ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)
MÁSTER IN THE ELECTRIC POWER INDUSTRY

RISK ANALYSIS FOR AN ELECTRICAL POWER PORTFOLIO GENERATION ASSETS

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Madrid
July 2017.

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ABSTRACT

This project aims at finding the margin and risk of the Spanish utility Endesa in different scenarios for the year 2025.

First, the scenarios have been created according to the possible evolution that may experience the Spanish electric power system. The scenarios vary considering the possible evolution of the generation mix and the demand.

Then, the model used to perform the analysis, ARIES, has been updated. For that, it is necessary to fed the model with historical and forward series of the different commodities intervening in the model, as well as other data like the demand growth, the capacity installed of the different technologies etc. Part of this data has been obtained from the Risk Management department of Endesa. Since this data is confidential, the results of the simulations have been described in a qualitative manner.

Finally, the model is executed and the obtained results are analyzed in other to establish which are the most advantageous scenarios for the company and what measures can undertake to limit the adverse effects.

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1 INTRODUCTION

In this section, the motivation, goals and methodology of the project are presented. The theoretical background is roughly presented as well as the steps followed in the realization of the project. Due to confidentiality reasons, the output of the model cannot be presented straightforwardly and therefore the results are presented in a rather qualitative than quantitative way.

1.1 Motivation

Risk management is a set of processes and elements of an organization that aim to identify the company's risk, define strategies to deal with them and establish control mechanisms to ensure a good execution of the above-mentioned strategies.

It is essential for an electric utility to perform risk management activities. This need comes from the increase on regulatory and market risks on the past years which impacts their margins, profits and ability to fulfill its obligations as well as the increasing demand from shareholders for more transparency and less volatility.

The financial risk of a company is defined as the possibility that this company loses money because of the volatility of its assets. For example, an investment fund with a single investment on a single company will have a variable risk depending on the variable value of that company: it is the value that the invested money can lose from a day to another with a given confidence level. For instance, the Value-at-Risk (VaR) is a measure of risk that reflects the maximum amount of money that the company can lose with a 95% of confidence (if everything is done right, the company will lose more money than the value of the VaR only 5% of the days).

The diversification of the company's portfolio greatly influences risk: more diversification means less variability and that lack of variability has a quantifiable value.

Diversification is therefore a risk management technique aiming to mitigate the risks of a portfolio via mixing a wide variety of investments within it. A portfolio constructed of different kinds of investments will yield higher returns with a lower risk on average than any individual investment part of that portfolio.

Considering two businesses A and B having the same expected future value (free cash flows hypothesis), if A has less variability than B that difference allows the first company

A to account with more capital for sure for the future, allowing it again to immediately invest it on other businesses. In short, A has an extra incremental value over B coming from the diversification of its investments.

To effectively deal with risk, it is necessary to manage it at different time intervals. For example, closing open positions of a specific portfolio or building a new generation unit both have impact on the risks of a company on different levels: the first is a short-term decision while the second is a long-term one. The analysis performed to establish the suitability of each operation are therefore differentiate and require different data and models, adequate to each case.

With this goal on mind, the Spanish electric utility Endesa and the Institute for Research in Technology (IIT), part of the Universidad Pontificia Comillas, came together and built a collaboration agreement for the development of three different models, exposed on Figure 1. These three models cover different markets and time lapses, allowing for a complete risk management capacity.

This project is based on the long-term model, ARIES, nevertheless the other two models are briefly explained in the following lines.

	AURIGA	ACUARIO	ARIES
Mercado	Gas	Electricidad	Electricidad
Horizonte	Corto/Medio	Corto/Medio	Largo
Simulación Series temporales	*Path dependent* (Browniano)	Centrada en *forward*	Schwartz-Smith, cointegración, ARMA
Modelo mercado/activos	Fundamental y financiero	Calibrado con datos externos	Fundamental (VALORE)
Programación	Excel/Matlab/GAMS	Excel/Matlab	Excel/Matlab/GAMS
Ámbito de Uso	Posiciones cartera Riesgo (MeR) y Griegas Análisis estratégico Análisis nuevas operaciones Análisis Peores casos Optimización de cartera	Delta Activos Generación Riesgo (MeR) y Griegas Análisis Peores Casos **Benchmark**	Análisis estratégico Análisis nuevas operaciones (EGP, DEI)

Figure 1 - Models developed by IIT for Endesa.

AURIGA is a model that analyses the gas market in the medium-short term. Its goal is to evaluate the risks of the gas market and help in the decision making and risk management for an interval up to 3 years. Two modules compose it: Simulation of Time Series (built in Matlab) and AURIGA Portfolio, a portfolio optimization module (built in

GAMS). Both modules are integrated in a Visual Basic Excel file.

ACUARIO analyses the electricity market in the medium-short term. It performs the same role as AURIGA but focused on the electricity market instead of the gas one. Their intervals are the same as well: up to 3 years in the future. Its data interface is built in Excel: it obtains the market data and configures the execution of the Matlab script. This script is the risk model: it simulates the prices and valorizes the costs, production and margins of each thermal unit. The model feeds another Excel file which provides the user with the final report of the analysis.

ARIES studies the electricity market as well but is focused in the long term. Its aim is to evaluate the risks coming from the electricity market and support risk management decisions for an interval of 10+ years. It is fed with data coming from a Simulation of Time Series module (Montecarlo method) built around Matlab and a Visual Basic Excel interface (similar to the one in AURIGA). It is explained in more detailed in chapter 2.

It is important to note that the model is fed with real data: forward spreads of commodities found by the risk department of Endesa. Thus, the results obtained with the model are real and reflect the actual position and risk of the company. For that reason, the results are confidential.

The actual results therefore are not shown in this report. However, some general description of them is provided to have a general idea of the model output. For the same reasons, the comparison between scenarios will be qualitative and not quantitative.

1.2 Goals

The main objective of this thesis is to perform a risk analysis for the horizon of the year 2025 for different future scenarios of the electricity system and study the position of the company in those scenarios.

This thesis has defined two different sets of goals: one for the student, author of the report, and others for the company.

For the student:

- Discover and master a decision-support model for long-term risk management.
- Define particular scenarios to perform long-term risk analysis based on the possible

evolution of the electric power system.

- Perform cost of risk analysis and compare the output of different scenarios.

For the company:

- Reduce its assets' long-term financial risk.
- Manage its assets optimally.
- Undertake changes in portfolios according to the results obtained by the model.
- Anticipate possible future situations with dangerously high risk.

1.3 Methodology

A set of long-term scenarios must be created to cover the maximum number of future situations that the company could face. These scenarios should be created considering not only the likeness of each one of them to become reality but the most unfavorable and risky ones as well, so the company can draw a plan to protect itself.

These scenarios are composed by different variables that will differ from one scenario to another. These variables may change depending on punctual events that may affect in some way the company, like an anticipated closure of the nuclear power plants or the coal-fueled thermal power plants, or the mothball of CCGT plants; other variables may directly be related to the evolution of the power system like the evolution of the demand or the penetration of renewable energy sources in the system; and finally, others related to the company itself like diversification of the generation portfolio or loss of clients.

Once these scenarios created, all the associated relevant variables are inputted in the model. Running the model, the results for that scenario are obtained. With the variables obtained, the risk of the scenario is estimated and a judgement has to be made, in order to consider if the risk is within an acceptable threshold. If judged unacceptable, a solution has to be proposed to protect the company against the eventuality of the scenario conditions becoming a reality.

Finally, once all the possible scenarios have been simulated, a comparison between all of them must be performed to verify in which of those the company is at risk.

Throughout the project, the use of Excel, Matlab and GAMS will be required to run the model and process the results.

2 STATE OF THE ART

In this chapter, the current state of the art concerning the project is described. To help the reader understand the functioning of the model, it is described with some of the theory behind it. To use the model, it will be necessary to create future scenarios of the electricity system. For that, it is first necessary to know the current state of it, which is done in two different sections, one concerning demand and the other concerning energy generation. In both these sections, the current general state is presented alongside with the participation of Endesa in the system.

2.1 The model ARIES

In this section, the used model, ARIES, is described. First, a general description of the model is provided, focusing on the relations between the different modules within it. Then, the two main modules, the price simulation module and the electric market simulator module, are explained in more detail. Finally, a quick relation of applications and functionalities of the model is shown.

2.1.1 General description of the model

As stated before, ARIES studies the electricity market and it is focused in the long term. Its aim is to evaluate the risks coming from the electricity market and support risk management decisions for an interval of 10+ years. It is fed with data coming from a Simulation of Time Series module built around Matlab and a Visual Basic Excel interface. The data is processed by a “Data Module” (Excel) then fed to the electric market model (GAMS) and finally the results are processed again in an “Output Module” (Excel). The different modules and the relations between them are represented in figure 2.

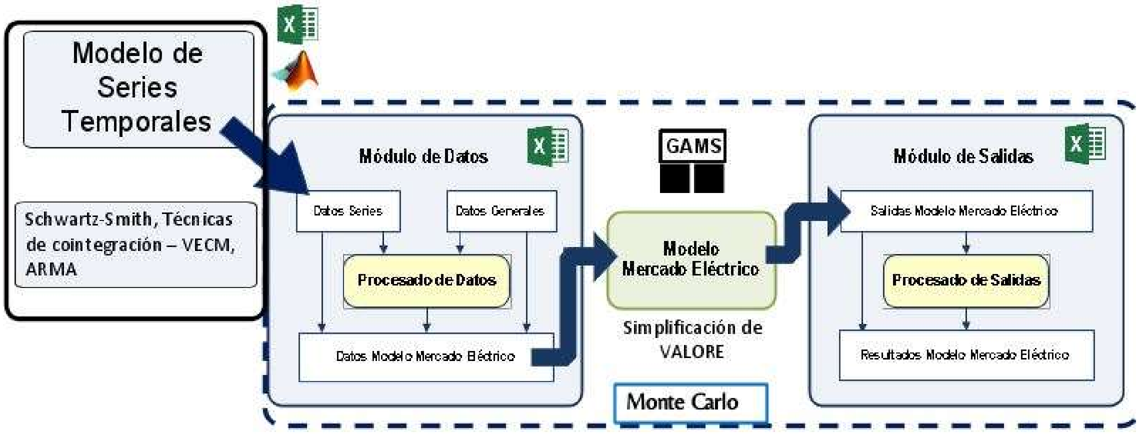

Figure 2 - Structure of the model ARIES.

As it can be seen, the prices simulation module is involved first and its output is fed into the electric market simulation module. Both modules are presented in the following sections.

2.1.2 Prices simulation module

The tool has been designed to be easily learnt and used. The human-model interfaces have been developed in VBA Excel while the temporary series models, explained below, have been programmed in Matlab.

The model needs an input of historical and forward series to adjust the different parameters of the models. This data is stored in .mat files and has to be updated by the user before launching the model. In these files, the historical and forward data of different commodities are stored, such as the API, NBP or the FOREX.

