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The Problem of Determining the Energy Mix: from the Portfolio Theory to the Reality of Energy Planning in the Spanish Case

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Abstract:

This paper deals with the problem of defining efficient portfolios of electricity production assets using the Portfolio Theory, that is to say, by applying the return-risk analysis not to a single asset (e.g. a power station, a wind farm, a combined cycle gas plant), but to the set of technologies operating in a territory at a definite time. First of all, we study to what extent this methodological approach can be implemented to solve the problem of defining efficient sets of power production technologies, considering the fact that the Portfolio Theory was initially proposed in the field of financial investment. We focus on the main concepts of this framework (return, risk and diversification) and its uses in the energy mix context. Second, the evolution of the Spanish generation mix during the ten year period 2001-2010 is analysed according to two different variables: capacity and produced energy. Furthermore, we pay attention to the Spanish Government 2020 energy planning and compare it with several scenarios suggested using different patterns observed during 2001-2010 period. Finally, the most important conclusions are drawn and some lines of future research are proposed.

Key Words: *Energy, Portfolio, Energy Production, Investment Diversification, Security of Supply*

JEL Classification*: E37, G11, L43, L52*

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1. Introduction

Sorting out the energy problem, which deals with the access to a quality energy at an affordable cost and with due respect for the environment, becomes a key point in the agenda of many governments. In fact, the recent adoption of the European directive 2009/28 CE expressly mentions the commitment of each member state in the common European energy policy. Hence, the action plans established by states lay down a series of annual targets for the implementation and development of renewable energy generation. Should any country solve its energy needs efficiently, this fact would increase its competitiveness within its territory and make it a receiver of productive investment. The Spanish energy situation has historically been characterized by a high energy dependency and a low degree of self-sufficiency, which added to the limited capacity of terrestrial electricity interconnection with Europe (across France), Spain is considered as an energy island. On the one hand, the imported petroleum products are substantial, and, on the other hand, the contribution of domestic products on the structure of energy consumption is low. These two features are specific to the Spanish energy history, and it is not until 2004 when there is a certain improvement in this aspect. The application of efficiency and energetic planning on renewable technologies increased the share of renewable energies for covering the domestic demand, and this increased energy self-sufficiency.

Eguiagaray (2008) argues that the security of supply, the environmental dimension –with regard to production and use of energy-sources-, and specific management processes of energy production and consumption are dimensions of socio-economic impact on the energy problem. Apart from these aspects, it should be pointed out that electricity generation of primary energy involves a series of intractable disturbances: the existence of externalities (social and environmental, mostly), conditioning of domestic and industrial consumption depending on availability, and unequal dependence on sources of energy that have an impact on a different level of supply security. Supply risks range from the availability of fuels, the variation in costs, wrong energy policies, political instability, etc. All this indicates that achieving the best set of technologies of electricity production becomes crucial for any country. Here is where arises the Portfolio Theory as an applicable methodology for finding those efficient combinations of electricity assets. The application of risk-return analysis to the set of technologies which operate in a territory is possible as long as that country is able to generate electricity efficiently.

There is a great number of studies, all of them using the Portfolio Theory as a basis and trying to incorporate consistent methodological innovations: Awerbuch and Yang (2007) on Europe and Doherty *et al*. (2005) on Ireland, taking both reference the 2020 horizon. Krey Zweifel (2006) and the Swiss and American case in 2003, Roques *et al*. (2008) study the British case, Awerbuch *et al*. (2008) the Scottish case with 2010 horizon and Jansen *et al*. (2006) the Dutch case which has 2030 horizon. On the role of renewable energies, Muñoz *et al*. (2009) studied the

Spanish development in the period 2005-2010 using the maximization of Sharpe index approach. While there are many contributions made by experts in the form of studies, such as those mentioned, only a few States apply or incorporate their advice on energy policy.

The Government of Spain has just made public the draft of the Plan de Acción Nacional de Energías Renovables - PANER-for the 2011-2020 horizon. This plan was born in response to the directive 2009/28 CE for the development of renewable energies. This scheme sets some energetic targets to be fulfilled by the Spanish state; the generation of electricity is included among them. This new plan replaces the Plan de Energías Renovables - PER- (2005-2010). We can affirm that Spanish State has sought to promote the introduction into its territory of renewable energy sources to reduce the important foreign energy dependence which is around 80%. However, if making a right trial on the Spanish 'renewable boost', it is necessary a study on the evolution of the sources of electricity generation. The combination of technologies both in electricity production (GWh) and installed power (MW) has been changing along the last ten years, attending to the Spanish energy planning. Therefore, it seems desirable studying the impact of the PER 2005-2010 on the generation portfolio and assessing the targets proposed by the 2011-2020 PANER, according to the Spanish experience and evolution in terms of electricity generation.

This paper attempts to address the problem of defining the electricity generation portfolio from the postulates of the Portfolio Theory and its application to the revision of the Spanish energy planning. Aiming this, a brief look at portfolio theory and its application to the problem of construction of efficient combinations of electric generation technologies becomes essential. Subsequently, it is discussed the energy mix of electricity generation in Spain, both in installed capacity and electricity produced, for the period 2001-2009. Year-on-year analysis assesses the results of the almost extinct PER 2005-2010, and an assessment of the proposal of the newly submitted PANER 2011-2020 is made. Finally, some conclusions are drawn and a couple of guidelines are proposed for coming research.

2. Application of the Portfolio Theory to Generation Assets

The application of the Portfolio Theory in order to sort out the energy problem is based on the search for those portfolios of electricity generation assets that are efficient. The application of the risk-return analysis to a set of technologies that operate in a territory, not to an isolated asset (a nuclear power plant, a wind farm, a minicentral or a combined cycle central, gas, etc.) will enable the definition of those efficient combinations of technology to be used in a territory. The theoretical basis of this approach can be found in Awerbuch (2000) and Awerbuch Berger (2003). These authors argue that the application of the Portfolio Theory to financial assets in order to build real asset portfolios is possible. This is not based on a strict assumption of the efficiency hypothesis of the efficient portfolios theory on financial markets. Among others, it would be non- immediate liquidity of energy investment, the possible discontinuity caused by markets of electricity generation…

The basis of the proposal is portfolio's joint profitability gained through the weighted sum of the profitability of each technology, as proposed by the Portfolio Theory. Thus, the expected performance of the portfolio, E (r_c), is determined by the expression:

$$E(r_c) = x_1E(r_1) + x_2E(r_2) + \dots + x_nE(r_n)$$

where xi are the proportions of participation of each "i" technology in the portfolio and the E(ri) are the expected returns for each "i" technology, expressed as the average of the results weighted by the probability of occurring. One of the most controversial aspects is the definition of the concept 'return' for each technology. The authors define the Holding Period Return (HPR) as 'the inverse of the costs of generation of technologies'. Performance is defined as 'the amount of output generation (kWh) per invested monetary unit'. Accordingly, a lower cost (monetary unit for energy generated) would be tantamount to a superior performance. Roques *et al*. (2009) define this proposal as a perspective of maximization of social welfare, inasmuch as the approach is based on the following idea: the development of efficient portfolios exposes society to the minimum level necessary to achieve the targets of generation with those given costs, meanwhile costs and risks are minimized (Awerbuch and Berger, 2003).

Portfolio risk is associated with the variability of performance, and it is measured by the standard deviation of that performance, σ_c. Therefore, it would be the task of the individual risk of each technology and its interaction:

$$\sigma_c = \{\sum x_i^2\sigma_i^2 + \sum\sum x_i\, x_j\, \rho_{ij}\, \sigma_i\, \sigma_j\}^{1/2}$$

where xi represents the proportion of participation of the "i" technology in the portfolio, σi represents the standard deviation of returns per period of the same technology and ρij is Pearson's correlation coefficient between "i" and "j" technologies. The theoretical basis is supported by the optimization of Markowitz's approach (1952): essentially, is consists of minimizing the portfolio risk target function subject to a series of linear restrictions related to the level of the portfolio return and the values of xi. Solving this problem allows to obtain the portfolios' frontier through successive executions, i.e. all those portfolios for each level of performance, enclose the lowest risk possible. The model would define the frontier of efficient portfolios with different performance-risk combinations for each considered technologies possible. Extreme combinations would imply the assumption of a very high-risk, having absolute dependence on a single form of production, that is to say, on a null diversification of the combination.

