Seafuel: Exploring Hydrogen Opportunities for Tenerife

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This report is prepared by the HyEnergy Consultancy in association with partners of the SEAFUEL project, an Atlantic Area funded project.

HyEnergy is an experienced consultancy with over 50 years of expertise within the global hydrogen and renewable energy sectors. It supports stakeholders including industry, local/regional public sector organisations and national governments in transitioning to sustainable energy solutions.

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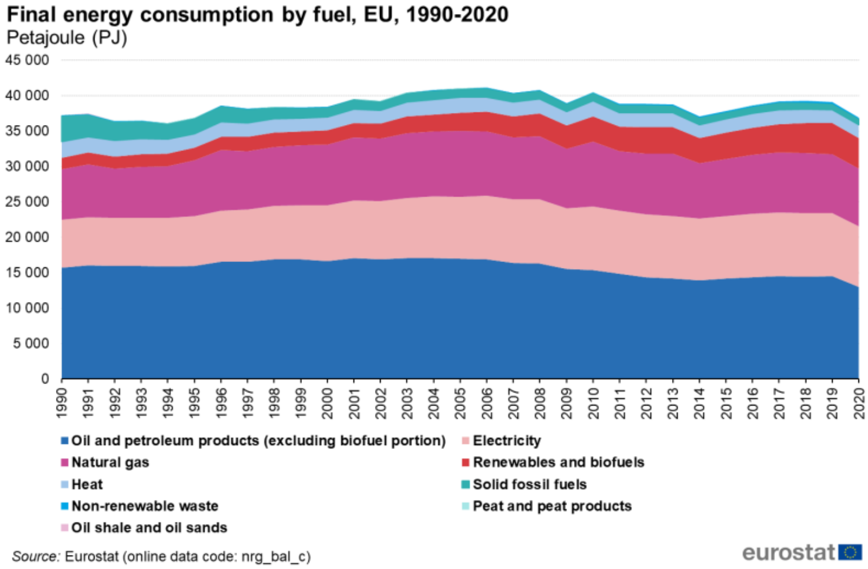
Executive Summary

The push for net-zero has never had more momentum. Hundreds of countries are now committed to legally binding agreements to achieve net-zero greenhouse gas emissions by 2050 through international agreements such as The Paris Agreement and COP 26. Thus, the focus of policymakers all over the world has turned to solve one key question – how can we maximise the impact of renewable and sustainable energy within global energy matrices?

So far, Renewable Electricity Sources (RESs) have made considerable progress decarbonising electricity grids – In 2020, 37.5% of gross electricity consumption in the EU was renewable, a 3.4% increase on the previous year. However, electrical demand represents just a small proportion of the overall energy consumption within the EU (23.2% 2020) - for comparison, Oil and Petroleum products account for 35% of final energy consumption whereas natural gas is just below 22%. Therefore, whilst decarbonising European electricity systems has been successful, more needs to be done to tackle emissions within hard-to-abate sectors where oil and gas remain dominant. Hydrogen will be key to enabling emission reductions in these areas, which has only been further confirmed by the European Commission's actions following the COVID-19 pandemic and tensions between Ukraine and Russia.



Mainland Europe's focus is on replacing the use of grey hydrogen (hydrogen produced from fossil-fuel feedstocks) and natural gas with zero-/low-carbon hydrogen particularly within industry and heating. For the continents' island communities, and isolated regions, however, this plan is not sufficient. These areas often lack local industry and energy networks to implement such solutions and thus require specialised hydrogen strategies. These strategies should consider each area's unique geographic challenges, as well as addressing how to fix the energy dependency and poverty issues which are unfortunately synonymous with living in these environments.

Within the SEAFUEL Hydrogen Opportunity Roadmaps, we have selected 5 of these regions based in the Atlantic Area – Tenerife, Madeira, West of Ireland, South West England, Northern Ireland – and analysed how an effective hydrogen sector could be established whilst taking into account each of their regional and national frameworks. This document, along with the regional SECAPs also produced within WP6 of SEAFUEL, provide local policy makers with a set of recommendations and targets to successfully foster a domestic, local hydrogen sector from a fledgling position to a thriving market.

Introduction

Spain is at the forefront of renewable energy integration, having built a robust electricity system, that utilises both wind and photovoltaics, to reach large renewable energy penetration in the 2000s and early 2010s. The country hopes to utilise its well-established gas storage and transport systems, alongside this success in renewable energy, to propel its green hydrogen production sector to become a major Spanish industry, with international status.

Approved in early October 2021, the Spanish National Hydrogen Plan (NHP) aims to imminently boost the country's clean hydrogen production. The plan seeks to drive rapid growth, with the primary aim of replacing grey industrial production and use of hydrogen with green, with secondary goals related to mobility and other adjacent sectors. The NHP will contribute significantly to achieving legally obligating greenhouse gas emission reduction targets, established through national and international legislation such as The Paris Agreement. The NHP with not only be pivotal to Spain's decarbonisation success, but also Europe's, with the Iberian Peninsula being one of the premier hydrogen production locations on the whole continent.

However, one area in which the NHP is lacking is specialised guidance for Spanish Islands. Their seasonal, highly touristic economies do not fit with the strategy's industrial focus. Thus, several islands have sought to kick-start their local hydrogen economies themselves through participation in European projects, such as Tenerife with SEAFUEL.

Through the creation of a roadmap for the region, the SEAFUEL project is helping the island of Tenerife to realise its hydrogen potential, despite a lack of specific national direction. The following document provides an assessment of local energy matrices, and their relative hydrogen readiness levels, to produce a set of recommendations designed for policy makers. The recommendations provide a broad assessment of what measures and activities Tenerife, along with the wider Canary Islands, can utilise to create a thriving hydrogen economy that plays to their unique societal and geographical strengths.

To understand how hydrogen can play a role in Tenerife, we must first examine the current energy demands of the province.

Tenerife Energy Mix

Spain's relationship with renewable energy has fluctuated since the late 2000s. Originally a massive pioneer of both solar and wind technologies, the country sought to take advantage of their geographically advantageous position for energy generation, but come the mid-2010s little more than 100MWs of installed renewable capacity was added each year due to various changes in government policy. Fast forward to 2019-onwards and renewables are the flavour of the month once more, achieving massive amounts of new installed capacity in an effort to achieve national climate goals and Paris agreement targets – leading to 44% renewable share in electricity production for 2021.

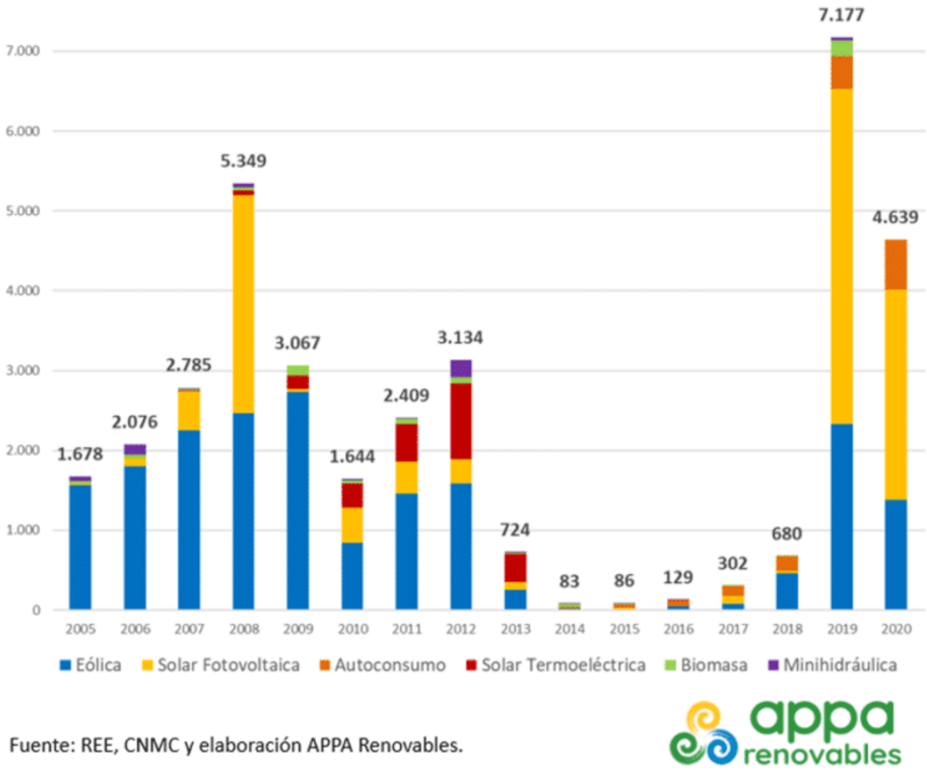


Figure 1: *Installed renewable capacity per year by source in Spain*

In terms of Spanish regions however, Tenerife is still somewhat of an outlier. The region is heavily reliant on imported fossil fuels, due to a lack of indigenous fossil resources, production or refining; with the island utilizing these fuels for the vast majority of their heat and transport energy requirements. In fact, the delta between production and demand are so large that the island's primary energy demand was 6900% of the islands domestic production capabilities in 2016.

Year	Domestic production (1)	Imports - Exports	Bunkers	Stocks Variations	Primary Energy	Final Energy	Final Energy (2)
2015	67,372	7,080,974	-2,372,032	-267,082	4,509,232	3,354,837	3,303,792
2016	68,189	7,015,082	-2,452,172	97,837	4,728,936	3,551,557	3,504,302
2017	70,491	7,321,567	-2,506,864	15,489	4,900,683	3,720,306	3,634,526
2018	100,563	7,219,769	-2,474,164	46,854	4,893,022	3,746,861	3,697,980
2019	145,784	7,032,340	-2,305,672	65,797	4,884,422	3,760,082	3,675,067
Cumulative annual increase (%)							
19/18	44.97%	-2.60%	-6.81%	-	-0.18%	0.35%	-0.62%

(1) Does not include non-energy uses
(2) In 2018, the energy from the hydroelectric power plant for pumping was considered for the first time, as well as the solar thermal energy installations contemplated in the BDFER and the contribution of photovoltaic solar energy generated for self-consumption

It can be seen in the table above that inland production increased by 45% in 2019 compared to the previous year, reaching a historical maximum of 145,784 Toe, this magnitude corresponding to the joint contribution of all renewable energies in the Archipelago (wind, photovoltaic, solar thermal, hydroelectric, mini-hydroelectric and landfill biogas). Despite this remarkable increase, this figure continues to represent a very small fraction of primary energy, its contribution being only 3% of the total in 2019.

In terms of final energy (excluding non-energy uses), the year 2019 has registered a decrease of 0.62% compared to the previous year, amounting to a total of 3,675,067 Toe.

Not only does Tenerife rely on fossil fuels, but they rely on the most polluting and outdated version of this class of fuels – oil. Tenerife, and the wider Canary Islands, does not have a natural gas grid to fall back on to provide energy for heating (etc.) and so a large proportion of their final energy demand is satisfied by oil (roughly 80%), which would otherwise be met by natural gas in mainland Europe. The island has tried to combat this through the introduction of more renewables and less polluting energetic practices, but a lack of land space and deep seawaters, alongside a dated electricity grid, makes the introduction of more and large-scale renewables a difficult process. Thus, currently renewables make up little more than 10-15% of the Canary Island power generation mix

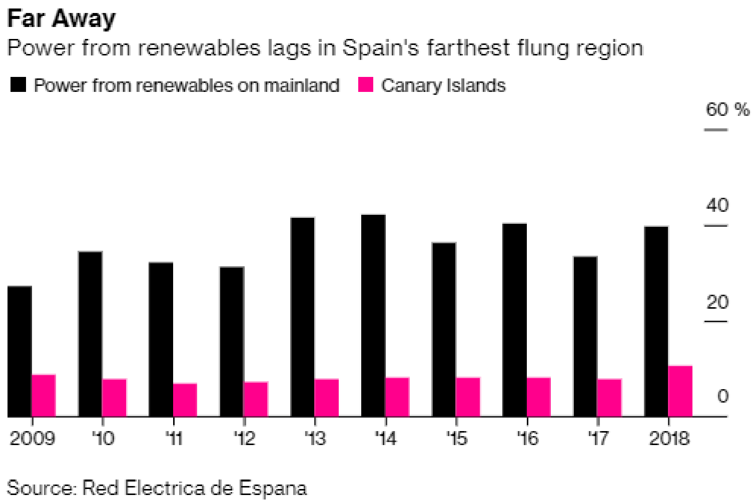


Figure 2: *Power generation from renewables, comparison between mainland Spain and the Canary Islands*

Tenerife's Energy Infrastructure

Electricity

Tenerife's electricity system is isolated from that of the other islands within the Canarys. In fact, this system is made up of six small electrically isolated systems (one for each island), with Fuerteventura's and Lanzarote's being the only interconnected grids. Red Electrica is responsible for the planning, developing, maintaining and operation of the transmission grid and extra-peninsular systems. The company are committed to providing a transparent and functioning energy sector for the Canary Islands, as can be seen from the availability of electricity demand real time data on their website.

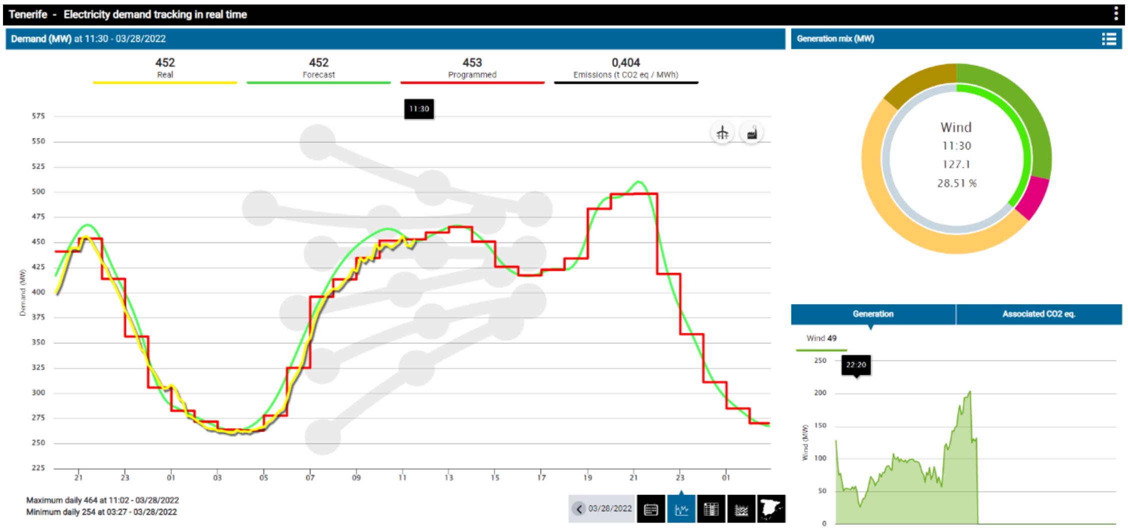


Figure 3*: Red* Eléctrica's Tenerife Real-Time Data (Taken from 28/03/2022, translated to English)

The total gross electrical power installed in the Canary Islands as of December 31, 2019 was 3,320 MW, increasing by 11.4 MW compared to the previous year, that is, an increase of 0.3%. It is observed that this increase was mainly due to the installed power in renewable energies (mainly wind and photovoltaic) in the islands of Tenerife, Gran Canaria and Fuerteventura. The increases in the rest of the islands are not significant.