Then, the general characteristics of the electricity system have to be update using the Excel file “Aries_datos”. Such characteristics include the total demand, the installed capacity of renewables, the generation portfolios of the different Spanish utilities (installed capacity of nuclear, coal, CCGTs… sorted by company), etc. With this file, the user can modify the hourly profiles too for the reference year as willing.

After this, the model is launched. Using an interface in Excel, the temporary series of the price for the commodities are generated according to the number of scenarios and the required time horizon. Using the interface, the user can easily select the desired models to be executed. Those models are mainly Schwartz-Smith and ARMA models.

Once the commodities paths have been generated, the user must execute a Matlab script that generates the variable costs of the desired scenarios. These variable costs are calculated with a formula specified by the user in the Excel file "Aries_datos" already mentioned before.

The output of the script consists on as many .dat files as scenarios specified. Those files together with the information of the general characteristics of the electricity system specified in the Excel file and the commodities prices are fed to the electric market simulation module, detailed in the next section.

2.1.3 Electric market simulation module

As shown in Figure 3, three sub-modules compose this module.

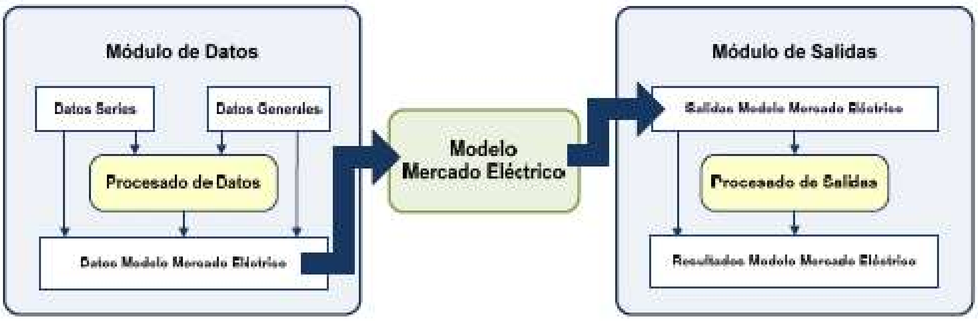

Figure 3 - Structure of the electric market simulation module.

These sub-modules are the data module, the model in GAMS and the output module.

Overall, the data module uses the data obtained from the prices simulation module and prepare them so they have the correct format for the electric market model in GAMS. This model solves the market equilibrium problem as an optimization problem and calculates its outputs. From here, the output module takes on processing this information and calculating the final results.

Two types of data have to be distinguished: the general data and the data coming from series. The latter refers to the data coming from the generator of temporary series (price of the commodities or annual electric demand) while the general data refers to data that don't often change, like the wind power production or the CO2 emission price.

Once all the input data has been processed, it is fed to the market model programmed in GAMS. For confidentiality reasons, it is not detailed in this report and will be treated as a black box.

The outputs of the model are fed into the output module. In this module, the results required by the user are calculated from the corresponding data and the output of the electric market model.

The results calculated are the average yearly price, in €/MWh, and the average yearly economic margin for the company, in millions of Euros. These are calculated for all the specified scenarios which makes possible to obtain a statistical distribution of the results, helpful to analyze the results.

2.2 Energy generation in Spain

The model ARIES predicts the company's long-term risk for a particular scenario. The estimation depends on certain variables and its evolution, own to the companies, the market, or the system in general. Said variables may be affected by political decisions such as the early closure of a certain type of technology, by technical and economic factors such as the implementation of energy efficiency techniques or the evolution of the price of certain key commodities such as coal, oil, or natural gas…

For that reason, it is necessary to define a varied spread of scenarios, as realistic as possible, covering all the possible variations of said variables.

This chapter is therefore dedicated to study the current state of the generation in the system and discussing its possible evolution. After the system-wide presentation, an approximation to the situation of the electric utility Endesa will be made.

To allow a better understanding of the current situation of said company, figure 4 shows the generation portfolio of the company as of December 31, 2016 (source: Endesa).

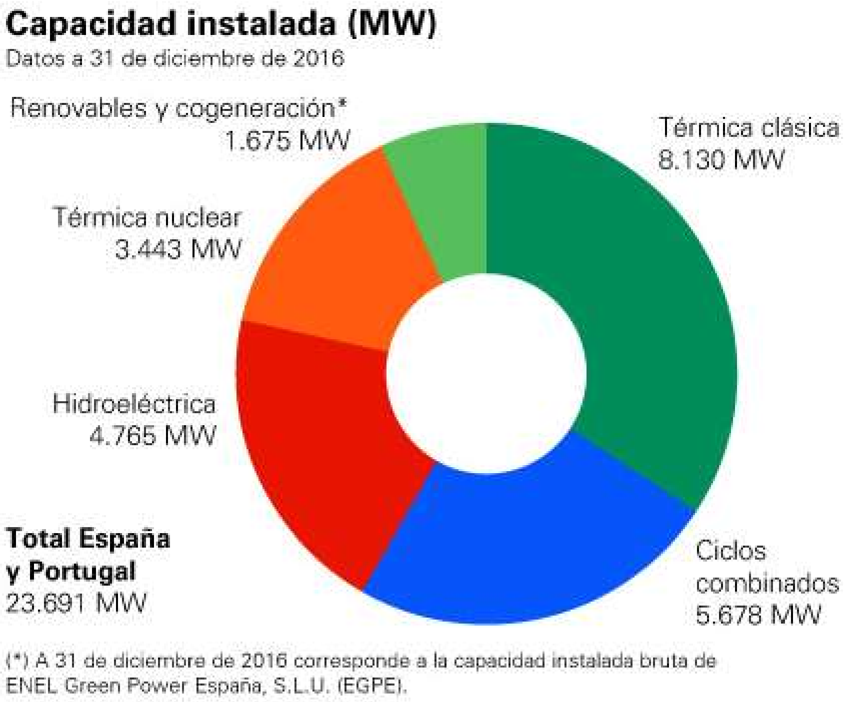

Figure 4 - Installed generation capacity owned by Endesa.

2.2.1 European Regulation

In this section, a description of the principal regulations affecting the electricity system (and more particularly, the next sections) is provided.

The main driver for change in the electricity system is the third European regulatory package, better known as the winter package. It was approved in 2009 and came into force in 2011. In particular, it defines the "20-20-20" targets defining environmental objectives to be attained by the member states. In 2020, the electricity systems of the member states must verify:

- A reduction of 20% in the emission of greenhouse effect gases.
- 20% of the total consumption of energy of the country must be generated by renewable sources.
- Increase of energy savings by 20% thanks to the application of energy efficiency measures.

Additionally, it fixes more objectives for the horizon of 2030:

- Achieving a reduction of 40% in the emission of greenhouse effect gases.
- 27% of the total consumption of energy of the country must be generated by renewable sources.
- Increase of energy savings by 25% with the application of further energy efficiency measures.

This regulation marks the start of a transition from the traditional energy systems, relying on pollutant technologies, to innovative clean energy systems, based on renewable energies such as wind power or solar power.

Following, brief descriptions of some regulations affecting directly the next sections of this chapter are provided. In order, the Plan Nacional de Transición (PNT), the Exemption by limited useful life (coal thermal power plants) and the Plan de Acción Nacional de Energías Renovables (PANER) are explained.

The PNT is designed to achieve significant reductions on the pollutant emissions from 2016 to 2020. For the facilities included in the plan, some reference values for the emissions are calculated. If a power plant emits less pollutant gases than the reference values, it is allowed to continue producing without furtherly invest in adaptation installation to limit those emissions. 97% of the existing power plants have joined the plan. It is expected to witness a reduction until 2020 of 60%, 70% and 40% for the emissions of respectively SO2, NOx and PM10, as shown in Figure 5 (Fernández Montes).

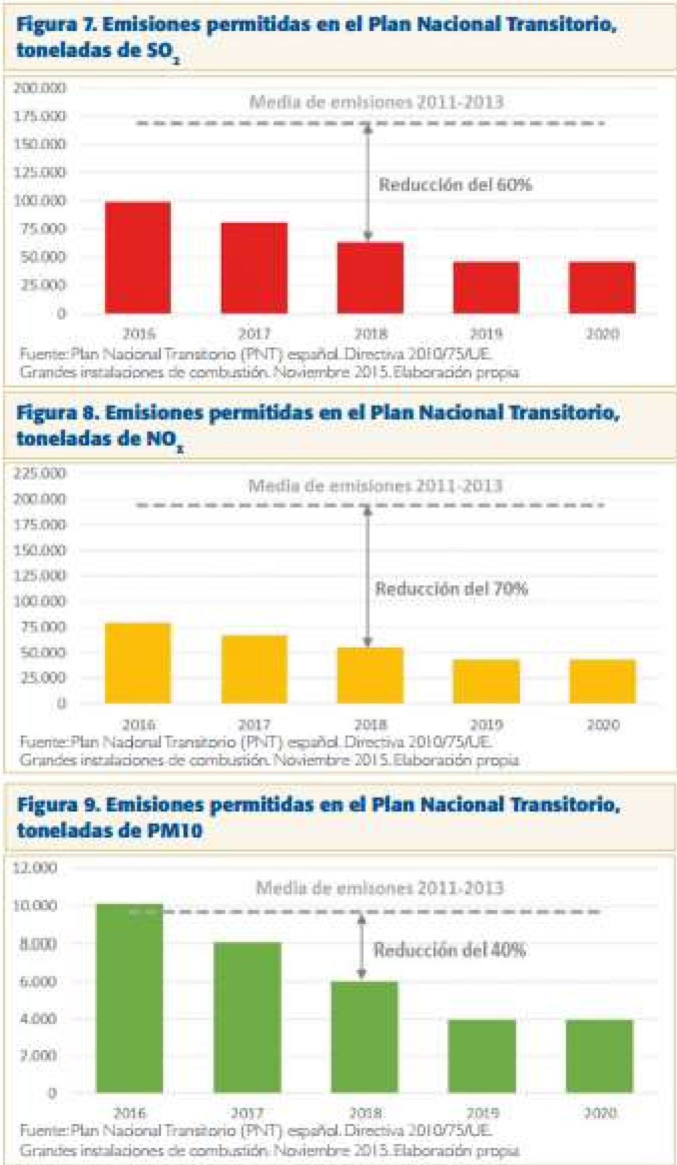

Figure 5 - Evolution of the expected emissions in Spain with the application of the PNT.

The exemption by limited useful life is only thought for those plants that won't invest to adapt to the new regulation and therefore know beforehand that they are going to close in the short term. These installations will be allowed to produce up to 2023 a maximum of 17,500 hours respecting the emission limits established at the end of 2015 (Fernández Montes).

The Plan de Acción Nacional de Energías Renovables de España (PANER), approved in 2010 and enforced for the period 2011-2020, consist on planifying the progressive investments necessary to do in the Spanish energy system to achieve the environmental targets fixed by the third regulatory package.

