are prepared to run on biogas as well.

3.3.1.7 Biobased saline batteries

SuWoTec will install a 120 kWh (50 kW charging capacity) biobased battery.

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3.3.1.8 Hydrogen water taxis

Due to a change of priorities for the shipowner external actor that was involved in the Ameland demonstrator, the water taxis cited in previous deliverables will no longer be used. Instead, a newly developed electrolyser will be installed in the Ballumerbocht which should produce enough hydrogen to fuel a hydrogen-based car.

3.3.1.9 Tidal Kite

The TidalKite development, installation, testing and operation will be executed in a separate project. The IANOS scope focuses on integrating the TidalKite into the Ameland grid and in the central dispatcher. The SeaQurrent TidalKite technology is developed to harness energy from tidal flows. It consists of an underwater kite that makes it possible to cover a larger energy harvesting area, perpendicular to the flow.

The TidalKite test setup near Ameland consists of a monopile mooring that anchors this system and a grid connection cable connected to the Ameland electricity grid as operated by Liander.

The total TidalKite system is approximately 100m long. A standard TidalKite has a capacity of 500kW and is connected to the grid via a 10kV power cable.

3.3.1.10 Auto generative High-Pressure Digester

The small-scale Auto-generative High-Pressure Digester (AHPD) described in previous versions of this report will no longer be realized due to financial and contractual obstacles. There are two potential candidates for bio-waste treatment, a digester, and a gasifier. The municipality is investigating the energy content of all available biomass and is developing a business case for the two types. Based on the business case, the possibilities of local entrepreneurship and the overall CO2 emission mitigation a choice between the two will be made.

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3.3.1.11 Electrolyser

A newly developed electrolyser will be installed in the Ballumerbocht. The electrolyser will be 50 kW and can produce up to 1 kg of hydrogen per hour. The hydrogen will be used by a car of the municipality.

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3.4 SWOT Analysis per sector

A SWOT analysis identifies Strengths, Weaknesses, Opportunities, and Threats orientated for the decarbonisation of the sectors with the most significant contribution to GHG emissions, namely Built Environment (heating of households), Energy Production and the industrial platform of NAM.

Other sectors which produce high GHG emissions, such as transport will be affected by new products and new legislation on a national and international level in such a way that the GHG emissions will be reduced "automatically".

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Table 4 - SWOT analysis per sector (Ameland).

Sector	Strengths	Weaknesses	Opportunities	Threats
Built Environment	• House owners are willing to reduce energy usage; • Most homes are privately owned (so the person paying will see return of investments).	• People must be guided into making investments in insulation and heating.	• Current projects which show the residents the "energy leakage" of their homes can seduce them to install better insulation and other types of heating (heat pumps) and/or participating in a heat grid.	• Changing prices (inflation) can withhold owners from making investments; • Bad press can result in lower social acceptance.
Energy Production	• Local Energy Cooperation willing to participate in projects.	• Large part of island is nature reserve and cannot be used for energy production;	• Higher RES utilization contributes to greater energy autonomy; • Increase energy efficiency; • Frontrunner title attracts companies willing to pilot their solutions.	• The islands' scale factor hinders the economic viability of investments.
NAM Platform	• Reduction of GHG emissions by changing the gas-compressor to an electrical compressor.		• Platform will terminate operations in 2035.	• Global energy needs may extend operational period of platform.

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4 Fellow Islands

4.1 Lampedusa

The islands of Lampedusa and Linosa, archipelago of the Pelagie Islands, located between Sicily and North Africa about 113 km from Tunisia and 205 km from Sicily, are administered by the City of Lampedusa and Linosa. From the last census, the islands are inhabited by 5,725 residents. Since 2003, the City of Lampedusa and Linosa manages the Marine Protected Area "Pelagie". Lampedusa covers a surface of about 20.2 km² and a coastline of about 26 km.

Figure 29 - Lampedusa location.

4.1.1 Overview of the current situation and future scenarios

The Effort-sharing Decision (ESD) for the 2013-2020 period required Italy to reduce its non-ETS GHG emissions by 13 % compared with 2005 and for the 2021-2030 period, Italy must reduce its emissions by 33 % against 2005 levels. Italy has remained consistently within its allocated emission allowances and estimates that its planned measures will result in the country slightly exceeding the 2030 target. Key measures for building stock include training, awareness activities and tax deductions, with 110 % refunds for some retrofits through the latest 'ecobonus' scheme, and more general energy retrofitting support available from the National Fund for Energy Efficiency. Heat pumps

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are expected to play a significant role for households, with business and public sector incentives to invest in cogeneration and district heating through the 'conto termico' and 'white certificate' schemes.

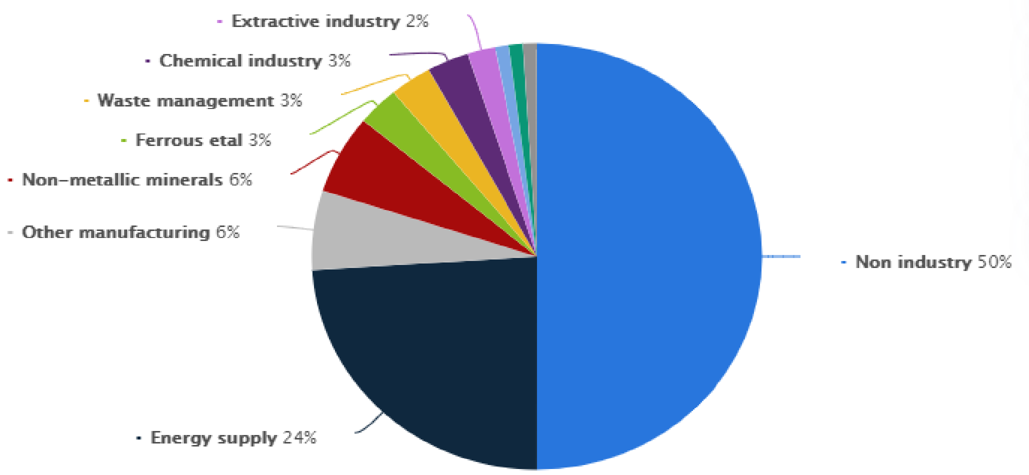
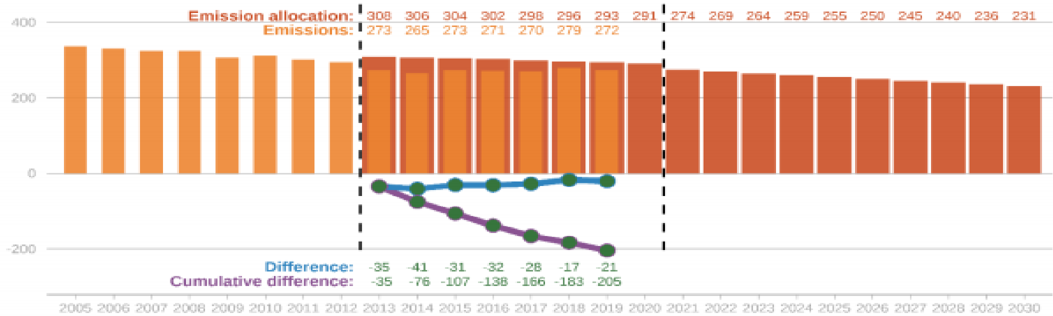


Figure 30- Distribution of industrial greenhouse gas emissions in Italy in 2019, by sector.



Data source: Commission ESD allocation, EUR-Lex and EEA, figures display rounded data.

Figure 31 - Italy's emissions under the Effort-sharing Decision/Regulation ($MtCO_{2e}$).

According to a report by Legambiente and CNR-IIA entitled [29], the greatest limits to development for the smaller islands are not technological and have significantly slowed the development of renewable energy. Here, the contribution of renewable energy to energy requirements does not exceed 6%, whereas in the rest of Italy the figure averages 32% [29]. In order to change this paradigm, the Italian government has encouraged the installation of renewable sources, the reduction of energy consumption and energy efficiency on the smaller islands not connected to the mainland grid.