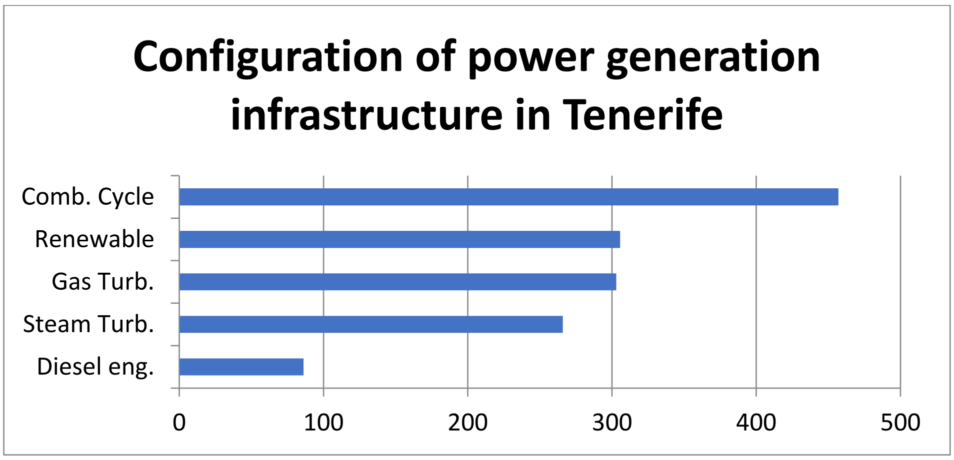


Figure 4*: Overview of the configuration of power generating infrastructure in Tenerife - based of data from Dirección General de Energía*

The small, isolated energy systems, which are presently deployed, lead to a less stable and secure electricity situation, when compared to larger, more interconnected systems where it is possible to guarantee supply through varying demand/production scenarios (e.g. peaks in demand or relatively low RES output). Therefore, it was identified that a change was needed. The Canaries have opted to incorporate energy storage systems, such as a pumped-storage hydropower-plant, to their electricity matrices, with the primary goal of improving the security of supply for the archipelago's residents. The development of new interconnections between islands, to enable mutual island support, whilst improving the meshing of the grid to alternative supply paths, is also seen as an essential improvement. These changes, alongside the constant endeavour to transition the Islands to deploy and incorporate a greater percentage of renewable, or zero-carbon, energies within their mix will see the area transition towards a completely different and new energy model – which is confirmed by the investment the area has accrued.

Investment in the Canary Islands	Key Actions
991M€ Development of the transmission grid: 2015-2020 infrastructure planning	• Strengthening of the transmission grid meshing to have alternative paths that ensure the security of supply in the event of incidents. • Construction of new infrastructure to facilitate the integration of renewable energy.
150M€ Grid Asset Improvement (MAR) project: improvements of assets acquired by Red Eléctrica in 2010.	• Development of new interconnections between islands, allowing mutual support between electricity systems. • Development of energy storage systems to be used as systems operation tools to improve the sustainability of the electric power system of the canary islands.
320M€ Energy storage: Soria-Chira pumped storage hydroelectric power station	• Improvement of the quality of existing electricity infrastructure.

Figure 5*: Recent Major Investment and Key Actions Overview*

One such investment is €103m to create a new interconnection between the islands of Tenerife and La Gomera. This new piece of infrastructure will significantly increase the ability of the two islands to share energy across a larger grid – meaning that there is a reduced requirement for energetic storage across the board. Furthermore, by creating a larger and more robust grid, the ability to integrate a larger amount of renewables can be facilitated in coming years.

Natural Gas

The introduction of *natural gas* in the Canary Islands as a fuel for electricity generation faces significant obstacles. The first of these is that of time: conceived its use in an energy plan approved three decades ago, the energy transition has made obsolescence what was presented at the time as avant-garde, and has left in the background the possible environmental benefit of its utilization.

The result is that the two most important generation plants on the Islands, the Endesa plants in Tirajana (Gran Canaria) and Granadilla (Tenerife) each have two combined cycle turbines that, ready to generate electricity by burning natural gas, will continue resorting to diesel, because the current regional government has shelved the development of gasification.

The National Commission of Markets and Competition (CNMC, Comisión Nacional de los Mercados y la Competencia) is not clear about the projects to install regasification plants in the Canary Islands. No longer, because it considers that they are outdated projects, with millionaire investments of very complicated digestion. CNMC made it clear in two reports, in which it showed its outright opposition to the declaration of public utility for the regasification plant project in Granadilla: 271 million euros for the plant itself and 38 million for the pipelines.

Moreover, regasification projects in the Canary Islands, planned since the end of 1980, are very similar to others that were late in the energy transition from diesel to natural gas as fuel for large thermal power generation plants. The paralyzed project in Granadilla replicates that of the El Musel regasification plant in Gijón (Asturias), a completed installation, which cost 400 million euros, never inaugurated or put into service, which is now seeking a second life as a green hydrogen storage plant.

Finally, the implementation of gas for domestic use in the Islands, the third vertex of the gas triangle, has been left in a deadlock in the Canary Islands after the cancellation, in March 2020, of the regional tender by which the Canarian Government awarded the Redexis firm the installation and operation of the city gas networks in the main cities of the Islands. Only a similar network operates in the Canary Islands, the one that distributes propane gas for hotel facilities in Arona and Adeje, on the island of Tenerife, and is managed by the leading marketer in the Islands, Disa.

Renewables in The Canary Islands, with a focus on Tenerife.

Tenerife, and the wider Canary Islands government, have recognised both the importance and necessity of renewable power to decarbonise their local energy systems. The region is looking to exploit their naturally occurring renewable resources, particularly solar and wind, in order to meet a target of 45% renewable energy share in electricity demand by 2025; a target which some islands have already achieved. The islands are targeting investments in efficiency gains, improvements to the transport network (which is one of the largest CO_2 emitting sectors within the region) and strengthening both interconnections between islands and existing networks to achieve these goals.

Tenerife is in the process of practically realising increases in domestic energy production via renewable energy sources but, currently, it still represents a small fraction of the primary energy mix. The Canary Island government must realise new solutions to tacking their major reliance on fossil-based products if they are to reduce their emissions significantly – as these products still account for 80.23% of the final energy balance (2016). Major renewables growth, such as that seen late 2000s-early 2010s, is unlikely to be seen again due to a lack of available land. Therefore, to further capitalise on growth opportunities, as seen amongst installed wind capacity on the islands in 2018, and reinitiate PV growth, offshore technologies and opportunities must be explored in order to increase renewables penetration whilst not compromising on the size of installations.

In 2018, the Canary Islands managed to reduce their reliance on fossil-based power plant energy, a feat which had not been achieved before when compared to previous year-on-year comparisons. Simultaneously achieving record high renewable energy penetration in the electricity grid (44%) – capitalising on the ~10% yearly penetration increases seen in 2016 and 2017 respectively. However, when taking an average of electricity demand coverage by source across the year, shows that there needs to be much more work done improving renewable capacity and penetration – with just 18.8% of the electrical demand in Tenerife being satisfied by renewables (2019).

	Wind	Photovoltaic	Mini-hydraulic	Hydroelectric	Biomass
Capacity (2019) (MW)	195.6	118.7	1.2	0	1.6
Production (2019) (MWh)	495.251	191.314	3.524	0	8.474

Table 1: *An overview of the current renewable infrastructure installed over the Tenerife (excluding solar thermal)*

During 2008 there was an increase in installed power of 47.4% compared to 2007 as a result of the photovoltaic plants that were installed during that year on the island of Tenerife.

In 2018 there was another large increase in installed power in the last 25 years (44.6%). In this case, the technology that drove the development of the sector was wind generation, installing 126.5 MW in Tenerife, 35.5 MW in Gran Canaria, 8.9 MW in Lanzarote and 13.6 MW in Fuerteventura.

For the year 2019, the increase in installed renewable power has been modest if we take what happened in 2018 as a reference. This increase has been estimated at 3.9%, reaching 636.09 total MW of renewable electric power.

Wind

The Canary Islands saw a major increase in installed wind capacity between 2018 and 2019, growing by over 86% from 184,430kW to 397,269kW with deployments right across the archipelago: eight in both Gran Canaria and Tenerife, two in Fuerteventura and one in Lanzarote. It was always going to be tough to maintain this kind of momentum, but even so the year that followed was markedly disappointing, seeing an increase of just 4% to 413,269kW of installed capacity.

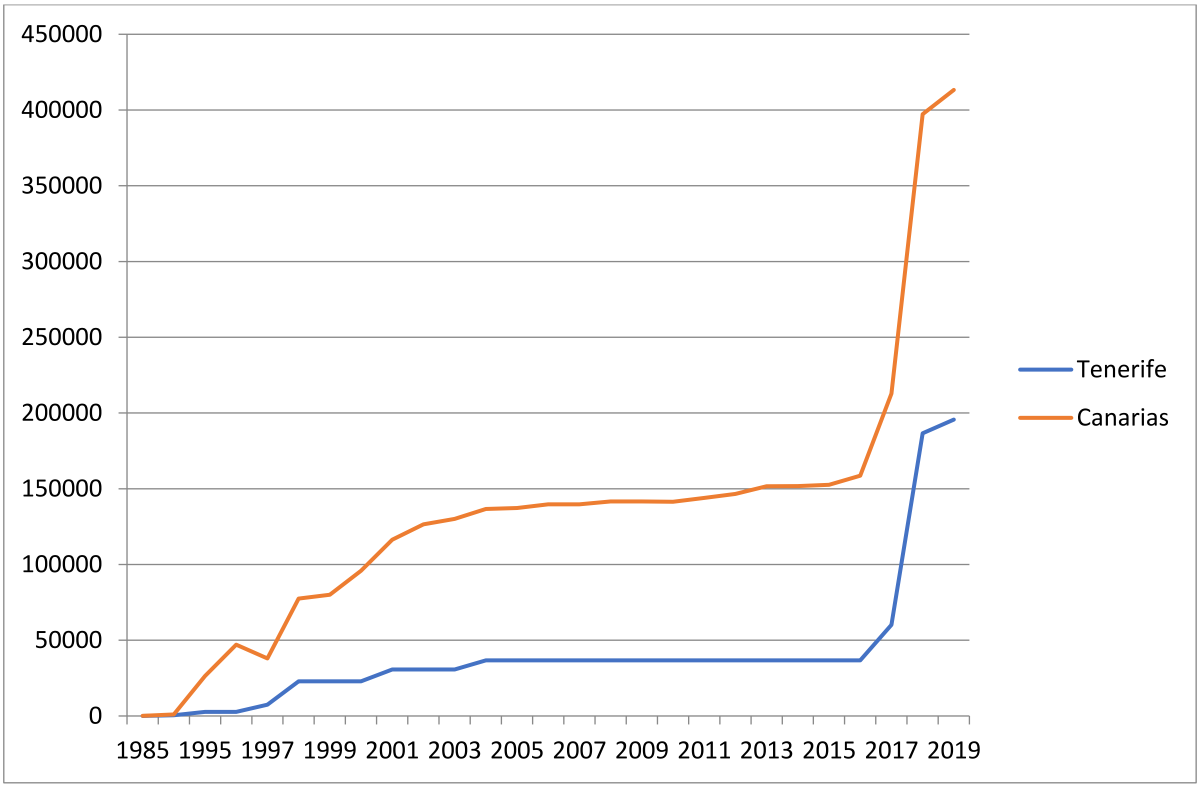


Figure 6: *Annual evolution of installed wind capacity in the Canary Islands vs. Tenerife (kW) as of December 31 each year.*

As of 2019, there were 74 operational wind parks across the archipelago, with a total of 476 wind turbines spread between them. Of the installed power, 91.9% of the wind installations pour all their energy into the islands power grid; 5.7% pump their electricity into the grid *and* use it to maintain operations, whilst the final 2.4% is used for the specific purpose of research, development and innovation through two 5MW farms both based in Gran Canaria.

As previously mentioned, given the geography of the islands, it can be very difficult to install large amounts of renewables, whether that be due to the limited land space, or the extreme volcanic topology of the islands. Therefore, instead of looking to the land for the answer, companies and the regional government are looking towards the sea. Offshore renewable electricity generation, particular wind, is considered a cornerstone technology by the European Commission and companies are starting to investigate how to deploy such technologies for European Islands, including the Canaries. For Example:

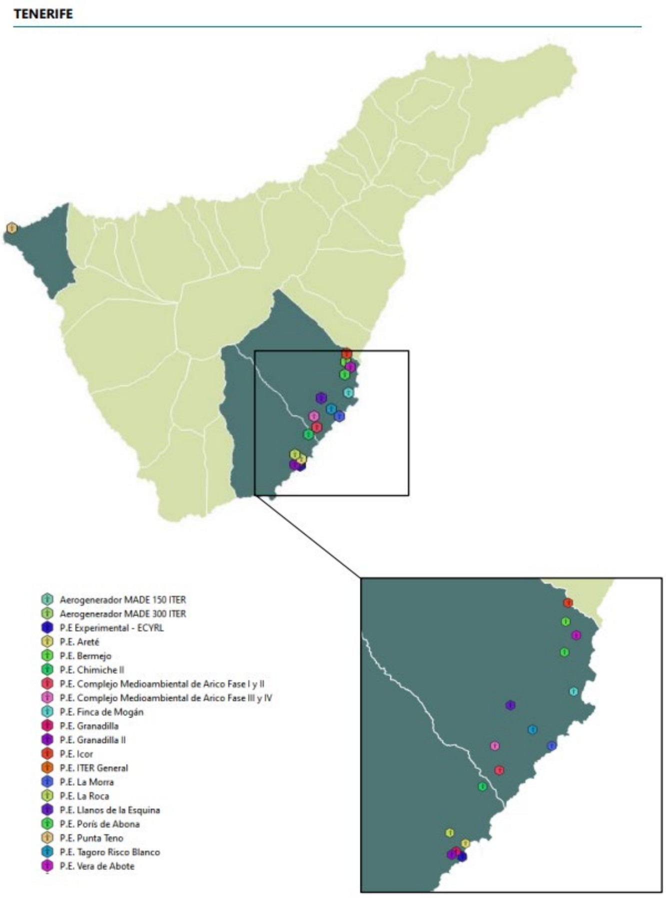


Figure 7*: Map of Tenerife's wind farm locations*

- Norwegian energy company Equinor ASA have expressed a strong interest in putting together a floating wind project off the coast of the Spanish archipelago, Gran Canaria to be exact, with pilot designs currently underway in France, Scotland and Portugal.

- Enzen, along with local government and water authorities, are further looking to jumpstart the industry with a 5MW floating wind turbine development off the coast of Lanzarote. The company, who are working alongside local government, is currently in the process of financing the €15-20m project, which will help to power a desalination plant in Arrecife by 2023. Throughout the Canary Islands, there are another 300 desalination plants which could benefit from similar direct power-purchase agreements. Alongside offshore wind, Enzen are looking to install 2 MW of tidal energy as part of their project as well.

- Finally, Greenalia, a Spanish independent power producer focused on renewable energy, submitted a planning application for a floating offshore wind farm off Gran Canaria. The project entitled 'Parque Eólico Gofio', features 50 MW of renewable energy in the form of four 12.5 MW turbines on floating foundations and will produce enough electricity to meet the demand of roughly 70,000 homes. Greenalia also expect this development to have a positive economic benefit, creating direct and indirect jobs in the process. This is just one project in an overall goal to achieve 310MW of offshore wind for the islands by 2025. Currently the islands have 5MW of wind installed as from an Elisa prototype turbine which was installed in summer 2018 and became operational in March 2019.

Solar

The installed Photovoltaic (PV) power across the Canary Islands, as of the end of 2019, was 194,305kW, with 99.4% of this feeding straight into the connected grid and 0.6% servicing isolated grids. This is a slight, 3.7% annual increase, which may sound small but actually represents the archipelago's largest annual PV increase since 2012. This recent decade of PV stagnation can largely be attributed to a lack of available and suitable land space; causing the deployment of large-scale PV developments to be rendered unfeasible, as well as changes in government policy making the technology less attractive to both the general public and private sector.