Those targets, briefly explained before, are accompanied with a path marking the minimum requirements for each year until 2020, where the goal of 20% of utilization of renewable energy sources should be achieved. PANER defines various possible future scenarios of demand, sets goals of installation of renewable capacity and proposes measures to achieve those goals, such as developing heating and cooling infrastructures or promoting the use of specific energy, for example the one generated with biomass (MINETAD, 2010).

2.2.2 Nuclear power plants

At this date, there are seven nuclear power plants operating in Spanish soil (Almaraz I and II, Ascó I and II, Cofrentes, Trillo and Vandellós II) to which an eight one might be added (Santa María de Garoña) if its currently expired operation license is renewed, which has been asked by its owner Nuclenor.

The principal characteristics of the previous power plants are summed up in Table 1 (Foro Nuclear).

Central nuclear	Empresa propietaria	Tipo de reactor	Potencia MWe	Inicio operación comercial
Almaraz I	Iberdrola (53%) Endesa (36%) Gas Natural Fenosa (11%)	PWR	1.049,4	Septiembre 1983
Almaraz II	Iberdrola (53%) Endesa (36%) Gas Natural Fenosa (11%)	PWR	1.044,5	Julio 1984
Ascó I	Endesa (100%)	PWR	1.032,5	Diciembre 1984
Ascó II	Endesa (85%) Iberdrola (15%)	PWR	1.027,2	Marzo 1986
Cofrentes	Iberdrola (100%)	BWR	1.092	Marzo 1985
Santa María de Garoña (*)	Nuclenor ** (100%)	BWR	466	Mayo 1971
Trillo	Iberdrola (48%) Gas Natural Fenosa (34,5%) EDP (15,5%) Nuclenor (2%)	PWR	1.066	Agosto 1988
Vandellós II	Endesa (72%) Iberdrola (28%)	PWR	1.087,1	Marzo 1988

Table 1 - List of the existing nuclear power plants in Spain and their main characteristics.

Nuclear energy generation represents an important part of the Spanish energy mix and its installed capacity is considerable, summing up for more than 7 GW. Moreover, the particular characteristics of such technology, with low variable costs and high start-up costs, make this technology as the base one implying that they operate almost every time and stop only for maintenance reasons. Nuclear power plants often bid at a price lower than its marginal in the day-ahead market to assure being dispatched and not incurring therefore in possible start-up costs, even if the resulting price of the market is not enough to recover the variable costs.

However, the operation licenses of these power plants expire in the following decade. Said licenses were allowed when the units started to produce for the following forty years. These expiration process will begin with Almaraz and Vandellós, whose licenses both expire in 2020.

Additionally, nuclear technology has been socially reprobated almost since its conception. The bombings of Hiroshima and Nagasaki added to the accidents at the nuclear power plants of Chernobyl and, most recently, Fukushima contributed to the idea that the technology is not safe to use.

Even if the energy generation with this technology is clean in the sense that it does not emit pollutant gases to the atmosphere, the problem of managing de nuclear residues, which require a long period of time to completely disintegrate, and the difficulty for security reasons of the processes of constructing, operating and dismantling a nuclear power plant add weight as well to the arguments of the detractors of this technology.

Therefore, a medium-term scenario where the licenses of these units expire and are not renewed, and therefore there is no nuclear generated energy in the system, is not hard to imagine.

This “anti-nuclear” scenario would not be an unusual one. Some countries are considering reducing their nuclear installed capacity and others have even already begun phasing out their nuclear capacity. Several examples are provided next.

Probably, the country that relies the most on nuclear energy is France. 19 nuclear power plants operate in the European country, accounting for 58 nuclear units and delivering the most part of the energy demanded by the system. However, this may soon change, since the recently elected president Emmanuel Macron has pledged to design an energetic transition plan. This plan would include an important reduction of the share of nuclear energy from 75% to 50%, the elimination of coal units and an increase of the renewables share (Schaub, 2017).

While France is still designing its transition, another very important country in the EU, Germany, is already carrying out a plan aiming to a complete closure of nuclear power plants by 2022. This plan also envisages the creation of new renewable energy facilities as well as an enhancement of the existing ones (BBC, 2011).

Other notable examples within Europe are Austria, country that banned the nuclear technology decades ago, or Switzerland, which approving on May 2017 by referendum a plan to ban new power plants and close the existing ones while subsidizing renewable energy to avoid any shortage of capacity (Reuters, 2017).

Within this context appears the debate of the nuclear licenses in Spain. As stated before, these permits expire all in the following decade and both the electric utilities and the Government have to start making decisions. For the two oldest power plants, Almaraz and Vandellós, the renewal of their licenses should have already been asked.

However, some Spanish electric utilities, led by Iberdrola, have asked for more time to the Government to decide, which was accepted. The reason of this is that these utilities are doubting if the nuclear would still be profitable in the future, arguing that with the addition of new taxes they would rather shut down the nuclear power plants. Other utilities, like Endesa, do not agree and support enhancing the lifetime of said power plants from 40 to 60 years. In the middle of this argument lies the Government, who has to present to the European Commission an energy mix plan for the horizons of 2035 and 2050 before March 2019 (Page, 2017).

Additionally, another problem adds to this discussion: the renewal of the license of the Santa María de Garoña nuclear power plant. Once again, the utilities Endesa and Iberdrola, both owners of a share of the power plant, face off: the first wants to reopen it while the latter wants to shut it down for good. Once again, the Government is in the middle of the discussion, having to take a decision concerning the central on August 2017 (Martínez, 04/2017).

As it can be seen, the nuclear energy debate in Spain is heated up and in the center of the debate and it will continue this way at least for two more years, until the Government decides if the licenses are renewed or not. In any case, the upcoming years will be determinant for the future of nuclear energy in Spain and for the Spanish electricity system itself.

Endesa owns entirely or partially the following nuclear power plants:

- Santa María de Garoña (expired license, 50%).
- Almaraz I (36%).
- Ascó I (100%).

- Almaraz II (36%)
- Ascó II (85%)
- Vandellós II (72%)
- Trillo (1%)

Nuclear generation is an important part in the generation portfolio of Endesa. The changes affecting this technology will affect deeply the future of the utility. Therefore, the position of the company concerning this technology is to renew their operation licenses so they can still generate energy for the 20 years more.

2.2.3 Coal-fueled power plants

Since the Industrial Revolution, coal is one of the main used fuels and therefore a very important and strategic resource. It was the first used in combustion, way before oil. Precisely, one of the elements that limited Spanish economic development historically is the absence of energetic resources, in particular the absence of oil and natural gas as well as the poor quality of the coal extracted in national soil. However, to reduce the dependence towards foreign countries, Spanish boosted its production of national coal.

The first power plants to be installed in the country were as well coal-fueled units. This technology dominated the Spanish energy mix until the development of CCGTs and the construction of nuclear power plants. Since then, its presence has faded but it still plays an important role in the Spanish electricity system.

It is necessary to distinguish the power plants consuming national coal from the ones consuming imported coal. The first one is more expensive and of less quality, which would result in power plants producing more expensive energy than the exact same ones using imported coal. However, several subsidies encouraging the consumption of national coal have been established over the years to support the mining industry in Spain and, as a result, thermal power plants fueled by national coal are cheaper than the ones using imported coal or even CCGTs.

However, with the new European Regulations fostering the use of non-pollutant technologies added to the prohibitions to manipulate the market by helping some types of power plants, putting them in an artificial power position with respect to its competition, are quickly ending with this system. The combination of these factors translates into an important loss of competitivity for the coal fueled power plants using national coal in favor of CCGTs and imported coal power plants.

This fact is reflected in the evolution of the mining industry in Spain, shown in Figure 6 (Martínez, 03/2016).

Figure 6 - Evolution of the number of hired people in the Spanish mining industry.

As it can be seen, at the end of the decade of 1980, almost the industry employed 50 thousand people while at this year barely 3 thousand miners are hired.

But the future of the thermal power plants consuming imported coal is surrounded in doubts as well. The new European regulations insist more than ever in the utilization of renewable energy sources in detriment of the traditional ones. In particular, the fight against global warming and the reduction of the emissions to the atmosphere of greenhouse gases are in the center of the discussion. Within this framework, the coal-fueled units are deeply harmed since they are the more pollutant units in the current energy mix. In 2014, 16.5% of the consumed energy in Spain was produced by coal units and however, this technology was responsible for 70% of the CO_2 emissions of the electric industry (REE, 2014).

In November 2010, Directive 2010/75/EU concerning industrial emissions was approved following the trend previously explained. It proposes a reduction on the emission of SO_2, NO_x and other particles to the atmosphere defining goals that have to be achieved progressively. The regulation defined two mechanisms to help complying with the defined limits so the investors are able to plan and define their investment decisions in the new framework. These mechanisms are the 'Plan Nacional Transitorio' (PNT) and the exemption by limited useful life ('Exención por vida útil limitada') (Fernández Montes), detailed in a previous section.

The application of these regulations defines the future of the installed capacity of coal power plants in Spain. 365 MW out of the installed capacity of 10,085 MW of coal generation are included in the exemption and therefore have to close before 2023. The rest of power units will have to respect the emission limits defined by the PNT and to do so, more than half of the existing power plants will require additional investments for reducing the emission of NOx while the rest will need to install desulfidation installations (Fernández Montes).

As stated before, the power plants operating with national coal are the ones that suffer the most the new regulation and which future seems the worse. Spanish electric utility Gas Natural announced June 6, 2017 the closing of one of its national coal power plants, Anllares (Monforte, 2017). Concerning plants with imported coal, it appears that their end is not as near. Utilities are planning future investments to enhance the efficiency and limit the emissions of these centrals. Such is the case for example of La Robla, owned as well by Gas Natural, which will be equipped with denitrification facility to respect the limits imposed by the European Union.

In the case of Endesa, the company has publicly announced its intention of closing the national coal power plants while investing furtherly in the ones consuming imported coal to make them cleaner, as a part of its plan to have a 100% renewable portfolio in 2050.

The strategic plan of the company implies the closure of the power plants of Compostilla and Teruel, both fueled by national coal. Concerning the other two coal power plants in the Iberian Peninsula owned by the company, Puentes and Litoral, the company is going to invest up to 300 million Euros to adapt them to the European environmental directives. With the purchase of the renewable facilities of ENEL in Spain and the intention of building another 300 MW of renewable capacity, the company is compromised with transitioning its generation portfolio from traditional energy sources to green, renewable ones (Loren García, 2016).

Added to this, the local government of the Balearic Islands have approved a plan foreseeing to close the power plant of Es Murterar, composed by coal power units and CCGT, in 8 years. The objective of this action is to reduce by 20% the emission of GHG and enhancing the production of energy with renewable sources (EFE, 2017).

