A description of the electricity system in Spain since 2005 and the economic potential for renewable energy technologies

by

Javier Izquierdo-Millan

A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree of
Master of Applied Science
in
Civil Engineering

Waterloo, Ontario, Canada, 2014

Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my document may be made electronically available to the public.

Abstract

The energy system in Spain can be characterized as being high energy intensive when compared to the rest of Europe and because of its high dependence on imported resources (around 84%). The focus of this document is to explore a novel approach to describe, as part of this energy system, the electricity system in Spain since 2005 and the economic potential for renewable energy technologies (RET) to replace the electricity generated from fossil resources by 2050. The heart of the design and implementation of any RET policy should be the reduction or elimination of fossil fuel dependency.

This document aims at describing the evolution of the Spanish electricity system in the last decade, and addressing the possible influence of certain factors in the design and implementation of the electricity system by using modern modeling technologies to evaluate the potential of RET. This will represent a novel approach to bridge the results from modeling technologies to policy makers. To ensure the credibility and reliability of the data researched, validation criteria has been used which includes the accuracy of information, the content (whether factual or opinion), time (limited to certain periods), format (validity of internet sources, journals, etc), authority (reputable authors and sources), objective reasoning, currency and links to other resources, and the quality of writings and its review among others.

The proposed research approach follows a methodology where the first step is to understand the electricity system in Spain, followed by the definition of the model of interest (optimization models) and the design of three different scenarios (Business as Usual, FIT and High fossil prices) for the evaluation of the potential of RET, finishing with the analysis of the results from the model and data collected from the perspectives of what has been done in previous RET policies and plans, and the possible influence of factors such as organizations and corporations on those policies and plans.

The results obtained from the model are analysed and compared to the Business as Usual scenario. The amount of electricity generated from fossil resources and to be replaced by RET is calculated using the scenarios, as well as the evolution of primary energy, imports, final energy consumptions and CO2 emissions.

In order to test the applicability of this approach, the results of the model have been compared with the current situation of the Spanish electricity system. Calculations using capacity factors of the RET and their share in the current electricity generation are performed in order to identify the final amount of power (MW) to be installed in order to replace the electricity generated (GWh) by fossil resources by 2050. Based on the conclusions, RET has the potential to replace the generation of electricity from fossil fuels but improvements in the efficiency of RET will be needed. In addition, it is recommended that significant considerations in RET policy like the energy and electricity systems should be a strategic component of the Spanish policy system, be done in order to set the Spanish electricity system in a more sustainable path.

Acknowledgements

I would like to express my special appreciation and thanks to my supervisors Professor Jatin Nathwani and Professor David Fuller, who have been tremendous mentors for me. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist. Your support and guidance have been incredible and without your extensive expertise, knowledge and kindness, this document would not have been possible.

I would also like to thank my readers Professor Ian Rowlands and Associate Professor Monica Emelko for serving as readers and for your brilliant comments, suggestions and valuable feedback.

I would especially like to thank Dr. Helena Cabal and Dr. Maryse Labriet for their academic and continued support and assistance over this past year.

A special thanks to my family. Words cannot express how grateful I am to my wonderful wife and children, Grace, Gabriel and David, for their love and inspiration and for all of the sacrifices that you have made on my behalf.

At the end I would like to express appreciation to my beloved wife Grace who I spent sleepless nights with and was always my support in the moments when there was no one to answer my queries. I love you and admire you, and you gave me the courage and strength needed to continue with this. Without your support, this document would not have been possible. I dedicate this document to you.

Table of Contents

List of Figures vii
List of Tables x
List of Abbreviations xii
1. Introduction 1
2. RET in Spain 6
  2.1. RET plans and RET in Spain 6
  2.2. Renewable policies in Spain 7
  2.3. CO2 emissions and contribution of RET 11
3. Framework of the PER 13
  3.1. Regulatory overview 13
  3.2. Targets of the PER 14
  3.3. Financing 17
  3.4. Policy tools 19
  3.5. Results of the PER 21
    3.5.1. Main results 21
    3.5.2. Achievements of the RET 25
    3.5.3. Investments of the RET 27
    3.5.4. Premiums of the RET 28
4. A review of the Spanish electricity system 30
  4.1. Possible factors influencing electricity plans 30
    4.1.1. Influence from corporations 30
    4.1.2. Evolution of regulations and its relationship to corporations 36
    4.1.3. The "revolving doors" effect 41
    4.1.4. Considerations of influences 44
  4.2. Current situation of the Spanish electricity system 47
5. Application of the TIMES-IB model to the Spanish energy system 66
  5.1. The Times model generator 67
  5.2. The Times-IB model 73
  5.3. Scenarios 76

6. Results ... 81
6.1. Primary energy ... 81
6.2. Final energy consumption ... 84
6.3. Primary energy-Imports ... 85
6.4. Electricity generation ... 86
6.5. Electricity generation-fossil resources ... 88
6.6. CO2 emissions ... 89
6.7. Summary ... 90
7. Analysis ... 93
7.1. Analysis of the PER ... 93
7.2. Understanding the Spanish electricity system ... 100
8. Conclusions and recommendations ... 111
8.1. Conclusions ... 111
8.2. Recommendations ... 115
9. Further work ... 119
References ... 120
Appendix A – Shell interface ... 130
Appendix B – Primary energy additional graphs ... 141
Appendix C – Primary energy imports additional graphs ... 144
Appendix D – Electricity generation additional graphs ... 147
Appendix E – Electricity generation from fossil additional graphs ... 150
Appendix F - CO2 emissions additional graphs ... 152
Appendix G - VEDA training course agenda ... 154
Appendix H - VEDA training course certificate ... 156
Appendix I – Wind data ... 157

List of Figures

Figure 1. Evolution of political decisions related to RET in the last 13 years 3

Figure 3.1. Expected RET supply mix by 2010 16

Figure 3.2. Primary energy consumption mix in 2005 and 2010 (March 2011) 22

Figure 3.3. Evolution of biofuels over gasoline and diesel 24

Figure 3.4. Premium to RET during the PER 28

Figure 4.1. Iberdrola's electricity generation in Spain (2012) 33

Figure 4.2. Evolution of political decisions related to RET in the last 13 years 37

Figure 4.3. Evolution of regulations 2000-2010 37

Figure 4.4. Primary energy in Spain (2011) 48

Figure 4.5. Composition of renewable energies in primary energy (2011) 49

Figure 4.6. Evolution of electricity generation in Spain (2013) 51

Figure 4.7. Evolution of electricity generation from conventional technologies in Spain (2013) 52

Figure 4.8. Comparison of electricity generated in Spain (2013) 53

Figure 4.9. Evolution of electricity generation from RET technologies in Spain (2013) 54

Figure 4.10. Annual demand coverage of electricity demand (2012) 57

Figure 4.11. Coverage of peninsular maximum hourly demand - 13 February 2012 (9:00 pm - 10:00 pm) (2012) 58

Figure 4.12. European electricity prices for residential consumers (2013) 60

Figure 4.13. Electricity bill composition in Spain 61

Figure 4.14. Evolution of CO2 emission in Spain 62

Figure 4.15. Evolution of CO2 emission from energy processes in Spain compared to total emissions 63

Figure 5.1. Overview of an energy system model 67

Figure 5.2. Illustration for market equilibrium. 70

Figure 5.3. Simplified TIMES objective function 72

Figure 5.4. Total annual cost simplified equation 72

Figure 5.5. Origins of Times-IB. 73

Figure 5.6. Single region reference energy system. 74

Figure 5.7. Model requirements. 75

Figure 5.8. FIT values in the model. 79
Figure 6.1 Primary energy consumption in the three scenarios. 81
Figure 6.2. Final energy consumption in the three scenarios. 84
Figure 6.3. Comparison of primary energy import results per scenario in 2050 (PJ) 85
Figure 6.4. Comparison of electricity generation results per scenario in 2050 (GWh) 86
Figure 6.5. Comparison of electricity generation from fossil resources results in 2050 (GWh) 88
Figure 6.6. Comparison of CO2 emissions before CCS results per scenario in 2050 (MtCO2) 90
Figure 7.1. Expected and real installed capacity of the PER. 95
Figure 7.2. Maximum hourly and daily demands in Spain. 100
Figure 7.3. Supply and demand aggregated curves. 101
Figure 7.4. Evolution of the tariff deficit in Spain (2013). 104
Figure B.1 Evolution of primary energy – BaU 141
Figure B.2. Evolution of primary energy – FIT 141
Figure B.3. Evolution of primary energy – HFOSPRI 142
Figure B.4. Primary energy share by 2050 – BaU 142
Figure B.5. Primary energy share by 2050 – FIT 143
Figure B.6. Primary energy share by 2050 – HFOSPRI 143
Figure C.1. Evolution of imports on primary energy – BaU 144
Figure C.2. Evolution of imports on primary energy – FIT 144
Figure C.3. Evolution of imports on primary energy – HFOSPRI 145
Figure C.4. Imports share on primary energy by 2050 – BaU 145
Figure C.5. Imports share on primary energy by 2050 – FIT 146
Figure C.6. Imports share on primary energy by 2050 – HFOSPRI 146
Figure D.1. Evolution of electricity generation – BaU 147
Figure D.2. Evolution of electricity generation – FIT 147
Figure D.3. Evolution of electricity generation – HFOSPRI 148
Figure D.4. Electricity generation share by 2050 – BaU 148
Figure D.5. Electricity generation share by 2050 – FIT 149
Figure D.6. Electricity generation share by 2050 – HFOSPRI 149
Figure E.1. Evolution of electricity generation from fossil resources – BaU 150
Figure E.2. Evolution of electricity generation from fossil resources – FIT 150

Figure E.3. Evolution of electricity generation from fossil resources – HFOSPRI.................... 151
Figure F.1. Evolution of CO_2 emissions before CCS – BaU 152
Figure F.2. Evolution of CO_2 emissions before CCS – FIT... 152
Figure F.3. Evolution of CO_2 emissions before CCS – HFOSPRI 153

