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Review

A Review of the Energy Policy and Energy Transition Objectives for 2040 in the Canary Islands (Spain)

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Abstract: The objective of this work is to analyze the possibility of compliance with the objectives committed to by the Canary Islands authorities, which aim to reach a completely decarbonized economy by 2040, meaning ten years earlier than the entire EU. Since historically, energy planning in the Canary Islands did not achieve its objectives by far, we will first identify the historical obstacles which had prevented the achievement of this planification, to later highlight the main differences between the energy transition foreseen by the current planning instruments of the government of the Canary Islands and the expected evolution of the energy transition of the archipelago. Beyond this point, and, within the frame of energy governance, we will understand how the root of this failure lies in planning instruments developed hierarchically, without including the view of the different stakeholders involved in the process. The final goal, after identifying the main barriers faced by the energy transition in the Canary Islands, is to provide a set of recommendations contributing to supporting a successful energy transition for the archipelago.

Keywords: energy governance; Canary Islands; energy scenario; sustainable energy transition; regulatory framework

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1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) is delivering continuous messages encouraging decision-makers to accelerate the energy transition and then, hopefully, stop climate change. The last IPCC report stated that each of the last four decades have been successively warmer than any decade that preceded it since 1850 and that global warming is likely to reach 1.5 °C between 2030 and 2052 [1]. This climate change relates to increases in greenhouse gas (GHG) concentrations since 1750, which are unequivocally caused by human activities [1]. The magnitude of the challenge has been tackled by the EU with its commitment to the Paris Agreement [2], a covenant aimed at an economy with net zero GHG emissions by 2050, which is at the core of the European Green Deal.

Afterward, the COVID crisis has been undertaken by the EU through its "Next Generation EU" [3], strongly bonded by energy transition since 30% of its destination should be dedicated to energy transition [4]. Nowadays, the Russian invasion of Ukraine in February 2022 deepened an already difficult policy landscape characterized by rising energy prices, and international supply chain disruptions, with exacerbating geopolitical tensions [5]. The combination of these crises has created an increasingly pressing social concern demanding an EU response aimed at reducing the dependence on imported fossils, and fostering energy transition while addressing the social consequences of the energy prices for the most vulnerable [6].

According to EU regulations (Governance of the Energy Union and Climate) [7], each state member shall submit an integrated national energy and climate plan. The government of Spain has fulfilled this obligation with the issuance of the PNIEC (Integral Plan for Energy and Climate 2021–2030) in September 2019. The main objectives of this plan for 2030 are reaching a 23% reduction in GHG emissions compared to 1990, achieving 42% renewable energy (hereinafter RE) in the final use of energy, and improving energy efficiency by 39.5%. These objectives have been superseded by the last energy policies issued by the EU. For instance, RepPower EU obliges reaching 45% RE instead of the 42% stated in PNIEC, and the EU Climate Law requires a 40% reduction in GHG emissions (instead of a 23% reduction in PNIEC) [8].

Energy planning in the Canary Islands (an autonomous region of Spain) has been developed historically through PECAN (Energy Plan for the Canary Islands) and EECan 2025 (Energy Strategy for the Canary Islands). Nowadays, the new planning instrument PTECAN (Energy Transition Plan for the Canary Islands) is under discussion. The previous planning (PECAN and EECan) did not achieve its objectives by far. However, PTECAN contains even more challenging energy transition objectives. The archipelago's energy planning philosophy has first addressed the need to reduce the islands' energy dependence through the introduction of RES, underpinning this process later with increasing attention toward actions to reduce GHG emissions.

This work is a general review of the situation in regard to the energy transition of the Canary Islands and aims to analyze the possibility of compliance with the decarbonization objectives committed by the Canary Islands authorities, namely reaching a completely decarbonized economy by 2040, which means ten years earlier than the entire EU. Since the historical energy planning in the Canary Islands did not achieve its objectives by far, we will first identify the historical obstacles preventing the accomplishment of the earlier energy planification, to later highlight the main differences between the energy transition foreseen by the current planning instruments of the Government of the Canary Islands and the expected evolution of the energy transition of the archipelago.

Beyond this point, and within the frame of energy governance, we will understand how the root of these failures lies in planning instruments developed hierarchically, without including the view of the different stakeholders. The final goal after identifying the main questions is to provide a set of recommendations contributing to support for a successful energy transition for the archipelago.

This is the first work that reviews past accomplishments and present perspectives of the energy planning objectives set by the Canary Islands from an energy governance perspective and therefore has a limited scope, and it should be emphasized that it is not a detailed analysis since it only aims to deliver a discussion in terms of energy governance. We expect this work to provide a valuable contribution to the understanding of current dynamics in the frame of energy governance in the main isolated energy systems among the outermost regions within the EU, with 40% of its total inhabitants.

This paper is structured as follows: Section 2 for materials and methods, starts with an introduction to the main features of the archipelago, followed by an analysis of the level of accomplishment reached by the historical energy planning instruments of the Canary Islands (PECAN and EECan) with an explanation for the main obstacles preventing a higher level of compliance, finalized with an analysis of the actual situation of the archipelago into EU energy policy. Section 3 is results, which provides an analysis of the currently under discussion PTECAN, providing first an introduction to its legal framework, followed by an explanation of its elaboration process and a general description, finalized with an analysis of the perspectives to achieve its main objectives. Section 4 is for discussion and delivers an analysis of the main barriers preventing a fast-track energy transition in the frame of energy governance and delivers a set of recommendations to overcome the current situation. Finally, Section 5 ends this work with a summary of our conclusions.

2. Materials and Methods—Historical Energy Planning Compliance (1986–2021)

2.1. Introduction to the Canary Islands and Its Energy System

The Canary Islands are a Spanish autonomous region and archipelago in the Atlantic Ocean, at their closest point to the African mainland, they are 100 km west of the African mainland shore. The islands have a population of 2.2 million, distributed in 7 inhabited islands, the most populated of which are Tenerife and Gran Canarias with almost 1 million each [9]. Figure 1 displays the geographical location of the archipelago.

Figure 1. Canary Islands geographical location Map.

The study of the archipelago energy system requires an initial understanding of certain characteristics that describe fundamental energy issues in the archipelago:

- The Canary Islands are the outermost region of the EU with the largest population (with 40% of its total population), and as an outermost territory has special treatment according to Article 349 of the Treaty on the Functioning of the European Union (TFEU);
- Its energy system is isolated and dependent on external sources of energy [10]. Each island has an independent electrical grid except for the connection between Fuerteventura and Lanzarote. Electricity generation comes mainly from thermal power plants with fossil fuels creating more risks for their energy systems planning [11], provoking a relatively high level of emissions. Penetration of renewable energy sources (hereinafter RES), mainly wind and photovoltaic (hereinafter PV) only reached 20% of the total installed power [12];
- Concern about climate change and the energy transition among the islands' citizens is affected by its level of environmental protection, with almost 40% of the archipelago facing ecological defense [13] related to the enormous importance of its tourism sector with 35% of its GDP related to tourism [14];
- The Canary Islands has a lower average income (14,990 €) in comparison with Spain (18,116 €) and the EU (20,682 €) [15], advising, therefore, to carry out an energy transition process especially oriented to people, addressing the issues of energy poverty with special attention [16].

2.2. Historical Energy Policy Plans Compliance: PECAN & EECAN (1986–2021)

In this section we describe the impact of the initial energy planification instruments issued by regional authorities, starting with the PECAN, and then followed by EECan 2025. Across these planning instruments, we can trace the path followed by the regional authorities in their journey of improving the energy system of the islands. Figure 2 depicts the energy planning path of the region across the years.