The Municipality of Lampedusa uses the Baseline Emissions Inventory (IBE) which quantifies the CO_2 emissions in the territory during the reference year

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2018. This data has been presented within the: "Action Plan for Sustainable Energy and Climate. (PAESC)" within the Pact of the Leaders for Climate and Energy. This pact involves thousands of local and regional authorities committed on a voluntary basis to achieve, on their territory, the EU objectives for energy and climate. With their commitment, the new signatories aim to reduce CO_2 emissions by at least **40% by 2030** and to adopt an integrated approach to address mitigation and adaptation to climate change. The Lampedusa Action Plan allows to identify the main anthropogenic sources of CO_2 emissions and, therefore, to assign the appropriate priority to the relevant reduction measures. The elaboration of the IBE is of crucial importance since the inventory will be the tool that will allow local authorities to measure the impact of their actions on climate change. The IBE shows the baseline for the local authority and subsequent emission monitoring inventories will show progress against the target. Lampedusa, decided to adhere to the Covenant of Mayors for Climate and Energy by committing individually to the target of **40% reduction in emissions** and strengthening resilience to climate change. The Municipality of Lampedusa and Linosa, as well as many other municipalities, has decided not to consider, at least in this initial phase, the CO_2 equivalent emissions related to other greenhouse gases such as CH_4 and N_2O and to use for the calculations the standard emission factors identified by the Guidelines prepared by the Joint Research Centre of the European Commission. The standard emission factors, in line with IPCC principles, include all CO_2 emissions from energy consumed in the municipal area, both directly, through fuel combustion within the local authority, and indirectly, through fuel combustion associated with electricity and heat/cooling use in the municipal area. In addition, as many other municipalities, has decided not to consider, at least in this initial phase, the CO_2 emissions from the sustainable use of biomass and biofuels, as well as emissions from certified green electricity are considered zero. In addition to this inventory, emission inventories will be compiled in subsequent years in order to monitor progress against the target. This type of inventory is referred to as an Emissions Monitoring Inventory.

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4.1.2 Total

In accordance with European guidelines, the electrical and thermal consumption, and related emissions of the Municipality of Lampedusa as consumer/producer of energy will be considered for the following sectors:

- Buildings /Industries and Plants:
    - Buildings, public buildings, and facilities (Municipal/public);
    - Buildings, technical equipment/ plants (not public);
    - Technical buildings;
    - Municipal public lighting;
    - Industries (not included the in the EU Emissions Trading System ETS)
- Transports:
    - Local car fleet/categories;
    - Public Transport;
    - Private and Commercial transport logistic.

Lampedusa used the "Standard emission factors" in line with IPCC principles: the inventory includes all CO_2 emissions resulting from the final energy consumption that take place within the municipal territory, i.e., the sum of direct emissions from fossil fuel combustion, including transport, plus the indirect ones that derive from the consumption of heat/cooling and electricity consumption in end uses. The standard emission factors are based on the carbon content of each fuel, as is the case for the national greenhouse gas inventories compiled under the European Union's Greenhouse Gas Inventory [30]. In particular, the final energy consumption and corresponding CO_2 emissions have been defined, in 2018, for the following sectors and sub-sectors is presented in the table above.

Table 5- CO_2 Emissions Distribution (2018).

Sectors/ Sub-sectors	tCO_2	% over the Total
Transport		
- Local car fleet/categories	218.40	0.87 %
- Public Transport (including ferry)	7,466.38	29.88 %
- Private and Commercial transport /logistic (including ferry)	196.99	0.79 %
Buildings, technical equipment/ plants		
- Agriculture	0.0	0.0%
- Residential Buildings households; holiday homes	6,377.62	25.53%
- Public buildings, Plants, and other facilities (Municipal/public)	2,076.61	8.31%
- Commercial Buildings, other technical facilities/ plants (not public), and hotels; other buildings	6,058.41	24.25%
- Municipal public lighting	519.23	2.08%
- Industries (not included the in the EU Emissions Trading System ETS)	2,072.07	8.29%
Other		
- Waste Water Treatment	0.0	0.0%
- Solid Waste Treatment	0.0	0.0%
- Other	0.0	0.0%

Tourism - an important sector in Lampedusa - is (now) included within sub-sectors of Residential building, other technical facilities, and traffic and transport.

The CO_2 emissions of the Municipality of Lampedusa and Linosa, for the reference year 2018 (IBE year), are equal to 24,985.7 tons (4.1 tons of CO_2 per inhabitant); in order to meet the target to 2030 (4% less than the emissions of 2018) it will be necessary to reduce them by more than 9,994 tons. The Municipality of Lampedusa and Linosa aims to reduce emissions by 15,771 tons of CO_2, that is 63% compared to 2018.

4.1.3 Building Environment

The main sector Building Environment is responsible for 70% of CO_2 emissions per year. The sector is divided in six subsectors, namely: Agriculture,

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Residential buildings/Holiday homes, Commercial Buildings/Plants and others, Public Buildings, Municipal public lighting, Industries. The graph below shows the part of the GHG emissions six subsectors are responsible for.

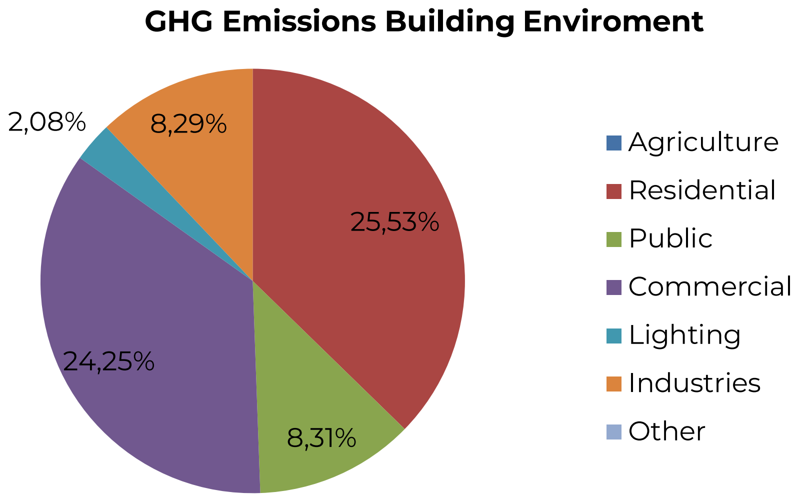

Figure 32- GHG Emissions per subsector of Building Environment.

It is noticeable that the Commercial Buildings and Residential Houses are responsible for the majority of the GHG emissions. Most buildings in this subsector are recreational buildings for hotels, bars, restaurant, for tourism and most of the Residential buildings are holiday houses. A lot can be gained by this subsector.

The Industry sector is very small on Lampedusa. In 2019 the sector in total produced 8% of CO_2 emissions. Regarding the island's labour market, commerce and the hotel sector present the greatest number of commercial activities while, for manufacturing activities, the sectors that present the highest number of local units are related to the production of food, concentrated especially in typical productions and fishing.

4.1.3.1 Traffic and Transport

The traffic and transport sector on Lampedusa emits 31.54% of CO_2 emissions per year in 2018. The sector is divided in three subsectors, namely: Local Car Fleet; Public Transport; Private and commercial Transport.

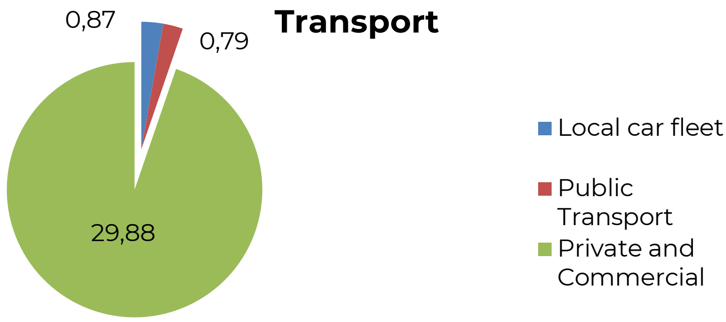

Figure 33- GHG Transport Emissions.