Therefore, it is clear that in the next years the coal generation portfolio of Endesa is going to suffer very important changes, reducing its installed capacity in a great scale.

Overall, Endesa owns the following coal thermal power plants:

- Litoral de Almería (1159 MW)
- Andorra – Teruel (1101 MW, planned closure in 2020)
- Es Murterar (585 MW; coal + CCGT, planned closure in 2025)
- Anllares (365 MW; small share; planned closure in 2017)

- Compostilla II (1199 MW, planned closure in 2020)
- Puentes (2318 MW; coal + CCGT)

2.2.4 CCGT power plants

At the moment, the CCGT power plants are underused and in the shadow of the renewable energy power plants. When they were built, it was expected that gas power plants would surpass the coal thermal plants in use, being less pollutant and more efficient, and the foreseen energy system resulted in one dominated by the CCGTs in detriment of the coal. However, the situation is radically different thing. The irruption and increased competitiveness of renewable energy sources as well as the subsidies to the coal technology have reduced the importance of CCGTs to a backup technology, used only when the renewables are not available.

This lack of usage has brought to the table the question of mothballing the CCGTs. Mothballing a power plant consists on temporarily closing the plant but having in mind that, past some time, it will operate again (it is not a dismantlement of the plant). A mothballed plant doesn't incur in fixed exploitation costs, which are the costs of simply maintaining an operative plant with or without producing energy.

Several Spanish electricity utilities, like Iberdrola, have requested to the Government the authorization to mothball some of their CCGTs claiming that in the current situation, operating a CCGT produces only costs and none profit. The Government have nonetheless rejected these petitions, considering that the CCGTs are important in case of lack of renewable generation. (Raso, 2016)

Therefore, the situation of the CCGTs is not the best it could be, to say the least. However, in the scenarios considered in this study, the other manageable generation power plants of the region are shut down, namely the nuclear and coal thermal plants. This gives a very important advantage to the CCGTs, its precise characteristic that the renewable power plants lack: the manageability. It is possible that in this system the CCGT regain the key role they were supposed to have in the first place.

The generation using gas would be affected as well by the new European norms penalizing pollutant technologies. However, being more efficient and less pollutant than coal thermal power plants, it is reasonable to think that CCGTs will surpass coal plants in competitivity and will occupy a more dominant part of the system.

Considering additionally that the renewable technologies, increasingly present in the system, have an intermittency trait (wind and solar power), the system will need the gas in order to cover a share of manageable energy able to help solving the energy deficits caused by the lack of wind or sun. It is clear therefore that the future of gas in electricity generation is assured in the medium term.

Additionally, if the future possible scenarios exposed in the previous sections came to reality, it is possible that the installation of new CCGT capacity would be necessary in order to achieve the desired reserve margin objective.

The reserve margin is the ratio between the difference of the installed capacity and the peak demand of the system, and the peak demand of the system, as shown next.

$$RM(pu) = \frac{Capacity - Peak\ Demand}{Peak\ Demand}$$

It is accepted that a reasonable value of reserve margin for an electricity system working properly in normal conditions should be around 1.1 pu.

As of December 31, 2015, the Spanish electricity system counts with an installed capacity of 101,027 MW (considering only the generation in the Iberian Peninsula). That same year, the peak demand was reached February 4 and attained a value of 40,726 MW (again, considering only the demand on the Iberian Peninsula). The reserve margin for year 2015 was therefore of 1.48, largely surpassing the required minimum (REE, 2015).

However, this may change depending on how the installed generation capacity and/or the demand behavior change. For the latter, as exposed in the next chapter, it will be necessary to consider if the demand will grow or if it will stay stable for the establishment of energy efficiency policies. Concerning generation, the situation of the nuclear and coal generation technologies (exposed in past sections) and the renewable generation (next section) should be studied.

It is necessary to check if the reserve margin of the different scenarios is at least equal to 1.1. For example, considering a hypothetical scenario where all the nuclear power plants are closed and the demand increases by a 10%, the resulting reserve margin will be around 1.05 pu. In this particular case, the installation of new CCGTs is required.

Therefore, it can be concluded that despite the current situation of stand-by of the technology, the existing CCGTs are going to have more important roles in the years to come, being even necessary to plan the construction of new ones.

Endesa owns the following CCGTs:

- Besós 3 (100%, 412 MW)
- Besós 4 (100%, 859 MW)
- Colón 4 (100%, 390 MW)
- Pego 3 (50%, 418 MW)
- Pego 4 (50%, 418 MW)
- Puentes 5 (100%, 834 MW)
- San Roque 2 (100%, 401 MW)

The gas portfolio of the company is less important than the coal generation one at the moment. However, disregarding if more CCGT capacity is installed in the following years, it may become the principal portfolio of the company after the already planned closures of coal power plants. This fact will depend on the future investments that the company may undertake in new renewable capacity.

2.2.5 Renewable energy sources

The year 2017 started with the news that, in June of the same year, a renewable capacity auction of 3000 MW would be held. Aiming at the goals fixed by the European Union within the “20-20-20” targets, Spain has to install more renewable capacity as will explained on this section.

Throughout the year 2017 and at the beginning of 2017, various renewable capacity auctions were held all over the world, having each and every one of them a common denominator: the price of solar PV had dropped and was now able to compete in equal footing with the other technologies on a wholesale market. As an example of this: the auction in Denmark from December 28, 2016, where 20 MW were allocated at 46$/MWh (Clover, 2016) or the auction in El Salvador from January 12, 2017, where 120 MW were allocated at 50$/MWh (Díaz López, 2017)

Being clear the economic solvency of the PV solar technology, the question lies with another very popular renewable energy source: wind power. This one, the cheapest technology after hydro power, very well could lose its advantageous position in front of the push of the PV solar, who is growing rapidly and appears to be entering finally in its maturity phase. However, it still has a major advantage with respect to solar PV energy: while this energy working hours are clearly bounded to the solar hours, wind power energy is able to produce during both day and night. This quality has proven to be determinant in some auctions, like the ones held in Spain during 2017, which were largely won by wind power due to its ability to produce during longer periods of time.

This competition between renewables, its increase in competitiveness against traditional energy sources and the international example of countries like Germany, in the middle of an aggressive transition towards an electric system centered in renewables with very telling measures such as the early closure of the German nuclear power plants, a scenario in which Spain decides to follow this example and hop in the "renewables train" is very plausible.

For the moment, the installed capacity of these technologies is not enough to achieve the targets fixed by Brussels. For 2015, the Spanish Government foresaw in its National Renewable Plan (Plan de Acción Nacional de Energías Renovables, PANER) that 16.7% of the total consumption of energy should come from clean sources, having in mind that 5 years later, in 2020, it should be at least of 20%. However, the actual consumption of renewable sources for that year was finally of 15.6%, one point below the objective (Planelles, 02/2017).

Figure 7 shows the evolution of consumption of energy coming from renewable sources in Spain (MINETAD, 2011):

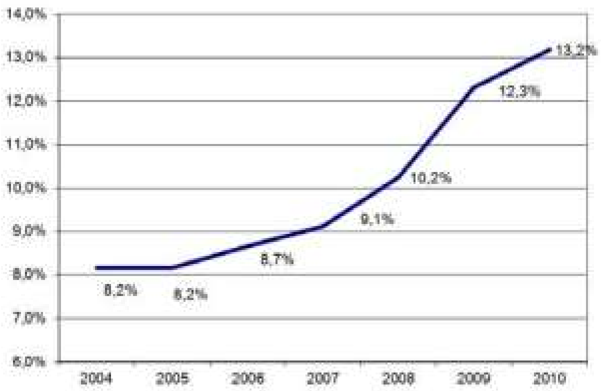

Figure 7 - Evolution of the usage of the RES in Spain for energy generation.

In the past ten years, the production of energy coming from renewable energy sources has progressively increased, doubling its volume in the process. The conventional generation has followed the opposite trend and has reduced its output. Although in past years this process has been stopped due to the tariff deficit created, in part, by the over-the-top renewable subsidies, renewables will start to grow again in Spain in the following years with new installed capacity allocated with the help of renewable energy auctions organized by the Spanish Government.

The total consumption of energy is the sum of three major consumptions: electricity generation, transportation and heating and cooling. Even though 36.9% of the electricity generated in 2015 came from renewable sources, the other two sectors are holding the renewable objective down. Improving in transportation is a difficult task, since the main solutions consist on encouraging the purchase of electric vehicles or favorizing the use of public transport. Some progress has been made in this direction, with a lot of cities launching municipal clean vehicle rentals with electric cars and electric bikes, but the traditional car, fueled by oil or diesel, is still the sovereign of the transportation sector. Concerning heating and cooling, some progress was made with to the year before, but were clearly not sufficient: clean sources grew from 15.75% to 16.78%. (Planelles, 03/2017).

For this reason, most of the weight for achieving the fixed goals lays on the electricity industry. The installed generation capacity in the electricity system has to be sufficient to cover for the deficiencies in the fulfilment of the European renewable objective by the other two sectors.

The Government hopes to fulfill with the European environmental goals with the help of the new capacity. In the last auction, 3000 MW of renewable capacity was auctioned. As a result, not only was all the auctioned capacity allocated, but the final conditions were very good for the Government and the system, since the 3000 MW were allocated without subsidies: for the first times, companies were assuring the installation of new renewable generation without requiring the economic help of the Government. Amongst all the players, one shined above all: the Aragonese company Forestalia, getting 1200 MW out of the 3000 offered. (Noceda, 2017)

Having seen the complete success of the recent auctions, the Spanish Government is organizing more auctions to push the installation of new renewable generation at competitive prices. The next auction, that will seek the allocation of another 3000 MW of renewable capacity, will be hold as fast as possible since the deadline for the fulfillment of the environmental targets for 2020 is fast approaching. If the trend defined by past auction held in Spain and all over the world doesn't vary, which seems unlikely, the result of this auction will be of new generation without subsidies as well. (Expansión, 2017)

Figure 8 shows the forecasts made by the Spanish Energy Ministry (Ministerio de Energía, Turismo y Agenda Digital) for the penetration of renewable energy sources on energy consumption (MINETAD, 2011).

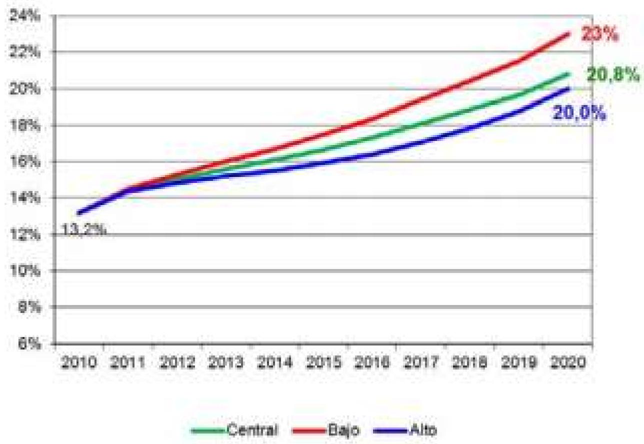

Figure 8 - Evolution of the penetration of the consumption of renewable energy in Spain.

