Unleashing Offshore Wind Potential in the Canary Islands: A Pathway to Carbon Neutrality and Socio-economic Growth

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Summary

This research report addresses two main problems identified through problem analysis: the high cost of deploying offshore wind in the Canary Islands and the region's high unemployment rates. The report aims to investigate the socio-economic feasibility of implementing offshore wind in the Canary Islands' energy system, focusing on the research question: To what extent can offshore wind be a socio-economically feasible alternative while contributing to the Canary Islands' goal of carbon neutrality by 2040, and if so, how can it be politically promoted?

To provide insights into the research question, four sub-questions were formulated and subsequently examined through individual analyses. The first sub-question explored the key stakeholders involved in offshore wind energy projects in the Canary Islands through stakeholder analysis. The second sub-question examined the technical and political environment surrounding offshore wind energy in the region using an energy system analysis. The third sub-question assessed the feasibility of offshore wind as a power generation alternative through a feasibility study. Finally, the fourth sub-question focused on developing policy recommendations to facilitate offshore wind deployment.

The report incorporated three theories: Radical Technological Change theory, Choice Awareness theory, and Innovative Democracy theory. These theories provided a framework for the analysis and helped define the analytical research approach. The analysis revealed that offshore wind projects in the Canary Islands have the potential to contribute to carbon neutrality and generate industrial and employment opportunities. However, the actual extent of these outcomes will heavily rely on the government's economic and political initiatives and the level of engagement with stakeholders.

The case study of Gran Canaria provided insights into the specific context of the island, and the findings can be to some extent generalized to other islands in the region. The report concluded that offshore wind is a socio-economically feasible alternative in the Canary Islands, but its success depends on various factors, including government initiatives and stakeholder involvement. Policy recommendations were formulated to support the deployment of offshore wind, covering aspects such as target setting, stakeholder engagement, support mechanisms, permitting processes, infrastructure development, market visibility, and regulatory stability.

Acknowledgement

This master’s thesis is grounded in my deep enthusiasm for offshore wind energy and the broader concept of energy transition. The completion of this project took place during the fourth semester of my master's program, specifically in the field of Sustainable Energy Planning and Management, at Aalborg University.

I would like to express my sincere gratitude to all those who have contributed to the completion of this research report. Firstly, I extend my heartfelt appreciation to my supervisors Frede Hvelplund and Pedro Jesús Cabrera Santana for their invaluable guidance, support, and expertise throughout this research journey. Their insightful feedback and encouragement have been instrumental in shaping the direction and quality of this work.

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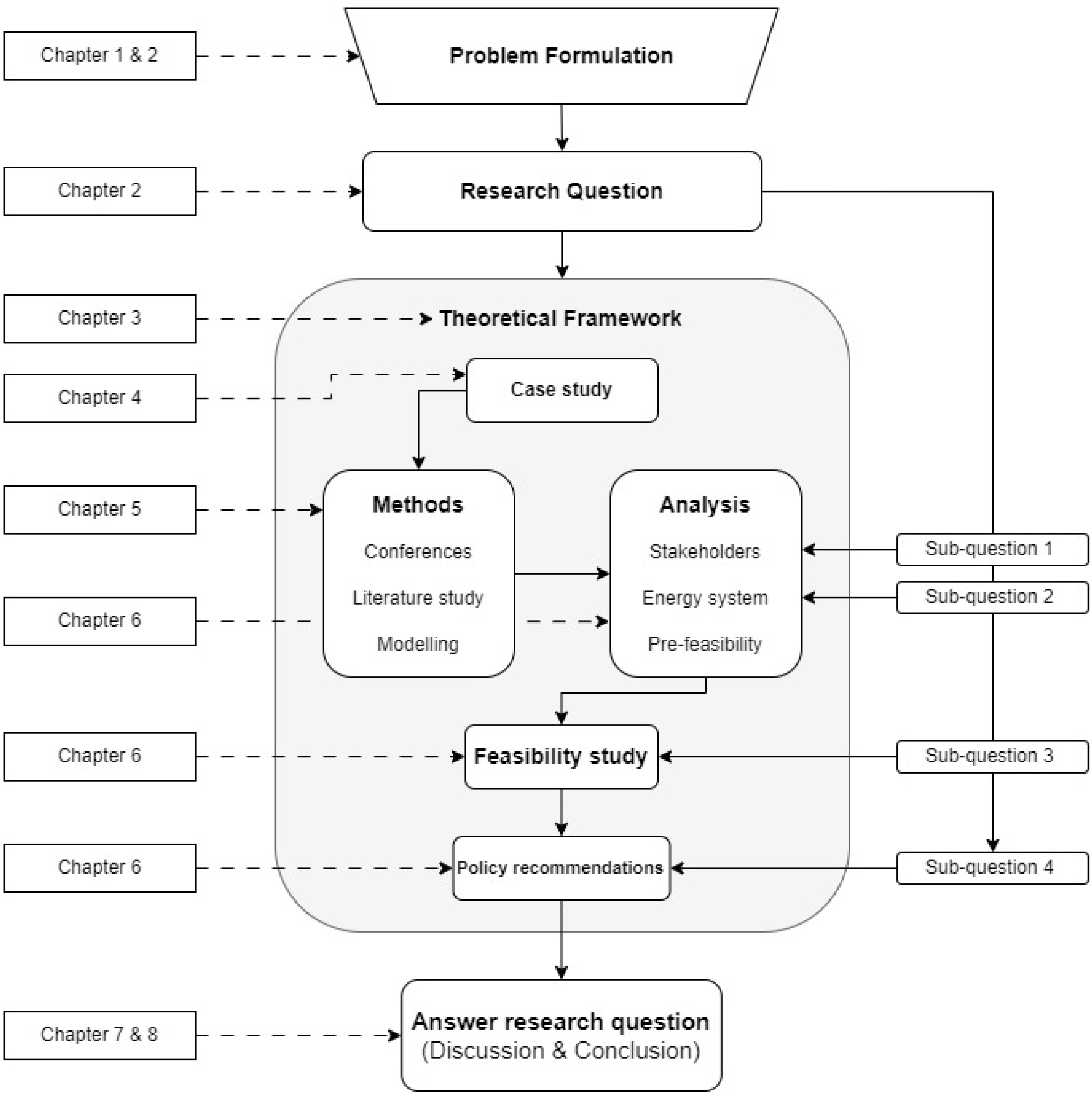
Reading guide

For reference in the present report, the Harvard style is used, which means the reference is as follows: (author, year of publication) e.g. (Seneviratne *et al.*, 2021). Sources which appear multiple times with the same name and year will be presented with a letter e.g. (European Commission, 2020a). Direct citations are presented as: Allen (2017).

The report is structured into eight chapters, each containing sections and subsections that are numerically marked. This includes tables, figures, and two appendices. The report utilized the average exchange rates for 2022 as provided by the European Central Bank. An overall structure of the report without the appendices can be observed in the next figure:



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List of abbreviations

AEP	Annual Energy Production
CAPEX	Capital Expenditures
CfD	Contract for Difference
CIT	Corporate Income Tax
CO2	Carbon Dioxide
DECEX	Decommissioning Expenditures
DEVEX	Development Expenditures
ETS	Emission Trading System
EU	European Union
EV	Electric Vehicle
FOU	Offshore Wind Foundation
FTE	Full Time Equivalents
GHG	Greenhouse Gas
HVAC	High-Voltage Alternate Current
HVDC	High-Voltage Direct Current
LCOE	Levelised cost of energy
MITECO	Spanish Ministry Ecological Transition and Demographic Challenge
NPV	Net Present Value
OPEX	Operational Expenditures
OSS	Offshore substation
OWF	Offshore Wind Farm
POEM	Planes de Ordenación del Espacio Marítimo
PTECAN	Plan de Transición Energética de Canarias
RE	Renewable energy
REE	Red Eléctrica de España
TSO	Transmission System Operator
WACC	Weighted Average Cost of Capital
WTG	Wind Turbine Generator

1. Introduction

The objective of this chapter is to prepare the groundwork for the study, emphasizing its importance, defining and justifying the research problem, and providing essential background information to guide readers. It aids readers in comprehending the research's purpose, context, and significance, while facilitating a clear understanding of subsequent sections in the report. The research primarily focuses on the regional level, however, was considered crucial to explore top-down the various levels of governance, both European and national, in order to fully grasp the contextual intricacies of the research problem.

1.1. Offshore Wind in the European level

Since the industrial revolution, greenhouse gases (GHGs) from anthropogenic activities have been released significantly into the atmosphere, contributing to the rise of the temperatures, a phenomenon commonly known as Global Warming (IPCC, 2007). This has a crucial negative impact on the planet altering its climatology, where extreme weather events are becoming more frequent and unpredictable causing natural, social, and economic impacts across the world (Seneviratne et al., 2021).

The organization Global Carbon Project, which aims to quantify GHG emissions and their causes, along with the IPCC, have demonstrated that the use of fossil fuels is the main responsible for the increase of GHG emissions, attributed to about 78% of the total from the period to 1970 to 2010 (IPCC, 2014). However, the high concentration of energy that fossil fuels provide, has proven to be hard to replace cost-effectively with other energy-carrier alternatives in the short term (Brundtland, 1987; Kåberger, 2018).

Acknowledging that global action is needed to tackle global warming, 196 state parties joined at the 2015 United Nations Climate Change Conference in Paris to adopt a long-term accord, known as Paris Agreement (UNFCCC, 2015). The agreement has the goal to limit the rise in mean global temperature below 2 °C above pre-industrial levels, and preferably limit the increase to 1.5 °C. It is also recognized that this would substantially reduce the effects of climate change and therefore, emissions should be reduced as soon as possible and reach net-zero by 2050. Based on this, long-term adaptation goals are included in the agreement, and countries must report on their adaptation actions, making it a parallel component with mitigations (UNFCCC, 2022).

The European Union (EU), on its way to fulfilling the Paris Agreement, is at the forefront of international climate negotiations with initiatives such as the Effort Sharing Regulation, the Emission Trading System (ETS) and the European Green Deal. For instance, the European Green Deal, which was launched in 2020, compiles a set of policies with the overarching aim of making the EU climate neutral in 2050, i.e. net-zero GHG emissions (European Commission, 2020d). As a part of The European Green Deal, in September 2020 the EU redefined more ambitious energy and climate targets from 2021 to 2030, called the 2030 Climate Target Plan (European Commission, 2020a). One of the targets is to reduce GHG emissions of the EU by 55% in 2030 compared to the level from 1990. In order to achieve these decarbonisation objectives, a drastic acceleration for energy transition is required, where emissions must be reduced in all sectors, from industry and energy, to transport and farming which implies the replacement of fossil energy sources by renewables. To do so, the European Green Deal aims to transform the EU into a resource-efficient and competitive economy, ensuring economic growth decoupled from energy dependence from external suppliers such as Russian and its natural gas. In light of Russia´s invasion of Ukraine, this last is more than justified (European Commission, 2022b).

Renewable energy (RE), as was mentioned, will play a fundamental role to reach the ambitious target set by the European Green Deal, and one of the most prominent sources of RE can be found at the sea. Currently, the EU is a world leader in offshore RE technology and has the potential for extensive development and deployment, since the EU possesses the largest maritime space in the world. Moreover, its advantageous location with different sea basins offers a variety of opportunities to harness offshore RE such as offshore wind, wave and tidal energy (IEA, 2019). For instance, Figure 1 illustrates the EU-accessible potential sea basins to develop offshore wind projects.

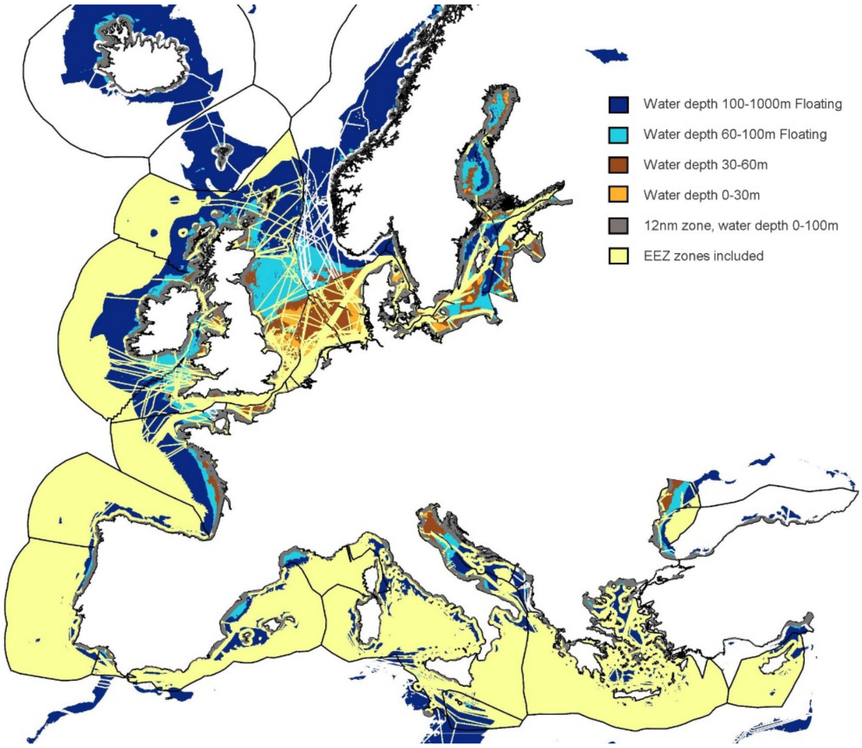

Figure 1. Offshore wind technical potential in sea basins accessible to EU27 countries. EZZ refers to Exclusive Economic Zones. The figure is published by Joint Research Centre (JRC), European Commission (JRC, 2019)

In the figure, the potential areas are classified by water depths, since it is the principal factor to deploy either conventional bottom-fixed offshore wind or floating offshore wind technology. Floating offshore wind turbines provide access to deeper water than bottom-fixed offshore wind turbines, which are limited to 60 m water depths, however floating technology lacks maturity despite its accelerated growth (IRENA, 2020).

Tapping into this technological potential could be crucial for the EU in its way to achieve ambitious targets and the European Green Deal communication fully recognized this potential for the path toward a resource-efficient and competitive economy purpose. Reaching the targets of the European Green Deal will require a significant scale-up of the offshore wind industry and the European Commission published an Offshore Renewable Energy Strategy intending to make this happen and maintain the EU's leadership in this sector(European Commission, 2020d).

Offshore Renewable Energy Strategy outlines a general framework which includes both opportunities and barriers of the different types of offshore technologies and includes certain goals and policies to be undertaken to incentive the technological development. These policies are adapted to the specific regional context since every sea basin in Europe is unique. The strategy goals are the following: to set ambitious targets for the growth of the offshore renewable energy sector; to encourage public and private investment in new infrastructure and research; to make it easier for different regions to work together more efficiently; to provide a clear and stable legal framework (European Commission, 2020c).

Regarding the ambitious targets, the strategy sets targets for an installed capacity of offshore wind of at least 60 GW and 1 GW of ocean energy by 2030, and 300 GW and 40 GW, respectively, by 2050 (European Commission, 2020c). This means to increase the European offshore wind capacity at least 25 times by 2050 as the installed offshore wind capacity in 2021 was 14.6 GW in the EU across all five EU sea basins. According to the Joint Research Centre (2020) the investment needed to reach this capacity is estimated at up to 800 M€. This will become a decisive challenge, which means a massive change of scale for the sector in less than 30 years, at a speed unparalleled by the past development of other energy technologies. Furthermore, the projected demand for renewable power that can offer a wider spectrum of end uses, such as the generation of Green Hydrogen, puts even more pressure in adding more offshore wind capacity. For instance, the European Commission communicates at the European Hydrogen Strategy the goal to reach the 40 GW of renewable hydrogen electrolysers by 2030, which part of the share will rely on offshore energy (European Commission, 2020b).

According to the European Commission, "[…] such a change in pace requires overcoming a number of obstacles and ensuring that throughout the supply chain all players can both accelerate and sustain this increase in deployment rate. A greater involvement of the EU and of Member States' governments is needed" (European Commission, 2020c). This emphasizes the need for engagement of the public institutions to stimulate and mobilize the private sector in order to increase offshore RE capacity. Therefore, effective long-term policy actions that reflect the cost development for investment decisions, will be crucial, where all EU members state should be involved.

EU has experimented with clear examples of deployment growth in offshore wind energy through the intervention of fiscal regulation and initiatives, especially in bottom-fixed technologies. Targeted subsidies, fossil fuel taxation, effective tariffs, incentives in the form of grid connections, site development and fund for R&D, are some of the actions that enabled to accelerate notably the maturity of the technology in countries such as Germany and Denmark (Brown et al., 2015).

Cumulative, the EU-27 member states have installed about 204 GW of wind energy capacity as of the end of 2022, of which 16.1 GW (8%) corresponds to offshore wind energy. More than 88% (14.2 GW) of that offshore wind capacity has been installed since 2013. Germany has been the largest investor with 7.6 GW of installed capacity, followed by the Netherlands with 3 GW (WindEurope, 2023).

The EU expects to meet its current offshore wind energy target of 60 GW capacity by 203, therefore, the EU will likely increase its offshore wind energy target in line with its aim to increase its renewable targets for 2030 from 40% today to up to 45% (European Commission, 2022a). Currently, assuming all the EU member states' national offshore wind energy targets, the sum is about 107 GW by 2030. This already doubles the EU's current target (60 GW), however, the projects in the pipeline would likely fall short of reaching national capacity ambitions (WindEurope, 2023).

As it was above-mentioned EU countries had already installed 16.1 GW of offshore wind capacity by the end of 2022, which means that in order to deliver 107 GW of capacity, EU countries will need to scale up installation almost sevenfold by the end of the decade. According to BloombergNEF (2022) data, indicates that most EU countries are at risk of falling behind their national targets for 2030 with a cumulative gap that could be as high as 36.5 GW. Based on this forecast, only Belgium (5.8 GW), Lithuania (0.7 GW), Poland (5.9 GW), and Italy (0.9 GW) are currently expected to reach their targets by 2030, while the remaining EU countries are at risk of falling behind their national targets (Rabobank, 2023). Portugal, Spain and the Netherlands, in particular, seem to have the largest gaps to bridge. In order to bridge this gap, these member states will need to overcome a number of barriers in the offshore wind supply chain.

1.2. Spain as a potential EU country in integrating offshore wind energy

Offshore wind presents an acceleration of its technological and industrial development, which can make its implementation in Spain viable thanks to the concepts associated with floating offshore wind, allowing its deployment in deep waters (AEGIR, 2022). Due to its high-capacity factors, offshore wind can generate electricity in a more stable and predictable way (when comparing onshore wind), increasing its production in the autumn and winter seasons, when solar radiation is lower, and consumption is higher. It is, hence, highly complementary to other REs, contributing to security of supply in the energy system and allowing greater harnessing of available endogenous resources (Bloomberg Finance, 2019).

On one hand, Spain possesses a key role as a global onshore wind development hub placing the country in a privileged position for the development of offshore wind power. More specifically, Spain is the third European country and the sixth country in the world in terms of capacity installed wind power, after China, the United States, Germany, India and the UK (GWEC, 2022), generating 22% of Spain's total electricity consumption (IEA, 2022). Furthermore, Spain is one of the three European countries with the greatest wind power industrial capacity and R&D&I investment in the sector. On the other hand, Spain has a consolidated shipbuilding industry (shipyards), a maritime-port sector, civil engineering capabilities, and an industrial ecosystem of materials and equipment that can serve the development of offshore renewables (Evwind, 2023).

The development of offshore wind in Spain will not only help to expand the market for this supply chain in Spain but will also help it to compete and provide services on a global scale. The existence of a local market in Spain will maintain the Spanish offshore industry's competitive positioning, increasing its contribution to GDP and the creation of skilled jobs (MITECO, 2022). For instance, Offshore wind could create over 7,000 new jobs in Spain by 2030 (30,000 currently), with more than 17,000 people working in the sector by 2050, according to estimates in a white paper released by the Spanish Wind Energy Association (AEE, 2022a). Furthermore, offshore wind is already assisting to diversify business strategies and stabilize workloads in associated industrial sectors.

In terms of energy contribution in Spain, the Integrated National Energy and Climate Plan (PNIEC, by its Spanish acronym) 2021-2030 anticipates 50 GW of installed wind power capacity by 2030, including both onshore and offshore wind (MITECO, 2021). This figure is nearly double the current 25.7 GW of wind power, for which estimated investments of more than 30 M€ are required in the period 2021-2030, in addition to those associated with the repowering of existing wind farms (MITECO, 2022).

As a result, the Spanish Ministry of Environment (MITECO, by its Spanish acronym) released a Roadmap, in accordance with the PNIEC, which defines the national targets for Offshore renewable energy, as well as the lines of action and efficient paths to achieve them. Similarly, its primary motivation and goal are to identify the challenges and opportunities for promoting the full development of offshore wind and marine energy in Spain in the short, medium, and long term. As a result, the Offshore Wind and Marine Energy Roadmap has four objectives:

- Establish Spain as a leading European hub for technology development, research, and innovation in the field of offshore renewable energy.
- Position Spain as an international and European leader in industrial capacities and the entire value chain of offshore renewable energy. This includes fostering European industrial leadership, creating employment opportunities, and developing circular economy practices throughout the life cycle of these energy sources.
- Prioritize sustainability as a fundamental pillar. The roadmap aims to align offshore renewable energy development with the natural values of the marine environment, biodiversity protection commitments, and sustainable practices.
- Ensure a well-planned deployment of offshore wind and other marine renewables to support industrial and technological growth. The targets set for 2030 include 1-3 GW of offshore wind capacity and 40-60 MW of marine energy capacity. (MITECO, 2022)

To achieve these objectives, the Roadmap establishes solid foundations and a suitable framework to generate the necessary interest in developers and investors, as well as key aspects to guide and favour coordination among all stakeholders involved, as well as the approach and guidelines for the sector's regulatory framework adaptation (MITECO, 2022). Finally, it aims to provide the necessary continuity and visibility to attract investment and to consolidate and boost industrial capacities and the value chain as a whole, as well as foster the generation of infrastructures and R&D&I projects around the activity generated. The following ranges are established as targets for the development of offshore renewables in Spain by 2030, based on the development of the framework proposed by the measures in the Roadmap: between 1 GW and 3 GW for offshore wind and between 40 MW and 60 MW for marine energy (referring to wave, tidal and current energy). WindEurope and the Spanish Wind Energy Association, Asociación Empresarial Eólica (AEE), estimate that at least 3 GW of offshore wind can be installed in Spanish waters by 2030, mostly floating given the water depths around the Iberian Peninsula (AEE, 2022b).

On February 28 of 2023, the Spanish Council of Ministers approved the maritime spatial planning plans, known as POEM, for the Spanish marine demarcations: North Atlantic, South Atlantic, Strait of Alborán, Levantine-Balearic Islands, and Canary Islands (MITECO, 2023c). The goal is to organize the uses and economic activities of Spain's million square kilometres of sea. Minister of Environment explained that the goal is to organize "current activities and those that can be carried out" at sea (EL PAIS, 2023). And one of those that has aroused the most attention is the development of offshore wind energy due to its potential in the fight against climate change, but also due to possible conflicts with other uses.

According to MITECO (2023c), these zones could theoretically support up to 24 GW of wind energy. However, wind energy development is not the only potential future use of these zones. Other activities will take place in the 5,000 km2 of sea space, including defence, shipping, research, extraction, fishing and aquaculture, and environmental protection. Spain can learn from other EU countries on how to coexist peacefully with offshore wind and these other sea uses. The nearly 5,000 square kilometres, divided into 18 polygons, account for only 0.46% of the national waters affected by the new POEMs (EL PAIS, 2023). Figure 2 shows the defined polygons within the different demarcations.

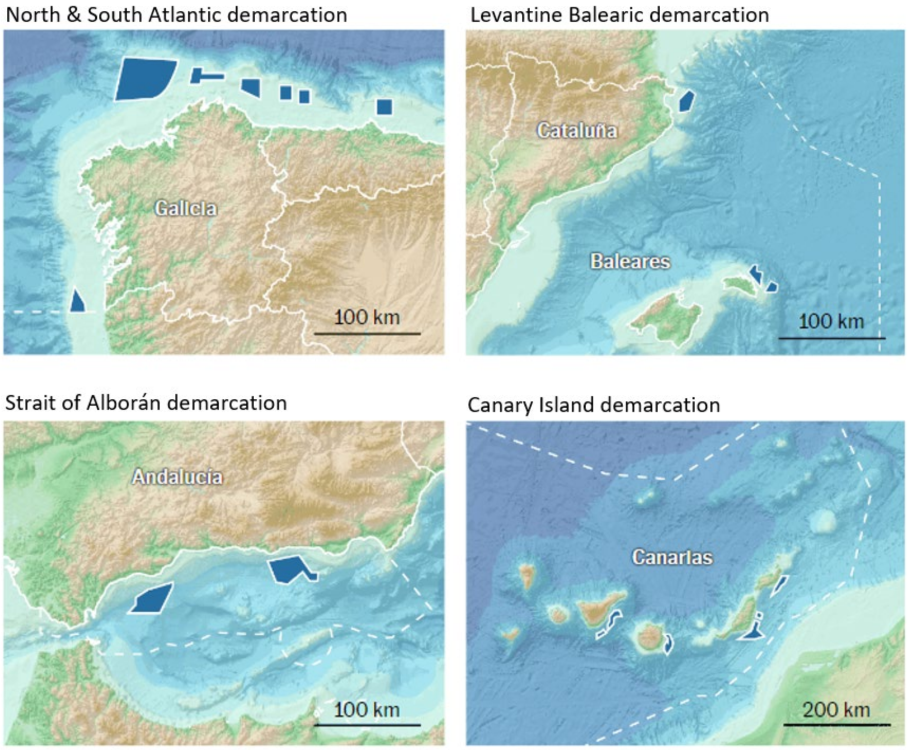

Figure 2. 18 areas where wind turbines can be installed. The figure is published by (EL PAIS, 2023)

The nation has yet to begin commercial offshore wind development. So far, offshore wind activity in Spain has been limited to pilot projects. The Canary Islands currently house Spain's only offshore wind turbine. The BlueSATH prototype was recently installed off the coast of Santander by SAITEC and RWE, and in 2020, a 2 MW floating DemoSATH project was assembled and tested in the coast of Bilbao (SAITEC, no date). Enerocean spent a year testing the Wind2Power prototype, a groundbreaking 2-turbine floating platform design, at the Oceanic Platform of the Canary Islands (PLOCAN by its Spanish acronym) in 2019 (PLOCAN, 2019). In addition, a consortium led by X1 Wind will test the PivotBuoy technology off the Canary Islands (PivotBuoy, 2021).

The Canary Islands will likely become a hub for early offshore wind development in Spain (WindEurope, 2021). The Canary Islands energy strategy aimed to develop around 410 MW of floating offshore wind by 2030 as outlined the Plan de Transición Energética de Canarias (PTECAN) (Instituto Tecnológico de Canarias, 2022a).

1.3. The introduction of offshore wind in the Canary Islands

Canary Islands is becoming the first mover for the deployment of offshore wind technology in Spain, especially the island of Gran Canaria, which is expected to accommodate most of the first commercial projects in the near future. This could bring a socio-economic opportunity for the region and contribute to the national climate commitments.

On the 20th of December 2021, the MITECO and Territorial Planning of the Government of the Canary Islands presented the Climate Action Strategy, which defines the planning framework for climate action in the region. This model establishes five Strategic Objectives: the reduction of GHG emissions and promotion of carbon absorption; improving energy efficiency; the implementation of renewable energies; sustainable mobility and transport with zero direct polluting emissions and adaptation and resilience. In terms of reducing GHG emissions, the regional objective for 2040 is to reduce them by 100% compared to the 1990 figure (Gobierno de Canarias, 2021b).

The EU's "first, energy efficiency" guiding philosophy is adopted by the Canary Climate Action Strategy. In this respect, the goal for 2040 is to achieve decarbonization by drastically reducing energy consumption, by 50% relative to the primary energy forecasts of the business-as-usual scenario. Its achievement will be based on the implementation of energy efficiency policies, the promotion of the circular economy and the change of habits and the reduction of the need for resources and their associated GHG emissions. Then the objective set for the implementation of renewable energies by 2040 must cover 92% of final energy consumption (Gobierno de Canarias, 2021b). José Antonio Valbuena (regional area councillor) pointed out, "Climate neutrality in the Canary Islands requires the reduction of non-renewable energies, which will gradually be replaced by energy efficiency and non-polluting energy sources" (Gobierno de Canarias, 2021a).

The Canary Islands present excellent potential in terms of renewable energies. The ample resources of wind and solar in the region have enabled to begin to the decarbonization of the isolated energy system (Barone *et al.*, 2021). However, nowadays the energy systems of the region still significantly rely on the importation of fossil fuels, which negatively impacts the island's energy security as well as its economy, environment and development (ISTAC, 2022). For instance, the average weighted cost of power over the entire Canary Islands in 2021 was 161.54 €/MWh. In Spain (the mainland), the average cost of power in that same year was 118.7 €/MWh. Hence, in 2021, the cost of electricity in the Canary Islands was roughly 1.4 times more than in Spain (the mainland) and three time in the year 2020 (Statista, 2023a). Those are further reasons to increase the level of energy self-sufficiency and, therefore, less dependence on external fossil fuels which are more expensive and polluting.

For instance, Cabrera et al. (2018) estimate a maximum share of RE of 75.9% in the energy system of Gran Canaria assuming technologies and strategies that are already mature enough to be implemented at the present time, but this does not include the potential of offshore wind in their analysis. Schallenberg-Rodríguez and García Montesdeoca (2018) estimate the offshore wind energy potential in the Canary Islands. They concluded the amount of offshore wind energy that could be put in the appropriate locations is 57 GW. As an example, the current energy system capacity in the Canary Islands stands at approximately 3 GW, with conventional power sources accounting for 90% of the total. The study found that there is a potential to generate 179 TWh per year of commercially viable offshore wind energy, which is significantly higher than the regional electricity demand of around 8 TWh in 2015. A more intriguing economic metric is the marginal cost at which offshore wind energy might provide each island with the same quantity of energy. According to the findings, the marginal cost of offshore wind power, which includes integration costs, is significantly less than the price of electricity now in all islands.

However, huge offshore wind capacity under isolated conditions makes these systems less stable and secure than large interconnected systems (Fernández-Guillamón *et al.*, 2019). Furthermore, the Canary Islands and their local particularities, such as the islands' big population, the year-round effects of numerous tourists, and its isolation from the European continent, tend to make the problem of this energy security even worse and prevents the penetration of more REs (Cabrera, Lund and Carta, 2018). Large interconnected systems, on the other hand, are able to guarantee supply at times when demand peaks or when faced with specific situations where there is a lack of generation, such as the lack of wind required for wind power production or failures and unavailability of grid elements (IEA, 2016).

Energy storage technologies, such as pumped storage facilities, whose primary function is supply security and system security and permits the integration of unmanageable renewable power, must be used to lessen the vulnerability of these electrically isolated systems (Amrouche, Rekioua and Rekioua, 2015). Similar to this, it's crucial to create new connections between islands that provide system support for one another and advance the transmission grid's meshing (Gils and Simon, 2017). However, this last can be more challenging due to the deep water basins of the archipelago.

It is therefore that Gran Canaria will be the only to have offshore wind, due to the fact that this island is the only one that has the storage system they need for offshore wind farms and the pumped hydroelectric power station. The installation of turbines in other zones of the sea in the archipelago will be restricted until the revision of the first version of the Canary Islands Energy Transition Plan, scheduled for 2027. The Government of the Canary Islands, together with the Government of Spain, will then make an energy planning decision regarding "whether or not" the offshore wind farms in the archipelago will be built (Canarias7, 2023).

Salto de Chira will be the first major energy storage project in the Canary Islands. The approved project will utilize the island's two significant inland reservoirs (the Chira and Soria dams) in order to construct a 200 MW pumped-storage hydroelectric power station and an energy storage facility with a 3.5 GWh capacity. The new infrastructure will require water to function, yet water is a limited resource in the archipelago. Hence, the project includes the construction of a water desalination plant in order to fulfil its purpose as an energy storage facility (REE, 2022).

By 2026, the power station will improve the island's renewable energy production by 37% more than it would have without it. This will increase the average yearly coverage of demand with renewable generation to 51%, however there may be instances when that percentage is substantially higher. As a result, annual carbon dioxide (CO_2) emissions will be reduced by an additional 20%. In addition, according to the Spanish transmission system operator (TSO), Red Red Eléctrica de España (REE), which is the developer of the project, points out that this will increase energy independence and will save in variable generation costs amounting to 122 M€ per year by reducing imports of more expensive and polluting fossil fuels (REE, 2022).