It is noticeable that the Private and Commercial transports, are responsible for most of the CO_2 emissions per year especially during summer period. According to the Municipality, the car fleet of Lampedusa, especially in the tourist period, consists mainly of motorbikes. It is worth to consider the emission values of the Dock source active as well from 9:00 to 15:00 that considers only an average distance of 300 meters made by vehicles, forklifts, heavy and light vehicles (in different quantities) that constitute the traffic related to the handling of goods. traffic related to the movement of goods to and from the ferry.

4.1.4 Characterisation of the Energy Sector

The supply of energy, since there is no direct connection with the mainland, is provided through a diesel thermoelectric power plant managed by the company S.EL.IS. Lampedusa S.p.A. The company has a power plant located close to the town centre, in the district of Pisana and consists of 8 generators coupled to equal number of diesel engines of a total power of 22.5 MVA. The generators work with different scheduling according to the hourly electrical load and the engines work alternating between the primary energy production system and the storage system. As expected, the minimum peak is when neither heating nor cooling is needed, and the tourist season has not yet begun. Differently the maximum peak is in the evening of August in which the island has the greatest number of tourists and the demand for air conditioning is at its peak. Between the winter period and the summer period the monthly value doubles, thus it is possible to affirm that the electric energy in summer is 4 times higher compared to the spring period.

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Table 6- Vector consumer/Electricity demand per year MWh.

Sector Energy Consumers	Electricity Demand (MWh)	%
Public Lighting	855	3%
Residents	9,438	29%
Non-residents	1,403	4%
Tourist Establishments	3,302	10%
Tertiary Activities	3,084	9%
Tertiary Activities such as Bars, Pizzerias and Restaurants	1,596	5%
Industries	1,975	6%
Municipal Users	322	1%
Water Plant and Sewage Plant	366	1%
Desalination Plant	3,509	11%
Hospital	313	1%
Airport	1,865	6%
Military Areas and Barracks	2,453	7%
Self-consumption Power Plant	2,389	7%

The processing of the data of the individual vectors is showing the greatest weight to the residential load, which accounts for 29% of the total load. The second highest weight is that of hotels, which, if added to that of residences intended for tourist accommodation, affects about 15% of the total load. The desalinization plant has a fairly significant weight being 10% of consumption. The consumption of municipal utilities, including those such as the hospital and the water plant and sewage system, are considered with overall cover 3% of global consumption. The very high value of the percentage of self-consumption, equal to 7% of the total, has been a value imposed at the time of data processing in order to take into account within it all those vectors that despite being good absorbers of electricity have been excluded from the research. It is confirmed that in Lampedusa that not all energy consumption is reported within the 12 vectors of consumption identified. In particular, it is important to consider that some users have not been considered because are not belonging to any of the identified categories, the energy requested by them has not been taking into account. Therefore, to include also these small

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deficiencies it has been decided to increase the value relative to the auto-consumption up to 7%.

A lot of effort on Lampedusa is set to produce (renewable) energy locally. Based on the evaluations previously made regarding the demand for electricity to 2025, the objective of this first scenario is to produce approximately 12,300 MWh/year of electricity from renewable energy sources. The first scenario of the project assumes its development in the period between 2016 and 2025 envisaging a mix of renewable energy sources, consisting exclusively of solar and wind energy to which is associated an electrical storage system.

As stated on D9.3, Lampedusa and Linosa have received funding in the order of 41 million euros to be spent on the island's green transition no later than 2026. The municipality of Lampedusa is currently analysing solutions to be implemented with these funds. In addition, solutions are being studied to use these funds as leverage for potential private investments that can exponentially increase RES production on the two islands [31].

Therefore, an overview of potential solutions to be implemented through Italian PNRR funds include for Lampedusa the:

- installation of 300 photovoltaic modules on public rooftops on the island of Lampedusa for a total of 92.4 kWp with an estimated production of 153.2 MWh/year;
- installation of a floating wind system for a total of 1,500/3,000 kWp and a production of more than 5,150 MWh/year at a distance of about 10km from the north coast of the island of Lampedusa;
- installation of a photovoltaic system on the island of Lampedusa for a total of about 2.3 MWp with an estimated production of 3800.0 MWh/year;
- installation of a 2,300kWh electrochemical storage system;
- installation of 15 electric vehicle charging infrastructure on the island of Lampedusa;

The foreseen interventions for Linosa, are respectively:

- installation of 78 photovoltaic modules on public roofs on the island of Linosa for an overall total of 40 kWp with an estimated production of 72.1 MWh/year;
- installation of a photovoltaic system on the island of Linosa for an overall total of 450 kWp and a production of 765 MWh/year;
- purchase of 1 electric-powered bus, 3 electric-powered mini-buses and 3 electric-powered vans to be divided in the two islands;
- installation of 5 electric vehicle charging infrastructures on the island of Linosa.

The municipality aims to conduct techno-economic and feasibility studies with the aim to provide better grid stability through defining effective RES penetration models into the island's grid and addressing critical grid challenges as of congestion, curtailment, and voltage variations, facilitating the island energy transition. IANOS will assist Lampedusa during those studies and the potential implementation of those solutions [31]. The goal for Lampedusa and Linosa is to figure out how to replicate the results achieved by UC 3, 5, 8 and 9. For this, a Master Use Case will be defined on D9.4 (2nd version of the Fellow Islands Replication and Scalability Plan).

In addition, it has been assumed that from 2020 the individual photovoltaic systems on the roofs of buildings will be integrated by as many storage systems with lithium batteries able to dampen even more the peaks of demand and stabilize more demand peaks and stabilize more the island's electricity grid. Regarding the storage system, it has been assumed to use pre-combined modules sodium nickel chloride batteries, salt batteries are in fact increasingly chosen for applications such as the power supply frequently for applications such as the power supply of electric vehicles and storage of energy from renewable sources such as energy from renewable sources such as solar or wind energy as they guarantee safety, reliability, and flexibility of installation. Their most important characteristic is that, thanks to the internal operating temperature of 270° C, they guarantee performance and service life independent of the environmental temperature.

Based on the evaluations previously made regarding the demand for electricity in 2035, the objective of this second scenario is to produce at least 29,000 MWh/year of electricity from renewable energy sources. The plants installed during the period of the first scenario (2025) will be maintained active and integrated with similar plants. They will be complemented by a large offshore wind farm, a wave power plant, and a fuel cell and electrolyser system to produce electricity from hydrogen.

The 2035 fossil free scenario will consider:

- An additional 1 MW of photovoltaic systems will be installed on the roofs of buildings;
- The installation of a 1 MW Tidal energy plant (it is assumed that this will be placed near the west coast of the island);
- The installation of the 1.5 MW offshore wind energy and hydrogen storage system, Lampedusa must wait until these technologies can be found on the market with competitive prices and production reliability. It is important to mention that in 2035 an offshore wind plant can be realized, maybe with floating technology, composed by 3 wind turbines of 1.5 MWp;
- A hydrogen storage system will be installed to serve the entire electrical system of the island.

Besides the continuous effort of AEC to help companies, farmers, and residents to install solar panels, a number of larger projects are underway, planned or envisioned.

A large part of that is done within the IANOS project, through the application of the Virtual Power Plant (VPP) as a cloud-based cluster of intermittent energy generators of wind turbines, solar panels, and sea wave energy in the case of Lampedusa, controlled from a central point. Lampedusa will for sure take advantages by IANOS applications especially for the energy and balance demand and supply of energy on the islands. The policy program of the municipality of Lampedusa sets the goals for a further reduction of CO_2 emissions and adopting more renewable resources in the energy mix. In general, the goal is to meet its own energy needs as much as possible while working on this together with inhabitants and tourists.

4.1.5 SWOT Analysis

The island of Lampedusa, as well as the majority of smaller Italian and Mediterranean islands, is not connected to the mainland electricity grid. Energy consumption and GHG emissions are mainly electrical and mostly associated with the residential and tertiary/tourist sectors. Since there is no direct connection to the mainland, electricity is supplied through a diesel-fuelled thermoelectric power plant, the main disadvantages of using diesel generators lie in the high environmental impact of this technology in terms of atmospheric and noise emissions.

