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UNIVERSIDAD PONTIFICIA
ICAI

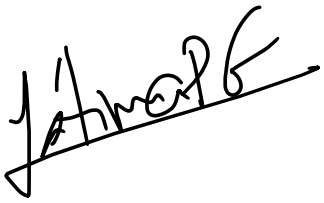
MASTER IN THE ELECTRIC POWER INDUSTRY

MASTER THESIS

Planning of generation mix and system costs in the Canary Islands

Author: Fátima Pérez de Guzmán Bermúdez Coronel

Contact: 202209761@alu.comillas.edu; +34 619027602



Supervisor: Javier Revuelta Alonso

Contact: Javier.revuelta@afry.com

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Chapter 1. INTRODUCTION AND MOTIVATION

The current electricity sector is undergoing constant change towards a more sustainable and low-emission model. Ambitious energy and climate objectives have been established at the European level through European Union policies. Among the latest legislative packages, one can find the Fit for 55 packages, in which member states are required to reduce greenhouse gas emissions by 55% by 2030.

In this context, Spain has also demonstrated its significant commitments regarding energy and climate matters. In the latest revision of the National Energy and Climate Plan (PNIEC), at the time of writing in draft form, it sets a target of 42 GW of installed wind power capacity and 76 GW of installed photovoltaic solar power capacity by 2025.Fuente:

Parque de generación del Escenario PNIEC 2023-2030. Potencia bruta (MW)				
Años	2019	2020	2025	2030
Eólica	25.583	26.754	42.144	62.044
Solar fotovoltaica	8.306	11.004	56.737	76.387
Solar termoeléctrica	2.300	2.300	2.300	4.800
Hidráulica	14.006	14.011	14.261	14.511
Biogás	203	210	240	440
Otras renovables	0	0	25	80
Biomasa	413	609	1.009	1.409
Carbón	10.159	10.159	0	0
Ciclo combinado	26.612	26.612	26.612	26.612
Cogeneración	5.446	5.276	4.068	3.784
Fuel y Fuel/Gas (Territorios No Peninsulares)	3.660	3.660	2.847	1.830
Residuos y otros	600	609	470	342
Nuclear	7.399	7.399	7.399	3.181
Almacenamiento*	6.413	6.413	8.828	18.543
Total	**111.100**	**115.015**	**166.939**	**213.963**

**Incluyendo el almacenamiento de solar termoeléctrica llega a 22 GW.*

Figure 1. Generation mix PNIEC 2023-2030

Moreover, since late 2020, prices in the daily market started to soar due to high gas prices. In Europe, clearing is carried out at the European level through a marginalist market. This means that the last unit to enter the hourly clearing will set the price for each MWh consumed

in that hour. Frequently in Spain, the marginal units are gas combined cycle plants, which were major importers of Russian gas. With the outbreak of the war in Ukraine, and gas reserves at a minimum, Spain faced an energy crisis while still recovering from the Covid crisis, which led to the closure of large, medium, and small industries.

In this context, the European Union pushed forward several policies to promote renewable energy penetration, notably the REPowerEU program. The objectives of this program are to promote energy savings, boost clean energy production, and diversify energy supply. Following spot market prices that reached €330/MWh, Spain, in line with the goals of the REPowerEU program, has been promoting renewable energy sources to reduce dependence on Russian gas.

Focusing on the subject of this master's thesis, in the current situation of the Canary Islands, the majority of energy demand is being met by fossil fuels. Considering the significant negative impacts this entails on the environment, as well as European policies promoting the use of indigenous energy sources in the country and Spain's potential to become a leader in sustainable energy sources, the Canary Islands generation mix will be modelled consistent with security of supply as well as with RES integration constraints.

The National Integrated Energy and Climate Plan (PNIEC) empowers the Canary Islands to lead their own energy transition and commits to promote a sustainable energy strategy in collaboration with regional and island governments. The plan aims to reduce energy costs and integrate renewables effectively, while addressing the challenges posed by the insular electrical system. Key measures include reducing fossil fuel dependency by at least 50% by 2030 and investing in unique projects to drive innovation and tackle specific challenges.

To this means, and aligning with the Spanish Recovery, Transformation, and Resilience Plan, in 2022 it was published Royal Decree 451/2022 to regulate the concession of incentives for the Balearic and Canary energy strategies financials. This Royal Decree transfers an amount of 301.7 M€ for the following actions in the Canary Islands:

a) Funding for the administrative costs that agents must incur including permitting, engineering, construction or even events needed for the projects.
b) Programs for grants for new power installations that help integrate renewables, give technical support to the network, stability and frequency services.
c) Promote projects that help develop "smart islands".
d) Investment Promotion Programs "Clean Energy for EU Islands".
e) Programs that promote storage and contribute to renewable development.
f) Initial Boost for Energy Communities Promotion, supporting the establishment of new communities and developing transition agendas for each island.