The ministry defines three scenarios: one with low penetration of renewable energy sources, a central one with the most probable outcome and an optimistic one with high penetration of renewable energy. In all three cases, the European targets are met.

Being these conditions very advantageous for the system since they reduce the cost of generation and having in mind the European environmental targets for 2030, which include cutting by 40% the emission of greenhouse gases and increasing at least 27% the share of renewable energy consumption, it is realistic to foresee that more auctions will be hold in the future and the installed capacity of renewable energy sources will not cease to increase in the following years.

In conclusion, the renewable installed capacity in Spain will grow sharply in the following years. For starters, 6000 MW are already planned to be installed before 2020, allocated through two renewable auctions held in 2017. Once the objective for 2020 is achieved, its growth may be slower but in any case, it should quickly rebound because of the phase out of some coal thermal power plants and the European environmental objectives for 2030.

Endesa acquired in the summer of the year 2016 the assets from Enel Green Power España (EGPE), consisting of 1,674 MW of renewable capacity installed in Spain (1617MW of wind power, 43MW of hydropower and 14MW of other renewable energy sources).

In the renewable auction held in May 2017 by the Spanish Market Operator OMIE, Endesa managed to get 540 MW to add to its portfolio, making a grand total of 2,157MW of wind power. Added to the 4,765MW of large scale hydropower, it accounts for 6,431MW of renewable capacity.

Therefore, the company is growing stronger in the renewable field with the EGPE assets and the new capacity from the latest auction. However, the company is still far away from the leader in renewables in Spain, Iberdrola, which had in 2015 an installed capacity of wind power of 5,576MW and a total renewable capacity of 27,870MW, including large scale hydropower.

2.3 Energy demand in Spain

The evolution of the energy demand is closely related with the economic and demographic developments. In Spain, the demand for electric energy grew every year without exceptions until the arrival of the 2008 economic crisis. The country entered in an economic recession, the GDP decreased as did the demand for the first time in History.

According to the forecasts from the Banco de España, as of June 2016, the GDP will grow 2.3 points in 2017 and 2.1 in 2018 (BdE, 2016). Even if this forecast may vary (and they probably will do so), they serve as an indicator of the general future evolution of the Spanish economy. A growth patron is observable though it is starting to decrease (the GDP grew by 3% in 2015 and by 2,7% in 2016). Therefore, one can imagine a scenario in which the total demand in Spain grows.

The evolution of the electric energy demand in the recent years is shown in Figure 9 (Energynews, 2015). Next, figure 10 represents the evolution of the Spanish GDP (Energynews, 2015).

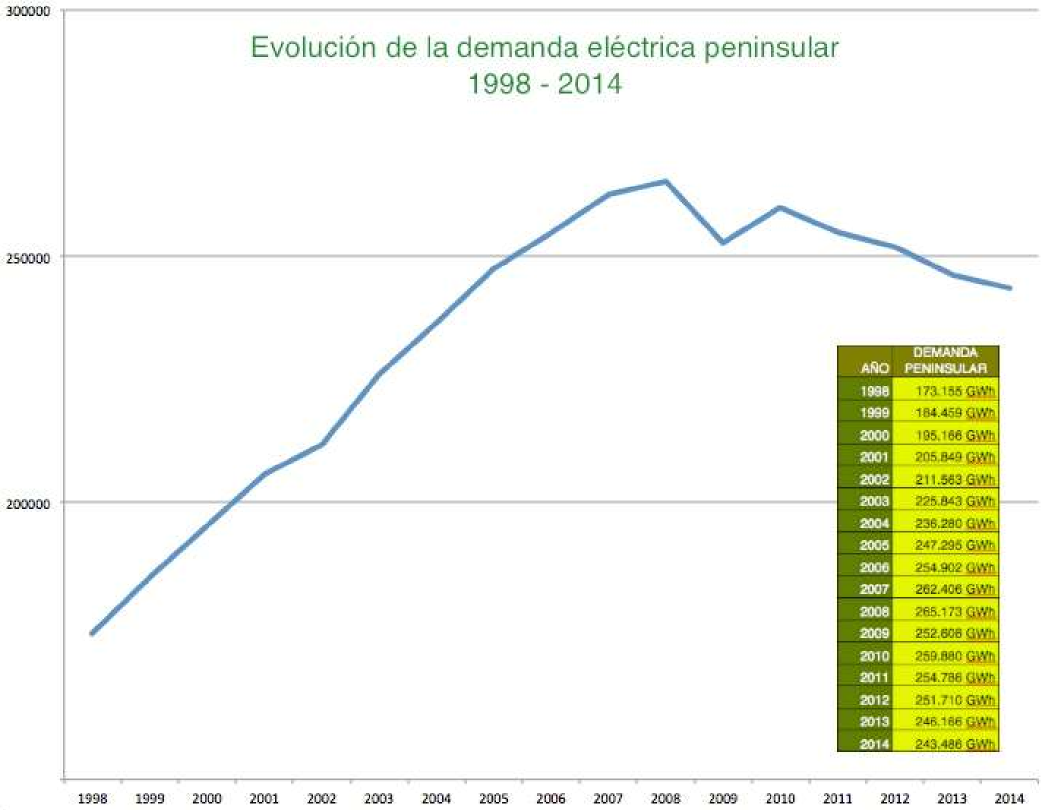

Figure 9 - Evolution of the Spanish peninsular electricity demand.

Figure 10 - Evolution of the Spanish GDP.

As it can be seen, both graphs are correlated. When the GDP starts decreasing in the year 2008, so does the Spanish electricity demand. After a brief upturn in the year 2010, when the demand grows once again and the correlation is thus broken, the demand starts once again to follow the evolution of the GDP.

The correlation between demand and GDP is clear studying the trends of its annual variations, as shown on Figure 11 (REE, 2015).

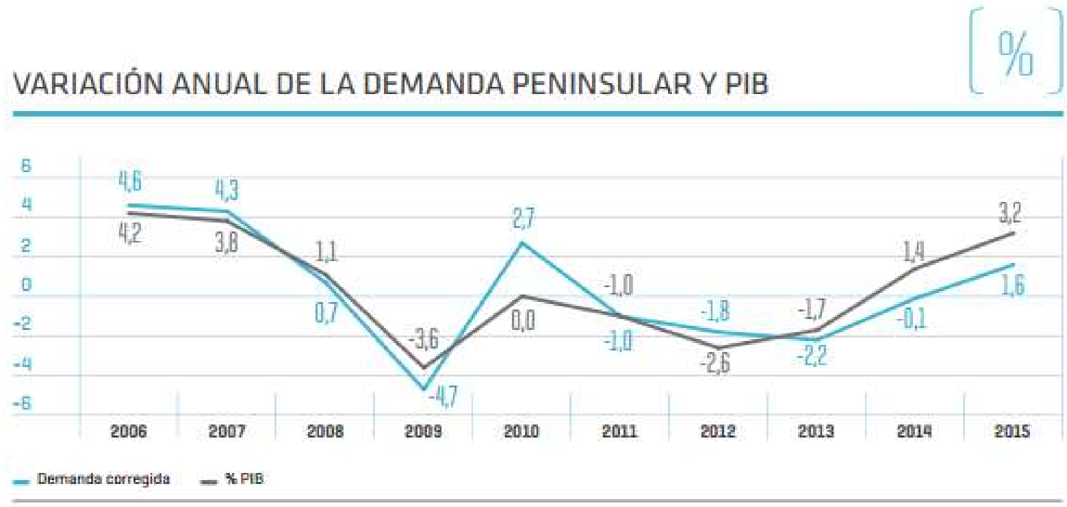

Figure 11 - Evolution of the annual variations of the Spanish peninsular electricity demand and the Spanish GDP.

The correlation is evident. Even if in some years the demand decreases while the GDP grows (i.e., 2014), the first derivatives of both variables are related.

However, the Ministerio de Industria started a national plan of energy efficiency, following the trend of the European regulations and directives. These policies are relatively new and the effects of its practical application in the system have never before been experimented. It is possible that, despite the economic and demographic growth and thus despite the apparent growth of the electric demand, the effective growth of the demand would be zero due to the application of these energy efficiency policies, which may neutralize the effects of the economic growth on the demand. In other words, this apparent correlation may not be valid.

Therefore, to get a full grip of what may happen in the future concerning the demand, it is necessary to see the whole picture and not consider only the possible economic growth.

On these considerations, the Department of Risk Management of the Spanish utility Endesa, collaborating with this report, updates every month a report with the annual forecasts of the electricity demand in Spain and Portugal for the next 20 years. As it is sensible and confidential information, it isn't shown in the report.

Whatever it may be, and as stated previously, the available capacity in the system has to be sufficiently high to have a reserve margin (ratio between the available capacity and the peak demand) superior to 1.1, value marking the acceptability threshold for an electric system. If the forecasted growth of the demand is sharp, the System Operator should plan the installation of new power units to fulfill the reserve margin requirements.

Concerning Endesa, the utility is situated in a comfortable position in the market. Its commercialization activity is summed up in the figure 12 (Endesa).

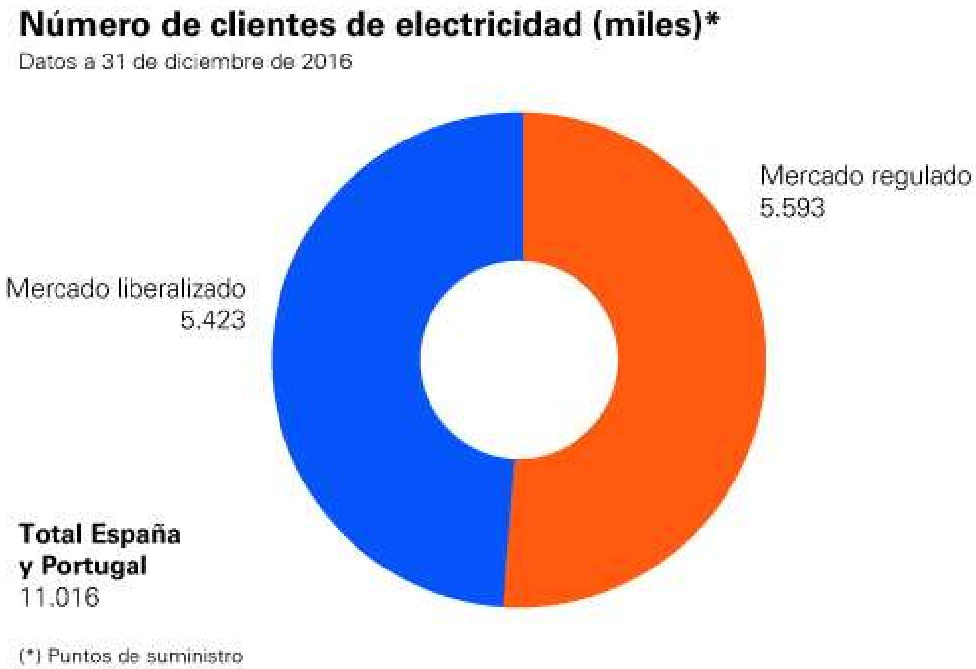

Figure 12 - Number of clients of Endesa.