A SWOT analysis identify Strengths, Weaknesses, Opportunities, and Threats orientated for the decarbonisation of the sectors with the most significant contribution to GHG emissions, namely Tourism, Energy (Energy Industry and Transports). The LULUCF (Forestry) sector is also mentioned due to its carbon sequestration function.

The tourism sector is the one with the most electric energy consumption and is related to the transport and mobility sector, therefore the decarbonisation of the electric sector and development of sustainable tourism via penetration of RES will have an expected impact on the economic activity of the islands.

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Table 7- SWOT analysis per sector (Lampedusa).

Sector	Strengths	Weaknesses	Opportunities	Threats
Tourism	• Improvement of Eco-tourism; • Growing the natural environment and protected areas; • Growing of Buildings energy efficiency.	• Low investments in the sector.	• Development of Energy communities; • Reduction of mainland dependency; • Development of sustainable tourism link to agriculture activities; • Possible investors for the development of local product export.	• Low social acceptance and community engagement.
Energy	• Targets achieved for renewable energy production; - presence of resources to support the transition; • Growth in public awareness and consensus and political recognition; • Presence of congenial areas due to their conformation; • Next Generation EU funds for Green Islands 2022-2026	• Islands with isolated micro-grids (unfeasible interconnection); • Diesel thermoelectric power plant managed by private company • High cost of electric vehicles. • NIMBY (Not in My Back Yard) syndrome; • Absence of perception in terms of opportunities (e.g., possibility of new jobs).	• European funding; • European programming; • Global trends.	• Inability and inefficiency on the part of institutional actors; • Changes in the democratic process do not guarantee continuity RES penetration.
Forestry (LULUCF)	• Increase in CO_2 sequestration capacity.	• Land use for agricultural production.	• - Economic alternative to traditional agricultural activity.	• Agriculture and farming.

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4.2 Bora-Bora

French Polynesia (in Tahitian: Pōrīnetia Farāni - Mā'ohi Nui) is an overseas collectivity of France located in the South Pacific Ocean. It is composed of 118 geographically dispersed islands and atolls, 75 of which were inhabited according to 2017 census. French Polynesia is divided into 5 clusters of islands stretching over more than 2,000 kilometres (1,200 mi): the Society Islands archipelago, the Tuamotu Archipelago, the Gambier Islands, the Marquesas Islands, and the Austral Islands.

Bora Bora is a small island located in the Society Islands archipelago (270 km northwest of Tahiti, Oceania). This cluster contains 14 islands, and is divided into two groups, the Windward Islands to the Southeast (Tahiti, Moorea... with a total of 207,333 inhabitants) and the Leeward Islands to the Northwest (35,393 inhabitants in 2017), where Bora Bora is located.

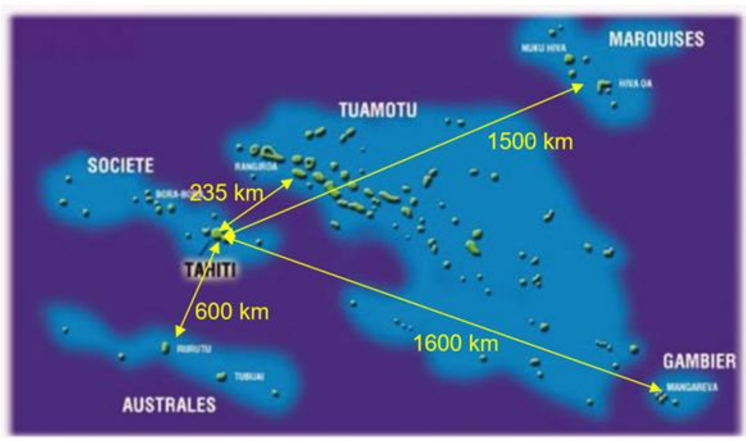

Figure 34 - French Polynesia Map.

Figure 35 - French Polynesia Map.

Figure 36 - Photo of Bora Bora, bird's-eye view.

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4.2.1 Overview of the current situation and future scenarios

The energy transition is core to current development policies in French Polynesia. Within that perspective, the local authorities of the archipelago have been pushing policies to enhance the share of RES in the total primary energy consumption. Several energy transition targets were set in 2013, with the country's law n°2013-27 which envisaged **increasing the share of renewable energies in electricity production to 50% by 2020**. On this point, a multi-year agreement for the period 2015-2020 has been signed between French Polynesia and ADEME (Agency for the environment and energy management). Building on such endeavour, the recent law adopted in 2019 (Law of the country n°2019-27) has set an **ambitious target of 75% of electricity production from renewable energy sources by 2030**. This target is to be met through a support program designed by the French Agency for Development and the Polynesian authorities. Thus, grid operators are required to give priority to electricity from renewable sources over electricity from fossil fuels.

However, electricity production in French Polynesia is still heavily dependent on fossil fuels despite the development of renewable energy sources. Henceforth, the production of electricity is the second greatest source of CO_{2e} emissions in French Polynesia, behind the transport sector.

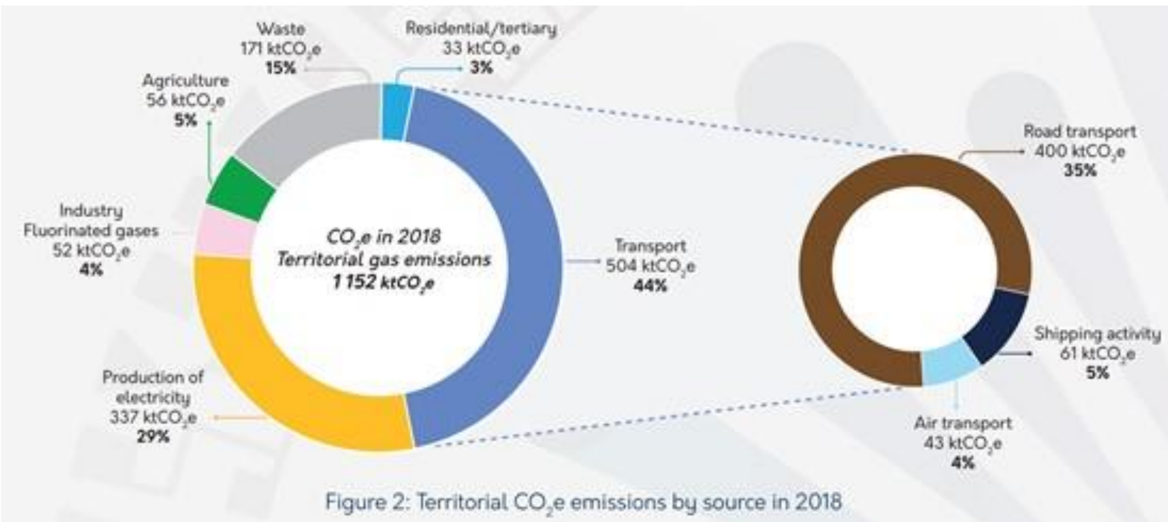

Figure 37 - Distribution of territorial CO_2 emission in French Polynesia by sector in 2018 [35].

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Additionally, electricity production and consumption are unevenly distributed over the territory as they are correlated with the geographical distribution of the population. Tahiti, where most of the Polynesian population is concentrated, will account for 79% of French Polynesia's electricity production and 71% of its electricity consumption in 2019, followed by Moorea (Society Islands), Bora Bora and Raiatea. Excluding Tahiti, Bora-Bora, and Moorea account for approximately 60% of the total energy produced (in "small islands").