Although floating platforms for wind turbines have been suggested for a number of years, it is only recently that technology has advanced enough to make such a serious consideration of overcoming the technical difficulties involved in designing effective machines. The offshore oil and gas business has shown that the technological obstacles can be overcome, but the economics of putting this industry's solution into practice would prevent any machine deployment in a market for wind energy that is highly competitive. The main difficulty is economic in nature (NREL, 2005).

For floating wind turbine platforms, the economics that made it possible to deploy hundreds of offshore oilrigs have yet to be proven. In place of driven monopiles or traditional concrete gravity bases, which are frequently utilized as foundations for shallow water turbines, a floating structure may be employed for deepwater wind turbines. To sustain the weight of the turbine and keep pitch, roll, and heave motions within acceptable bounds, a floating structure must offer sufficient buoyancy. Because of this, it is anticipated that the economics of deepwater wind turbines will be primarily determined by the additional costs of the floating structure and power distribution system, which are offset by higher offshore winds, close proximity to significant load centres (e.g., shorter transmission runs), and greater public acceptance due to lower visual and environmental impacts (DNV, 2022).

Filgueira-Vizoso (2022) evaluated the economic feasibility of different floating offshore renewable energies in Canary Islands. The method created generates economic maps, which facilitates the election of the best area where install offshore renewable energy farms in the location selected. In addition, it also allows to select what is the best marine technology to be exploited in this area. Gran Canaria showed best results, assuming 300 MW offshore wind farm, based on the three indicators of feasibility: internal rate of return, net present value (NPV) and levelised cost of energy (LCOE). However, this is assuming an electric tariff of 250 €/MW that it is 1.5 times higher than the current price for the production (ISTAC, 2022).

Historically, the difference cost would be assumed covered by the government in order to support and promote innovative RE technologies (e.g. Contract for Difference). Even though, this can mean a significant expenditure for the government (IEA, 2019). However, this expenditure could be compensated whether socio-economic value is added, e.g. reducing national CO2, promoting employment and contributing to the GDP, which are social issues that the governments want to overcome for their society.

For instance, the unemployment rate in the Canary Islands is one of the highest in Europe, despite it showed a downward trend from 2013 to 2022. By the last quarter of 2022, the unemployment rate was 14.57% (35.2% rate for those less than 25 years old), while the mean in the EU was about 6.9% (Eurostat, 2023; Statista, 2023c). Offshore wind could be an opportunity to create significant new local employment, as has been demonstrated in other European regions.

On the other hand, the Canary economy is based primarily on tourism, which receive about 12 million tourists per year. Construction makes up nearly 20% of the GDP and tropical agriculture, primarily bananas and tobacco, are grown for export to Europe and the Americas. The GDP per capita is 21,244 euros, the fourth lowest in Spain. The region has been falling short of the national average since the beginning of this century and is currently 20% below it. The heavy dependence on the tourism sector, which generates more than 30% of regional GDP, has meant that the archipelago has suffered the economic consequences of mobility restrictions more sharply due to the pandemic. The GDP of the Canary Islands fell by 18% in 2020, far worse than the contraction of Spain's total GDP (10.8%) (BBVA Research, 2022). It is therefore, the Canary Government is willing to diversify its economy and reinforce the industry sector (Canarias7, 2022). Establishing a wind industry may be an opportunity for the region to this regard, which could play an important role for the wind technology supply chain within the national and international level.

2. Problem formulation and research question

The chapter summarises the above problem analysis that leads to the formulation of the research question.

Offshore wind has been introduced and explained throughout the previous chapter, along with its prospective place in the Canary Islands' energy system. Offshore wind can be the necessary solution for the Canary Islands to end up with the energy-source dependency, and therefore it could enable to reduction of the emissions from the energy system as well as reduce the cost of production of electricity, which nowadays is significantly expensive. Thereby, offshore wind can potentially assist to reach the goals set by the Canary government for become carbon neutral by 2040, and at the same time, contribute to the national goal of install 1 to 3 GW of offshore wind capacity by 2030 as part of its PNIEC. However, due to the nature of water depths basins in the region it would lead to the use mainly of Floating Offshore wind. Despite the potential of Floating Offshore Wind, it is still not a widely used technology and although the offshore oil and gas sector has shown that the technological obstacles can be overcome, its deployment will be an economic matter. Therefore, the promotion of offshore wind in the area may require a substantial financial investment and political commitment.

Based on the problem analysis, two main problems have been identified. The first problem pertains to the high cost associated with deploying offshore wind in the Canary Islands from a business economic perspective, particularly in transitioning the energy system. The second problem concerns the region's alarmingly high unemployment rates, which rank among the highest in Europe. However, both of these problems could potentially be resolved by considering a socio-economic perspective. By incorporating offshore wind, the Canary Islands could not only contribute to reducing CO_2 emissions to achieve carbon neutrality by 2040 but also generate significant industrial and employment opportunities for the region. Consequently, the objective of this report is to investigate the socio-economic effects and feasibility of implementing offshore wind in the Canary Islands' energy system. This will be accomplished by addressing the following research question:

To which extent can offshore wind be a socio-economically feasible alternative while contributing to the Canary Islands' goal of carbon neutrality by 2040 and if so, how can be politically promoted?

2.1. Sub-research questions

The sub-questions are formulated in accordance to assist in answering the research question and delineating the specific areas that will be analysed.

1. ***Who are the key stakeholders involved and what impact do they have on the implementation of offshore wind energy projects in the Canary Islands?***
2. ***What is the existing technical and political environment concerning offshore wind energy in the Canary Islands, and how does it hold the potential to make a substantial contribution towards achieving carbon neutrality by 2040?***
3. ***Could this offshore wind contribution be feasible and provide regional socio-economic benefits it is implemented as a power generation alternative?***
4. ***Which policies should be considered and established to facilitate this deployment?***

2.2. Scope and limitations

This section discusses the limitations of the research scope in addressing the research and sub-questions mentioned earlier. However, additional methodological delimitations pertaining to the project are outlined in Chapter 5 and further discussed in Chapter 7. In this report, certain aspects were given greater emphasis and others were intentionally excluded, allowing for a more focused and accurate analysis. The selection of these elements aimed to ensure the reliability of the findings presented in this research. However, the author of this research is aware that other aspects are worth analysing to offer more insights into the results, but this was not possible due to time and resource limitations.

In the context of this report, the term "socio-economic" requires clarification as it pertains to conducting a socio-economic analysis. The term refers to examining the interplay between economic and social factors within a specific area of focus. This approach enables a comprehensive understanding of the given topic. In the case of this report, the social aspects of offshore wind encompass employment opportunities and CO_2 savings, while the economic aspects are represented by the Net Present Value (NPV).

The project solely focuses on examining the societal potential of offshore wind in the Canary Islands. As a result, the findings of this project are specific to the Canary context. However, they may offer insights into the potential effects in other countries with similar energy systems and political frameworks as the Canary Islands. Although the research primarily centres on the Canary region, it utilizes a case study approach, using Gran Canaria as the case. The results are subsequently evaluated to consider their generalizability to other islands within the region.

To examine the socio-economic effects of offshore wind in the case study, a feasibility study is conducted, which includes an analysis of the energy system. The energy system analysis focuses primarily on the electric sector and does not consider other sectors within the overall energy system. Additionally, this analysis incorporates qualitative analysis, but it should be noted that incorporating quantitative data and modelling the energy system could provide a more comprehensive assessment of the technical viability of offshore wind compared to other power generation units and storage options in the electrical system. It is important to acknowledge that this study does not explicitly address whether the scenarios used ensure the quality and reliability of the power supply to meet future demands. It is assumed that these aspects have been considered in the strategies and plans analysed.

Neither is included an analysis of whether the proposed alternative scenario, which incorporates offshore wind, achieves the goal of carbon neutrality by 2040. This would require modelling the entire energy system and estimating the amount of CO_2 equivalent emissions. However, it is assumed that the proposed alternative, based on the analysis of government strategies, can technically meet the expected carbon neutrality goal as stated in the PTECAN (Strategic Energy Plan of the Canary Islands).

The analysis conducted in this report was hindered by limited data availability. Considering the long-term horizon (2030 and 2050) and the exploration of an emerging and niche sector, there was a scarcity of accessible data, necessitating the use of assumptions for certain parameters. This study estimates the cost breakdown for developing and constructing the offshore wind farms in the evaluated scenario based on indicators and approximations from previous work (Aguilera, 2023). However, it should be noted that the actual costs may vary significantly due to the evolving nature of the technology. Interviews were not conducted as part of this research, but incorporating them could provide more up-to-date values for the cost breakdowns.

Instead of conducting interviews or surveys for data collection, the researcher chose to attend conferences as an alternative approach. This decision was motivated by the opportunity to participate in the WindEurope event in 2023 and its conferences that attract key stakeholder groups essential to the research. The annual WindEurope event is a major gathering focused on the wind energy sector, making it a valuable venue for gathering relevant information and insights.

3. Theoretical framework

The overarching theoretical framework for the research problem is described in this chapter, which aids in establishing the report's context. The theoretical framework is created before the analysis since it creates an appropriate scope that enables the researcher to comprehend the problem more deeply. The following theories are considered in order to strengthen the analysis of this project and gain a deeper understanding of the context of the research subject.

3.1. Radical technological change

According to section 1.3, a technological change is required within the Canary energy system because floating offshore wind is still a novelty technology in the system. A more fundamental and complete understanding of technology and how technological change can occur is therefore important.

Technology can be separated into four major components from a holistic standpoint: technique, knowledge, organisation and products. These can be defines as:

- Technique is the joining of technique, labour objects and labour processes.
- Knowledge is the joining of ability, insight and intuition in the labour process.
- Organisation is leadership and coordination of labour in the work process.
- Product are the outcome of the work processes which represent user value (Muller, Remmen and Christensen, 1985).

These four components are all linked, and changes in one of them result in changes in all four. When technology is examined in a societal perspective, the primary components are also linked with societal changes (Muller, Remmen and Christensen, 1985). This is exemplified in Figure 3, which shows how changes in one component of technology can affect other components of society and vice-versa.

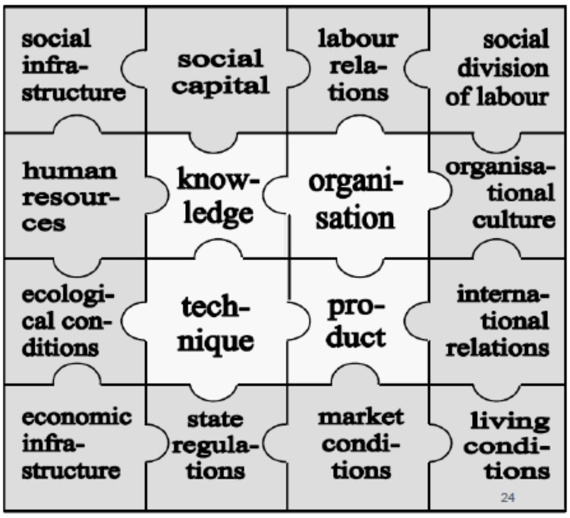

Figure 3. The four components of technology and the link between social change. Figure from (Muller, Remmen and Christensen, 1985)

Muller et al (1985) with this, remarks that open-ended technology conception is needed, which enables us to comprehend the relations between technological and social change. Thereby, in order to solve problems related to technological transformation, it is required the use of inter-disciplinary methods.

The compliance in between the pieces of Figure 3, are constantly changing and depending on the characteristic of a given change, it can cause a radical technological change in the system. Hvelplund (2013) addresses the term radical technological transformation by adding a fifth dimension to the definition of technology in the form of the component *profit*, since he considers it as a fundamental dimension when analysing changes within the energy sector. Radical technological change, therefore, is characterized as a significant change in more than one of technology's five dimensions. Consequently, according to Hvelplund (2013), a successful radical technological change can impact all the other components in time since all of these are interlinked as indicated in Figure 4.

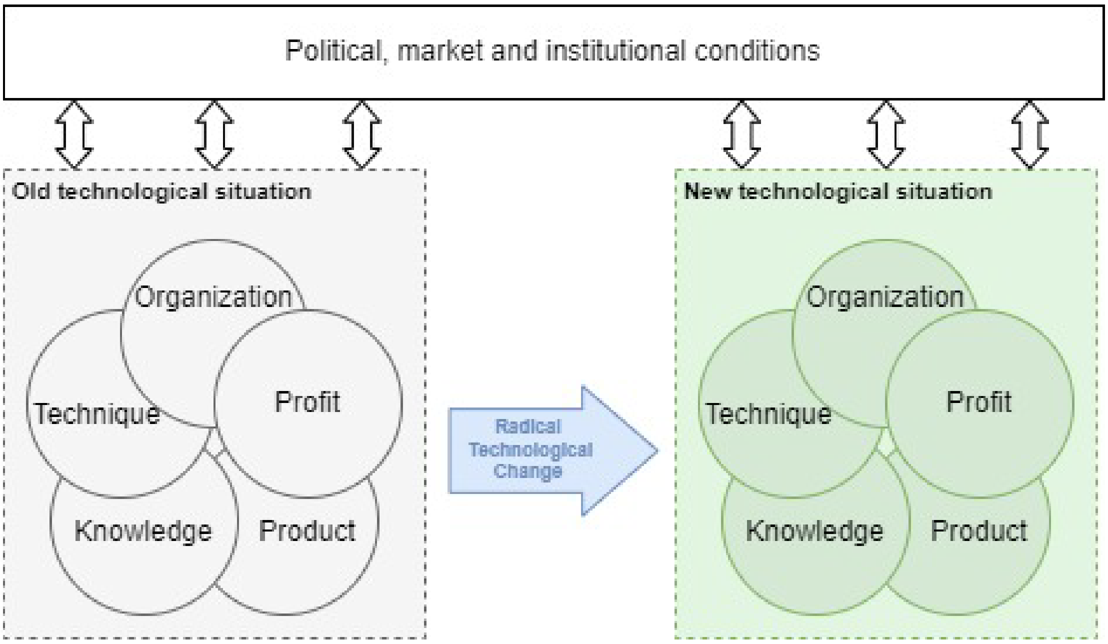

Figure 4. Process of radical technological change influenced by the political, market and institutional conditions. Own figure based on (Hvelplund, 2013)

New technology, on the other hand, can be abandoned over time if it is unable to produce significant change. This can happen as a result of the given historical situation and institutional context in which the new technologies must be developed. As a result, new technological change compete against existing and established technologies that have developed through time inside the existing political, market and institutional framework, therefore it is important to consider the organisation component while analysing the penetration of new technology such as offshore wind within the conventional energy system. The report investigates these five dimensions, but with regard to the research question, the aspects of profit and organization are regarded as the components that will have an impact on the other components. As a result, a more thorough analysis will be dedicated to these particular aspects.

3.2. Choice awareness

The theory of Choice Awareness can be examined to gain a better understanding of how radical technological change in an existing energy system can be accomplished.

The Choice Awareness theory appears in chapter 2 of the book *Renewable Energy Systems* by Lund (Lund, 2014a). The theory focuses on how to implement radical technological change in the existing energy system under the current organizations and institutions which attempt to disregard certain choices in the political decision-making process to preserve their own interests and already established technologies. To do so, the theory is composed of two theses that will be described below.

The first thesis of Choice Awareness describes how these social relations are affected by stakeholders, discourse as well as power and influence of the decision-making process to implement radical technological change. These social relations can favour certain choices and eliminate alternative choices or institutional changes. According to Lund, the counterstrategy for this is to raise public awareness of the fact that alternatives *do exist* and that it is possible to make a choice. The second thesis of the Choice Awareness theory focuses on this counterstrategy to promote alternatives through new strategies, plans, and projects on all levels of society. Lund proposes several strategies of creating choice awareness when facing these problems. The strategies are summarised in Figure 5.

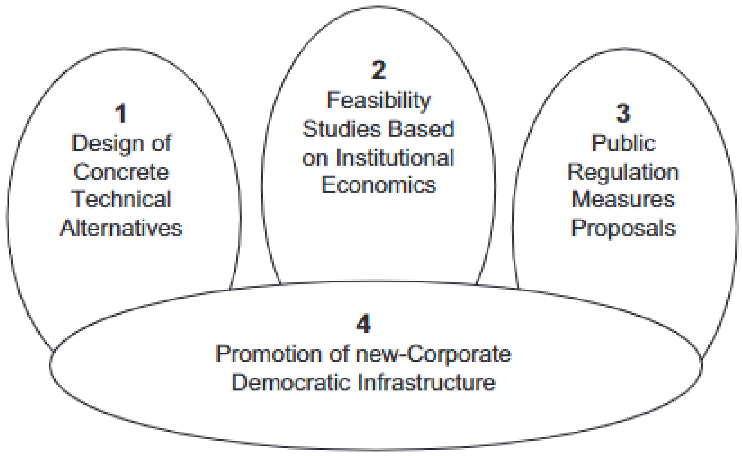

Figure 5. Process of radical technological change influenced by the political, market and institutional conditions. Figure from (Lund, 2014a)

Lund proposes to begin by describing and promoting concrete alternatives (1), followed by an assessment of relevant socio-economical or environmental objectives for the society by including them in a feasibility study (2). Then, regulation measures should be designed and recommended for public institutions based on the identification of market barriers (3). Lastly it should be considered that these actions are not made by their own, but rather require proposals for the improvement of the democratic infrastructure and institutions (4).

The theory emphasizes the importance to consider all the socio-economic parameters to determine the alternatives which should be included in a feasibility study in order to examine a radical technology change that can benefit society more than the traditional available choices. Moreover, the theory emphasizes investigating the current context, which involves the real market (distinguished by the free market) and the current institutions, since technical solutions often require new organization and institutions.

3.3. Innovative democracy

Innovative Democracy outlines the need for the shift of the institutional market based on the “free market”, into an institutional market designed for the real world. This shift enables the transition of the existence of energy systems (reliant on fossil fuels) toward RE systems. The diagram in Figure 6 represents the concept of Innovative Democracy and it is used to understand the theory of Hvelplund (2013).

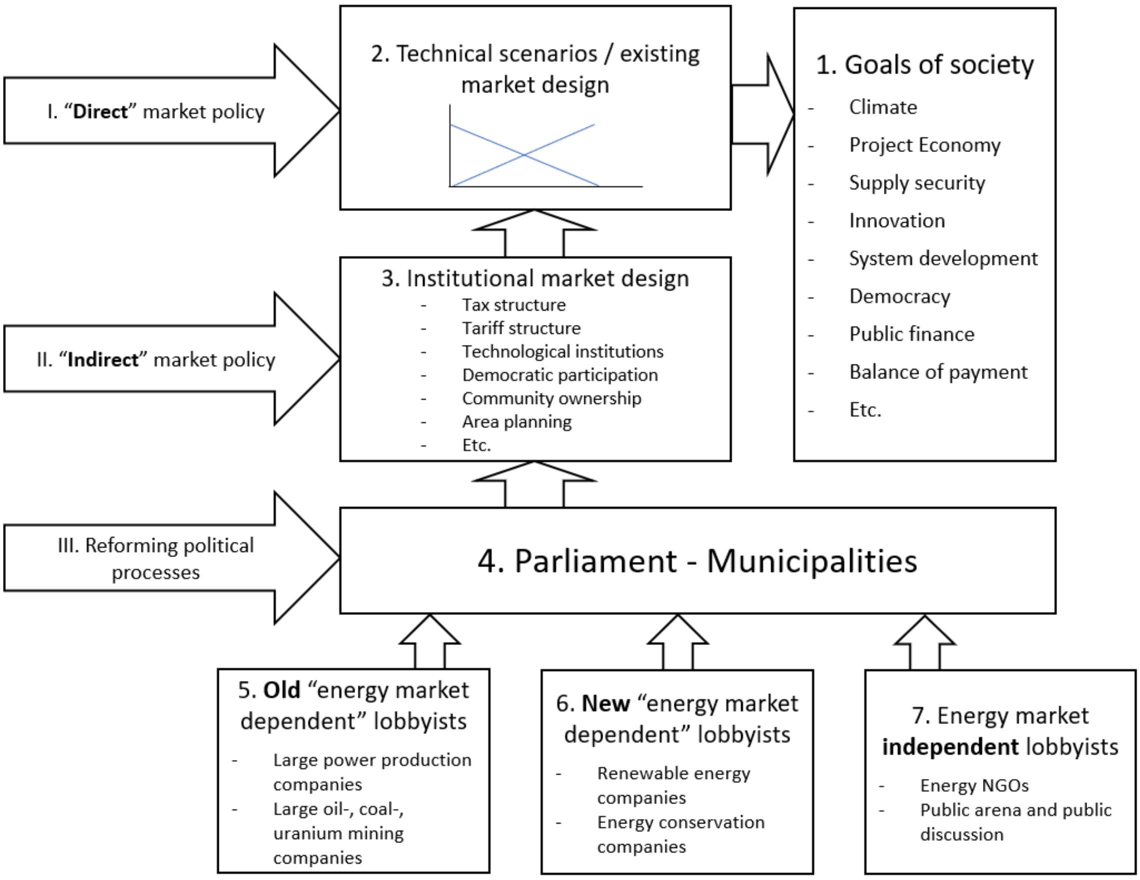

Figure 6. Innovative Democracy diagram. Own illustration based on (Hvelplund, 2013)

To begin with the description of Innovative Democracy, the first neoclassical economics approach must be defined, since it is globally adopted as the main econometric model. Neoclassical economics is based on a "free market", i.e., the prices for goods and services are self-regulated under the law of supply and demand in an open market. Within this market, market institutions are present to ensure the conditions of the existing free market to prevail. Based on this, it is assumed that the economy is optimum. Both consumers and sellers will pursue to maximize their benefits under the established institutional rules and therefore, it will be the best for the society, where everyone can participate.

However, Hvelplund claims that this "free market", which tries to create a democratic market, is not a free market in reality. He argues that free democratic markets can be interfered with by public regulations, while in neoclassical "free markets", public regulation should not intervene in the process of the market, but rather must intervene to ensure the institutional preconditions of the "free market" because it is assumed optimum. The public sector, in a neoclassical economy, keeps as neutral, which produce its good and services, and redistribute the income. Thereby, economy cannot be optimum ("real market") and there will be a better economic situation to benefit the society as a whole, but for it, the political process (III. in Figure 6) should be reformed. It is in an innovative democracy where the "real market" predominates against the "free market" in one economy.

Regarding policymaking to mitigate climate change (1. *Goals of society*), it would not be viable from a neoclassical perspective, where public institutions maintain the market preconditions. To mitigate climate change, policies must be designed involving technological innovation, like REs, which can replace fossil-fuel energies and thereby, decarbonize the energy sector. However, according to Hvelplund, implementing technical solutions it is required new organizations as well as new institutions, and therefore a reform of the political process should take over. This phenomenon is known by Hvelplund as “political liberalisation”. In an Innovative Democracy, this political process should consider the requirements and the concerns of both energy market dependent (5. and 6.) and energy market independent (7.). Old energy market dependent (5.) will adopt a “free market” ideology, which will demand no intervention by public regulations that may affect them negatively. On the other hand, new energy market dependents (6.) will demand public regulations that can favour the implementation of REs over fossil-fuels for economic interests. While energy market independents (7.) request the implementation of REs without economic interest.

New market rules should be designed throughout the political process to achieve the societal goals. These new rules should reflect the requirements and the concerns of all the actors as a democratic representation. These new rules or policies can include both direct (I) and indirect (II) market measures that will recondition the existing market. New decarbonizing policies such as CO2 prices (direct) green origination certificates and removing the subsidies from old fossil fuel technologies (indirect) for instance, can encourage the incorporation of RE technologies and new organizations in the energy sector. These new policies would favour f and g actors, but on the other hand, they would exclude 5. A transition can be both winners and losers, but in an innovative democracy, the design of new rules should try to find optimal solutions to minimize the negative impacts that can have on existing actors or “losers”. For instance, green subsidies for decarbonising fossil-fuel energy systems can enable 5. to transform their business models toward new ones.

Whether a new technology is to be implemented as offshore wind in the Canary Islands, the innovative democracy approach emphasizes the importance of organizational change, which is also remarked in sections 3.1 and 3.2. The innovative democracy approach is thus said to be successful when the effect of reforming political processes establishes alternative goals for society and, as a result, opportunities for technological change in existing markets and the institutional market condition (Hvelplund, 2013).

Analysing the introduction of offshore wind as a change in the energy system makes understanding this innovative democratic approach crucial. Consequently, conducting a stakeholder analysis in this report becomes important to evaluate the potential effects on the involved parties who may be influenced positively or negatively. Their influence, to some degree, can impact the adoption of the new technology.

3.4. Adequate framework

Developing an adequate framework, according to Hvelplund (2001), establishes from where the investigator departs regarding the questions to be analysed in relation to the defined research question. The investigator performs an analysis through theories and a structure of reality which affect the analysis and consequently the results. The adequate framework is therefore clarifying and scoping the research area for the analysis. The approach is inspired by the concept of *adequateness* by Hvelplund.

The adequate framework is underlying a set of governing policies that have shaped the current reality and the specific circumstance under investigation. This framework of reality is known as the first order governance system, which is the fundamental condition and structure in society. This system is built by the governance systems and institutional structures that exist at the time the subject is investigated and can only be modified on a long-term basis through political processes (Hvelplund, 2001, 2013). Based on the problem formulation (see chapter 2), the reality of the Canary Islands offshore wind energy sector can be regarded unique. This is also evident in the current national offshore wind regulatory structure, which does not exist because no official regulations and legislation are enacted for the offshore wind sector yet, as opposed to onshore wind (MITECO, 2022). MITECO has recently launched a public consultation prior to the design of a regulatory framework for the development of offshore wind and sea energy facilities (MITECO, 2023b). Nonetheless, the sector is indirectly impacted by rules and regulations affecting other sectors and areas, including as the POEM, regulation of oil and gas activities, tariff-structures and access and connection to the electricity transmission and distribution networks for instance (MITECO, 2023a).

Outlining the overarching framework for offshore wind in Canary Islands as a second order system illustrates the relevant elements and relative macro-structures influencing the offshore wind industry at all structural levels. The second order system is underlying the previously described first order system (see Figure 7), which outlines the appropriate macro-structure for offshore wind in the Canary Islands. Unless a scoped set of specifications is provided, the potential macro-structures for a second order system can be said to be endless.

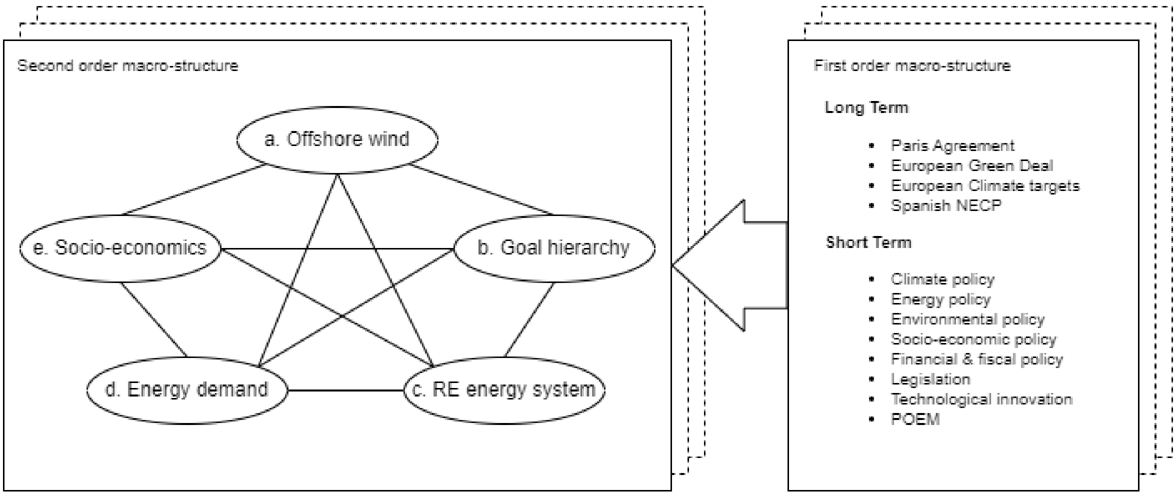

Figure 7. Adequate macro-structure in the first and the second order of offshore wind in the Canary Islands. Own figure based on (Hvelplund, 2001)

The goal hierarchy from Figure 7 and the accompanying action organization for offshore wind in Canary Island, which scopes the appropriate macro-structures to the research topic, provide these specifications. The dashed boxes in the illustration, represents the infinite number of other macro-structures that can be identified based on the question to be investigated (Hvelplund, 2001).

Introducing the associated first and second order systems allows for a better structured knowledge of the topic, allowing the investigator to sufficiently scope the study to answer the research question. The establishing of the adequate system can as such qualify the results and the discussion which is related to the following statement:

Offshore wind in Canary Islands (a) can be an important technology to end up with the energy-source dependency and to achieve carbon neutrality by 2040 (b) while RE are added in the energy system (c) in order to meet the demands (d). However, the deployment of offshore wind can be significantly costly, but may be the socio-economic effects that can counterweight (e).

Figure 8 clarifies the core information to answer the elements in the second order system as macro-structures, and therefore what is relevant to address in relation to the research question. From this, it becomes clear that the current deployment of the offshore wind technology in the Canary Islands (a) is relevant to examine and access to determine what the potential of it is in this context. To understand the potential of offshore wind to reduce imported energy-sources and reduce CO2 emissions (b), it is necessary to sketch out the present goal hierarchy, which is dictated by overarching governmental goals as well as stakeholders. It is also necessary to address the relevant regulatory framework. This must be examined in connection to energy system outputs with the combination of other REs (c) and fluctuated demand (d). Lastly, it is also relevant to examine the socio-economic effects to determine whether the offshore wind can be a feasible choice (e).

In Figure 8, the microstructures and institutional interrelationships between the entries are presented in the second order macrostructure for offshore wind in the Canary Islands.

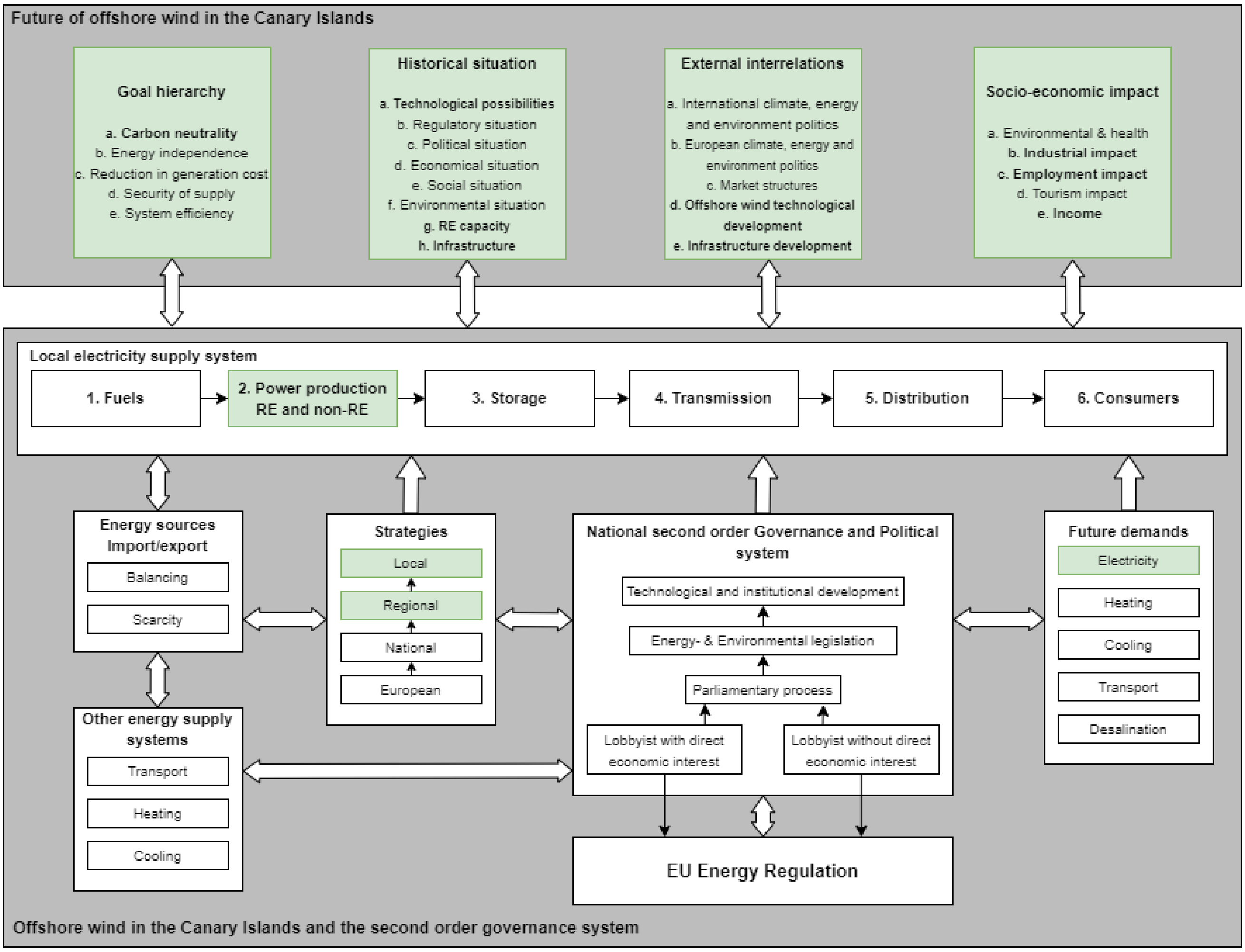

Figure 8. Adequate second order system with the macro- and microstructure for offshore wind in the Canary Islands. Own figure based on (Hvelplund, 2001)

The diagram depicts how several variables are interconnected by microstructures, providing clarity to the inputs and outputs crucial to deploy offshore wind in the Spanish region. It is also seen how the overarching EU level influences the local level via the institutions and micro-structures. The existing infrastructure within the local energy supply system presents possibilities or constraints depending on what electricity produced in the wind farm can be stored and delivered, which is an important consideration when considering the integration of offshore wind. As observed in the diagram, the goal hierarchy, the historical situation, the external interrelations and the socio-economic impacts will shape the offshore wind scene in the islands. It is important to note that Figure 7 is included within Figure 8 and is thus influenced by the overarching macrostructures in both the first and second order systems.