List of Tables

Table 3.1. Targets of the PER for 2010 (2010).. 14

Table 3.2. Situation in 2005 and targets of the PER for 2010 – Generation in primary energy terms... 15

Table 3.3. Situation in 2005 and targets for 2010 according to PER – Installed capacity 16

Table 3.4. Situation in 2005 and targets for 2010 according to PER – Generation...................... 17

Table 3.5. Financial analysis of the PER 17

Table 3.6. Public financial support to the PER.. 18

Table 3.7. Endowment of the PER.. 18

Table 3.8. PER budget and AACC contribution... 19

Table 3.9. Financial analysis of the PER (thousands of euros) 20

Table 3.10. Premiums of the PER (2005)... 21

Table 3.11. Primary energy consumption in 2005 and 2010 (March 2011)................................. 22

Table 3.12. Generation and gross consumption of electricity in Spain, 2005-2010..................... 23

Table 3.13. REE’s 2010 Electrical Power Balance.. 24

Table 3.14. Real installed capacity and degree of achievement of the PER (March 2011).......... 25

Table 3.15. Real electricity generated and degree of achievement of the PER (March 2011)..... 26

Table 3.16. Final electricity generated after the PER (March 2011) 27

Table 3.17. Forecasted and real investment of the PER (March 2011) 28

Table 4.1. Installed capacity per corporation (2008) 31

Table 4.2. Connections of politicians and electricity generators (2013) 43

Table 4.3. Level of dependency of external sources (2011) 49

Table 4.4. National Electricity Balance (2013) 51

Table 4.5. Installed capacity in Spain (2012) 55

Table 4.6. Evolution of capacity factors in Spain (2013) 56

Table 4.7. Levelized cost in Spain (2013) 56

Table 4.8. Evolution of premiums toRES in Spain (2013)... 59

Table 6. Color coding for main technologies... 81

Table 6.1. Share of primary energy per scenario in 2050... 82

Table 6.2. Share of primary energy imports per scenario in 2050.. 85

Table 6.3. Share of electricity generation per scenario in 2050 87
Table 6.4. Share of electricity generation from fossil resources per scenario in 2050 88
Table 7.1. CO2 emissions from the Spanish electricity sector 109
Table 7.2. Values for the Spanish electricity and energy systems (2012-2013) 110

List of Abbreviations

AACC	Autonomous Communities
BP	British Petroleum
CNE	Comisión Nacional de la Energía (National Energy Commision)
CPI	Consumer´s Price Index
EE	Energy Efficiency
EEA	European Economic Area
EU	European Union
FIT	Feed-In-Tariff
IDAE	Institute for the diversification and the energy saving
IEA	International Energy Agency
MITYC	Ministry of Industry, Tourism and Commerce
MIEYT	Ministry of Industry, Energy and Tourism
MMA	Ministry of Environment
MtCO2	Millions of tons of CO2
PER	Spanish renewable energy plan 2005-2010
PFER	Spanish renewable energy plan 2000-2010
PP	Popular party (Political party)
PSOE	Socialist party (Political party)
REE	Red eléctrica de España
RET/RET	Renewable energy sources/Renewable energy technologies
TIMES	The Integrated MARKAL–EFOM System
TIMES-IB	TIMES Iberia (Spain + Portugal)
TNCs	Transnational corporations

1. Introduction

The Spanish energy system has been characterized by higher energy intensity than the rest of Europe, by a high dependence on energy imports (around 84%) and also by rapid changes of the energy system in the last few years (IDAE 2005) (MIEYT 2011). The Spanish renewable energy plan 2005-2010 (Plan de Energías Renovables - PER) represented a revision of the Spanish promotion plan for renewable energy 2000-2010 (PFER) in force up until 2005. As stated in the PER, this revision happened because the initial forecast of absolute growth of renewable energies (RET) set up in the PFER were not met, energy consumption was growing continuously and over forecasted, and there was a need to comply with new international environmental commitments set by the Government of Spain (GOS) in terms of climate change and sustainable development.

The PER set three main targets and only one was fulfilled (and not to its full extent). When it comes to plans of this kind, it does not matter how ambitious the targets can be and how successful policy tools are, if it is continually lacking on considering fundamental and structural changes to the system. For instance, and based on further reviews in this document of the evaluations carried out by the Evaluation´s State Agency of public policies and the quality of services of the PER, the creation of a central unit for the Spain's energy strategy and a real cooperation between the GOS and the Autonomous communities (AACC) should have been at the core of the PER. In addition, it was detected that the AACC had too much power and influence during the last decade and it made them key players in any policy deployment. These influences, in addition to the transferred powers and competences associated to RET policies and politicians, should have been revised during the deployment of the PER (AEVAL 2011).

The economic crisis is still hitting many European countries and Spain is struggling to cope with factors that are damaging its economy (a high unemployment rate of more than 25% by 3Q/2013). In addition, the Spanish energy system appears to be unsustainable as there is a high dependence of imported resources; the Spanish energy system generates high CO_2 emissions; and there is high uncertainty of nuclear policy in the future (Cabal and Lechon 2011).

In particular, in 2010, around 80% of the total primary energy was from fossil resources and 77% of the total primary energy was imported (MITYC 2010). Also, up to 2007 CO2 emissions' trend was upward, well above the agreed target in the Kyoto Protocol (protocol approved by the EU through the Decision 2002/358/EC), and exceeding 51% from base year levels. Unfortunately the trend has gone upward again and Spain will have to buy carbon credits from other EU countries[1] in order to not exceed the 15% increase in emissions from the year base (1990) during the period 2008-2012 (Kyoto commitment). Finally, there will be a withdrawal from nuclear energy (fission) in 2028 in Spain with the decommissioning of the last nuclear facility, and due to the Fukushima accident, the society is questioning this type of energy again.

This situation implies the need to review the Spanish energy and electricity systems through possible changes in demand and supply. The following concepts should be taken into account:
a) the dependency of external sources (imports) for primary energy;
b) the scarcity of fossil resources;
c) the uncertainties over the nuclear future, and
d) the potential of renewable energy and the maturity of some of these technologies.

In order to look at these issues in a comprehensive approach, the following research questions will be investigated:

- Is there an economic potential for RET to replace electricity generated from fossil resources by looking at the current situation of the electricity system?
- Is there potential to reduce CO2 emissions by using RET in Spain?

This document will aim at contributing to the description of the evolution of the Spanish electricity system in the last decade, to address the possible influence of various factors (i.e. corporations and organizations) in the design and implementation of electricity systems and the use of modern modeling technologies to evaluate the performance of energy and electricity systems. All together, they will represent a novel approach to bridge the results from modeling technologies to policy makers.

[1] http://www.energias-renovables.com/articulo/espana-sigue-gastando-millones-de-euros-por-20121023/

This novel approach follows a methodology where the first step is to understand the electricity market of the jurisdiction of analysis (in this case Spain), and to ensure the availability and credibility of the data to be used. It is followed by the definition of the model of interest and the design of the scenarios, and finalizing with the analysis of both results from the model and data collected from the perspectives of what has been done in previous RET policies and plans, and the possible influence of external factors in those policies and plans.

It was also found that the best way to clearly understand such a complex area of analysis, which is energy and electricity models and its implications, was on a timeframe approach, where, starting in the year 2000, the storyline could be told following the path up to 2050. Figure 1 shows the timeframe related to the first 13 years (2000-2013) including the most important political decisions related to RET. The remainder of the period of analysis, up to 2050, will be covered by the preliminary results from the model of interest.

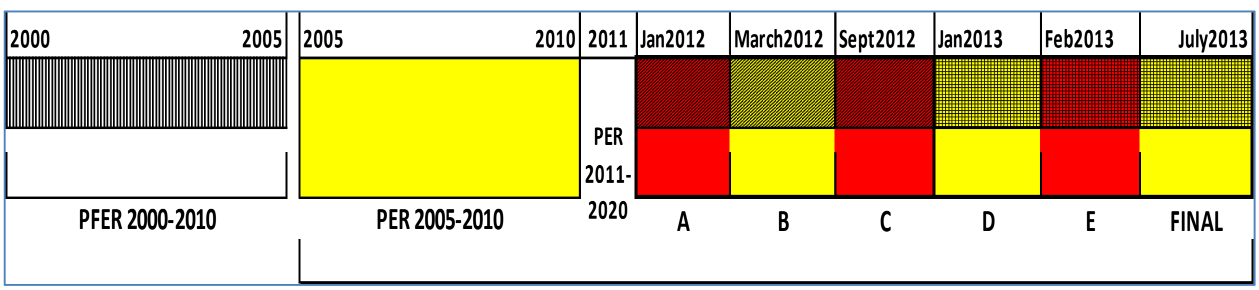


Figure 1. Evolution of political decisions related to RET in the last 13 years

Previous studies of electricity markets using modelling techniques have been done extensively. Fuller (2008) described market equilibrium models with continuous and binary variables, where binary variables were introduced into nonintegrable models (not based in social welfare maximization). In a different approach, Linares et al. (2008) used an oligopolistic, long-term generation expansion model to design three scenarios to analyze whether current policies could be able to achieve sustainability by themselves.

San Cristobal (2012) used a goal programming model for environmental policy analysis with an application for Spain, and Burgos-Payan et al. (2013) discussed the case of the effects of the integration of RET in Spain by empirically reviewing Spanish RET support schemes and the balance between the cost increase for the system and the reduction in wholesale prices, while including the effect of the cost of CO2 allowances needed to cover the greenhouse emissions, as given in Sensfuss et al. (2008) and Saenz de Miera et al. (2008).