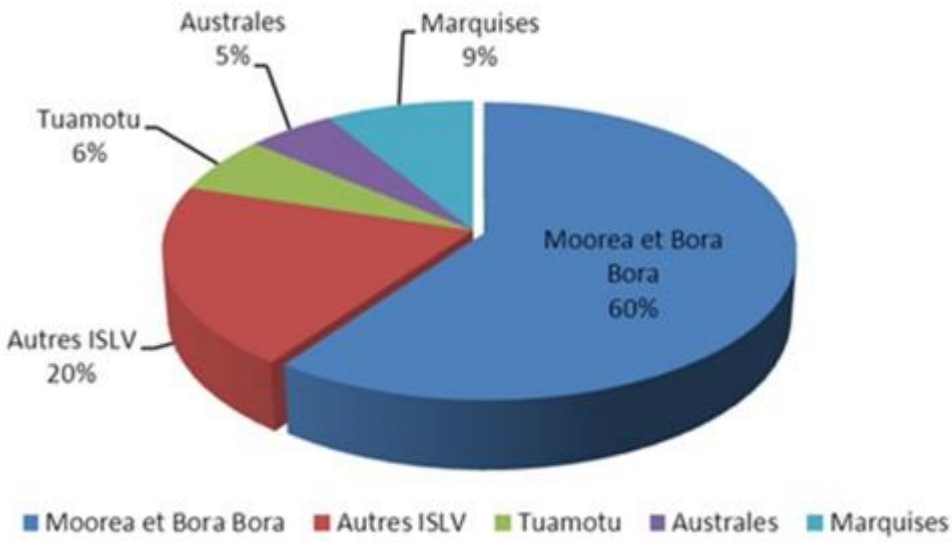

Figure 38 - Power production distribution in French Polynesia in 2013 excluding Tahiti (ISLV designates the Îles-sous-le-Vent, to be translated as the Leeward Islands).

Bora Bora wants to be the first island in Polynesia to achieve the targets of 75% up to 100% for 2030. Within this objective, Bora Bora mayorship has been pushing new policies in the field of electricity production and transports, using renewable energies. The local authorities have set three intermediary milestones to reach its energy transition goals:

- 2024:
  - Reach commissioning and start operation of a 2.5 MWp solar greenhouses power plant run by Akuo;
  - Reach commissioning and start operation of an electric battery storage run by EDT (grid operator);
  - Stop one diesel generator.
- 2025:

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- Reach commissioning and start operation of a 2.5 MWp solar farms and rooftops;
- Stop a second diesel group.

- 2030:
  - Implement hydrogen mobility;
  - Implement Pyrolyzer (thermal elimination of waste + energy production);
  - Reach commissioning of an OTEC (Ocean Thermal Energy Conversion). This OTEC would be the first one to be installed on an industrial scale. Bora Bora is the ideal place to commission this ambitious technology as it benefits from strong local support and from perfect environmental conditions as it requires a warm water surface temperature (located in the tropics) and a cold deep-water temperature (volcanic islands benefit from very steep slopes underwater). The OTEC would act as a baseload, by replacing all diesel units and enabling the 100% renewable energy mix target that would not otherwise be possible;
  - Reach 100% Renewable energy.

These RES objectives support food supply targets, which is a major issue for the island. There are currently 2 boats per week to supply Bora Bora with fresh fruits and vegetables from Tahiti and overseas. The production on the island is very scarce. This situation costs the municipality 1 million €/month, simply to import fresh fruits and vegetables. Building on the objectives for a greater independence and sustainability of the island, mostly through the boost of RES deployment, the mayorship of Bora Bora aims at developing agriculture on the island and enhance its yield through the construction of solar greenhouses, thereby meeting the food security and energy transition goals of the islands, while considering its restricted land availability.

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4.2.2 Total

Following with European guidelines, the electrical and thermal consumption, and related emissions of the municipality of Bora Bora as consumer/producer of energy will be considered in the following sectors:

Transports:

- Road transport;
- Shipping activity;
- Air transport.

Electricity production:

- Fossil fuels-based electricity production;
- RES-based electricity production.

Like most islands, Bora Bora faces pollution from transports and dependency on foreign fossil fuels, whose price is structurally high because of its remoteness. This dependency affects the electricity production capacities of the island.

Electric mobility lies therefore at the crossroads of Bora Bora decarbonization challenges. Being equally important on the roads of the island (EVs) as on the lagoon (electrical boats), in the context of RES development is particularly promising, although the feedback from other islands is extremely important to help to build a strategy.

The data that will support the following sections have been extracted from the 2019 and preceding reports produced by various stakeholders (e.g., EDT, ADEME, Observatoire Polynésien de l'Energie...), for the data from the 2020 and 2021 reports were affected by the COVID pandemic and thus did not best reflect the energy situation of Bora Bora and French Polynesia.

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4.2.2.1 Transport

The main sector Transports was responsible for 44% of CO_2 emissions in 2018 in French Polynesia. This sector is divided in 3 sub-sectors, namely: Road transport, shipping activity, and air transport. The graph below shows the distribution of GHG emissions between these 3 sub-sectors:

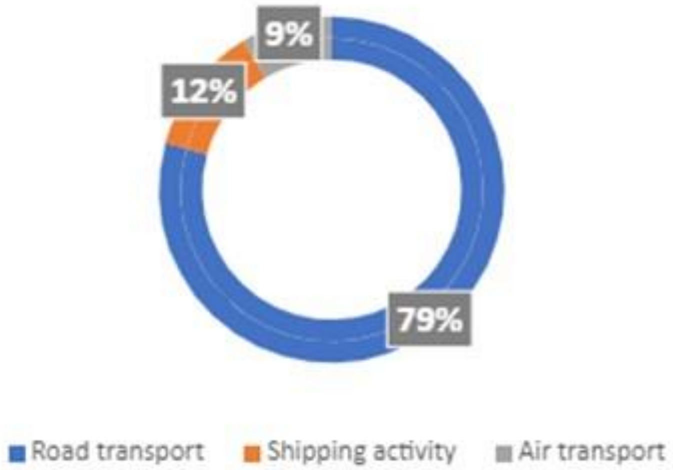

Figure 39 - GHG emissions per sub-sector of transports in French Polynesia, in 2018.

It is noticeable that road transport is responsible for the majority of GHG emissions. Most activities in this sub-sector concern the transport of goods and people. Through the electrification of mobility, decarbonization goals can be substantially advanced in this sector.

4.2.2.2 Production of electricity

The population of Bora Bora is about 10,000 people. Nevertheless, the island welcomes more than 150,000 tourists each year. As the number of people visiting the island is increasing colossally, consumption is even higher in hotels, particularly in terms of electricity and air conditioning, while the network is not sufficiently structured to meet the high demand. In French Polynesia and Bora Bora, air conditioning can account for up to 50% of electricity consumption due to country's year-round tropical climate.

As a result, due to the fragility of the network and electricity systems, all the needs related to tourism sector are difficult to meet. In addition, the price of electricity is very high due to the isolation of Bora Bora from the mainland.

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The electricity production sector is divided in 2 subsectors: fossil fuels-based electricity production and RES-based electricity production. Fuel oil is the main resource of electricity supply, all throughout French Polynesia.

Table 8 - Electricity production sources in French Polynesia, in 2017.

2017	Production inputs		Production		
	m³	KTep	GWh	KTep	%
Fuel oil	69,215	69,4	511	44	70,70%
Diesel oil	44,549	39,8			
Sub-total fossil fuels	113,764	109,2			
Wind		0,01	0,08	0,01	0%
Hydro		15,2	176	15,2	24,40%
Solar		3	35	3	4,90%
Sub-total RES		18,1	212	18,2	29,30%
Total	**113,764**	**127,3**	**723**	**62,2**	**100%**

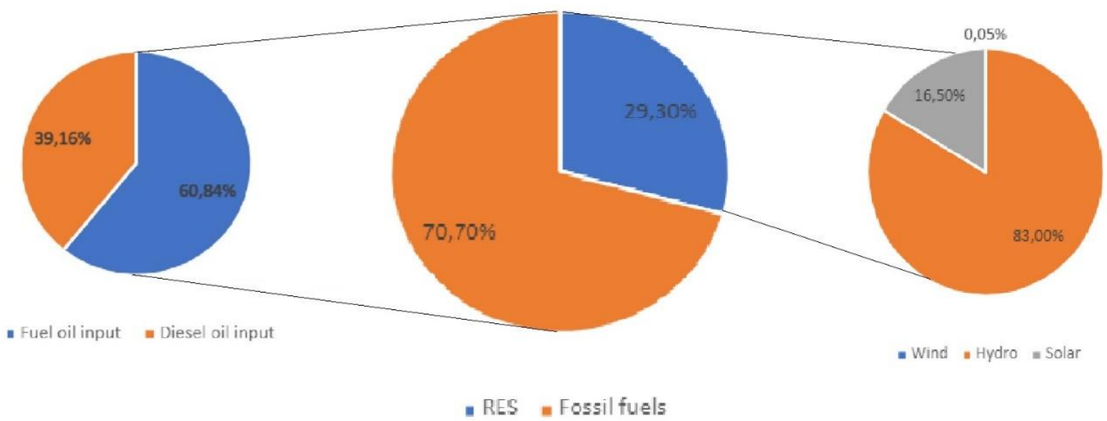

Figure 40 - Breakdown of electricity generation by energy type in French Polynesia in 2017.