Initially, the Government of the Canary Islands issued different energy planning documents under the name of PECAN, from the first, issued in 1986, to the last in 2006. PECAN's fundamental lies in decreasing energy dependence by promoting the efficient use of energy and fostering indigenous production through RES. The main objectives of PECAN (1986, 1989, and 2002) were: (i) PECAN 1986: diversification of external energy sources advocating the use of coal for electricity generation, promoting the development of

own resources and efficient use of energy; (ii) PECAN 1989: shares the main objective of the previous one, emphasizing the need to protect the environment and introducing the need to improve the liberalization of the electricity market; and (iii) PECAN 2002: shares the direction of its antecessors, underlining RES potential and for the first time proposing the introduction of natural gas in the islands for electricity production.

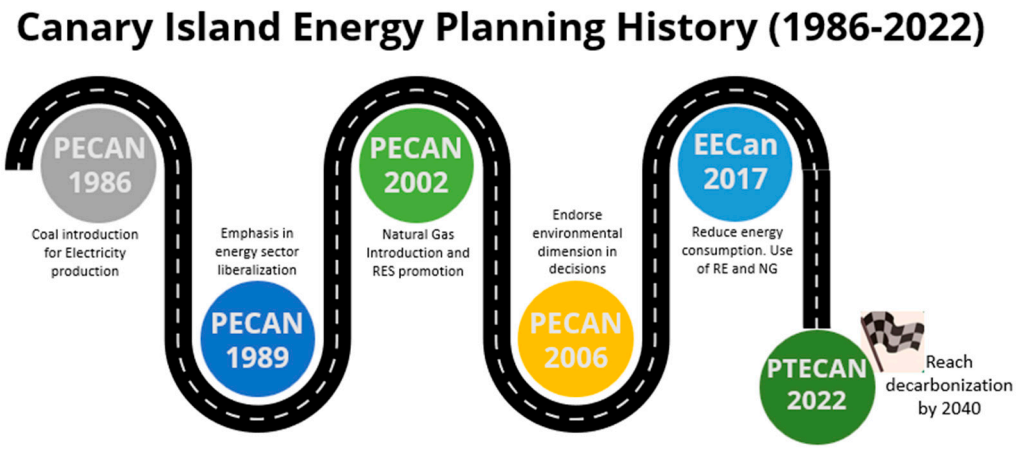

Figure 2. Canary Islands Energy Planning History. Own elaboration.

The last PECAN issued was PECAN 2006 with a landscape from 2006 until 2015. The plan was according to these principles: (i) ensure the supply of energy in optimal conditions; (ii) maximize the rational use of energy; (iii) promote the use of RE; and (iv) introduction of natural gas [17]. Table 1 provides the PECAN 2006 objectives for 2015 with a comparison of the results finally achieved.

Table 1. Comparative: 2006 Initial Situation, Objectives Set by PECAN 2006 and 2019 situation. Own elaboration according to the energy yearbooks of the Canary Islands 2019 and PECAN 2006.

PECAN 2006 Objectives	2006 Status	2015 PECAN Goal	2019 Actual
Reduce Oil Dependence	99%	72%	97%
Reaching 8% in self supply in primary energy	2%	8%	3%
Introducing natural gas in the energy mix by 20%	0%	20%	0%
Reaching 30% of the energy mix with RE	6%	30%	18%
Reaching 1025 MW based on Wind production	140	1025	413
Reaching 460,000 m^2 in thermal solar panels	88,562	460,000	123,719
Reaching PV installed capacity of 160 MW	1	160	194
Reaching 40 MW with other RE	4	40	28

PECAN goals were not achieved, even beyond the landscape of 2015. The only goal which had been achieved by 2019 was reaching 160 MW of installed PV capacity. In fact, the following planning instrument issued by the Canary Islands government (EECan 2025) makes the following mention regarding PECAN, stating [18]: "Since the date of its approval, PECAN 2006 had a minimal impact on the existing energy model in the Canary Islands, having been fulfilled, only in a very limited way. There has been no significant improvement concerning the excessive external vulnerability of the Canary Islands in the period since 2006".

The following planning instrument for the energy transition was EECan 2025 (Energy Strategy for Canary Islands) issued in 2017 with a horizon until 2025; albeit EECan 2025 was not finally approved. EECan 2025 established as main lines of action: (i) developing energy infrastructures to ensure a low carbon, diversified, and secure energy supply; (ii) reducing dependence on oil in the transport sector; (iii) replacing LPG with the use of RES and natural gas for residential use. Table 2 compares EECan 2025 objectives with the 2019 actual results achieved (source Energy Yearbooks Canary Islands 2020 and EECan 2025).

Table 2. Comparative: Objectives Set by EECAN 2025 and 2020 situation.

EECan 2025 Objective	EECan 2025 Goal	2020 Status	% Achieved
NEW Fostering EV (number of vehicles)	107,000	2813	3%
Natural Gas Introduction (Yes/No)	Yes	No	0%
Wind Generation (MW)	1025	457	44%
PV Generation (MW)	300	182	60%
Off-shore Generation (MW)	310	0	0%
Biofuel Generation (MW)	25.5	3.7	14%
Energy Storage (MW)	211.5	16.8	8%
NEW Islands Interconnections (number)	2	0	0%
Surface with solar panels (m^2)	300,000	255,731	85%
Biomass boilers (tep/y)	590	1221	206%
Low enthalpy generation (kW)	30,000	0	0%

As happened with the PECAN, most of the objectives planned in EECan 2025 were far from being achieved at least according to the last data available (2020 Energy Yearbook Canary Islands). It is relevant to mention that biomass production has exceeded by two folds the planned production and that the surface with solar panels is very close to achieving its objective of 85% accomplished by 2020. Objectives such as wind and PV generation are in a medium rate of accomplishment with 44% and 60% respectively. On the other hand, we can witness that relevant investments to improve the energy systems remain unsolved as happens in the natural gas introduction and the new interconnections between islands. Offshore generation still does not exist in the islands, as is happening with low enthalpy projects, while the development of EVs is still scarce with only 3% of the planned objective achieved by 2020.

2.3. Identifying Historical Barriers for Energy Plans: PECAN & EECan (1986–2021)

PECAN 2006 acknowledges that: "planning in the energy sector does not have awakened in the public authorities of the Archipelago during all these years (referring to the period from 1990 to 2006) the interest deserved even though it is considered a strategic sector and even though its evolution conditions the well-being and the Economy of families and enterprises" [19]. In this sense, it is worth mentioning that certain questions remained unresolved, the most relevant are the following:

- The introduction of natural gas has not been achieved, leaving electric production highly dependent on fuel oil with 80% of electricity produced by fuels [12] and a high level of emissions, with 87% of its GHG emissions, related to energy processing [12]. A new potential solution could be a new project based on a small-scale LNG (liquefied natural gas) offshore facility tailor-made for the needs of the main islands (Tenerife and Gran Canaria) [20]. It is worth mentioning that natural gas is used for electricity production since entails a reduction of GHG emissions [19] compared with electricity production through other fossil fuels (fuel-oil and diesel) and can play an important role in RES integration [21];
- PECAN follow-up was entrusted to the Canary Islands Energy Institute, which later has not been enacted, creating a significant breach, since it should be the body responsible for control, systematic revision, and updating of the plan [22].
- The region has relevant delays in RES introduction with a myriad of PV and wind projects at standstill: (i) 2126 MW of PV and wind projects with permission only to access the grid (connection permits are still pending); (ii) 413 MW are in the process of obtaining access and connection authorizations; and (iii) 590 MW have been rejected due to technical problems [23]. Figure 3 depicts the situation comparing the annual

installation of RE capacity, with planned installation during EECan 2025 showing the accumulated difference.