Labriet et al. (2010) used an analysis to evaluate the energy strategies to be implemented in Spain in order to satisfy the EU Renewable Directive. The modelling framework of this work relied on the techno-economic model TIMES-Spain, part of the Pan-European TIMES model, and is used to discuss the dynamics of the RET implementation in Spain, given the European targets as well as the national targets and context. The model of interest used in this document follows this approach and utilizes and modifies the existing model of the TIMES-IB (IB stands for Iberia: Spain and Portugal). The TIMES-IB model is a techno-economic model of the Spanish and Portuguese energy systems which resulted from the interaction and participation of various European projects. This model was selected as it best represents the Spanish energy system and is a reputable source for modelling technologies.

This document represents a summary of the RET and RET plans in Spain, as well as the PER and its results. It provides a review of the evaluation carried out by the evaluation and quality agency of the Government of Spain, and it analyzes the results focusing on the electricity generation from RET. The document also provides current available information for installed power and generation from both RET and conventional sources in Spain, as well as the current premiums for the generation of electricity from RET, the capacity factors and levelized costs for selected generating technologies in Spain, and the peninsular instantaneous peak power demand (in MW) for the current time and for the period of the PER.

This information will be supported by the analysis of the results from the identified model which considers three possible scenarios: a Business as Usual scenario, which includes the suspension of Feed-In-Tariff (FIT) incentives in Spain since January 2012, a FIT scenario, which maintains the FIT incentives, and a high fossil fuel scenario, where prices for imported fossil fuels have been increased in 10% to see the response of the system such increase. These three scenarios have been defined under these concepts because they represent the most real situation of the energy and electricity systems (Business as Usual scenario); they consider the hypothesis of continuing with the FIT incentives (FIT scenario); and analyses the reaction of the systems under an increase of imported resources (high fossil fuel scenario). The scenarios will be analysed in order to reflect the anticipated situation in 2050. The document will also provide comprehensive conclusions and recommendations that might help understand the complexity of implementing these types of plans and its consequences.

The document is structured as follows. Chapter 2 briefly describes the renewable energy context in Spain including renewable energy plans and renewable energy policies in Spain, CO2 emissions and the contribution of RET to mitigate them. Chapter 3 briefly describes the framework of the PER and its main targets, it presents the results, including the achievements of the RET, the investment in RET and the premiums to RET. Chapter 4 reviews the Spanish electricity system focusing on possible external factors that might influence RET plans, as well as providing current data available in the Spanish energy and electricity sectors. Chapter 5 introduces the modelling framework used for the analysis (TIMES-IB) and the defined scenarios. Chapter 6 presents the most important results obtained for the different designed scenarios, and chapter 7 analyzes the PER results and the current data available in the Spanish electricity sector. Finally, conclusions and recommendations are provided in chapter 8.

2. RET in Spain

This chapter further elaborates the renewable energy context in Spain, taking into consideration the RET plans and RET in Spain. It provides a brief review of the renewable energy policies over the last 15 years and the evolution of CO_2 emissions with considerations for the contribution of RET to mitigate them.

2.1. RET plans and RET in Spain

A cost-effective reduction in CO_2 emissions should require both the implementation of effective Energy Efficiency (EE) technologies and practices, and also give priority to low carbon technologies in the energy mix including RET. In this context, most governments adopted measures aimed at overcoming economic, technical and nontechnical barriers to deploy RET. The specific objectives and the support mechanisms employed have varied from country to country, reflecting specific interests, economic context, market and industrial situation, technology potential, and also the idiosyncrasies of each culture. The degree of success of these measures has also been variable, both in terms of cost and deployment effectiveness (Lewis and Wiser 2007) (Komor and Bazilian 2005). Spain has often been cited as an example for its success in the rapid deployment of alternative energy technologies, particularly wind, concentrated solar thermo electric, and photovoltaic (PV) (Martinez et al. 2009). However, there have been serious concerns about the rising costs of RET support in a country that has been badly hit by a financial crisis.

For the last two decades, Spain has undergone a rapid economic expansion accompanied by a similarly fast growth in energy consumption. Between 1990 and 2005, Spain's gross domestic product (GDP) grew by 49.1% and its primary energy use by 61.3%, compared to 12.0% and 15.1% in the EU, respectively (IEA 2008). Despite the lack of fossil fuel resources in its national territory, the Spanish energy model is highly centralized and is dependent on conventional technologies. As a reference, of the 142 070 ktoe of primary energy used in 2008, 47.6% came from oil-derived products, 24.3% natural gas, 10.7% nuclear power, 9.7% coal, and 7.6% renewable energies. Imports accounted for 68.6% of the coal, 99.8% of the oil, and 99.9%

of the natural gas consumed (MITYC 2009). In addition, prior to the development of incentive programs, the use of RET in Spain was limited to small-scale biomass combustion installations for heat generation and small hydropower plants.

Several studies analyzed the future of RET in Spain. Linares et al. (2008) described different scenarios with estimations for 2020 that ranged from 16% (nonintervention) to 53% (ambitious RET policies including large hydropower investments). Resch et at. (2008) calculated that RET contribution in Spain would need to reach 40% of electricity (mostly from wind, large-scale hydropower, and biomass) and 21% of heat in order to comply cost effectively with 2020 EU objectives. The Spanish government approved the "Planning of the Electricity and Gas sectors 2008–2016," which included a national indicative target for RET generation of 32% in 2016 (129,472 GWh).

2.2. Renewable policies in Spain

The Spanish policy on the promotion of RET needs to be analyzed within an international context. On one hand, the European Union sets the common ground in the form of directives which are subsequently transposed and developed into national legislation while, on the other hand, international commitments on CO2 emissions (like the Kyoto Protocol) became legally binding to EU Member States following ratification in 2002.

The Kyoto Protocol allowed Spain a 15% increase in CO2 emissions above the 1990 values for the reference period 2008–2012. This allocation has been exceeded due to a larger than expected economic expansion in that period. GHG emissions peaked in 2005 (52.9% above 1990 values) and were subsequently reduced to 42.7% in 2008 due to low economic activity levels as a result of the economic crisis (more information about CO2 emissions in Spain will be provided in following chapters).

Other international and European contexts affecting the Spanish policy were:

- The most recent RET Directive (*Directive 28/2009/EC* on the promotion of the use of energy from renewable sources) which set the regulatory framework and a target for renewable energies in Europe (20% RET in the final energy consumption, including electricity, heat, and transport sectors combined).
- *The European Climate Change and Energy Package* (2008) (also referred to as 20/20/20 by 2020) included three binding targets for the EU to be achieved by 2020: To reduce emissions of GHG emissions by 20% by 2020 (with respect to 1990), to increase energy efficiency to save 20% of EU energy consumption by 2020, to reach 20% of renewable energy in the total energy consumption in the EU by 2020, and to reach 10% of biofuels in the total consumption of vehicles by 2020.
- *The Biomass Action Plan* (2005) sets out a strategy aimed at doubling the use of biomass for energy purposes in the EU from 69,000 ktoe in 2004 to around 150,000 ktoe in 2010.
- *Directive 2003/96/EC* restructuring the Community framework for the taxation of energy products and electricity allowed Member States to apply low (or even zero) fuel tax rates for biofuels.
- The Biofuels Directive (*Directive 2003/30/CE* on the promotion of biofuels for transport) set non-legally binding targets on the share of biofuels on transport fuels (2% in 2005 and 5.75% in 2010).
- The RET Directive (*Directive 2001/77/EC* on the promotion of electricity produced from renewable energy sources in the internal electricity market) sets specific targets for RET-E generation in Member States and included several technical and administrative measures intended to achieve an overall objective of 21% by 2010.

Spain has been one of the most successful countries in the public promotion of RET, particularly wind electricity (Del Rio 2008). This support has been regulated through a feed-in tariff (FIT) scheme (FITs are subsidies per unit of energy (kWh) generated paid in the form of a total quantity (tariff) or as an amount on top of the wholesale electricity price (premium) fed into the grid and combined with a purchase obligation by the utilities). This instrument is also used in most other EU countries with different degrees of success both in terms of effectiveness and cost (Del Rio 2008) (Linares et al. 2008).

The success of RET support policies does not depend only on the type of support scheme being implemented, but is significantly affected by the design elements of those instruments. The basic structure of the Spanish FIT system was first implemented in 1998 but has been subsequently modified in 2004 and 2007 (2008 for solar PV). Despite the legislative changes, there has been continuity and stability in the RET promotion framework under different governments (Del Rio 2009). The main regulations regarding RET promotion in Spain according to San Miguel et. al (2010) were:

Law of the Electricity Sector (Law 54/97): this law established a "Special Regime" in which RET was given a special treatment with the aim of achieving the EU target of 12% of the gross energy consumption from RET in 2010. The basic framework for RET support was provided by this law, which included guaranteed grid access and a price support for RET producers. In addition, RET plants lower than 10 MW would receive a premium set by the government.

Royal Decree on the Special Regime (RD 2818/1998): this Royal Decree developed the support system for RET producers, who could choose between two alternatives: (1) A fixed premium on top of the electricity market price and (2) a fixed total price (fixed feed-in). These values were adjusted annually, which allowed generators to know their revenue in advance regardless of changes in the market price. The cost of implementing this scheme is finally paid by consumers through their electricity bill.

Royal Decree 436/2004: RET generators were allowed to sell their electricity to distributors or directly to the market. In both cases, support was defined for each renewable technology as a percentage of the average electricity tariff (AET). The rapid increase in the AET that took place in that period led to an excessive increase in the costs of RET support. This led to the approval of another Royal Decree.

Royal Decree 661/2007: this Royal Decree provided the current RET regulatory framework in Spain. RET support was tied to the evolution of the consumer price index (CPI). In addition, a cap-and-floor system for RET support levels was implemented. If the market price plus the premium are above the cap value, then RET generators only receive the cap level. If they are below the floor values, they receive the floor price. The goal was to avoid excessive costs for consumers (cap), while simultaneously encouraging investments (floor).