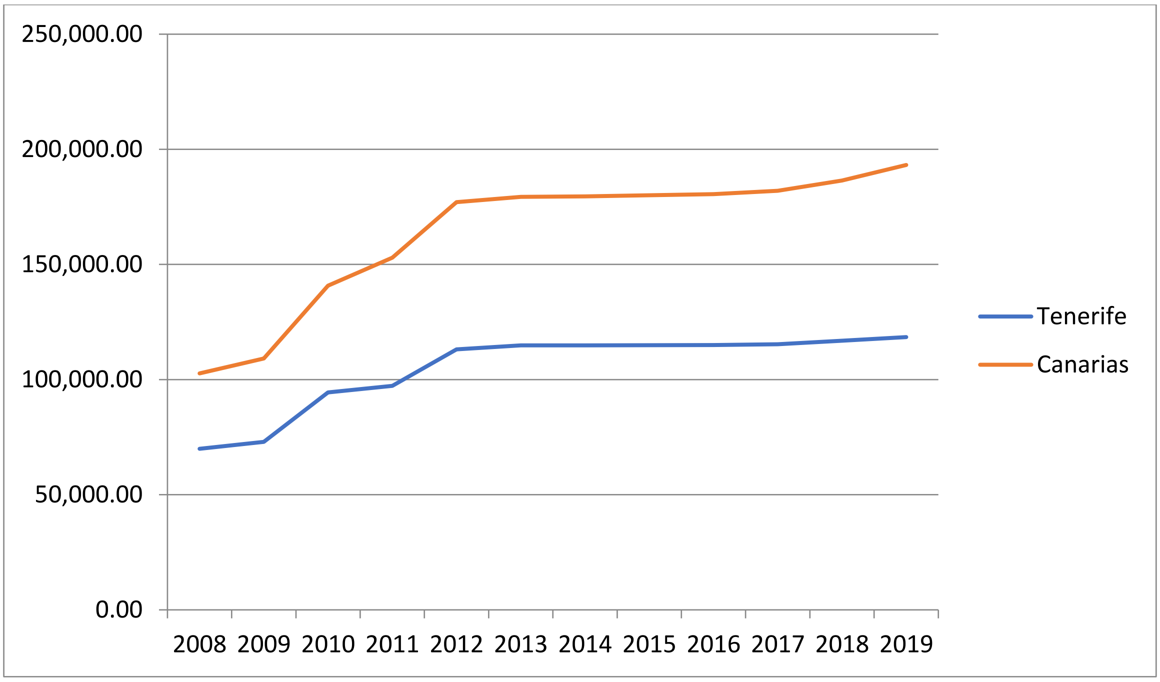


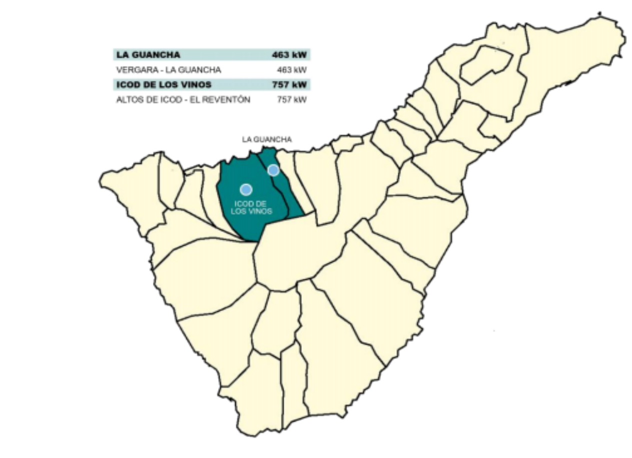
Figure 8:*Annual change of the installed PV capacity in the Canary Islands connected to the grid*

In total, 289GWh of electricity from photovoltaics was produced across the whole archipelago in 2019, enabling a saving of just under 230 tons of CO_2 in comparison to fossil-fuel alternatives. Tenerife was the most active of all islands in this area of renewable electricity, producing 68.1% of the 289 GWh themselves. However, under recently announced plans, the island of Gran Canaria will overtake Tenerife in this position thanks to the 'Solcan' programme, which is partly funded by the European Regional Development Fund. Through Solcan, the Canary Islands will install 255MW of photovoltaic energy capacity including – 119.5MW across 36 projects in Gran Canaria, 102.1MW across 18 projects in Fuerteventura and 26.6MW across just 6 projects in Tenerife.

The Canary Islands are also investigating the possibilities of floating solar technologies through involvement in the BOOST (Bringing Offshore Ocean Sun to the Global Market) project. Ocean Sun and Fred. Olsen Renewables, along with local partners, are designing, building, maintaining and operating a 0.25MW floating solar unit off the coast of Gran Canaria. This location poses very difficult conditions, such as 10-foot meter waves and high winds – therefore, if it can succeed then it will be ideal for deployment in most other applicable locations.

Hydro Power

The hydrological resources of some of the Canary Islands are limited, therefore there are only three mini-hydraulic plants present on those islands with the greatest potential. La Palma is home to the El Mulato power station, which saw the first of these mini-hydraulic power stations built in 2004, with a capacity of 800kW. The other two stations however are both based on Tenerife, with Vergara-La Guancha and Altos de Icod El Teventon home to a 463kW and 757kW plant respectively. There has been no modification, or expansion of mini-hydraulic power in the Canaries since 2009.



Fuente: elaboración propia

Figure 9*: Tenerife's mini-hydraulic infrastructure*

Hydro-wind

In 2014, the 'Aprovechamiento Hidreólico de El Hierro' development integrated a wind farm, with a pumping station and hydroelectric power plant. The site, which became operational in August of that year, supplies electricity from the wind farm to the grid whilst also feeding a pumping station that services the reservoirs of a hydroelectric plant to pump water and generate electricity. Hydro-wind technology is only present on El Hierro within the Canary Islands. The development has seen constant annual increases in terms of MWh of electricity produced since its inception in 2014 – rising to ~23.5MWh in 2018; representing 56.4% of the island's total annual electricity demand. El Hierro is a pioneering island in terms of renewables and energetic self-sufficiency, having managed over 5,000 hours of complete renewable energy coverage of El Hierro's energy demand since 2015.

Figure 10*: One of El Hierro's reservoirs*

Biogas

There are two biomass plants located in the Canary Islands – a 1.6 MW plant in Arico, Tenerife, which has been operational since 2008, and a biomethanzation plant in the Zonzamas' environmental complex, in Lanzarote, home to two identical 1.05 MW units. The success of biogas plants is dependent upon the feedstock and therefore, the amount of energy plants produce can fluctuate frequently. For instance, despite seeing a 13.1% decrease from 2017 to 2018, the plants saw a 7.9% annual increase electricity production to 10.142 MWh in 2019 – this variability is an intrinsic quality of biogas production.

Solar Thermal

The surface area of solar thermal panels installed in the Canary Islands is estimated to be 123,719 m^2 (2019). The majority of these panels are located fairly equally between Tenerife (38.0%) and Gran Canaria (38.3%). It is estimated that all the installations saved a total of 501 tons of CO_2 over the course of 2018.

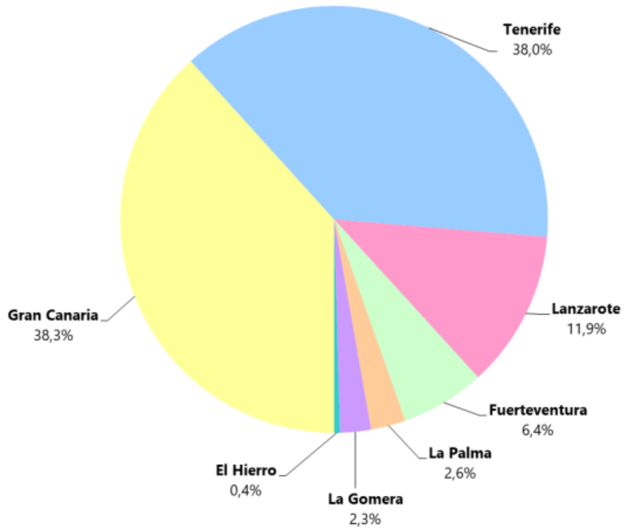


Figure 11*: Percentage distribution of solar thermal panels across the Canary Islands, 2019*

Spanish Energy Landscape

Spain is now right at the forefront of renewable energy integration worldwide, having built a robust electricity system that utilises both wind and solar PV to achieve large renewable energy penetration within its electrical grid. Therefore, as the country looks to its energy future, it has identified that cross-border connections will be pivotal in enabling Spain to play an EU-wide role as a renewable energy, liquefied natural gas or hydrogen provider.

However, before Spain can play a major role continentally, it must first focus on decarbonizing and securing its own energy requirements. In December 2020, Spain produced 50.4% of its power from renewable resources, according to latest estimates from Red Electrica de Espana. In fact, over the 12-month period of 2020, renewable-related power generation achieved a 44% stake of the year's demand, producing a total 110,577 GWh of energy. Under the National Renewable Energy Action Plan (NREAP) 2010, the share of renewables in power generation was expected to reach only 40% by 2020. The country has now set new, revised goals within the country's National Integrated Energy and Climate Plan 2021-2030 (NECP); including plans to reduce GHG emissions by 21% in comparison to 1990 levels; a 39.6% improvement in energy efficiency, a 74% renewable share in electricity generation and a 22% share of renewables in transport all by 2030.

Renewable Source and its (expected) capacity in MW	2015	2020	2025	2030
Wind	22,925	27,968	40,258	50,258
Solar PV	4,854	8,409	23,404	36,882
Solar Thermal	2,300	2,303	4,803	7,303
Hydro	14,104	14,109	14,359	14,609
Biomass	677	877	1,077	1,677

Table 2: *Expected Spanish renewable expansion by technology (data from renewablesnow.com)*

Spain has the sixth largest energy consumption figures in Europe (after Germany, France, UK, Italy and Turkey), and thus still has to rely on fossil-based energy for a lot of its demand due to the current state of renewable technologies. Moreover, due to a lack of domestic natural gas and liquid fuel reserves, the vast amount of Spain's fossil fuel consumption must be imported. For example, in 2016, Spain imported nearly 1.3 million barrels of oil per day, leading to an energy dependency of 73.9% in 2017 – much higher than the EU average of 55.1%.

The only real indigenous supply of energy, aside from renewables, Spain has access to is coal. Spain has reserves of well over a thousand million tonnes (1,308 MMst) of coal, but consumes just over 21 million tonnes per year and produces even less than that domestically (just over 2 million MMst/annum – all figures as of 2016). Over the past 20 years the country has tried to reduce consumption and production of coal in order to achieve a greener economy. This can be seen through the number of mine closures – in 1990 there were 167 coal mines across Spain in 2015 there were 40. Furthermore, Spain's government, led by Pedro Sanchez, have struck a deal with the unions to phase out the use of coal power completely from electricity production by 2025, having closed seven coal plants in 2020 with a combined capacity of 3.95GW.

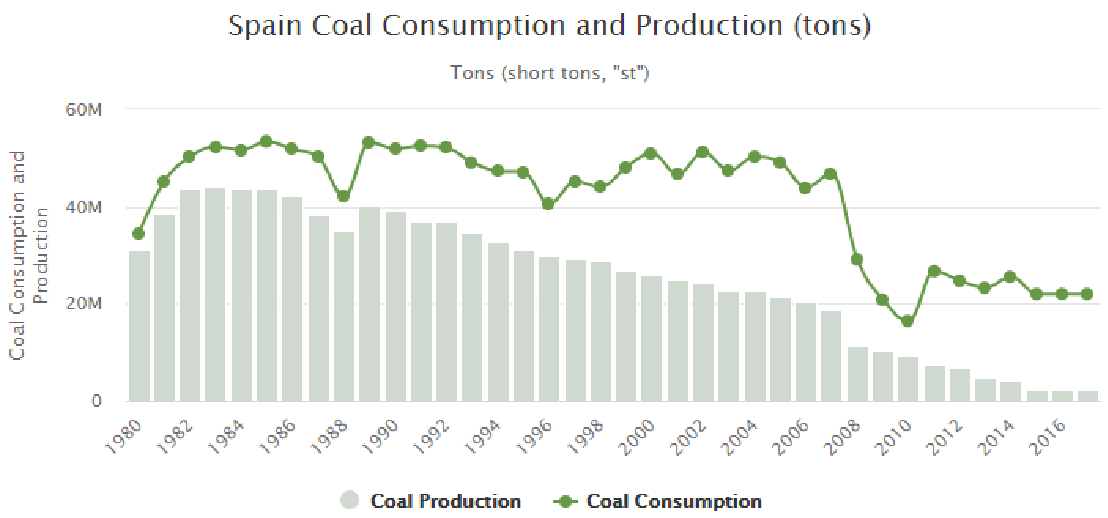


Figure 12*: Spain's coal consumption and production from 1980 -2018 (worldometers.info)*

Whereas, unlike coal, Spain's natural gas consumption has seen an overwhelming rise in consumption from 1990 levels (190,000 MMcf to 1,104,334 MMcf (2017)), and further unlike coal there is virtually no domestic production whatsoever. This could be in part to act as a less carbon-emitting replacement for the consumption of coal, as natural gas is 50% less carbon intensive and could help to act as a bridge as transitions to decarbonise occur – or the possibility of Spain trying to utilise and justify their expensive LNG market which has been in development since the early 2000s and has yet to see major success. In fact, 40% of domestic gas bills in Spain go towards maintaining gas infrastructure, even when it is under-utilised, with this figure reaching 70% for industrial customers.

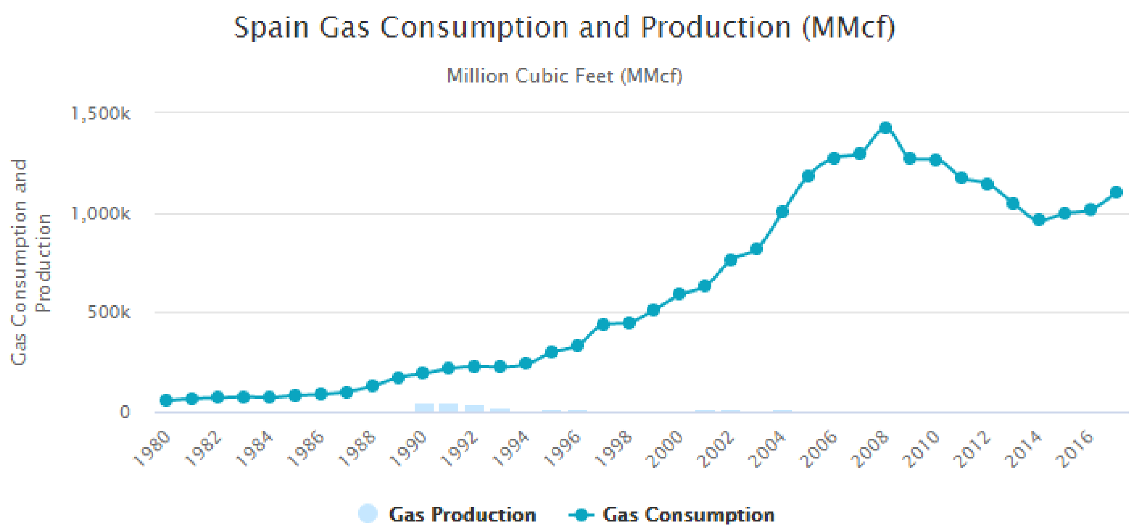


Figure 13*: Spain's natural gas consumption and production from 1990-2018 (worldometers.info)*

In 2016, LNG accounted for nearly half of Spain's natural gas imports (466 Bcf). Spain has access to 7 LNG terminals (Seen in blue below), with a combined capacity to regasify 2.4 trillion cubic feet per year of LNG – the highest in all of Europe. Despite LNG receiving serious backing from the Spanish government, as a key technology to offset coal consumption, utilisation rates are still comparatively low – perhaps due to lack of large-scale storage capacity (~134 million cubic feet nationwide).