The ordinate at the origin would represent the investment in renewable energies, considered by Awerbuch and Berger (2003) as devoid of risk[4]. The line between the mentioned point and the portfolio market, being tangent to the latter, is considered the capital market line or CML. Multitude of portfolios that would result from the investment in a certain mix of hazardous energy technologies (portfolio "M") and the asset without risk (renewable energy) are located on this line. These combinations dominate Markowitz's efficient portfolios which offer increased performance for each level of risk.

In Kienzle *et al*. (2007) we find a theoretical review of the implementation of the Portfolio Theory. In this work, the forenamed authors refer to the study of Bar-Lev and Katz (1976), who were the first to apply the Portfolio Theory to energy assets of American electric power generation in relation to that obtained from fossil resources industry. They calculated the efficient frontiers of fossil resources for different regions and compared them with other current frontiers of regional companies. It concludes that while businesses are efficiently diversified, their portfolios are characterized by high risks and returns. They suggest that many times, companies opt for high risk combinations encouraged by policy-makers. In the theoretical analysis, Kienzle *et al*. (2007) start from the approach of Awerbuch and Berger (2003) clarifying the term 'kWh per invested monetary unit' is not dimensionless, and could be multiplied by the price of electricity ($ cents per kWh), in order to eliminate the dimensional aspect. They conclude that it is not positive, because the consideration of the price of electricity in the short term can lead to future uncertainty in the model. The authors defined performance and risk in the following way:

$$\text{Return} = -(Y_t - Y_{t-1})/Y_{t-1}$$
$$\text{Risk} = \sigma \text{ Return}$$

where it would be observed in the "t" time costs. This implies that the performance would be negative if costs increase. According to this, maximizing performance would mean to minimize the generation costs' increase. It would be a negative exchange index in the production costs. The authors of the study devoted themselves to analyze the assets of the Swiss BKW company's current production as well as to examine the possible coming scenarios.

In order to find an analysis based on incomes from electricity sales, benefits, premiums for renewable or electricity prices, Muñoz *et al*. (2009) must be considered. These authors provide a new perspective for income calculation. While the positions of Awerbuch and Berger (2003) and Kienzle *et al*. (2007) were the minimization of costs (maximizing social perspective) and the understanding of the performance as the inverse of the costs of generation, Muñoz *et al*. (2009) use the

[4] One portfolio 100% composed by wind technology of renewable generation means to assume a null risk ($\sigma=0$) and a very low performance (0,25 Kwh/c$).

Internal Rate of Return (IRR) as a measure of performance calculated from the free cash flow for each considered technologies (renewable in this case, wind, photovoltaic, mini-hydraulic and thermal). Deviations of the internal rates of return are considered as measures of associated risks. The studied portfolio incorporates all the available technologies of a linear system of equations. It provides a series of maps of efficient frontiers according to different funding scenarios. They take their reference data from the Spanish PER which has a 2005-2010 horizon. The use of economic models allows calculating earnings, costs of operation and maintenance, credits, depreciation of facilities, benefits, etc. Thus, it is possible to calculate coming cash flow in order to calculate in turn the TIR, which is a determining value in the investment decision-making.

The TIR allows considering uncertainty of the electricity prices and future of defining risk, very different from the Awerbuch and Berger, focused on performance uncertainty arising from changes in the price of fossil fuel and their availability-centric approach. The TIR adjusted to risk allows determining whether the calculated performance is appropriate for that considered risk. The authors establish the Sharpe index to measure the performance in relation to its risk. Thus, if this index can be maximized, an optimal combination of technologies that maximize straight lines' slope which can be generated by the various technologies can be achieved. It would have to solve the following system:

$$\text{Max } m = (IRR_{portfolio} - r_f)/\sigma_{portfolio}$$
$$\text{Subject to: } IRR_{portfolio} \in \text{frontier}$$
$$\Sigma\omega_i = 1$$

where IRRportfolio would be obtained from each technology's average profitability, rf would be the profitability offered by treasury bills with zero risk and σportfolio would be the risk of the overall portfolio. Awerbuch and Yang (2007) perform a mean-variance analysis of portfolios' optimization, developing and evaluating combinations of generation business-as-usual (BAU) for the European Union for the 2020 horizon (EU-BAU 2020). They conclude that incorporating a larger proportion of non fossil fuel - nuclear technologies or wind-, a combination of technology generation EU-2020 with risk implies a reduction of overall risk, total costs and CO2 emissions. Although the introduction of a non- fossil fuel technology has a higher individual cost, it is possible to optimize the combination and increase security of supply through the diversification effect. The authors stress the importance of the existence of portfolio-based policies, that is to say, national economic policies which favor a diversification of the electricity generation assets portfolio.

Doherty *et al*. (2005) perform an analysis of generation portfolios in Ireland for the 2020 horizon under an uncertain environment and limitation of CO2 emissions. They assess portfolios from two perspectives: the reduction of CO2 emission and their exposure to sudden changes in fuel prices. The authors stress the importance of explicit cost of CO2 emissions in the market and the need to incorporate wind energy, with a maximum generation of 3.800 MW and being capable of covering 22% of total electricity demand. The authors use a linear programming algorithm to find the mix of generation at the minimal cost technologies. The algorithm optimizes both the capacity installed for each technology portfolio as the manner of use for the duration of the load curve. Results suggest that combined cycles of gas are the least costly alternative in terms of portfolio for both high and low emission cost. In addition, the findings suggest that the incorporation of wind power into the portfolio is related to the reduction of CO2 emissions and its cost increase. That is why the authors propose to enhance diversification on the Irish portfolios of future generation through regulatory actions - CO2 rates, incentives, etc – that, without meaning a reduction of market liberalization, could encourage the creation of diversified efficient portfolios.

Incentives to diversify in liberalized markets are studied by Roques *et al*. (2008) on the techniques of portfolios' simulation and optimization. Their approach is being changed to stress the importance of the private investor and his incentives – it is not focused on the user-. It will be needed to search for maximizing the financial returns of investments bearing in mind the risk. The authors used Monte Carlo simulation methodology for calculating generation plant yields, risks and their correlations. They start from a cash flow discount model on three plants, each with its own generation technology (combined cycle, coal and nuclear), which can be currently built in England. Data obtained by simulation are the basis of the analysis through the Portfolio Theory to identify optimal portfolios composed by the three technologies. These authors propose the mean-variance utility function[5] as standard mode of equilibrium between risk and performance. Authors estimate parameters from electricity, fuel and CO2 series of prices. Roques et al. (2008) suggest that a major diversification of the optimal portfolio would be achieved if introducing more nuclear and coal energies. Proposed measures to be applied in the market are linked to the establishment of bonuses, credit guarantees for the investment and mechanisms to achieve less cost of capital for investments.

The role of the technology of wind generation, within the context of efficient portfolios, is positively assessed from the point of view of the diversification and security by Awerbuch *et al*. (2008), who propose in their study an analysis of the Scottish NNGC 2010 mix of generation (National Grid Transco). They start from the Portfolio Theory and try to evidence that the increase of the wind capacity in Scotland reduces significantly total costs of generation. The result shows that the introduction of wind power serves to isolate the Scottish mix from the risk originated by systematic and correlated movements of gas and coal. In this case, Krey and Zweifel (2006) point that the diversification effect is reinforced by the lack

[5] $U = E(r_p) - 1/2 * \lambda * VAR(r_p)$. U is the utility of generation of the considered portfolio; E(rp), is the foreseen performance in terms of the VAN of the "p" portfolio which contains "n" "i" assets; λ, the risk aversion coefficient; and VAR (r_p), the variance of performance of that portfolio.

of correlation between the prices of fossil fuels and costs of generation in Scotland, leading to a reduced risk of the portfolio.