However, back in 2008 there were already concerns about the rising costs of the system, an inherent problem of effective FIT schemes. Although the unitary support (eurocents/kWh) was capped, a relatively high FIT made RET investments very attractive, which lead to a high increase in the total support. Official data from the National Energy Commission (2008) showed that the total amount of RET support increased more than threefold from 1,740 million euros in 2004 to 5,702 million euros in 2008. Particularly problematic was the rise in the total support between 2007 and 2008 (from 3,369 million euros to 5,702 million euros, a 69% rise). Although total support increased for all technologies, the greatest growth in relative terms was experienced by Solar PV (fivefold increase) and in absolute terms by wind (it added €1,100 million to the support received in 2007). The fact that the total installed Solar PV electricity capacity in Spain in 2008 was 3,210 MW, when its target for 2010 was only 400 MW, suggests that the FIT was set at a very high level.

In order to deal with FIT increases, the Spanish government put a cap on the price and on the quantity (RET deployment), leading to a high increase in the total support. This was done first in the solar PV realm.

In September 2008, the Spanish government approved the Royal Decree 1578/2008, which set not only a cap price on this technology but also a quantity cap (through the requirement for a preregistration). This was done in order to keep the overall support costs at reasonable levels. For the other RET, there was an attempt to limit the overall costs of the system by requiring renewable energy projects to pre-register, limiting the right to receive the FIT to those already preregistered before June 7, 2009 (Royal Decree-Law 6/2009). The aim of this preregistration was, according to the government, to encourage a "sustained growth" for the different technologies in order to avoid technical problems and excessive costs (Hernandez 2009).

2.3. CO2 emissions and contribution of RET

Spanish CO2 emissions in 2008 were 42.7% above base-year levels (1990), which compares poorly against the Kyoto target of 15% in 2008–2012. Energy and transport sectors were the main contributors to the CO2 emissions. The analysis of the factors behind these emission trends is beyond the scope of this document, although there is a relation to the strong economic and demographic growth, and the increase in energy demand.

The two main pillars to mitigate emissions are policies aimed at Energy Efficiency (EE) and the promotion of RET. Regarding the former, most instruments to promote EE in Spain are the result of transposition of EU directives into national law which predominantly fall under the Spanish Energy Efficiency Strategy (E4) 2004–2012. The other main pillar of a low carbon economy is RET, which contributes to the reduction in CO2 emissions and Kyoto compliance.

A particularly decisive effort should be made in sectors not covered by the EU emissions trading scheme (EU-ETS), also called diffuse sectors (mainly transport and residential/commercial), where emissions are expected to increase by 65% (MMA 2007). Substitution of conventional fuels for RET in electricity generation would facilitate compliance with the EU-ETS by power companies. In addition, the implementation of renewables in transport and heat would contribute to the control of emissions in the diffuse sectors. However, this will not be enough to reduce emissions to the required levels (MMA 2007).

Therefore, recourse to Kyoto units[2] were needed to cover emissions both in sectors covered and non-covered by the EU-ETS. For covered sectors, private companies (mostly in the electricity sector) needed to purchase Kyoto units (1,302 MtCO2 for 2008–2012). In addition, the government purchased 159 MtCO2 to cover diffuse emissions, thus promoting the development of RET abroad.

The long-term problem is that emissions from diffused sectors are difficult to tackle with renewable energy measures and other more decisive instruments have been neglected. In

[2] Emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries that have emission units to spare - emissions permitted them but not "used" - to sell this excess capacity to countries that are over their targets.

particular, fiscal instruments (taxes) within an ecological tax reform, with corresponding reductions in social security contributions by employers have been proposed by economists in Spain with little success. Instead, the approach should be a more politically feasible one (but less socially desirable), i.e., to subsidize the large emissions increase in the diffuse sectors by buying Kyoto units through the public budget.

Deployment of renewables will reduce CO2 emissions in Spain. The initial plan indicates that about 70% of the reduction should be attained in the electricity generation area, followed by 20% in biofuels, and 10% in thermal uses. However, there are currently no official calculations on how Spain is expected to achieve its 20% renewable energy target in 2020 and the resulting CO2 emission reductions. Only some prospective studies for the electricity sector can shed light on this issue.

The following chapter provides a detailed explanation of the latest RET plan deployed in Spain, the PER (2005-2010).

3. Framework of the PER

According to IDAE (2005) Spain has been undergoing rapid growth in energy intensity for the last fifteen years. Spain's excessive and growing dependence on external energy supplies — around 83% over the last few years— and the need to preserve the environment, made it necessary to promote effective formulas for efficient use of energy and the use of clean sources of energy. It was believed that there were enough reasons to promote effective formulas for efficient use of energy and the use of clean sources of energy.

3.1. Regulatory overview

Since 1997 Spain has undergone its own liberalization process, going from a strong interventionist policy, almost a monopoly status, to a more open market for generation and commercialization (IDAE 2005). Following the European framework, promotion policies for renewable energies (RET) have been developed around the liberalized market set up by the Law 54/1997. In particular, Article 4 of the 54/97 Law for the Electrical Sector, stated that "the national electricity planning will be indicative except for those concerning transmission facilities, with the participation of the Autonomous communities (AACC)".[3]

This "indicative planning" should include: notes to the evolution of market conditions, the expectations about the behaviour of the demand and the resources to fulfill it, the need of new power, correction of the imbalances between generation and demand, and the criteria for environmental protection. In this planning process, AACC should have had special significance due to their authority to decide the preferential location of the resources within its own territory, although, it could represent an opposition to any national electricity policy. Under this regulatory overview, the targets for the PER were set.

[3] The State is organized into municipalities, provinces and autonomous communities (AACC): 17 autonomous communities and two cities (Ceuta and Melilla). These AACC are: Andalusia, Aragón, Principality of Asturias, Balearic Islands, Basque Country, Canary Islands, Cantabria, Castile-La Mancha, Castile and Leon, Catalonia, Extremadura, Galicia, La Rioja, Madrid, Region of Murcia, Navarre, and Valencian Community.

3.2. Targets of the PER

The targets set in 2005 expected a contribution from RET (hydro included) of 12.10 % of primary energy consumption in 2010, electricity generation from RET of 29.4 % of the gross electricity consumption, and biofuels consumption of 5.75 % of gasoline and diesel use for transport in 2010 (IDAE 2005). Table 3.1. summarizes the three main targets for 2010.

Target #	Targets of the PER	2010
1	Renewable energies / Primary energy	12.10 %
2	% of electricity from renewable sources / Gross consumption of electricity	29.4 %
3	% of biofuels (gasoline and diesel) use for transport	5.75 %

Table 3.1. Targets of the PER for 2010 (2010)
Source: Adapted from the PER targets, IDAE (2005).

These targets were broken down by the electricity generation technologies considered in the PER (see Table 3.2.) and classified into primary energy terms (ktoe) for the first target, and into installed power (MW) and generation of electricity (GWh), for the second target. The third target was classified as a percentage of biofuels consumption over the consumption of gasoline and diesel.

In order to evaluate the achievement of the first target, the PER considered to move from a 6.88 % of RET of the total consumption of primary energy, to a 12.10 % share of RET's total country's consumption by 2010. The following table shows the targets for the generation of electricity from RET in primary energy terms (ktoe).

Renewable energy source / ktoe	Output in primary energy terms (ktoe)	
	2005	2010
Hydro-electric (>50MW)	1,979	1,979
Hydro-electric (10-50MW)	498	557
Hydro-electric (<10MW)	466	575
Biomass power station	680	3,586
Biomass Co-combustion	0	1,552
MSW	395	395

Wind power	1,683	3,914
Solar PV	5	52
Biogas	267	455
Solar Thermoelectric	0	509
Biomass Thermal	3,487	4,070
Low temperature solar Thermal	51	376
Biofuels	228	2,200
Total renewable energy source	**9,739**	**20,220**
Consumption of primary energy	**141,567**	**167,100**
% of renewable energy / primary	**6.88 %**	**12.10 %**

Table 3.2. Situation in 2005 and targets of the PER for 2010 – Generation in primary energy terms
Source: Adapted from the PER targets, IDAE (2005).

For the second target, the PER aimed at installing more than 15,400 MW from RET by 2010 with an increase of more than 17% in wind power. Hydro-electric (>50MW) was planned to stay at the same capacity and therefore having a decrease of more than 18% at the expense of other RET. Other technologies presented only increments of around 1% (solar PV, biomass power stations, etc). Table 3.3. shows, for the installed power, the situation in 2005, the targets set by PER for 2010, and the expected increases for this period. In addition, Figure 3.1. shows the expected percentages of RET installed capacities by 2010.

Renewable energy source / MW	Situation in 2005 (MW)	Target for 2010 (MW)	Expected increase 2005-2010 (MW)
Hydro-electric (>50MW)	13,521	13,521	0
Hydro-electric (10-50MW)	2,897	3,257	360
Hydro-electric (<10MW)	1,749	2,199	450
Biomass			
Biomass power station	344	1,317	973
Co-combustion	0	722	722
MSW	189	189	0
Wind power	8,155	20,155	12,000
Solar PV	37	400	363
Biogas	141	235	94
Solar Thermoelectric	0	500	500
Total installed capacity from RET	**27,033**	**42,495**	**15,462**

Table 3.3. Situation in 2005 and targets for 2010 according to PER – Installed capacity
Source: Adapted from the PER targets, IDAE (2005).