Understanding the second-order system is essential for grasping the impact of changes in the Canary Islands' offshore wind industry on the appropriate framework of this report. It reveals the areas where change can take place and how it influences the appropriate framework through the macro- and micro-structures illustrated in Figure 8. This holistic understanding contributes to a more comprehensive view of the observed reality within the scope of this report. Moreover, it aids in clarifying the energy sector and narrowing down the scope of what is considered suitable and relevant to address the research question.

Figure 8 is a representative map that compiles all the essential factors of interconnection that may influence the successful implementation of offshore wind. However, the factors highlighted in green are the ones that will be taken into account in this report as it addresses the research question. These particular factors are considered that represent the boundaries and limitations described in Section 2.2.

The impact of the various macro- and micro-structures for the growth of the offshore wind industry in the Canary Islands varies significantly depending on the stake entrenched in the particular stakeholders and institutions. With this in mind, it is also crucial to consider how these stakeholders and their particular perspective of reality may affect the future of offshore wind in the region and therefore this adequate framework is used for the development of the Stakeholder analysis (Section 6.1).

4. Case study

This chapter introduces the case study and why is interesting to investigate, and how to process the results of the following report with the aim to clarify whether the results can be generalized to other cases.

This research uses the Gran Canaria island as a case to investigate the feasibility and the socio-economic impact of implementing offshore wind in energy system from a regional level. This does not exclusively embraces a focus upon solving a problem for the single Island. According to the introduction, the transition of the energy system to achieve carbon neutrality, is an issue of concern for the whole region, even other island in the world (see section 1.3). In order to determine whether the findings of the following report can be applied to other cases, such as other islands, it is interesting to research how to analyse the findings as a case study. In the part that follows, the method for adapting a case study is explained with the intention of laying out the framework of the investigation.

A case study is appropriate to explore the phenomenon related to a contemporary problem when the research problem starts with a how or why. The contemporary phenom is defined as the real-life context in which the initiated problem occurs. So, how to do a case study depends on the situational context, which attempts to elucidate in order to comprehend the factors contributing to the current issue (Yin, 2003).

Although while case studies have been used as a method in many studies, concerns about its validity and reliability continue to be voiced. According to Flyvbjerg (2006), there exist five misunderstandings about case studies, which are as follows:

> *"[...] (a) theoretical knowledge is more valuable than practical knowledge; (b) one cannot generalize from a single case, therefore, the single-case study cannot contribute to scientific development; (c) the case study is most useful for generating hypotheses, whereas other methods are more suitable for hypotheses testing and theory building; (d) the case study contains a bias toward verification; and (e) it is often difficult to summarize specific case studies*." (Flyvbjerg, 2006)

The five misunderstandings are argued against in Flyvbjerg (2006), whereas the one stating that case studies are not suitable to generalise upon and to contribute to scientific knowledge, is in this case interesting to look into. The argument behind is that case studies do not conform the reliability of its results as in natural science, where statistical measurements of e.g. samples can support the reliability of the investigated phenomenon. But according to Yin (2003), case studies can contribute to scientific knowledge in case of researches, where the context and the investigated initial problem cannot be distinguished or are deeply interconnected. In such situations, the case study is applicable and valid since a case study embraces and can clarify the context that has an impact upon the results. Compared to natural science, case studies can therefore provide practical knowledge, which is important in order to understand the situation that might generate the problem. This includes single cases as well. Though, it is accepted that large samples are important to ensure validity and statistical representativeness, e.g. to understand an observable phenomenon. Even though, if something within the case study cannot be observed according to the phenomenon, the test cannot be assumed valid and is therefore rejected, or as a minimum revised. In that regard, it is important in order to conduct a case study, and afterwards to generalise the results, to understand the strategy behind structuring the case study since it gives an understanding of the 'reality' and how to handle the specific case (Flyvbjerg, 2006).

Flyvbjerg (2006) defines four strategies and associated types of case studies:

- The critical case: To gather information that allows logical deduction of the kind that if it does (does not) apply in the following case then it does (does not) apply for all cases.
- The extreme or unique case: To gather information about unusual cases, which can be particularly great/successful or particularly problematic.
- Cases with maximal variation: To gather information about the importance of the prerequisites regarding the case process and results.
- The paradigm case: To develop development patterns, a prototype, or a metaphor for the area, the case concerns.

In the following report the critical case is applied, which makes it a single based case. According to Flyvbjerg (2006), a critical case is defined as a case study connected to one specific phenomenon. In that regard, the context is crucial to clarify since the context is deeply connected to the results of the single-based case. But the aim of a critical case study is to conduct a study for which the results is "most likely" valid, for other cases alike. Therefore, the aim behind processing the following investigation is to find solutions which can to a certain degree be generalised for other cases, through an investigation of a single based case, which is neither extreme or unique. In accordance with the scope of the report, the case study makes it possible to understand, along with the theoretical framework, the reality (context) of offshore wind in Gran Canaria, which could most likely be the same for other islands in the region.

4.1. The application of a critical case study

In order to determine whether offshore wind can be a feasible solution for the Gran Canaria to end up with the energy-source dependency and contribute to reach carbon neutrality by 2040, which can be argued valid in the context for the other islands within the Canary region, it is fundamental to state the key elements and characteristics of the phenomenon and context for the respective critical case. The key characteristics describing the context of the critical case study, are following stated:

- Isolated energy system
- Elevated levels of unemployment
- Economy heavily reliant on the tourism sector
- Aiming to achieve carbon neutrality in the energy system by 2040
- Seeking to diversify and promote local industry
- Maritime zones designated for offshore wind projects with considerable water depths
- Abundance of wind resources resulting in high capacity factors

To process the results of the critical case study to be most likely valid, the above mentioned characteristics must be the reality of other cases that encounter the same problem. Even though this case study is a single-based one, important scientific drawing can be comprehended based on a societal investigation and can be relevant for cases experiencing the same phenomena (Flyvbjerg, 2006). However, it is accepted that the context of the following critical case study can be further defined, and that the context of other islands always needs to be specified. This is further discussed in Chapter 7.

5. Methodology

The objective of the upcoming chapter is to provide a comprehensive overview of the methodologies employed during the research. These methodologies were implemented to establish a robust analytical framework that facilitates the exploration of the main research question and sub-questions. This encompasses the data collection process and the subsequent analysis. Each method utilised is described, along with a discussion of the specific approaches employed. The chapter also addresses the delimitations associated with the chosen methodologies.

5.1. Research design

The purpose of this section is to elucidate the research strategy employed as a roadmap for addressing the primary research question and its associated sub-questions. Additionally, this section serves as a guide for readers, providing a comprehensive overview of the stages and phases covered in the report.

The research design is influenced by the principles outlined in the book *Research Design in Urban Planning* According to Farthing (2016), the research design should incorporate a reflective approach that involves making decisions throughout all stages of the research process. This is essential because research design is considered an iterative process, and unforeseen factors can impact its feasibility. As a result, it is crucial to continuously reassess and re-evaluate the chosen strategy. The research question and sub-questions play a fundamental role in shaping and defining the structure of the study, as depicted in Figure 9.

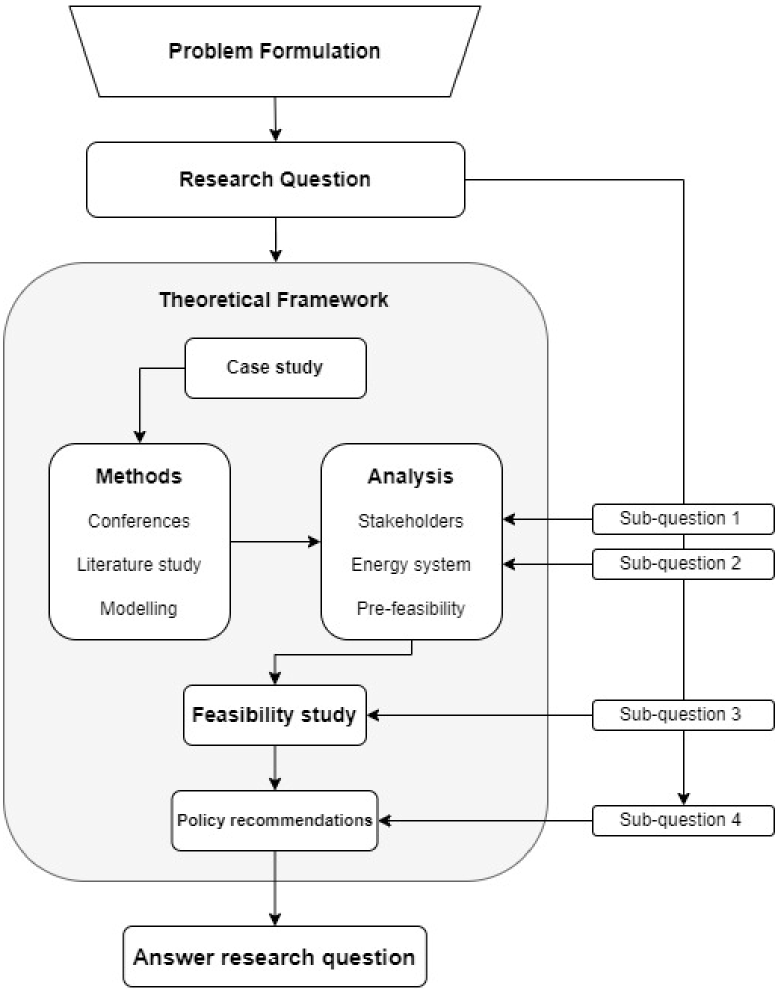

Figure 9. Flowchart which represents the research design of the project. Own illustration.

The flowchart illustrates the research strategy devised to address all stages involved in resolving the research question. These stages are divided into chapters, which are further subdivided into sections and subsections. The process begins with a problem analysis (introduction), leading to the formulation of research questions and sub-questions (refer to Chapters 1 and 2). The theoretical framework provides a comprehensive framework that allows the researcher to gain a deeper understanding of the problem and strengthen the analysis within the research context (see Chapter 3). Subsequently, a case study is conducted to determine the generalizability of the findings to other cases (see Chapter 4). Methods are employed for data collection and for the conduction of the analysis (see Section 5.2). The analysis chapter is focused on answering the sub-questions (see Chapter 6). Sub-question 1 is addressed through stakeholder analysis, evaluating their involvement and influence in offshore wind implementation (see Section 5.3.1). Sub-question 2 is tackled by examining the potential viability of offshore wind within the energy system of the case study (see Section 5.3.2). Sub-question 3 is answered through a feasibility study that assesses the economic and socio-economic aspects of offshore wind (see Section 5.3). Lastly, policy recommendations are proposed to address sub-question 4 (see Section 5.3.3). Once all four sub-questions are addressed, a comprehensive answer to the main research question is provided in the discussion (see Chapter 7).

5.2. Data collection

The process of choosing an appropriate research method begins by identifying the research question and study objectives. When research questions cannot be adequately addressed by either quantitative or qualitative methods in isolation, a mixed methods design is suitable for providing comprehensive answers.

The data collection in the report employs a mixed-method approach, which involves combining qualitative and quantitative data to improve the overall comprehensiveness and reliability of the results. This enables a more thorough exploration of the relationships or disparities between the qualitative and quantitative data collected, leading to a deeper understanding. This enhances the understanding and validity of the report's findings (Shorten and Smith, 2017). The mixed methods research approach serves various purposes and can be classified into four types:

- Explanatory sequential
- Exploratory sequential
- Parallel
- Nested

The primary focus of this report revolves around utilizing the *nested* type. The nested type of mixed methods research is a design in which one method is encompassed within another. This approach entails the collection and analysis of both quantitative and qualitative data, with one method assuming a primary role and the other method contributing supplementary or supportive insights. In this design, one method takes precedence as the main focus or core of the study, while the other method is employed to enhance or enrich the findings. The nested design facilitates a thorough investigation of the research problem by integrating diverse data types, resulting in a more comprehensive exploration (Shorten and Smith, 2017).

The report incorporates a combination of qualitative and quantitative data, collected as both primary and secondary sources. The secondary data were derived from literature reviews and document analysis. On the other hand, the primary data is usually obtained through interviews, while in this particular case, attending conferences was chosen as an alternative approach.

5.2.1. Primary data

The purpose of conducting a literature review and document analysis in this study is to identify pre-existing information and data pertaining to offshore wind and the current structures within the overall policy and regulatory framework. Throughout the study, qualitative and quantitative data is continuously collected, and the analysis includes the examination of the following items:

- Articles and scientific papers
- News articles
- Policy documents such as strategies, roadmaps, proposals
- Public datasets

The purpose of utilizing these documents is to acquire a more comprehensive understanding of the offshore wind industry and establish the foundational knowledge required for conducting the analyses. This encompasses examining the case study and its background, understanding offshore wind technology, studying yearly datasets related to the energy system, identifying the involved stakeholders, and considering relevant socio-economic factors. These inputs collectively contribute to the stakeholder analysis in section 6.1, the energy system analysis in section 6.2, and ultimately the primary feasibility study in section 6.3 and 6.4.

5.2.2. Secondary data

To collect secondary data, the decision was made to attend the WindEurope annual event and participate in relevant conferences that represented key stakeholder groups crucial to the research. The WindEurope annual event is a significant gathering that centres around the wind energy sector. The primary goal of these conferences is to promote knowledge exchange, collaboration, and the sharing of the latest research and industry insights among attendees. These conferences offer various activities such as presentations, panel discussions, workshops, and networking opportunities, attracting industry professionals, researchers, policymakers, and stakeholders.

Attending these conferences was considered an excellent opportunity to gain an understanding of market dynamics and identify factors influencing the feasibility of offshore wind projects and hence, it could assist on the elaboration of potential policies that can promote such technology. Therefore, it was fundamental for the development of the Policy recommendation Section 6.5, which addresses sub-research question 4.

Table 1 provides a comprehensive overview of the attended conferences. The table encompasses the stakeholders and their respective groups, along with concise descriptions of the topics covered in each conference. Therefore, the reader can have concise overview of the different conferences that were considered relevant for the development of the research. Further explanation of the approach is outlined in Section 5.3.4.

Table 1. Overview of the attended conferences of the WindEurope 2023 Annual Event for secondary data collection

Conference	Stakeholder representation (participants)	Topic description
Strengthening Europe's wind supply chain	- Regulatory institution (EU Commission, EIB, German Ministry for Economic Affairs and Climate Action) - Developers (EDPR, Nordex, Shell) - Suppliers (ZF Wind Power, Siemens Gamesa, Sif Group, LM Wind) - Lobbyists (Green Power, WindEurope)	Debate to unpack the key enablers to bringing the European wind supply chain back to profitability while ensuring it can deliver the objectives set by REPowerEU and the long-term European decarbonisation goals. Topics: - Status of the industry - Securing level playing fields - Manufacturing, R&I and skills
Offshore Wind: turning huge ambition into reality	- Regulatory institution (EU Commission, Danish Energy Agency, Minister Energy, Federal government of Belgium, Lithuanian Ministry of Energy) - Developers (RWE, Equinor, Ocena Winds, BP, Shell, Osterd) - Suppliers (TenneT, Hitachi Energy, Vestas, Siemens Gamesa, General Electrics) - Lobbyists (Renewables Grid Initiative)	By harnessing the power of wind resources offshore, countries can significantly increase their RE capacity, drive innovation, create jobs, and contribute to a sustainable energy future. Topics: - Volumes, investments - Grids, offshore hybrids and happy coexistence - Supply chain, technology, ports
Boosting Europe's wind industry through non-price criteria in auctions	- Regulatory institution (EU Commission, Ministry of Economic Affairs and Climate Policy of the Netherlands) - Developers (Mainstream Renewable, Eneco) - Suppliers (LM Wind, Vestas) - Lobbyists (WindEurope)	As from 2022, the State Aid Guidelines allow EU states to weave in up to 30% on non-price criteria to better balance price-only competition in auctions. Discussion about how these non-price criteria in auctions can support a rapid and robust expansion of the European wind energy supply chain.
Floating: how to get a supply chain?	- Regulatory institution (EU Commission, Norwegian Ministry of Petroleum and Energy) - Developers (Equinor, Mainstream Renewable, Ocean Winds, BlueFloat Energy, Corio Generation) - Suppliers (Prysmian Group, Port of Port La Nouvelle) - Lobbyists (WindWorks Jelsa)	Debate to find out where investments should go and which incentives are needed to boost the floating supply chain expansion. Topics: - Mass production of components - Port infrastructure: assemble and install - Auction design: rewarding additional value
Upscaling port infrastructure	- Regulatory institution (EU Commission) - Developers (Osterd) - Suppliers (General Electrics) - Lobbyists (Port of Rotterdam, Port of Esbjerg, Port of Ferrol)	Ports have key role to play in the development of offshore wind in Europe. This session will focus on the developments and bottlenecks that European ports are facing to upscale their infrastructure. Discussion about possible solutions and to ways forward for ports to be more efficient.
Floating: lessons learnt so far and engineering challenges	- Developers (Equinor, RWE) - Suppliers (Principle Power) - Lobbyists (PEAK Wind) - Academia (NTNU)	Addressing the floating offshore wind technological advances, what has been done so far and debate what the following steps are to accelerate its development.

All the conferences that were decided to be attended, had to cover the following topic-criteria in order to contribute with the scope of the research:

- Offshore wind technology advances, involving both bottom-fixed and floating
- Policy development and regulative frameworks
- Market trends and project financing,
- Social and environmental considerations,
- Industry and infrastructure

Notes taking from every conference can be found in the *Appendix II: Conference notes.*

5.2.3 Delimitations

In order to meet the timeframe of this report, it was decided to exclude the interviews. However, it is important to acknowledge certain limitations and make the reader aware of them. Interviews serve as a valuable research tool for obtaining comprehensive information and insights from stakeholders, which is particularly relevant in this study where the influence of stakeholders on the deployment of offshore wind has been emphasized. By not utilizing interviews, there is a possibility of missing out on the wealth of data that can be obtained through direct interaction with these stakeholders identified in the stakeholder analysis. The data collected through attending conferences, which was the method employed to gather primary data, may not offer the same level of depth and nuanced understanding as direct contact with conference speakers would have provided. For example, interviews enable the exploration of participants' individual viewpoints, beliefs, experiences, and emotions in their own language. The absence of interviews could make it difficult to capture the subjective and personal dimensions of participants' experiences, thus restricting the researcher's comprehension of the phenomena being investigated. Moreover, in the context of interviews, there would be the chance to pose additional questions, seek clarifications, and explore specific areas of interest in greater depth. This interactive process can reveal valuable insights and subtleties that might not be evident from alternative data sources.

5.3. Analytical approach

This part of the report describes the methods utilized for conducting the analyses addressed in Chapter 6. These methods were designed specifically to tackle the sub-research questions at hand.

The primary objective of the report is to examine the socio-economic feasibility of implementing offshore wind in Gran Canaria by 2040, considering the accompanying technological changes. To investigate this, a feasibility study is conducted, influenced by the strategies proposed by the theory of choice awareness. This theory suggests that in order for a technology alternative to be promoted effectively, it must contribute both socially and economically, and may require institutional changes and public regulation (Lund, 2014b).

To achieve this, the feasibility study is supported by a stakeholder analysis, which identifies the relevant stakeholders for offshore wind development in the regional context of the Canary Islands and examines their potential impact on future development. Additionally, an energy system analysis is performed to assess the integration of offshore wind into the energy system. This analysis evaluates the technical and economic aspects, with a focus on CO2 reductions and employment generation.

Once the feasibility of deploying offshore wind under these conditions is established, an analysis is conducted to determine effective policy recommendations for promoting offshore wind in the region. This analytical approach also involves presenting and describing the relevant theories, which are part of the theoretical framework presented in chapter 3.

5.3.1. Stakeholder analysis

The stakeholder analysis serves to identify the pertinent stakeholders involved in the development of offshore wind in the context of the Canary Islands and assess their potential impact on future developments The section describes the method approach employed to conduct the analysis and be able to answer sub-question 1 (see Section 2.1).

To comprehend the present state of offshore wind in Gran Canaria and make informed predictions regarding its future significance, it is crucial to acknowledge the various stakeholders involved. All these stakeholders have a potentially different level of power, often can have a conflict of interest with one another and can show different interest in the transition as well. By comprehending the dynamics and relative strengths of these stakeholders, researchers can attain a more holistic understanding of the social, economic, and environmental factors that might impact the success of offshore wind development. Furthermore, stakeholder analysis is relevant when researching the success of offshore wind development because it can help identify potential barriers, build stakeholder support, ensure regulatory compliance, and maximize economic benefits. By taking a stakeholder-centred approach, researchers can develop more effective strategies for promoting the successful development of offshore wind projects. So, it is also crucial for giving an answer to sub-question 4 (see Section 2.1).

A stakeholder analysis entails the identification and evaluation of the interests, concerns, and potential influences of diverse stakeholders. While there isn't a singular approach to creating a stakeholder map, the initial step remains consistent. To conduct a stakeholder overview, the first task is to investigate the relevant actors within the industry. This was accomplished through a literature study, which is detailed in section 5.2.1 and was done by looking at the entire political, operational, business, and social sector in the international, national and local level. Next, the stakeholders were prioritized according to a Power-Importance Graph. The graph of power against importance is a useful tool for stakeholder analysis and involves plotting stakeholders on a two-dimensional graph based on their level of power and importance shown in 10 (Kørnøv, 2007).

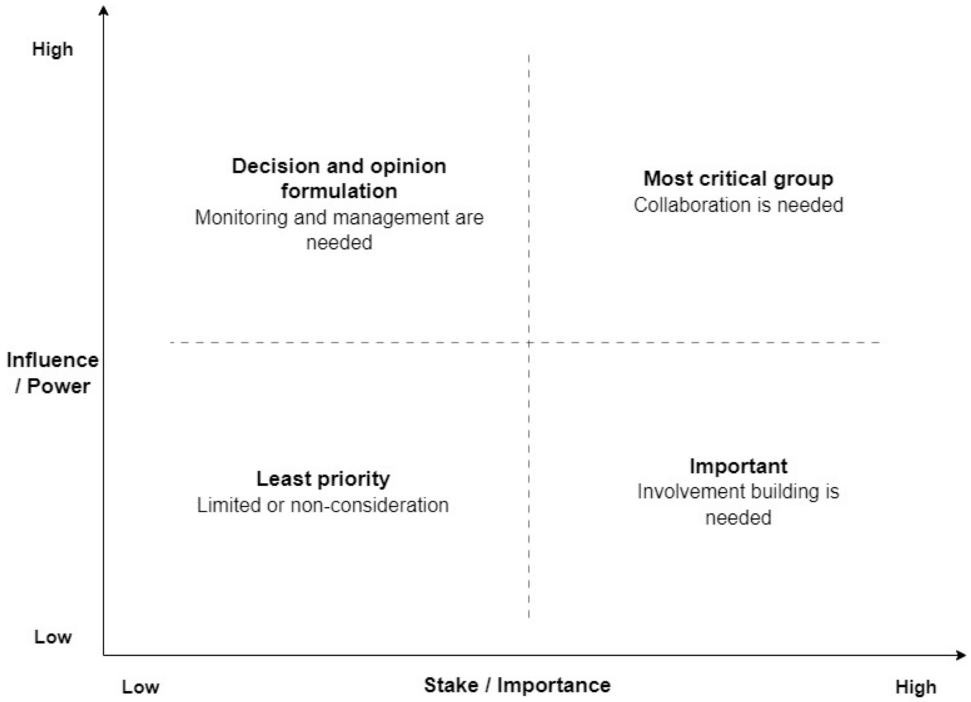

Figure 10. Classifications of stakeholders defined by importance (x axis) and power (y axis). Own figure based on (Kørnøv, 2007)

By mapping the stakeholders, as depicted in Figure 10, valuable insights can be gained regarding their significance and influence in the decision-making process. Given that the research question in this report focuses on determining the socio-economic feasibility and providing policies to promote offshore wind by 2040, the stakeholder analysis offer valuable insights into the potential sources of barriers and opportunities. Moreover, the stakeholder analysis is conducted within the broader theoretical framework outlined in chapter 3, which enhances our understanding of the macro- and micro-structures within which these stakeholders are presented.

5.3.2. Energy system analysis

The energy system analysis investigates the current situation of regional energy system and the potential penetration of offshore wind within the research's designated time horizon. This analysis utilizes the primary data collected, as outlined in section 5.2.1, with the objective of addressing the sub-question 2 (see Section 2.1).

To identify the current state of the energy system, the approach involved examining various publicly available data sources to describe the components and characteristics of the energy system, including energy sources (renewables and fossil fuels), energy carriers (electricity, heat and cooling), infrastructure (thermic power plants, transmission grid network, etc.), and energy consumption sectors (residential, commercial, industrial, transportation, etc.).

Creating a visual representation of the current energy system helps stakeholders and researchers understand the complex relationships and interdependencies between different components. Furthermore, it also helps identify the connections and interactions between various elements of the energy system, such as energy sources, conversion technologies, infrastructure, and end-use sectors. This understanding is crucial for assessing the impacts of changes in one component, in this case offshore wind, on the overall system (Gielen *et al.*, 2019).

On the other hand, to identify the potential penetration of offshore wind within the energy system of Gran Canaria, was opted to analyse the different strategies and plans proposed by the government of Canary Islands, instead of conducting a quantitative analysis. This involves developing and exploring different future scenarios for the energy system provided by the *Instituto Tecnológico de Canarias*. These scenarios are plausible representations of different pathways based on varying assumptions about factors such as energy demand, technological advancements, policy frameworks, and socio-economic conditions. By examining this, it can be evaluated the potential opportunities associated to offshore wind. Table 2 compiles the documentation reviewed to conduct the analysis, which ultimately informed the assessment of the potential capacity of offshore wind integration into the energy system within the specified time frame.

Table 2. Documentation used for analysing the potential penetration of offshore wind in Gran Canaria (Gobierno de Canarias, 2023)

Plans	• Canary Islands Energy Transition Plan (PTECAN)
Strategies	• Strategy for photovoltaic self-consumption in the Canary Islands • Energy storage strategy in the Canary Islands • Electric vehicle strategy in the Canary Islands • Strategy for manageable generation in the Canary Islands • Canary Islands geothermal strategy • Strategy for marine renewable energy in the Canary Islands • Green hydrogen strategy of the Canary Islands • Strategy for demand management and smart grids in the Canary Islands

5.3.3. Feasibility Study

The main aim of conducting a feasibility study is to evaluate the practicality and viability of a particular solution in addressing a specific problem, considering both business and socio-economic aspects within the present circumstances. Hence, it was deemed appropriate to address sub-question 3.

The analysis approach conducted in this report is grounded in the theory *of Feasibility Studies* by Hvelplund and Lund (1998). This approach becomes particularly important in situations where radical technological change is involved, as the study can be structured to assess the feasibility of alternative technical options that encompass comprehensive evaluations of their social, environmental, and economic implications. Such an approach assists in identifying preferable alternatives that may not be automatically implemented given the current market conditions, as it is outlined in the Choice awareness theory (refer to Section 3.2).

The feasibility study can be categorized as either a socio-economic feasibility study, which assesses the feasibility of a solution from a societal perspective, or a business feasibility study, which evaluates the feasibility of a solution for a specific company. It is crucial to determine the purpose and perspective of the feasibility study and the reasons behind it. When conducting the feasibility study, it is also relevant to consider the specific historical context (as done in the adequate framework section 3.4) and understand the infrastructure and organizations involved in order to discuss long-term solutions (as it was address in both the Stakeholder and Energy System analyses, section 5.3.1 and 5.3.2).

This study has the potential to serve as a bridge between short-term and long-term effects of the proposed alternative being investigated and facilitating the identification of an appropriate pathway, in form of policy recommendations (see section 5.3.4), between the conventional existing technologies and the necessary future technologies for the society. This can be illustrated, as shown in Figure 11, where a capital-intensive technology with a long technical lifespan, which is more beneficial for society as a whole, requires modifications to market regulations in order to compete with existing technologies (Hvelplund and Lund, 1998).

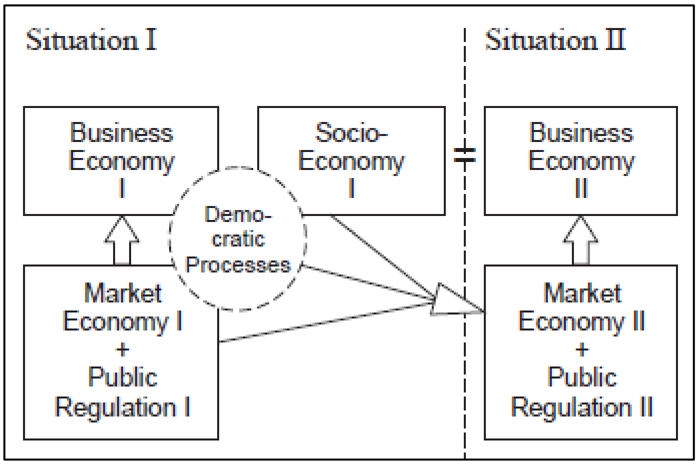

Figure 11. The relationship between business economy, socio-economic and public regulation. Figure from (Hvelplund and Lund, 1998)

The figure illustrates how the democratic process can link the present conditions (shaped by market economy and public regulation) business economy studies and socio-economic studies (which considers the goal of the society) to create new public regulation where socio-economic value is embedded in business economic study. In other words, the impact of the market economy on the business economy can vary depending on the economic paradigm, which was explored in Institutions Chapter 3. Public regulation, on the other hand, can influence the business economy through mechanisms such as support schemes, taxation or legislation (Hvelplund and Lund, 1998).

It is worth noting that the feasibility study is not limited to examining solely the business economic aspects of a system, but also encourages the investigation of socio-economic factors. If a particular case is deemed beneficial for society but not necessarily for business, it should be deliberated in the democratic arena. This deliberation has the potential to lead to the formulation of new public regulations that support and enable such cases.

Consequently, the feasibility study serves as a means to understand the combined socio-economic and business economic value, ultimately aiming to create an ideal situation that benefits society as a whole (Hvelplund and Lund, 1998).

Following the methodology suggested by F. Hvelplund, a feasibility study is structured into three distinct stages. The initial step involves conducting a WWW-analysis, which addresses three fundamental questions and establishes the study's purpose:

- What should be studied?
- For whom the feasibility studies are made?
- Why is the study made?

The investigation has effectively responded to and tackled these three inquiries through the completion of the problem analysis, formulation of the research question, establishment of the theoretical framework, and execution of the case study. Additionally, as per Hvelplund's recommendation, the time horizon must be specified during the initial stages, involving calculations and analysis of the results. Typically, time horizons align with the technological lifetimes of the investment options. However, for this particular study, the time horizon was set for the long term, considering two target years based on the national low-emissions strategies: 2030 and 2040 (Instituto Tecnológico de Canarias, 2022a).

The second step typically involves conducting a Diamond-E analysis to define the scope and content of the feasibility study by identifying the analytical criteria to be followed. However, in this report, the Diamond-E analysis step from the methodology propose be Hvelplund (1998) was omitted, and a pre-feasibility analysis was chosen as an alternative. This serves as a preliminary evaluation to determine whether content to include in the feasibility study. Moreover, the analysis helps to identify the crucial information for determining whether it is worthwhile to proceed with a comprehensive feasibility study.