As one of the last resort retailers, it sells energy to over 5 million consumers choosing the last resort tariff (PVPC: Precio Voluntario al Pequeño Consumidor) accounting for a grand total of 13,815 GWh, translated into a return of 2,412 million Euros. Added to this, the company is present as well in the Iberian liberalized market, selling 79,675 GWh which accounted for a return of 8,213 million Euros in 2016.

With over 11 million clients, Endesa is one of the top retailers of electricity and is therefore very much affected by the variations of the electricity demand.

3 COST OF RISK IN RELATION TO THE GENERATION MIX

3.1 Inputs to the model

3.1.1 Historic and forwards of the commodities

The model needs historic series and forward prices of certain commodities to be able to generate the time series for the market model. Those commodities are API4, NBP, C4, EUA and FX.

The historic values are public and easily obtainable. However, the commodities forward change every day and forecasting the future value of said commodities for a certain year is tricky. For this reason, the department of Risk Management has shared its forwards for commodities and demand for the realization of this project. Since this data is confidential, they cannot be reproduced in this report.

As stated previously, the update historic and forward series of the commodities are used in the generation of time series for the electric market model.

3.1.2 Scenario definition

Based on the analysis of the possible evolution of the different generation technologies and the demand, a set of scenarios for the different considered variables have been built, being more or less likely.

It is important to note that, for all these scenarios, the NSE Price has been considered to be 300 €/MWh and not the current value of 180 €/MWh.

At this date, Spain is the only member state of the European Union that limits the wholesale market price to 180 €/MWh, for historic reasons. The majority of European states price its non-served energy at 300 €/MWh. However, due to the increased integration of the different national electric systems within the European Union, it is not very likely that this situation will continue in the future. To favorize integration and probably as a requirement by the European Union, the Spanish non-served energy price will be 300 €/MWh, homogeneous with the rest of the Union. This project is based on this scenario.

The different scenarios are the following.

NUCLEAR GENERATION:

- Closure of the power plants: not a single nuclear power plant operating in the Spanish electric power system in 2025, either because of an early closure or because of the expiration of the licenses.
- Renewal of the licenses: the regulatory authority considers that the Spanish electric power system cannot be operated without the nuclear power plants and therefore the operation licenses are renewed. In this case, all the power plants would be still in action.

COAL GENERATION:

- Early closure of the coal power plants: due to the expiration of the operation licenses, because they are not profitable anymore due to the reduction of competitiveness due to the new environmental regulations in favor of CCGTs or because the high penetration of renewables has put the technology aside, there are no coal power plants in the 2025 Spanish electric power system.
- Early closure of the power plants fueled by national coal: national coal stops being competitive with respect to the imported coal due to the lack of subsidies and the weakened position of the technology as a whole due to the environmental regulations. Thus, national coal is can no longer compete against the imported one and the power plants specifically designed for the first have to close. In this case, the only coal plants in the system are the ones fueled by imported coal.

CCGT:

- The reserve margin is superior to 1.1: there is no need to install new CCGT capacity. The ones already present in the system are enough.
- The reserve margin is inferior to 1.1: new CCGTs have to be built. The technology will grow in importance due to the lack of other generation and Will most probably enter the intraday market with more regularity that in the current system.

DEMAND:

- Spot on forecast of demand growth: the yearly demand growth forecasted by the risk management team of Endesa is spot on and the demand grows following the defined trends.
- Conservative forecast of demand growth: the real demand growth trend is sharper than the one of the yearly demand growth forecasted by the risk management team. The previsions of demand growth inputted into the model are increase by 25%.

RENEWABLES:

- The "20-20-20" targets are not fulfilled: the penetration of renewable energy sources in lower than 20% of the total energy consumption. Pessimistic case scenario.
- The targets for 2020 are fulfilled but the ones for 2030 are still far away to be achieved: the penetration of renewable energy sources is superior to 20% of the total consumption of energy, but less to 27%. Moderate case scenario.
- Both targets are fulfilled by 2025: the penetration of renewable energy sources is superior to 27% of the total consumption of energy. Optimistic case scenario.

Ideally, there should be as many simulations as different possible combinations of the previous scenarios.

For obvious reasons, this is not possible. Running the model for a single scenario takes around ten hours, and the variations between some possible scenarios are almost neglectable. Therefore, four representative scenarios have been created, from more to less conservative. They are displayed in table 2.

Scenario	Nuclear	Coal	CCGT	RES	Demand
1	Yes	Only imported	Existing	2020 fulfilled	+0%
2	Yes	Only imported	Existing	2030 fulfilled	+0%
3	No	Only imported	RM	2030 fulfilled	+0%
4	No	Only imported	RM	2030 fulfilled	+25%

Table 2 - Scenarios simulated with ARIES.

For all scenarios, the base data (installed generation, base demand, etc.) corresponds to the Spanish electric power system in 2016.

Concerning CCGTs in the scenarios 3 and 4, the reserve margin has to be calculated to decide if new CCGT capacity should be installed in the system. Scenarios 1 and 2 respect the reserve margin: originally, in the current state of the system, the reserve margin limit is respected and in those scenarios the addition of generation is superior to the removal.

As stated previously several times, the demand growth values are confidential and therefore the calculations of the reserve margin cannot be shown. After calculating it for both scenarios, the following results are obtained.

Scenario	RM lower bound	RM upper bound	Conclusion
3	1.14	1.25	Additional CCGTs not necessary
4	1.14	1.19	Additional CCGTs not necessary

Table 3 - Reserve Margin for scenarios 3 and 4.

These four scenarios have been inputted within the price scenario module and the resulting data has been fed into the electric market simulator. The results are shown in the different subsections of section 3.2.

3.2 Risk Analysis

For all of the four scenarios, 1000 simulations have been held. The horizon simulated has been from the year 2017 to 2025 and the output from the model is the average yearly price and the average yearly margin for the company. Therefore, for each year of each scenario there are 1000 values of market price and company margin.

It is possible to build a normal distribution using those 1000 values as it will be shown below. The different tools used to evaluate the risk, presented in the next section, are based on such distributions.

Although the only results that concern this report are the ones of the year 2025, in the section corresponding to the analysis of the first scenario the results of other years will be shown, to see the effects of simulating further in time and comparing the results of different years for a same scenario.

3.2.1 Risk evaluation tools and definitions

The risk analysis is going to be performed based on normal distributions as stated before. The profitability of the scenarios is measured by the mean value of the average yearly margin normal distribution while the risk is measured by the Margin at Risk (MaR). An additional tool, the Return on Risk-Adjusted Capital (RORAC) is used to compare the four scenarios and establish in which one the company is better positioned.

As stated numerous times in this report, the results obtained are confidential and therefore cannot be shown in a literal way. This applies to the results obtained with the risk analysis tools as well. Instead, a qualitative analysis of each scenario based on the actual results is proposed with the aim of comparing the four different scenarios.

Since it is a normal distribution, its mean can be found straightforwardly by simply calculating the mean of the 1000 different scenarios.

The Margin-at-Risk, MaR, is a measure used to manage risks due to variations in commodity markets. It quantifies the worst margin call case in function of the market prices for a certain degree of confidence. It can be calculated knowing its normal distribution. For a degree of confidence of 95%, corresponding to Z=1,65, the MaR is:

$$MaR = 1.65 * \sigma + \mu$$

In order to compare the different scenarios, the RORAC tool is used. It is generally defined as the mean return of a portfolio, or the net income, divided by the allocated risk capital.

$$RORAC = \frac{Net\ Income}{Allocated\ Risk\ Capital}$$

This measure helps to compare different scenarios with different risk profiles, since it considers not only the expected return of each scenario but also the risks, performing a complete analysis. Since the data concerning the inversion is not available, the allocated risk capital has been approximated with the Margin-at-Risk. The measure calculated is not properly the RORAC, but it allows a better understanding of the global behavior of the distribution and therefore, serves as a basis for the comparison of the scenarios.

3.2.2 Scenario 1

The electricity system simulated in the scenario 1 has the same characteristics as the Spanish electricity system during year 2016 with an additional installed capacity of 6000 MW of wind power generation, allocated during renewable auctions held by the Government in order to achieve the European environmental targets for 2020, and without the installed capacity of coal energy generation with national coal. The eliminated generation capacity accounts for a 2314 MW for Endesa and a combined amount of 5664 MW for all the Spanish utilities.

In this section, not only are the results of scenario 1 going to be presented, but also some figures detailing the behavior of the margin distribution with the time that are general to all the scenarios.

In Figure 13 the distributions for the different years of the simulation are shown.

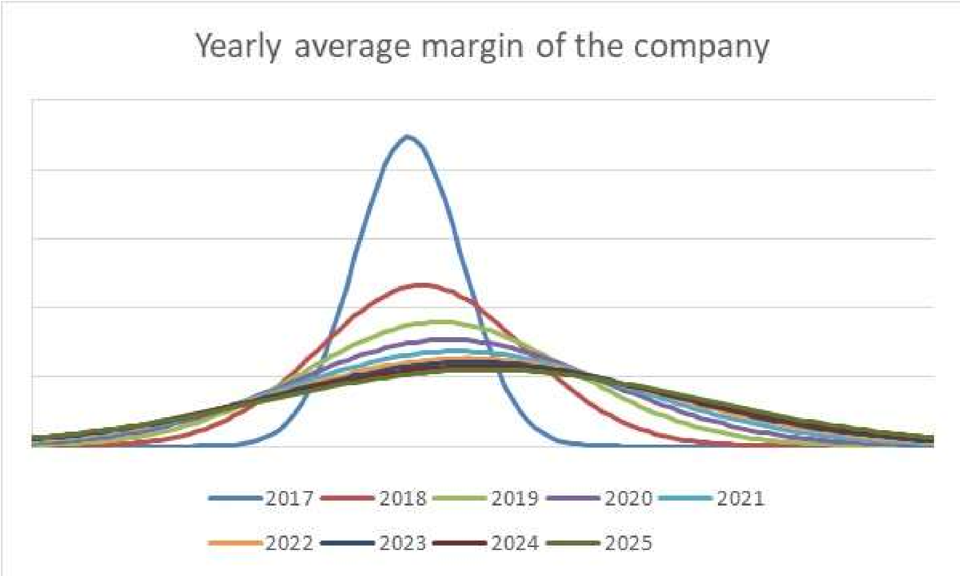

Figure 13 - Margin distribution for the interval 2017-2025 simulated in scenario 1.