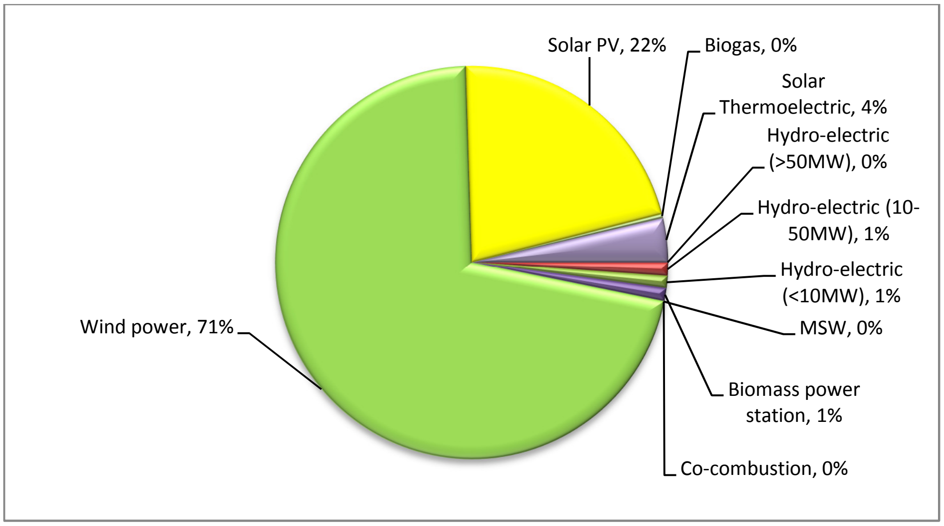


Figure 3.1. Expected RET supply mix by 2010
Source: Adapted from MIEYT (2011)

The targets of the PER aimed at increasing by more than 42,000 GWh the electricity generation from RET, with an important increase coming from wind power, almost 12%, at the expense of reduction in generation from hydro-electric. Table 3.4. shows the situation in 2005, the targets set in the PER for 2010 for the generation of electricity from RET, and the expected increases for this period.

Renewable energy source / GWh	Situation in 2005 (GWh)	Target for 2010 (GWh)	Expected increase 2005-2010 (GWh)
Hydro-electric (>50MW)	25,014	25,014	0
Hydro-electric (10-50MW)	5,794	6,480	686
Hydro-electric (<10MW)	5,421	6,692	1,271
Biomass			
Biomass power station	2,193	8,980	6,787
Co-combustion	0	5,036	5,036
MSW	1,223	1,223	0
Wind power	19,571	45,511	25,940
Solar PV	56	609	553
Biogas	825	1,417	592

Solar Thermoelectric	0	1,298	1,298
Total electricity generated from RET	**60,097**	**102,260**	**42,163**

Table 3.4. Situation in 2005 and targets for 2010 according to PER – Generation
Source: Adapted from the PER targets, IDAE (2005).

3.3. Financing

The PER estimated that around 23,598 million euros would be the volume of investment needed in order to achieve the targets over the period 2005-2010 (see Table 3.5). This volume required equity financing (developers) of 4,720 million euros, with the rest to be provided by the market (18,198 million euros) and public subsidies (681 million euros).

Source of finance	Amount (millions of euros)	%
Developers	4,719	20
Debt (external)	18,198	77
Public subsidies	681	3
Total	**23,598**	

Table 3.5. Financial analysis of the PER
Source: Adapted from the PER targets, IDAE (2005).

The total public financial support for renewable energies was estimated to be approximately 8,492 million euros, where 3,536 million euros (2,855 + 681) were going to be strictly public aid, and charged to the national budget partly in the form of investment subsidies and partly as tax incentives for the production of biofuels, and 4,956 million euros for the total support over the period through the premium system for the generation of electricity from RET. Thus, under the "Public aids" denomination, the PER considered three categories as financing sources: Public subsidies, Tax incentives for the use of biofuels, and Premium to electricity generation from RET. Table 3.6. shows a summary of these categories and the allocated budget and percentage to the total.

Public aids	Amount (millions of euros)	%
Public subsidies	681	8
Tax incentives for the use of biofuels	2,855	34

Premiums to electricity generation from RET	4,956	58
Total	**8,492**	

Table 3.6. Public financial support to the PER
Source: Adapted from the PER targets, IDAE (2005).

Public subsidies included the conventional non-recoverable subsidies and those intended to improve the conditions for the financing of the investments (681 million euros). Tax incentives for the use of biofuels consisted on the tax exemption on hydrocarbons in the selling price of biofuels or zero tax rate (2,855 million euros), and the Premiums to electricity generation from RET was a financial support for the bulk of electricity generated with RET. Only in two areas, solar PV and solar thermoelectric, were premiums planned to be supported with investment aids. The implementation of the indicative premiums proposed in the PER implied a steady annual increase in the average reference tariff of approximately 0.6 %.

Table 3.7. illustrates the total endowment of the PER, and its distribution during the implementing period.

	2005	2006	2007	2008	2009	2010	TOTAL
Public subsidies (millions of euros)	62	82	115	126	137	156	**678**
Tax incentives for the use of biofuels (millions of euros)	18	153	328	517	751	1,085	**2,852**
Premiums to electricity generation from RET (tariff contributions) - (millions of euros)	79	264	521	909	1,352	1,828	**4,953**
Total	**159**	**499**	**964**	**1,552**	**2,240**	**3,069**	**8,483**

Table 3.7. Endowment of the PER
Source: Adapted from the PER targets, AEVAL (2011).

This financing was planned to be provided by the GOS and by the AACC, although the latter had a scant economic contribution. The following table summarizes the estimates for this financing.

	2005	2006	2007	2008	2009	2010	TOTAL
PER budget (millions of euros)	160.20	499.12	965.95	1,554.28	2,241.94	3,070.70	**8,492.19**
AACC contribution (millions of euros) -	30.00	44.00	75.00	86.00	95.00	113.00	**443.00**
% of contribution	18.70%	8.81%	7.76%	5.53%	4.23%	3.67%	**5.21%**

Table 3.8. PER budget and AACC contribution[4]
Source: Adapted from the PER targets, AEVAL (2011).

3.4. Policy tools

Following the European model, generation and commercialization of electricity in Spain are both deregulated, while transportation and distribution are regulated activities with tolls and tariffs. Electricity generation in Spain has two different regimes: the ordinary regime (OR), to which all the conventional generation technologies belong to, and the special regime (SR), to which the renewable energy generation belongs. Although a wholesale electricity market was created at the end of the 90s, a high proportion of domestic consumption continued to be supplied at regulated tariff. The regulated rate does not cover all generation and distribution costs, thus leading to a deficit (tariff deficit), which is through credits backed by revenue from the electricity system. The National energy commission (CNE) estimated that this deficit could be more than 43,000 million euros by 2020[5]. According to Linares et al. (2008), the Spanish market is a concentrated market, with two large firms covering almost 80% of the generation market with four other small firms with only some generation capacity.

The SR grants grid access priority and ensures higher remuneration to RET producers. The extra cost of the RET is passed on to the electricity system and to consumers through tolls and consumption rates. The feed-in-tariff (FIT) of the PFER incorporated both fixed total prices and price premiums added to the electricity market price. Tariffs were updated in May 2007 by curbing profits for wind generators and setting incentives for other types of renewable energies. The new rules set by the PER aimed at guaranteeing an internal rate of return of 7% to wind and hydroelectric plants that chose to sell power to distributors directly, and returns of 5% and 9% respectively if they participated in the electricity pool market.

As outlined in the PER, project developers had to choose between transferring electricity to the system through the transport or distribution grid and therefore being paid a FIT (premium) for it

[4] The differences observed between this table and the previous totals reflect literally which was contained in the PER.
[5] http://www.20minutos.es/noticia/1356305/0/

(constant for all the programming periods), or selling the electricity on the wholesale electricity market, having the electricity sale price being the hour price resulted in the wholesale market supplemented if any, with a premium. The following table was prepared in the PER to show the financing plan per technology.

Renewable energy source	Total financing			Premium for period	Tax incentives	Total investment
	Developer	External	Public		Exemption	
Wind	190,013	760,051	0	189,062	0	**950,063**
Hydro	2,351,278	9,405,113	0	2,598,870	0	**11,756,391**
10MW	10,915	43,662	0	0	0	**54,577**
10-25MW	142,019	284,039	284,039	0	0	**710,097**
25-50MW	392,919	1,571,677	0	1,059,922	0	**1,964,596**
Solar Thermoelectric	231,366	925,464	0	0	2,855,095	**1,156,830**
Solar PV	23,932	95,726	0	49,425	0	**119,658**
<100kW w/monitoring	536,922	1,799,610	348,078	0	0	**2,684,611**
<100kW fixed	432,500	1,723,800	6,200	559,514	0	**2,162,500**
>100kW	33,021	95,762	36,324	0	0	**165,107**
Biomass	374,842	1,493,070	6,299	499,415	0	**1,874,211**
Totals	**4,719,728**	**18,197,974**	**680,939**	**4,956,208**	**2,855,095**	**23,598,641**

Table 3.9. Financial analysis of the PER (thousands of euros)
Source: Adapted from the PER targets, AEVAL (2011).

Based on the PER's financial analysis, project developers would have to invest approximately 4,719 million euros and the financial markets would have to lend around 18,197 million euros. The three public measures considered by the PER were previously described in section 3.3.

In general, the main source of aid for electricity generation from RET was the one provided by the PER's premiums system. This incentive constituted the main mechanism supporting the development of these sources. The following table shows the premiums quoted in the PER (2005) per generating technology. The following section will present the results of the PER and the current available information to help in analysing the results and understanding the complexity of implementing these types of plans.

Electricity Generation	Premium (c€/kWh)
Wind	2.9322
Hydro	
10MW	2.9322
10-25MW	2.9322
25-50MW	2.1991
Solar Thermoelectric	18.326
Solar PV	
<100kW with monitoring	38.4846
<100kW fixed	38.4846
>100kW	18.3260

Electricity Generation	Premium (c€/kWh)
Biogas	2.9322
Biomass	
Energy crops <15MW	5.8643
Energy crops 15-50MW	4.3982
Agricultural and forestry wastes	4,3982
Agro-industry waste	4.3982
Timber industry waste	2.1991
Co-combustion	1.4661

Table 3.10. Premiums of the PER (2005)
Source: Adapted from the PER targets, IDAE (2005).