The pre-feasibility study encompasses four key aspects that provide guidance for the design of the feasibility study and offer the main inputs for the execution of the feasibility study. These areas are as follows:

- **Offshore wind evolution (Section 6.3.1)**: This section proposes a scenario for offshore wind deployment to meet the needs identified in the energy system analysis.
- **Cost of offshore wind deployment (Section 6.3.2)**: Here, the costs associated with implementing the proposed offshore wind deployment scenario are outlined, including relevant assumptions.
- **CO2 savings (Section 6.3.3):** This section estimates the potential reduction in GHG emissions resulting from the integration of offshore wind.
- **Employment (Section 6.3.4):** This area focuses on estimating the potential job creation resulting from the incorporation of offshore wind.

The considerations addressed in the pre-feasibility study are providing the input for the feasibility study and therefore pave the way for the last step, which is the conduction of the feasibility study. Based on the findings of the pre-feasibility analysis, it was determined that a socio-economic analysis would be the central focus in meeting the established criteria and gaining a comprehensive understanding of the potential of the proposed scenario. This socio-economic analysis involves evaluating the economic aspects, including costs and benefits associated with the implementation of the propose alternative, as well as assessing social and environmental factors such as employment generation and CO2 reduction. Additionally, a sensitivity analysis was conducted to assess the impacts of fluctuations in calculation parameters within the socio-economic analysis, following the recommendation of Hvelplund (1998).

To evaluate the proposed offshore wind deployment, economic calculations were performed using a discounted cash flow model. This model estimates the investment's value by considering its anticipated future cash flows, including projected expenditures and revenues associated with the examined scenario. The specific model utilized in this report was originally developed for a project conducted by the author of this report, titled "A modelling tool which enables EU member states to engage developers to promote offshore wind projects to meet the European targets". The aim of that project was to provide institutions with a tool for assessing the feasibility of offshore wind projects and designing support schemes to promote such projects. Given its relevance and suitability, the same model was deemed appropriate for use in this study (Aguilera, 2023).

The economic model used in this study calculates the anticipated future returns from the wind farm investments by incorporating a discount rate and the study's time horizon. This calculation enables the determination of the NPV. The equation utilized in the economic model to derive the NPV is described in detail below (Serup, 2003):

$$\boldsymbol{NPV(i,n)} = \sum_{t=0}^{n} \frac{\boldsymbol{R_t}}{(\boldsymbol{1+i})^{\boldsymbol{t}}} \quad \boldsymbol{t}$$

Where,

- $\boldsymbol{R_t}$ is the net cash flow i.e. cash inflow minus cash outflow during a single period time
- $\boldsymbol{i}$ is the discount rate, which might be a hurdle rate for a project based on a company’s cost of capital
- $\boldsymbol{t}$ is the number of time periods

The primary inputs incorporated into the modelling tool to calculate the NPV are:

- Investment costs (Development Expenditure (DEVEX) and Capital Expenditures (CAPEX)
- Operational Expenditures (OPEX)
- Decommissioning Expenditures (DECEX)
- Electricity price projections
- Weighted Average Cost of Capital (WACC) as discount rate
- Corporate Income Tax (CIT)
- Support Scheme

A detailed explanation of the aforementioned parameters is discussed in the project conducted by Aguilera (2023). The inputs were primarily derived from the pre-feasibility study and literature review, serving as the main sources of primary data. In cases where certain inputs were unavailable, assumptions were made based on relevant literature and related studies. A comprehensive description of all the inputs and assumptions utilized in the model can be found in the analysis section of this report (Chapter 6.4).

The socio-economic analysis considered the social aspect by including assessments of CO2 savings and employment, as estimated in the pre-feasibility study. The calculation of CO2 savings involved multiplying the energy consumed by the emission factor associated with each energy source. These emission factors indicate the amount of GHG emitted per unit of energy produced or consumed. In terms of employment estimations, they were derived using employment factors that take into account the installed capacities of each alternative over time.

The assessment considers both direct and indirect employment and evaluates labour in terms of Full-Time Equivalents (FTEs) per unit of installed capacity, such as gigawatts. Lambert and Silva (2012) propose three categories for classifying employment in RE projects, which have been taken into account in the model. These three categories are:

- Technological development
- Installation/uninstallation (referred in the model as *one-off*)
- Operation and maintenance (referred in the model as *recurrent*)

The three groups were utilized to identify and categorize job creation at the national and regional level, as the analysis aims to assess the potential employment within the region.

After completing a feasibility study, according to Hvelplund (1998), it is advisable to perform a sensitivity analysis. This is necessary due to the inherent uncertainties that can arise from conducting feasibility studies over long time periods and making certain assumptions. By conducting a sensitivity analysis, the level of uncertainty in the results of the socio-economic model can be assessed. This analysis offers valuable insights into the parameters that have the greatest impact on feasibility and can aid in informing policy-making decisions. The sensitivity analysis was conducted by changing the inputs used in the modelling tool and the criteria is describe in section 6.4.3.

5.3.4. Policy recommendations

This section focuses on comprehending the process of formulating policy recommendations within the analysis part of this report in Section 6.5, and the influence of other methodologies on this process. The development of new policy recommendations or modifications to existing policies should impact the progress of the explored offshore wind alternative. The implementation of new policies has the potential to steer the direction of the offshore wind sector in the region towards a more feasible trajectory, aligned with the future goals of the Canary Islands. Therefore, this section tackles sub-question 4 by providing policy recommendations that aim to promote the growth of offshore wind while simultaneously supporting employment and local industry development. These recommendations also seek to reduce greenhouse gas emissions in line with the 2040 carbon neutrality goal and ensure profitability for developers and investors.

In the Choice Awareness theory, Lund (2014b) proposes an approach that outlines the aspects that need to be analysed for recommending new policies. The feasibility study corresponds to socio-economic feasibility studies, while policy analysis pertains to the examination of current market conditions and public regulations. Analysing these aspects lays the groundwork for developing a new policy scenario and introducing a new business economy scenario in the Canary Islands. However, this report does not include an examination of the current policy adopted by the Canary Government in the formulation of these policy recommendations. This exclusion is due to time constraints in the research process, as conducting such an analysis would require a comprehensive evaluation of the Spanish taxation system, different institutional structures, strategic collaboration with regulatory institutions, and other factors. Instead, the policies presented in this report focus on the essential elements required for an ambitious offshore wind policy.

In order to develop policy recommendations, it was essential to take into account the findings derived from the varied outcomes of the Analysis (Section 6) and analyse the perspectives gathered from the conference notes (Section 5.2.2). This was crucial as it provided insights from different stakeholder groups and enables to identify the barriers that hinder the progress of offshore wind deployment. As a result, policy recommendations were formulated to specifically address these aspects.

5.3.5. Delimitations

The method used for the stakeholder analysis offers a solid structure to conduct it in the analysis section. However, this is not the only method that exist for this purpose and other aspects were not explored. Therefore, other approaches might lead to different outcomes and identification of other relevant stakeholders. Furthermore, for this analysis, only a power-importance grid was used which may not cover all aspects of each stakeholder as perhaps not everything revolves around power-interest relationships.

The energy system analysis approach employed in this study may have certain limitations, one of which is the lack of precision. Without utilizing quantitative analysis, it becomes challenging to gain an accurate understanding of the energy system and its future projections. Quantitative analysis offers numerical data and measurements that provide a higher level of precision. However, the data utilized in this study is based on information provided by the local official institution, which employs modelling and simulation techniques to project future scenarios. It would be valuable to incorporate quantitative data and compare it with the data provided by the Instituto Tecnológico de Canarias to model potential project trends and evaluate different alternatives.

Drawing on the Choice Awareness strategy proposed by Lund (2014b), the Feasibility Study for radical technological change necessitates the analysis of various alternatives. However, in this report, the emphasis is placed solely on one option, deemed the most conservative for the case study. It is important to note that the researcher acknowledges the existence of other technical alternatives, as mentioned previously, which can also be taken into consideration.

Lastly, as address in policy recommendations, the policies that are proposed did not go too much in detail and will give more general policy ideas that could be adopted by Canary Islands. In fact, there is no analysis of the consequences and effects of each policy, as policy making is a rather complex process that have to take a lot of other different factors into account. That is because the report does not focus on specific policy-making theories and methods, but rather attempts to show the potential policies that could promote the offshore wind sector in the region, as it is addressed in sub-question 4. The list is therefore not complete and most likely further policies will be needed to support the suggested policy recommendations addressed in Section 6.5.2.

The Discussion section (Section 7) of the report will cover a discussion of the delimitations, boundaries, and their impact on the obtained results and will be considered other approaches.

6. Analysis

The objective of this chapter is to provide responses to the four sub-questions presented in the research. It commences with a stakeholder analysis, which identifies the key individuals or groups involved in the implementation of offshore wind energy projects in the Canary Islands. Subsequently, an energy system analysis is conducted to examine the current technical and political landscape of offshore wind energy in the Canary Islands, as well as its potential contribution towards achieving carbon neutrality by 2040. The following section focuses on a feasibility study, evaluating the practicality and viability of adopting offshore wind as an alternative power generation method in the Canary Islands, considering socio-economic factors. Lastly, policy recommendations are devised to facilitate the implementation of offshore wind projects in the Canary Islands.

6.1. Stakeholder analysis

In this section, an analysis is conducted to examine the stakeholders involved in the implementation of offshore wind energy projects specifically in the context of the Canary Islands. The purpose of this analysis is to identify the entities that need to be taken into account when considering the implementation of offshore wind in this region. By understanding the relevant stakeholders, it becomes possible to gain clarity on the pathway towards implementing offshore wind projects. The Adequate Framework (Section 3.4) played a crucial role in this analysis by identifying potential stakeholders who could have significant roles in the process. This framework provides insights into the microstructures of the context and the institutional relationships between the various entities involved in offshore wind in the Canary Islands. These stakeholders were categorized into Regulatory Institutions, Offshore Wind Developers, Suppliers and Infrastructure stakeholders, Lobbyists, and Academia.

6.1.1. Regulatory institutions

Group which is responsible for legally regulating aspects of offshore wind activities. The role of these regulatory bodies is to establish and strengthen standards and ensure consistent compliance with them. This can be done at various levels and can affect different domains of offshore wind projects. Overall, this group has both high power and high importance as is represented in Figure 12.

EU

The EU plays a significant role in shaping laws, regulations, and financial support programs that impact the energy industry in the Canary Islands. Its objectives include ensuring safe, sustainable, competitive, and affordable energy for all Europeans and meeting climate targets. The EU directly influences offshore wind development through various regulations and financing projects that connect business, research, and innovation. Key areas addressed by these initiatives include grid infrastructure, High-Voltage Direct Current (HVDC) technology, cost reduction in the offshore supply chain, permitting processes, skills development, and social acceptance. (European Commission, 2022c).

Due to the distance between the project level in the Canary Islands area and the EU's decision-making arena, the EU is not seen as one of the most crucial stakeholders. To date, the EU has not issued any regulations regarding offshore renewable energy; instead, it has only published a strategy to guarantee that offshore renewable energy can help the EU meet its ambitious energy and climate goals for 2030 and 2050. However, they still have the ability to influence the growth of offshore wind in each and every EU member state due to their supranational authority (European Commission, 2020c).

Parliament of Spain

The national regulatory framework is set forth by the Spanish Parliament, which also has the power to control how the offshore wind industry is grown on Spanish soil. The parliament is viewed as one of the most potent stakeholder because it directs the country toward the national energy strategies through legislative and fiscal mechanism such as subsidies and taxes. However, Spain has a fairly decentralised governance system, which is divided into 17 autonomous communities, each with its own parliament. This gives great importance to how the central government interacts with these regions and their representatives, who have competence to implement key national energy and climate policies. In the energy sector, the autonomous communities are responsible for areas such as authorising power plants and energy networks. The decentralised governance system has benefits, as regions and municipalities can work more directly with end users to promote changes in the energy sector (Cortes Generales, 1978).

Ministry for the Ecological Transition and the Demographic Challenge

The political frame which involves the competencies on fight against climate change within the national level are leaded mainly by the Ministry for the Ecological Transition and the Demographic Challenge (MITECO). MITECO relies on its legislative branch concerning energy and mining including its regulation to the Secretary of State for Energy (SENER). Among many energy law-makings, SENER assigns legislation which promotes RE, ensures energy supply, regulates energy tariffs, taxes and prices and incentives energy conservation according to the EU regulation. To do so, SENER coordinates seven departments (Deputies) and several external institutions which shares those competencies. Among those external institutions, one should noteworthy, since are relevant for the development of strategies regarding the areas to work on. The first one is the Institute for Energy Diversification and Savings (IDEA), whose activities include public awareness, technical advice, and project financing of technology innovations with the objective to decarbonize the Spanish territory (BOE, 2020).

Other branch to be considered which also falls under the MITECO is the Secretary of State for Environment (SEMA). This branch is in charge of directing and coordinating the execution of the competences that correspond to MITECO in relation to the formulation of climate change policies and environmental. SEMA leads the Maritime Spatial Planning (OEM), which on the 28th of February approved the maritime spatial planning plans of the five Spanish marine demarcations (POEM) involving the areas for offshore wind activities (Royal Decree 150/2023). Within the SEMA are the Spanish Office for Climate Change (OECC) and the National Climate Council (CNC) co-ordinates the development and monitoring of climate change policies and measures of the central government (BOE, 2020; CUATRECASAS, 2023).

Subsequently, MITECO has also both high power and importance in regard to offshore wind development in the national and regional level.

Parliament of Canary Islands

The Parliament of the Canary Islands is the elective body that exercises legislative power, approves the budgets of the Canary Islands and promotes and controls the action of the Canary Islands Government. The Parliament of the Canary Islands, as the other autonomous communities of Spain, exercises and executes their right to self-government within the limits set forth in the constitution and their autonomous statutes. Therefore, it possesses high importance in regard to offshore wind development but slightly less power than the national parliament (PARCAN, 2023).

Counselling of Ecological Transition, Fight against Climate Change and Territorial Planning

The political frame which involves the competencies in the fight against climate change at the Canary regional level. It is responsible to set the decarbonisation targets for 2030 and 2040 in the Archipelago and dictate the main lines of action to achieve these targets. To do so, the counselling elaborated a draft of the Canary Islands Energy Transition Plan (PTECAN) which compiles eight strategies to fulfil the full decarbonization of the energy system by 2040. Furthermore, as mentioned in the Section 1.3, the counselling is the authority which plans and decides the maritime zones intended for offshore renewable energy within the Canary territory. It is therefore, this stakeholder is considered crucial important with significant power (Instituto Tecnológico de Canarias, 2022a).

6.1.2. Offshore wind companies and developers

Offshore wind energy developers are the providers of electricity developed from an offshore wind energy generation project, i.e. the companies that are directly involved in the offshore wind sector by designing, structuring and administrating the offshore wind projects. The offshore wind developers, therefore, have large importance and interest in floating offshore wind technology to become developed to the point where it can be competitive and market-ready, as it would allow them to access sea basins that were previously excluded due to water depth (Thomsen, 2012b). This report listed some of the major stakeholders who are currently involved in the Canary projects: Saitec, RWE, Greenalia, Iberdrola, Ocean Winds, Enerocean, Narturgy and Equinor.

6.1.3. Suppliers and Infrastructure stakeholders

Group which is responsible for facilitating and accommodating the development of future offshore wind projects. In general, this group presents a high importance but not so much power as is represented in the Figure 12.

Red Eléctrica de España

Red Eléctrica de España (REE) is a partly state-owned and public limited Spanish corporation which operates the national electricity grid in Spain, where it operates the national power transmission system (TSO) as well as Baleares and Canary islands. As the TSO, REE establishes the forecasts for the demand for electricity and operates the electricity generation and transmission facilities in real time, ensuring that the scheduled production at the power plants coincides at all times with consumer demand. Regarding offshore wind, REE will have the role for selecting the most appropriate connection point to shore, considering potential onshore congestions, expected future generators' connections, and necessary network development or reinforcements. Due to REE guarantees the operation of the system and the technical management of the inland network as well as to ensure the future offshore grid is considered a relevant stakeholder. Furthermore, REE owns the project Salto de Chira, a pumped hydroelectric power station in the south of Gran Canaria which will enable to increase the production of RE in the island by up to 37% (REE, 2022, 2023).

In minor relevancy, local Distributor system operators (DSO) may have an important role, specially if they can provide essential infrastructure at the local level for the landfall connection for the future wind farms (Stock *et al.*, 2018).

Port authorities

Ports are essential for the development of offshore wind projects. They provide the necessary infrastructure for the assembly, installation, maintenance, and repair of wind turbines, as well as the transportation of materials and personnel, and the connection to the electrical grid. While ports are important for both fixed-bottom and floating offshore wind development, they play an even more critical role in the latter due to the unique challenges associated with assembling, installing, maintaining, and accessing floating turbines at sea. It is therefore, port authorities have a huge importance and a significant influence (WindEurope, 2022).

The Public Body State Ports is the main authority within the Spanish territory. It is a body reliant on the Ministry of Transport, Mobility and Urban Agenda and responsible for carrying out the government's port policy, coordinates and oversees the performance of the 46 ports of general interest that make up the Spanish State-owned Port System. Its collaboration will be crucial for the development of offshore wind in the region (Puertos del Estado, 2023).

Local industry

Local industries can play a critical role in the development of offshore wind. For example, the manufacturing of floating foundations, mooring system blades, and other components required for offshore wind farms requires specialized skills and expertise. In addition to manufacturing, there are other industries that can benefit from offshore wind development. For instance, the installation and maintenance of offshore wind turbines require a skilled workforce that can include divers, boat operators, and electrical engineers. Local businesses that offer these services can benefit from the growth of the offshore wind industry and by supporting the development of these industries, local communities can create jobs and attract new businesses to the area (Thomsen, 2012a; Inside Climate News, 2019).

6.1.4. Lobbyists and partners

Lobbyists are professional advocates who labour on behalf of people and organizations to influence political decisions. This advocacy could lead in the introduction of new legislation or the modification of current laws and regulations.

Lobbyists for offshore wind development can include a range of individuals, organizations, and companies that advocate for policies and regulations that support the growth of the offshore wind industry. Some of the key groups that may be involved in lobbying for offshore wind development include: offshore wind companies and developers; industry associations; environmental and RE groups; labour unions; and local/regional governments. They can all work to support the growth of the offshore wind industry and advocate for policies and regulations that will help to achieve that goal (Tethys, 2023).

However, on the other hand, are several groups and individuals who may be opposed to offshore wind development, for a variety of reasons. Some of the key groups that may be lobbying against offshore wind development include: fossil fuel companies and their supporters; local electric utility companies; fishing and other marine industry groups; property owners and residents; Environmental groups with concerns about specific offshore wind projects; and Military groups (Tethys, 2023).

It's important to note that opposition to offshore wind development is not universal or consistent across all projects and locations. Some stakeholders may be more supportive of offshore wind development in certain areas or under certain conditions. Overall, the success of offshore wind development will depend on careful consideration of a range of stakeholders and their concerns, as well as effective communication and collaboration among all parties involved as is addressed in Innovative Democracy theory (Section 3.3).

6.1.5. Academic organizations

Academic institutions play a vital role in providing research and expertise related to the technical, economic, and societal aspects of offshore wind technology. They also contribute to the public discourse and offer input to government bodies regarding the future development of offshore wind at both regional and national levels. In addition, academia can challenge the energy scenarios proposed by institutions such as PTECAN and offer alternative scenarios for the future development of the energy system in the Canary Islands. Through their research on all aspects of offshore wind technology, including floating offshore wind, as depicted in Figure 12 (Section 3.1), academic institutions can conduct an impartial analysis of offshore wind development in the Canary Islands. Consequently, they can generate new knowledge, promote the technology, and influence public and governmental opinion on offshore wind.

One of the most relevant R&D stakeholders based in Canary Islands is he Oceanic Platform of the Canary Islands (PLOCAN). It is a singular scientific and technological infrastructure with the aimed to accelerate the development of knowledge and technologies for the responsible and sustainable use of the ocean, in line with the United Nations Sustainable Development Goals and strategy of Blue Growth Strategy established by the EU (PLOCAN, 2023).

Other relevant academic organization is the Instituto Tecnológico de Canarias is a technological institute located in the Canary Islands, Spain. It is a research and development organization focused on promoting and supporting technological innovation in various sectors, particularly in RE, environmental protection, and sustainable development. The ITC holds significant relevance in driving the strategies for energy transition in the Canary Islands by providing expertise, research, and technological support to facilitate the adoption of RE and the overall sustainability goals of the region (ITC, 2023).

6.1.6. Power-Importance Graph

After addressing the relevant stakeholders, a Power-Importance Graph is conducted using the approach outlined in Section 5.3.1, which offers a suitable basis for the subsequent analysis. The objective is to elucidate how power (influence) and importance (stake) are allocated among the stakeholders concerning the development of offshore wind in Gran Canaria. Figure 12 illustrates the positioning of the pertinent stakeholders based on their power and importance.

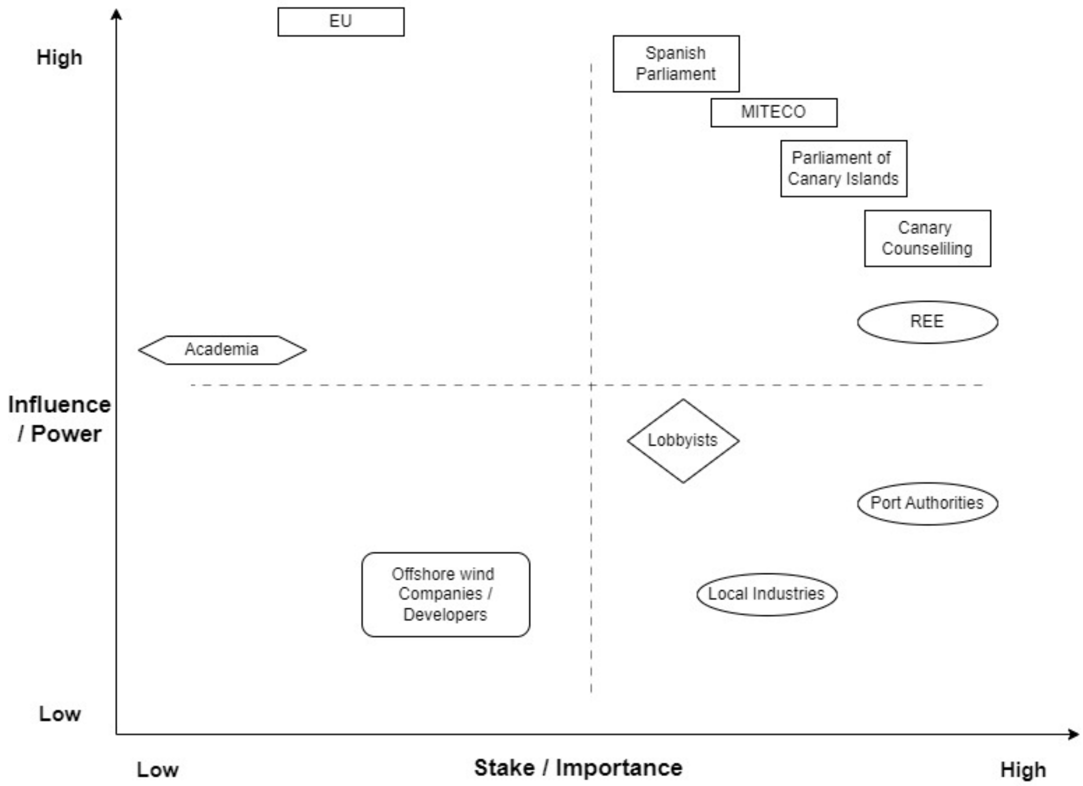

Figure 12. Placement of the stakeholders within the power-importance grid for development of offshore wind in Gran Canaria. Own figure

The stakeholder analysis encompasses the entirety of offshore wind development in the Canary Islands, recognizing the interconnectedness of various pathways for this technology. Notably, Figure 12 highlights that changes in infrastructure developments for offshore wind, involving Spanish Transmission System Operator (REE) and Port authorities, have the potential to impact all offshore wind pathways. Therefore, these entities hold significant importance, but their actions are regulated by the appropriate institutions.

The stakeholder analysis provided a systematic approach to understanding the diverse range of stakeholders, their interests, and the potential impacts of offshore wind policies. Consequently, the findings of the stakeholder analysis were utilized in conducting Section 6.5 to help provide a response to sub-question 4.

6.2. Energy system analysis

As discussed in Section 5.3.2, the energy system analysis focused on evaluating the existing technical and political landscape surrounding offshore wind energy in the Canary Islands, as well as its potential role in attaining carbon neutrality by 2040. Consequently, this analysis allows for the exploration and response to sub-question 2.

6.2.1. Identification of the electrical energy system in Gran Canaria

Gran Canaria is among the seven main islands forming the Canary Islands, which is an archipelago belonging to Spain located off the northwest coast of Africa in the Atlantic Ocean. With a population estimate of 853,262 in 2022, Gran Canaria is the third largest island in the Canary Islands (Statista, 2023b).

The electrical system of Gran Canaria consists of an isolated network with two thermal power plants (Jinámar and Barranco Tirajana) and 28 substations. Figure 13 showcases the spatial distribution of the electrical grid network in Gran Canaria.

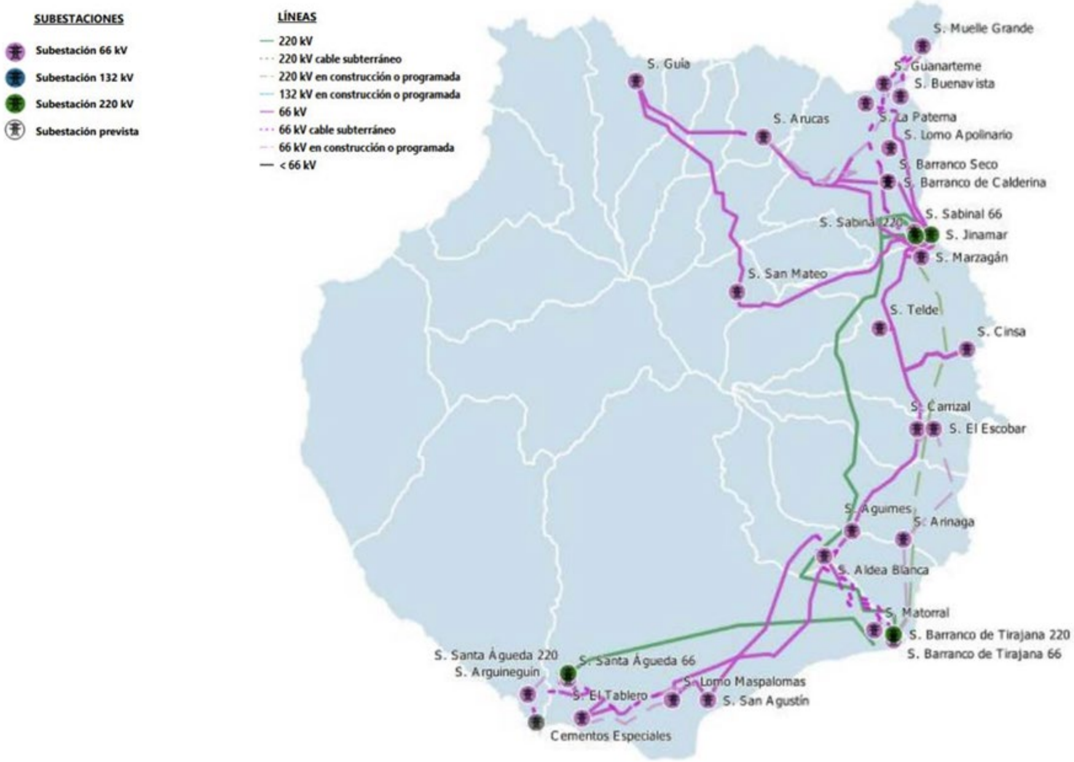

Figure 13. Geographical distribution of the electrical network in Gran Canaria. Figure from (Instituto Tecnológico de Canarias, 2022b)

The figure illustrates the representation of different voltage levels, with purple indicating 66 kV, blue indicating 132 kV, and green representing 220 kV. Additionally, the figure includes the two thermal power plants, Jinámar and Barranco Tirajana. By examining Figure 13, it becomes apparent that the electric transmission system is predominantly concentrated on the eastern side of the island, where the populated areas are situated. Understanding the location and significance of these thermal power plants is crucial for comprehending and advancing the content of the report. The figure illustrates the interconnection between the two main thermal plants that supply a significant portion of the power demand. The total power demand is covered with an installed total net power capacity of 1274.96 MW, distributed as shown in Table 3.

Table 3. Installed net power capacity in MW of Gran Canaria, year 2022. Own table based on (Instituto Tecnológico de Canarias, 2022c)

Steam turbine	Diesel engine	Gas turbine	Combined	Cogeneration	Onshore wind	Offshore wind	PV	TOTAL
280	84	173.45	461.73	24.88	193.94	5	52.5	**1274.96**

In Gran Canaria, the cogeneration cycles are owned by Emalsa, comprising two steam turbines with a capacity of 12.1 MW each. Additionally, the Amadores hotel operates its own cogeneration cycle. The remaining generation units are owned by the two main thermal power plants.

With the increase in the participation of renewable energies in recent years, a situation of increased consumption of fossil fuels that had been taking place as a result of the increase in demand has been reversed. Therefore, although fuel consumption increased by 2.6% in 2016 and 3% in 2017, there was a drop of 4.1% in 2018 and 5.7% in 2019. However, RE accounts for only 20% of the total installed capacity for power generation in Gran Canaria (ISTAC, 2022).

Figure 14 displays the monthly breakdown of net electricity production by energy source within the electrical system of Gran Canaria.

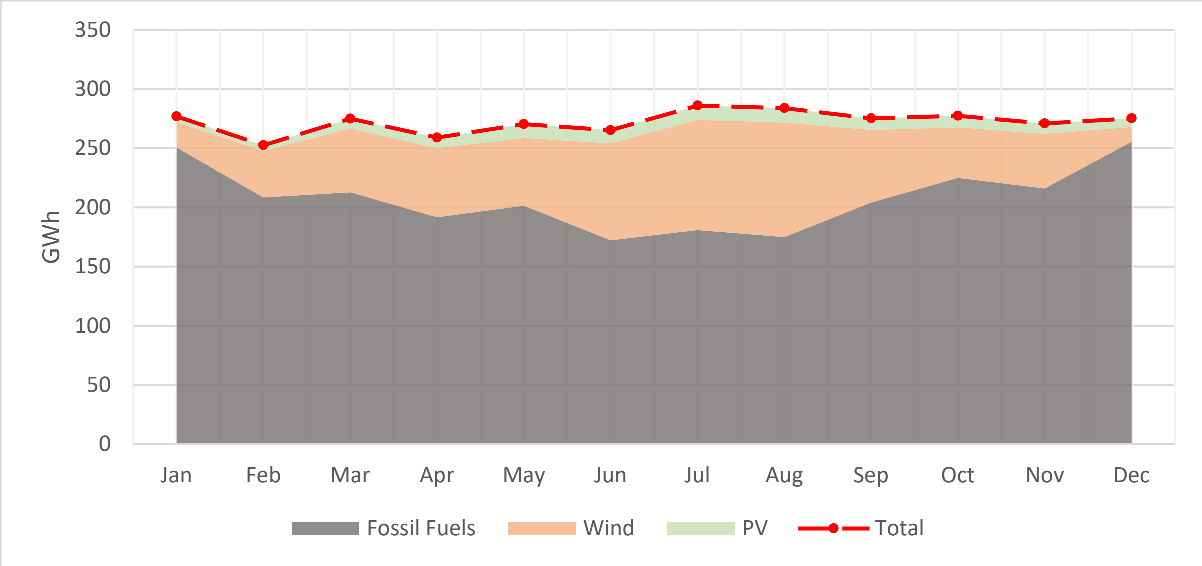

Figure 14. Net electricity production by energy source in the electrical system of Gran Canaria, year 2022. Own figure based on (ISTAC, 2022)

In 2022, the island had a total electricity demand of 3.27 TWh, being the most demanded month in July with 286 GWh and a the lowest in February with 252 GWh in February. Within the RE sector, offshore wind energy constitutes a mere 5 MW. The existing wind turbine in operation off the coast of Gran Canaria is the Elisa prototype. This prototype was installed during the summer of 2018 and commenced operation in March 2019 (ISTAC, 2022).

It is relevant to remark, that approximately 51% of Gran Canaria's total water demand is fulfilled by desalinating seawater. Currently, nearly 97% of the fresh water produced through desalination is obtained from seawater and brackish water using reverse osmosis technology. The electricity consumption associated with desalination, which can be significantly optimized, accounts for approximately 15.9% (521.93 GWh for the year 2022) of the overall electricity demand (ISTAC, 2022).