As it can be seen, as the years go by, both the mean value and the standard deviation of the distribution increase. This means that the expected margin is higher but the risk is also higher and therefore there is more uncertainty.

The normal distribution for the company margin obtained for the year 2025 in this scenario is shown in Figure 14.

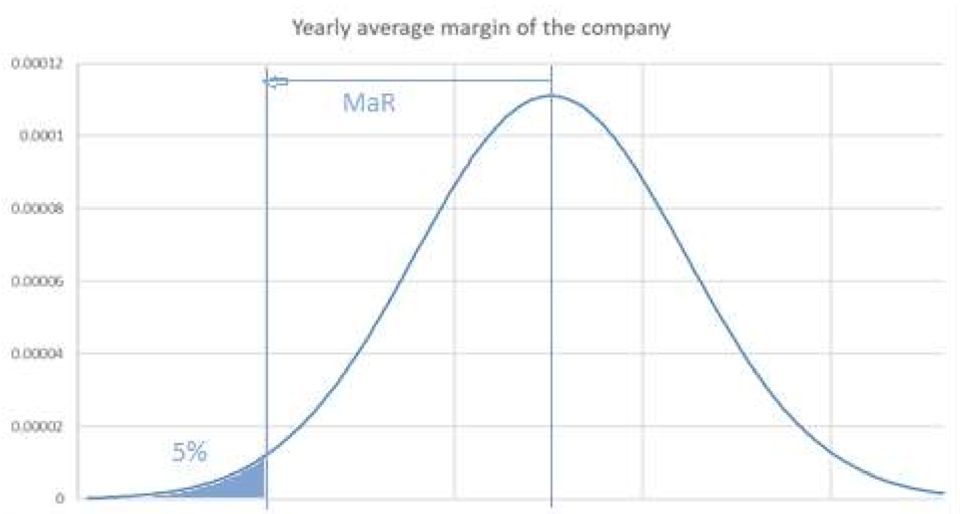

Figure 14 - Margin distribution for the year 2025 simulated in scenario 1.

For the scenario 1, the mean margin grows with the years and it reaches its maximum value for the year 2025. The standard deviation follows the same trend though and therefore, the MaR too. For the year 2017, the MaR of the scenario was positive (with

95% of confidence, in the worst-case scenario the company does not lose money but wins less). However, for the year 2025, the MaR is negative (and therefore, in the worst-case scenario the margin shrinks and the company loses money).

3.2.3 Scenario 2

The electricity system simulated in scenario 2 is the same as the one of the first one with the addition of another 6000 MW of wind power to direct the electricity system towards the environment goal of having a 27% of the total energy consumption in the country produced by renewable energy sources in 2030.

The results for this scenario are shown in Figure 15.

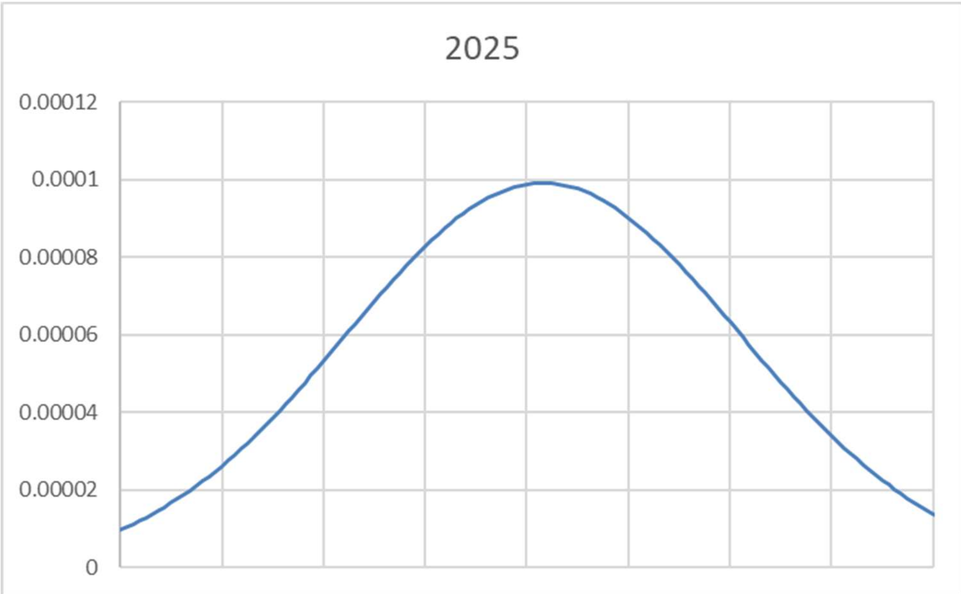

Figure 15 - Margin distribution for year 2025 in scenario 2.

The results for this scenario are very similar to the ones from the first scenario. The MaR and the mean margin follow the same trends. The difference here is that the margin is less important while the MaR is bigger. The renewables introduced in the system enter in the market instead of the CCGTs, which are an important part of Endesa’s portfolio, which would explain the reduction in margin and the higher uncertainty.

3.2.4 Scenario 3

The electricity system simulated in scenario 3 is the same as the one of the second one without the nuclear generation capacity. In this scenario, it has been considered that the operation licenses are not renewed and therefore, all the nuclear plants are closed. It was studied as well if additional CCGT generation was necessary, but since the reserve margin is sufficient, the installed capacity of combined cycles stay the same.

The results for this scenario are shown on Figure 16.

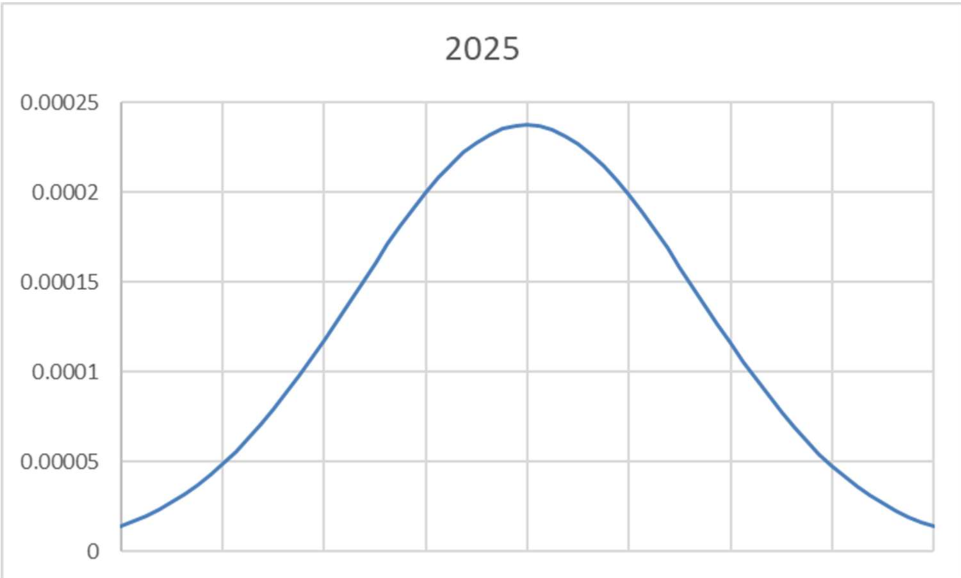

Figure 16 - Margin distribution for the year 2025 in scenario 3.

The difference between this scenario and the first one is more important than the difference between the two first scenarios, as it is shown in section 3.2.6. The MaR and the mean margin follow the same trend as in scenario 1 but a lot smoother. In this case, the Margin-at-Risk is positive for two years in a row and the maximum attained at 2025 is lower for both the MaR and the mean margin. This may be explained by the exit of the nuclear generation from the system: Endesa loses its nuclear generation, an important source of income, and its margin suffers the consequences. However, the spot left free by the nuclear is occupied by the CCGTs, unoccupied until then. The utilization of the CCGTs softens the drop of the margin and reduce the uncertainty since now it is more probable that the CCGTs are dispatched in the wholesale electricity market.

3.2.5 Scenario 4

The electricity system simulated in scenario 4 is the same as the one of the third one with an increase in the total demand of the system. As stated previously, for confidentiality reasons it is not possible to explicit the yearly demand growth rate. In this scenario, this growth rate was augmented a 25%.

The results for this scenario are shown in Figure 17.

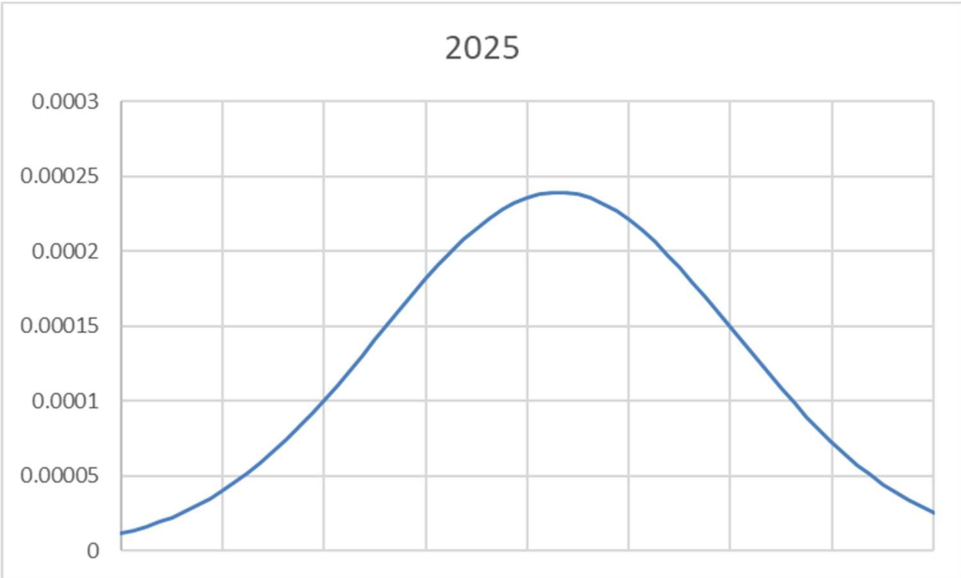

Figure 17 - Margin distribution for the year 2025 in scenario 4.

Parallelly to the relation between the two first scenarios, this scenario is pretty similar to the third one due to the softness of the change between scenarios. The demand increase results in an increased quantity of energy sold by the company and therefore the mean margin grows while the standard deviation representing the uncertainty slightly shrinks.

3.2.6 Scenario comparison

In this section, the four scenarios presented previously are compared.

Figure 18 represents graphically the distributions of the four scenarios.