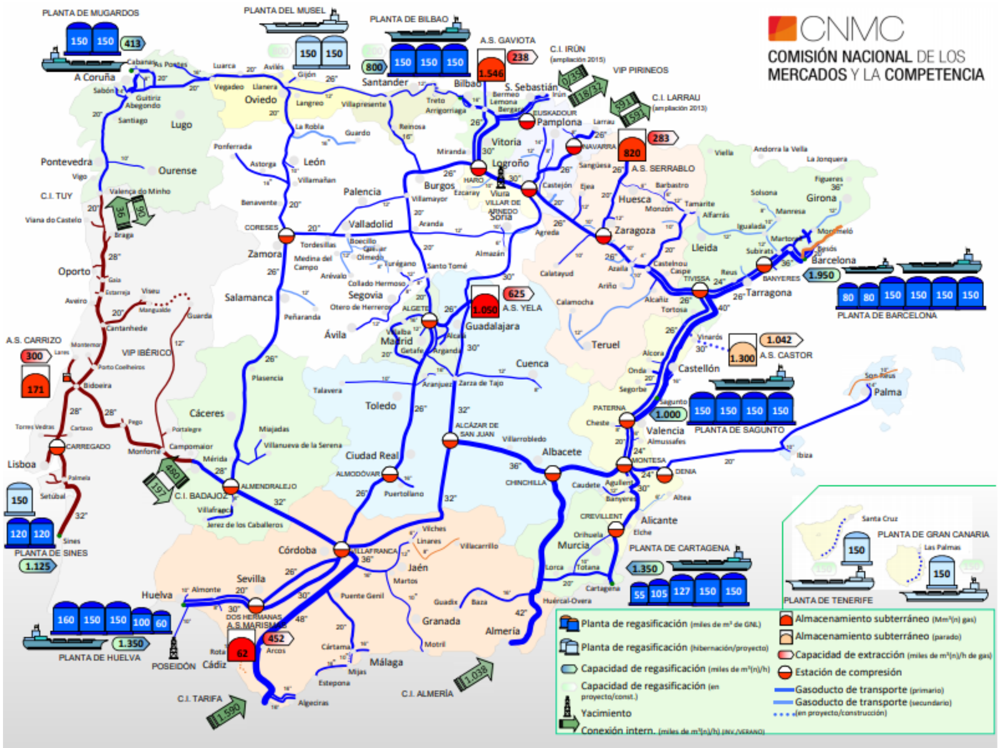


Figure 14*: [Spanish LNG Network]*

Since 2000, Spain has pursued a dash for gas policy. More than 50 combined cycle power plants (the third highest number in Europe) have been built but these plants have been used at less than 17% of their potential capacity from 2011 to 2018. There are a number of poorly performing gas infrastructure projects, including a regasification plant which is yet to open at the port of El Musel, which was given the green light in December of 2008 and has cost €400 million. At the end of 2018, there were just under 88,000km of natural gas pipelines in Spain, and with more pipelines and LNG terminals being installed, Spain needs to find a way to improve the utilisation of this infrastructure soon. However, as Spain progresses with their plans to reduce their reliance on coal and nuclear power (which accounted for 22% of power generation in 2019), these combined cycle plants and LNG terminals will likely see higher use rates as the premier mechanism to help balance the intermittencies of renewable energy.

So where does Spain go now?

Spain, much like the Canary Islands, has a major mismatch in its domestic energy supply/demand balance. With few oil and natural gas reserves of its own, it depends heavily on other countries to supply its demand, simultaneously weakening the position that Spain has over its own energy security, whilst costing consumers more via importation or the expensive infrastructure the country is maintaining.

Whilst the country has made strides within the renewables sector in the past decade, its reliance on fossil fuels (as seen below) is still too great, requiring further, more substantial change over the next decade, as set out in the NECP. Increasing renewable deployment is a straightforward step that should, and will, be taken to improve RES penetration but the extensive gas network, alongside the ever-increasing presence of natural gas within Spain's energy mix, make hydrogen ready-positioned to make an impact.

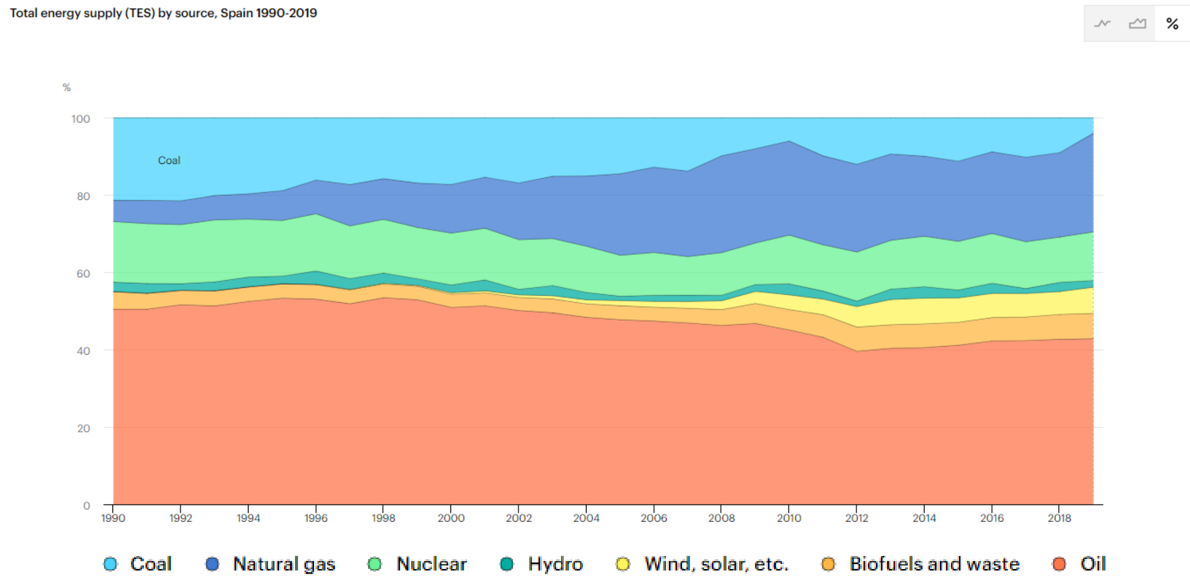


Figure 15: *Total energy supply by source, Spain 1990-2019 (data from IEA)*

Renewable-energy production locations could deploy electrolysers to prevent energy losses from curtailment and provide a resource that aids decarbonisation amongst more difficult-to-abate sectors (e.g. transport and heating). This hydrogen could then initially be blended into underutilised pipeline locations, to prove the technology and boost public acceptance, before full conversion to hydrogen. The money the government has set aside to help reskill the mining industry could help to instigate the production of a hydrogen sector and workforce, with a lot of key skills already at their disposal. Finally, the production of hydrogen, and use of it in the energy supply, would help to decrease the reliance Spain has on surrounding areas for helping to secure its energy supply and, once economies of scale are applied to the process, bring down energy prices for Spanish residents and even enable an export market.

Hydrogen

European Union Hydrogen

Hydrogen Strategy

What are the main goals for the EU's hydrogen sector, from the commissions point of view?

- **The priority is to develop renewable hydrogen**. With the vast majority likely to be produced by utilising wind and solar energy, renewable hydrogen is the most compatible and long-term solution for the EU's climate neutrality and zero pollution goals. Furthermore, green hydrogen offers the opportunity to produce change within a variety of sectors (industry, mobility, heating etc.) to provide a fully integrated energy system.
    - **However, in the short to medium term, other forms of hydrogen will be needed**. For instance, blue hydrogen will be just one of the forms of hydrogen used to bridge the gap between large-scale green hydrogen production, and the grey hydrogen that is currently used to satisfy hydrogen demand whilst enabling a reduction in carbon emissions.
    - To develop a hydrogen ecosystem across Europe, it is likely that a **gradual trajectory** will be seen with different areas progressing faster in hydrogen readiness than others. This requires a broad set of policy solutions to satisfy all the different challenges faced across Europe whether for large scale deployment, or local communities trying their best to reduce their emissions.

Hydrogen Policies

Hydrogen policy has gone through many iterations since its introduction to the European landscape as part of the Renewable Energy Directive in 2008. However, since its introduction, hydrogen has never been higher on the priority list, in terms of policy and legislation, than it is now amongst the European Commission, Parliament and member states.

Given hydrogen's application areas it is initially important to understand the drive to zero emission within those application areas, as hydrogen benefits from the application of these policies.

Transport is one of the problem areas for Europe. CO_2 emissions from the sector, although there has been a slight decrease since the levels reached in 2007, overall, remain much higher than 1990 levels. Aviation has had the largest CO_2 emission increase since 1990 with +129% (2018), followed by international shipping and then road transport with a respective increase of +32% and +23%. European transport still relies on oil for 94% of its transport needs; in fact, Europe import dependency hit a record high in 2020, when 96.96% of its oil and petroleum products were imported with a staggering cost to the EU economy. The Alternative Fuel Infrastructure Directive has been developed with this in mind – Europe needs to develop other, less emitting fuels together with the support infrastructure that each require, to have a greener, more energy independent future.

The Renewable Energy Directive (RED) was first introduced in 2009 and set a target for the EU of achieving 20% renewables by 2020, whilst also initialising national binding targets for member states to achieve themselves. All EU countries, under this directive, also had to ensure that at least 10% of their transport fuels came from renewable sources by the same year. However, as 2020 approached the European Commission thought it fit to recast the RED, as part of the wider Clean Energy for all Europeans package, which aimed to further progress the EU's position as a global leader in renewables whilst simultaneously helping the region to achieve Paris Agreement targets.

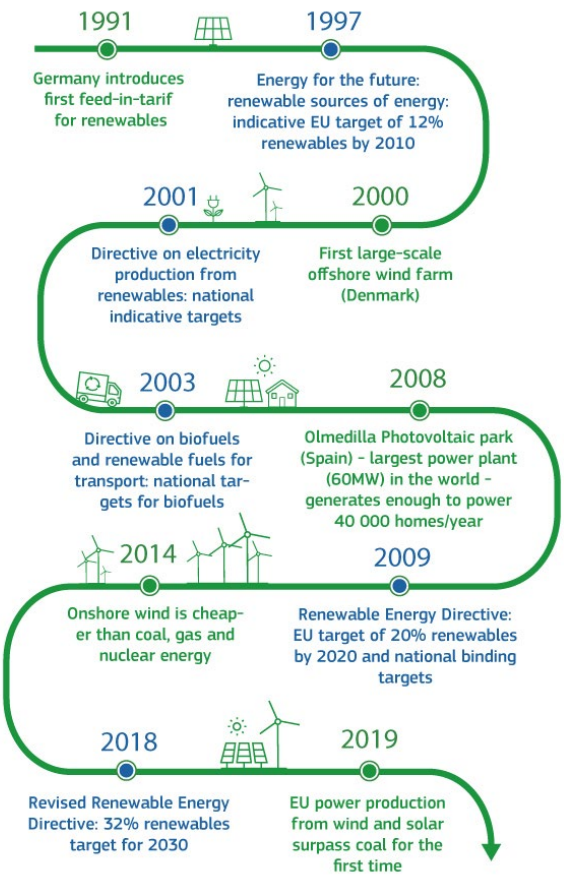


Figure 16*: Timeline for Renewable Energy in the EU*

Under the revisions, RED II emerged with several reworked targets but with a more binding the legal framework for achievement by 2030, instead of 2020. This included a new EU target for RES consumption of 32%, instead of the 27% from the initial RED, as well as a new, specialised RES transport sub-target which aimed for a minimum of 14% of the energy consumed by road and rail transport to be renewable. In order to enact these goals, the Energy Union Governance Regulation was designed, and eventually agreed in June 2018, as a way to aid the designing of national energy and climate plans for each member state – this umbrella piece of legislation is paramount to the success of the EU's 2030 energy/climate targets.

The Clean Mobility Package features a second element which is focused on the promotion of clean and energy efficient road transport – the clean vehicles directive. This directive aims to succeed where its previous iteration failed and boost the uptake of clean (low/zero-emission) vehicles. This iteration also aims to ensure it provides clear, long-term market signals and that provisions are both simple and effective. With the EU adopting the report into this directive, it put in stone targets for both light and Heavy-Duty Vehicles (HDVs) over the coming ten years (until 2030). For the former, 35% of light duty vehicle sales should be clean up to 2025 with an increase to 50% beyond 2025; adding that at least 70% of minimum procurement targets for clean light duty vehicles in the first period should be low-*or* zero-emission vehicles and that in the second period 70% should *only* be zero-emission. Clean HDVs market share, under the same legislation, was amended upwards towards the 10-15% mark, depending on the country; with at least 75% of minimum procurement targets for clean HDVs met by zero-emission or purely biomethane running vehicles by 2030. EU member states also agreed on an emission reduction target of 15% by 2025, and 30% by 2030 for HDVs when compared to 2019; with additional incentives for zero-emission vehicle deployment such as an additional 2-tonne weight allowance.

When it comes to maritime policies, very little has been committed to currently. However, the Internationale Mertieme Organisatie have established a voluntary 30% emission reduction target for the period between 2008-2030, progressing to 50% reduction by 2050.

However, it isn’t just transport and vehicles the EU is focused on. Directives on buildings and energy efficiency measures have been released as well. These documents establish a common framework of measures for the promotion of energy efficiency within the Union in order to meet its climate goals. Within their energy markets Member States are asked to inter alia: encourage demand side resources, such as demand response to participate alongside supply in wholesale and retail energy markets, promote access to and participation of demand response in balancing, reserve and other energy system services markets.

Following the COVID-19 pandemic global economies were looking for reliable areas of growth to instigate financial recovery, with the majority of them selecting green growth to spearhead their efforts. The EU was no different. Announcing the ‘Green Deal’ in 2020, the EU Commission was equally motivated to foster growth in sustainable sectors with investment exceeding €1 trillion over the next decade. Hydrogen will be a key instrument to enabling the goals of the Green Deal, by enabling clean, affordable and secure energy. Under the EU’s plans hydrogen will behave as an energy storage mechanism to increase the penetration of renewables in hard-to-abate areas, particularly industry, transport, and power.

The EU doubled down on this position within their ‘Fit-for-55’ package – a piece of legislation designed to achieve 55% greenhouse gas emission reduction target by 2030. This package includes actions such as the amendment of RED II to include sub-targets for the use of Renewable Fuels of Non-Biological Origin (RFNBOs) – 50% in industry and 2.6% in transport by 2030, equivalent to 10 million tonnes of hydrogen. There are also targets for the increased uptake of sustainable fuels in both aviation and maritime – with hydrogen to play a key role whether that be directly or via synthesis of other fuels – whilst also revising the Energy Tax Directive so that these sustainable/alternative fuels would benefit from a zero-tax rate (As opposed to the proposed €10.75/GJ minimum).

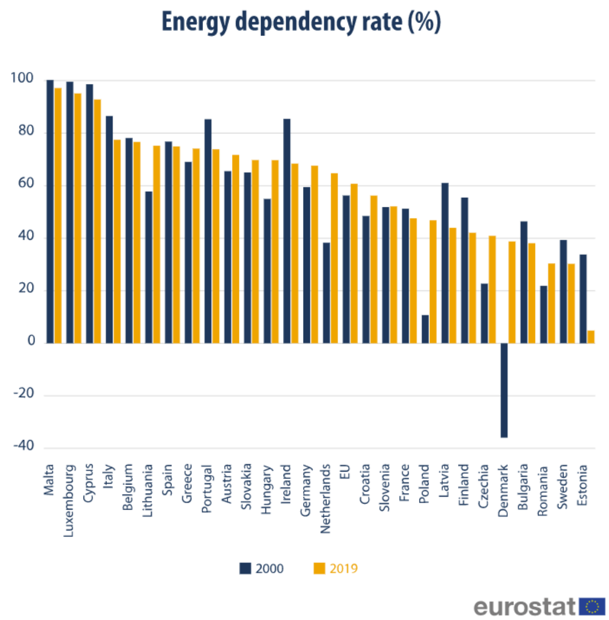


Figure 17*: Energy dependency is a critical issue for almost all EU countries, only exacerbated by recent tensions in Ukraine*

Recent developments, such as increasing fossil-fuel prices following the war between Ukraine and Russia, have put an added emphasis on obtaining European energy security, in particular decreasing reliance on large amounts of energy imports. REPowerEU was published in March 2022 with the focus to minimise European energy dependency whilst still achieving legally binding climate targets. Within this strategy are plans to nearly triple currently installed wind and PV capacity, with a dedicated for the installation of additional renewables capacity for hydrogen production – as outlined in the Fit-for-55 package. This increased momentum has moved the EU's target from 3 million tonnes of green hydrogen production per year by 2030 to 15 million tonnes in the same timeframe – although it is likely a large proportion of this target will be imported from high renewable potential areas (e.g. North Africa and Saudi Arabia).