Henceforth, the bulk of electricity in French Polynesia is produced by thermal plants. The production of electricity in French Polynesia is consequently responsible of a large share of GHG emissions throughout the archipelago. In 2018, electricity production activities emitted 29% of CO_{2e}.

Bora Bora is not connected to Tahiti and there is only one thermal power plant (with 8 diesel generation groups – 0.64 MW + 3x1,8 MW + 2 MW + 2,85 MW + 2x3,88 MW) that provides electricity to the island. Based in Faanui, it is

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authorized to operate by the decree n°5368/MSE/ENV of August 5th, 2010. At the end of 2019, the guaranteed capacity was 10,890 kW with a peak capacity of 7,690 kW.

In 2019, the island relied on fossil fuels for 99,6% (46,146 GWh) of its electricity generation. Solar production accounted for the remaining 0,4%. This ratio has barely evolved since 2014.

Table 9 - Bora-Bora's energy mix for electricity production (2018).

Source \ Year	2014	2015	2016	2017	2018	2019
Thermal production (GWh)	42,63	42,376	44,045	45,556	44,759	46,146
RES production (GWh)	0,193	0,222	0,186	0,178	0,179	0,198
Total production (GWh)	42,823	42,598	44,231	45,734	44,938	46,344

Henceforth, Bora Bora, and more generally the archipelago, are entrenched in an environmental novice and virtually total dependency on imported fossil fuels. This largely unsustainable situation has been in the scope of several public policies, which seek to change the energy sector not only of Bora Bora, but of the entire French Polynesia.

In Bora-Bora 50% of the water production for the population's consumption is the result of desalination, with high electricity consumption (99.6% fossil fuel).

4.2.3 IANOS Project: Benefits for Bora Bora

The IANOS project should enable the Bora Bora municipality to move closer to its ambitious objectives. The IANOS project, will help the mayor of Bora Bora to achieve 2020' and 2030's objectives. The sector transport will also be concerned. Indeed, all passengers arriving at the airport (in the North-East part of the Island) need to take a boat to travel from the airport to the main island of Bora Bora. Thus, with the creation of a single charging station, which will supply electric vehicles and boats, for their travel from the airport to the centre of Bora Bora.

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On the other hand, with the IANOS project, the application of the Virtual Power Plant (VPP) as a cloud-based cluster of intermittent energy generators of solar panels controlled from a central point, Bora Bora could take advantages by IANOS applications especially for the energy and balance demand and supply of energy on the islands. The policy program of the municipality of Bora Bora sets the goals for a further reduction of CO_2 emissions and adopting more renewable resources in the energy mix. In general, the goal is to meet its own energy needs as much as possible while working on this together with inhabitants and tourists.

4.2.4 Master Use Case (Bora-Bora)

According to D9.3, the main objective of Bora-Bora Island is to increase its energy self-sufficiency for both the supply and demand side by local resources and the proposed replicated solutions by the project. By 2030, Bora-Bora wants to accomplish essential decarbonisation setting the goal of generating 75% of its electricity from RES. IANOS will assist in the deployment of 2 MWp PV agricultural greenhouses and 2 MWp PV shading structures integrated with an energy storage system. The creation of a desalination unit, the installation of solar panels and onshore maritime thermal energy (2 MWth) to support the renovation of the airport's air conditioning, and the building of an electric boat charging station are also in the plan. Relevant UCs to be replicated are UCs 2,3,5 and 8. The Master Use Case, supported by a more detailed dimensioning of envisioned interventions, on the level of systems, will be defined in D9.4 (2nd version of the Fellow Islands Replication and Scalability Plan). [31]

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4.2.5 SWOT analysis

A SWOT analysis identifies Strengths, Weaknesses, Opportunities, and Threats orientated for the decarbonisation of the sectors with the most significant contribution to GHG emissions, namely Energy and Tourism (tertiary sector.

Although the Tourism sector is not identified, it has a great impact on CO2 emissions from the Energy sector, namely with electricity consumption and transport.

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Table 10 - SWOT analysis per sector (Bora-Bora).

Sector	Strengths	Weaknesses	Opportunities	Threats
Energy	• Strong public acceptance and engagement for RES deployment. • Well-spread use of online tools for energy consumption. • Ambitious targets for energy transition. • Growth in public awareness, consensus, and political recognition	• Restricted available acreage for new solar farms. • Island with isolated micro-grids (unfeasible interconnection); • High cost of EVs. • Absence of perception in terms of opportunities (e.g., possibility of new jobs).	• Creation of local energy communities; • Higher RES utilization contributes to greater energy autonomy; • European funding; • European programming • Global trends.	• The islands' scale factor hinders the economic viability of investments.
Tourism	• Improvement of eco-tourism, attraction of new customers. • Bolstering of natural environment and protected areas.	• Activity sector with high relevance in Bora Bora's economic and social structure. • Restricted access to fresh products. • Land use for agricultural production.	• Creation of local energy communities • Reduction of mainland dependency. • Development of sustainable tourism linked to agricultural activities. • Possible investors for the development of local product export.	• Changing prices (inflation) can withhold owners from making investments
Waste and water management	• Resilient and proofed water management systems • Relevant drinking water resources supply	• Remote island with restricted water resources	• Water lenses resources available for drinking water	• High dependency on fossil fuels-based electricity.

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4.3 Nisyros

Nisyros is a volcanic Greek island located at the centre of the Dodecanese Island complex in the Aegean Sea (see figure blow). Its' geographic area is ~40,000 m^2 and the island is inhabited by ~1,000 individuals on a permanent basis. However, the island receives a considerable flux of tourists, their total number topping 75,000 individuals every year, the majority of which visit Nisyros via boat between June and September.