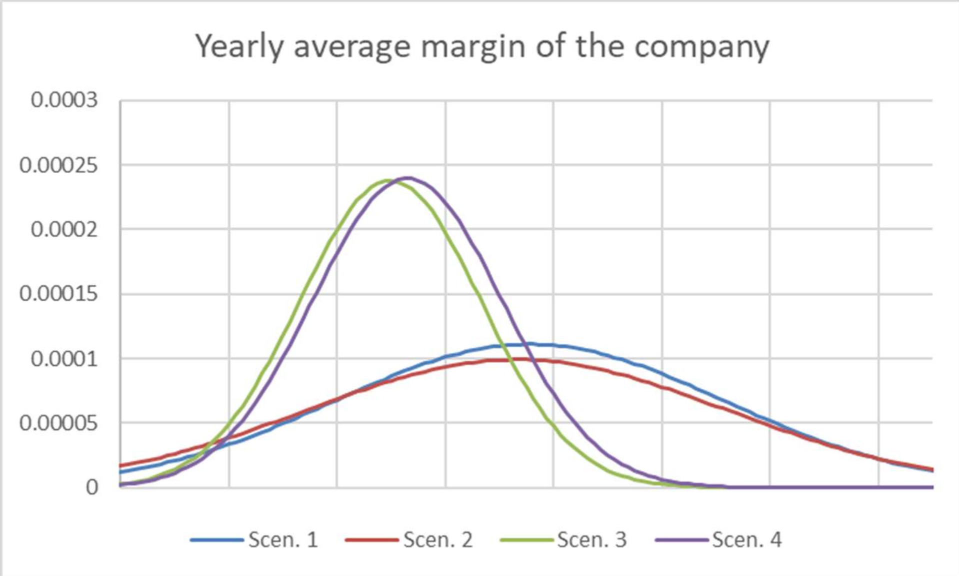

Figure 18 - Comparison between the margin distributions obtained in the different scenarios.

It can be seen that scenarios 3 and 4 are clearly differentiated from scenarios 1 and 2. This is because the change between scenarios 2 and 3 (loss of the nuclear generation) is by difference the roughest of them all. In comparison, the changes from 1 to 2 (increase of the non-dispatchable renewable capacity) and from 3 to 4 (increase of the demand growth) are much slighter. However, those changes are still noticeable, as it is observable that scenario 4 has bigger mean margin than scenario 3 and the same for scenario 1 with respect to scenario 2.

At a single glance, it is clear that the margin of the company is bigger for the scenarios 1 and 2. However, the risk and uncertainty of said scenarios are bigger too and therefore it is hard to establish which scenario is more profitable at first glance.

A qualitative summary of the measures associated with each of the scenarios is provided in Table 4. The different scenarios are ranked in function of the values of the different measures applied to them.

Note that the higher the mean margin or the RORAC, the better. For the case of the MaR, the lower it is, the better.

Scenario	Mean margin	MaR	RORAC
1	I	II	II
2	II	I	IV
3	IV	III	III
4	III	IV	I

Table 4 - Comparison of the results of the different scenarios.

The most profitable scenario for the company is therefore the fourth, followed in order by the first, the third and finally the second.

The main driver behind the good position in the scenario 4 is the CCGT portfolio, that would acquire a dominant role in the system in that scenario, and the increase in demand.

In the scenario 3, the company goes down because of the very important loss of its nuclear portfolio which represents an important loss of market power. To hedge against this situation, the company should prepare an energy transition plan to furtherly diversify its portfolio towards renewable energy sources.

Finally, for both scenarios 1 and 2 the main problem is the little presence that the company has in the renewables sector. The margin of the company is high because the nuclear generation portfolio is still active in those scenarios but the important presence of renewables, accentuated in the second scenario, increase dramatically the uncertainty because this technology kicks out of the system the CCGT and remaining coal generations, very present in the company's portfolio. The best solution here is therefore to continue the line of the previous years and become strong within the renewables market.

4 CONCLUSIONS

In this project, four risk analyses have been performed with the model ARIES to study the future position of the company Endesa considering several hypothetical changes in the Spanish electric power system.

It has been found that a high penetration of renewables increases the risk of the company due to its investments in coal and CCGT generation. These two technologies would be kicked off the market by the increasing number of renewables and the presence of nuclear generation, acting as manageable base technology. A nuclear closure would also affect the company reducing its margin because of the important share of nuclear generation owned by Endesa. On a positive note, it would reduce the risk since the coal and CCGT plants would be more demanded than ever by the system.

Prior to the realization of this project, the model ARIES was very rarely used in the company. As a result, the data was outdated. For the realization of the project, the model has been reupdated and is ready to be used once again for future analysis.

These future analyses may consist on modelling the client's portfolio to assess the impact that the variations on the client's behavior can have on the margin and risk of the company.

Even if in this project, the model has been used as a tool to study the possible future of the company, ARIES is also designed as a decision support model. Using the analytical tools described in this report, the model can show the possible effects that two different investment decisions may have on the company on the long term, and helping management to decide.

BIBLIOGRAPHY

In order of appearance.

(MINETAD, 2010) *Plan de Acción Nacional de Energías Renovables de España (PANER) 2011-2020,* Ministerio de Industria, Turismo y Comercio, June 30, 2010.

(Fernández Montes) Fernández Montes, Y., *La directiva de emisiones industriales y las centrales térmicas de carbón en España*, Cuadernos de Energía, EDP España.

(Foro Nuclear) *Energía Nuclear en España*, Foro Nuclear, http://www.foronuclear.org/es/energia-nuclear/energia-nuclear-en-espana, consulted 24/03/2017.

(Schaub, 2017) Schaub, C., *Transition énergétique: l'écolo et le lobbyiste*, Libération, http://www.liberation.fr/futurs/2017/05/18/transition-energetique-l-ecolo-et-le-lobbyiste_1570600, May 18, 2017, consulted 30/06/2017.

(BBC, 2011) *Germany: nuclear power plants to close by 2022,* BBC, http://www.bbc.com/news/world-europe-13592208, May 30, 2011, consulted 30/03/2017.

(Reuters, 2017) *Swiss voters back plan to phase out nuclear power*, Reuters, https://www.nytimes.com/2017/05/21/world/europe/swiss-voters-back-plan-to-phase-out-nuclear-power.html, May 21, 2017, consulted 30/06/2017.

(Page, 2017) Page, D., *El Gobierno cede ante las eléctricas y da más tiempo para decidir si amplían las nucleares*, El Independiente, https://www.elindependiente.com/economia/2017/05/26/gobierno-cede-ante-las-electricas-da-mas-tiempo-decidir-amplian-las-nucleares/, May 26, 2017, consulted 30/06/2017.

(Martínez, 04/2017) Martínez, V., *Iberdrola y Endesa chocan en Garoña y dejan en el aire el futuro de las nucleares*, El Mundo, http://www.elmundo.es/economia/empresas/2017/04/27/5900d63eca474199568b464b.html, April 27, 2017, consulted 30/06/2017.

(Martínez, 03/2016) Martínez, V., *Los últimos mineros del carbón*, El Mundo, http://www.elmundo.es/economia/2016/03/20/56eaf35ae2704e78128b4607.html, March 20, 2016, consulted 30/03/2017.

(REE, 2014) *El sistema eléctrico español 2014,* Red Eléctrica de España, 2014.

(Monforte, 2017) Monforte, C., *Gas Natural anuncia el cierre de la central de carbón de Anllares, en el Bierzo*, El País, https://cincodias.elpais.com/cincodias/2017/06/06/companias/1496737630_078640.html, June 6, 2017, consulted 30/06/2017.

(Loren García, 2016) Loren García, E., Monforte, C., *Endesa prevé cerrar sus centrales de carbón nacional en 2020*, El País, https://cincodias.elpais.com/cincodias/2016/11/23/empresas/1479888016_442702.html, November 23, 2016, consulted 30/06/2017.

(EFE, 2017) *El Govern quiere cerrar la mitad de la central de Es Murterar antes de 2020*, El Mundo, http://www.elmundo.es/baleares/2017/06/20/5948fd76e5fdea72278b45e5.html, June 20, 2017, consulted 30/06/2017.

(Raso, 2016) Raso, C., *El sector pide con urgencia la normativa de hibernación de los ciclos combinados,* elEconomista.es, http://www.eleconomista.es/energia/noticias/7859054/09/16/El-sector-pide-con-urgencia-la-normativa-de-hibernacion-de-los-ciclos-combinados.html, September 29, 2016, consulted 22/06/2017.

(Clover, 2016) Clover, I., *Danish solar auction delivers European low cost of US 1.81 cents/kWh*, PV Magazine, https://www.pv-magazine.com/2016/12/28/danish-solar-auction-delivers-european-low-cost-of-us-1-81-centskwh/, December 28, 2016, consulted 30/06/2017.

(Díaz López, 2017) Díaz López, B., *El Salvador adjudica 119,9 MW solares a precios desde US$ 49,55 el MWh*, PV Magazine, https://www.pv-magazine-latam.com/2017/01/12/el-salvador-adjudica-1199-mw-solares-a-precios-desde-us-4955-el-mwh/, January 12, 2017, consulted 30/06/2017.

(Planelles, 02/2017) Planelles, M., *España incumple el objetivo que se fijó en el uso de renovables*, El País, http://economia.elpais.com/economia/2017/01/31/actualidad/1485871507_148415.html, February 1, 2017, consulted 30/06/2017.

(Planelles, 03/2017) Planelles, M., *España se estanca en el uso de renovables*, El País, http://economia.elpais.com/economia/2017/03/14/actualidad/1489495279_805186.html, March 14, 2017, consulted 30/06/2017.

(Noceda, 2017) Noceda, M. Á., *Forestalia se adjudica el mayor paquete en la subasta de renovables*, El País, http://economia.elpais.com/economia/2017/05/17/actualidad/1495019321_178263.html, May 17, 2017, consulted 22/06/2017.

(Expansión, 2017) EFE, *El Gobierno hará una nueva subasta de renovables de 3000 MW antes del verano,* Expansión, http://www.expansion.com/empresas/energia/2017/05/25/5926aae8ca4741bd058b46a9.html, May 25, 2017, consulted 22/06/2017.

(MINETAD, 2011) *Planificación energética indicativa según lo dispuesto en la Ley 2/2011, de 4 de marzo, de Economía Sostenible*, Ministerio de Energía, Turismo y Agenda Digital, July 2011.

(BdE, 2016) *Proyecciones macroeconómicas de la economía española (2016-2018): contribución del Banco de España al ejercicio conjunto de proyecciones del Eurosistema*, Banco de España, June 2016.

(Euronews, 2015) *La demanda eléctrica en España no remonta mientras el crecimiento económico se acerca al 3%,* energynews.es, http://www.energynews.es/la-demanda-electrica-en-espana-no-remonta-mientras-el-crecimiento-economico-se-acerca-al-3/, June 2, 2015, consulted 30/06/2017.

(REE, 2015) *El sistema eléctrico español 2015*, Red Eléctrica de España, 2015.

(Endesa) *Comercialización*, Endesa web page, https://www.endesa.com/es/sobre-endesa/a201610-comercializacion-electricidad-comercializadoras.html, consulted 30/06/2017.