Thus, from these plans, it is clear to see that hydrogen will play a serious role within the EU's decarbonisation plans, confirmed by this quote from European Commission President, Ursula von der Leyen "… I can assure you that Europe is serious about clean hydrogen. Clean hydrogen – is part of our future.".

EU Island Policies

Within the European Commission's Hydrogen Strategy, island specific policies and strategies are barely mentioned. In fact, the word 'island' is only mentioned once within the whole document. In the second phase of the Commission's extensive plans (from 2025-2030), hydrogen will move from a development fuel to an intrinsic part of Europe's energy systems, with >40 GW of renewable hydrogen electrolysers expected in operation by 2030 – but what does this mean for islands?

Within this phase, "Hydrogen Valleys" - areas which develop both hydrogen applications and production simultaneously within a localised area - are expected to be deployed in places such as remote areas or islands, as well as conventional regional ecosystems. It is anticipated that within these valleys, hydrogen will be used for traditional uses such as industry, transport, and electricity balancing, whilst also playing a role in the heating of residential/commercial buildings too.

Several projects encompassing this valley model are starting to be brought together and some have already seen funding. For instance, under the FCHJU, the Green Hysland project in the Balearic Islands obtained an EU grant worth €10m, the second largest grant handed out by the FCHJU and the largest ever to a Mediterranean country. Furthermore, this project was earmarked as an example of creating a 'green hydrogen ecosystem' as part of the EU's Hydrogen Strategy and is part of the Spanish government's national hydrogen roadmap. Thus, Green Hysland perhaps acts as the perfect exemplar to other fledgling projects being developed on other Spanish islands.

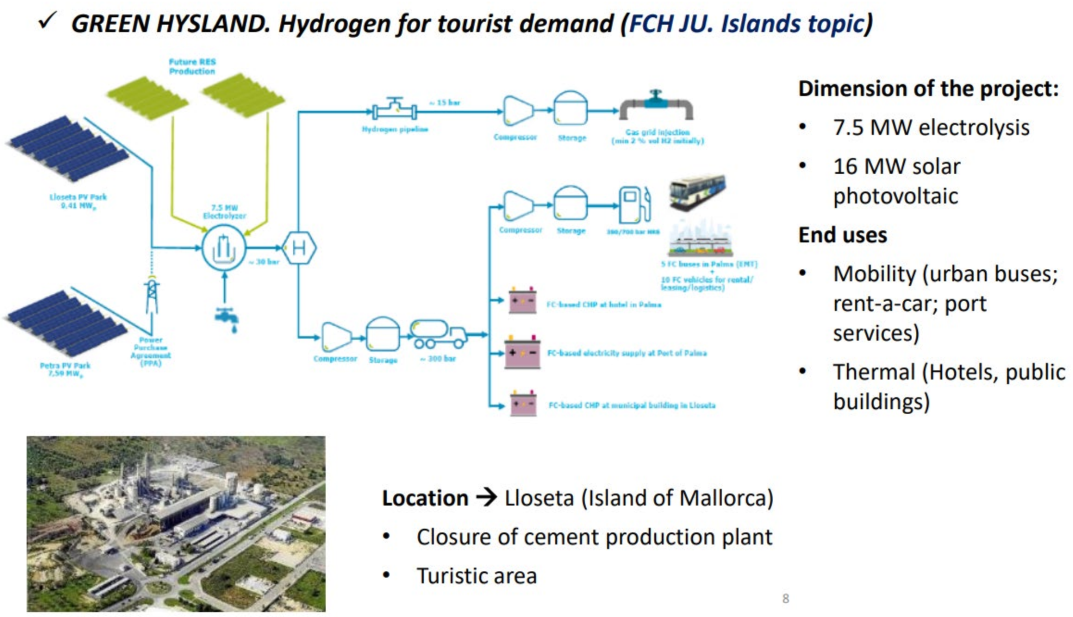


Figure 18: *The Green Hysland project overview*

GREEN HYSLAND recognised that globally over 15 million people live across 310 inhabited European islands, with the majority of these islands living in energy isolation leading to high energy dependencies as they import the majority of their demand from their respective mainlands' in the form of polluting diesel or other fossil fuels. They also understood that hydrogen based local energy ecosystems have the potential to provide integrated, flexible solutions for decarbonisation of islands, as well as offering further benefits in terms of security of energy supply, promoting sustainable tourism and reindustrialisation, and creating socio-economic opportunities by establishing a local/regional economy based on green hydrogen and renewable energy.

In an effort to balance economic needs with environmental sustainability, the Balearic government has made commitments by signing up to the EU Clean Energy Island initiative and the UNEP Mediterranean Strategy for Sustainable Development 2016-2025, designing the Climate Change Mitigation Action Plan in the Balearic Islands 2013-2020 and now by being part of GREEN HYSLAND. This project will develop full business and commercial models for H2 supply, infrastructure and end-user solutions to be deployed within the project ensuring that they continue operation beyond FCH JU funding. The project seeks to address common problems and challenges such as the curtailment associated with mass RES deployment, or integration of H2 with existing electricity and gas infrastructure, as well as more specific island focused challenges to the commercialisation of hydrogen and how these can be overcome and then replicated across other EU islands.

If Tenerife wants to seriously consider implementation of hydrogen technologies and the development of a specialised sector on its islands, then it should take serious note of Mallorca and the GREEN HYSLAND project. This first-of-its kind hydrogen-valley approach could provide pivotal learning opportunities which could enable Tenerife's hydrogen sector to be even more successful.

Away from purely island-focused hydrogen policies, the EU Clean Energy Islands Initiative aims to advance an overall clean energy transition of European islands. This declaration was born out of the recognition that islands, and their regions, face a particular set of energy challenges, and opportunities, due to their specific geographic/climatic conditions. This venture brought to light the potential that islands have to pioneer the energy transition for Europe, and beyond, which was recognised by the commission in its communication on 'Clean Energy for all Europeans'. At its core, this initiative seeks to help develop the best clean energy technology for islands whilst keeping the concerns of their inhabitants at the forefront of the energy transition and the policy developments surrounding it.

Spanish National Hydrogen Plans

Approved in early October, the Spanish National Hydrogen Plan (NHP) aims to imminently boost the country's clean hydrogen production, with a long-term view to build enough infrastructure to become a major European hydrogen player. Spain hopes to utilise its well-established gas storage and transport system, alongside its bountiful supply of naturally occurring resources (mainly solar and wind) to propel its green hydrogen production position to the point it will be a major Spanish industry, even exporting energy across borders.

Targets

There is only one way to obtain a European leading position in renewable hydrogen production and that is through mass electrolyser deployment. Spain agrees. Their National Hydrogen plan seeks to drive rapid growth within this area, deploying 300-600 MW of operational capacity by 2024, growing exponentially to 4GW by 2030 – a relatively moderate target given Spain's leading renewable energy resources when France and Germany have set targets of 6.5GW and 10GW respectively (Germany's target was 5GW but was increased in late 2021).

With this increased production capacity, Spain's primary aim is to replace almost a quarter of the 500,000 tonnes of fossil-based hydrogen production consumed by industry every year. There are also a number of mobility goals that complement the increased production capacity well, including the deployment of at least: 150 hydrogen buses; 5,000 FCEVs and two trainlines (operating on the peripheries of the country) all operational by 2030. Spain is expecting to achieve 4.6M tonnes of CO_2 reductions, once all aspects are operational, from their investment - which totals €8.9 billion.

Why These Areas?

Spain has identified renewable hydrogen as a key resource in their fight to achieve carbon neutrality by 2050, in line with a number of pieces of legislation including the Paris Agreement. The EU have a wider hydrogen vision for net producing countries and net consuming countries in order to satisfy key demand centres. Spain is a key example of such a hydrogen production country as it possesses some of the most favourable conditions for making green hydrogen in all of Europe and thus is positioning its national policy around large-scale production.

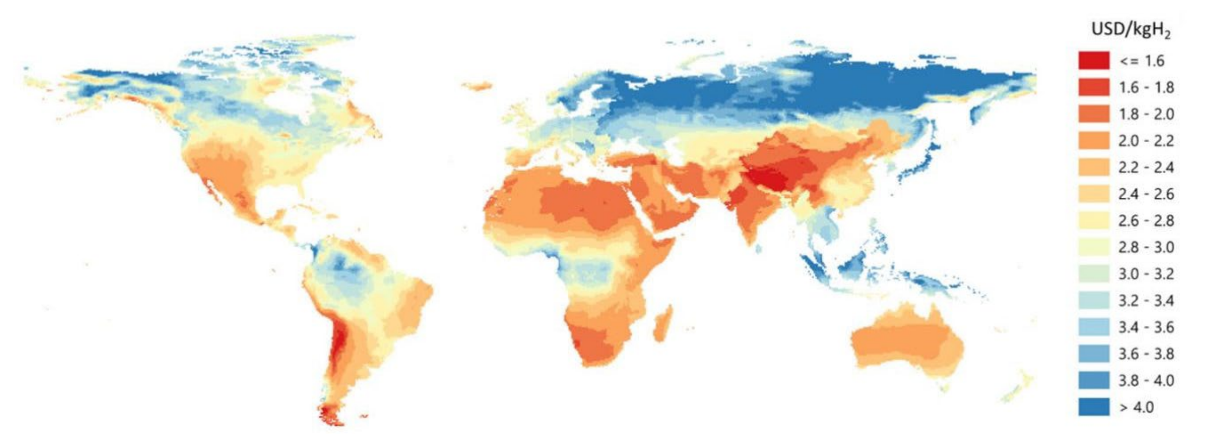


Figure 19: *Hydrogen costs from hybrid solar PV and onshore wind systems (long-term)*

Although Spain is envisaging exporting hydrogen in the medium-to-long-term, as of right now they are focused on making steps to decarbonize their own economy, as can be seen through the commitment to reduce 25% of industrially consumed hydrogen with its zero-carbon alternative. By focusing on the industrial sector (e.g., oil refineries, fertilisers, chemicals etc.), Spain is hoping to create a secure a reliable baseload demand for their renewable hydrogen activity which they can spur further growth around. In fact, these locations could make for ideal clusters to form hydrogen valleys around – a location where production, storage and distribution, and consumption are co-located. Valleys are seen as an opportunity to drive down cost of both hydrogen production, and the surrounding infrastructure, by enabling economies of scale through larger deployments. Spain is already home to three such valley deployments in various stages of their lifecycle development, including Green Hysland, Basque Hydrogen Corridor (BH2C), and Green Crane.

Spain does see hydrogen playing a role within decarbonizing mobility as well, with plans to implement both light- and HDVs, but this is currently less of a focus. Hydrogen will be considered for end-uses where electrification is not deemed to be the most efficient solution. Therefore, it is likely that hydrogen will be deployed more to satisfy larger, load-bearing transport such as public transport, trucks, boats, and planes rather than smaller passenger vehicles for which battery-electric is expected to be better suited.

Finally, Spain, given its unique geographical position for producing low-cost renewable hydrogen, are taking a vested interest in the development of a European/global hydrogen market. The NHP states that any short-term hydrogen deals could still see a preference for grey-hydrogen and therefore environmental impacts of hydrogen types must be adequately considered when making these decisions – which will become easier with the introduction of a European hydrogen certification system. Furthermore, green hydrogen standards must be implemented uniformly throughout the EU to facilitate cross-border deployment, whilst the introduction of a combination of CO_2 taxes and an emissions market should help to build the 'brand' of renewable hydrogen amongst consumers.

How will Spain Achieve its Goals?

Currently hydrogen production is considered an industrial activity within Spain, as it's classified as a chemical industry process for the production of inorganic gas. This has knock-on implications for the sector, for instance, the construction of hydrogen production infrastructure can only take place on land that is classified as industrial. Whilst this may not be a problem for the on-site industrial production of hydrogen, this could have a substantial effect for hydrogen that is being produced at renewable sites around the country. Therefore, a number of measures have been set out to try and address this, as well as similar issues that are hampering hydrogen activity.

The NHP features a total of 60 measures to be undertaken, split into four main categories: Regulatory Instruments; Sectorial Instruments; Cross-Cutting Instruments and Boosting R&D. Which can be further broken down into their specific target area

Regulatory Instruments	Sectorial Instruments	Cross-Cutting Instruments	Boosting R&D
Administrative simplification and elimination of regulatory barriers to hydrogen production.	Monitoring of hydrogen production and consumption	Information campaigns and professional skills by sector	Support for R&D&I of renewable hydrogen value chain technologies
Creation of a Guarantee of Origin system (GoO5)	Boosting the application of renewable hydrogen in industry	Renewable hydrogen production and consumption potential in Spain and socio-economic impact	
Fostering the competitiveness of renewable hydrogen	Boosting the application of renewable hydrogen in transport	Contribution to the just transition, the struggle against the demographic challenge and the circular economy	
	Ground Transportation	Updating and renewing the Roadmap as a continuous process	
	Maritime Transport	Reinforcement of Spain's position in the international hydrogen market	
	Air Transport		
	Integration of Energy Vectors		

Table 3: *Specific Target Areas of the NHP'S Measures Categories*

Where will these measures leave Spain?

All of these measures have two common goals, to foster a national, and subsequently continental, hydrogen sector *and* to help achieve decarbonisation targets, but what are the official goals set out in the NHP that Spain want to achieve?

- Eliminate greenhouse gas emissions in sectors and processes that are *difficult to decarbonize* to achieve a climate neutral economy by 2050, as required by legislation.

- Develop hydrogen value chains with Spanish technology at their core. Through promotion, innovation and growth of the industry, value-added will be generated alongside the creation of high-skilled jobs along each step of the supply chain. This is similar to policy suggested as part of Spanish Strategy for Science, Technology and Innovation 2021-2027, which stated Spain should seek to pioneer Spanish technologies through the introduction of industrial renewable hydrogen and general decarbonisation use.

- A greater percentage of RESs energies and, with hydrogen, a greater degree of manageability. Conventional renewables come with an intrinsic degree of intermittency issues which can cause grid operators real trouble, when supply and demand aren't matched. However, this barrier can be overcome by utilising hydrogen as an energy storage mechanism, to capture any excess energy that would otherwise be wasted. This hydrogen can then be used in any number of ways whether it be purely energy generation or for heating, mobility (etc.).

- The indigenous production of a renewable, non-carbon emitting fuel, means that Spain will need to rely less on fossil fuel imports to satisfy its energy requirements, therefore improving the country's energy balance and decreasing energy dependency simultaneously.

- Make Spain one of the European leaders in renewable energy generation. Spain, thanks to its geographical location, is one of the most advantageous areas to produce green hydrogen in Europe – it can only be seen a win-win situation for all parties if Spain develops its hydrogen sector with considerable value added to the Spanish economy and cheaper hydrogen for those who demand it.