This master thesis seeks to contribute to the decarbonisation of the Canary Islands, specifically Tenerife, taking into account the key challenges these isolated systems proposed and the different regulatory incentives there are in place for the development of the system.

Chapter 2. MASTER'S THESIS OBJECTIVES

Following the description made in the introduction, the main focus of this piece of work will be the development of a planning of generation mix and system costs in the Canary Islands for 2040 outlook.

1. Understanding and analysing the functioning of the electricity regulation in the Canary Islands.
2. Build iteratively a scenario of demand and generation capacity mix in Tenerife out until year 2040, consistent with security of supply as well as with RES integration constraints.
3. This scenario will be used to project total annual system costs, both fixed investment costs and variable fuel costs. In turn, these costs will be used to project the extra-costs of the Canary Islands to be socialized in national electricity grid tariffs.

Chapter 3. PRELIMINARY TABLE OF CONTENTS

The Project will be structured as followed:

Chapter 4. DESCRIPTION OF THE METHODOLOGY

4.1 REFERENCES

As electricity systems in the non-mainland territories do not follow the same approach as the mainland, it is needed an exhausted revision of the pertinent regulation to understand the functioning of it. Royal Decree 738/2015 regulates the activity of energy production and procedures for non-mainland dispatch, and it has been a key piece of legislation on this project.

In addition, the Canary Islands Energy Yearbooks have been the main source of information for the data base of passed energy consumptions and installed capacity evolution. These reports have been at the same time developed using REE's data.

4.2 METHODOLOGY

System planning requires several complex and interrelated inputs. The so-called 'energy trilemma' seeks to design power systems at the best trade-off between high security of supply, high sustainability and low cost. Whilst investment decisions in generation are frequently driven by return expectations of private investors, there are generally several forms of public interventions through carbon pricing, or RES auctions, or Capacity Market payments. In the case of the Canary Islands, there is a specific regulatory framework and electricity pricing formula for merchant investments in renewable energies, and specific ad-hoc regulation for some storage projects.

The study will assess and iterate with capacity mix scenarios to produce a final proposal that (a) meets the projected hourly demand with sufficient security, and (b) does not lead to excessive RES curtailments and therefore unprofitable investments. It will use hourly time series for wind, solar power and demand, adapting both the annual energy to include the

future growth drivers, as well as changes in hourly demand patterns to reflect charging behaviour of flexible demand such as EVs.

As regards integration of RES, a model will be developed to quantify expected market curtailments from a capacity mix, considering simplified operational constraints (such as 'must-run' constraints from thermal plants to control frequency and voltage) and hourly system demand. Some qualitative assessment will provide views on the level of RES curtailments that seems acceptable from an economic point of view for the investor and for the electricity consumers.

Finally, the study will develop a simplified total cost model for the corresponding island's power system (Tenerife), replicating the calculation of remuneration of fixed construction costs and variable operational costs. Then, applying a simplified projection of Spain's mainland market costs based on forward trading products, the study will estimate the volumes to be paid by the national end-user grid access charges.

Demand will be projected according to a multiple regression model based on population growth, GDP growth and energy efficiency development. It will also incorporate key demand growth drivers such as Electric Vehicles.

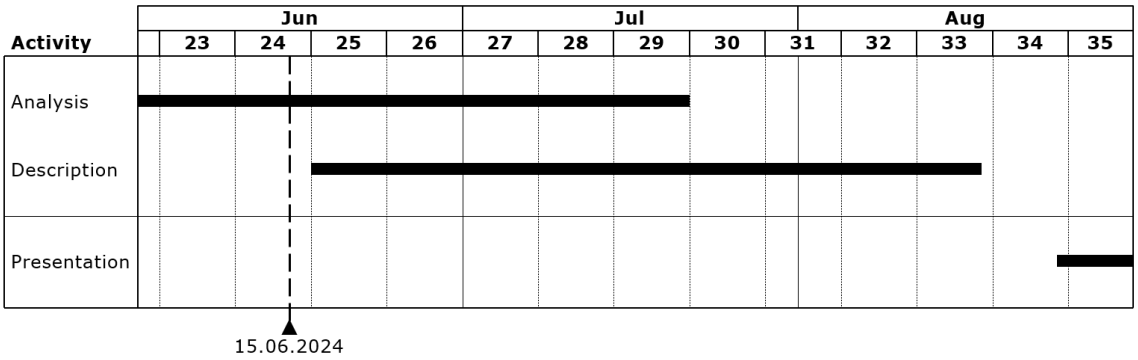

Figure 2. Work plan organisation