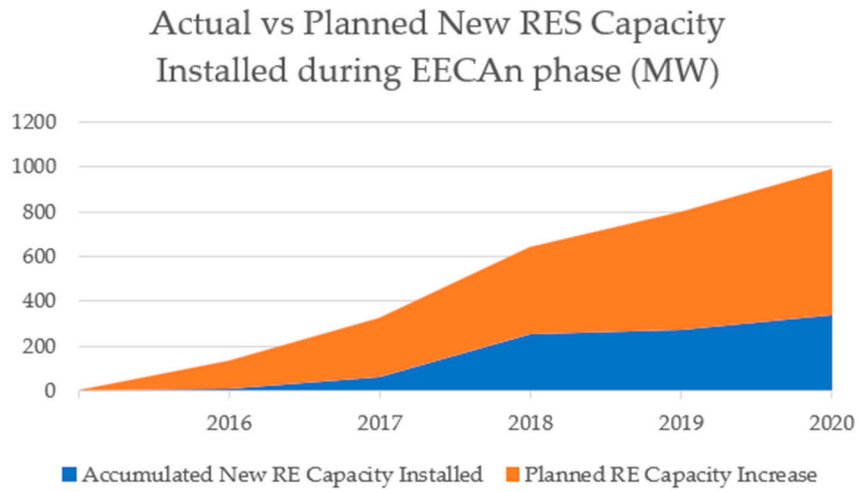

Figure 3. Yearly RES capacity installed (actual vs. planned) during the EECan phase 2020. Sources: Own elaboration sourced with the *Canary Islands Yearbook*.

2.4. The Energy Transition of the Canary Islands within the Framework of the EU

Achieving the best integration of the Canary Islands into the EU requires a good understanding of the functioning of the EU to develop the possibilities of specific treatment guaranteed to the outermost regions within the EU. The Treaty on the Functioning of the European Union (TFEU), in its article 349, establishes that EU regulations must consider the special circumstances of the outermost territories by providing law and special financing with EU funds such as regional development funds, among others.

The procedures for approving energy policies at the EU level are multidimensional in nature, given that their decision making requires the consensus of their main governing bodies, namely the European Parliament, European Commission, and European Council, which are composed of people of different nationalities and political perspectives, which makes the nature of the decisions a game in constant motion with the need for horse trading deals between its members to achieve final decisions. The presence of the Canary Islands' interests in European decision-making bodies is essential to seize these development opportunities.

In this regard, the European Commission issued in May 2022 communication to the European Parliament: "Putting people first, ensuring sustainable and inclusive growth, unlocking the potential of the EU's outermost regions" [24], encouraging member states and outermost regions to introduce regulations that promote RE and energy efficiency, supporting the implementation of small-scale RE solutions with EU funding packages such as "REPowerEU" or the "EU Islands Energy Initiative" to reduce energy dependency and unlock current infrastructure constraints.

According to this EU communication, the authorities of the Canary Islands were commissioned to include special regulations promoting energy transition in their territory. Reinforcing this possibility, the 2018 reform of the Statute of Autonomy of the Canary Islands established in its article 37 [25] areas of competence of the region, energy saving, and the promotion of RE. Moreover, according to article 149 of the same statute, the region has competence over the following matters:

- Installation of production, distribution, and transport of energy in its territory;
- Fostering and management of RE and energy efficiency;
- Authorize installation for the production, storage, and transportation of energy;
- The right to participate as a region in regulation and planification at the national level in the energy sector if there is a special impact for the region.

In our opinion, the potential of the Canary Islands as an outermost region of the EU in the framework of the EU energy transition has not yet been fully explored and could be one of the fundamental pillars that inspire the best path to be followed by the agents involved in the energy sector of the islands, as the initiatives are lead by the Secretariat for Clean Energy in the EU Islands [26,27].

3. Results: PTECAN Analysis

In this chapter, we will provide an extensive analysis of the subsequent planning instrument issued by the regional government, the PTECAN (Energy Transition Plan for the Canary Islands). It should be considered that PTECAN is still under discussion and delivers a long-term vision subject to modifications. For this reason, we are not going to carry out an exhaustive analysis of every aspect of PTECAN, choosing an analysis focused on its main aspects determining its compliance with its objective. Also, it is important to say that the PTECAN, once approved, will be binding until 2030, although it contains projections that reach 2040. This chapter is structured with a first section explaining its elaboration process and a general description, followed by a section with an analysis of its main goals.

3.1. PTECAN Regulatory Frame and Governance

The commencement of PTECAN began with the climate emergency in the Canary Islands declared in 2019 [28] and ratified unanimously in the Canary Islands Parliament in 2020. This declaration set as its main objective to achieve the complete decarbonization of the Canary Islands by 2040, which means ten years before the decarbonization objective established at the EU, and Spanish levels.

The aforementioned emergency declaration includes an obligation to approve the Canary Island Law on Climate Change and Energy Transition (LCCCTE), now in its approval phase. The Canary Islands Authority for Ecological Transition, Fight against Climate Change, and Territorial Planning is entrusted with the preparation of an energy transition plan for the Canary Islands. The LCCCTE structures several strategies, one of the more relevant to the Canary Island Strategy for Climate Action (ECAC) and the PTECAN as its main planning instrument. ECAC is self-defined as the long-term vision to make the Canary Islands a climate-neutral society and climate-resilient economy by 2040, showing the path forward and bolstering actions across the Canary Islands' society and economy. The detail of measures and concrete actions shall be specified in PTECAN [29]. Figure 4 below summarizes the PTECAN regulatory frame.

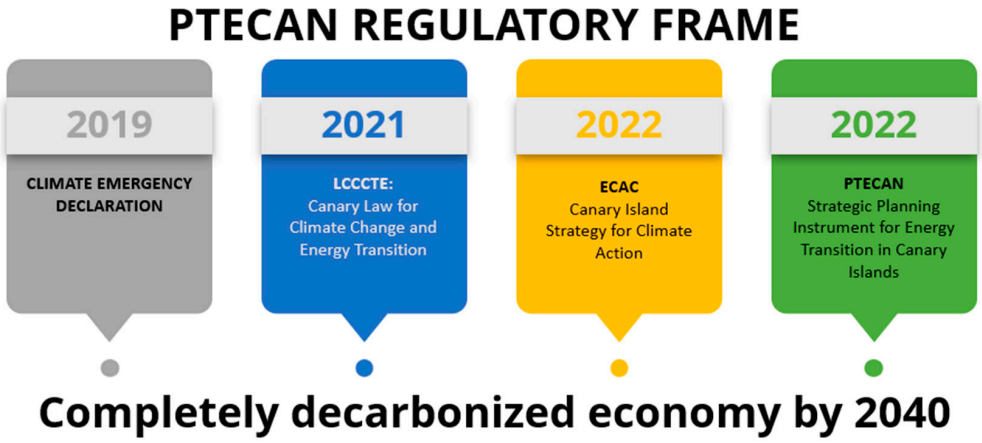

Figure 4. PTECAN Regulatory Frame. Source: Own elaboration.

Once the PTECAN is officially ratified, the results of this plan will be mandatory and will be valid for ten years from its publication and may be reviewed every five. Although it has a time horizon of 2030, the document contains projections to achieve complete decarbonization in 2040. Supporting PTECAN, it has developed several specific strategies

for the energy sectors considered as priorities to achieve complete decarbonization: PV self-consumption, energy storage, electric vehicle, geothermal energy, manageable generation, marine renewable, green hydrogen, and smart grids. These strategies have as their main objective to determine the development potential of technologies that are considered of special interest in the challenge of decarbonization and generate commitments that should be considered as priorities to achieve complete decarbonization by 2040.