Potential for Hydrogen Production on Tenerife

Fossil-based, traditional ('grey') hydrogen production methods can become carbon-neutral with the addition of carbon capture technologies. However, these so called 'blue' hydrogen production methods are not readily available on Tenerife due to two factors: a lack of domestic grey hydrogen production, and a lack of opportunities to sequester captured CO_2 whether that be through industrial utilisation or pumping into underground caverns. Therefore, with high levels of renewable electricity, and an electricity grid and economy that struggles to deal with energetic intermittency, Tenerife is an ideal location for the production of 'green' – emission-free - hydrogen. Hydrogen, and its ability to act as an energy storage mechanism, can enable the deployment of larger renewable energy sites around the island without the need for extensive grid connection infrastructure. Instead, the renewable energy can be used to create hydrogen, which can then be stored and turned into electricity (or heat etc.), using fuel cells, engines, and turbines, when it is needed – helping to deal with the seasonal energy issues, as well as wasted curtailed energy, which is regularly seen in touristic islands like Tenerife.

The potential of hydrogen within Tenerife and the wider Canary Islands is starting to be realised through, not only projects such as Seafuel, but also large industrial bodies like Enagás and DISA. The two have built a consortium of ~20 institutions to investigate the feasibility of a 'Canarian Renewable Hydrogen Cluster Hub' that would have the capability to produce around 1,850 tonnes of green hydrogen per annum by 2030. This will be produced with 17MW of renewable energy, 6.8MW of which will be based on Tenerife. Therefore, by utilising the groundwork set by key projects like this, Tenerife can rapidly expand its hydrogen sector and green hydrogen production capabilities due to its early mover status and the region's familiarity with hydrogen processes.

Potential Hydrogen Enabled Applications in Tenerife

Industrial feedstock

Unsurprisingly, industry makes up a small percentage of Tenerife economy, just 7-8% of GDP, as the island is much more reliant on the size of its tourism industry, and to a lesser extent agriculture, for the majority of its income. Tenerife's industrial activity consists primarily of the food and tobacco sectors. The island previously featured an oil refinery, based in Santa Cruz de Tenerife, however the facility, which was capable of refining 4,500,000 tonnes per year, was shut down in 2015, after being operational for over 70 years.

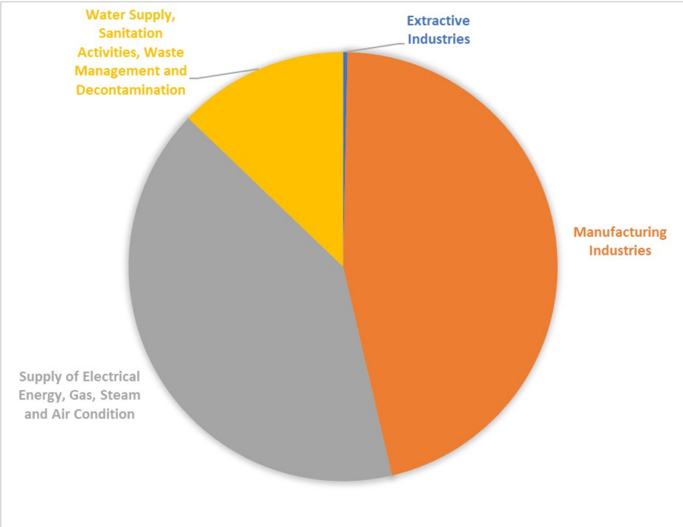


Figure 20*: Relative size of industrial subsectors by economic turnover*

H2 Transport for Tenerife

Current Transport Landscape

Unsurprisingly, road transport is the most common form of transport on Tenerife, with private passenger cars owning the lion's share of the road vehicles on the island.

As for public transport, buses are the predominant option for, not just Tenerife but, the whole of the Canary Islands. There are two bus companies on Tenerife – Transportes de La Esperanza, which has only 4 bus routes, and TITSA, which owns 523 buses covering 176 different routes (98% of the bus lines on the island). In 2017, TITSA completed 1,612,109 journeys, consequently totalling 33,118,868 KM travelled and consuming 15,675,946 litres of fuel. Infrastructure related to these public bus companies is spread across Tenerife, with the two most important transport exchangers located in the metropolitan areas of San Cristóbal de La Laguna and in Santa Cruz de Tenerife.

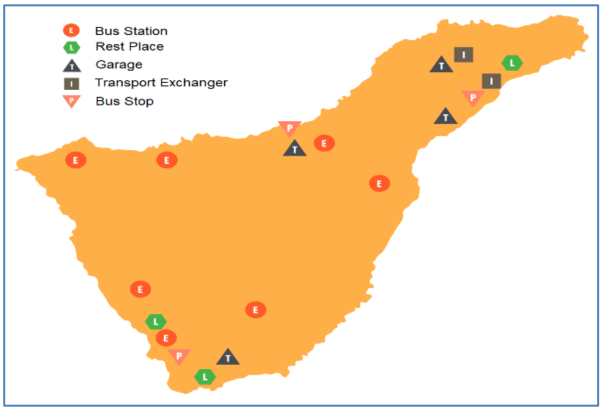


Figure 21: Public bus infrastructure in Tenerife

Tenerife also boasts a tram system that has been operational since 2007. There are two tram lines which both operate in the metropolitan area of the island. The first connects the two main cities of the island, La Laguna and Santa Cruz and the second connecting Tincer and La Cuesta.

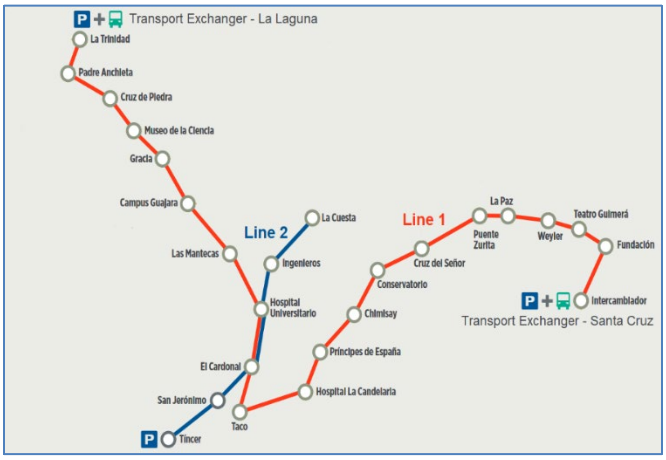


Figure 22*: Tram lines and stops in Tenerife*

The transport sector is accountable for a considerable portion of the final energy demand of the Canary Islands, with the three major modes, land, air, and sea, holding a 74.7% share. A major change in transport towards low-/zero-emission vehicles on the islands could have a transformative effect on the emissions because of this dominant energy position – particularly amongst land and air transport which are responsible for 66.89% of this 74.7% figure.

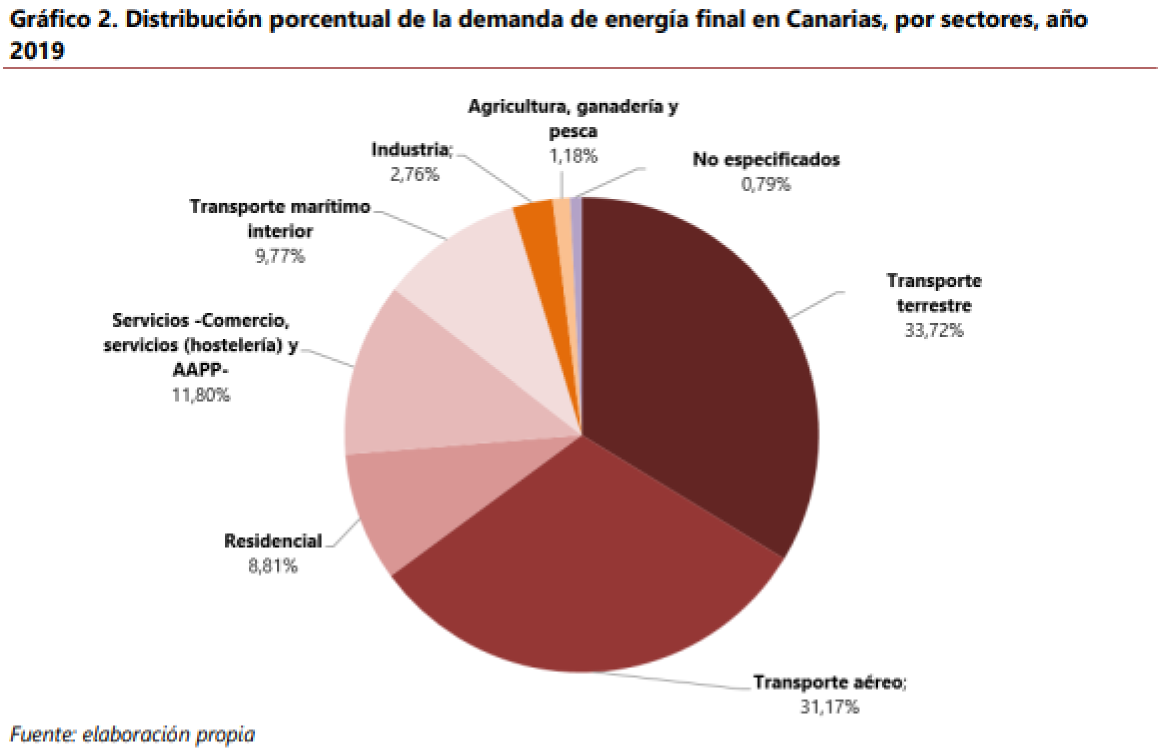


Figure 23*: Percentage distribution of final energy demand in the Canary Islands, by sector for 2019.*

The substitution of diesel- and petrol-powered vehicles in Tenerife could have a substantial effect on greenhouse gas emissions, due to the high ratio of vehicles per inhabitant exhibited on the island. However, it's not quite as simple as the waiting for the public to replace their emitting vehicles of their own accord – uptake of hydrogen vehicles will be dependent on the generosity/harshness of new policies for replacing passenger cars as well as the surrounding infrastructure available to hydrogen customers (e.g. will there be enough HRSs to make the switch easy and straight forward?). Therefore, it is imperative to keep the public and policy-making institutions engaged and active-participants in demonstration projects to enable a full, adequate and smooth decarbonisation of mobility.

Spain is achieving this through the implementation of necessary policy measures - such as:

- Spain has already announced that there will be a ban on the sale of greenhouse gas emitting vehicles as of 2040 as part of the Climate Change Law announced in 2021. With Spain also earmarked to support EU bills surrounding an earlier ban on polluting vehicle sales.
- The Spanish government has passed measures aimed at reducing electricity prices whilst promoting further deployment of renewable technologies.
- At COP26, Pedro Sánchez, the country's prime minister, announced intentions to increase yearly climate financing by 50% to €1.35b per year by 2025.

Maritime

Maritime transport across the Canary Islands in 2019 used 2,763,598 tonnes across both international and national journeys. This is a significant 4.3% reduction on 2018, and unlike previous years, represents a decrease in all major fuel use types. The overwhelming majority of maritime transport fuel usage occurs in Gran Canaria, which accounts for just over 80% of all of the Canary Island's maritime fuel usage. Tenerife comes in second with 19% of maritime fuels.

	Gasolina	Gasoil	Diesel oil	Fuel oil	Total
2017	170	470,924	150.519	2,283,131	2,904,743
2018	162	506,141	234.833	2,147,094	2,888,230
2019	211	491,055	221,364	2,050,969	2,763,598

Table 4*: Maritime fuel consumption data in tonnes (Data taken from Anuario Energético de Canarias 2019)*

When it comes to hydrogen, ports are seen as one of the key enablers for a successful sector. In Europe, the expected increase in offshore renewables technologies, particularly wind as is mirrored in Tenerife, meaning ports are likely to become green hubs where renewable energy is brought ashore from these developments.

Given the importance ports play across Europe, particularly to island life, there is significant potential to develop renewable energy and hydrogen value chains from sea-to-shore. To realise the energy potential of the Canary Islands' ports, continual interfacing is required between regional and national government to adequately assign offshore space for specific activities, including energy generation.

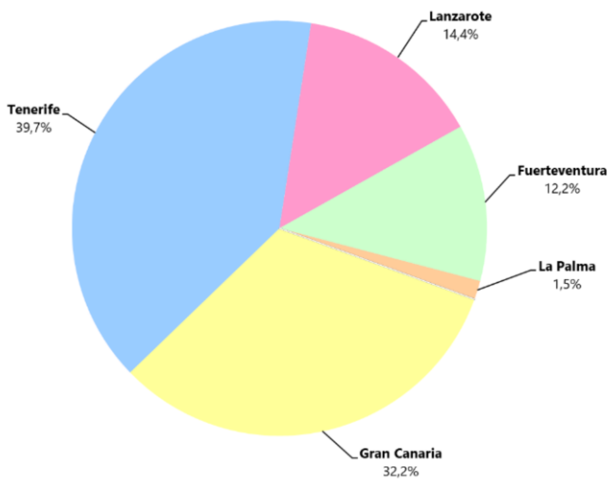
A study published in 2020 found that 99% of ocean traversing vessels in 2015 could have been powered by green hydrogen. The study, which was carried out by the International Council on Clean Transport, said nearly all vessels crossing the pacific could have been powered on LHY – 43% requiring no journey alterations, and just over half managing it with a 5% replacement of cargo for fuel space or an extra port stop for refueling.

Unsurprisingly, the maritime sector is strongly considering how to transition to more sustainable practices. Norway (Norled) and Scotland (HySea3) are considering and exploring the options for hydrogen ferries and even cruise ships (Viking), synonymous with much of the marine travel seen in the Canaries. Also synonymous are the inland waterways applications being developed in Netherlands, Germany and France, whose focus is on large, short sea applications – all of which the Canary Islands should take note of when determining their own options.

For the Canary Islands, there are a number of options. Firstly, inter-island travel could be targeted by replacing the current maritime fleet with fuel cell-electric analogues. This could help to build hydrogen value chains across islands gradually, with the most frequent and heavily travelled routes being addressed first, whilst also gaining residents' acceptance with public facing vehicles that they use for transport regularly. Secondly, with the great size of the region's tourist sector, cruise liners could be targeted as they are large polluters both whilst travelling and sitting dockside. If these large ships could transition to hydrogen fueling systems, as is currently being explored, then Tenerife could be an ideal place to dock for refueling as they travel back towards mainland Europe or further down the African coastline. Furthermore, these large ships also rely on the harbors they dock at to provide them with power, so onboard functions can be carried out whilst stationary – this is called cold ironing. This process could be serviced by hydrogen, as has been proven by the BIGHIT project in Orkney, thereby reducing stationary maritime emissions. The deployment of a mixture of these options is likely to lead to the best results for the Canary Islands, although the large demand that cruise liners would require could spur hydrogen sector growth around it leading to further, connected emissions savings for both other maritime vessels, or portside activities (e.g. hydrogen fuel cell HDVs or forklifts).

Aviation

Aviation in the Canaries has seen a recent peak in fuel usage (pre-COVID-19), with almost all of the 1,115,339 tonnes of fuel being made up of kerosene (>99%). However, unlike maritime transportation, aviation sees a much more even split in fuel usage amongst the Archipelago, albeit with Tenerife and Gran Canaria still being the largest consumers.



Fuente: elaboración propia

Figure 24*: Aviation fuel usage by island (Anuario Energético de Canarias 2019)*

The Aeronautics industry, much like ports, play a huge role in Europe's global presence. The EU see it as one of their key high-tech sectors and thus they are likely to be central to the transformation of aviation over the energy transition.

Hydrogen aviation is still very much in its fledgling era, with experts from across EU projects (including EnableH2, Horizon 2020 and the FCH JU) agreeing it is still likely that we are 8-10 years away from having hydrogen powered demonstrator aircraft in the sky regularly carrying passengers.

Within the FCH JU's critical analysis of the journey to clean aviation by 2050, they assessed two varying decarbonization scenarios – maximum decarbonisation vs. efficient decarbonisation. These scenarios predicted demand of 10 million or 30 million tons LHY by 2040, rising to ~40 or 130 million tons by 2050 respectively. For Canarian airports, and other regional airports, to convert 10% of their fuel infrastructure to LHY it would require ~5,000 tonnes of hydrogen per year.