3.5. Results of the PER

3.5.1. Main results

The PER considered three main targets: 12.10 % of RET over the total primary energy consumption, 29.4% of electricity to be generated from RET, and biofuels consumption of 5.75 % of gasoline and diesel use for transport by 2010. The results presented in this section were provided by the IDAE in April 2011 (last ones available).

i) Target 1: 12.10 % of renewable energies over the total primary energy consumption.

The target for primary energy consumption was not fulfilled. Table 3.11. shows that the final primary energy consumption from RET was of 11.30 % and therefore did not achieve the 12.10 % targeted.

Primary energy source	2005	2010
Natural Gas	20.04 %	23.50 %
Oil	49.39 %	47.30 %
Coal	14.58 %	6.30 %

Nuclear	10.32 %	12.20 %
Renewable Energies	**5.76 %**	**11.30 %**

Table 3.11. Primary energy consumption in 2005 and 2010 (March 2011)
Source: Adapted from the AEVAL report (2011).

Figure 3.2. shows the primary energy consumption mix in 2005 and in 2010, where wind and hydro representing only 2.9% and 2.8% respectively in 2010.

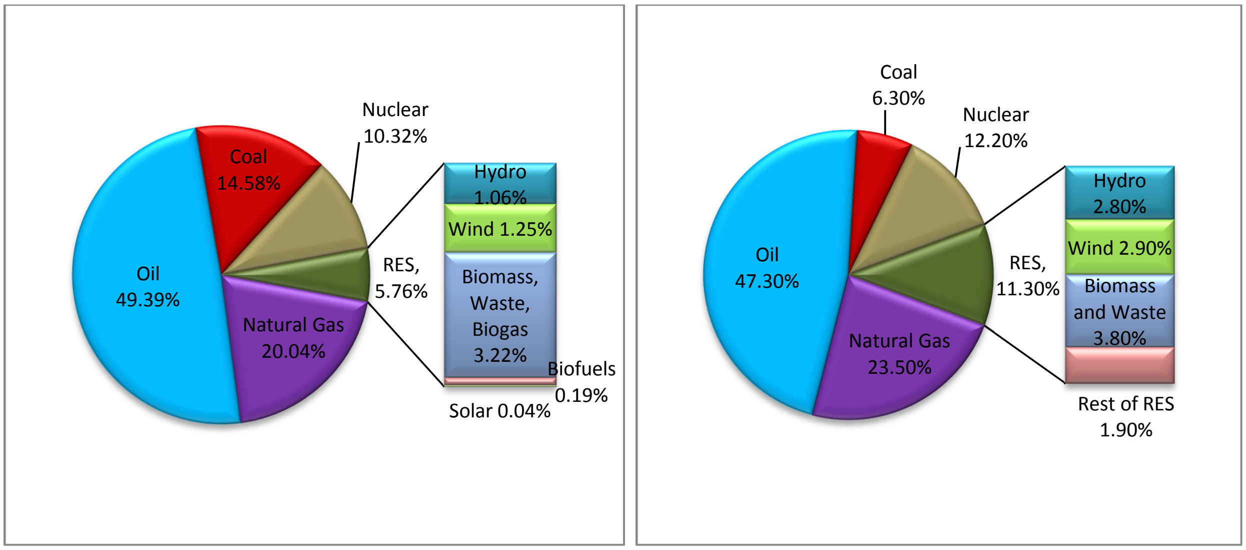


Figure 3.2. Primary energy consumption mix in 2005 and 2010 (March 2011)
Source: Adapted from the AEVAL report (2011).

ii) Target 2: 29.4 % of electricity to be generated from RET.

The target for the share of electricity produced from RET was fulfilled according to the results presented in the E4 report. For this case, electricity generated from RET reached 33.3 % of the total electricity production in 2010. Table 3.12. shows the generation and gross consumption of electricity in Spain during the period of the PER.

Electricity generation	2005 (GWh)	2006 (GWh)	2007 (GWh)	2008 (GWh)	2009 (GWh)	2010 (GWh)
Conventional						
Coal	81,458	69,850	75,505	49,892	36,864	25,493
Nuclear	57,539	60,126	55,102	58,971	52,761	61,788
Natural Gas	82,819	94,706	98,272	122,964	109,565	96,216
Oil	24,261	22,203	21,591	22,099	20,074	16,517

Hydro from pumping (not RET)	5,153	3,941	3,289	2,817	2,831	3,106
Total conventional (GWh)	**251,740**	**250,826**	**253,759**	**256,743**	**222,092**	**203,120**
Renewables						
Hydro	17,872	25,890	27,233	23,271	26,353	42,215
Wind	21,175	23,297	27,568	32,496	38,091	43,708
Solar PV	41	119	501	2,541	5,939	6,279
Solar Thermo	0	0	8	16	103	691
Thermal RE (Biogas, Biomass, etc)	2,652	2,774	2,898	3,696	3,876	4,228
Total renewables	**41,740**	**52,080**	**58,208**	**62,020**	**74,362**	**97,121**
Total gross generation	**292,970**	**302,906**	**311,967**	**318,763**	**296,457**	**300,241**
International exchange (export)	-1,344	-3,279	-5,751	-11,039	-8,106	-8,338
Gross consumption	**291,626**	**299,627**	**306,216**	**307,724**	**288,351**	**291,903**
Evolution of RET contribution	**14.3%**	**17.4%**	**19.0%**	**20.2%**	**25.8%**	**33.3%**

Table 3.12. Generation and gross consumption of electricity in Spain, 2005-2010
Source: Adapted from CNE, IDAE, Energy Deputy Office and the Ministry of Industry (March 2011).

However, if the results of Red Electrica Española's (REE – the Spanish Transmission Operator) annual report are applicable, the RET contribution to the total reaches a share of 21.76 %. This reduction is caused because the REE's annual report considered RET in a different way than the PER. The PER considered all hydro generation as a renewable source but did not consider all hydro generation for the PER. Hydro (more than 50MW) from the ordinary regime is not considered as a renewable source receiving premium since it does not belong to the special regime, where hydro (minihydro, up to 50MW) receives a premium for generation of electricity. Table 3.13. shows the REE's annual results for 2010.

Electricity generation	GWh	%
Ordinary regime		
Hydro	38,653	13.39%
Nuclear	61,990	21.48%
Coal	25,478	8.83%
Fuel/Gas	9,553	3.31%
Combined Cycle	68,595	23.77%
Total ordinary regime	**204,269**	**70.79%**
Consumption in generation	-7,572	
Special regime		

Hydro	6,811	2.36%
Wind	43,692	15.14%
Solar PV	6,311	2.19%
Solar Thermo	692	0.24%
Thermal RE (Biogas, Biomass, etc)	5,316	1.84%
Thermal not renewable	29,045	10.07%
Total renewables	**62,822**	**21.76%**
Total special regime	**91,867**	**31.84%**
Total net generation	**288,564**	
Consumption in pumping	-4,458.00	
International exchange (export)	-8,333.00	
Demand	**275,773.00**	
Balance	**12,791.00**	

Table 3.13. REE's 2010 Electrical Power Balance
Source: The Spanish electricity system summary, REE (2010).

iii) Target 3: 5.75 % of biofuels (gasoline and diesel) use for transport.

The target for the use of biofuels as an alternative for gasoline and diesel was not fulfilled. Figure 3.3. shows the evolution of the consumption of biofuels over gasoline and diesel (%) during the period of the PER. The consumption reached only a 5 % share, below from the 5.75 % targeted.

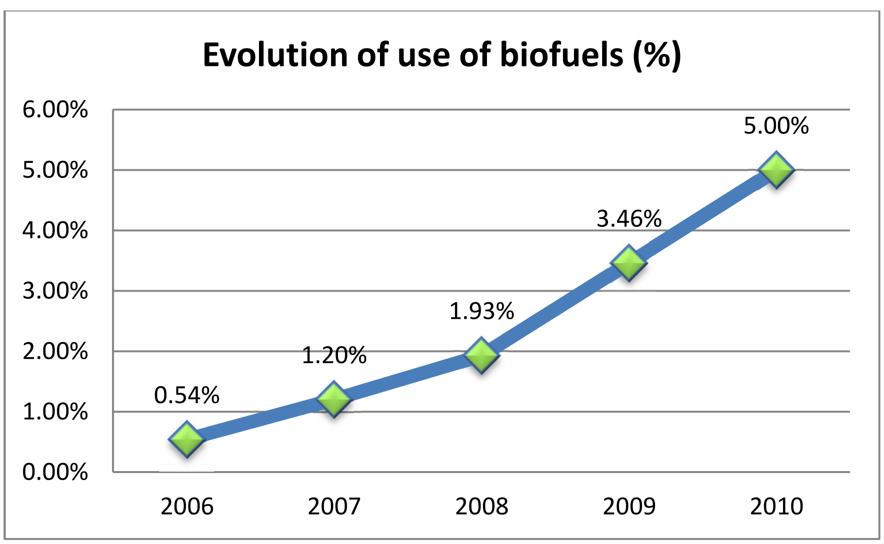


Figure 3.3. Evolution of biofuels over gasoline and diesel
Source: AEVAL report (2011)

3.5.2. Achievements of the RET

Installed capacity

Renewable energy source / MW	Expected increase 2005-2010	Real installed capacity increase 2010	% of target achieved
Hydro-electric (>50MW)	0	0	100 %
Hydro-electric (10-50MW)	360	192	53.33 %
Hydro-electric (<10MW)	450	173	38.44 %
Biomass			
Biomass power station	973	188	19.32 %
Co-combustion	722	0	0 %
MSW	0	0	0 %
Wind power	12,000	12,426	103.55 %
Solar PV	363	3,749	1,032.78 %
Biogas	94	59	62.77 %
Solar Thermoelectric	500	632	126.40 %
Total installed capacity from RET	**15,462**	**17,419**	

Table 3.14. Real installed capacity and degree of achievement of the PER (March 2011)
Source: Adapted from the AEVAL report (2011).