PTECAN elaboration was entrusted to the Energy Department of the Canary Islands Government and then developed by the Instituto Tecnológico de Canarias (ITC) a state-owned company created by the Canary Islands government [30]. ITC's purpose is the implementing of regional policies for the promotion of research and innovation, and developing technologies aimed at maximizing the penetration of RES, especially in island grids and remote areas. The ITC was previously in charge of the elaboration of the previous PECAN and is defined by itself as an instrumental body of the Canary Islands government [30].

PTECAN came across with a public consultation process with the participation of stakeholders. The consultation process undergoes surveys and a request for concept documents. The survey was done through five groups: (i) public authorities at the EU and national level; (ii) public authorities of the Canary Islands region and more relevant majors of the islands; (iii) professional associations and universities; (iv) companies related to the energy sector; and (v) consumer organizations and environmental groups. Additionally, some participants collaborated with concept papers, and a total of 38 documents were received [29]. PTECAN documentation does not show traces of the final impact of this public consultation process in its documents, nor the view of the incumbents in the document, and therefore, we cannot observe the contributions of other involved parties.

For PTECAN governance, PTECAN itself describes the creation of a Canary Climate Action Agency (ACAC), which shall oversee mitigation, adaptation, governance, and communication actions. It will operate through a law to be developed. The agency will coordinate the efforts of the involved stakeholders in the energy transition process. Until ACAC is enacted by its correspondent law, the General Department of Energy of the Canary Islands government will be acting on its behalf. PTECAN established as well a system for issuing periodic reports with a list of indicators for monitoring its progress [29].

3.2. PTECAN Objectives

PTECAN's purpose is to promote a sustainable energy model based on energy efficiency and RE aimed at reaching a decarbonized economy by 2040. Article 18 of the LCCCTE defines PTECAN with relevant competencies, for instance, to establish the criteria for the location of RE facilities. Once PTECAN is officially ratified, the results of this plan will be mandatory. PTECAN has validity for ten years from its publication and may be reviewed every five years to update the scenarios and objectives. Although PTECAN has a time horizon until 2030, the document contains projections to reach complete decarbonization by 2040.

PTECAN delivered several alternatives for the archipelago's energy transition, choosing finally the alternative number two (slow-paced energy transition) where decarbonization would also be achieved by 2040. However, the implementation of immature technologies is delayed until the decade 2031–2040 [29].

At the time of the elaboration of this document, a draft of the energy transition plan is available, which includes the electricity sector (production, storage, and transportation), land, air, and maritime transportation, and sectorial policies for energy efficiency and saving. PTECAN proposes by 2030 the reduction of 37% of greenhouse gases (GHG) compared to 2010, as well as an 82% penetration of RE in electricity generation. In the land transport sector, the progressive electrification of transport stands out with a notable increase in demand, with a forecast for 2030 of 225,000 electric vehicles (EVs). Regarding PV, the installation of approximately 500 MW of self consumption is contemplated for 2030. For wind generation, it is expected to have a capacity of 2000 MW, of which 300 MW at sea (offshore), while PV generation will reach 760 MW, with an additional 30 MW offshore.

3.3. PTECAN Main Topics Analysis

Figure 5 describes the structure of our analysis which was constructed first with a general overview, followed by an analysis of the diversity of supply sources. First, electricity generation by thermal power plants (the main electricity producer), followed by conventional RES deployment, energy storage through hydro generations, EVs, state of art technologies, and final analysis of the financial sources for the plan development. Our analysis contains a description of its main features, underlining differences between the energy transition foreseen by PTECAN and the expected evolution of the energy transition in the archipelago. Therefore this analysis has a limited scope since it only aims to deliver a discussion in the following chapter in terms of energy governance.

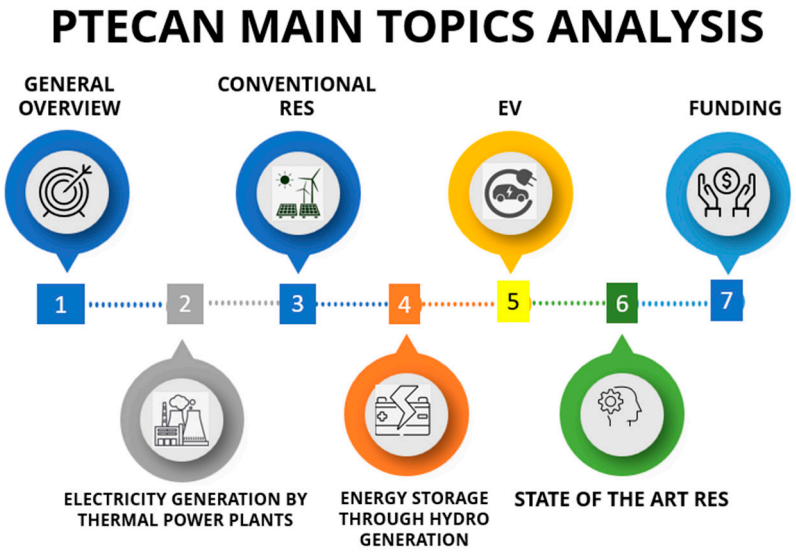

Figure 5. PTECAN main topics analysis structure. Source: Own elaboration.

- **General Overview:**

First, it should be emphasized that in its challenging character, PTECAN's objective is to reach by 2040 a completely decarbonized economy, ten years earlier than the rest of Spain and the EU, starting in a relatively backward position in terms of the energy transition. For instance, today, the islands manage most of their electricity production (83% in 2020) [12] with thermal power plants fueled with fuel oil and diesel with a high level of emissions for generating electricity, compared with Spain and the EU.

The relatively backward position of the Canary Islands' energy system in terms of the energy transition is explained in Figure 6, which displays a picture of the current scenario comparing the current situation in the EU, Spain, and the Canary Islands according to the following structure: (i) RES penetration in the electricity mix; (ii) comparison between GHG emission related with electricity production; (iii) external energy dependence; and (iv) number of EV per inhabitant.

The above comparison shows that in relevant matters the situation in the archipelago is behind the rest of Spain and the EU, except for the number of EVs per inhabitant, where the archipelago is behaving slightly better than the rest of Spain. It is worth highlighting the relatively high level of GHG emissions since the islands are producing electricity with fuel oil and diesel to cover 87% of their electricity demand [12]. By simply replacing thermal power plants fueled by diesel and fuels with natural gas, the archipelago will reduce 25% of its GHG emissions related to electricity [31] and achieve therefore a 10% reduction in their total GHG emissions.

The PTECAN view means a strong reconfiguration of the current electricity mix of the archipelago, with a very significant reduction of thermal power plants from 80% to 29%, covered with an increase of the RES: (i) wind from 14% to 42%; (ii) PV from 5% to 16%; and (iii) state of art RES with 13%. Figure 7 depicts this expected evolution.