The authors argue that a real wind power underdevelopment exists. Wind participation is inferior to the targeted one, 5-10% in the case of the offshore and 31% in the case of the onshore. This deficient development leads to the assumption of a risk higher than desirable by portfolios' combinations. As a consequence, its energetic security is reduced. The proposed final conclusion is to remove the belief that the development of renewable sources requires a final cost increase. Once this idea is ruled out, this kind of analytic studies should help policy-makers in order to re-consider their energetic policies.

Jansen *et al*. (2006) study the portfolio of future electricity generation within the application of the Portfolio Theory. They conclude that in most of analyzed assumptions none of the targeted combinations is efficient. Diversification originated due to introduction of renewable sources (wind and biomass) allows reducing risk until 20% and costs 4%. Besides, obtained results point that those combinations which do not incorporate renewable sources are more risky (almost 10%, depending on the considered scenario). The result also points that a high CO2 price improves renewable sources' position and impacts positively on the security supply. The authors note that the policy-maker should endeavor to promote offshore wind power as stimuli strategy. In addition, they warn about the weight of the gas generation for 2030 in the Netherlands. If considering renewable sources' entry in the portfolio, it leads to its removal. The impact on cost and risk depends on the considered scenario in each case and on their specific pre-assumptions (CO2 cost emissions, gas and coal price and renewable energies' cost).

Krey and Zweifel (2006) focus on the Portfolio Theory to determine the efficient frontier, like Awerbuch and Berger (2003). Switzerland and the USA are the case studies. These authors apply SUR estimation (Seemingly Unrelated Regression) to filter the systematic components of the covariance matrix on technologies' performance. It is expected to consider the correlations between the errors of the regressions of the foreseen performance. The correlations between unobserved changes of the technologies' performances are introduced to improve estimations. As shown in the US case, correlation coefficients of errors between technologies are low, indicating that market explains almost all the correlations. The authors calculate the degree of concentration-diversification and security supply using the Shannon-Wiener (SW) and Herfindahl- Hisrschman (HH) index[6]. One combination of technologies can be efficient in cost-risk terms, but it does not have to be feasible or recommendable in terms of security supply, dependency or market concentration. According to the results, it is possible to move towards the efficient frontier, increasing the wind participation in the proposed portfolios, apart from the targeted AP 2003 portfolio. In order to fulfill the analysis, SW and HH index show

[6] $HH = \Sigma p_i^2$, where pi is the participation of the "i" technology (using a percentage).

that the portfolios are not diversified enough. According to the authors, Switzerland generates electricity in an efficient way, being the degree of diversification of FW index acceptable. The entrance of a wider quota of renewable (wind power in the US and solar in Switzerland) would imply to reduce risk and a better performance due to the portfolio effect, as remarked by the authors. Obviously, the independence towards fossil fuel changes is fundamental in the analysis and conclusions in both cases

3. The Meaning of Energy Security

It is necessary to check the evolution of the electricity generation portfolio in Spain (considering both installed power capacity and final production) in order to introduce the Spanish case's assessment. The composition of this technologies portfolio in Spain along the last years has experienced some changes and transformations. Since the '90s, gas and renewable resources technologies have notoriously increased their participation in the generation portfolio. The appearance and establishment of co-generation and, mainly, combined cycle plants have contributed to increase gas's participation. On the other hand, the Spanish power planning developed by the State has been successful since 2000, when the *Plan de Fomento de las Energías Renovables en España*[7] 2000-2010 started to apply, according to the *Ley 54/1997 del Sector Eléctrico* and the European White Book. Later, this plan was revised, coming up the *Plan de Energías Renovables* –PER-2005-2010. As reported by this plan, it aims that renewable sources suppose at least 12% of the total power consumption and 29.4% of total power generation. Additionally, biofuels must mean at least 5.75% of total fuel used in transport. These policies, which are expected to be implanted and developed, gave as a result that the participation of renewable sources was around 25% of the power production portfolio in 2009. On the contrary, those energetic sources whose participation decreased are coal, oil and nuclear power. In fact, renewable sources have exceeded the former since 2007 -and so far-. The aforementioned renewable sources have had a stable participation since 2005, when the impact of the climatic changes fell down. It means a better system, inasmuch as it reduces the negative effects of the discontinuities during their generation. In short, according to data provided by the *Ministerio de Industria, Turismo y Comercio* (MITyC), the electric production of renewable resources increased quite steeply (40% throughout the last ten years). Overall, renewable energy sources supposed 9.3% of primary energetic supply and 12.4% of the final gross energy.

The outcomes of the study on the evolution of the Spanish power generation portfolio (installed power capacity and final electric production) are shown below.

[7] Renewable Sources Promotion Plan in Spain. Period 2000-2010. Its revision took to a new plan, the PER, Renewable Sources Plan 2005-2010.

The chosen period is 2001-2009, due to the availability of data provided by the MITyC and the Government of Spain, such as annual energy balances and other publications.

3.1. Quantifying Energy Security

As previously pointed out, all these data come from official documents provided by the MITyC, the annual energy balances made in Spain. Analyzing the period of study (2001-2009), it can be highlighted that Spain increased 72% its globally installed power capacity to generate electricity. It implies that cumulative annual growth rate ('g' rate) was approximately 7% for this period, as shown in Table 1. A minimal increase (close to 1%) took place during the last two years (2008-2009), when dealing with the economic crisis.

Table 1. Spain's electricity production capacity (MW). Period 2001-2009.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	g rate 2001-2009
Conventional Thermal	**28217**	**30556**	**32323**	**36070**	**39952**	**43342**	**47837**	**49002**	**48803**	**7.09%**
Coal	12205	12205	12205	12205	12064	12064	11996	11999	11800	-0.42%
Oil (cogeneration included)	8735	8254	8288	8092	8322	8321	7321	7612	7612	-1.71%
Natural gas (co-generation + combined cycle)	7277	10097	11830	15773	19566	22957	28520	29391	29391	19.06%
Nuclear	**7816**	**7876**	**7880**	**7876**	**7876**	**7716**	**7716**	**7716**	**7716**	**-0.16%**
Pumped	**2546**	**2546**	**2546**	**2546**	**2546**	**2546**	**2546**	**2546**	**2546**	**0.00%**
Renewable Sources	**18845**	**20857**	**22891**	**25511**	**27373**	**29300**	**31219**	**38460**	**39721**	**9.77%**
Hydro (conventional and mixted)	15462	15532	15698	15773	15815	15900	16013	18623	16189	0.58%
Wind on-shore	2884	4366	5976	8263	9930	11611	13786	15709	18300	25.98%
Pv (photovoltaic)	12	16	27	36	70	119	623	3331	4165	107.76%
Biomass, biogas, USW	487	943	1190	1439	1558	1670	797	797	1067	10.30%
total	57424	61835	65640	72003	77747	82904	89318	97724	98786	7.02%

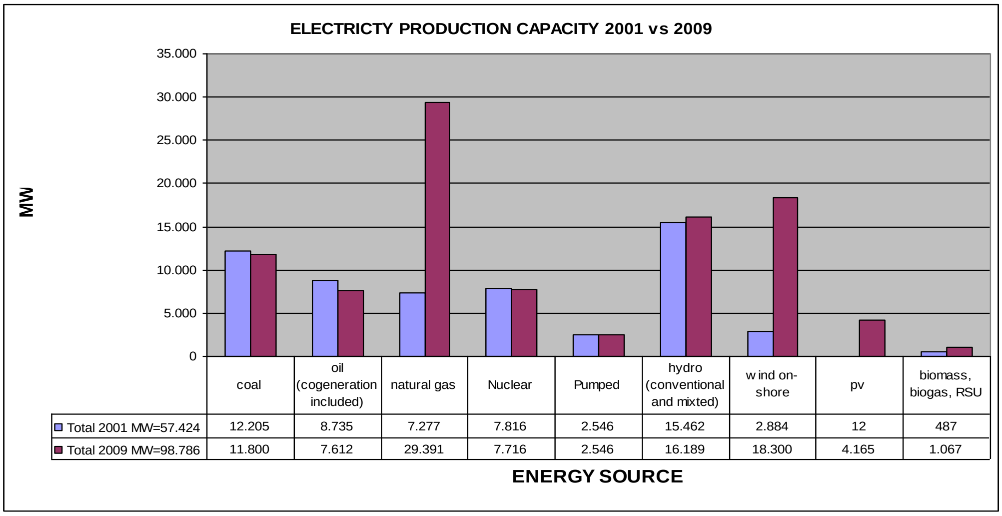
Source: Annual Energy Balance of Spain.