6.2.2. Penetration of offshore wind to the energy system of Gran Canaria

The population of Gran Canaria is projected to increase by 17% by 2040, reaching a total of 1,003,208 residents. Despite the growth of population, the Canary Islands government anticipates a decrease in power demand from the current level of 3.27 TWh to 2.91 TWh by 2040. This reduction is based on the assumption that energy efficiency policies outlined in the strategy will be successfully implemented. Nevertheless, the electrification of the transportation sector has the potential to result in an increased demand for electricity. Figure 15 provides a visual representation of the two projected demands, taking into account the electrification of small- and medium-sized vehicles as well as the maritime sector (Instituto Tecnológico de Canarias, 2022a).

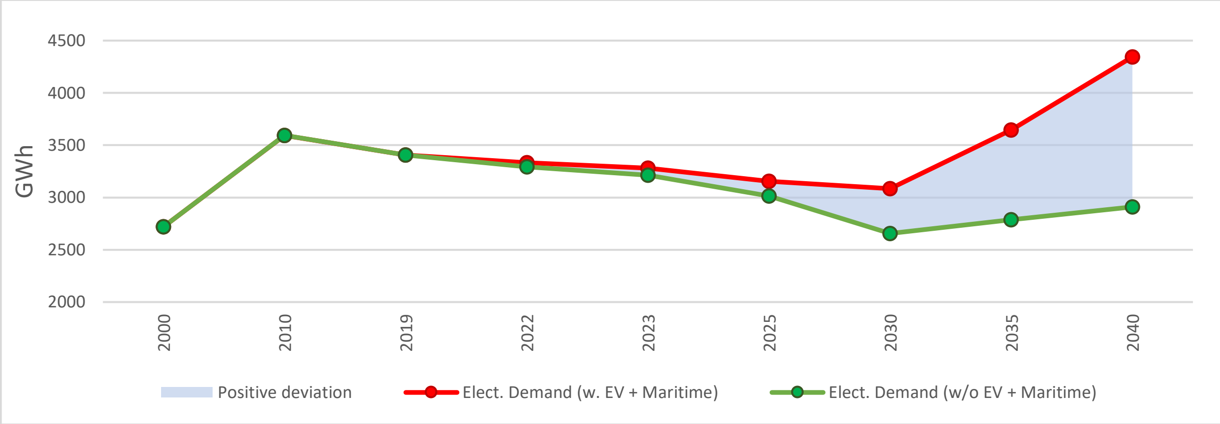

Figure 15. Projection of the power demand applying energy efficiencies policies w. or w/o. electrification of the transport sector Own illustration based on (Instituto Tecnológico de Canarias, 2022a)

The introduction of electric vehicles (EV) would result in a rise in electricity consumption (red line in Fig 15), reaching 4.33 TWh by 2040 according to the estimations. This represents a significant rise of 30% compared to the consumption levels in 2022. However, this does not imply a loss of overall energy system efficiency. This increase in electricity usage would be counterbalanced by a significant reduction in the consumption of domestic fuels, particularly gasoline and diesel.

The PTECAN proposal indicates that 13 units in the two thermoelectric plants will surpass their Regulatory Useful Technical Life by 2030, which means that there is no assurance for a total of 415.24 MW of power by that year. In addition, 80 MW of wind energy will be lost by 2040 because they will have exceeded their useful life, affecting between 23 and 28 wind farms (assuming that only certain parts of their facilities need to be dismantled). As for photovoltaic plants, their installed capacity reached 52.5 MW in 2020. Although some facilities will reach their regulatory useful life before 2030, the total power output barely surpasses 0.4 MW, which will have little impact on the available power generation capacity (Instituto Tecnológico de Canarias, 2022a).

In Gran Canaria, if the units that have reached their regulatory useful life are not available, 299.14 MW of electricity generated in 2019 would be lost. Table 4 below provides a comprehensive year-by-year analysis until 2040, specifically focusing on the unique circumstances of Gran Canaria Island.

Table 4. Demand coverage requirements for the island of Gran Canaria. Own table based on (Instituto Tecnológico de Canarias, 2022c)

Year	Demand [GWh]	Peak [MW]	Peak Thermic [MW]	Required [MW]
2022	3,333	592	581.58	120
2023	3,281	598	581.58	120
2024	3,218	597	581.58	120
2025	3,155	593	581.58	120
2026	3,141	594	581.58	120
2027	3,126	595	581.58	120
2028	3,112	595	444.18	240
2029	3,097	596	375.48	300
2030	3,083	597	375.48	300
2031	3,195	601	375.48	390
2032	3,308	605	77	640

2033	3,42	610	77	660
2034	3,533	614	77	680
2035	3,645	618	77	700
2036	3,785	625	77	720
2037	3,925	633	77	750
2038	4,064	640	77	770
2039	4,204	648	0	840
2040	4,344	655	0	870

As presented in the table, upon analysing the timeframe from 2021 to 2030, it is projected that a gradual installation of approximately 300 MW of additional power in category A generators will be necessary, in comparison to the existing capacity. This will involve a maximum installation of 120 MW between 2021 and 2023, and between 240 MW and 300 MW from 2028 to 2030. This estimation is reasonable considering that the Juan Grande power plant's combined cycle 1, which currently provides 137 MW, is expected to be decommissioned in 2028. Moving into the second planning period, 2031-2040, it is observed that a significant portion of the installed thermal power will exceed its regulatory lifespan. Therefore, it is anticipated that the additional power required during this period will surpass the figures from the first period, spanning 2021-2030. Specifically, in 2032, the installed thermal power will transition from 375.48 MW to 77 MW. Consequently, there will be a need for an additional 250 MW of power compared to the preceding year. Furthermore, in 2039, the installed thermal power will decrease from 77 MW to 0 MW, necessitating the installation of 70 MW of additional power compared to the previous year.

The potential solutions for the island include utilizing the Chira-Soria hydroelectric power plant, which could generate 200 MW of power through hydraulic turbines that are comparable in performance to traditional thermal generation. This would allow for the integration of renewable energies into the system. The project includes the construction of a water desalination plant in order to fulfil its purpose as an energy storage facility, with a 7,800 m^3/day of production capacity. The proposal suggests using photovoltaic panels to generate electricity for the desalination plant's self-consumption during sunny hours. Additionally, a cutting-edge energy recovery system for brine is integrated to utilize the energy present in it, significantly reducing the energy needed for producing each cubic meter of desalinated water through reverse osmosis process, with a value below 2.85 kWh/m^3 (REE, 2022). Despite this, there would still be a deficit of 100 MW by 2030 and 870 MW by 2040, necessitating the provision of additional capacity from alternative facilities.

The Government of the Canary Islands along with the Instituto Tecnlógico de Canarias, with the aim to overcome the above and to facilitate the transition of the fossil generation facilities in the Canary Islands, has proposed alternatives of Category A solutions that could uphold the existing supply's safety standards. The alternatives are outlined in the PTECAN and proposes an Alternative 0 to simulate the Business As Usual (BAU) scenario, and two planning alternatives (Alternative 1 and Alternative 2) aimed at meeting the future demand while achieving decarbonization by 2040. However, these alternatives assume different growth rates between the horizon of the PTCan (2030) and the expected horizon for total decarbonization (2040). The proposed alternatives are presented in Table 5 (Alternative 1) and Table 6 (Alternative 2).

Table 5. Alternative 1 starting data in Gran Canaria [MW]. Own table based on (Instituto Tecnológico de Canarias, 2022a)

Year	Thermal	Hydrogen turbine	Onshore wind	Offshore wind	Onshore PV	Offshore PV	PV Self-consumption	Biomass	Wave power
2022	699.4	0	196.9	5.2	73.1	0	37	5.05	0
2023	698.9	0	230.9	5.2	90.2	0	54.5	5.05	0
2025	697.9	0	309	55	129.7	3	94.5	5.05	1
2030	468.5	5	561.1	200	264.6	10.8	224.8	7	1

Table 6. Alternative 2 starting data in Gran Canaria [MW]. Own table based on (Instituto Tecnológico de Canarias, 2022a)

Year	Thermal	Hydrogen turbine	Onshore wind	Offshore wind	Onshore PV	Offshore PV	PV Self-consumption	Biomass	Wave power
2022	699.6	0	189.4	5.2	70.8	0	35.4	5.05	1
2023	699.2	0	229.4	5.2	91.5	0	55.8	5.05	1
2025	698.1	0	336	150	146.5	4.7	109.9	5.05	1
2030	467.6	0	770.8	250	374.4	14.9	323.4	7.9	1

Both options demonstrate a substantial integration of RE, yet Alternative 2 exhibits a greater level of ambition as it involves the deployment of a larger quantity of each RE unit. However, Alternative 1 is chosen as the most viable option to initiate and establish a gradual transition towards a carbon-neutral system by 2040. Table 7 presents the strategic distribution of the energy system for both the years 2030 and 2040.

Table 7. Manageable generation strategy for the years 2030 and 2040 in Gran Canaria. Own table based on (Instituto Tecnológico de Canarias, 2022c)

Year	Thermal [MW]	Hydrogen turbine [MW]	Onshore wind [MW]	Offshore wind [MW]	Onshore PV [MW]	Offshore PV [MW]	PV Self-consumption [MW]	Biomass [MW]	Wave power [MW]	Reversible pumping [MWh]	Storage [MWh]
2030	468.5	5	565.1	200	264.6	10.8	224.8	7	1	5,000	83
2040	0	255	1,672.5	1,089.7	658.4	30.6	259.5	18	5	5,000	971

It can be observed that the majority of the proposed category A options for the future are closely linked to energy storage solutions. Hence, it is crucial to have an ample capacity of generation to effectively support the electrical system.

Similarly, another important strategies in the decarbonization process involves the electrification and utilization of hydrogen for specific energy demands that are currently fulfilled by direct use of fossil fuels, such as transportation and industrial sectors. As a result, the demand for offshore wind energy in the Canary Islands is expected to grow significantly, potentially leading to even higher capacity requirements by 2040.

As an illustration, a study outlined in the Canary Islands Green Hydrogen Strategy indicates that the demand for hydrogen in Gran Canaria to decarbonize the transport sector is projected to be 17,991 tH2 by 2030 and 98,876 tH2 by 2040. The majority of the demand in 2040 would be attributed to road transport (61.2%), followed by maritime transport (32.5%), inter-island air transport (3.3%), and re-electrification (3%). To meet this demand, approximately 646.3 MW of wind power and 558.8 MW of photovoltaic power would be required, along with an electrolysis capacity of 170 MW. Considering the variable nature of renewable resources, the average power of the electrolyser would be around 139.6 MW throughout the year, resulting in a capacity factor of 82.1%. By 2040, the installed power in electrolysers would need to be expanded to 970 MW in order to decarbonize heavy land transport, inter-island maritime transport, and inter-island air transport. The most efficient approach would involve the establishment of 15 production centres. As a result, there is a potential for increased demand for offshore wind energy to meet the growing requirements of green hydrogen production (Instituto Tecnológico de Canarias, 2022e).

The following Figure 16 shows the distribution of generation by unit type for both 2030 and 2040 based on the above-mentioned analysis.

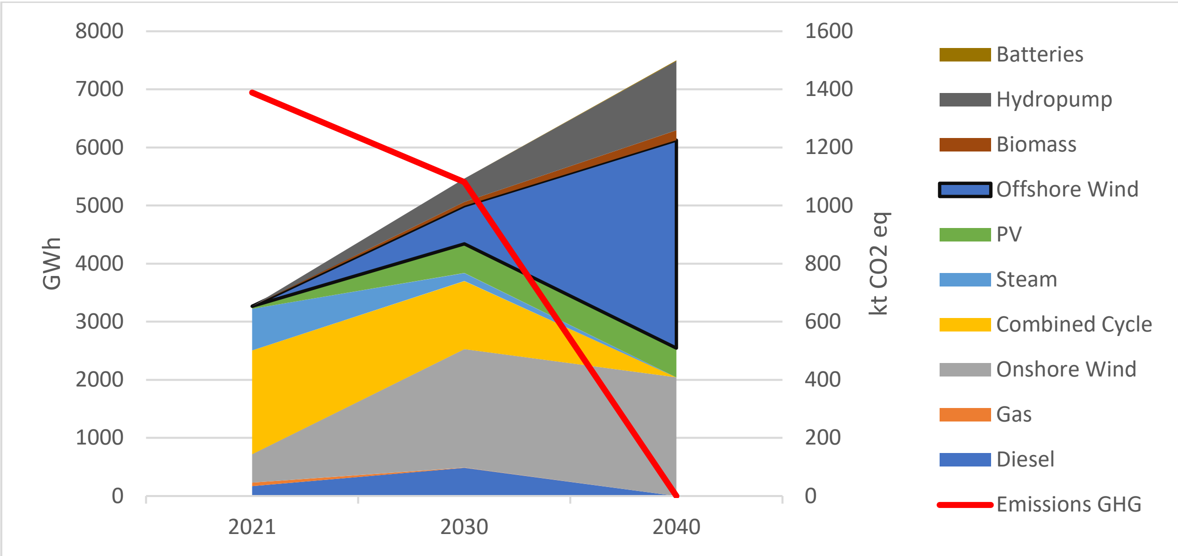

Figure 16. Distribution of generation by type of units in Gran Canaria applying manageable strategy. Own illustration based on (Instituto Tecnológico de Canarias, 2022a)

Based on the findings of the manageable generation strategy studies, the potential capacity of offshore wind power installations could reach 200 MW by the year 2030 (357 GWh/a assuming 38% of capacity factor). Looking ahead to 2040, considering factors such as the electrification of vehicles, complete decarbonization of the electricity sector, and the decarbonization of inter-island maritime and air transport, the required offshore wind power capacity would need to be approximately 1,090 MW (3,580 TWh/a assuming 38% of capacity factor).

It should be remarked that the analysis conducted thus far does not consider the ability of each electrical system to accommodate the energy generated by these facilities. Furthermore, for further studies it is essential to ensure that the quality and reliability of the power supply are maintained at satisfactory levels.

6.3. Pre-feasibility study

As discussed in Section 5.3.3, the preliminary feasibility study concentrates on four crucial factors that offer direction in designing the feasibility study and act as the primary inputs for its implementation. These areas include offshore wind evolution, cost of offshore wind deployment, CO2 savings, and employment.

6.3.1. Offshore wind evolution

The designated area in the southeast of Gran Canaria, chosen for offshore wind power installation, benefits from the direct impact of trade winds. The island's shape and topography accelerate these winds, resulting in a significant offshore wind resource. Power densities at a height of 100 m can reach 800 W/m^2, with some areas even reaching 1,200 W/m^2 (onshore regions typically consider 500 W/m2 as an excellent wind resource for wind farms), making it one of the most attractive regions in Europe for offshore wind farms.

However, there is a challenge related to bathymetry in this area. Within 12 km from the coast, there is a drastic drop in depth, ranging from 500 to 1,500 m in just 400 m. This creates difficulties for anchoring floating platforms that would support wind turbines, making it currently unfeasible. Despite this, there is a platform in the region covering approximately 91 km2 with bathymetry ranging from 50 to 100 m, which makes it an ideal location for the installation of floating wind farms. In the following Figure 17 can be observed a representation of the designated area for offshore wind power installation, along with any limitations or constraints, included in the Canary Offshore Renewable Energy Strategy (Instituto Tecnológico de Canarias, 2022d).

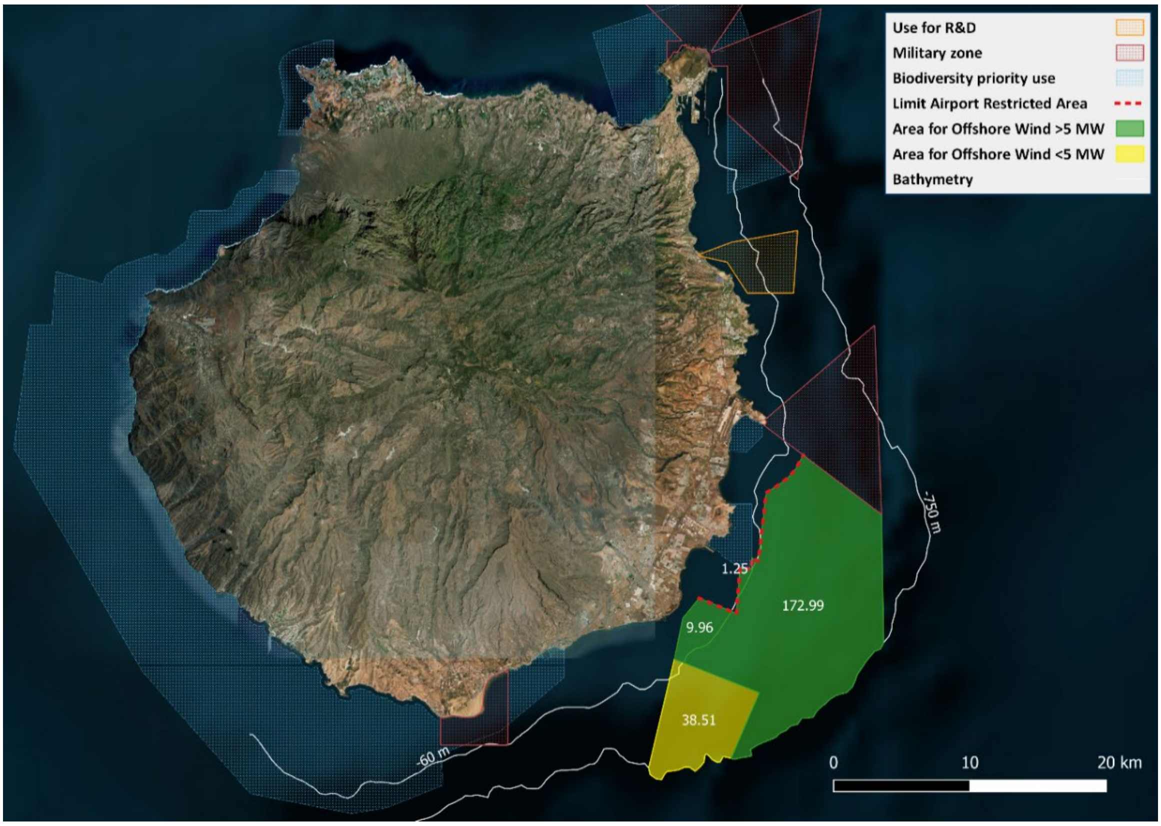

Figure 17. Defined area for the installation of offshore wind power in Gran Canaria. Own illustration based on (Instituto Tecnológico de Canarias, 2022d)

The figure illustrates the zoning of the designated area for offshore wind power, taking into account factors such as bathymetry, maritime traffic, and military zones. The maximum allowable depths for wind power installation are set at 750 meters. The main area, bounded by the Gran Canaria Airport easement and the military zone near the Gando Air Base, offers a significant wind resource ranging from 9 to 11 m/s at a height of 150 m. Based on this, the area of greatest interest for wind farms with bottom-fixed foundations covers approximately 11.21 km^2 (assuming bathymetric limit of 60 m), while for floating foundations, it extends to 172.99 km^2 (assuming bathymetric limit of 750 m). However, there are height restrictions between 340 and 520 m within these areas due to the proximity to the airport, and consequently this may constraint the use of new generation wind turbines (above 15 MW) which tip height can potentially exceed these heights (Instituto Tecnológico de Canarias, 2022d).

In terms of energy transmission to the mainland, the south-eastern region of Gran Canaria stands out as the most suitable location for potential offshore wind farms connections. As seen in Figure 13 the El Matorral substation, located near the Barranco de Tirajana Thermal Power Plant, offers the most favourable conditions for energy evacuation. Currently, it has the highest short-circuit power on the island (220 kV), making it a more feasible option for accommodating the power generated by future wind farms. However, the final assessment of this criterion must require a detailed evaluation by the TSO.

To date, Gran Canaria has taken advantage of the opportunity to establish itself as a leading national testing centre for offshore technology, primarily through initiatives like PLOCAN. However, the island has not yet commenced commercial offshore wind development and offshore wind activities have been restricted to pilot and precommercial projects. Nonetheless, numerous offshore wind projects are presently in progress and undergoing environmental evaluations. These projects are awaiting the first auctions for the biddings process, which will allocate the initial commercial offshore wind lease areas in Gran Canaria.

The following part of the research involves scanning and gathering information on various ongoing projects that are currently under development and have been submitted to MITECO as part of the legislative framework for environmental processing.

According to both developer and the authority institutions, the initial advancements in the floating wind industry will prioritize locations with water depths below 100 m and wind resources exceeding 4,000 hours per year (with a 45% capacity factor). Based on existing technology, depths beyond 100 m introduce greater challenges in terms of anchorage systems and the installation of grid connection cables, rendering projects financially unviable yet. It states that the initial commercial projects will be restricted to utilizing bottom-fixed foundation technology and floating foundations in areas with shallow water depths (Gobierno de Canarias, 2023).

EYRA Instalaciones y servicios S.L. initiated the environmental processing of the FLOCAN V project in 2016. This project involves a 25 MW wind farm consisting of five floating wind turbines, each with a nominal power of 5 MW. It also includes the installation of a marine evacuation line, a medium voltage land line, and a transformer station in the El Matorral area (4C Offshore, 2023).

Greenalia, for instance, Spanish developer, has started the permitting process for five floating wind farms off the Gran Canaria (The Gofio, Dunas, Mojo, Guanche, and Cardón projects), each of capacity over 50 MW with a total capacity of 250 MW. Gofio could most likely be Spain's first floating offshore wind park, generating enough energy to power 75,000 homes (EnerData, 2022).

Several projects in 2020 and 2021 submitted their Initial Project Document for the optional phase, aiming to determine the scope of the Environmental Impact Study. One such project is the Gran Canaria Este Wind Farm, presented by OceanWinds to MITECO. This project is proposed to have a capacity of 144 MW and will be located in the marine area southeast of Gran Canaria. It involves the installation of 12 floating wind turbines, each with a capacity of 12 MW, along with marine and terrestrial connection lines leading to a 66/220 kV booster substation and transformer near the Barranco de Tirajana Thermal Power Plant (4C Offshore, 2023).

In 2021, six Initial Project Documents were submitted in the same region. Firstly, between January 29, 2021, and February 3, 2021, Grupo Cobra presented four offshore wind farms, each with a nominal power of 49.9 MW. These wind farms utilize fixed gravity structures with ELISA technology. The four wind farms are named Parque Eólico Alisio, Parque Eólico Sahariano, Parque Eólico Colombino, and Parque Eólico Cabildo. Located at depths ranging from 30 to 60 meters, these wind farms are situated closer to the coastline. Grupo Cobra also added two floating wind projects added in its pipelines, Canawind I and II, of 250 MW each (4C Offshore, 2023).

Lastly, Canarrays S.L., owned by ENEROCEAN S.L., initiated the optional procedure for two Canarray I wind farms. These wind farms are situated on the southeast coast of Gran Canaria, facing the T.M. of San Bartolomé de Tirajana. With a total nominal power of 48 MW, each wind farm consists of four floating platforms utilizing W2Power technology, housing two wind turbines each, resulting in a total of eight 6 MW wind turbines. Additionally, slightly further north is the Canarray II wind farm, comprising twelve floating platforms using W2Power technology and featuring a total of 24 6 MW wind turbines. The Canarray II wind farm has a combined nominal installed power of 144 MW (4C Offshore, 2023).

Iberdrola is also developing the 238 MW San Borondón floating wind project off also in the southeast coast of Gran Canaria Island and Bluefoat in collaboration with Sener is developing a 255 MW project. In addition, Enerocean is also developing two project with a total capacity of 180 MW (Canarray I and II projects) (EnerData, 2022). On the other hand, according to EnerData (2023), Naturgy and Equinor are collaborating on the development of the 200 MW Floating Offshore Wind Canarias (FOWCA) project, which would be also located in the area addressed in Figure 17 and is expected to participate in an offshore wind power auction in 2023.

All the presented projects above, are gathered in Table 8 along with their total capacities and type of foundation technology.

Table 8. The list of offshore wind projects in Gran Canaria under environmental processing and registered in MITECO

Project name	Capacity [MW]	FOU technology	Developer
FLOCAN V	25	Floating	EYRA
Gofio	50	Floating	Greenalia
Dunas	50	Floating	Greenalia
Mojo	50	Floating	Greenalia
Guanche	50	Floating	Greenalia
Cardón	50	Floating	Greenalia
Gran Canaria Este	144	Floating	OcenaWinds EDPR
Alisio	49.9	Bottom-fixed	Grupo cobra
Cabildo	49.9	Bottom-fixed	Grupo cobra
Sahariano	49.9	Bottom-fixed	Grupo cobra
Colombino	49.9	Bottom-fixed	Grupo cobra
Canawind I	250	Floating	Grupo cobra
Canawind II	250	Floating	Grupo cobra
Canarray I	48	Floating	Enerocean
Canarray II	144	Floating	Enerocean
Tarahal	225	Floating	BlueFloat & Sener
San Borondón	238	Floating	Iberdrola
FOWCA	225	Floating	Equinor

From this scanning, a total portfolio of 2 GW is identified within the environmental processing. This substantial figure exemplifies the favourable prospects for commencing offshore wind deployment in the region. In order to create an effective structure that can accommodate commercial projects and foster mutual benefits for both developers and the region, it is essential for the government to develop a well-designed auction system. This system will provide the optimal framework necessary to facilitate the success of these projects and ensure positive outcomes for all stakeholders involved.

Considering the range of capacities identified in the aforementioned underdeveloped projects, which span from 50 to 200 MW, the research proposes an offshore wind deployment evolution that aligns with these capacity ranges and is used for the feasibility study. The objective is to align the proposed evolution with the projected evolution of offshore wind outlined in the PTECAN. Figure 18 shows both evolutions.

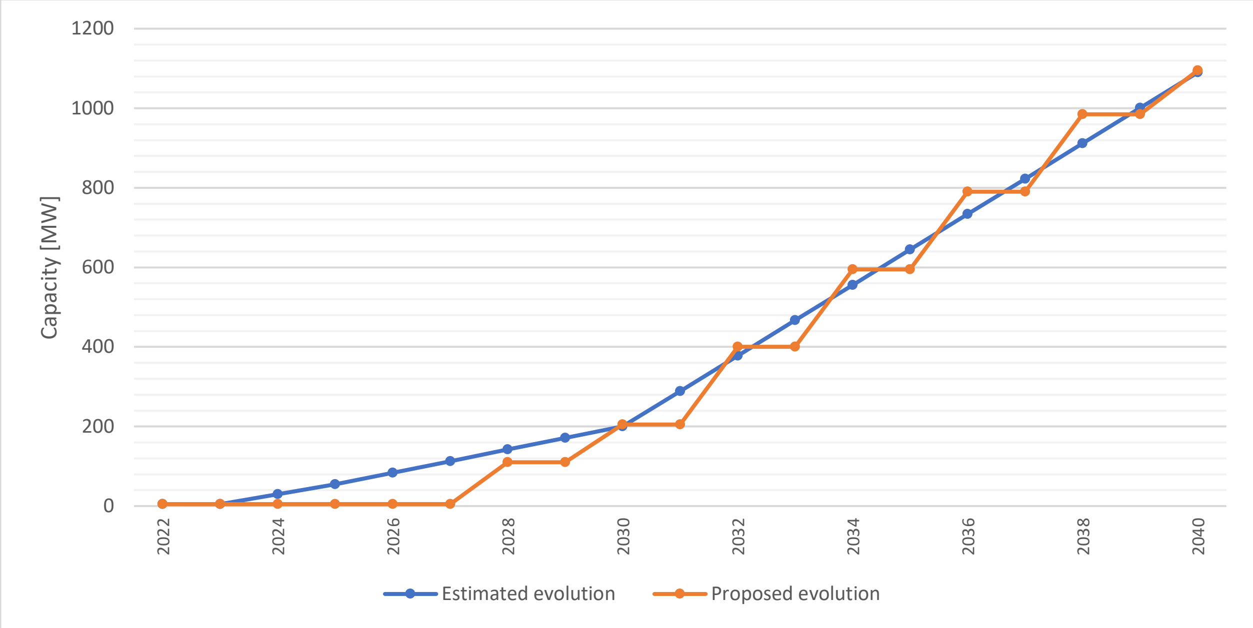

Figure 18. Estimated offshore wind evolution based on the Canary Manageable Generation Strategy against the proposed evolution for the study. Own illustration based on (Instituto Tecnológico de Canarias, 2022c)

The estimated growth in the strategy follows a linear progression. However, for the feasibility study conducted in this research, a more realistic evolution is proposed. This approach is adapted to meet the necessary provision of additional capacity within the specified time horizon. The analysis conducted in Section 6.2.2 indicates a projected shortfall of 100 MW by 2030 and 870 MW by 2040 and a total of 1,090 MW of offshore wind will be needed. To address this, it is assumed that the offshore wind development zone can provide a capacity factor of 38% (same capacity as Instituto Tecnológico de Canarias has used in its simulations), equivalent to 3,329 hours of full operation. Furthermore, this approach takes into account the realistic timeframe required for constructing an offshore wind farm of theses scales (100-200 MW), around 2 years, from the date of the Final Investment Decision (FID) to the Commercial Operations Date (COD). Based on this, a total of seven wind farms were proposed for the time horizon with a total of 1,095 MW. Technical description of these seven wind farms is further described in the following section, which is employed to estimate the cost of such wind farms.

6.3.2. Cost of offshore wind deployment

As it was mentioned in the Section 6.3.1, seven wind farms are proposed that align with the identified offshore wind evolution from the energy system analysis. This section provides an estimation of the cost breakdown for constructing the seven proposed wind farms and outlines the underlying assumptions used in the analysis.

Despite the likelihood of future wind farms featuring different types of wind turbines and power ratings, as seen in Section 6.3.1, this study assumes the use of a 15 MW WTGs for the seven wind farms. The following Table 9 illustrates the main assumptions of every wind farm.

Table 9. Main assumptions for the prosed wind farms. (*) Jacket FOU most preferable option for water depths of 60 m and Semi-submersible most common type of floating FOU used by developers.

	FID	COD	OWF size	Positions	Water depth	FOU	FOU technology(*)	IAC length
Park 1	2026	2028	105 MW	7	60 m	Bottom-Fixed	Jacket	21 km
Park 2	2028	2030	105 MW	7	60 m	Bottom-Fixed	Jacket	21 km
Park 3	2030	2032	195 MW	13	300 m	Floating	Semi-submersible	43 km
Park 4	2032	2034	195 MW	13	300 m	Floating	Semi-submersible	43 km
Park 5	2034	2036	195 MW	13	300 m	Floating	Semi-submersible	43 km
Park 6	2036	2038	195 MW	13	300 m	Floating	Semi-submersible	43 km
Park 7	2038	2040	105 MW	7	300 m	Floating	Semi-submersible	24 km

Park 1 and 2 are the sole wind farms that utilize bottom-fixed foundation technology, as it has been acknowledged that initial commercial projects will likely be constrained to this type of foundation. For the remaining wind farms, floating technology is assumed, with water depths limited to 300 meters. These specific water depths, in conjunction with a spacing configuration of 6-10RD, were used to estimate the total length of inter-array cabling for each wind farm. According to (Stevens *et al.*, 2017), the recommended distance between large-sized wind turbine generators (WTGs) in the prevailing wind direction is 10 times the rotor diameter (10RD), while in the direction perpendicular to the prevailing wind direction, the distance should be 6RD.

For the designing of the offshore wind farm (OWF), were defined the parameters and technical specifications that the seven wind farms will have in common. Table 10, gathers all these common parameters.

Table 10. Common OWF parameters for the prosed wind farms

Parameter	Units	Value
OWF Parameters		
Operational time	years	25
Turbine OEM	-	IEA
Turbine model	-	IEA 15 MW RWT
Net Capacity Factor	%	38%
Export cable type	-	HVAC 275 kV
IAC voltage	kV	66
Type of substations	-	HVAC
No. of OSS	-	2
No. export cables	-	4

The IEA-15MW RWT model was chosen as the turbine model, which should be noted is a conceptual design provided by the IEA rather than an actual turbine. This model serves as a reference for studies exploring new technologies or design methodologies, making it suitable for the purposes of this study (NREL, 2020). Currently, there are no commercially available wind turbines with such capacity. However, it is assumed that the market will offer this capacity by the year of construction, which is used for the scenarios.

It is also assumed same capacity factor for the seven wind farms as it was used by Intituto Tecnológico de Canarias in their simulation. This net capacity factor is assumed to include the loss factor which includes all the losses present in an operational wind farm.