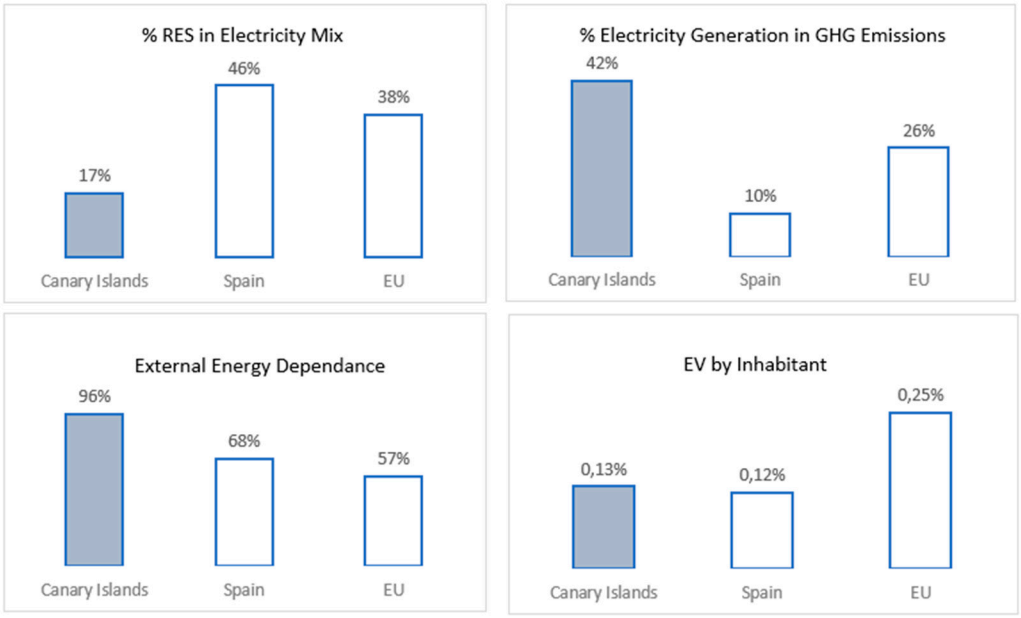

Figure 6. 2020 Data. Own elaboration sourced with the 2020 *Canary Islands Yearbook*, Spanish Ministry for Energy Transition, and Eurostat.

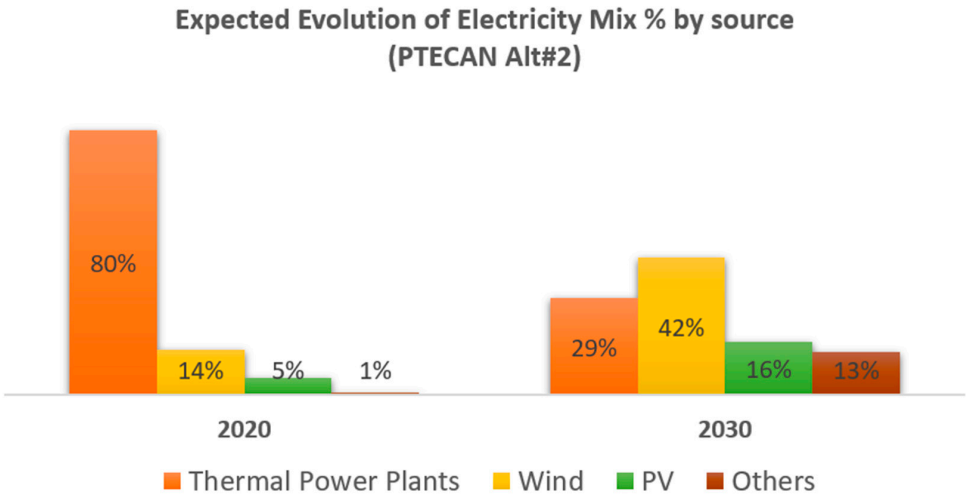

Figure 7. Expected evolution of electricity mix by weight in percentage. Source: Own elaboration sourced with the *Canary Islands Yearbook* and PTECAN.

- **Electricity Generation: Thermal Power Plants:**

The archipelago has a power generation system mainly based on fossil fuels to manage its isolated location with high reliability. At the time of this report, electricity production with fossil fuels is at 80% [12]. However, this weight is decreasing due to the integration of RES. Electricity production with thermal power plants accounts for 42% of GHG emissions [12]. This high level of emissions for electricity production is largely due to the nonintroduction of natural gas in the energy mix as a bridge technology [10], at least, until achieving greater penetration of RES and moreover having the availability of a manageable electricity production system based on RES, such as, for instance, hydrogen. The PTECAN objective for 2030 still means maintaining 17% of its electricity mix with thermal generation since lowering this level is very complicated in an isolated system.

The Spanish National Commission for Markets Competency (CNMC) published in its article: "Report for Gas Natural Fuel in Canarias and Melilla" [32] that the existing power generation plants have an average age of around 28 years, with plants exceeding 40 years, and are therefore highly aged. Of this generation of plants, 18 of them have been declared

unavailable due to not complying with the environmental requirements established by EU Directive 2010/75/EU [33]. The question about the replacement of this generation of plants is historically unresolved. PTECAN is not advocating for the introduction of natural gas as a bridge technology toward a decarbonized economy. However, it was a clear objective in PECAN and EECAN 2025, and even more, Deloitte/Endesa report for decarbonization advocates for actions in the current thermal park extending their working life with a conversion to natural gas [34] and afterward to hydrogen over a longer period.

- **Conventional RES Capacity Deployment:**

Isolated systems with a scarcity of supply, as is the case of the archipelago [35], need encouragement, especially regarding RES development. The historical behavior shown by the region in terms of its ability to install a new RES capacity has been always below the objectives previously set in regional planning (PECAN and EECan). As we have explained, the PTECAN implies a rate of installations of new RESs of 320 MW per year, when the average of the renewable installation region is only 67 MW. Therefore, with only 21% compliance with the objective. Figure 8 provides us with the detail and shows us that achieving the average pace that the PTECAN forecast is quite beyond the current development.

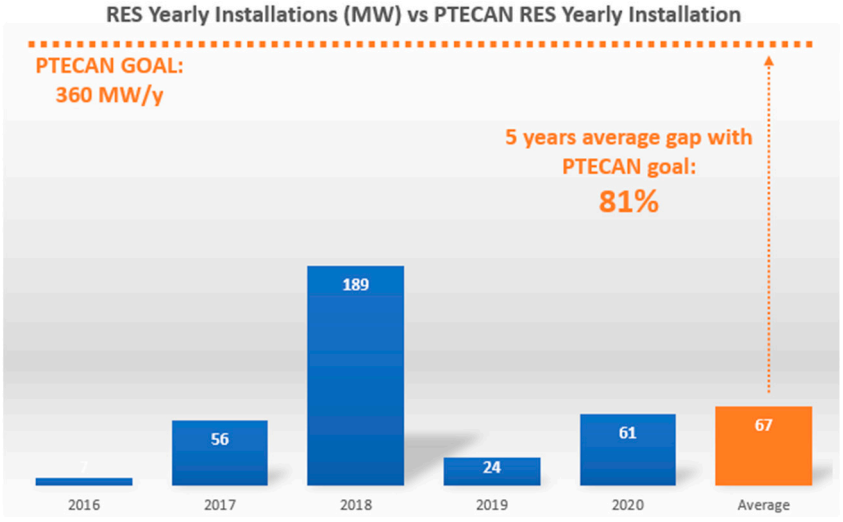

Figure 8. RES yearly installation vs. PTECAN RES yearly objective. Source: Own elaboration sourced with the *Canary Islands Yearbook* and PTECAN.

The slow-paced penetration of RES in the electricity mix could be explained by the following factors: (i) the region has the lengthiest permitting process among the regions in Spain [36], partly since almost 40% of the archipelago has a certain level of environmental protection [37]; (ii) partly due to accumulating the biggest volume among the regions of Spain of electricity transportation network planned, approved, and not carried out by the Transportation System Operator (REE) [38]; and (iii) the Canary Islands did not develop specific measures to streamline permitting process [39].

