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Interconnecting isolated electrical systems. The case of Canary Islands

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A B S T R A C T

This paper aims to quantify, from an economic and environmental lens, the impacts of the interconnection Tenerife–La Gomera in terms of energy independence, emissions and costs. Alternatively, the development of La Gomera as an isolated system through a high deployment of renewable energies and energy storage systems is also assessed. The results reveal that the interconnection is the most promising alternative in terms of cost, emissions and energy independence, provided that generation is powered by NG. If not, the isolated development mainly based on electric batteries and photovoltaic systems would be the best option. The results of this work may be very useful for policy-makers and energy planners in other territories with similar characteristics.

1. Introduction

The European Union has promoted a set of targets for preventing climate change and several energy issues by 2020 and 2050. Energy security and vulnerability, sustainable energy generation and the implementation of an energy market are on the spotlight of the recent European energy policies [1]. Regulations are particularly sensitive to EU outermost and isolated areas, since they are facing considerable challenges in meeting their energy needs in a sustainable and affordable way [2]. The geographic isolation exacerbates drawbacks such as high fuel prices or high costs in fuel transportation, causing a strong external energy dependency [3]. However, some European countries have overlooked the special sensitivity of isolated regions.

Spain merits a special mention since 75% of its Total Primary Energy Supply (TPES) stems from importations, mainly of fossil fuels, whereas the European average is close to 50%. Among the Spanish regions, the Canary Islands is the area most deeply affected by the external energy dependency. Furthermore, this is the most important European outermost region in terms of population and GDP. The archipelago consists of seven islands (and six electric systems) located off the northwest coast of Africa, making it impossible for any interconnection with the mainland. In figures, around 98.6% of the TPES in the islands is covered by fossil fuels and only 1.4% stems from Renewable Energy Sources (RES). Regarding electricity production, RES represent less than 8%. As a result, in 2015, the average electricity generation cost was close to 182 €/MWh in the Canaries, as opposed to 50.32 €/MWh in the rest of the Spanish territory [4,5]. Fig. 1 illustrates the region's main characteristics of interest.

The energy policy in the Canary Islands is based on two pillars [6]. First, it promotes RES as the main energy source in order to reduce generation costs and emissions and to increase energy independence. Second, it also advocates for the gradual replacement of oil-based generation with Natural Gas (NG), a proposal that has not yet been developed. Moreover, the different energy plans acknowledge the special relevance acquired by two technologies for isolated systems: (i) electrical interconnection between islands and (ii) Energy Storage Systems (ESS). The first electric interconnection in the Canary Islands has been implemented between Fuerteventura and Lanzarote. A recent

Abbreviations: Battery Energy Storage, BES; Canary Islands Energy Plan, PECAN; Capital Cost, CC; Combined Cycle, CCGT; Energy Storage Systems, ESS; European Emissions Allowances, EUA; Fuel Cost, FC; Gas Turbine, GT; Green House Gases, GHG; Levelized Cost of Electricity, LCOE; Natural Gas, NG; Other Cost, OC; Pumped Hydro Energy Storage, PHES; Reciprocating Diesel Engine, RDE; Renewable Energy Sources, RES; Steam Turbine, ST; Total Operation and Maintenance Cost, TOMC; Transmission System Operator, TSO

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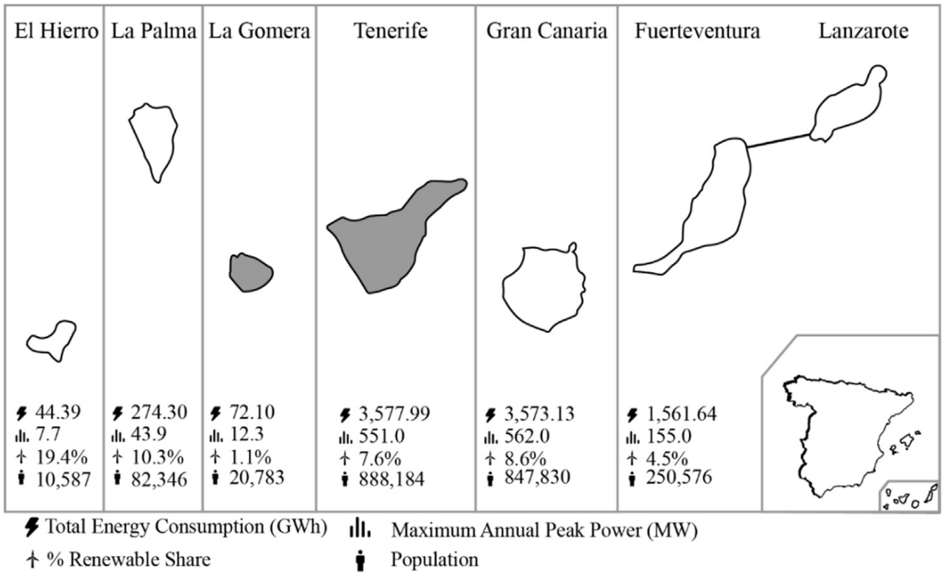

Source: Own elaboration based on the Canary Islands' energy statistics.