The conventional thermal production dramatically increased (72%) during the considered period (2001-2009), being 7% its 'g' rate (Table 1). Meanwhile coal and oil decreased their participation, the use of natural gas increased. Oil dropped considerably, 12% with regard to 2001. Actually, its annual decrease rate is 1.71%. The major fall of oil by-products was -12% between 2006 and 2007, coinciding with an important increase in gas natural share (24%), because of the new combined cycle plants. On the other hand, coal's participation diminishes (3.32% during this period), being its cumulative annual decrease rate 0.45%. Gas natural is one of the sources that increased remarkably (303%), if comparing data of the installed capacity at the beginning of the period (7277 MW) and at the end (29301 MW). This evolution can be checked in the Figure 1. The 'g' rate, which is close to 20% (19.06%), evidences this technology's substantial growth. The sustained increase in gas capacity occurs between 2001 and 2007, due to the aforesaid boost given by combined cycle (since 2005) and co-generation new facilities. Examining in contrast data belonging to 2001 and 2009, respectively, referring to final participation in the mix of installed power, coal and oil reduce their participation 50%, while natural gas doubles it (from 12% to 29.75% of the total installed power).

Nuclear power reduces 1.28% its participation. The main drop happens between 2005 and 2006, due to the closure of one nuclear unit (José Cabrera), meaning less nuclear power stations (from 9 to 8) and less production (it decreased 160 MW, which will be recovered never again). Previously, production decreases had happened due to the planned maintenance shutdowns in some groups (Vandellós II and Cofrentes).

Pumping hydraulic remains constant throughout this period (2.546 MW), as shown in Figure 1, although their importance decreases (it goes from 4.43% share in 2002 to 2.58% share of the total installed power capacity in 2009).

Figure 1. Electricity Production capacity. 2001 vs 2009.



	coal	oil (cogeneration included)	natural gas	Nuclear	Pumped	hydro (conventional and mixted)	wind on-shore	pv	biomass, biogas, RSU
Total 2001 MW=57.424	12.205	8.735	7.277	7.816	2.546	15.462	2.884	12	487
Total 2009 MW=98.786	11.800	7.612	29.391	7.716	2.546	16.189	18.300	4.165	1.067

Source: Spain Annual Energy Balances

The participation of renewable sources increased steadily, attending to installed power capacity during the period 2001-2009. The growth index is 110.78%, comparing the installed power in 2001 with that one in 2009. In addition, the cumulative annual growth rate (‘g’) is 9.77%, meaning these renewable sources more than 40% of the total installed power, increasing almost 8% since 2001.

Considering the installed power of hydraulic energy, data point out the existence of a slight increase (4.7%) since 2001. Its ‘g’ rate is scarcely 1% (only 0.58%). Power even diminishes 10% in 2005, remaining around these levels in 2006-2007, although it recovers in 2009, increasing 23%. Although the installed hydroelectric power represented 16.39% of the total in 2009, it was 26.93% in 2001.

The onshore wind technology increased its capacity 534%, comparing data of MW installed in 2001 and 2009, as shown in Table 1. Its ‘g’ rate is getting on for 25.98%, going from 2884 MW overall (5.02% of the total) in 2001 to 18300 MW overall (18.52% of the total) in 2009. The major proportional increase happens in 2002 (51%), being the annual increase close to 1500 MW. The installed onshore wind power means almost 20% of the total installed capacity and 46% of the total renewable sources.

Solar photovoltaic is the renewable energetic source which most increased since 2001, when 12 MW were installed. However, 4165 MW were installed in 2009. The growth index is 34608% for this period and the ‘g’ rate 107.76%. Photovoltaic energy went from 0.02% of the total of the installed power portfolio in 2001 to 4.22% of the installed total in 2009. The Energy Balance 2008 affirms that the task was complete –by far-, because the new photovoltaic solar power installed in 2007 was more than that had been planned by the Government of Spain for the period 2005-2010, as contained in the Plan de Energías Renovables (PER). The increase of this renewable source has not been constant along the time, insomuch as three periods can be considered regarding its growth (Table 2). The first period (2001-2006), whose ‘g’ rate was 58.22%, was followed by a second one (2006-2008), being 429.07% its growth rate. During the third period (2008-2009), the ‘g’ rate was 25.04%. According to the Energy Balance 2008 provided by the MITyC, this growth occurred because of the ‘strong and increasing rates of development of the area along the recent past’ and the approval of the Real Decreto 661/2007 on May 25, 2007, where the paybacks for this type of facilities (between 100 kW and 10 MW) were notoriously increased. Likewise, in 2007, it had reached 85% of the 371 MW aimed in the PER for the photovoltaic solar energy connected with network in 2010.

Table 2. Spain´s ‘g’ rate by periods. Photovoltaic energy source. Electricity capacity.

“g” rate by periods. Photovoltaic energy source. Electricity Capacity.		
2001-06	**2006-08**	**2008-09**
58.22%	429.07%	25.04%

Source: own authors´ calculations.

Renewable sources like biomass, biogas and urban solid waste experienced a 119% increase, if comparing 2001 data with those in 2009. The ‘g’ rate reaches 10.3%. Notwithstanding this, if dividing the period 2001-2009 in three stages, it must be stressed the decrease (31%) in the installed power capacity for the period 2006-2008 (

Table 3). Despite this fall, biomass installed capacity increased –if considering the total installed power- from 0.85% in 2001 to 1.08% in 2009.

Table 3. Spain´s "g" rate by periods. Biomass, biogas and USW energy source. Electricity capacity.

"g" rate by periods. Biomass, biogas and USR. Electricity Capacity.		
2001-06	**2006-08**	**2008-09**
27.95%	-30.92%	15.71%

Source: own authors´ calculations.

3.2. The Mix of Final Electric Production Spain 2001-2009.

The production of electricity in Spain rose 26% during the period 2001-2009. As shown in Table 4, the 'g' rate close to 3% (2.93%) points a moderate increase on the electricity production. It is remarkable the productive drop in the last years (2008-2009), close to 6%. Electricity production decreased in 2009 (approximately 5.5%, compared to 2008). In this case, a decrease occurs in the production coming from coal (-21%), oil (-4%), natural gas (-10%) for the first time, as well as nuclear power stations (-9.55%). Although renewable sources increased their production (10000 GWh), it is not enough to compensate the steep decrease in other sources (30000 GWh). Some reasons are the economic crisis's negative impact on the energy demand and technical and consumption aspects, like the improvement of energetic efficiency.

Table 4: 'g' rate in the period 2001-2009; Cumulative annual growth rate by technologies.

"g" rate	Total	Conventional Thermal			Nuclear	Renewable Sources			
	2.93%	4.41%			-2.20%	4,05%			
		Coal	**Oil**	**Natural gas**		**Hydro**	**Wind on-shore**	**Pv**	**Biomass biogas USW**
		-7.33%	-2.99%	21.60%		-5.14%	22.33%	97.08%	3.65%

Source: own authors´ calculations.