Figure 9 details the current pace of development of conventional RES (onshore wind and PV) considering the average installation of RES during the period 2018–2020 as business as usual with the annual objective targeted in PTECAN. The figure depicts that conventional RES development needs to be twice as fast to achieve planning targets. The unresolved question mark is how the current regulation will evolute in the future to comply with this objective.

At this point, it is relevant to discuss the current balance between PV and wind capacity and the penetration level of each technology of RES to be achieved since different types of RES can be introduced to the system to cover the growth in demand [34]. Considering that the archipelago as a group of isolated electric systems has fewer possibilities to balance fluctuations in power generation since electricity transmission between the islands is very limited or not available at all [34]. In this sense, PV production fits better than

wind in terms of predictable production, allowing the optimization of the size of the storage required. Another consideration is the surface needed for PV compared with wind, although according to the Deloitte report for decarbonization in the islands by 2040, this will mean 1.9% of the total surface of the region, occupying only 15% of the current agricultural surface [34].

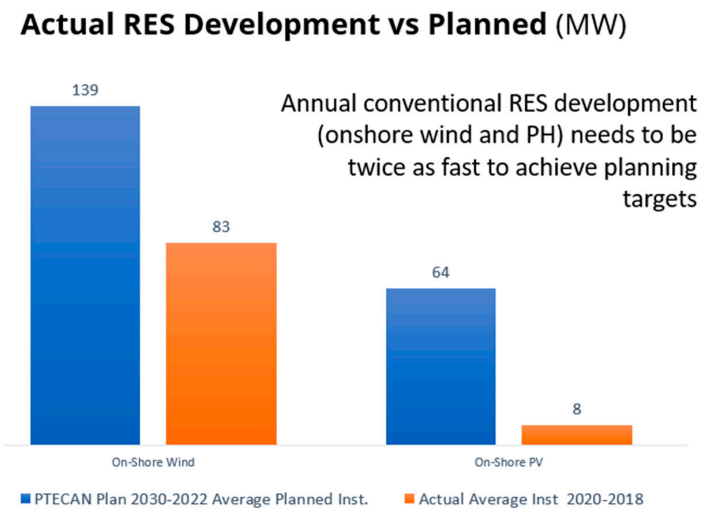

Figure 9. RES yearly installation breakdown of conventional RES.

- **Energy storage through hydro generation and island connections:**

Isolated electrical systems, being small and not connected to other systems, present greater management difficulties since small generation-demand imbalances produce, proportionally to the size of the system, a greater impact. In the case of the archipelago, each island has its own isolated energy system (except for Fuerteventura and Lanzarote linked through a submarine connection), thus multiplying the potential problems that arose from the grid or generator failures. An additional connection between the islands of Tenerife and La Gomera is currently undergoing, and it is expected to be operational before 2025.

The variability of wind and PV RES requires a storage system or a fossil fuel production system. In this respect, PTECAN is proposing as the main solution the construction of hydro generation facilities following the example of the Gorona del Viento plant. The Gorona del Viento Plant is a wind-pumped hydropower station designed to supply El Hierro island with electricity produced from water and wind. This installation has a total capacity of 11.3 MW and allows the variable component of the wind energy source to pump water between two reservoirs set at different altitudes, then produce electricity during times of wind shortage.

PTECAN advocates as a storage solution the replacement of the highly aged thermal power plants with constructions like Gorona del Viento, apparently providing a perfect solution to the question. In the cases that a similar facility cannot be constructed for the rest of the islands, PTECAN proposes the following alternatives: (i) self-storage systems based on residential generation [29], complemented with storage in electrical substations dedicated for consumers without the capacity to produce enough electricity (ports, tunnels, or factories); (ii) hydro generation systems using water at sea level as a lower deposit and seawater as generation fluid; (iii) geothermal generation; and (iv) hydrogen.

Wind-pumped hydropower facilities require a rare combination of space, water, and high wind production. The reality is that similar projects are only (i) under approval, such as Chira-Soria for Gran Canaria, with a commercial start date expected by 2030, or (ii) under study, as is the case for Tenerife and La Palma islands. Achieving these commercial start dates will not be an easy task, especially for Tenerife and La Palma islands since large investments shall be needed and involve a complex permitting process. In addition, it should be noted that 200 MW is approximately one-third of the peak demand of the two

largest islands. Battery storage has advantages over hydro pumping in the Canary Islands in terms of cost, space occupation, efficiency, and scalability of the solution, and by 2030 it is expected that batteries shall be a more cost-competitive technology than pumping for any operating regime [34].

- **EV and transportation:**

In the case of the Canary Islands, transportation represents 42% of CO_2 emissions [12]. PTECAN aims to promote the introduction of EVs and increase energy efficiency [29] through collective transportation, thereby reducing the proportion of vehicles per capita.

Reducing emissions effectively through fossil-fueled vehicle replacement by EVs requires a certain level of penetration in the energy mix since fossil fuels are the variable to increase when electricity demand increases, and therefore the additional demand for EVs could entail an increase in GHG emissions [40,41]. The most accurate estimation for this level is between 10–16% of RES in the energy mix [42], which is a level that has been currently exceeded in the archipelago electricity mix. With respect to the category of EVs, considering the relatively small size of the islands (and therefore of the average trip), research reveals that plug-in hybrid electric vehicles (PHEVs) have currently the best potential to reduce GHG emissions [43].

PTECAN has foreseen the introduction of 466.968 EVs by 2030 (28% of the total vehicles), with the installation of 257.156 charging points with a slow-paced charging method associated with houses and offices which is in line with the Spanish PNIEC assumptions. According to PTECAN, EVs should be considered as an instrument to improve the manageability of island electricity systems, through the development of smart grid technologies that will make EVs not an additional new energy demand, but a provider of electricity storage capacity.

PTECAN included a forecast of 43.398 VE for 2022, while the actual figure for the same year only reached 5.844 [44], with this initial difference expected to be wider in the coming years. The figure itself of EVs for 2030 is challenging since PTECAN envisages EVs to reach 446.968 EVs by 2030 among its 2.2 million inhabitants, thus making a ratio of 20% EV/population, while the EU's last forecast is to reach 30 million EVs to be distributed among its 447 million habitants, thus making a ratio of 6.7% EV/Population [45]. Figure 10 depicts the situation for EVs for 2022 and 2030:

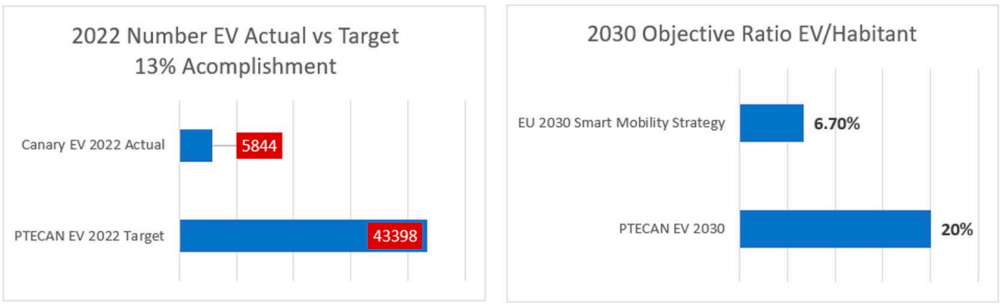

Figure 10. EV 2022 actual vs. objective (PTECAN) and 2030 objective (ratio EV/habitant) PTECAN vs. EU Smart Mobility Strategy.

- **State of the Art RES:**

PTECAN objectives require support from state-of-the-art RES technology, which is more relevant for offshore wind generation with 330 MW. At this point, it should be said that the Canary Islands sea platform depth near its shore is often beyond 1.000 mts, which makes these developments extremely difficult since wind turbines without fixed foundations mean higher development costs [46] and there are no practical offshore wind projects in waters with a depth greater than 100 m [47].