Smaller hydrogen aviation projects are just starting to take off. ZeroAvia has led the way recently but there has been interest from Boeing and Airbus have also been notably interested in fuel cell technology, with the latter having released hydrogen airbus concept designs in 2020 and recently becoming an ever more vocal supporter of hydrogen.

For the Canary Islands, hydrogen aviation is likely to still be some way off. However, demonstration activities, like ZeroAvia's which has gained sizable investments from a number of major companies including Amazon and Shell, could pave the way for small-scale, zero-emission short-haul flights either between islands or to neighboring countries. By 2023, ZeroAvia is hopeful of being able to run commercial hydrogen-electric, 20-seater flights with a range of up to 500 miles, with a view to be able to commercially transport 100 people by hydrogen aircraft in 2027, as well as provide conversion kits to retrofit regional aircraft to hydrogen-electric powertrains. Once these technologies are viable, the Canary Islands could be a perfect deployment center for the first commercial fleets of these planes, with frequent travel between islands or to Spain and nearby African countries, all of which are likely to produce large quantities of green hydrogen and are in a suitable range.

It is imperative that whatever zero-emission aviation strategy is decided upon for Spanish airports, that local representation from Spain's island communities are consulted for their opinions on how best solutions can be implemented within their unique geographies. Both the Canary and Balearic Islands could be key innovation hubs for aviation technologies as outlined above, but without local stakeholder input this position may not be realised or even considered.

Hydrogen for the Gas Grid

After rejection from the Canary Islands supreme court, along with the Spanish supreme court's endorsement, the possibility of deploying a natural gas grid is seemingly dead in the water for The Canary Islands, despite their best efforts. The plan, which predicted a 30% reduction in CO_2 emissions when compared the emissions from burning oil for synonymous activities, provided a lot of promise including supplying energy to 425,000 homes and 5,800 businesses; although the government could not seem to justify giving the go-ahead for a polluting technology such as natural gas, even though it was a marked improvement on the current situation. Therefore, if another, either zero-emission or low CO_2 option were put forward it could be treated more favourably and see support from communities which annulled previous plans. Step forward hydrogen.

The installation of a dedicated green hydrogen pipeline could lead to even larger carbon emission savings with the replacement/updating of surrounding apparatus (e.g. boilers and other associated pipeline networks). This hydrogen pipeline could be designed to displace the same amount of oil products as the natural gas network, but lead to greater CO_2 savings. Whilst this deployment could be connected to mainland Spain and renewable hydrogen could be redistributed from there to the Canaries, a more sensible approach would be to work with North African countries (as mentioned in the Geological Advantage section) and connect a pipeline to their production centres, as they are expected to have a massive surplus of renewable energy. This could be seen as a win-win proposition for the two regions, reduction on oil imports and CO_2 savings within Spain whilst boosting foreign relationships and providing value added for the North African economy.

Furthermore, with the ban on funding for natural-gas pipelines from EU sources, money is instead ringfenced for renewable infrastructure, such as clean-hydrogen networks. EU Energy commissioner Kadri Simson explained "it is time to re-design their TEN-E regulation so that it helps deliver investments we need in future-proof cross-border infrastructure", including hydrogen. This could provide the impetus to drive such an emphatic and pivotal change within Spain.

Although hydrogen dedicated pipelines are not in public use currently; a number of trial projects have taken place to showcase the potential of blending hydrogen into existing natural gas infrastructure. In the UK, the HyDeploy project has been trialling 20% hydrogen mixed with natural gas on Keele's university campus; whilst the H21 project has positively assessed the techno-economic viability of converting the gas grid in North of England to 100% hydrogen. Hydrogen pipelines have long been a feature of the industrial hydrogen landscape where they run through residential areas and along major roads between production sources and their industrial customers. Additionally, a number of European gas TSOs, including Spain's Enagas, came together in July 2020 to produce a hydrogen vision for the future of the sector and the gas can help transform the transmissions of the sector. It was determined that although expensive, this repurposing of infrastructure would not be as costly as some of the alternatives, therefore, deploying pipelines across the islands may be a favourable proposition, especially if they can then interconnect with a Europe wide gas grid.

Microgrid and Power-to-Power

A microgrid is a localised group of electricity sources that can operate in isolation, otherwise known as 'islanded mode' – whether connected to a more traditional synchronous grid or not. These types of small installations have the capability of providing efficient, clean (if renewable sources are used), and more importantly reliable and resilient energy, as the electricity travels straight to where it is needed, not through a main grid.

Microgrids are on the rise worldwide, their ability to serve isolated communities, preventing often experienced power outages, whilst also providing a renewable energy opportunity to offset carbon emissions means that they are gaining a larger and larger following. In fact, the microgrid sector is expected to grow just 19% over the next 5 years (2020-2025). This upwards trend can also be seen in the Canary Islands, with an over 10% rise in the capacity of non-grid-connected PV systems in each of the years from 2015-2018.

Año	Gran Canaria	Tenerife	Lanzarote	Fuerteventura	La Palma	La Gomera	(*) El Hierro	Canarias	Δ Canarias
Conectada a red									
2008	23.691,16	69.950,44	2.795,43	4.196,77	2.035,69	0,00	24,53	**102.694,02**	285,0%
2009	24.476,57	72.991,62	3.598,24	5.730,54	2.291,17	9,24	33,77	**109.131,16**	6,3%
2010	30.181,87	94.413,89	4.572,82	7.581,24	3.993,14	9,24	33,77	**140.785,96**	29,0%
2011	34.003,04	97.304,17	6.489,00	10.678,74	4.418,46	9,24	33,77	**152.936,42**	8,6%
2012	39.010,68	113.101,42	7.664,83	12.706,45	4.530,47	9,24	33,77	**177.056,86**	15,8%
2013	39.205,32	114.865,39	7.729,55	12.935,13	4.598,41	9,24	33,77	**179.376,81**	1,3%
2014	39.290,92	114.896,07	7.729,55	13.026,09	4.598,41	9,24	33,77	**179.584,05**	0,1%
2015	39.590,73	114.934,63	7.766,30	13.048,18	4.598,41	44,84	33,77	**180.016,87**	0,2%
2016	39.966,74	114.968,63	7.820,30	13.076,18	4.598,41	44,84	33,77	**180.508,88**	0,3%
2017	40.387,38	115.342,35	8.058,44	13.471,77	4.648,41	44,84	33,77	**181.986,96**	0,8%
2018	41.519,24	116.848,38	9.023,68	14.124,47	4.878,74	45,64	34,82	**186.474,98**	2,5%
2019	44.953,27	118.455,46	10.149,30	14.186,05	5.308,29	48,94	98,72	**193.200,03**	3,6%
Incremento anual acumulativo (%)									
19/18	8,27%	1,38%	12,47%	0,44%	8,80%	7,23%	183,53%	3,61%	-
Aislada de red									
2008	104,27	146,01	128,10	54,45	32,28	11,53	13,68	**490,30**	2,0%
2009	117,25	157,40	137,06	54,45	34,32	11,53	13,68	**525,68**	7,2%
2010	117,25	159,11	137,06	54,45	34,32	11,53	13,68	**527,39**	0,3%
2011	117,25	166,32	144,00	54,45	34,32	18,33	13,68	**548,34**	4,0%
2012	118,81	179,08	150,46	54,45	34,32	18,33	13,95	**569,39**	3,8%
2013	119,37	180,18	150,46	54,45	35,07	23,83	13,95	**577,30**	1,4%
2014	121,62	180,18	150,46	76,80	35,07	23,83	13,95	**601,90**	4,3%
2015	124,12	180,18	150,46	76,80	35,07	23,83	16,55	**607,00**	0,8%
2016	124,12	180,18	150,46	209,64	38,07	23,83	16,55	**742,84**	22,4%
2017	163,46	184,01	195,09	228,63	47,07	23,83	16,55	**858,64**	15,6%
2018	168,08	212,35	224,76	269,98	50,18	24,02	19,55	**968,92**	12,8%
2019	267,93	198,63	201,74	309,87	82,40	24,02	20,75	**1.105,34**	14,1%

Figure 25: *Year-on-year PV capacity statistics over the Canary Islands (See Aislada de red for non-grid-connected)*

However, microgrids can utilise more than just electricity – by deploying electrolysers at these sites, the electricity can be turned into hydrogen which in turn can serve more purposes than the electricity alone, such as heating or transport. This could represent a further increase in the deployment opportunities for these grids (for example fuel for taxi services, or heating for flats); in addition hydrogen could also unlock improvements in the efficiency of existing micro-grids, by cutting curtailment in favour for the production of a commodity that can be used for energy storage or sold for economic gain.

Oxygen

When water is fed into an electrolyser to create hydrogen, it also creates oxygen as a by-product in the process. For every kilogram of hydrogen produced, 8 kg of oxygen is produced. Just like hydrogen, oxygen can be captured from this process, purified and sold for a variety of applications including manufacturing, chemicals, pharmaceuticals and waste-water treatment. Oxygen capture from electrolysers is economically challenging. It is possibly economically viable if electrolysers are co-located with their potential oxygen demand or are located in remote areas/on islands.

Recommendations

Tenerife needs a specialised hydrogen strategy.

Spain's NHP is centred around the decarbonisation of industry, with targets such as a 25% replacement of grey hydrogen consumed within the sector intrinsic to its success. However, with very little industry on Tenerife, and the surrounding Canary Islands, different targets are required. Tenerife has a unique geographical setting. It has the potential to exploit the abundance of naturally available resources even more than is being attempted at the moment, whether that be solar or wind, onshore or offshore, all have the potential to play a part. Furthermore, with the Spanish NHP, first and foremost, prioritising the creation of green hydrogen, and the RES capacity increase required to facilitate it, then deploying hydrogen technologies to an area like Tenerife must be considered vital – simultaneously allowing for greater efficiency of RESs and green hydrogen production by utilising curtailed energy for hydrogen production.

Realistically, there are two avenues Tenerife can pursue. The first, as described in the SNHR, is to try and establish themselves, or the archipelago, as a hydrogen valley/cluster – an area in which production, transformation and consumption are spatially concentrated. This approach would likely allow for the largest deployment of hydrogen technologies, by satisfying both production and demand at the same time, rather than having one lag behind the other. Alternatively, rather than deploying a large number of synonymous projects to make a larger hydrogen cluster, Tenerife could seek to deploy a number of smaller, cutting-edge, technological projects and establish itself as a testing ground for various renewable electricity and hydrogen production technologies. These projects could help to establish the suitable technologies for the next stage of the Canaries' or Spain's energy transition, whilst, at the same time, building a skilled sector and workforce, utilising their experience gained within these types of projects, such as SEAFUEL, already. Moreover, when such projects experience notable levels of success, expansion and replication in other locations, whether they be other Canary Islands or mainland Spain, adds value into Tenerife's economy through outsourcing of the unique, cutting-edge, expertise.

Hydrogen fits with national climate goals

Across Europe and globally, we have seen increasing awareness of the environment as a key political topic. Hydrogen has entered the public consciousness as a strategic mechanism for delivering part of a sustainable energy transition. Influenced by this, and the need to drive a post Covid-19 recovery, countries have begun publishing hydrogen strategies outlining their commitment to using hydrogen as a tool in their future national energy strategies.

The entire energy community agrees that developing a hydrogen economy is key to producing energy systems and value chains which will lead to a complete energy system reduction of carbon emissions. Countries signed up to the Paris Agreement are beginning to translate that commitment into nearer term local carbon targets and strategies for delivery. Spain, as one of the 195 signatories, has agreed to play its part towards achieving global net-zero CO_2 emissions by 2050, which has only been further backed by the introduction of the country's Climate Change and Energy Transition Bill. By 2030, the government pledges to reduce emissions by at least 20% from 1990 levels and raise RES energy penetration to >35%. Whilst industry is the primary focus of the Spanish government's hydrogen decarbonisation plans, a number of sustainable transport measures have been set out within this Climate bill with the main aim of phasing out diesel vehicles by 2050. This will be achieved by ensuring all new vehicles purchased from 2040 are zero carbon; boosting e-mobility and recharging infrastructure (such as charging ports) as well as enforcing all Spanish cities with more than 50,000 inhabitants to establish low-emission zones by 2023.

Over the next 10 years, in accordance with their National Integrated Energy and Climate Plan (NECP), renewable energy power penetration is expected to improve by roughly 30%, with a simultaneous nearly 40% increase in energy efficiency. However, with increased renewable deployment, comes increased curtailment, causing precious green energy to be wasted when it could be displacing more fossil-based resources. Hydrogen can allow this otherwise wasted energy to be captured, and stored, with the potential to service more than just the grid in other energy sectors such as heating or transport, which the NECP also contains a 22% renewable energy supply goal for. Furthermore, by utilising this curtailed energy, the energy efficiency of these renewable systems is increased – satisfying both initial criteria. Then, if Spain wants to make the most substantial environmental changes it can over the coming decade, this hydrogen should be either produced or transported to and used by the most isolated areas of the country (including The Canary Islands) – i.e. those regions with the most outdated energy infrastructure.

Creating hydrogen value chains will be an imperative part of the energy transition, not just to cut curtailment, but for gas grid injection, servicing heat, fuelling vehicles (particularly heavy duty) and getting a head start could allow Spain to progress their way towards being a major hydrogen exporter, technology centre and expertise cluster which could bring substantial value added back to the Spanish economy as the rest of Europe seeks to do the same.

Reducing Local Fuel Poverty, Energy Dependency and Stabilising the Energy System.

Discussions surrounding domestic energy affordability are intrinsic to the energy transition debate in across the whole of Europe, not just Spain. With rising energy prices, for older out-dated fuels, and ever greater household energy use expected as a result of the COVID-19 pandemic, it is important the most vulnerable continue to be supported to minimise energy poverty.

In Spain, the government-approved National Strategy against Energy Poverty 2019-2024 was established to address the situation of 3.5 - 8.1 million residents (7.4%-17.3% of the population) and guarantee them access to safe, sustainable, and modern energy. For each of the indicators being monitored, the strategy aims to establish a minimum reduction target of 25% by 2025, with a wider goal of 50%, if achievable. However, according to data from Eurostat, Spain's energy poverty rate has rose to 10.9% in 2020 – the 6th highest percentage in the whole of Europe. These figures are only likely to be aggravated further by increasing gas prices following tensions between Russia and Ukraine.

Therefore, for a region of Spain that imports the majority of its energy demand year-on-year, how can the Canary Islands realistically transform their situation to adhere to and pioneer this new strategy? Hydrogen. Hydrogen not only allows Tenerife to utilise their own naturally occurring geographical resources to a greater degree, whether they be wind or solar, but it also allows for greater energy security. With the importing of fossil fuels only likely to increase in cost, as carbon taxes are introduced and production decreases with the introduction of more renewable/alternative fuel infrastructure, Tenerife's energy system is crying out for a renewable fuel that can be produced locally and applied in a variety of uses along the value chain (e.g. transport, mobility…) - hydrogen can be that fuel.

The Canary Islands, Working Together

Shared Mobility

Boats and Ferries

Shipping is a large and ever-growing source of greenhouse gas emissions, given the sector's increasing size due to the growth in online retail and distributors. Therefore, the EU is supporting global wide action to tackle these emissions. Overall, maritime transport emits around 940 million tonnes of CO_2 annually, being responsible for roughly 2.5% of greenhouse gas emissions globally. The Canary Islands marine sector is no different; although exhibiting a 4.3% decrease in marine fuel consumption from 2018, 2019 marine fuel consumption, of 2,766,598 tonnes. This represents the second concurrent year of a decrease in consumption of maritime fuel.

A number of European projects, such as BIGHIT and GREEN HYSLAND, have already shown the potential of hydrogen to decarbonise associated maritime activities, such as dockside power for cold ironing. These sorts of solutions would be beneficial for deployment on Tenerife due its lion's share of the Canary Island shipping industry, as well as frequenting tourist cruise liners that have to keep their polluting diesel engines running when docked.