Therefore, the seven wind farms have the potential to produce a total net Annual Energy Production AEP of 3,640.04 GWh when fully operational. Regarding the electrical configuration, it is assumed that a total of two offshore substations (OSS), each with a capacity of 500 MW, will be constructed and utilized for the seven wind farms. The power generated by the wind farms will be transmitted to the onshore area through two export cables connected to each OSS. For the location of the electrical onshore substation, the area close to the Juan Grande Thermal Power Plant was proposed, close to the entrance area of the marine evacuation line. The electrical specifications depicted in Table 10 were determined based on the technical characteristics of a 1 GW offshore wind farm and the distance to the shore (Giebel and Hasager, 2016; BVG, 2019; Maclean, no date).

After establishing the technical assumptions, the focus shifted towards estimating the breakdown of costs. Table 11 presents the assumed cost values for various categories. As a reference, the Guide to an offshore wind farm developed by BVG (2019), which provides cost estimates for OWF development, was consulted. Additionally, the work of Aguilera (2023) provided useful cost indicators for this analysis.

Table 11. Costs assumed for the different cost breakdown categories for every wind farm

Category	Park 1	Park 2	Park 3	Park 4	Park 5	Park 6	Park 7	TOTAL
Capacity	105 MW	105 MW	195 MW	195 MW	195 MW	195 MW	105 MW	**1,095 MW**
DEVEX	14 M€	14 M€	28 M€	28 M€	28 M€	28 M€	14 M€	**155.22 M€**
CAPEX								
Wind Turbines	105 M€	105 M€	195 M€	195 M€	195 M€	195 M€	105 M€	**1,095 M€**
IAC Cables	4.52 M€	4.52 M€	16.31 M€	16.31 M€	16.31 M€	16.31 M€	7.23 M€	**74.28 M€**
FOU Jackets	41.3 M€	41.3 M€	-	-	-	-	-	**82.6 M€**
FOU Floating	-	-	130 M€	130 M€	130 M€	130 M€	70 M€	**556.39 M€**
Offshore Substation *	19.18 M€	19.18 M€	35.62 M€	35.62 M€	35.62 M€	35.62 M€	19.18 M€	**200 M€**
Onshore Substation *	0.96 M€	0.96 M€	1.78 M€	1.78 M€	1.78 M€	1.78 M€	0.96 M€	**10 M€**
Operation Base *	0.38 M€	0.38 M€	0.71 M€	0.71 M€	0.71 M€	0.71 M€	0.38 M€	**4 M€**
Installation	53.55 M€	53.55 M€	59.67 M€	59.67 M€	59.67 M€	59.67 M€	32.13 M€	**377.91 M€**
OPEX								
Operations	3 M€	3 M€	5.7 M€	5.7 M€	5.7 M€	5.7 M€	3 M€	**31.8 M€**
Maintenance & Service	6.2 M€	6.2 M€	11.5 M€	11.5 M€	11.5 M€	11.5 M€	6.2 M€	**64.6 M€**
DECEX								
Decommissioning	40.16 M€	40.16 M€	37.05 M€	37.05 M€	37.05 M€	37.05 M€	19.95 M€	**248.48 M€**
CAPITAL COST*	**2.28 M€/MW**	**2.28 M€/MW**	**2.39 M€/MW**	**2.39 M€/MW**	**2.39 M€/MW**	**2.39 M€/MW**	**2.37 M€/MW**	**2,850 M€ - 2.6 M€/MW**

The justifications for each assumed cost value in the table are provided in *Appendix I: Justification for each assumed cost value* to explain the reasoning behind them. Considering the cost values presented in Table 11, the total investment cost (DEVEX + CAPEX) is estimated to be 2.85 B€, which equates to approximately 2.6 M€ per MW installed. However, it should be noted that these values do not account for the cost reductions resulting from the increasing maturity of the technology and the learning curve. Therefore, for the purpose of the feasibility study, these values were adjusted by applying a cost reduction factor of 2%, as shown in Figure 19.

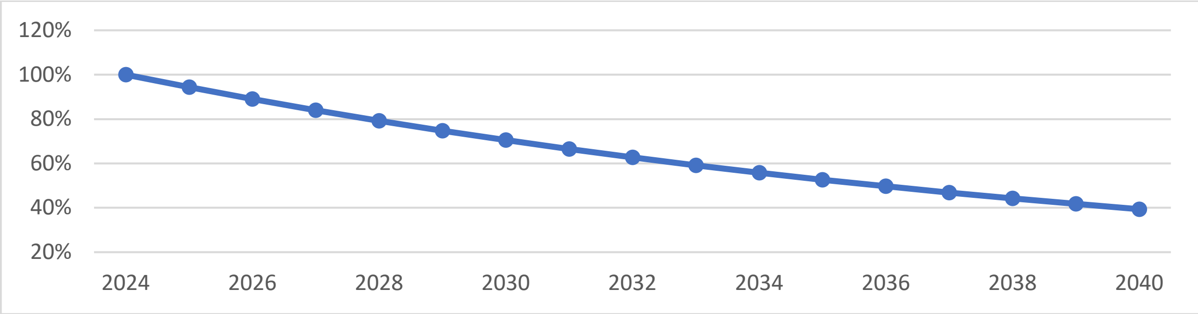

Figure 19. Cost reduction over the years assuming 2% as cost reduction factor. Own figure.

The cost reduction factor of 2% is not applied to OPEX since operation and maintenance costs remain relatively stable over the years, and therefore it was determined that the factor would not be used in this case.

The aforementioned costs do not include the expenses associated with upgrading the necessary infrastructure to support offshore wind deployment. Adequate port infrastructure and grid interconnection must be modified to accommodate the integration of offshore wind. Ports play a vital role in the progress of offshore wind projects as they serve as bases for constructing and assembling offshore wind infrastructure. They provide the required facilities and equipment for manufacturing, assembly, and pre-installation testing of wind turbine components. Additionally, they facilitate the transportation of these components from manufacturing sites to offshore installation locations and can serve as O&M bases for ongoing servicing activities of offshore wind farms. Therefore, it is crucial to rely on a port that can fulfil these functions (WindEurope, 2022).

Finding a port that meets the requirements for accommodating offshore wind, such as land spacing, water depths, and bearing capacities, poses a challenge. Consequently, it is likely that ports near potential offshore wind farm sites will require upgrades and expansions. Port development is inherently a long-term investment that necessitates long-term prospects and a sustainable business plan spanning several years before financial feasibility and permit approval for upgrades or expansions can be achieved. This translates to significant capital requirements and years of development. In the case of Spanish ports, which fall under the jurisdiction of the State (as observed in Section 6.1.3), the responsibility for development and investment in upgrades lies with the public, making it a cost borne by the government (society) in this study (Appendix II: Conference notes).

A potential harbor has been identified in close proximity to the offshore wind zone defined by the POEM, located approximately 3 km from the boundary area. The harbor is situated in the municipality of Agüimes, near the border with the municipality of Santa Lucía de Tirajama. It was specifically designed as a dock to cater to the needs of industries located in the Arinaga Industrial Park, as well as to enhance the services provided by the Port of Las Palmas for the tourism sector in the southern region of Gran Canaria. The harbor consists of two docks: the Arinaga dock, which features a 466 m berthing line with water depths ranging from 7 to 10 meters, and the Agüimes dock, which includes a fixed ramp with a depth of 14 meters and a berthing line spanning 317 meters. The total concession area measures 94,830 m2, with 46,000 m2 allocated for berthing purposes. For a visual representation of the port, please refer to Figure 20 (Puertos de Las Palmas, 2023).

Figure 20. Aerial picture of the Muelle de Arinaga port. Figure from (Puertos de Las Palmas, 2023)

The scope of this report does not include an assessment of the suitability of the identified port or whether it needs additional upgrades to accommodate the proposed offshore wind developments in the case study. The reason for this is that the cost of expanding a port to support offshore wind operations can vary greatly depending on factors such as the scale of the expansion, existing infrastructure, geographical location, and project-specific requirements. Without a detailed study, it is difficult to provide an exact investment cost in this report, and such information is not included. Instead, a separate report was identified that evaluates port expansion for offshore wind farms in South Korea, which can serve as an indicator to estimate the cost for this study (COWI, 2020).

According to a report by COWI (2020) the expansion of a port to accommodate a 500 MW bottom-fixed offshore wind project can range from 100 to 200 M€. The lower end of the range applies to ports that require minimal upgrades, while the higher end applies to those requiring more extensive upgrades. Considering that this report assumes a maximum capacity of 195 MW every 2 years, including floating wind projects that have more significant requirements than bottom-fixed ones, an estimate of 100 M€ was chosen as the investment cost for upgrading the selected port of Agüimes for the proposed seven wind farms.

It is important to acknowledge that the provided estimate may deviate significantly from the actual cost, and as such, it should be regarded as an assumption. To obtain a more precise approximation of the expenses associated with adapting the current port to accommodate future offshore wind projects in the area, further studies are necessary.

6.3.3. Savings emissions

As addressed in Section 5.3.3, the feasibility study takes into account the socio-economic benefits by assessing the reduction of GHG emissions achieved through offshore wind power generation compared to conventional thermal power plants. This section provides an analysis of the potential CO2 emissions reduction resulting from the implementation of the proposed capacity outlined in this study, as well as the corresponding economic savings associated with these emissions reductions.

Based on the energy system analysis, it was identified that the future trajectory of the electric generation system toward a carbon neutrality by 2040. Table 12 illustrates the distribution of conventional power generation units in terms of installed power capacity over the specified time horizon. Additionally, the table incorporates the emission factor associated with each fuel (US EPA, 2011).

Table 12. Distribution of conventional power units and the emission factor of the fuels. Own table based on (US EPA, 2011; Instituto Tecnológico de Canarias, 2022c)

	Diesel Engine	Gas Turbine	Combined Cycle	Steam Turbine
2021	22%	2%	55%	5%
2030	27%	0%	64%	9%
2040	0%	0%	0%	0%
Emission Factor [tCO2/MWh]	1.27	0.49	0.35	0.387

An emission factor corresponding to industrial oil was utilized for the steam turbine. Using the assumptions provided in Table 12 and the estimated power generation associated with implementing one of the alternatives from the PTECAN, the annual GHG emissions depicted in Figure 21 were calculated.

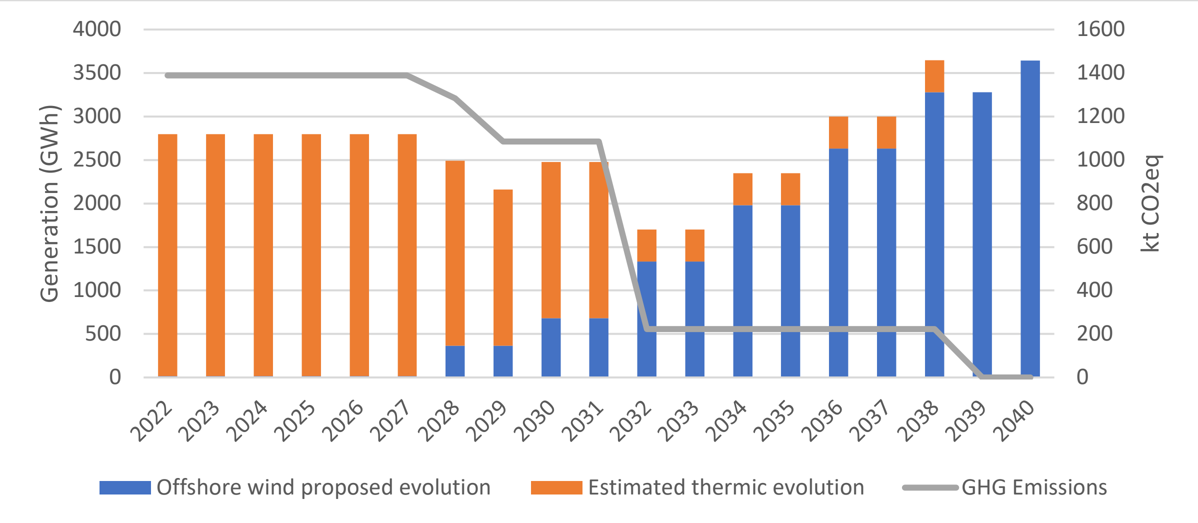

Figure 21. Estimation of the power generation by source and the annual emission evolution. Own figure

It can be observed how the amount of CO2eq released from the power generation decreased according to the replacement of the conventional thermic units for RE alternatives, but only the addition of offshore wind is presented in the figure.

Figure 22 illustrates the future savings in EU carbon permits by estimating the amount of GHG emissions that would be released if a conventional thermal power plant had to generate the same amount of electricity as the proposed offshore wind capacity. The assumption is that this hypothetical conventional thermal plant would be divided among the four previously used A-category technologies (steam turbine, diesel engine, combined cycle, and gas turbine), with each technology contributing 25% to the total generation.

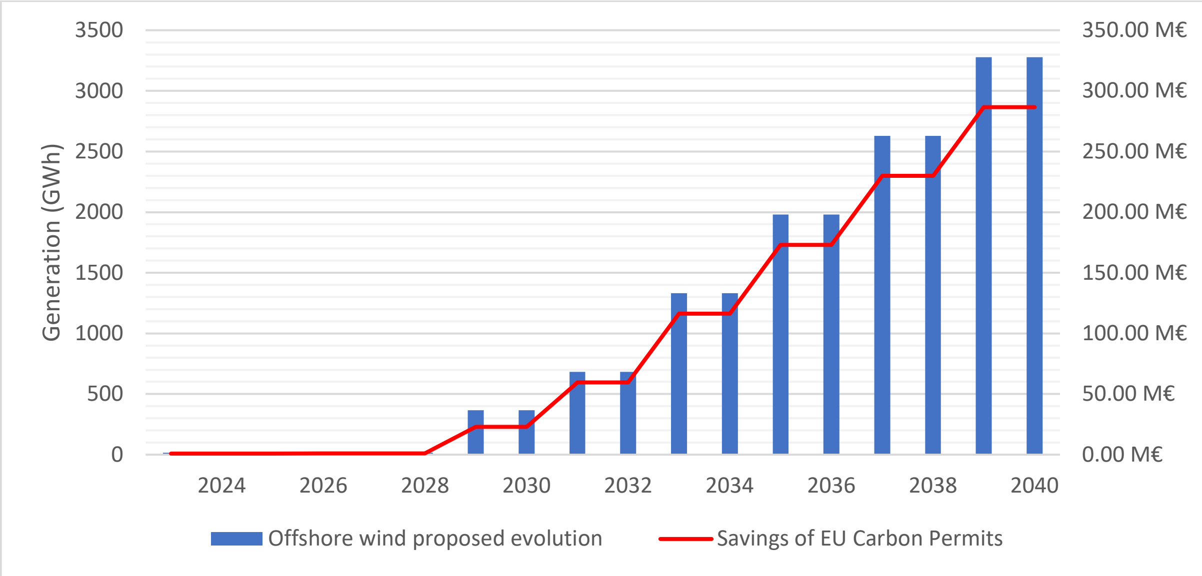

Figure 22. Estimation of the power generation by offshore wind and the cumulative savings of EU carbon permits. Own figure

As seen in the figure, it was that the deployment of offshore wind over the specified time frame can result in a total savings of 12,883.62 ktCO2eq compared to a conventional thermal power plant, i.e. approximately 2,078 tCO2eq saved per MW installed per year. These savings translate to a significant value of 1.78 B€ in EU Carbon Permits. These findings were based on the assumption of projected average CO2 prices in the EU ETS: 85.45 €/tCO2eq for the period 2023-2025; 100 €/tCO2eq for the period 2026-2030; and 140 €/tCO2eq for the period 2031-2040 (Statista, 2023b).

6.3.4. Employment

This section examines the potential employment opportunities associated with the deployment of offshore wind and aim to quantify the scale of both national and local employment that would arise from the implementation of the proposed capacity outlined in this study.

The manufacturing, installation, operation, and maintenance sectors associated with marine energy systems, particularly offshore wind, have witnessed significant growth in recent years, leading to an estimated 150,000 jobs across Europe. The rapid expansion of offshore wind farms and offshore converter farms will directly contribute to the creation of high-quality jobs that involve advanced knowledge, with the potential to generate around 5.4 million jobs in the maritime sector according to the GWEC (2022). This growth will also result in a gross added value of nearly 500 B€ annually.

Equinor, drawing on its experience, to provide a broader assessment of the job and value creation associated with the FOWCA project, commissioned a study by the University of Las Palmas de Gran Canaria (ULPGC). This study focused on the impact of a 200 MW floating offshore wind farm in Gran Canaria on local employment and the economy. The study involved interviews with industry stakeholders in the Canary Islands and other regions of Spain, and it utilized a methodology previously applied in similar studies. The ULPGC study examined various scenarios, all of which demonstrated a highly positive effect. In terms of Gross Domestic Product (GDP), the study indicated a potential increase ranging between 550 and 780 M€. The Canary Islands possess significant capacity and expertise in advanced technical services, including two large shipyards, along with an existing service base in the port of Arinaga where offshore wind energy R&D activities have already taken place (Equinor, 2018).

According to the socio-economic study, the construction phase of the project could generate a substantial number of jobs, including both direct and indirect positions. During the construction phase (which is estimated to span 2-3 years), there could be between 1,000 and 3,000 temporary jobs created, while the operational phase in Gran Canaria (which is expected to exceed 20 years) could sustain approximately 200 FTE jobs (Equinor, 2018).

The employment figures used in this study are sourced from several reports (CE Delft (2021) NJEDA (2022) and the included the conducted by ULPGC. The employment rates utilized in this study gathered in Table 13, represent the average values presented in the examined reports and encompass construction phase, operational phase and indirect employment opportunities.

Table 13. Employment rates utilized in this study

	2030	2040
Direct full employment construction phase	6.9 FTE/MW	5.5 FTE/MW
Indirect full employment construction phase	8.5 FTE/MW	10.2 FTE/MW
Direct full employment Operationl phase (25 years)	1.2 FTE/MW	0.8 FTE/MW

It is presumed that these employment rates can be applied to floating offshore wind projects, taking into account the larger offshore wind sector as a whole. However, it is anticipated that by 2040, there will be a reduction in the number of workers needed for the direct construction phase, as the use of floating technology requires less manpower for installation. Conversely, indirect employment is expected to increase as the supply chain for floating wind necessitates a larger workforce. Using this information, an estimation was made to determine the potential job opportunities that could arise from the implementation of the suggested offshore wind deployment showcased in Figure 23. It is important to highlight that in this scenario, the assumption is made that all the necessary employment can be sourced within Spain, without taking into account the involvement of foreign workers. However, it is highly probable that specialized workers from other countries will play a role in different parts of the value chain.

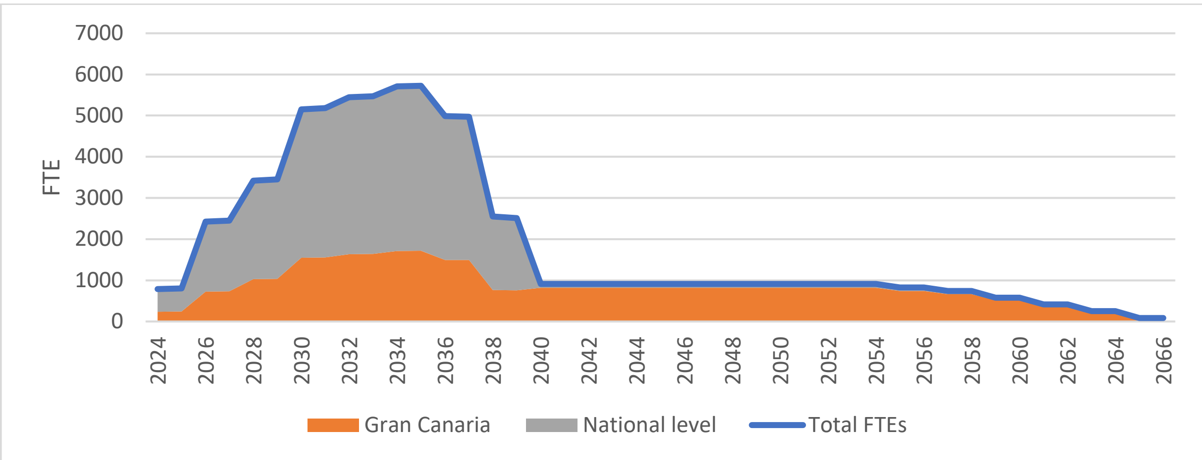

Figure 23. Potential FTEs related to the proposed offshore wind deployment. Own figure

The figure presented provides an estimate of the overall employment generated at the national level, as well as the potential employment opportunities at the local level. Based on the findings, there is a projected peak of 5,724 FTE jobs in the year 2035. Out of these, approximately 1,717 FTE jobs would be potentially created in Gran Canaria. It assumes that approximately 30% of the total employment could be filled by local individuals in the construction phase and 90% in the operational phase. However, it is important to note that these percentages are not fixed and can vary depending on various factors, including the specific project, its location, the availability of a local workforce, and relevant government regulations. The aim is generally to maximize local job creation to foster economic benefits within the local community. Developers and authorities should carefully consider strategies for promoting local employment and establish appropriate targets or agreements to ensure a fair distribution of job opportunities for local residents (Appendix II: Conference notes).

If we consider indirect jobs as representative of the offshore wind industry's supply chain, a portion of this employment could be considered permanent. This means that the newly created jobs can contribute to the supply chain of other projects, both nationally and internationally. Consequently, this can promote local industrialization. The considerations regarding this aspect were discussed in Section 6.5. It is worth emphasizing that the study does not take into account job-related activities associated with infrastructure upgrading, such as port upgrading and extension of the transmission grid.

In 2022, the Spanish government allocated approximately 24.34 M€ towards unemployment subsidies. Based on the unemployment rate of 13.01% during that year, this equates to an average of 7,780 euros per unemployed person. Using these values as a benchmark, the calculation was performed to determine the potential savings in employment subsidies over the given time period. The outcomes of this analysis are illustrated in Figure 24 (Civio, 2022).

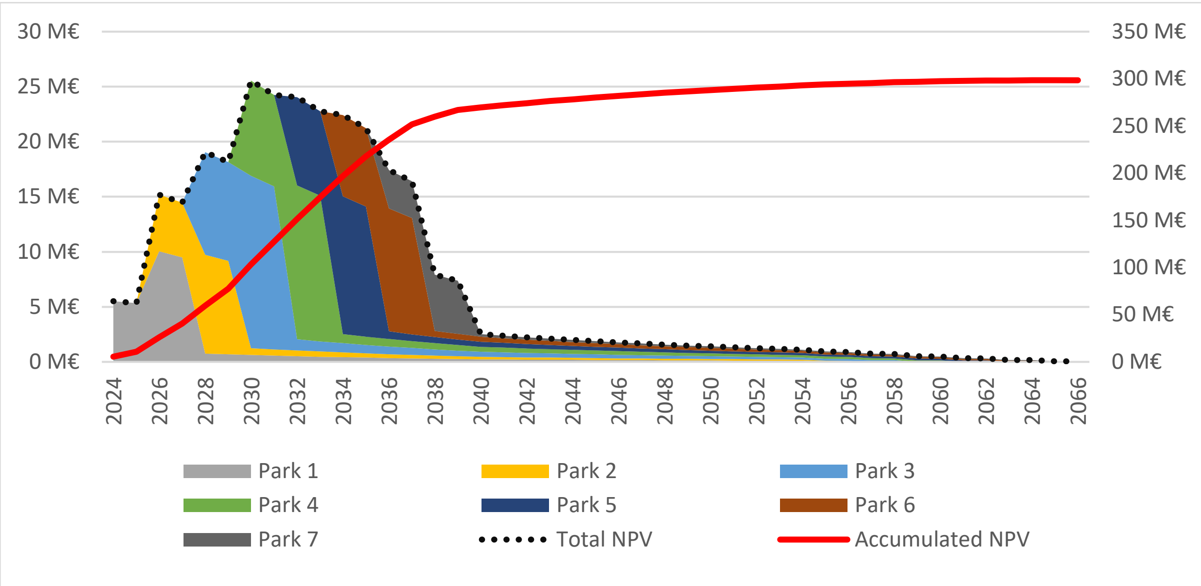

Figure 24. Potential FTEs related by wind farm and the cumulative savings of unemployment subsidies. All the calculations are properly adjusted to the same discount factor. Own figure

The figure clearly demonstrates that the implementation of the proposed offshore wind farms would result in significant cost savings. A total of 300 M€ could be saved, with approximately 90% (274 M€) of this amount concentrated between the years 2024 and 2040. This is primarily due to the high levels of employment during the construction phase, which necessitates intensive work and contributes to the majority of the savings.

6.4. Feasibility study

The purpose of this section is to address sub-question 3 by conducting the feasibility study. This analysis involves calculating the NPV of the proposed scenario and assessing the impacts of incorporating CO2 savings and employment. Furthermore, a sensitivity analysis is included in this section to gain valuable insights into the parameters that significantly affect the feasibility, which can then be utilized for developing comprehensive policy recommendations.

Once the pre-feasibility study was addressed, to begin with the calculations in the model, the last parameter to include respect project finance were also determined. These parameters are financial factors that play a crucial role in assessing the viability of an investment project. These parameters include various elements related to the project's financial structure, cash flows, costs, and risks. They are used to evaluate the financial feasibility and profitability of the wind farm project. Table 14 compiles the project finance parameters utilized in the execution of the feasibility study.

Table 14. Project finance parameter used in the feasibility study

Parameter	Units	Value
Inflation rate	%	2%
Corporate Income Tax (CIT)	%	25%
Depreciation method	-	Linear
Support scheme	-	CfD
Support Amount	€/MWh	135
Period support scheme	years	15
WACC (Nominal post-tax)	%	6%

The inflation rate for the scenarios in the study was determined based on the average annual increase of the EU-Harmonized consumer price index (HIPC) over the past 20 years, which was 2% (Eurostat, 2022). The current CIT values used were obtained from Spain's CIT rate (KPMG, 2020). The chosen method for depreciation was a straight linear method, as it is commonly used and does not require the use of a depreciation rate. It was decided to be used a Contract for Difference (CfD) as support scheme, since provides the necessary financial incentives, price stability, and long-term revenue certainty that make offshore wind projects attractive and viable in countries that are starting to adopt this technology (Osterd, 2021). The support amount for this CfD was selected to align with the average electricity production price over the past 15 years (135 €/MWh), and a support period of 15 years was assumed for the provision of this support amount. Lastly, the WACC used for calculations was estimated using onshore wind farms as a reference and adjusted for factors such as support scheme type, technology maturity, and CIT (CE, 2020; AURES II, 2021).

Before running the modelling tool and commencing the calculations, it was essential to establish the projected electricity prices as the final parameter. Two projection scenarios with high and low electricity prices were utilized for the feasibility study. Figure 25 presents the anticipated price trends throughout the technical lifespan of the wind farms.

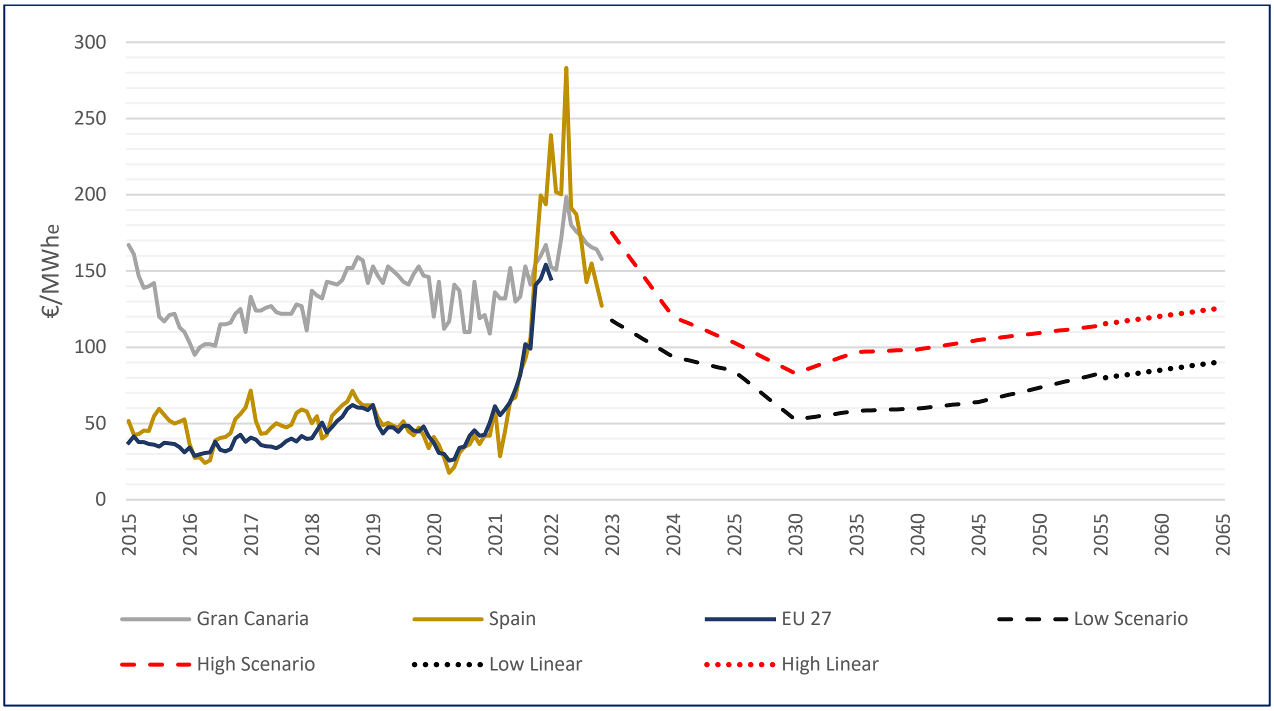

Figure 25. Evolution of electricity price and representation of the two scenario projections. Own figure based on (ENTSO-E, 2022) and (Energy Brainpool, 2022)

The scenarios for electricity prices were determined by referencing the *EU Energy Outlook to 2060*, as published by Energy Brainpool (2022). This report provides insights into the development of electricity prices for the EU 27, including Norway, Switzerland, and the UK. Additionally, historical prices from Gran Canaria and Spain were incorporated to observe the costliness of electricity production on Gran Canaria compared to Spain and the EU27.

In the coming years, electricity prices will be affected by the existing high prices, which are expected to gradually decrease until 2030. According to the outlook, starting from 2030, the rising prices of CO2 and the growing demand for electricity will have an increasing impact on power prices. However, the continuous increase in RE feed-ins will mitigate this trend, as stated in the Energy Brainpool report (2022).

After defining all the parameters, they were incorporated into the modelling tool, and the outcomes are presented in the subsequent section.

6.4.1. Economic calculations

The outcomes derived from the modelling tool are displayed in Table 15. The table presents the results in four scenarios, taking into account the absence (Zero-subsidy) or presence of the support scheme (CfD) and the assumption of low or high electricity prices. The results encompass the LCOE, as well as the NPV for both investors/developers (NPV-D) and for the government/society (NPV-G). The NPV-G represents the expenditures associated to the economic support provided by the government and the income received through taxation.

Table 15. Economic outcomes of every scenario obtained from the modelling tool, depicted in terms of LCOE and NPV. The results are presented in nominal post-tax

	Zero-Subsidy						Contract for Difference					
	Low Price			High Price			Low Price			High Price		
	LCOE	NPV-D	NPV-G	LCOE	NPV-D	NPV-G	LCOE	NPV-D	NPV-G	LCOE	NPV-D	NPV-G
Park 1	82.3	-79.67	4.6	91.46	23.14	38.87	96.99	85.18	-122.24	99.21	110.04	-28.82
Park 2	79.96	-56.43	7.58	89.33	37.09	38.75	94.35	87.2	-96.77	96.49	108.56	-13.68
Park 3	81.16	-88.9	13.19	90.62	67.24	65.24	95.23	143.29	-146.03	97.31	177.68	-11.07
Park 4	78.67	-57.58	16.92	88.12	81.09	63.14	92.42	144.29	-113.76	94.48	174.51	2.2
Park 5	76.97	-34.81	19.19	86.35	87.86	60.08	90.33	139.79	-87.44	92.39	166.77	11.51
Park 6	75.33	-15.64	21	84.64	82.72	57.12	88.21	134.24r	-65.25	90.31	18.65	18.91
Park 7	72.13	3.13	12.88	81.36	54.58	30.03	84.5	72.12	-24.44	86.61	83.87	14.07
TOTAL	-	**-329.9**	**95.36**	-	**433.72**	**353.23**	-	806.11	-655.93	-	840.08	-6.88

As an initial observation, all four scenarios demonstrate LCOE figures that are below the threshold of 100 €/MWh. At this time, LCOE estimates for floating offshore wind projects ranged from around €120-150/MWh. However, according to the NREL (2022) Floating wind technology development will enable the LCOE to drop below 100€/MWh by 2025 and reach the 60€/MWh by 2040. Therefore, the results obtained seems to follow this trend.