PTECAN also includes a total of 31 MW with offshore PV energy production for 2030, a technology far from its maturity. The estimate of the Netherlands government for 2030 is that

the North Sea will have 100 MW sourced with offshore PV [48], however, the Netherlands has more than 17 million inhabitants, surrounded by economies such as Germany, Belgium, the UK, or Poland compared with the merely two million people on the islands.

Another milestone needed to back PTECAN to be accomplished is 30 MW of power with high enthalpy geothermal, which relies on exploratory drilling activities that have not been done yet. The islands have a promising potential for high enthalpy [49] (especially Lanzarote and Tenerife), however, for the time being, exploration and drilling companies did not take investment decisions in the archipelago, even after performing exploratory drillings from the seventies.

Regarding hydrogen, PTECAN includes, by 2030, a production of 20.629 tons/y, which shall require 200 MW RES to feed the process of hydrogen separation (green hydrogen). PTECAN envisages the final use of hydrogen mainly for land and sea transportation. It is worth mentioning that PTECAN does not include any consideration about the cost of engine conversion, nor is presenting any explanation about the way to create the needed logistic chain.

It is relevant to mention that, for the time being, there is no presence of any of these technologies in the islands, and its total planned contribution to the archipelago generation mix for 2030, according to PTECAN, will reach 330 MW, which is 9% of the total electricity generation mix. Neither PTECAN nor LCCCTE include special provisions for encouraging the development of these disruptive technologies, leaving the development of these technologies in a competitive field, where nowadays, fossil fuels and conventional RES have the upper hand.

- **Funding the Energy Transition:**

The PTECAN indicates that the financing needed to achieve its objectives for 2030 will reach 6248 million euros, specifying that private investors must participate with a figure of 4910 million euros, 78% of the total [50]. This estimate is in line with the forecast of the PNIEC which is estimated to be 80% financed by private capital [51].

In this sense, there are rising concerns in the business world about the installation of new RES capacity, which we may summarize as follows: (i) lack of transport capacity to develop new RES projects, which implies urging REE (National Company for Electricity Transportation) to execute the delayed investments already approved in their planning; (ii) the lengthy permitting process, which should be reduced to less than two years; (iii) lack of clarity in the regulatory field, which is especially weak for delimiting exclusion zones, environmentally protected areas, and areas with preferential implementation of RE; and (iv) the absence of an hourly pricing mechanism for each isolated electricity system, allowing a more cost-effective deployment of RES. The following Figure 11 shows the annual deployment and technologies foreseen in the economic report of the PTECAN:

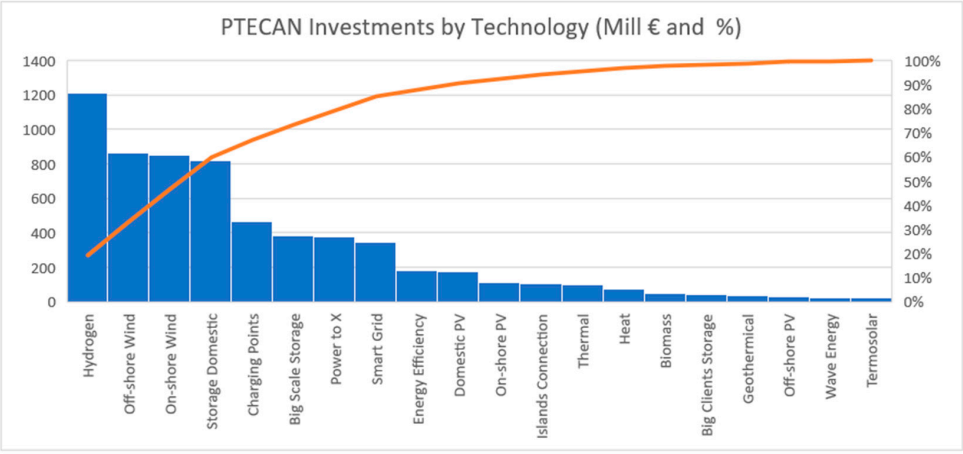

Figure 11. PTECAN Investment by Technology and %. Own elaboration sourced with PTECAN.

The first four items depicted in Figure 10 exceed 800 million euros and account for 60% of the total. These amounts are dedicated to investment in hydrogen (1200 million), in both modes of wind energy (onshore and offshore) and domestic storage. The amount dedicated to EV charging points exceeds 500 million euros. PTECAN shows a clear long-term commitment to the use of hydrogen from RES, and a higher weight to wind energy compared to PV.

- **Best Practices Proposals:**

Figure 12 provides a scheme with some relevant suggestions in the frame of energy governance that could be implemented, complemented with remarkable best practices experiences already in place for islands within the EU that could be studied and afterward introduced in the Canary Islands:

Proposals towards accelerating Canary Island Energy Transition

Obstacle	Proposal	Best Practices
Replace highly aged thermal power plants	Natural Gas Introduction for electricity production and maritime transportation	Replacing fuel oil for electricity production with a small-scale LNG solution supplying natural gas to insular regions as happens in Madeira (Portugal) with 350000 inhabitants [*] or Sardinia (Italy) with 1,6 Million inhabitants
Speed-up conventional RES development	I) Creating a specific authorization process for special projects II) Streamline permitting process	Tilos (Greece), where a desalinization plant is powered through a RE project benefited from a special authorization process [*]. Additionally, hydrogen production based on RES (green hydrogen) can be into this category of special projects Germany "Konzentrationswirkung": plan approval decision includes all the necessary permission (including environmental or construction permits). RES development is considered a public interest and therefore prioritized [***]
Energy Storage	Consider the introduction of battery storage when wind-pumped hydropower is not feasible, since from 2025-2030 batteries shall be more cost-competitive, allows modular installation and needs far less land use [**]	Second Life Project: Enel and Nissan collaboration for the city of Melilla (an isolated system of Spain). EVs batteries at the end of their use lify (Nissan LEAF model) are recycled and assembled in a large fixed storage installation for electricity accumulation, incorporated in the conventional plant in Melilla.
Accelerate EVs introduction	Support the creation of new business models involving local and private sector for the investment and use of e-mobility infrastructure	Syros (Greece): implemented this model fostering local economic development. This concept could be organized through a cooperative or an energy community, allowing for a variation in pricing for the island's local community, businesses, and visitors. [*]
Encourage disruptive technologies	Create a public entity leading the investment in the geothermal resource of the archipelago. A similar structure could also be considered for off-shore RES production	In the Azores (Portugal) during the last 30 years, there has been a significant increase with its contribution growing from 5% to 37%. [*]

** European Commission. Clean Energy for EU islands: From Vision to Action, how to tackle transition in EU Islands. 2022*
*** Deloitte&Endesa, Los Territorios No Peninsulares 100% descarbonizados en 2040: la vanguardia de la transición energética en España, p8, p31, p44. https://www2.deloitte.com/es/es/pages/strategy/articles/territorios-no-peninsulares-descarbonizados-2040.html. 2020.*
**** PWC. Impulso de las tramitaciones eléctricas para la transición energética, p10. https://www.pwc.es/es/sala-prensa/notas-prensa/2022/mejora-procesos-tramitacion-instalaciones-electricas-clave-cumplir-transicion.html. 2022*

Figure 12. Scheme with main proposals and best practices.

4. Discussion of Results and Energy Policy Implications

In this work, we have analyzed the more relevant aspects that must be tackled to achieve the objectives set for the energy transition to occur by 2040 in the Canary Islands. We will summarize each of the key aspects and try to suggest some proposals that could contribute to a more successful energy transition.