The conventional thermal production increased 41% during the period 2001-2009, as shown in Table 4. The 'g' rate (4.41%) shows how the cumulative decrease in production from coal (7.3%) and oil (2.99%) was counteracted with the relevant increase in production from natural gas (its 'g' rate is 21.6%). Since the starting year (2001) until 2009, the increase index of natural gas was 378%. The appearance of new combined cycle and co-generation stations, as well as the decreasing importance of coal and oil by-products favors gas leadership (with a 36% share of the total production in 2009) in regard to the mix of electric production –it was a 10% share in 2001-. Coal production coal only increases in 2002, 2004 and 2007, mainly due to the necessity of compensating the decrease in production from hydroelectric and/or nuclear energy. The participation of coal in the production portfolio experiences a gradual decrease. While this energy meant 30% of the total in 2001, it was 10% of the total in 2009. Oil by-products' relevance fell down in a similar way.

Electric production from nuclear power shows a marked decrease (16%) between 2001 and 2009. The cumulative annual decrease rate reaches 2.2%, driving to a position against the use of nuclear power as a source for producing energy, despite its growth in 2004, 2006 and 2008. It coincides with some planned maintenance shutdowns (like in Vandellós II and Cofrentes) in 2005 and 2007. The aforesaid decrease can also be noticed in the progressive loss of importance respect to the total production portfolio. Electricity production from nuclear power meant 27% of the total in 2001, turning into 17.8% of the total in 2009.

The production from renewable sources meant 23%-25% of the total of the production portfolio along the period 2001-2009. 2002, 2004, 2005 and 2008 were bad years regarding hydroelectric production –under the cumulative historical average-, leading to its decrease. Despite the continuous rise in wind power and the increasing use of photovoltaic, biomass and solid urban waste, they do not manage to counteract this hydroelectric drop. Accordingly, the participation of hydroelectric energy on the total production portfolio in 2009 is almost 9%, but this percentage is half of the one in 2001. Comparing the production from the set of renewable sources between 2001 and 2009, it is seen a 37% increase, being 4% the 'g' rate.

The production from onshore wind power increased 400% during the period 2001-2009. The 'g' rate is over 22%, leading to think of a continuous increase. Onshore wind power means almost 12% of the total production portfolio in 2009, much more than 3% of the total production portfolio which was in 2001. 6960 GWh in 2001 turned into 34900 GWh in 2009. Therefore, wind power generates half of the renewable sources' production in 2009.

Photovoltaic solar energy increased spectacularly during the period 2001-2009, in regard to electric production. 28 GWh provided in 2001 became 6.372 GWh in 2008. It rose 22657%, being 97% its 'g' rate. As shown in Table 5, the major cumulative annual growth took place between 2006 and 2008 (2008-2009 was also quite dramatic). However, these figures are unreliable, because photovoltaic solar energy provides only 2% of the total production portfolio (in 2001 it was a minimal amount which meant 0.01%).

Table 5: Spain´s 'g' rate by periods. Photovoltaic energy source. Electricity production.

"g" rate by periods. Photovoltaic energy source. Electricity production.		
2001-06	**2006-08**	**2008-09**
43.27%	286.69%	152.16%

Source: own authors´ calculations

Biomass, biogas and solid urban waste contribution remains constant throughout the period 2001-2009 (whose 'g' rate was close to 1.6%). They increased

33%, with 3.65% as ‘g’ rate. It is remarkable that they reached 8353 GWh in 2006. However, some sources of Energy Balances provide conflicting information in this point, leading to unanswered questions.

4. Revision of the Plan de Energías Renovables[8] 2005-2010

The PER was approved by the Spanish Government on August 26, 2005. The previous plan was revised in order to stress the importance of improving the energetic efficiency, as well as the growth of renewable energetic sources. These two main aims are included within a global energetic planning, which is a economic, social and environmental strategy with potential positive outcomes. The latter’s application as part of the Spanish energetic planning proposed for the period 2005-2010 tries to accomplish several missions: achieving a greater diversification of generation sources (and, additionally, a better security of supply), looking after and making the environment better, increasing competitiveness through the industrial modernization and upgrade, creating jobs and attaining regional development.

Goals 2010:

The PER 2005-2010 was determined to fulfill a set of goals. Achieve that 12.1% of the primary energy consumed would be provided by renewable sources. Likewise, 30.3% of the gross electricity consumption (100,000 GWh) would be met by renewable sources and 5.83% of the foreseen consumption of petrol and diesel oil for transport should be provided by biofuels. In 2009, renewable sources mean 9.3% of primary energy supply (far from the foreseen 12.1%). Regarding gross final energy, renewable sources provide 24% (it means a huge distance until the goal). Despite this, the evolution of the participation of renewable energies was positive if considering the gross consumption of energy: it was 8.8% in 2007 and 10.1% in 2008.

The PER also set some goals for those energies coming from renewable sources. An evaluation on its fulfillment is made below:

Wind power

The wind forecast for 2010 was to achieve 20155 MW of installed power (Table 6) and the approximated production was 45511 GWh. It means an increase of 12000 MW in installed power capacity in onshore wind farms since 2004. To achieve this increase, it was decided to help with bonus to the production contemplated within the Special Regimen. The calculation of the total value of these bonuses would be 2599 millions of € (815 millions of € would correspond with those in 2010). In 2009, 18300 MW were installed and 34900 GWh were produced. The goal of installed power capacity (20155 MW) can be presumably achieved, considering the current growth rate. On the contrary, having 45511 GWh as final

[8] PER 2005-2010: Renewable Sources Plan for Spain. Period 2005-2010.

wind production in 2010 would require a 30% increase in 2010 (the previous years' rates were between 10% and 20%).

Hydraulic energy

The PER expected to increase power 810 MW since 2004. 450 MW would be for mini-hydraulic facilities (≤ 10 MW) and 360 MW for units between 10 MW and 50 MW. Contributions would also be bonuses set for the Special Regimen. This would mean 189 million of € for the period 2005-2010. The final capacity total in 2010 would be 16583 MW, as foreseen (table 6). This goal is not probably going to be achieved, because in 2009 394 MW were missing, almost 50% of the total amount planned for the five-year period.

Photovoltaic solar energy

The increase set out in the PER for this type of energy was 363 MWp (installed power capacity). This increase added to the existing 37 MWp in 2004 would mean 400 MWp in 2010. This increase should come from units linked to networks with less than 100 KWp of unitary power (317 MWp), 31 MWp from units linked to networks with more than 100 KWp and 15 MWp for isolated units. This aim has been successfully fulfilled, inasmuch as photovoltaic energy reached 4.165 MW in 2009 (1000% over the foreseen amount).

Table 6. Spain´s PER 2005-2010 Renewables goals. Installed power capacity

PER 2005-2010 Renewable goals. Electricity capacity installed.	OBJETIVO TOTAL MW	MW AÑO 2009	MW DIFERENCIA 2009-2010	NECESSARY GROWTH 2009-2010	MEDIUM GROWTH 2007-2009
hydro	16583	16189	-394	2.43%	0.28%
wind on-shore	20155	18300	-1855	10.14%	15.22%
pv	400	4165	+3765	-	229.86%
biomass, biogas, RSU	3228	1067	-2161	202.53%	16.94%

Source: PER 2005-2010. Government of Spain

Biomass and biogas

There was a foreseen increase in installed power of 1695 MW for the biomass with electric uses. 973 MW of the total 1695 MW would be for biomass plants and 722 MW for co-combustion programs in conventional thermal power stations. For this, it was planned a joint co-combustion program of coal and biomass in thermal power stations (of coal), an payback increase of that electricity generated in facilities of electric biomass and the stimulation of the *Comisión Interministerial de la Biomasa*. With regard to biogas, an increase of the installed power capacity in 94 MW was foreseen, which would mean to have 235 MW in 2010. It could lead to the possible generation of 592 GWh in 2010. Overall, the increase of power pointed out would be 1789 MW. The aimed final installed power would be 3228 MW in

2010. The total of biomass, biogas and solid urban waste reached 1067 MW in 2009. Hence, those 2161 MW not achieved yet would require a 202% increase regarding data from 2009 (when the increasing rate was 34%). However, as aforementioned, some data are contradictory in some points of this type of technology. As a result, this information should be considered cautiously.