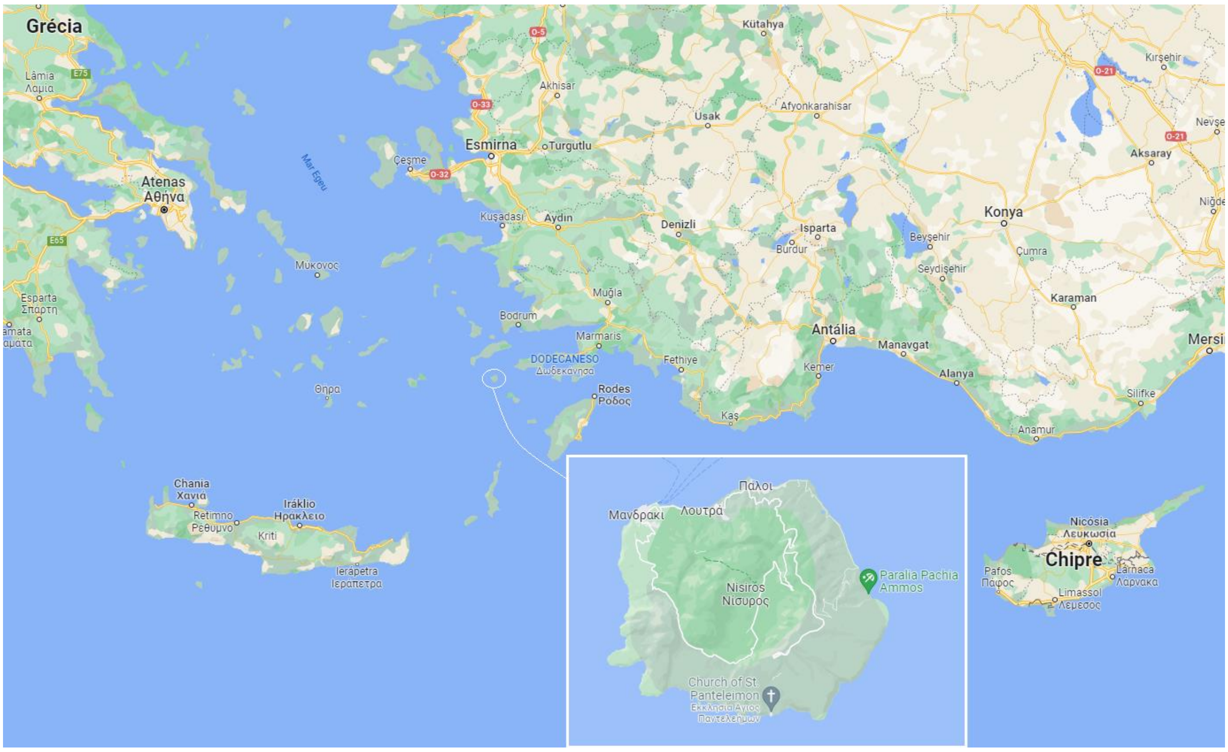

Figure 41 - Geographic location of Nisyros.

4.3.1 Overview of the current situation and future scenarios

The island's energy needs present significant variation, and seasonality, since it is one of the most touristic islands in Greece.

According to the Greek National Statistics for GHG Emissions 6,39 tons of CO_{2eq} are produced every year per citizen [32]. Considering Nisyros' permanent population, the yearly produced CO_2 GHG emissions are thus calculated at an approximate 6,500 tons of CO_2 per year (2016 statistics). These emissions stem mainly from the following sectors:

- Domestic Consumption;

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- Commercial Consumption;
- Transportation and Mobility (diesel fuel based).

Taking into consideration the approximate doubling of the number of inhabitants during summer, the above emissions numbers approximately double. The figure below provides an overview of the electricity consumption on the island, per sector [33].

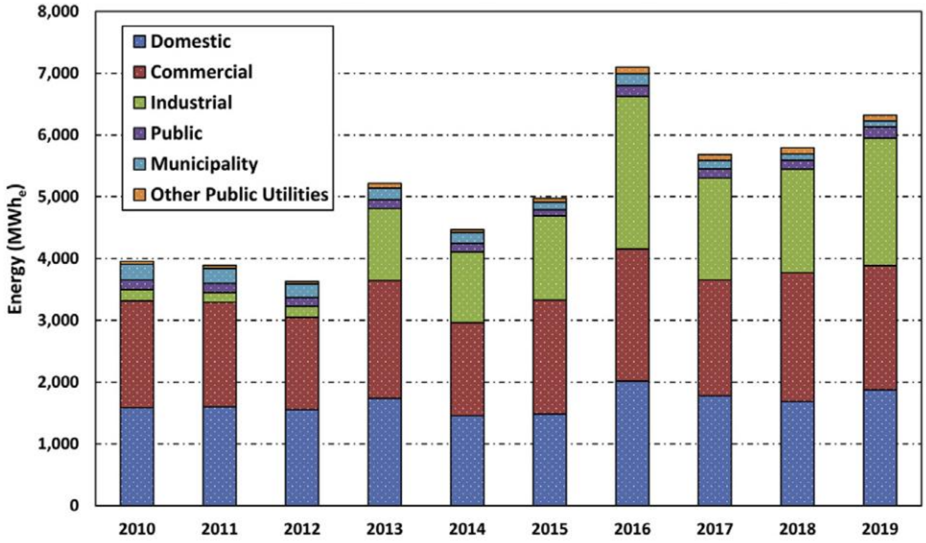

Figure 42- Nisyros Electricity consumption breakdown [34].

As mentioned, Nisyros receives its electricity through an underground cable connecting the island to an oil engine-based microgrid situated in Kos. The underwater interconnection with Kos is often problematic, causing frequent blackouts particularly on the south of the island. Apart from domestic consumption, GHG emissions also relate to Mobility on the Island during the years, as cars, motorcycles, and trucks use oil and diesel from the local gas station. Finally, one of the major sources of GHG emissions is the **Desalination Plant**, which is the biggest energy consumer (1,500 MWh per year) and uses Diesel and accounts for most of the industrial consumption of fig. 42. Peak load demand on the island for the next decade is estimated at approximately 1.6 MWe [33].

In terms of Nisyros' **potential for renewable energy production**, the total horizontal annual solar radiation during the years 2018 and 2019 was 2.500 kWh/m^2, indicating high potential for solar PV installation coupled to BESSs. Nisyros' mean annual wind speed in the southwestern part of the island may

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exceed 6.5 m/s. The island's wind potential at 70m above ground is displayed in Fig. 43.

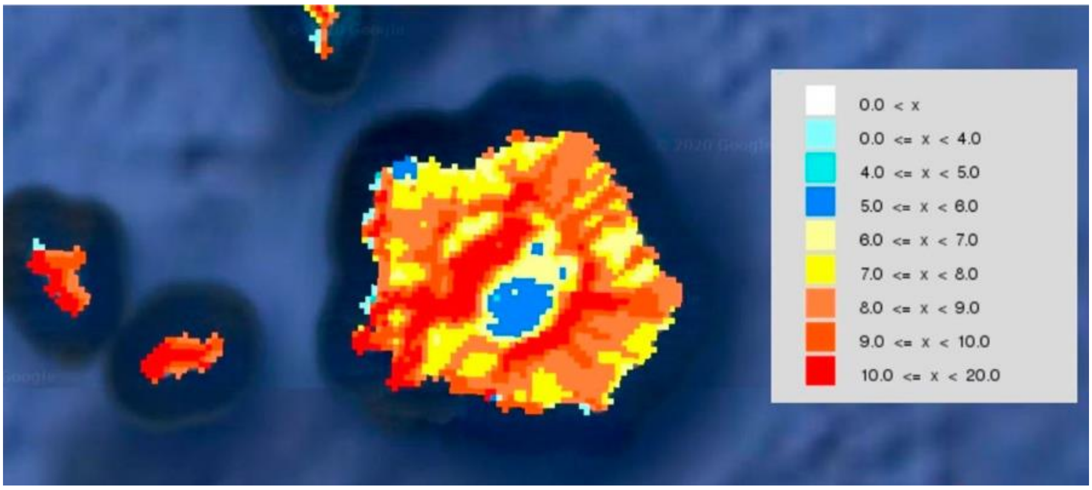

Figure 43 - Nisyros wind potential at 70m above ground.

In addition, Nisyros is endowed with Greece's second-largest confirmed high enthalpy geothermal field. However, despite the island's promise in terms of geothermal energy and also wind energy these technologies have been met with hostility at the community level and have not been systematically pursued further. Finally, the island's biomass production is not considered sufficient for production of energy at significant levels.

Particularly solar and geothermal, and secondarily wind power, therefore present excellent potential for increasing RES penetration and decarbonizing amongst others both the desalination plant and also part of the mobility sector. In this scenario PVs could be used for powering the charging stations. Kaldellis et al. Recently presented various scenarios for adoption of EV mobility on Nisyros (see figure below).

EVs – integration scenarios	Annual energy consumption (MWh_e)		Fuel saving (lt)		Liquid fuels percentage reduction	EVs' charging stations required
	Min	Max	Min	Max		
S-1: 10	15	20	8000	10,000	3%	3–5
S-2: 50	75	100	40,000	50,000	15%	10–15
S-3: 100	150	200	80,000	100,000	30%	15–20

Figure 44 - Scenarios for introduction of EVs in Nisyros.

From the above analysis and data, it is obvious energy plays a crucial role on the GHG emissions. Therefore, Nisyros recently designed an Energy transition

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towards RES using friendly methods as a result to achieve the ZERO Status (Zero Waste and Zero Emissions).