First, we would like to highlight the general context referring to the concept of energy governance. Any energy transition process implies profound changes in our habits of generating and consuming energy and significant investments in infrastructures. It also implies a sociopolitical and institutional reordering in the broadest sense [52]. The role of public administrations at all levels is fundamental, and what is more, the role of companies and representatives of the citizenry has paramount importance. An integrated vision is necessary to plan the energy system adequately and develop its energy transition.

A growing number of scientific papers analyze the participatory governance framework to implement energy policies while trying to understand the aspirations and perceptions of different actors and social groups [53]. As we have pointed out in the previous section, energy planning in the Canary Islands has never met the objectives set by the policymakers and there is a risk of leaving unresolved questions from the PECAN phase. From our point of view, this failure was closely related to the centralized way of proposing objectives without the participation of all the social agents involved. Although the PTECAN carried out a public consultation process, it is not known how the different visions of the involved stakeholders have been incorporated into its design.

Good governance requires three fundamental elements [54]: (i) a regulatory framework that establishes the strategy and provides the resources; (ii) a mechanism where the path for the participation of all public and private agents involved is established and, finally, (iii) mechanisms for monitoring and periodic control of compliance with the goals set [55]. Although steps have been taken in this regard, for instance, some aspects for monitoring the objectives, in fact, the minimum basic rules have not yet been established. An example of this is that the economic-financial plan, and the responsibility for its execution, should be better defined. The first years of plan development need to be specially addressed with a proper follow up and a contingency plan tackling discrepancies between plans and actuals, even more, if we consider the magnitude of the challenge, which is a totally decarbonized economy ten years earlier than the rest of the EU.

This task requires the creation of an authentic system of control and governance of energy and climate [22]. We believe that the Canarian Climate Action Agency (ACAC) should be enacted immediately by law with an adequate regulatory description of its responsibilities. This agency must function independently and ensure compliance with the mitigation, adaptation, and governance objectives in this transition process. All the public and private social agents involved should participate, with a system with periodic reports with a list of indicators to monitor their progress. ACAC should especially address social aspects of the energy transition, with mechanisms to monitor and mitigate energy poverty.

Another important aspect to consider is the isolation condition of the insular systems. Most energy policies are drafted at the national level without considering local or island conditions. This results in a mismatch between the applicability of the policy for the mainland and its suitability for the archipelago [56]. Despite the increasing interest in energy transitions in the European Union, little attention has been paid conceptually to regional energy transitions. In our opinion, the potential of the Canary Islands as the outermost region, within the framework of the current discussions on the energy transition in the EU, has not yet been fully explored and could be the right path to follow for the authorities and economic agents involved.

Going through specific aspects of the energy transition process, and according to the structure developed in the previous section we found several unresolved question marks regarding the energy transition envisaged by PTECAN, which are primarily:

- Its inability to provide a solution for the highly aged conventional generation thermal plants replacement, since PTECAN does not consider the introduction of natural

gas. Moreover, the Canary Islands needs an LNG solution to supply its maritime transportation, according to the last regulations issued by the International Maritime Organization [57]. In this respect, a solution should be a small-scale FLNG regasification facility customized to the size of the Tenerife and Gran Canaria islands. This solution is proposed in the Deloitte/Endesa report, which advocates for actions in the current thermal park to extend their working life using natural gas [58]. Extending current the thermal plants' working life or installing new thermal power facilities as PTECAN mentioned [29] is probably not the best solution [17].

Concerning the introduction of RE and storage, a clear strategy must be developed to unleash the following bottlenecks:

- The limited electricity transportation network needs to be further developed to allow new RES to be installed. It is of the utmost importance to encourage the REE (Electricity Transportation System of Spain) to develop the necessary investments.
- The lengthy permitting process should be reduced to less than two years. Research investigations [59] studied the Canary Islands' energy transition through a Delphi methodology survey. The results show that the regulatory obstacle is a threat to the energy transition. Even more, these regulatory constraints deepen the difficulties of achieving a transition with energy justice and collaboration between the involved stakeholders. According to this study, the most significant barrier perceived is the administrative/political sector's bureaucracy and the grid constraints for further implementation of RE.
- The remuneration of electric activities (including storage) is linked to the peninsular market, and it is necessary to rethink the model to generate the appropriate price incentives to properly align electricity demand with the RES production profile.

Finally, another relevant aspect to be considered is that a good energy transition process should not leave anybody behind, especially with the climbing prices of energy. The last energy poverty analysis for La Palma Island (2022) shows that 28% of the houses were unable to keep an adequate temperature and that almost 15% of the houses had problems paying their electricity bill [60]. The LCCCTE and PTECAN contain provisions with the aim of alleviating this question. With this background, deteriorated by the current energy prices, the future landscape of energy for the archipelago needs to go beyond the objective of reaching a completely decarbonized economy by ensuring an energy system that protects its most vulnerable participants.

5. Conclusions

The Canary Island archipelago is an isolated energy system depending almost entirely on fossil fuels as its primary energy source. The Canary Island Law on Climate Change and Energy Transition (LCCCTE) is the regulatory response to achieve climate neutrality and resilience in the Canary Islands by 2040, anticipating the objective set for the whole EU and Spain in 10 years. In the field of energy planning, PTECAN's purpose is to promote a sustainable energy model based on energy efficiency and RE, with a set of actions aimed at the timely achievement of this objective.

This bet for a completely decarbonized economy arose through the climate emergency declaration unanimously ratified by the regional Parliament in 2020. However, to reach this challenging objective, it is needed to clear the previously unresolved questions which still tangle the energy transition of the archipelago. Only after clearing these previous obstacles, mainly through natural gas introduction for electricity production and easing RES development, the region will clean its pathway towards its energy transition.

The current development envisaged by PTECAN still contains main problems that shall curtail its development, as it happened with the previous PECAN, since it was again constructed hierarchically, without measures encouraging the rest of the stakeholders' participation, especially for private investors, and relies upon technological solutions still far to be implemented in the scale required, such as a wind-pumped hydropower station (however, it is unsure of the potential to construct these facilities in many islands); off-shore

wind energy (with near shores with more than 1000 mts. depth); or off-shore PV (based on the sea). All of these are solutions for the future, leaving the present questions unresolved.

The decarbonization of the economy should be better achieved through (i) cleaner electricity production with lower GHG emissions, by replacing thermal plants fueled with fuel oil with natural gas for electricity production projects; (ii) the progressive introduction of EVs; (iii) greater penetration of RES; and (iv) energy storage systems capable of managing new RES developments. The challenge of the target requires appropriate measures within the frame of energy governance, providing a clear regulatory framework with a comprehensive view of all stakeholders, a planning instrument tackling previously unresolved questions, and establishment of an independent body in charge of the follow-up of the plan and entitled to take the required corrective actions.

We want to highlight the paramount importance of the EU financing initiatives (Green Deal, Next Generation, Clean energy for the EU islands, etc.). These programs are not automatically granted and require a continuous exploration to get the most out of the potential advantages of the archipelago, as the most populated outermost region of the EU, with this option being the right direction to be followed by authorities and involved stakeholders.

On the other hand, it is relevant to mention that the archipelago energy transition should be envisioned as a route towards developing the capacities of this archipelago and its citizen to change their current level of energy dependence and emissions, by developing their own energy resources. To support this view, the authors will develop future scientific articles, focused on the energy transition of the archipelago [61], seeking to investigate the creation of an integrated strategy for the stakeholders involved in the energy transition, followed by research about the most suitable energy mix in regard to the future energy transition for the islands.

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