5. The New “Plan de Accion de Energías Renovables en Espana”.

The PANER 2011-2020[9] is being elaborated at the moment. It is the answer to the provision of the *Real Decreto* 661/2007, which urged to begin the study of a new Renewable Energy Plan 2011-2020. Subsequently, the guideline 2009/28/CE of the European Parliament and the Council, on April 23, 2009, establishes a set of compulsory goals for renewable energies to be achieved for each member state in this period (whose horizon would be 2020). For planning it, the MITyC considered the evolution of energy consumption, oil prices' behavior comparing them with those along the '90s and the notable intensification of the saving and energetic efficiency plans.

The PANER 2011-2020 contemplates the challenges of the Spanish energy policy for this period. Amongst them, they can be pointed out: reducing the high energetic consumption per unit of GDP, acting on a high energetic dependency and reducing greenhouse gases' emissions. The development of the Spanish energy policy sets its main goals: increasing security of supply, improvement of economic competitiveness and the guarantee of a sustainable economic, social and environmental development.

Strategies to achieve it are based upon the liberalization and promotion of markets' transparency as a means to have more efficient markets. The plan contemplates the development of energetic infrastructures, the reinforcement of security and diversification of supply sources. It also pays attention to the coverage index and the networks' modernization, installing re-gasification plants and acting on the storages of liquefied natural gas. The improvement and increase of the capacity of international interconnections is a crucial element regarding planning. A more important share of the renewable sources in the sustainable mix of generation will be possible as long as the electric interconnection with the rest of Europe is wider and becomes better. A sustainable and efficient management is possible if integrating in the system the peak hours of renewable sources, balancing production and consumption. Advances on the construction of the two interconnected networks which cross France through the Pyrenees (the Oriental Pyrenees interconnection, which will start to work in 2014, and the just projected Central Pyrenees interconnection) must be achieved. In any case, it would be important to reach a capacity in the interconnections of the 10% of the installed power capacity. It would mean a capacity of 10000 MW, very different from the currently planned 2000 MW.

[9] PANER 2011-2020: Renewable Sources National Action Plan for Spain. Period 2011-2020.

The promotion of generation sources which have a renewable origin and, additionally, the energetic saving which comes from the energetic efficiency gives rise to benefits. Among them, they would be the sustainability of sources, the reduction of polluting gases' emissions, technological change, the possibility of increasing the diversification of sources, reduction of the energetic dependency, reduction of trade balance deficit, as well as better levels of employment and the plausible development of rural areas. The most relevant costs which can imply the use of renewable sources are limited and tend to decrease along the time, having an effect on the –high and stable- economical benefits.

The evolution of the use of renewable sources makes possible the displacement of technologies along the learning curves. At this moment, it is possible to predict and manage these energies. This is due to advances in the management and the use of some techniques, such as pumping and the capacity of storage in renewable facilities. The mechanism which carries out the promotion of renewable energies is the 'feed-in-tariffs', where the remuneration is for technology superior to the wholesale market price. Thereby, financing of additional costs is made through the electricity tariff. Costs are shared between producers and consumers, as the former have a final price inferior to the energy sold (provoked by electricity produced by energy which comes from renewable sources). It is expected that renewable sources mean 25% of the total electricity generation, that is to say, 12.3% of the final energy consumed.

5.1 Foreseen Scenario. Period 2011-2020.

There are four key defining elements of the scenario foreseen for the period 2011-2020 by the MITyC: the GDP prevision, the Brent oil price, the prevision of population growth and the evolution of the energetic efficiency. With regard to the GDP, a 2.2% growth rate is contemplated in 2011, 2012 and 2013, rising to 2.5% from 2014 to 2020. The Brent oil price will be 100$ in 2020, as estimated considering 2010 prices as constant, while gas natural price will be approximately 23 €/MWh, being 1.35$ per euro its exchange rate. Attending to the population prevision, it is expected a total increase of a million of inhabitants by 2020, becoming 47 million of Spanish people instead of 46. This is a slight increase if comparing it with the migratory movements occurred since 2000. Considering the energetic efficiency, diminishments of the final energetic intensity (1.7% per year) and electric intensity –relation between the final electric consumption and GDP- (0.4% per year) are expected.

5.2 Planning of the Mix of Electric Generation. Spain 2009-2020.

When assessing the possible portfolio of electric generation 2020 in Spain, three possible scenarios will be considered, attending to the data: a 'pure continuo scenario', applying a growth rate according to the behavior during the studied period 2001-2009 and with horizons 2020, another one denominated 'edited continuo', with the same basis than the previous one, but correcting the unreal growth rates and, finally, the ‘MITyC 2020’ scenario, where foreseen data by the MITyC for this horizons are displayed.

5.2.1. The 2020 mix: installed capacity power

The forecasted installed power for the horizons 2020 diverges so much depending on the contemplated scenario, as shown in Table 7.

‘Pure continuo’ scenario:

It contemplates a sustained growth, like the one for the period 2001-2009. According to this, changes were not necessary in any of the applied policies. Obtained results point that the maintenance of growth rates during the period 2001-2009 are not sustainable from a technical and economic perspective. So, bonuses for electricity generation from renewable sources are not sustainable. Likewise, a major capacity of some energy sources, like gas, wind and photovoltaic do not respond to the possible demand growth, much smaller in any case. Photovoltaic development in 2009 exceeds 1000% the planned aim by the PER 2005-2010, 400 MW installed in 2010 versus 4165 MW already existing in 2010. The aforesaid over-development was not considered by the PER and it was due to external reasons (and not to the planning), such as the through bonuses of this technology. As a consequence, the network will be in serious troubles to assume such amount of non-manageable energy from renewable sources (13215740 MW).

‘Edited Continuo’ scenario:

This scenario contemplates a sustained growth like the one during the period 2001-2009 for all the technologies, except for that which display unreal results. For those technologies which show an excessive growth (Table 7), like natural gas, onshore wind and photovoltaic, their ‘g’ rate is changed by the forecast of the mean of the GDP growth rate, contemplated in the PANER, 2.41%[10]. In this scenario, the revision of the results of the pointed technologies give as result one total installed capacity superior to the current, with important increases of renewable sources and natural gas. However, it is a scenario which shows the total weight of the renewable technologies around 40%, quite far from the MITyC 2020 scenario, where they represent 55% of the total. Alternatively, some technologies, like oil, nuclear and coal reduce their participation, having levels lower tan those in 2009.

[10] This GDP rate is selected as a constant rate to allow the authors´ calculations

Table 7. Spain´s foreseen installed electricity capacity in 2020.

FORESEEN INSTALLED CAPACITY 2020	YEAR 2009	Pure Continuo Scenario	Edited Continuo Scenario	Ministry MITyC Scenario 2020
Total MW	**98,786**	**13,443,797**	**113,708**	**135,086**
Conventional Thermal	**48,803**	**217,931**	**56,128**	**47,583**
coal	11,800	11,265	11,265	8,130
oil[11]	7,612	6,300	6,300	1,682
natural gas[12]	29,391	200,366(*)	38,193	37,771
Nuclear	**7,716**	**7,581**	**7,581**	**7,256**
Pumped	**2,546**	**2,546**	**2,546**	**5,700**
Renewable Sources	**39,721**	**13,215,740**	**47,824**	**74,547**
hydro	16,189	17,245	17,245	16,662
wind on-shore	18,300	232,182(*)	23,780	35,000
wind off-shore	0	0	0	5,000
PV	4,165	12,963,176(*)	5,412	15,685
biomass, biogas, RSU	1,067	3,137(*)	1,387	2,200

Source: PANER and own authors´ calculations.