From the business economic perspective, the least favourable scenario would be the zero-subsidy option with low prices, as it only generates positive revenues for the government, while all projects except Park 7 show negative NPVs. In this scenario would imply that the project is not expected to generate enough profits to compensate for the costs and risks associated with it. In such cases, investors may choose to reconsider or reject the investment opportunity.

On the other hand, the most favourable scenario would be the zero-subsidy option with high prices, as it generates positive NPVs for both developers and the government. However, this would result in higher prices for the population, with an average price of around 110 €/MWh in the pool market for the 2030-2065 period. In this scenario, although the developers' NPVs are positive, they may appear relatively low, with profits of approximately 2.5 M€ per year.

Alternatively, by implementing a CfD with a strike price of 135 €/MWh over a 15-year period in the high price scenario, the developers' profits would double, while the cost for the government would be around 7 M€. Contrariwise, in the low price scenario (average price of 75.7 €/MWh for the 2030-2065 period), it would entail a significant cost of 656 M€ for the government, since it has to compensate all those period that the market price is bellow the strike price agreed in the CfD.

Based on the results, government intervention is crucial to ensure the profitability of offshore wind as a viable alternative for achieving their energy system goals. In the following part of the research will focus on evaluating the CfD-Low price scenario, as it is the scenario that has the most adverse impact on the government. The objective is to determine whether the government can offset this cost by incorporating socio-economic value.

6.4.2. Socio-economic value effect

In accordance with Section 5.3.3, if a specific situation is considered advantageous for society but not necessarily for business, it should be discussed within the democratic arena. Hence, this section examines whether the CfD-Low price scenario, which yields the most unfavourable outcomes for the government, can generate socio-economic benefits by incorporating CO2 reduction and employment. Consequently, it could provide a response to sub-question 3.

In order to accomplish this, the values derived from the pre-liminary feasibility study (see Section 6.3) were incorporated into the economic calculations and appropriately adjusted to align with the discount factor employed in the analysis. The progression of the NPV for the CfD-Low price scenario, considering the inclusion of these socio-economic externalities, is illustrated in Figure 26 presented hereafter.

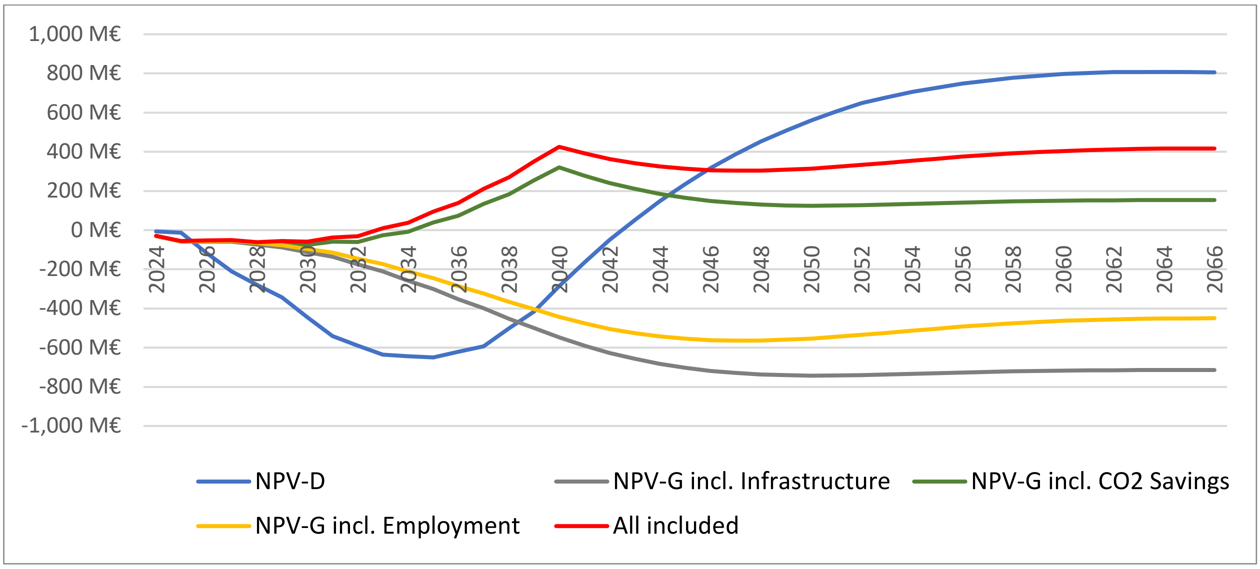

Figure 26. Developments of NPV in CfD-Low price scenario from the business and socio-economic perspectives. Own figure

It is important to emphasize that the depicted figure includes an NPV that incorporates the expenses associated with port upgrading (referred to as NPV-G incl. Infrastructure). This is necessary because the results obtained in Section 6.4.1 do not account for these specific costs, as the modelling tool does not allow for the inclusion of external costs associated with the government. Consequently, an amount of -714.2 M€ NPV is considered by including the expenses associated with the port upgrades.

As shown in the figure, the inclusion of employment generated in this scenario could result in savings from subsidies for unemployment, potentially amounting to 264.1 M€. However, this alone would not be sufficient to achieve a positive NPV for the government. Nevertheless, incorporating the savings from carbon permits generated through the integration of offshore wind into the power generation system would result in a positive NPV of 153 M€, while also contributing to the reduction of greenhouse gas emissions by 12,883.62 ktCO2eq until 2040.

By considering the incorporation of both employment and CO2 savings, as indicated by the red line in the figure, it could lead to an NPV of 417.3 €/MWh. This demonstrates how the combined impact of these two external factors, which hold significance for the government's goals (carbon neutrality and reduce unemployment), can justify the substantial economic support required for implementing offshore wind in one of the most challenging scenarios evaluated (CfD-Low price).

6.4.3. Sensitivity analysis

Sensitivity analyses assist in identifying the most significant factors or variables in a policy analysis. By systematically varying these factors within a defined range, decision-makers can understand which parameters have the greatest impact on the outcomes. In the context of policy-making, the parameters selected for the sensitivity analysis specifically relate to project financing, as they hold particular relevance for evaluation. Consequently, based on the results it can help to prioritize resources and focus attention on the most critical areas. Table 16 presents the different parameters chosen for the conduction of the sensitivity analysis and the values employed for determining the degree of sensitivity.

Table 16. Overview of parameters for sensitivity analysis with the respective value variations

Parameter	Units	Ref Value	Lower Value	Higher Value
Corporate Income Tax (CIT)	%	25%	15%	30%
Support Amount	€/MWh	135	120	150
Period support scheme	years	15	5	25
WACC (Nominal post-tax)	%	6%	4%	8%

A decision was made to utilize a range of 15-30% for the CIT rate, with the current value in Spain set at 25%. This range could encompass the CIT rates observed across Europe, with the lowest rate found in Ireland at 12.5% and the highest rate in Germany at 29.9% (Bray, 2023). In terms of the support amount for the CfD, a range of ± 15 €/MWh was employed. The variation for the support duration was ± 10 years, taking into account the assumed technical lifetime of the wind farms, which was set at 25 years. Additionally, the WACC was subject to a variation of ± 2%. This is because a WACC of 4% is considered the average for onshore wind projects in Spain, making it relevant for comparison as Spain is a mature market for this technology and has one of the lowest WACC rates in Europe (AURES II, 2021).

The sensitivity of the economic parameters for the scenarios CfD-Low price distinguished between NPV-D and NPV-G is shown in Figure 27 below.

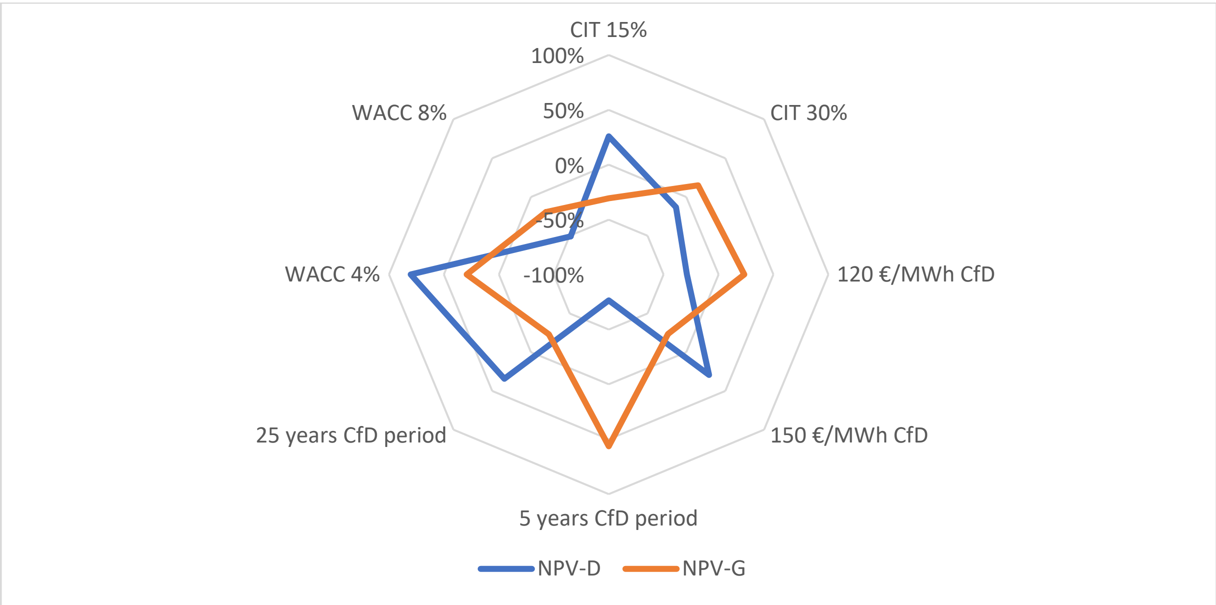

Figure 27. Result for the sensitivity analysis of the economic parameters for the scenarios CfD-Low price distinguished between NPV-D and NPV-G. Own figure

As depicted in Figure 27, various outcomes are evident, with the most notable impacts observed for NPV-D and NPV-G resulting from the WACC of 4%. This particular variation in the parameter leads to an 80% increase in NPV-D and a 29% increase in NPV-G. It is worth noting that this is the sole parameter variation that enables positive NPV for both the developers and the government. On the other hand, increasing the WACC to 8% would drastically impact for the both NPV values.

Regarding the CIT, lowering it to 15% would positively impact the developer, resulting in a 26% increase in revenue. However, this would lead to a -30% impact on the government, increasing its expenditure to 855.3 M€. Conversely, raising the CIT to 30% would increase NPV-G by 15%, reducing the cost to 557.8 M€, while NPV-D would only decrease by 13% in this scenario.

Similar outcomes can be observed when altering the values of the CfD support scheme. Reducing the amount from 135 €/MWh to 120 €/MWh would result in a 23% increase in NPV-G and a 29% decrease in NPV-D. Conversely, increasing the amount from 135 €/MWh to 150 €/MWh would lead to a 29% increase in NPV-D and a 23% decrease in NPV-G. It is important to note that these changes have a proportional impact on the outcomes. However, when varying the period of the support scheme by 10 years, the results differ more significantly. In a scenario with a support period of 5 years, NPV-G would increase by 56%, which significantly reduces the government expenditure from the reference value of 655.9 M€ to 285.7 M€. However, this would have a considerable negative impact of -77% on NPV-D, although it would still maintain a positive NPV of 188.9 M€. Lastly, by extending the period to the entire technical lifetime of 25 years, NPV-D would increase by 34% and NPV-G would decrease by 23%.

In conclusion, a lower WACC would have a positive impact for both the developer and the government, it is therefore to consider this parameter as relevant to design effective policies that can enable the reduction of the WACC. Additionally, increasing the CIT and reducing the CfD period could be viable options to enhance NPV-G without significantly impacting NPV-D. For example, instead of a 5-year CfD period, extending it to 10 years could be considered. These aspects were taken into account during the development of Section 6.5, where policy recommendations were formulated.

6.5. Policy recommendations

This section aims to address the sub-question 4 by providing policy recommendations in order to promote offshore wind in the region of Canary Island. To provide effective policy recommendations, it is essential to acknowledge the barriers that hinder the progress of offshore wind deployment. However, it is important to note that the policy recommendations outlined in this project do not delve into extensive detail. Such an effort would require a comprehensive analysis of the Spanish taxation system, different institutional structures, strategic collaboration with the regulatory institutions, among other factors. Instead, the policies presented here concentrate on the key elements necessary for an ambitious offshore wind policy. These elements aim to support employment and local industry development, reduce greenhouse gas emissions in alignment with the 2040 carbon neutrality goal, and ensure profitability for developers and investors.

6.5.1. Examination of barriers and requests

Based on the attended conferences and the analysis of the notes extracted in these conferences (See Appendix II: Conference notes), several barriers have been identified and can be addressed. Table 17 gathers these barriers as identified by the stakeholders, while also outlining the requirements perceived by each stakeholder for the successful deployment of offshore wind.

Table 17. Barriers and request identified form the stakeholders

Stakeholder group	Barriers	Requests
Regulatory institutions	- Unclear targets - Lack of knowledge and expertise sharing - Lack of strategies to enhance the necessary supply chain	- Set clear RE and Industrial targets - Non-criteria auctions - Reindustrialization - Collaboration and partnership
Developers	- Lack of predictability and transparency - Lack of a robust and reliable supply chain - Slow administrative and permitting process - Lack of access to finance - Lack of suitable port infrastructure - Lack of maturity among suppliers - Lack of access to grid connection - Lack of local engagement	- Support mechanisms - Improve market visibility - Streamline permitting process - Facilitated access to grid connection - Enable port infrastructure development - Engage local authorities - Reindustrialization - Collaboration and partnership
Suppliers	- Lack of predictability and transparency - Lack of skilled workers - Slow administrative and permitting process - Lack of access to finance - Lack of suitable port infrastructure - Lack of local engagement	- Support mechanisms - Improve market visibility - Streamline permitting process - Enable port infrastructure development - Engage local authorities - Reindustrialization - Collaboration and partnership
Lobbyist	- Lack of local industry - Lack of predictability and transparency - Lack of stakeholder engagement - Lack of access to finance - Lack of suitable port infrastructure - Lack of local engagement	- Non-criteria auctions - Reindustrialization - Collaboration and partnership - Support mechanisms - Improve market visibility - Enable port infrastructure development - Engage local authorities
Academia	- Unclear targets - Lack of knowledge and expertise sharing - Lack of strategies - Lack of predictability and transparency	- Set clear RE and Industrial targets - Reindustrialization - Collaboration and partnership - Improve market visibility

As presented in Table 17, stakeholders concur on various barriers that impede the efficient deployment of offshore wind energy. One key concern highlighted by all stakeholders is the insufficient collaboration and engagement among the different actors involved in offshore wind development. The stakeholders recognize that establishing strong interconnections would enable the exchange of knowledge, expertise, and best practices. This sharing of information would empower companies to learn from one another, identify innovative solutions, and implement industry-wide advancements. This could be also link with one of the barriers that most of the stakeholders hold, which is the lack of predictability and transparency.

Investors typically prioritize stability and clarity in market conditions and regulatory frameworks before making significant financial commitments to projects. When the policy environment is characterized by constant changes or lacks clear direction, investors may hesitate to invest as they cannot accurately assess the risks and potential returns. To foster investor confidence, it is crucial to establish a clear and consistent policy framework and a stable regulatory environment that facilitate long-term planning and investment, i.e. Predictability. However, challenges arise when electricity market prices fluctuate and uncertainties surround future energy demand. These factors make it difficult for investors to accurately project revenue streams and project profitability. The feasibility study conducted in this report (refer to Section 6.4) demonstrates the impact of such challenges. To mitigate these risks and attract investors, it becomes essential to provide support schemes and financial incentives that help minimize risk, but the availability and terms of such agreements should not be affected by evolving nature of energy policies.

In this report was assessed the implementation of CfD as support mechanisms to mitigate the investment risk of the inversion for the developers, assuming a massive cost for the government. However, this cost can be offset by considering the socio-economic benefits. Additional types of support schemes and financial incentives can be further analysed and optimized. Nevertheless, based on this analysis, it is evident that government intervention is crucial for the successful deployment of offshore wind in a new market.

Another barrier identified is the lengthy and complex administrative and permitting process, which can have an impact on investment decision-making. Offshore wind projects are subject to various assessments to ensure compliance with regulations and minimize potential negative impacts on the environment and energy system. These assessments include environmental impact assessments, cumulative assessments, navigation and maritime safety assessments, and grid connection assessments. Carrying out these comprehensive assessments requires time and coordination among multiple stakeholders, as highlighted in Section 6.1 of the report. To facilitate investment and project development, it is crucial to simplify and streamline the permitting and approval processes for offshore wind. This can be achieved by developing clear and efficient regulatory frameworks that establish transparent criteria for environmental, technical, and social considerations. By providing a clear roadmap and guidelines, the process can be accelerated while still ensuring proper assessments and meaningful stakeholder engagement.

Insufficient access to infrastructure is a significant obstacle identified by stakeholders. This includes the need for suitable port infrastructure and access to grid connections. Upgrading ports to accommodate offshore wind projects entails substantial investment costs, as discussed in Section 6.3.2 of the report. The relatively short construction phase of offshore wind projects may not sufficiently justify these expenses. Ensuring the availability of well-equipped ports is crucial. To achieve this, the government can encourage local industries to capitalize on the new infrastructure and expand their operations. Appendix II includes insights from port authorities experienced in offshore wind, who highlight the importance of the next 2-3 years for investment. The utilization of existing infrastructure by emerging businesses, such as hydrogen production, will intensify competition. The government plays a vital role in engaging OEMs and collaborating with local port authorities to find mutually beneficial solutions that meet technical requirements. By doing so, both parties can mitigate investment risks and leverage opportunities.

Non-criteria auctions, as requested by regulatory institutions and lobbyists, have the potential to bring numerous advantages to offshore wind deployment and make positive contributions to the local socio-economy. These auctions can facilitate the development of specific regions with untapped offshore wind potential, leading to economic growth, job creation, and improved infrastructure in those areas. To achieve these outcomes, it is essential to include requirements related to local content, job opportunities, supply chain development, and community engagement. Non-criteria auctions offer the flexibility to integrate such criteria, incentivizing developers to prioritize socio-economic factors in their projects. However, there are concerns among developers and suppliers that incorporating these criteria could result in more delays during the permitting process. Therefore, it is crucial to ensure that these requirements do not place excessive administrative or managerial burdens on market participants. In the initial years, non-price criteria auctions should play a significant role in meeting the needs of the value chain in Gran Canaria.

In summary, addressing these barriers identified in Table 17, the offshore wind sector necessitates a comprehensive approach that involves supportive policies, partnerships between public and private entities, innovative financing methods, and strategies to mitigate risks. Key measures to address these barriers should include offering specific financial incentives, creating dedicated funds, fostering collaboration among industry stakeholders, and promoting the use of standardized contracts and procurement frameworks. By implementing these measures, access to finance can be improved, and the growth of offshore wind in the region can be facilitated. In the following Section 6.5.2, a set of policy recommendations, that encompass the factors examined in this section, are presented.

6.5.2. List of Policy Recommendations

This section provides policy recommendations that include the factors analysed in section 6.5.1.

I. **Set clear RE targets:** Set clear and ambitious long-term targets for RE, including specific goals for offshore wind capacity. This will provide a transparent and predictable environment for developers, investors, and the market, encouraging increased investment and the advancement of offshore wind projects.

II. **Promote stakeholder engagement and establish regional cooperation:** Promote meaningful involvement of local communities, fishing industries, environmental organizations, and other relevant stakeholders to address their concerns, foster open and transparent communication, and enhance social acceptance of offshore wind projects. Moreover, foster regional cooperation and collaboration among neighbouring regions to share best practices, coordinate grid connections, and harmonize regulatory frameworks.

III. **Implement support mechanisms and financial Incentive:** Implement a range of support mechanisms, including the CfD model explored in this study, as well as other options such as Feed-in Tariffs (FiTs) or RE Certificates (RECs), to ensure stable and predictable revenue streams for offshore wind projects. Furthermore, offer financial incentives such as grants, tax credits, and low-interest loans to encourage project development and attract private investments in offshore wind. These diverse mechanisms effectively incentivize investment and mitigate the financial risks associated with the development of offshore wind projects.

IV. **Streamline permitting processes:** Simplify and streamline the approval and permitting procedures for offshore wind projects by establishing clear and efficient regulatory frameworks. These frameworks should outline the necessary environmental, technical, and social criteria to expedite project development while ensuring thorough assessments and meaningful stakeholder engagement.

V. **Facilitate grid connection and foster the development of power storage technologies**: Improve the process of connecting offshore wind projects to the grid by offering transparent guidelines, technical support, and prioritized access to the grid infrastructure, requiring the participation with the TSO REE.

This will facilitate the seamless integration of offshore wind energy into the current grid system. Additionally, implement various strategies and initiatives to encourage the development, deployment, and adoption of power storage technologies that can facilitate the penetration of offshore wind in the energy system.

VI. **Enable infrastructure development**: Promote the growth of port facilities and necessary infrastructure to facilitate the production, assembly, and maintenance of offshore wind components. This encompasses ensuring adequate land availability, fostering collaboration among relevant parties, and offering financial incentives, such as funding programs to expand port infrastructure. Additionally, allocating funds to establish specialized companies within the offshore wind sector will help develop a strong and reliable supply chain.

VII. **Enhance market visibility:** Establish strategies to improve market visibility and minimize obstacles in the industry, for example, by introducing dedicated auctions tailored specifically for offshore wind projects. These auctions would encourage price competition among participants and stimulate the expansion of the market.

VIII. **Implementation on non-criteria price auctions:** Implement non-criteria price auctions with the objective to incentive developers to prioritize socio-economic factors in their projects. These auctions must include requirements related to local content, job opportunities, supply chain development, and community engagement. Furthermore, these auctions should be designed in a way that avoids imposing excessive administrative or managerial burdens on market participants.

IX. **Training programs to promote offshore wind employment and generate local skilled workers:** Foster employment opportunities in the offshore wind sector and cultivate a pool of skilled workers within local communities. These programs must address the need for skilled labour within the offshore wind industry, which requires expertise in areas such as turbine installation, maintenance, electrical engineering, and project development. This helps in promoting socio-economic growth and reducing unemployment rates in those areas.

X. **Encourage Research and Development**: Encourage partnerships and cooperation among academia, industry, and government agencies to stimulate innovation in floating wind technology and reduce costs within the sector.

XI. **Ensure a stable regulatory environment:** Government must foster a stable regulatory environment that promotes investment, encourages innovation, and supports the sustainable growth of local industries. Implementing clear and transparent regulations is essential to provide a stable foundation for businesses and investors. Moreover, government should strive for a long-term perspective in their regulatory approach, providing stability and predictability for industry players. When regulations change unexpectedly, it can undermine the financial viability of projects and erode investor confidence.

7. Discussion

This chapter offers a thorough examination and interpretation of the acquired findings, as well as an exploration of the applicability of the case study results to other cases. The focus is on discussing the findings in relation to addressing the research question: *To which extent can offshore wind be a socio-economically feasible alternative while contributing to the Canary Islands' goal of carbon neutrality by 2040 and if so, how can be politically* *promoted?* To answer this main research question, the chapter addresses four sub-questions that play a significant role.

Prior to diving into how the sub-questions were answered, a research design was formulated. This design facilitates the answering of the research question and incorporates various theories and analyses. A summary of how these theories and analyses are combined to address the research question is depicted in Figure 28.

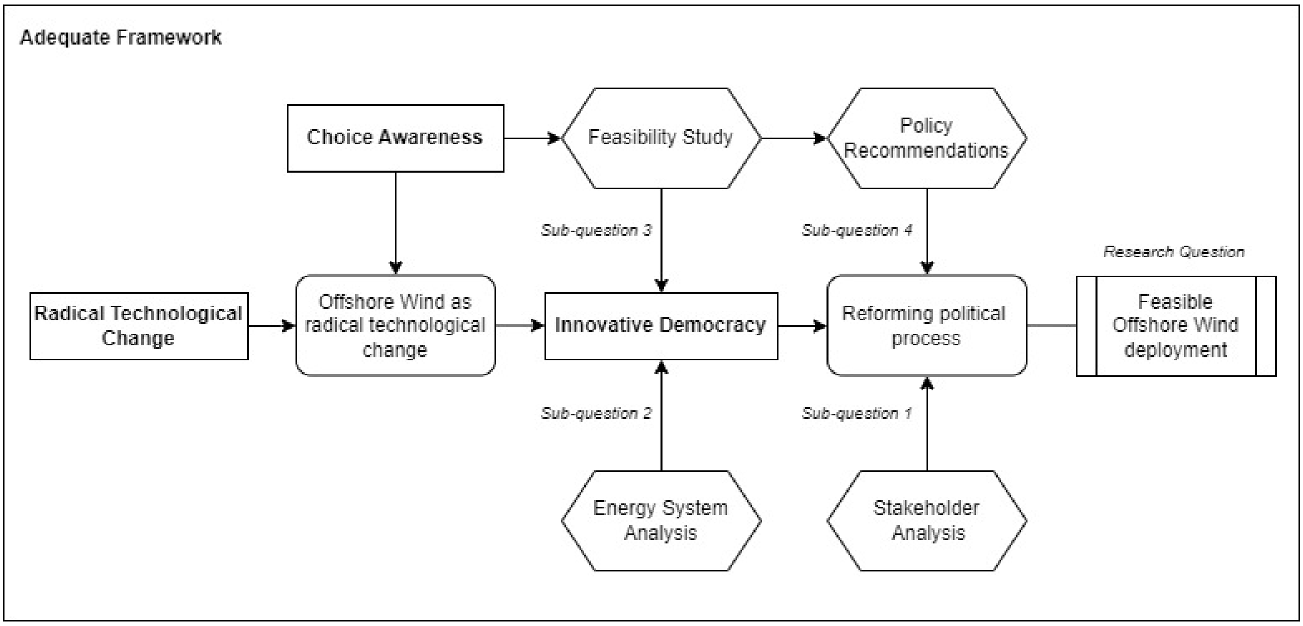

Figure 28. Summary of the interrelationship and impact between theories and analysis. Own figure

It is important to note that the figure should not be interpreted as a linear system, but rather as a representation of how the analysis and theories were utilized to ultimately arrive at a conclusion or solution.

The utilization of the Radical Technological Change theory can define the transition of the energy system from fossil fuels to RE. Specifically, the introduction of an innovative technology like offshore wind leads to a radical technology change in the system. The Choice Awareness theory suggests a strategy when implementing a technological change, which involves the use of feasibility study to determine the feasibility of the new technology and the recommendation of policies to promote this one.

When aiming to implement a radical technology change, the Innovative Democracy theory can be employed to comprehend how societal changes can occur and be facilitated through the reforming of the political process. By the utilization of Energy System Analysis in combination with the Feasibility Study, valuable knowledge can be obtained regarding the required reformation to the current markets to ensure the feasibility of the new technology in the given application context. This analysis facilitates the identification of organizational levels where the change needs to occur and allows for the formulation of policy recommendations. The stakeholder analysis gives knowledge of which actors have the power and importance to promote the technological change.

This summary enables for a better understanding of the approach utilized for addressing the research question. Every analysis included in this report was assumed to give an answer to every sub-question as the Figure 28 illustrate. The following part outlines the results of the analyses answering every sub-questions.

7.1. Sub-question 1

Sub-question 1 pertains to the identification of key stakeholders involved and their impact on the implementation of offshore wind energy projects in the Canary Islands. To address this, a stakeholder analysis was employed.

The adoption of an Adequate Framework allowed for a comprehensive representation of the interacting forces and a clear understanding of the essential inputs and outputs crucial for the deployment of offshore wind in Spain. This framework was instrumental in identifying potential stakeholders who could play significant roles and should be considered in the research. These stakeholders were categorized into Regulatory Institutions, Offshore Wind Developers, Suppliers and Infrastructure stakeholders, Lobbyists, and Academia.

Once the relevant stakeholders were identified, a Power-Importance Graph was employed to examine the allocation of power (influence) and importance (stake) among them concerning the development of offshore wind in Gran Canaria. Notably, the analysis revealed that changes in infrastructure developments related to offshore wind, involving entities such as the Spanish Transmission System Operator (REE) and Port authorities, have the potential to impact all offshore wind pathways. These entities hold significant importance, but their actions are regulated by appropriate institutions. Hence, both regulatory institutions and infrastructure stakeholders can exert a major influence on the deployment of offshore wind in the region. The findings from the stakeholder analysis were utilized to inform the formulation of policy recommendations in response to sub-question 4.

It is important to note that this research solely employed a power-importance grid approach, which may not encompass all aspects of each stakeholder, as not all dynamics revolve solely around power-interest relationships. Considering the specific context, objectives, and available resources of the project or study, it is crucial to select the most appropriate stakeholder analysis approach. Each approach offers distinct perspectives and insights into stakeholder dynamics and can aid in effective stakeholder engagement and management strategies. For instance, a network analysis approach could be relevant for this project as it focuses on mapping relationships and interactions among stakeholders, identifying key actors, central nodes, and communication patterns within the network. Such an analysis would help identify influential stakeholders and potential alliances or collaborations, thereby assisting in policy-making (Mok and Shen, 2016).

7.2. Sub-question 2

To address sub-question 2, which focuses on the current technical and political environment of offshore wind energy in the Canary Islands and its potential contribution to achieving carbon neutrality by 2040, an energy system analysis was conducted.

The energy system analysis conducted in this study aimed to examine the current state of the regional electric energy system and assess the potential integration of offshore wind within the designated time horizon of 2040, therefore it was split into two parts.

Firstly, to understand the present condition of the energy system, publicly available data sources were utilized to describe its components and characteristics. This understanding was crucial for providing context to the reader and evaluating the impacts of introducing offshore wind, a component with low deployment in the system. The findings revealed that RE accounted for only 20% of the total installed capacity for power generation in Gran Canaria, with offshore wind energy contributing a mere 5 MW. This indicated a lack of substantial deployment of offshore wind in the region.

Secondly, to assess the potential penetration of offshore wind in Gran Canaria's energy system, the study opted to analyse the strategies and plans proposed by the government of the Canary Islands instead of employing a quantitative analysis. This examination aimed to identify potential opportunities associated with offshore wind. Based on the timeframe of the study, it was projected that additional power capacity of approximately 100 MW by 2030 and 870 MW by 2040, categorized as Category A generators, would be required in the future energy system. To address this, the government and the Instituto Tecnológico de Canarias proposed Category A alternative solutions that would maintain the existing supply's safety standards. Considering the most conservative alternative to offshore wind, the analysis determined that potential offshore wind power installations could reach 200 MW by 2030 and 1,090 MW by 2040.

The energy system analysis approach employed in this study did not incorporate quantitative analysis, but it is worth noting that incorporating quantitative data and modelling the energy system could provide valuable insights into potential project trends and alternative evaluations. Additionally, a quantitative analysis would allow for the assessment of the feasibility of the offshore wind alternative in comparison to other power units and storage options in the electrical system. It is important to ensure that the quality and reliability of the power supply are maintained at satisfactory levels. For future studies, considering the validation and viability of the alternatives provided by the Instituto Tecnológico de Canarias is crucial, and incorporating quantitative analysis can enhance the evaluation process (Ahmadi, Saboohi and Vakili, 2021).

7.3. Sub-question 3

Sub-question 3 inquires whether implementing offshore wind as a power generation alternative is both feasible and capable of providing regional socio-economic benefits. To address this, a feasibility study was conducted. The primary objective of conducting such a study is to assess the practicality and viability of a specific solution in solving a particular problem, taking into account both business and socio-economic factors under current circumstances. Consequently, it was deemed appropriate to address sub-question 3. The analytical approach employed in this report is based on Hvelplund and Lund's (1998) theory of Feasibility Studies. This approach is particularly crucial in situations involving radical technological change, as it allows for the evaluation of the feasibility of alternative technical options through comprehensive assessments of their social, environmental, and economic implications.

According to Hvelplund's approach, one of the steps in conducting a Feasibility Study involves using a Diamond-E method. However, in this case, the Diamond-E method was replaced with a pre-feasibility study. The pre-feasibility study focuses on four key aspects that provide guidance for designing the feasibility study and serve as the main inputs for its execution. These areas include offshore wind evolution, cost of offshore wind deployment, CO2 savings, and employment.

The offshore wind evolution section of the study aimed to propose a scenario for deploying offshore wind to meet the identified needs in the energy system analysis. It was found that a total of 2 GW of offshore wind projects are currently under development, undergoing environmental processing, and awaiting the first auctions in Gran Canaria. This significant figure demonstrates the favourable prospects for initiating offshore wind projects and the necessity of designing an auction system. Considering the range of capacities observed in the identified projects, which range from 50 to 200 MW, the research suggested an offshore wind deployment evolution that aligns with these capacity ranges and is used in the feasibility study. A total of seven wind farms were proposed for the specified time horizon, with a combined capacity of 1,095 MW. Although various evolutions of offshore wind deployment can be proposed, this study aimed to align the progression with the most realistic approach, as the energy system cannot accommodate massive capacities in the short term, particularly involving floating wind technologies.