The possibility of hydrogen powered maritime travel is also being explored by a number of companies. For the Canary Islands, this could be best implemented in the form of a hydrogen interisland transport vehicle. Targeting interisland travel will provide a number of benefits; firstly, it will increase the amount of publicity and public acceptance opportunities, by expanding hydrogen outreach to more people and areas, rather than condensing activities to a single island. Secondly, including more islands within these activities will enable the establishment of a larger and more comprehensive hydrogen value chain, by leaning on the historical expertise of islands to create a sustainable and reliable sector for years to come, that addresses a number of the main energy issues (emissions, dependency and security). Finally, ports are already expected to be points of energy importance in years to come, due to their pivotal role in bringing renewable energy ashore with the ramp up in offshore technologies, in line with the NECP. Therefore, having access to a load-management and energy storage technology, such as hydrogen, will be key to ensure the maximum running efficiency of these systems – whilst the hydrogen, with demand from maritime, can be supplied to end-users within the port, both lowering cost and emissions by minimising the need for transport and storage.

Heavy Duty Vehicles (HDVs)

With limited statistics available on HDVs in the Canary Islands it is difficult to know exactly their carbon-impact within the area accurately. However, HDVs account for a large share of transport emissions despite an overwhelming market share of passenger vehicles, in fact, lorries, buses, and coaches are responsible for about a quarter of CO_2 road emissions in the EU (6% of total emissions).

With limited statistics available on HDVs in the Canary Islands it is difficult to know exactly their carbon-impact within the area accurately. However, within a European context, they account for a large share of transport emissions despite an overwhelming market share of passenger vehicles, in fact, lorries, buses, and coaches are responsible for about a quarter of CO_2 road emissions in the EU (6% of total emissions).

A number of European projects feature the replacement of HDV fleets with hydrogen analogues (e.g. Gencomm, JIVE 1 and 2, TRL's H2 buses) as this initial step provides a baseline H2 supply that can spawn surrounding value-chain growth, whether that be direct (renewable energy and vehicle fleets) or indirect (fabrication and materials). Moreover, at this point, unlike the aforementioned projects, hydrogen HDVs are relatively proven technologies and are starting to be deployed on larger scales –

such as H2bus which plans to put 1,000 hydrogen buses on the road or Hyundai planning to bring 1,600 trucks to Swiss roads by 2025. For the Canary Islands, this could manifest in the form of an island wide bus, tram or taxi project. Transforming the public transport network using low or zero-emission vehicles whilst allowing residents and tourists to engage with hydrogen fuel cell vehicles on a regular basis. This will improve the public acceptance of hydrogen and its applications, in turn making it easier to implement further projects and developments.

Additionally, if the EU decide to form a unified island approach (See 'All Islands Approach' section), by deploying similar technologies to many islands, the funding and subsidies available for this type of transport could make it more economical to deploy than current alternatives, especially with the potential introduction of carbon taxes. Therefore, a low-emissions HDV application could prove to be a lucrative and worthwhile opportunity for the Canary Islands.

Tourism

Tenerife has a very large tourism sector, welcoming millions of non-residents to the island every year, and as such has an abundance of tourist vehicles, whether that be rental fleets, taxis, or buses, that service their transportation needs. These vehicles, particularly taxis, often require high levels of operability 24 hours a day and thus to achieve decarbonisation would require a solution that allows businesses to maintain this practice and reliably serve customers. Battery vehicles will not be able to meet this demand as their conventional AC recharging period would leave fleet operators without access to vehicles for 6-8 hours, whilst also struggling to deal with the volcanic terrain of the island. DC charging shortens the charge time but requires robust electrical infrastructure which, as we have discussed, is less likely to be in place in remote island communities.

Hydrogen could be the answer. Hydrogen Fuel Cell Electric Vehicles (FCEVs) offer similar refuelling times to current fossil fuel vehicles (~5 mins for cars and ~15 mins for larger vehicles) and, therefore, reduce the downtime of vehicles significantly in comparison to their battery alternatives. Furthermore, FCEVs not only offer a larger range, but also power density too – meaning they'll be able to deal with the terrain *and* travel further without the need for extensive and thorough refuelling infrastructure. Just 10-20 hydrogen refuelling stations could be enough to service the whole island – much fewer than the number of chargers required to maintain the same fleet, which would also cause significant problems to the already constrained grid of the Canary Islands. Therefore, the tourism sector represents a unique opportunity to introduce hydrogen mobility fleets swiftly as much of this technology is already mature.

Codes and Standards

Hydrogen rules and regulations are still being created and evaluated, even those right at the forefront of the energy transition are still having to adapt policy as and when issues are encountered. With Spain being part of the EU, it is likely that the Canary Islands will be required to follow most of the codes and standards set out by the commission, as they are adopted by the mainland and subsequently imposed on its principalities as well. Whilst not all of these rules will be best suited to the unique island environment that Tenerife is, it is important that the region doesn't look to reinvent the wheel in terms of its own hydrogen sector advancements. Straying too far from the norm, in terms of codes, standards and regulations, will lead to difficulty when it comes to cross-border projects if substantially different pressures, equipment or methods are used. Therefore, the archipelago should look to take advantage of activities on a national and European level, this will allow for the greatest improvement in the Canary hydrogen sector by bringing funding in from other regions whilst helping to embed accepted practices in its infancy.

Supply Chain

There's a real opportunity for the Canaries to interdependently build a hydrogen sector around a common objective, such as interisland travel. This overarching goal can stimulate growth across all islands, generating the operational knowhow that is not available elsewhere, especially within the marine area. Focusing on this goal has the potential to bring manufacturing, operation and maintenance jobs, across all the islands, in technology, production and renewables (for green hydrogen production); fabrication and manufacturing (for the creation of pallets, hydrogen gas systems and supplementary apparatus); operation and distribution (e.g. transporting hydrogen form production to end-users, or selling in the forms of service stations) – adding value to individual island communities as well as the archipelago as a whole.

Furthermore, if positioned correctly, the development of the region's hydrogen sector could be seen as a critical opportunity to improve employment figures across the Canary Islands. Including educational pathways could help to retrain fossil-fuel and other contracting industry staff and help young people, who are disproportionally affected by unemployment, with jobs that extend all year-round rather than being reliant on tourist seasons for employment – which are struggling to return to 'normal' post the pandemic. Moreover, once trained, these skills and expertise can then be made available to neighbouring regions, who are exploring hydrogen related-solutions to bring value-added back to the Canary Islands economy and build a wider, cross-border hydrogen economy.

Hydrogen Coordination Body

Hydrogen co-ordination bodies are present around the European Union, whether they are continent wide such as the EHA or Hydrogen Europe, or nationally based such as AéH2 in Spain. These bodies help to investigate, advise, recommend and regulate hydrogen-based activities using their local knowledge, contact database and sectorial expertise. The Canary Islands would benefit greatly from the formation of one of these bodies given the uniqueness of the area – geographically, economically, and politically.

Such a body would involve members from the renewable industry, governments, hydrogen touching industries and residents to ensure decisions are being taken with the best interests of all parties taken into account and ensuring maximum transparency. Given the high court and supreme justice of the Canary Island's dismissal of plans for natural gas infrastructure, it would also be useful to have representatives from appropriate public bodies or even one one of these parties to ensure all decrees are being complied with, as well as helping to maintain a healthy relationship with the area's public sector.

A body like this would also serve as a useful first point of contact for new potential stakeholders to engage with to understand more about the area and the benefits and challenges to deploying hydrogen ventures within the Canary Islands.

Geographical advantage

Tenerife has an advantageous position in terms of renewables producing potential, with a great deal of land based solar and wind already being harnessed. The next step for the area is to look towards the construction of offshore floating developments, including these technologies, as well as the deployment of possible large scale tidal (depending on advancements with the technology), in order to fully harness their potential despite limited available land-space which currently hinders development.

Spain's targets to increase the penetration of renewables in most of its significant sectors by 2030 (particularly within electricity generation and transport), will see an increase in the deployment of renewables. This, therefore, increases the importance of a power balancing mechanism, such as hydrogen, as an increase in intermittency issues will be seen, especially whilst there is a lag between renewable power increase and a decrease in the output from fossil-based energy production facilities. With the deployment of electrolysers to key renewable sites, Spain could produce green hydrogen with curtailed energy, to improve the efficiency of their renewable electricity sites whilst producing a commodity that can be used to offset fossil fuels in other sectors. The mainland could then distribute this hydrogen to the areas which experience the most energy challenges (e.g. poverty and dependency on foreign imports), including the Canary Islands, to help, and subsidise, their way to transitioning their own energy situation.

Alternatively, Spain now has a number of energy ties with Northern Africa. The country imports natural gas (using two undersea pipelines) and LNG from Algeria, accounting for 52% of their natural gas imports from 2016. Spain could extend its African influence as the area starts to become a mass renewable energy producer, as is predicted in the coming decades. However, these areas (e.g. Morocco, Algeria etc.) are expected to produce far more energy than their domestic demand and thus could produce green hydrogen from this excess and export it to the surrounding countries to add value to their domestic economy – similar to that suggested by Hydrogen Europe's 2050 plans for the EU. The closest of the Canary Islands is situated just 67 miles from the coast of western Africa, therefore hydrogen could be transported to Tenerife and the surrounding islands, either by boat or pipeline (with purpose-built infrastructure) – helping to reduce Tenerife's emissions whilst allowing the African renewable energy outlets to operate at higher efficiencies and add value to their domestic economy, a win-win situation.

Hydrogen Timetable in Tenerife

How would this scale-up towards a green hydrogen economy take place? There are likely to be three defining phases that will occur to ensure success. To foster such a timeline, policy must then adapt between periods, allowing changes in incentives to create a favourable environment for the desired economic and societal effect.

The first is market development – up until 2030 there is a requirement to simultaneously grow both hydrogen production and end use applications. At the same time policy and regulations are rapidly implemented and passed through their relevant bodies to ensure beneficial, symbiotic growth of hydrogen-influenced sectors.

From 2030-2040, constant and rapid market development will occur, with the optimisation and critiquing of suitable technologies for specific geographic locations and situations. Renewable energy systems will continue to increase share of the energy market. New hydrogen applications will proliferate, new supply chains will be created. Companies will innovate in and around the new hydrogen market.

Once the market has become fully established between 2040-2050, we will see the mature market development phase of these optimised technologies, reaching large scale production and mass deployment. There will be rationalisation of supply and application systems. Policy must drive the retention of local economic value and skills, to ensure that in a widely developing global market, local positions are not lost to international rationalisation.

The need for support mechanisms

Initial support, likely both CAPEX and OPEX, to build on early successes will be key to driving growth within the sector - as well as obtaining public buy-in. As the technologies become established, past a demonstration level, support can be decreased.

Mechanisms such as carbon taxes, GOO's, feed-in tariffs or market support constructions will be required for green hydrogen, until economies of scale can be exploited to a degree that it achieves competitiveness with established alternatives. It is widely appreciated that a green/low carbon hydrogen certification mechanism is crucial for the uptake of hydrogen and other renewable fuels. The UK RTFCs or Dutch HBOs are good examples of how these sorts of certification systems can work in practice – however, currently, they only apply to certain transport applications and renewable fuels, making their impact rather minimal, particularly given the need to decarbonise other sectors such as heating. Spain can learn from these two systems and seek to deploy a wider, more inclusive RTFC-style scheme to progress the hydrogen economy from its developmental stage into a fully-fledged competitive sector.

An All-Islands Approach (EU)

The EU is home to over 310 inhabited islands with a cumulative population of over 15 million people. The majority of these islands live in energy isolation; they're incredibly dependent on their respective mainland's, and other neighbouring regions, to satisfy the majority of their energy demand, more often than not in the form of polluting fossil fuels. With the announcement of a succession of national hydrogen plans, as well as the EU green deal, most hydrogen focused funding will now be targeted towards big businesses, with large demands that drive down the cost of hydrogen production – it is imperative that these, smaller, island communities are not forgotten during the energy transition. With the advancements in hydrogen valley projects, both localised to island geographies (GREEN HYSLANDS) and those which aren't (HEAVENN), the EU and the hydrogen sector is getting an ever-better grasp on what hydrogen technologies will be successful and popular for large-scale deployment anywhere, and those which are more niche and suited to specific geographies.

Utilising this accrued knowledge can produce a 'cookie-cutter' for the EU's island communities, which unites both proven methods of hydrogen deployment, e.g. public transport networks, and couples them with technologies required to tackle island specific issues – such as the deployment of hydrogen pipeline infrastructure to reduce the reliance on outdated, and carbon-emitting, heating fuels technologies, particularly oil. This focus should build on previous successes found in various European hydrogen island-based projects, such as SEAFUEL, Big Hit and GREEN HYSLAND and focus on developing a whole hydrogen value chain from start to finish with the community at its core.

First focus should be on increased renewable deployment, complimented with electrolysers, which will ensure the greatest efficiencies for RESs possible, whilst producing a fuel that can be utilised domestically, in various applications, to reduce emissions and increase fuel resiliency. These RESs will be in the form of offshore deployment of wind, solar and tidal (depending on area) as island land-space is a scarce resource – this can also help the EU achieve targets of at least 60 GW offshore capacity by 2030, increasing to 300 GW in 2050, although with the Commission's Fit-for-55 package increasing renewable energy penetration targets from 32% to 40%, installations are expected to exceed this pace (>15GW per year through 2021-25 alone).

The deployment of such technology is only useful with demand, however. Thus, this cookie-cutter plan needs to feature fuel cell applications to build up supply & demand simultaneously, preventing a ‘chicken and egg’ type scenario. The most beneficial in terms of carbon emission savings and addressing issues such as fuel poverty and energy security would be the installation of hydrogen pipeline infrastructure connecting renewable production directly to residents’ homes as well as offices, hotels, hospitals (etc.), although this would come with some disruption during the deployment phase the end would easily justify it. An alternative could be the deployment of fuel cell public transport fleets (both buses and ferries), particularly around port areas which are central to many EU islands’ communities. Port areas are likely to act as energy hubs as offshore energy is often brought to land through them, thus they could act as the perfect location to deploy hydrogen infrastructure, being both a production and a demand point. In terms of vehicles, fuel cell buses are proven technology across several European locations and are starting a commercial mass deployment phase, whereas boats/ferries, although further behind in their development cycle, are crucial to island life and a large project like this could see their technology develop and thrive. For both cases, if the EU committed to the deployment of these technologies to a number of island communities, then the economies of scale associated with large orders of vehicles and infrastructure could be cost-efficient. These initial applications can serve a number of purposes alongside driving demand, including increasing public acceptance amongst residents and instigating local hydrogen policy generation. Islands within such a project could work together symbiotically and share problems as they are encountered and resolve them with sensible and effective solutions for all participants.

Finally, if such a plan is implemented, the EU should look to prioritise islands which attract the most European tourists to their shores per year. When these tourists visit destinations and travel on hydrogen buses and taxis or see hydrogen systems heating their homes and hotels then they will take note and be more accepting of the technologies when returning to their home countries. Therefore, destinations like Tenerife should be not only be high on the EU’s list of priorities in terms island-based carbon emissions but due to possible knock-on effects as well. Also, depending on how wide spread a decarbonisation effort is within these regions, they could become ‘eco-tourism’ hotspots; as an increasing number of consumers now preferentially look more for destinations which are more environmentally conscious over their alternatives – adding more value to their domestic economy from foreign contributors

HyEnergy

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HyEnergy Consultancy

This report is prepared by the HyEnergy Consultancy in association with partners of the SEAFUEL project, an Atlantic Area funded project.

HyEnergy is an experienced consultancy with over 50 years of expertise within the global hydrogen and renewable energy sectors. It supports stakeholders including industry, local/regional public sector organisations and national governments in transitioning to sustainable energy solutions.

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