‘Ministry’ –MITyC- scenario 2020:

As shown in Table 8, ‘g’ rates proposed by the MITyC present a certain growth slow down. Generation sources, like coal and oil notoriously decrease, like the nuclear, although more slowly. Natural gas has a small ‘g’ rate, with regard to the period 2001-2009 (19%). Where a major increase occurs is in the pumping hydraulic (7.6%). Amongst the renewable sources, photovoltaic has the highest ‘g’ rate, which doubles the capacity in 2009, whose ‘g’ rate was 12.81%. It is followed by the wind onshore and biomass, which doubled the quantity from 2009 in 2020, having a 6 % “g” rate. It is noticed a quick development of the offshore wind power, which had a 167.41% “g” rate. It is also seen (Table 8), that “g” rates in the edited continuo scenario are smaller than in the MITyC 2020 scenario for wind power and photovoltaic. In these cases, the MITyC understands that the ‘g’ rate increase is higher than that of the expected GDP. Gas natural and hydraulic ‘g’ rates almost coincide with that one in 2009. In any case, the ‘pure continuo’ scenario is not sustainable in comparison with the MITyC scenario, which slows down the growth of the leader technologies regarding its own growth during the period 2001-2009 (natural gas, photovoltaic, onshore wind and biomass).

[11] Cogeneration included.

[12] Cogeneration and combined cycle included.

Table 8. Spain´s foreseen 'g' rate installed electricity capacity 2020.

"g" RATE INSTALLED ELECTRICITYCAPACITY in 2020	Pure Continuo Scenario	Edited Continuo Scenario	Ministry MITyC Scenario 2020
Total	**56.31%**	1.29%	**2.89%**
Conventional Thermal	**14.57%**	1.22%	**-0.23%**
coal	-0.42%	-0.42%	-3.33%
oil	-1.71%	-1.71%	-12.82%
natural gas	19.06%(*)	2.41%	2.31%
Nuclear	**-0.16%**	-0.16%	**-0.56%**
Pumped	**0%**	0%	**7.60%**
Renewable Sources	**69.54%**	1.70%	**5.89%**
hydro	0.58%	0.58%	0.26%
wind on-shore	25.98%(*)	2.41%	6.07%
wind off-shore	0%	0%	167.41%
PV	107.76%(*)	2.41%	12.81%
biomass, biogas, RSU	10.30%	2.41%	6.80%

Source: PANER and own authors´ calculations.

5.2.2 The mix 2020: final electricity production

The foreseen produced electricity is different depending on the contemplated scenario, as in the case of installed power capacity (as shown in Table 9).

'Pure continuo' scenario

As it was pointed out previously, the defining feature of this scenario is to consider a similar growth to that for the period 2001-2009, applying the same policies. Obtained results show again the idea that it is impossible to maintain 2001-2009 'g' rates. Astronomical results regarding total production for natural gas and renewable sources reflect that it is not possible to continue with the bonuses' system for electric generation, and also the necessity of reconsider 'g' rates within the global energy planning.

Table 9. Spain´s foreseen 'g' rate installed electricity capacity 2020.

FORESEEN ELECTRICITY PRODUCTION 2020	YEAR 2009	Pure Continuo Scenario	Edited Continuo Scenario	Ministry MITyC Scenario 2020
Total Production (GWh)	**299,617**	**12,468,440**	**294,713**	**371,731**
Conventional Thermal	**168,818**	**980,641**	**174,286**	**148,789**
coal	39,060	16,906	16,906	34,380
oil[13]	19,268	13,801	13,801	6,300
natural gas[14]	110,490	949,933(*)	143,578	108,109
Nuclear	**53,340**	**41,782**	41,782	**55,600**
Pumped	**2,450**	**2,450**	**2,450**	**8,023**
Renewable Sources	**75,009**	**11,443,568**	**76,195**	**159,319**
hydro	28,757	16,092	**16,092**	33,900
wind on-shore	34,900	320,348(*)	45,351	71,350
wind off-shore	0	0	0	12,400
pv	6,372	11,099,736 (*)	8,280	29,669
biomass, biogas, RSU	4,980	7,391	6,471	12,000

Source: PANER and own author´s calculations.

'Edited Continuo' scenario:

In this case, like for the installed power capacity, the 'g' rate of natural gas, onshore wind and photovoltaic are substituted by the forecast of the mean of the GDP growth rate contained in the PANER for this period, 2.41%. The reason is the excessive growth of these technologies, attending to the rates experienced along the period 2001-2009.

It can be seen that data of renewable sources' production are inferior to the MITyC's 2020 proposed scenario and scarcely mean an increase with regard to 2009. In this scenario, foreseen GWh of hydroelectric, wind and biomass are almost twice those that had been foreseen for the 'edited continuo' scenario and thrice those of the photovoltaic. It is forecasted, comparing 2009 and 2002, an important reduction of coal (more than a half) and oil as sources of generation, becoming the natural gas even more relevant. Pumping hydroelectric does not experience any change, while nuclear energy diminishes its weight within the portfolio of generation, like it had expected during the last years of the previous period (2001-2009). Except from the hydroelectric (whose production drops by half respect to 2009), all the renewable technologies rise.

[13] Cogeneration included.

[14] Cogeneration and combined cycle included.

Table 10. Spain´s foreseen 'g' rate electricity production 2020 .

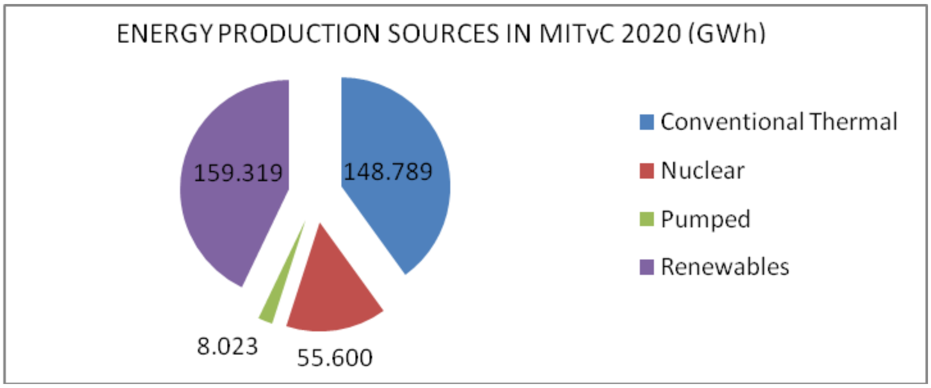
"g" RATE ELECTRICITY PRODUCTION in 2020	Pure Continuo Scenario	Edited Continuo Scenario	Ministry MITyC Scenario 2020
Total Production	**40.35%**	**-0.15%**	**1.98%**
Conventional Thermal	**17.34%**	**0.29%**	**-1.14%**
coal	-7.33%	-7.33%	-1.15%
oil	-2.99%	-2.99%	-9.66%
natural gas	21.60%	2.41%	-0.20%
Nuclear	**-2.20%**	**-2.20%**	**0.38%**
Pumped	**0%**	**0%**	**11.39%**
Renewable Sources	**57.94%**	**0.14%**	**7.09%**
hydro	-5.14%	-5.14%	1.51%
wind on-shore	22.33%	2.41%	6.72%
wind off-shore	0%	0%	190.43%
Pv	97.08%	2.41%	15.01%
biomass, biogas, RSU	3.65%	2.41%	8.32%

Source: PANER and own authors´ calculations.

'Ministry' MITyC scenario 2020:
As seen in

Figure 2, the two main sources of generation keep being renewable and conventional thermal energies. The 'g' rate contemplated by the MITyC is getting on for 2%, under the foreseen growth rate of the GDP for that period. Generally speaking, conventional thermal generation sources have a negative growth forecast (including natural gas, which has experienced a significant increase along the period 2001-2009). On the other hand, other sources of generation, like pumping hydroelectric, which had scarcely increased during the period 2001-2009, present a 'g' rate close to 12% (that is very high), bearing in mind its stabilization in the previous period. It must also be highlighted that the growth 'maintenance' of the onshore wind power almost reaches 7% per annum. Photovoltaic also plays an important role in the portfolio of electric production, with a 'g' rate around 15%. A notable development of offshore wind power takes place, meaning that the PANER 2011-2020 is for this type of energy as a 'new' renewable source. Annual growth rates are almost 200%, reaching 12,400 GWh.