Fig. 1. Location, population, energy demand and RES share in the Canary Islands (Spain).
Source: Own elaboration based on the Canary Islands' energy statistics.

work has demonstrated the high profitability and the proper technical performance of such linkage [7]. Consequently, two additional interconnections have been projected [8]. The first one will connect the island of Gran Canaria with the Fuerteventura-Lanzarote electric system by 2021. The second interconnection will connect the electric systems of Tenerife and La Gomera by 2020. This latter interconnection involves two electricity systems of very different sizes and it requires an important investment. Thus, the option of keeping the smaller island isolated by introducing RES and ESS could be an interesting approach from an economic and environmental lens. This is due to the fact that EES add flexibility, intermittency control and provide uninterruptible power supply to the network, driving a strong renewable incorporation [9].

The interconnection projected between Tenerife and La Gomera is particularly interesting for the latter. Generation costs in Tenerife are lower because its electric power system is the largest in the Canaries (173 €/MWh). In fact, the peak of the electric system of La Gomera represents only 2.2% of the peak demand in Tenerife (see Table 1 for further information) [4]. The contribution of RES in both islands is remarkably low, being almost negligible in the case of La Gomera. Furthermore, whereas conventional generation in Tenerife is powered mainly by fuel-oil and gas-oil, in La Gomera it is based on diesel-oil, which causes additional overruns and higher vulnerability. As a result, generation costs in La Gomera are close to 256 €/MWh. The interconnection projected could contribute to reduce not only the electricity generation costs, but also to reduce the emissions due to electricity production and to increase energy independence.

Table 1
Installed capacity, energy sources and generation costs in Tenerife and La Gomera.

Technology	Tenerife	La Gomera
Installed capacity (MW)	1266	23.0
Peak power demand (MW)	551.0	12.3
Share of renewable energies	7.60%	1.10%
Photovoltaic	5.19%	1.08%
Wind	2.11%	0.02%
Hydro	0.10%	–
Biogas	0.20%	–
Share of conventional	92.4%	98.9%
Steam turbine (fuel-oil)	32.4%	–
Diesel engine (diesel-oil)	8.22%	98.9%
Gas turbine (gas-oil)	5.50%	–
Combined cycle (gas-oil)	46.3%	–
Generation costs (€/MWh)	256.25	173.06

Source: Own elaboration based on [4].

In accordance with all the aforementioned facts, the aim of this paper is to quantify the impacts of the interconnection of Tenerife and La Gomera in terms of energy independence (RES share), emissions (CO_2) and costs (Levelized Cost of Electricity –LCOE). To attain these aims, a two-step simulation model has been used. Firstly, a model simulator of the electric power system has been used to define seven scenarios [10,11]. The first four scenarios are based on the interconnection projected, alternating between generation with NG and oil-based fuels. The remaining three scenarios consider La Gomera as an isolated electric system supported by a high deployment of ESS. Secondly, the shares calculated for each technology are used as input variables to calculate the generation cost within the seven scenarios. Finally, a sensitivity analysis on prices of both fuel and CO_2 market is conducted, ensuring a comprehensive assessment.

The present paper contributes to research into this field in several veins. An assessment of the effects of the electrical interconnection projected between Tenerife and la Gomera is conducted for the first time. The study provides an energy economic and environmental comparison of the effects that both the interconnection and the deployment of ESS have on costs, emissions and energy independence, while the literature is mainly focused only on costs. This paper also provides a comparison taking into account whether the baseload generation is powered by NG or by oil-based technologies. The results and the energy policy implications of this study can be very useful for planners in other territories with similar characteristics.

The remaining of this paper proceeds as follows. Section 2 provides a review on the literature relating to interconnections, ESS and the effects of NG technologies on interconnected areas. Section 3 details the methodology used to carry out the corresponding assessment. Results and discussion are presented in Section 4. Finally, Section 5 draws the main conclusions and further research.

2. Interconnections, energy storage and natural gas deployment

According to [7], islands sustainability can be increased through