Table 3.14. indicates that wind energy and solar thermoelectric achieved their targets as planned, with approximately 103% and 126% respectively of target achievement. The degree of achievement for Solar PV was more than 1,032%, installing more than 3,700 MW. The rest of the technologies did not achieve their targets. The total installed capacity by the PER was of 17,419 MW by 2010. The final installed capacity after the PER finished can be seen in the following table. Wind power installed 20,581 MW (46.30 %), and Solar PV installed 3,786 MW (8.52 %).

Renewable energy source / MW	Final Installed capacity in 2010
Hydro-electric (>50MW)	13,521
Hydro-electric (10-50MW)	3,089
Hydro-electric (<10MW)	1,922
Biomass	
Biomass power station	532
Co-combustion	0

MSW	189
Wind power	20,581
Solar PV	3,786
Biogas	200
Solar Thermoelectric	632
Total installed capacity from RET	**44,452**

Table 3.15. Final installed capacity after the PER (March 2011)
Source: Adapted from the AEVAL report (2011).

Generation

Renewable energy source / GWh	Expected increase 2005-2010	Real generated increase 2010	% of target achieved
Hydro-electric (>50MW)	0	0	100 %
Hydro-electric (10-50MW)	686	627	91.40 %
Hydro-electric (<10MW)	1,271	585	46.03 %
Biomass			
Biomass power station	6,787	1,317	19.40 %
Co-combustion	5,036	0	0 %
MSW	0	0	0 %
Wind power	25,940	24,137	93.05 %
Solar PV	553	6,261	1,132.26 %
Biogas	592	268	45.27 %
Solar Thermoelectric	1,298	1,144	88.14 %
Total electricity from RET	**42,163**	**34,340**	

Table 3.15. Real electricity generated and degree of achievement of the PER (March 2011)
Source: Adapted from the AEVAL report (2011).

Table 3.15. illustrates that only the generation from Solar PV achieved the target with a 1,132% degree of achievement, corresponding to 6,317 GWh generated, representing around 5,700 GWh generated more than what was targeted. Wind power was close to the target with a 93% degree of achievement as well as Hydro-electric (10-50MW) with around 91% of degree of achievement. The following table shows the final electricity generated by RET in 2010 as a consequence of the PER.

Electricity Generation (GWh)	Final electricity generated in 2010
Hydro-electric (>50MW)	25,014
Hydro-electric (10-50MW)	6,421
Hydro-electric (<10MW)	6,006
Biomass	
Biomass power station	3,510
Co-combustion	0
MSW	1,223
Wind power	43,708
Solar PV	6,317
Biogas	1,093
Solar Thermoelectric	1,144
Total electricity generated from RET	**94,437**

Table 3.16. Final electricity generated after the PER (March 2011)
Source: Adapted from the AEVAL report (2011).

After the PER finished , the final total electricity generated by RET was 94,437 GWh. Wind power generated 43,708 GWh (46.3 %), and Solar PV generated 6,317 MW (26.49 %).

3.5.3. Investments of the RET

According to the results of the PER, the total investment planned for the PER was approximately 23,084 million euros (see table 3.7. in section 3.3. for more details). The real investment, in 2010, was approximately 39,237 million euros, an increase of almost 70% of the forecasted budget. Per technology, in 2005 wind was planned to receive almost 51% of the total investment by 2010, but the final investment received was only 35%. In monetary values, Wind received more than was planned (13,630 million euros versus the 11,757 million euros planned).

Solar PV was planned to receive an investment of approximately 2,000 million euros (8.8% of the total) but it ended up receiving 19,697 million euros or 50.2% of the total invested in RET in 2010. This is an increase of more than 865% of the investment planned. Table 3.17. shows the planned and real investments per technology in the PER.

Electricity generation	Plan Invesment (M€)	
	Plan Forecast	Real (2010)
Wind power	11,757.00	13,630.00
Hydro-electric (<10MW)	700.00	258.90
Hydro-electric (10-50MW)	250.00	167.90
Solar Thermal	2,685.00	1,331.50
Solar Thermoelectric	2,163.00	1,924.00
Solar PV	2,039.30	19,697.00
Biomass Thermal	764.40	316.10
Biomass electrical	1,448.90	553.10
Biogas	119.70	129.90
Biofuels	1,156.70	1,229.30
Total investment	**23,084.00**	**39,237.70**

Table 3.17. Forecasted and real investment of the PER (March 2011)
Source: Adapted from the AEVAL report (2011).

3.5.4. Premiums of the RET

Premiums for the generation of electricity from RET (under the special regime) during the period of the PER (2005-2010) were a total of 9,448.50 million euros, where around 66% (6,250 million euros) went to the Solar PV technology. Figure 3.4. illustrates the unbalanced distribution of the premium among the different technologies.

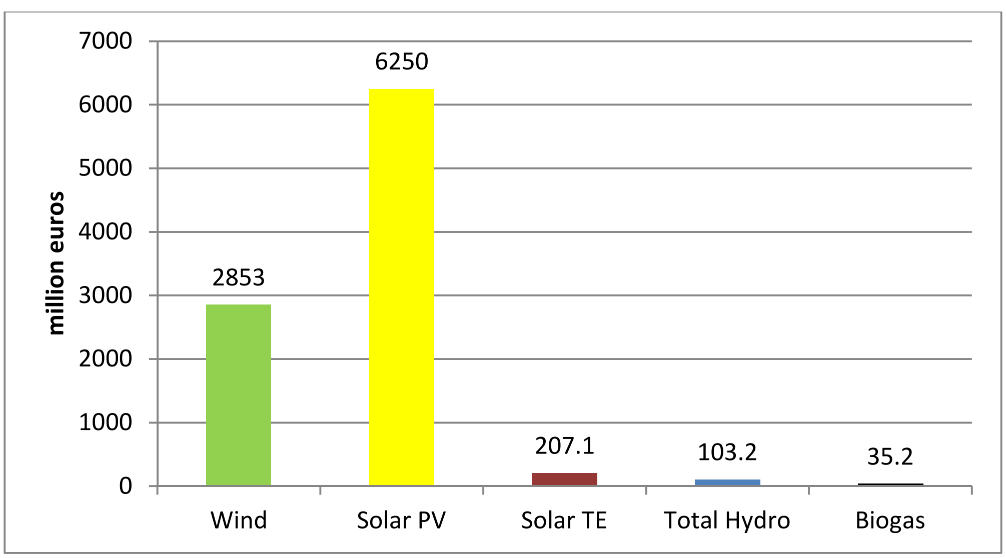


Figure 3.4. Premium to RET during the PER
Source: AEVAL report (2011)

After this brief description of the framework of the PER and its main targets and final results, the following chapter will look into possible external factors that could have influenced some key decisions regarding the deployment of RET policies. As well, it will provide a brief summary of the current situation of the Spanish electricity system.

4. A review of the Spanish electricity system

This chapter reviews various literatures related to possible factors that might influence the design and implementation of electricity and energy plans, and concludes with information on the current situation of the Spanish electricity and energy systems.

4.1. Possible factors influencing electricity plans

The first part of the chapter looks at possible external factors that might influence the design and implementation of electricity plans in Spain. The section will attempt to shed some light on how organizations, corporations, and politicians could have influenced decisions in the design and implementation of energy plans in Spain.

4.1.1. Influence from corporations

Since the early 1970s, the United Nations has considered the role and impact of transnational corporations (TNCs). Yet over a period of three decades, the UN's mediated efforts have shifted decisively from a ‘‘between-state’’ focus in the regulation of TNCs to a globalized, multi-stakeholder ‘‘beyond-state’’ process of TNC standard setting (Coleman, 2003).

Transnational corporations (TNCs) are central players. They influence the policies of governments worldwide and the destinies of individual economies in the developing world. They also have a crucial impact on the eco-system, and they can cause first world countries to bend to their demands. According to Lewis and MacLeod (2004), it has been detected that the traditional Westphalian conception of international law being state-centered is becoming increasingly inappropriate in a global society where non-state actors wield great power.

As illustrated in Table 4.1., Iberdrola shares 35% of the installed capacity under the ordinary regime and 17% under the special regime, followed by Endesa with 29% and 11% respectively. It can be noted that 66% of the electricity generators under the special regime (mainly RET) are not related to large corporations.

Electricity generating corporation	% of net installed capacity – ordinary regime	% of net installed capacity – special regime
Iberdrola	35%	17%
Endesa	29%	11%
Unión Fenosa	10%	2%
Gas Natural	5%	3%
Hidroeléctrica cantábrico	4%	-
Enel	4%	-
Rest	13%	66%

Table 4.1. Installed capacity per corporation (2008)
Source: Adapted from MITYC (2008) and corporation's websites.

Some relevant players that may influence the Government of Spain in the design and implementation of the Spanish energy plans are: Iberdrola, Endesa, Gas natural-Fenosa, E-On and EDP. These five corporations are the only five members of Unesa, the Spanish Association for the electrical industry. Unesa is an organization for the representation, promotion, management and defence of the common and general interests of its members as well as the electricity sector. Red Electrica Española (REE), the Spanish TSO (Transmission System Operator) and the sole transmission agent and operator of the Spanish electricity system is also considered due to its relevance in the electricity sector.

The influences of TNCs in Spain should be seen by identifying the owners of these TNCs, their business interests, their influence in the successive Governments to regulate the electricity system, and the relationship of those TNCs with members of the successive Government members (known in Spain as the "revolving door's effect"[6]). Iberdrola is owned by a construction company called ACS (19%), Qatar Holding (8.4%), Chase Nominees (8,3%), State Street Bank & Trust (5.9%), Suez (5%), and three Spanish banks (16.4%) among others. ACS is owned by the stock market (35%), Private banking (18%), four private investors (31.9%), and Southeastern Asset (6.5%) among others.