4.3.2 Overview of the Decarbonisation plan of Nisyros

At a national level, Greece has carved out its intentions and strategy relating to decarbonization and its future energy mix in a broader "National Plan for Energy and Climate" (2019) [35], followed by a more specialized "Plan for a Fair Energy Transition" (2020) [36].

At a regional level, the Decarbonisation Plan of Nisyros is based on the Master Plan for the Energy Transition of the Island where the Municipality aspires to develop Renewable Energy sources through Photovoltaics, Small Wind Turbines as well as Geothermal power with low enthalpy. To be more specific the plan of Nisyros is the following:

- Delivering and installing photovoltaics in Public Buildings;
- Working with local Universities, European Union authorities as well as the Greek authorities as a result to design and install photovoltaics on the Households buildings apart from others. With this goal Nisyros aims to eliminate the Energy poverty and from the other side to create all the necessity initiatives as a result the citizens to participate in an Energy community;
- Making the Desalination and Wastewater treatment facility to be powered by Energy systems with Smart PV systems with sufficient storage as a result the system to work with self-sufficiency and the facilities to work with Solar Energy. The photovoltaics will be installed in Public areas with total coverage 8,900 m^2;
- Apart from that, according to the energy transitions plan of Nisyros, two small wind power turbines with 250 kW capacity each will be installed, as a result to create sufficient energy that will supply the energy needs;
- Regarding mobility on the Island, the Municipality together with the Scientific authorities has designed the transition to Electric mobility, installing 15 Electric Vehicle Chargers in all the Island regions including

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the four (4) villagers. In addition, initiatives are going to be established to encourage citizens to substitute their vehicles with electric ones.

To these ends, the Nisyros Municipality is actively participating in various projects, at different levels, aiming initially at carrying out the relevant studies (feasibility, dimensioning) relevant to the introduction of RES. Nisyros is thus a Follower Island in the IANOS project; a beneficiary island in the EU-funded project NESOI; a beneficiary of the European Union City Facility of the Covenant of EU Mayors; a member of the Greek DAFNI Network; and others

Through participation in a multitude of EU-funded projects and energy related networks, Nisyros aspires to eventually reach its goal of zero emissions, and to be able to produce all the energy it consumes.

4.3.3 Master Use Case (Nisyros)

Nisyros aims to boost RES penetration and decarbonize its energy grid via the construction of both a PV park and a wind farm with a total capacity of 570kW and 1.7MW respectively. The existing municipal fleet (32 vehicles) will be replaced by electric vehicles (EVs) powered by 12 PV-based charging stations that will be coupled with innovative grid scale storage systems. The Master Use Case will include the innovative technologies of Saline Battery (SuWoTec) and Flywheel (Teraloop) that are demonstrated in IANOS project. UCs 1, 4, and 8 are expected to be considered for the formulation of the MUC [31]. The following system assets and interventions will be considered:

- PV park (570kW);
- Wind farm (1.7MW);
- 12 EV charging stations: (AC 22kW each);
- Energy storage systems [240kWh] (2 bio-based saline batteries in the 120-kWh variant, developed by SuWoTec);
- A Flywheel (with a capacity of 250 kW) (developed by Teraloop).

This Master Use Case will be further elaborated in the D9.4 (2nd version of the Fellow Islands Replication and Scalability Plan).

4.3.4 SWOT analysis

A SWOT analysis identifies Strengths, Weaknesses, Opportunities, and Threats orientated for the decarbonisation of the sectors with the most significant contribution to GHG emissions, namely Energy (Energy Industry and Transports) and the Tourism (tertiary sector).

Table 11 - SWOT analysis per sector (Nisyros).

Sector	Strengths	Weaknesses	Opportunities	Threats
Energy	• Potential for use of RES, particularly solar and geothermal, and secondarily wind; • Short distances by car facilitate electric mobility; • Active municipal authorities.	• Current microgrid connection to Kos is problematic; • High costs of EV technology; • Desalination plant places particular strain on the grid.	• EV technologies are promising owing also to the island's small size; • Availability of EU funding; • Creation of energy communities.	• Low social acceptance for some RE technologies; • The island's scale factor could hinder potential economic viability of some investments.
Tourism (tertiary sector)	• Active municipal authorities.	• Tourist amenities that depend on grid stability cannot be provided in a consistent manner.	• Provision of improved services to tourists by avoiding blackouts; • Potential development of eco-tourism.	• Low social acceptance for energy transition.

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5 Conclusions and Next Steps

According to the information presented in this document, the energy sector is the biggest contributor to GHG emissions. This sector includes both electricity production, transports, and the building environment.

Terceira is the biggest of the 5 islands, with a population of 53,311 inhabitants and is electrically isolated (micro-grid). The energy sector, namely the subsectors of electricity production and transport, and the agriculture sector are the most relevant in the emission of GHG. The energy sector is the one that presents the most possibilities for decarbonisation through the electrification of consumption and the substitution of electricity production from thermal origin (fuel oil) for electricity produced from renewable sources with the commissioning of the BESS System (Battery Energy Storage Systems). On the other hand, being agriculture one of the main sectors of economic activity on the island, its decarbonisation presents a more difficult path.

Ameland Island presents a different reality from Terceira since it has a connection to the continental electrical grid and has a population of about 3,700 inhabitants, receiving 600,000 tourists per year. Therefore, the sectors that contribute more to the emission of GHG are the Built Environment, Traffic and Transport. To reduce emissions, the municipality has invested in increasing installed PV power and energy efficiency to decrease electricity imports from the mainland.

The distribution of Lampedusa's emissions is similar to the previous ones due to tourism. Thus, the Building Environment sector is responsible for 70% of the emissions, namely the Residential (25.53%) and the Commercial (24.25%) subsectors, while the remaining 30% corresponds to the Transport sector. Based on the information obtained it can be seen that the path towards decarbonisation can be done essentially through energy efficiency policies and investments in renewable energy sources with storage solutions.

In a similar way as the other islands involved in this project, most emissions in Nisyros are related to the energy sector, i.e., electricity production and transport. It is also worth mentioning that this island is electrically connected to the islands of Kos and Tilos through a subsea cable, and they use conventional diesel generators. The main consumer of electricity on Nisyros is the desalination plant, which runs on diesel. Thus, to change this situation, they will invest in the installation of renewable resources and regarding electric mobility, 13 chargers will be installed to encourage the use of electric vehicles.

Bora-Bora has a high dependence on fossil energy sources, both for the production of electricity (99.6%) and for transport. Similarly, to the other islands, tourism is the activity sector with the greatest impact on the island economy, with a population of 10,000 inhabitants it receives more than 150,000 visitors per year. This activity sector is one of the largest contributors to the emission of GHG resulting from the high consumption of electricity (especially HVAC) and transport, both of tourists and the high necessity of importation of products (food: vegetables and others). Therefore, decarbonisation involves increasing the production of RES, which is expected to reach 75% in 2030. The results of IANOS could help Bora-Bora to identify solutions to achieve this goal.

There is a clear commitment by each of the local/regional governments to maximize the use of renewable resources production on each island. This will lead to an increased installed capacity of renewable sources every year. They tend to achieve the decarbonisation goals with an increase in efficiency and with the electrification of consumptions that were previously made by fossil fuels.

The successful implementation/integrity of the different solutions that make up the project may be vital for the identification of the best path to decarbonisation adapted to the specific reality of each of the islands. In this context, we highlight the role of the following tools: Island Energy Planning and Transition (IEPT Toolkit) Suite helping in energy planning decisions and the Virtual Power Plant (iVPP) in the optimization of integrated management of the different solutions.

Moreover, eventually, new developments/contributions to the plan may arise from preliminary information obtained from the initial implementation phase of the different solutions.

As this is the last version of the document, there will be developments in the project that have not been included, reason why the reading of other deliverables is important, namely D9.2 and D9.4, which aim to present a replication and scalability plan for the different islands of the project. Through the development of the

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project, it may be necessary to submit a new version of the Decarbonisation Master Plan to include the results of the project.

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