The section on the Cost of offshore wind deployment presented an estimation of the cost breakdown for constructing the seven wind farms proposed in the study, along with the underlying assumptions used in the analysis. The technical assumptions were derived from a literature review. The cost estimation relied on the Guide to an offshore wind farm developed by BVG (2019) and previous research conducted by the author Aguilera (2023), which provided valuable cost indicators for this analysis. Based on the cost values, the total investment cost is estimated to be 2.85 B€, which translates to approximately 2.6 M€ per MW installed. These values were adjusted by applying a cost reduction factor of 2%. Additionally, the costs associated with upgrading the port infrastructure were considered, assuming an investment cost of 100 M€. It should be emphasized that the provided cost breakdown is an approximation, and a more precise approach should be adopted. To achieve this, conducting interviews with offshore wind developers would be beneficial in obtaining more accurate cost indicators.

The CO2 savings section aims to estimate the potential reduction in GHG emissions that can be achieved through the integration of offshore wind. To accomplish this, emission factors were utilized for each power unit, enabling the estimation of CO2eq emissions from power generation based on the projected capacity. Additionally, the future savings in EU carbon permits were calculated by estimating the amount of GHG emissions that would be released if a conventional thermal power plant were to generate the same amount of electricity as the proposed offshore wind capacity. The results indicate that, over the specified time period, a total savings of 12,883.62 ktCO2eq can be achieved. These savings equate to a significant value of 1.78 M€ in EU Carbon Permits. It is important to note that these findings rely on assumptions about projected average CO2 prices in the ETS. However, since this is a projection, variations in these values can significantly impact the outcome. The sensitivity analysis conducted in this study did not include this aspect as a parameter for evaluation, but it is recommended to determine the degree of uncertainty.

The employment section of the study focuses on estimating the potential job opportunities that would arise from the integration of offshore wind energy. The assessment takes into account both direct and indirect employment and evaluates the workforce in terms of FTE positions per unit of installed capacity, measured in GW. The employment data used in this analysis are derived from various reports, and the employment rates utilized represent the average values found in those reports, covering the construction phase, operational phase, and indirect employment prospects. Based on the findings, it is projected that there will be a peak of 5,724 FTE jobs in the year 2035. Specifically, approximately 1,717 FTE jobs could potentially be created in Gran Canaria. This could result in substantial savings of around 300 M€ in unemployment subsidies that the government would otherwise have to provide. It is crucial for the government to recognize the significant employment potential associated with offshore wind energy. However, the generation of employment through offshore wind power at the local level will ultimately rely on government initiatives.

Assessing new employment opportunities in the offshore wind sector is challenging due to factors such as limited historical data, the complexity of the value chain, the need for multi-disciplinary skills, regional variations, and continuous technological advancements. To obtain more reliable results, it would be necessary to employ surveys or conduct interviews with relevant stakeholders, including employees, employers, and industry experts. These methods can provide valuable insights into employment patterns and contribute to more accurate assessments (Knol and Coolen, 2019).

The four sections of the pre-feasibility study address certain considerations that serve as input for the feasibility study and ultimately pave the way for the final step, which is conducting the feasibility study. The initial phase involved assessing the economic aspects of the proposed offshore wind project through economic calculations, utilizing a discounted cash flow model specified in a report by Aguilera (2023). Additionally, parameters for project finance were defined, encompassing various elements associated with the project's financial structure, cash flows, costs, and risks. Another crucial aspect was establishing the anticipated electricity prices as the ultimate parameter for evaluating the feasibility of the proposed wind farm. This evaluation was conducted against two projection scenarios representing high and low electricity prices.

From a business economic perspective, the results were presented in four scenarios, considering the presence or absence of a support scheme (CfD) and assuming either low or high electricity prices. Among these scenarios, the least favourable for the government was identified as the CfD-low price scenario, which would result in a significant cost of 656 M€ for the government. Consequently, this particular scenario was evaluated from a socio-economic perspective, taking into account both employment and CO2 savings. By considering the incorporation of employment and CO2 savings (represented by the red line in the figure), the evaluation indicated that this scenario could lead to a positive NPV of 417.3 €/MWh. This demonstrates how the combined impact of these two external factors, which hold significant importance for the government's objectives of achieving carbon neutrality and reducing unemployment, can provide justification for the substantial economic support required to implement offshore wind in one of the most challenging scenarios assessed (CfD-Low price).

It is worth noting that the evaluation did not consider the cost borne by the government to bridge the gap between the pool price and the actual cost of electricity production in the Canary Islands. The genuine cost of electricity generated from the hydrocarbon-fired thermal power plant in Gran Canaria varies between 100 and 200 €/MWh, depending on oil prices. Historically, the pool price in Gran Canaria has ranged from approximately €20 to €80/MWh (currently higher due to elevated prices in Europe) as it artificially mirrors the pool price on the mainland. The disparity between the pool price and the real cost of electricity generation in the Canary Islands is compensated through a system of subsidies that amount to around 600 and 1,000 M€ annually. In this context, floating offshore wind power can compete with thermal energy in terms of costs, without considering the socio-economic factors outlined in the study (ISTAC, 2022; Statista, 2023a).

Lastly, as recommended by Hvelplund (1998), it is advisable to conduct a sensitivity analysis to account for the inherent uncertainties that arise during long-term feasibility studies and the reliance on certain assumptions. Performing a sensitivity analysis helps assess the level of uncertainty in the results of the socio-economic model. However, in this analysis, the sensitivity assessment focused on project finance parameters instead of the two socio-economic externalities: CO2 savings and employment. By evaluating project finance parameters, the aim was to identify the most significant factors or variables in policy analysis, which can aid in resource prioritization and focus on critical areas. The results highlighted that a lower WACC would have a positive impact for both the developer and the government. Therefore, considering this parameter becomes relevant for designing effective policies to facilitate WACC reduction.

It is important to note that Hvelplund distinguishes four types of sensitivity analysis based on economic, technical, and social parameters. However, in this report, only economic parameters, specifically project finance parameters, were assessed. Addressing the remaining two types of sensitivity analysis would provide a more comprehensive understanding of uncertainty, particularly concerning the two socio-economic externalities, as they are vital factors in determining the socio-economic feasibility of the studied offshore wind alternative. Nevertheless, due to time constraints in this project, it was not possible to explore different value ranges for CO2 savings and employment. However, it would be valuable to include these ranges by conducting surveys and interviews, as they would enhance the description of uncertainty and provide a more thorough analysis of the two socio-economic externalities.

7.4. Sub-question 4

Sub-question 4 pertains to the question of "Which policies should be considered and established to facilitate this deployment?" In order to tackle this, policy recommendations were provided and discussed. These recommendations aimed to provide guidance on the policies that should be taken into consideration and implemented to support the successful implementation of the deployment.

To formulate policy recommendations, it was crucial to consider the diverse outcomes of stakeholders and sensitivity analysis, as well as analyse the perspectives derived from conference notes. Attending conferences and analysing the extracted notes helped identify several barriers and stakeholder requests for the successful deployment of offshore wind from their respective viewpoints. The evaluation of this information led to the conclusion that the offshore wind sector requires a comprehensive approach encompassing economic support initiatives, innovative financing methods, collaborations and partnerships between public and private entities, and strategies to mitigate uncertainty and risks.

By implementing these measures, there can be an improvement in access to finance and facilitation of offshore wind growth in the region. Based on these findings, a set of policy recommendations was developed:

I. **Set clear RE targets**
II. **Promote stakeholder engagement and establish regional cooperation**
III. **Implement support mechanisms and financial Incentive**
IV. **Streamline permitting processes**
V. **Facilitate grid connection and foster the development of power storage technologies**
VI. **Enable infrastructure development**
VII. **Enhance market visibility**
VIII. **Implementation on non-criteria price auctions**
IX. **Training programs to promote offshore wind employment and generate local skilled workers**
X. **Encourage Research and Development**
XI. **Ensure a stable regulatory environment**

The proposed policies do not delve into extensive details but rather provide general policy concepts that could be adopted by the Canary Islands. The report acknowledges that there is no comprehensive analysis of the specific consequences and impacts of each policy. Policy-making is a complex process that requires considering various factors. The report does not primarily focus on specific policy-making theories and methods but aims to present potential policies that can foster the offshore wind sector in the region and align with the future goals of the Canary Islands. These goals include promoting the growth of offshore wind while simultaneously fostering employment opportunities and supporting the development of local industries. Moreover, by implementing these policies, there is the potential to mitigate risks and create a more favourable investment environment, which could result in a reduction of the WACC and have a positive impact on feasibility, as it was highlighted in the sensitivity analysis.

In formulating these policy recommendations, the report did not include an examination of the current policies adopted by the Canary Government. Instead, it focused solely on analysing regional strategies to assess the potential for offshore wind implementation in the case study of Gran Canaria. The reason for this omission is the time limitations during the research process. Conducting a comprehensive analysis of the political system and interviewing policy-makers would be necessary to align the proposed policy recommendations in this report with the current government's considerations. Further research could delve into a thorough policy analysis to evaluate the proposed policies and assess the impact of more specific policies involving alternative policy methodologies.

7.5. Case Study

In Chapter 4 was addressed the utilization of Gran Canaria as case study to investigate the feasibility and socio-economic impact of implementing offshore wind in the region of Canary Islands. Therefore, the case study aims to explore whether the findings can be generalized to other cases, in this case to the other island of the Canary region. To do so it was provided a framework for analysing the results.

The chapter discusses the appropriateness of using a case study method to examine contemporary problems and addresses concerns about the validity and reliability of case studies. It argues against five common misunderstandings about case studies and emphasizes their value in providing practical knowledge and understanding complex contexts. The chapter also presents four strategies for conducting case studies: critical case, extreme or unique case, cases with maximal variation, and paradigm case. The critical case strategy is applied in this study, focusing on a specific phenomenon in Gran Canaria.

In the chapter was outlined the key characteristics of the critical case context of Gran Canaria: isolated energy system, high unemployment, reliance on tourism, carbon neutrality goals, local industry promotion, designated offshore wind zones, and abundant wind resources.

In order to ensure the applicability of the findings to other instances, such as different Canary Islands, it is important to assess whether these characteristics align with similar contexts facing comparable challenges. Although this study focuses on a specific case, it offers valuable insights that can be relevant to other situations experiencing similar phenomena. However, it is essential to take into account the specific circumstances of each case. For example, while the entire region shares the common objective of achieving carbon neutrality by 2040, the energy systems and available resources for implementing offshore wind may differ among the islands, potentially not matching the conditions of the case study. Despite this, stakeholders could be considered similar, and the policy recommendations outlined in this report, which are broadly based on the requirements at the European level, could also be applicable to other islands in the region that are considering offshore wind as a means to achieve their goals.

8. Conclusion

The report addresses two main problems identified through problem analysis: the high cost of offshore wind deployment in the Canary Islands and the region's high unemployment rates. However, these issues can potentially be resolved by considering a socio-economic perspective. By incorporating offshore wind, the region can contribute to carbon neutrality and generate industrial and employment opportunities. The report's objective is to investigate the socio-economic effects and feasibility of implementing offshore wind in the Canary Islands' energy system, focusing on the following research question:

To which extent can offshore wind be a socio-economically feasible alternative while contributing to the Canary Islands' goal of carbon neutrality by 2040 and if so, how can be politically promoted?

To answer the above-mentioned research question of the report, four sub-questions are formulated that encompass different analytical parts of the research:

1. ***Who are the key stakeholders involved and what impact do they have on the implementation of offshore wind energy projects in the Canary Islands?***
2. ***What is the existing technical and political environment concerning offshore wind energy in the Canary Islands, and how does it hold the potential to make a substantial contribution towards achieving carbon neutrality by 2040?***
3. ***Could this offshore wind contribution be feasible and provide regional socio-economic benefits it is implemented as a power generation alternative?***
4. ***Which policies should be considered and established to facilitate this deployment?***

In order to provide the most suitable response to the research question, a case study was introduced, focusing on Gran Canaria. Additionally, a research design incorporating a theoretical framework and employing various methods was implemented throughout this report.

The report incorporates three theories: the Radical Technological Change theory, Choice Awareness theory, and Innovative Democracy theory. The Radical Technological Change theory focuses on transitioning to RE and highlights the significance of innovative technologies like offshore wind in driving transformative change. The Choice Awareness theory proposes the use of feasibility studies and policy recommendations to facilitate the implementation of new technologies. The Innovative Democracy theory helps in comprehending societal changes through political reforms. The researcher performed an analysis through theories, which enable to define the analytical approach for the research, i.e. clarifying and scoping the research area for the analysis.

The first sub-question was examined by conducting a thorough analysis of stakeholders. The stakeholder analysis identified key stakeholders involved in the implementation of offshore wind energy projects in the Canary Islands. These stakeholders were categorized into regulatory institutions, offshore wind developers, suppliers and infrastructure stakeholders, lobbyists, and academia. Regulatory institutions and infrastructure stakeholders were found to have a significant influence on the deployment of offshore wind in the region.

The second sub-question was tackled through an analysis of the energy system. The energy system analysis examined the current technical and political environment of offshore wind energy in the Canary Islands and its potential contribution to achieving carbon neutrality by 2040. The analysis revealed a lack of substantial deployment of offshore wind in the region, with offshore wind energy contributing only a small portion to the total installed capacity for power generation. However, there were proposed strategies and plans by the government and the Instituto Tecnológico de Canarias to increase offshore wind capacity in the future, aiming to reach a total of 1,090 MW by 2040.

The third sub-question was approached through a feasibility study. The feasibility study assessed the practicality and viability of implementing offshore wind as a power generation alternative proposed by the researcher in the case study of Gran Canaria. The study considered social, environmental, and economic implications using the theory of Feasibility Studies. It evaluated offshore wind evolution, cost of deployment, CO_2 savings, and employment opportunities. The analysis showed favourable prospects for offshore wind projects in the region, with potential CO_2 savings and job creation.

Finally, policy recommendations were developed to address the four sub-questions comprehensively. Policy recommendations were formulated to facilitate the deployment of offshore wind in the Canary Islands. These recommendations included setting clear RE targets, promoting stakeholder engagement and regional cooperation, implementing support mechanisms and financial incentives, streamlining permitting processes, facilitating grid connection and power storage development, enabling infrastructure development, enhancing market visibility, implementing non-criteria price auctions, promoting offshore wind employment through training programs, encouraging research and development, and ensuring a stable regulatory environment.

Since the research question pertains to the Canary Islands region, one of the islands was chosen as a case study, and it was important to discuss the generalizability of the results. The case study focused on highlighting the key characteristics specific to Gran Canaria's context and emphasized the significance of considering similar contexts when applying the findings. While each case may have its own distinct circumstances, the policy recommendations derived from the study s can still hold relevance for other islands in the region that are considering offshore wind as a means to achieve their goals.

Based on the research question, it can be concluded that offshore wind in the Canary Islands, specifically focusing on the case of Gran Canaria, is considered a socio-economically feasible alternative to a certain degree. This alternative aligns with the Canary Islands' objective of achieving carbon neutrality by 2040. The feasibility is attributed to the following factors: substantial reduction in CO_2 emissions, job creation, and the development of industrial activities at regional level. However, the actual degree of these outcomes will significantly depend on the economic and political initiatives taken by the government, as well as the level of engagement and collaboration with stakeholders.

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Appendices

Appendix I: Justification for each assumed cost value

Table 18. Cost justifications for the Park 1 and 2 (Bottom Fixed, 105 MW each)

Category	Value	Justification
DEVEX	14 M€	Assuming 0.143 M€ per MW installed
CAPEX		
Wind Turbines	105 M€	Assuming 15 M€ per 15 MW WTG
IAC Cables	4.52 M€	Assuming 0.216 M€ per km of 66 kW cable installed
FOU Jacket	41.3 M€	Assuming 5.9 M€ per Jacket FOU
Offshore Substation	19.18 M€	Assuming 196 M€ total cost of two OSS, of 500 MW (including export cables) split by the capacity of wind farm
Onshore Substation	0.96 M€	Assuming 9.14 M€ for upgrade onshore substation of 1 GW split by the capacity of wind farm
Operation Base	0.38 M€	Assuming 0.037 M€ per MW installed
Installation	53.55 M€	Assuming 0.52 M€ per MW bottom-fixed installed
OPEX		
Operations	3 M€	Assuming 0.029 M€ per MW installed
Maintenance & Service	6.2 M€	Assuming 0.059 M€ per MW installed
DECEX		
Decommissioning	40.16 M€	Assuming 0.038 M€ per MW installed

Table 19. Cost justifications for the Park 3, 4, 5 and 6 (Floating, 195 MW each)

Category	Value	Justification
DEVEX	28 M€	Assuming 0.143 M€ per MW installed
CAPEX		
Wind Turbines	195 M€	Assuming 15 M€ per 15 MW WTG
IAC Cables	16.31 M€	Assuming 0.377 M€ per km of 66 kW Dynamic cable installed
FOU Floating	130 M€	Assuming 10 M€ per Jacket FOU
Offshore Substation	35.62 M€	Assuming 196 M€ total cost of two OSS, of 500 MW (including export cables) split by the capacity of wind farm
Onshore Substation	1.78 M€	Assuming 9.14 M€ for upgrade onshore substation of 1 GW split by the capacity of wind farm
Operation Base	0.71 M€	Assuming 0.037 M€ per MW installed
Installation	59.67 M€	Assuming 0.306 M€ per MW bottom-fixed installed
OPEX		
Operations	5.7 M€	Assuming 0.029 M€ per MW installed
Maintenance & Service	11.5 M€	Assuming 0.059 M€ per MW installed
DECEX		
Decommissioning	37.05 M€	Assuming 0.019 M€ per Floating MW installed

Table 20. Cost justifications for the Park 7 (Floating, 105 MW)

Category	Value	Justification
DEVEX	14 M€	Assuming 0.143 M€ per MW installed
CAPEX		
Wind Turbines	105 M€	Assuming 15 M€ per 15 MW WTG
IAC Cables	7.23 M€	Assuming 0.377 M€ per km of 66 kW Dynamic cable installed
FOU Jacket	70 M€	Assuming 10 M€ per Jacket FOU
Offshore Substation	19.18 M€	Assuming 196 M€ total cost of two OSS, of 500 MW (including export cables) split by the capacity of wind farm
Onshore Substation	0.96 M€	Assuming 9.14 M€ for upgrade onshore substation of 1 GW split by the capacity of wind farm
Operation Base	0.38 M€	Assuming 0.037 M€ per MW installed
Installation	32.13 M€	Assuming 0.306 M€ per MW bottom-fixed installed
OPEX		
Operations	3 M€	Assuming 0.029 M€ per MW installed
Maintenance & Service	6.2 M€	Assuming 0.059 M€ per MW installed
DECEX		
Decommissioning	19.95 M€	Assuming 0.019 M€ per Floating MW installed

Appendix II: Conference notes

First Conference - Strengthening Europe's Wind Supply Chain

- *Dominant focus on grid infrastructure and electrification and supply chain resilience*
- *Offshore wind deployment requires a robust and reliable supply chain to deliver the necessary equipment, components, and services. By interconnecting net-zero companies and suppliers, there is a greater potential to strengthen and diversify the supply chain. This enhances its resilience, reduces dependence on specific suppliers, and mitigates the risks of disruptions or delays in the delivery of crucial components.*
- *Factors which can strengthen and accelerate wind industry: Permitting, supply chain, grid and electrification*
- *Ambitious national targets necessitate the immediate adaptation and expansion of the supply chain to support the achievement of these targets (German Ministry)*
- *Emphasis for new regulation which sets an optimal framework focusing on the above*
- *The government's role is to engage all the actors within the value chain and cover their needs to ensure and sustain the massive production*
- *EU is prioritizing the decarbonization of the energy system and recognizes that this entails a process of reindustrialization. Many companies have to take significant investment decisions with high risk.*
- *Collaboration and partnership are essential for minimizing risks as they offer predictability to investors.*
- *The visibility of Green Hydrogen can also provide predictability, as its demand is increasing and it will require a significant amount of green energy to meet that demand.*
- *List of the issues for the investors:*
    - *Slow Permitting process. The intricate aspects of offshore wind development, encompassing various regulatory, environmental, and stakeholder factors, result in permitting delays. These delays, characterized by prolonged periods of uncertainty, can significantly impact investment decision-making.*
    - *Access to finance. The offshore wind market can be subject to regulatory changes, policy shifts, and market volatility. Uncertainties regarding future demand, government support, and market dynamics can make lenders and investors hesitant to provide long-term financing for supply chain expansion, as they may perceive higher risks associated with market uncertainties.*
- *Addressing these finance barriers requires a combination of supportive policies, public-private partnerships, innovative financing mechanisms, and de-risking strategies. Measures such as providing targeted financial incentives, establishing dedicated funds, fostering collaboration between industry stakeholders, and promoting standardized contracts and procurement frameworks can help improve access to finance and facilitate the growth of the offshore wind supply chain.*
- *The European Union has established a favourable framework, but it is the responsibility of individual member states to leverage it and develop their own strategies to enhance the necessary supply chain for offshore wind implementation.*
- *Suppliers agree upon the good framework established by the EU, but there is room for improvement.*
- *Knowledge and Expertise Sharing: The interconnection of net-zero companies and suppliers allows for the exchange of knowledge, expertise, and best practices. This sharing of information enables companies to learn from each other's experiences, identify innovative solutions, and implement industry-wide improvements. It facilitates the transfer of technology, skills, and lessons learned, which can accelerate offshore wind deployment and enhance the overall quality of projects.*
- *Facilitate the access to raw materials is also crucial for the supply chain competitiveness.*
- *Overall, the interconnection of net-zero companies and suppliers is important for creating a robust, collaborative, and innovative ecosystem that can support the successful deployment of offshore wind projects. It fosters resilience, scalability, cost reduction, and market expansion.*

- *Suppliers and developers are requesting substantial financial support from regulatory institutions to facilitate supply chain adaptation. While regulatory institutions assert the availability of funds, it is necessary to develop strategies for accessing these funds, emphasizing the need for synchronization.*

Second Conference - Offshore Wind: Turning Huge Ambition into Reality

- *The demand for offshore wind projects in Europe is declining as a result of challenges related to permitting and interconnection. Developers emphasize the significant influence that local authorities hold in addressing these issues. By leveraging their regulatory knowledge, engaging stakeholders, coordinating efforts, providing effective planning, and supporting economic development, local authorities can play a vital role in improving the permitting process for offshore wind projects. Their involvement helps ensure a well-managed, environmentally sustainable, and socially accepted deployment of offshore wind in their respective regions.*
- *Suppliers emphasize that there is a lack of skilled workers in Europe and also remark that there are administrative barriers. They ask for the optimization of the supply chain, ensure benefits for the manufacturers, involvement of the government in the all the different levels of governance,*
- *According to suppliers, the current manufacturing capacity allows the production of 200 monopiles per year. However, with a €300 million investment, they could increase this capacity to manufacture up to 500 monopiles annually.*
- *It is the responsibility of the EU to revamp the framework in order to enhance the competitiveness of the European supply chain and enable it to effectively compete with international suppliers. The existing offshore wind supply chain currently relies on Asia, with component assembly taking place in Europe.*
- *Suppliers highlights that a significant portion of manufacturing occurs in Asia, with certain components being assembled in Europe. This transition is shifting us away from dependence on Russian energy towards reliance on a single supplier source.*
- *Developers also encounter a lack of maturity among providers, which hinders the ability to expand renewable energy development.*
- *There was a significant dedication, particularly regarding the supply chain. Nevertheless, no Final Investment Decisions (FID) were made last year*
- *Although the cost of technology has considerably decreased, the presence of high-interest rates creates uncertainty and hinders the necessary investor confidence for developers to invest in offshore wind.*
- *Power Purchase Agreements (PPAs) play a crucial role in accelerating project readiness. To foster the growth of offshore wind, developers suggest maintaining straightforward PPAs and utilizing support schemes like Contracts for Difference (CfD). This approach ensures accessibility and minimizes potential disruptions.*
- *Participation with local industry but is required infrastructures.*
- *Essentially, the key to advancing floating technology on a larger scale is to shift from pilot projects to commercial projects and establish a predictable regulatory framework as a pathway for progress.*
- *Suppliers have expressed their lack of interest in expanding manufacturing capacity, especially in Europe, despite their willingness to do so. Their primary focus lies in finding more qualified personnel.*
- *The EU prioritizes creating value rather than solely pursuing the cheapest projects. Biodiversity is a significant criterion for the EU, one that many stakeholders tend to overlook as it poses challenges to growth due to extensive permitting requirements.*
- *Lithuania has recently conducted its inaugural auction, where the selection criteria for awarding projects were primarily based on the financial standing and experience of developers*

- *As per the feedback from many participants, enhancing predictability is the primary factor for driving capacity growth. While standardization is important, developers should not place excessive emphasis on demanding it from OEMs.*

Third Conference: Boosting Europe's Wind Industry Through Non-Price Criteria in Auctions

- *The Energy State Aid Guidelines of the European Commission permit up to 30% of the evaluation scoring in Contract for Difference (CfD) auctions to be allocated based on non-price criteria.*
- *In the case of the Netherlands, they have chosen not to utilize CfDs, allowing them to allocate an even higher percentage to non-price criteria.*
- *France has incorporated non-price criteria for 25% of the evaluation scoring in their most recent offshore wind auction, specifically for a 1 GW wind farm located off the coast of Normandy.*
- *The German Government has established four non-price criteria for offshore wind farms that will not receive government support.*
- *Evaluating the potential environmental consequences of the project, encompassing its impact on biodiversity, marine ecosystems, and protected regions. Projects that demonstrate a reduced environmental footprint and implement effective measures to mitigate adverse effects may be given preferential consideration.*
- *Developers invest significant resources in their bids to ensure their projects perform strongly across all non-price criteria. Unfortunately, even with competitive bids, those who are not successful will be unable to proceed with any project, which is concerning considering Europe's pressing need for increased generation capacity to tackle the energy crisis. One possible solution to this issue is to conduct auctions for a larger capacity simultaneously, allowing more projects to be developed and addressing the urgent demand for energy.*
- *Encouraging projects that prioritize the use of local suppliers, labor, and services, thereby creating jobs and fostering economic development in the region.*
- *Taking into account the project's strategy for connecting to the grid, which involves assessing its feasibility, reliability, and compatibility with the current electricity infrastructure. Projects that present efficient and dependable grid integration solutions may receive preferential treatment.*
- *Recognizing projects that introduce or employ advanced technologies, such as floating wind turbines, novel foundation designs, or improved turbine efficiency, to drive innovation and further advance the industry.*
- *Assessing the developer's efforts in engaging and consulting with local communities, stakeholders, and considering their concerns and incorporating their feedback into project planning and execution.*
- *The inclusion of these criteria acknowledges the broader societal benefits of wind energy, such as safeguarding biodiversity and ensuring the efficient functioning of the overall energy system. These criteria aim to incentivize and acknowledge the investments made by the wind industry in these aspects, including the development of pertinent technologies.*
- *It is important that non-price criteria should possess clarity, comparability, and ease of measurement while also complementing existing policies. It is crucial to ensure that these criteria do not impose excessive administrative or management burdens on market players. Furthermore, they should capitalize on the strengths of the wind industry and provide incentives for continued innovation.*
- *Evaluating the developer's previous experience in successfully delivering offshore wind projects and their track record in meeting project milestones and operational targets.*

Fourth Conference: Floating: How to get a supply chain?

- *Industrialization is still in its early stages. Scaling up production will decrease costs and drive intensive industrialization.*
- *It is crucial to address the lack of supply caused by insufficient investment. This is critical for achieving an optimal concept. The presence of numerous concept designs hampers suppliers' ability to make final investment decisions for accommodating new production.*
- *The EU refers to its 2020 strategy and has taken actions to engage suppliers in providing the specific components required for floating wind technology.*
- *The cable industry is prepared to meet the expected demand and volumes, but it awaits confirmation on which projects will be executed to proceed with their investments. Therefore, they demand more transparency to expand their production capacity.*
- *Foundation suppliers also emphasize the importance of transparency and predictability. While they are capable of constructing larger foundations, they require a larger scale. They also highlight the need for smooth interfacing throughout the value chain.*
- *It is proposed to have discussions with the major developers and establish concrete long-term project execution as a benchmark.*
- *The EU's Innovation Fund is a large-scale mechanism available to advance mature floating concepts. Additionally, the net-zero industrial act serves as a mechanism for scaling up manufacturing. Including non-price criteria in auctions can expedite the permitting process.*
- *The main bottleneck in mass production relates to cable supply. Dynamic cables have numerous accessories, and there are limited suppliers capable of providing them. Installation is also a potential bottleneck, as the current fleet is not suitable for handling dynamic cable installation.*
- *Developers must commit to engaging the entire supply chain and addressing concerns.*
- *Ports play a crucial role in the success of the floating wind industry and are gaining recognition. It is important to prioritize upgrading ports to facilitate the deployment of floating offshore wind. However, upgrading ports requires significant investment costs, and the short construction phase of offshore wind projects may not adequately compensate for these costs. Ensuring a busy port is essential.*
- *Developers emphasize the importance of port selection and agreements with port authorities to reach a final investment decision (FID).*
- *Non-price criteria auctions should play a prominent role in the initial years to meet the value chain's needs.*
- *The government should also ensure that costs are included as criteria to ensure profitability.*
- *Developers and suppliers consider it crucial to avoid slow development processes due to administrative and permitting issues. Examples from South Korea are cited as a reference, where the first commercial project will take place.*

Fifth conference: Upscaling port infrastructure

- *The selection of ports plays a crucial role in the development of offshore wind projects. However, it is becoming increasingly challenging to meet the expected future demand.*
- *For instance, the port of Esbjerg, despite its experience with 265 GW, is unable to handle the upcoming pipeline of projects.*
- *The next 2-3 years will be crucial in terms of investment, as other upcoming businesses will rely on existing infrastructure, leading to increased competition.*
- *Developers have various concerns, including technical requirements from Original Equipment Manufacturers (OEMs), which demand significant space and bearing capacities to accommodate the growing size of wind farm components. Commercial availability is another concern, as the increasing demand may impact the availability of port terminals.*

- *Suppliers are concerned about the scarcity of specific equipment, such as cranes, which may lead to increased mobilization costs. Job creation is also a concern, as skilled professionals are required to work in port environments.*
- *Port authorities are more inclined towards cooperation rather than competition with other port authorities.*
- *Port authorities demand predictability for their investment decisions and expect financial support from institutions.*
- *OEMs need to collaborate with port authorities to determine port selection solutions that meet the technical requirements for handling wind farm components. The engagement of both parties is necessary to identify required upgrades that can benefit both sides and reduce investment risks.*
- *Decommissioning of offshore wind farms should also be considered, and ports need to be available for dismantling the wind farms.*
- *Due to the nature and size of floating offshore wind farms, installations may need to be segmented across different ports. Therefore, coordination among the ports to be utilized is crucial.*
- *Ports with experience, such as Esbjerg and Ferrol, emphasize the importance of securing strategic plans now instead of waiting until the last moment. Investment decisions must be made promptly, although uncertainty surrounding project execution poses difficulties.*

Sixth conference: Floating - Lessons learnt so far and engineering challenges

- *The group aims to share the industry's accomplishments and learnings thus far.*
- *The Norwegian Institute of Technology's Marine Technology department discusses the lessons learned from the Highland floating offshore wind farm, emphasizing the importance of including technology qualification in the roadmap.*
- *Creating a regulatory framework is crucial to support technology development.*
- *According to the World Bank, the roadmap should encompass four pillars: Strategy, Policy, Framework, and Delivery, which are necessary for successful offshore technology development.*
- *The findings indicate that stakeholders lack communication, participation, and knowledge sharing, which hampers effective development in the pillars.*
- *Competency is important, but there should be certain conditions for competition and a mature market is necessary.*
- *The permitting process and communication are relevant factors that can expedite the process. Collaboration among stakeholders, the government, and engineering teams enhances understanding.*
- *It is important to establish policies that prioritize visibility and predictability of the global pipeline of offshore wind projects.*
- *Optimizing design at an early stage is crucial for aligning predictions with reality and adapting the supply chain accordingly.*
- *Collaboration between fabricators, manufacturers, and designers is essential for improving designs.*
- *Efforts are being made to improve the connection between technology suppliers, local communities, and the supply chain for their initial project. Designing goals for site-specific motion conditions is important.*
- *Investments in the supply chain and infrastructure plans, particularly for ports, are necessary.*