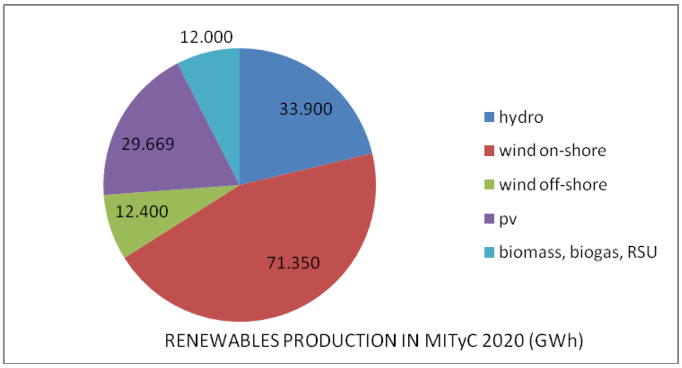
Figure 2. Spain's energy production sources in the MITyC 2020 scenario.



Source: MITyC. Government of Spain.

As a conclusion, the growth forecast pointed out by the Ministry is close to the foreseen GDP for this period. This increase of some technologies rests upon a negative increase of the conventional thermal sources (coal, oil and natural gas), as well as on the maintenance of the nuclear relevance and a positive increase of the previously constant pumping hydraulic and renewable sources. Wind power and photovoltaic, which were leaders of yesteryear, slow down their growth rates. The PANER 2011-2020 proposes to give an incentive to photovoltaic, wind offshore and biomass with high growth rates. Anyhow, the most important renewable energy is the wind power, which means 52.56% of the renewable total, followed by the hydroelectric (21%) and photovoltaic (18%) as shown in Figure 3.

Figure 3. Spain's renewables production in the "MITyC 2020" scenario.



Source: MITyC. Government of Spain

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6. Conclusion

The first part of this paper has focused on exposing the application of the methodology of Markowitz´s Portfolio Theory (1952) to obtain a proper mix of electricity generation technologies. The second part tried to present the results of the study of Spain's portfolio of electricity generation along 2001-2009. This portfolio approach has focused on the point of view of installed power capacity and final electricity production. Later, the Spanish energetic planning throughout the last 5 years was assessed, evaluating the PER 2005-2010. Eventually, the new energetic planning of Spain adopted for next ten years 2011-2020 was assessed through the approach of three feasible scenarios: 'Pure Continuo' scenario, 'Edited Continuo' scenario and 'Ministry' MITyC 2020 scenario.

Thus, when trying to implement the Portfolio Theory to solve the problem of defining an electricity generation mix, it is very important to consider some aspects as concluding remarks.

Firstly, it is necessary to assume the resulting differences from the object of investment, as result of considering no financial assets, but real assets of electricity generation. According to this approach, renewable energies (wind, solar, tidal, etc.) would play the role of free risk assets of the original model.

Secondly, it is appropriate to assume some conceptual adaptations, particularly referred to return and risk definitions. In the case of return, some authors have initially assumed that this concept can be assimilated inversely of its global production cost (Awerbuch, 2000). Recently, other authors -Muñoz et al. (2009)- identified return and internal rate of return (IRR) obtained from the calculation of free cash flows for each considered technologies. Although other possible differences between financial and energetic areas can be pointed out, these are assumable –in general- and they do not prevent the application of the risk-return couple to the selection of portfolios of technologies/assets of electricity production. The revised studies agree on the necessary consideration of the generation technologies as a whole and not in isolated assets. A change of perspective exists, and then the determination of an efficient mix becomes the goal. This is more acceptable socially and for policy makers, more efficient and justifiable. The revision made provides some different methodological aspects in relation to the problem formulation. Likewise, the risk-return approach allows the construction of future energetic scenarios in any studied area.

The composition of the Spanish technologies portfolio for the period 2001-2009 has been changing until placing natural gas and renewable sources like the most important technologies in the energetic mix, both in installed power capacity (they mean 70% of the total share) and in electricity production (actually, they provide more than 60% of the total). This leads to affirm that the Spanish energetic planning has achieved a widespread implantation and development of renewable sources (in the European Union context and at the world level). The application of the *Plan de Fomento de las Energías Renovables* in Spain 2000-2010, and its revision, the PER 2005-2010, has succeeded in changing the composition of the mix of electricity generation, increasing the renewable share. The strong increases of wind and photovoltaic energies, joined to weight loss technologies like coal or oil products, make renewable sources to reach 40% of the total installed power and 25% of the total electricity produced in 2009. Natural gas is one of the sources that experienced the greatest increase, representing 9% of the total production portfolio in 2001 and reaching 37% of the total production in 2009. On the other hand, nuclear energy that has scarcely changed attending to installed power capacity, remained with a capacity of production constant since the beginning of the studied period. However, this energy meant 26% of the portfolio in 2001 and it was 17% in 2009.

The implementation of the PER gave some conflicting results. An exorbitant increase of photovoltaic technology, due to the application of the *Real Decreto* 661/2007, a constant growth of the onshore wind power and a new growth of hydraulic technology, previously invariable, and of biogas and solid urban waste could question the level of performance of the aforementioned plan and the basis which gave rise of it, taking into account the existence of excesses (photovoltaic) or easily located faults (hydraulic, wind, biomass, biogas, solid urban waste…), both in installed power and final production. Nowadays, one year prior to the end of the period of the plan, some aims seem that they cannot be achieved because of the production decrease due to the economic crisis, joined to the own behavior of each renewable source: renewable sources can provide neither 12.1% of primary energy consumption in 2010 (9.3% in 2009), nor 30.3% of primary gross electricity consumption (2009 data point to 12.4%).

The future PANER 2011-2020 is born as an answer to the European obligation set by the Directive 2009/28/CE of the European Parliament and the Council, on April, 23, 2009. The contemplated scenario for this period in the plan looks more questionable. Crisis time extension conditions GDP growth rates (2.5%), a slight increase of the population and notable improvements in the efficiency and electric intensity. It leads to think of an optimistic scenario which contemplates some strong increases in some technologies (for instance, offshore wind and photovoltaic) and important increases in the area of the biomass and the offshore wind. In any case, a clear slow down of the implantation rates of all the renewable technologies is contemplated. The experienced evolution for the period 2001 by the renewable sources does not seem to be sustainable along the time in order to generate a malfunction on the retribution system of this type of energies, it is to say, in the system of bonuses for electric generation from renewable sources. The generation portfolio foreseen by the MITyC in 2020 forecasts a reduction of participation of all the conventional thermal sources (coal, oil and natural gas), a strong boost of the pumping hydraulic and a final participation of renewable sources of 55%, attending to installed power, and 43%, considering final electric production. Eventually, the current economic context, with regard to the future evolution of the electric consumption and indeed in the industrial field, seems to advice a revision of the principles and basis which give rise to the PANER's forecasts (2011-2020).

Finally, two researching guidelines are proposed:

First of all, advancing in the financial definition of the return and risk measures for the different electricity generation assets considered and, by extension, to the entire portfolio.

Second, applying the methodology of the Portfolio Theory to the Spanish case of generation and make a comparison with the mix 2020 proposed by the MITyC. Given the specific circumstances which occur in the Iberic peninsula due to the integration of the Spanish and Portuguese markets and their connections failure with the rest of the European continent, it seems reasonable the elaboration of a single energetic mix for these two states, according to the application of the return-risk methodology. It would contribute to define an optimum portfolio of electric generation for a singular and identifiable territorial area, as the indicated one.

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