[6] http://blogs.elconfidencial.com/espana/mientras-tanto/2013-12-22/los-verdaderos-culpables-de-la-subida-de-la-luz_69265/.
http://www.eldiario.es/economia/electricas-expresidentes-exministros_0_192130890.html

Endesa is owned 92% by the Italian Electricity generator Enel, which is owned at the same time by the Government of Italy. Gas Natural Fenosa is owned by the Spanish Bank La Caixa (36.6%) and by the Oil company Repsol (31.2%), which is also owned by Free Float (68% including 42% of international investments) and PEMEX Mexico (9.5%). According to Sterlacchini (2012), Enel is the fifth largest electricity generation company in the world producing 404.3 Billions of kWh, and Endesa is the eight largest electricity generation company producing 202.3 Billions of kWh. Together, they produce 607.6 Billions of kWh, making them the first in the world. In this respect, Red electrica de España (REE), the Spanish TSO (Transmission System Operator) should also be considered. REE is the sole transmission agent and operator of the Spanish electricity system and is controlled by more than 70% by the stock markets. Due to its dominant position in the transportation of electricity in Spain, REE influences the system.

One of the primary goals of corporations is to maximize shareholder value. When the shareholders are financial institutions, investment funds, and other large corporations (i.e. in the cases of Iberdrola and Endesa), the operations of these corporations will be in line with this principal of maximizing the value for shareholders. When looking at Iberdrola's profile, the company's main revenue activities between 2005-2012, both in Spain and in the foreign market was 85,01% from conventional technologies, and 14.99% from RET (excluding large hydro) (Iberdrola corporation 2005-2012).

In 2012, Iberdrola's conventional technologies generation was 78.62% of the total, with RET being 21.38% of the share. Figure 4.1. illustrates the Iberdrola's electricity generation in Spain, per technology.

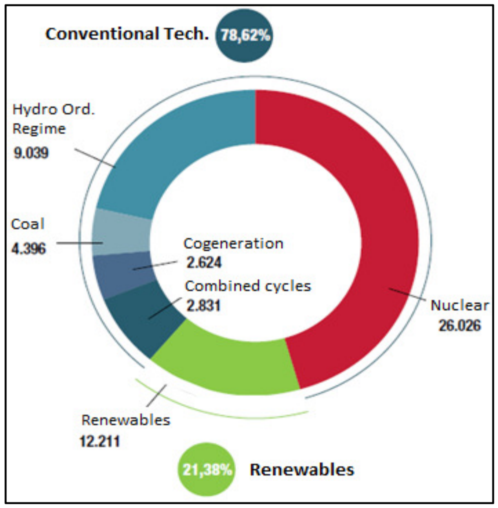


Figure 4.1. Iberdrola's electricity generation in Spain (2012)
Source: Greenpeace (2013) and Iberdrola's Annual report (2012)

The total generation of nuclear energy represented 45,55%. Iberdrola is a company with a large nuclear component in Spain. In addition, in 2012, the generation from combined cycle power plants was only 4.9% of the total. This is key to understanding Iberdrola's actions and influences on the Spanish electricity system.

The significant decline in the generation from combined cycle facilities and the rise in the percentage of generation from RET (17.25% in 2011 versus 21.38% in 2012) could have been seen as a move to RET by Iberdrola, but this is not clearly a consequence of an increase in RET investments by the company. This decline is more due to the fact that over the past five years the large electricity companies decided to focus large parts of their business activity in the gas sector, and installed massively this type of technology (27,123 MW in Spain, which 5,893 MW are Iberdrola's) (REE 2013).

But there was a great planning problem. In the Spanish electricity system, the combine cycle thermal plants contributes to the regulation of the system and they go into operation only when there is a high demand for electricity that cannot be covered with others sources such as RET. The massive installation of these facilities coincided with a significant increase in the RET capacity installed, the Decree of aids to the generation from coal, and to a significant fall of the

demand of electricity, which, resulted in a strong decline in the generation of electricity from thermal gas plants. In addition, Iberdrola is also a gas producer (Iberdrola 2012).
The large Spanish electricity generation corporations (the Unesa members) are focused on conventional technologies (see Table 4.1.) and have constantly argued about the unsustainability of RET in the Spanish system[7]. In addition, they have also managed to mitigate partly the losses related to the combined cycle plants by influencing the successive governments' decision on regulation.

In the Spanish energy regulatory system, particularly in the electricity sector, multiple laws, decrees, Ministerial orders, norms, etc are being developed. This makes it very difficult for all these regulations to be known and understood in detail. This is something that favors only large electrical corporations (Greenpeace 2013). According to the same Greenpeace report, the Unesa members have managed to influence the different governments in Spain to develop norms that favor their interests over the last thirty years. Some of these achievements stated in the report are:

Costs of transition to competition: Law of the electric Sector 1997, which established the liberalization of the sector. This law had Mr. Jose Maria Aznar, from the Popular Party – Conservative (PP) as Prime Minister, Mr. Josep Piqué as Minister of industry and Mr. Rodrigo Rato as Minister of economy (all from the PP party). This law was the end of the liberalisation process of the electricity sector. One of the main consequences of the accomplished liberalization was the political decision of unlinking costs and revenues of the electric system, so the creation of the so-called tariff deficit. This system forces consumers to pay a surcharge each year for the deficits of previous years, and requires future consumers, for 15 years, to withstand surcharges for what is left each year to pay. In this process the electricity companies also gained an additional 3,396 million euros for the so-called costs of transition to competition (CTC)[8], which could have been used against the tariff deficit, but was not returned. This debt reamins since none of the Governments claimed the return of the 3,396 million euros.

[7] http://cincodias.com/cincodias/2011/10/27/empresas/1319882343_850215.html
[8] http://cincodias.com/cincodias/2008/07/02/empresas/1215005981_850215.html

In addition, during the energy planning carried out under the Governments of Aznar (1996 – 2004), priority to natural gas was given and this, together with the way in which the "liberalization" was made, gave rise to the gas bubble, which entailed the construction of tens of thousands of MW of this technology.

"Windfall profits" or the benefits coming from nowhere: these are benefits that are not a result of real competition in a free market but a consequence of the Regulation. This is due to the fact that certain facilities (hydro and nuclear) are already redeemed and paid off but still receive the price of other technologies that price set the price to meet the demand. In the case of both nuclear and hydro power plants, the extra cost or benefits are around 3,000 million euros per year.

CESUR auctions: this is the system to set the price of electricity and was established in 2010. This action, both complex and opaque, is to set the prices every term (it has been denounced by the National consumer's organization and investigated by the CNE). The two main issues in the auction were the possible alteration of the market prices and the excess of price between the set at the auction and subsequent actual price that is paid in the market. The difference between both prices would be what theoretically consumers would be paying as a guarantee of having a fixed energy price during the term of the tariff and, therefore, not being exposed to variations of the same kind in the electricity market.

Initial understandings indicated that the attendees to the auction are divided into two, the energy sellers (electrical companies) and the marketers of the last resort (TUR), that are five: Iberdrola, Endesa, Gas Natural-Fenosa, E.ON y HC Energía, coinciding with the largest electricity generators. The reality is different: the market operator (OMIE), pre-qualifies approximately 50 firms interested in participating (although approximately only half are normally admitted), but only a quarter of them are groups with distributors of the TUR (the only ones that can provide the tariffs). In the auction, approximately 65% are firms with headquarters in Spain and only 35% belong to groups with subsidiaries of generation in the Spanish market. In the auction process there are also numerous banks, investment funds, and trading companies, and sometimes their names are not published[9]. Around 1,000 million euros annually is estimated by Greenpeace

[9] http://www.serviciosenergeticos.org/2011/09/vuelta-con-las-subastas-cesur-el-cuento.html

that consumers could be saving, but instead goes into important profits for the companies participating in the auction. At the time of preparation of this document (end of December 2013), the new CNE, the CNMC (National Commission for the Markets and Competition) has suspended the CESUR auction planned to set the price of electricity for the first term of 2014.

Payments for capability: in order to cover the investment made by Unesa's members, and due to the excess of installed combined cycles, these facilities charge 20,000 euros/MW for ten years. In 2011, the payments for capacity were of 1,535 million euros.

Payments for availability: Mr. Miguel Sebastian, former Minister of industry during Prime Minister Jose Luis Rodriguez Zapatero, 2004 – 2011 (PSOE – Socialist party) approved just three days before the general election on November 20, 2011, to pay for the availability of the combined cycle plants (as requested by Iberdrola and criticised by the CNE)[10]. This represents a disbursement of 190 million euros per year.

Securitisation of the tariff deficit (Matea 2013): the procedure adopted for the securitisation of the tariff deficit is a surcharge of 5,000 million euros for the consumers who have to pay the interest on this debt to the banks that own it.

Reduction targets by 2020: the Unesa members have fought to reduce to 20% the 2020 RET target on the final consumption of energy, which is the minimum required by the European directive (Directive 2009/28/EC). The first National draft for the RET action plan 2011-2020 set the objective at 22.7% but ultimately was set to 20.8%.

4.1.2. Evolution of regulations and its relationship to corporations

The last two Administrations, Prime minister Jose Maria Aznar (1996 – 2004) and Prime minister Jose Luis Rodriguez Zapatero (2004 – 2011) have been particularly sensitive to the Unesa demands since it seemed that many of the elaborated norms favored the conventional technology sector and served to curb the development of RET in Spain. The best way to look at

[10] http://www.boe.es/boe/dias/2011/11/18/pdfs/BOE-A-2011-18064.pdf

all these norms and changes is by looking at their evolution on a timeline approach. Figure 4.2. summarizes the main stages in the evolution of the Governments decisions regarding RET in Spain, which seems to have been on a rollercoaster for the last three years.

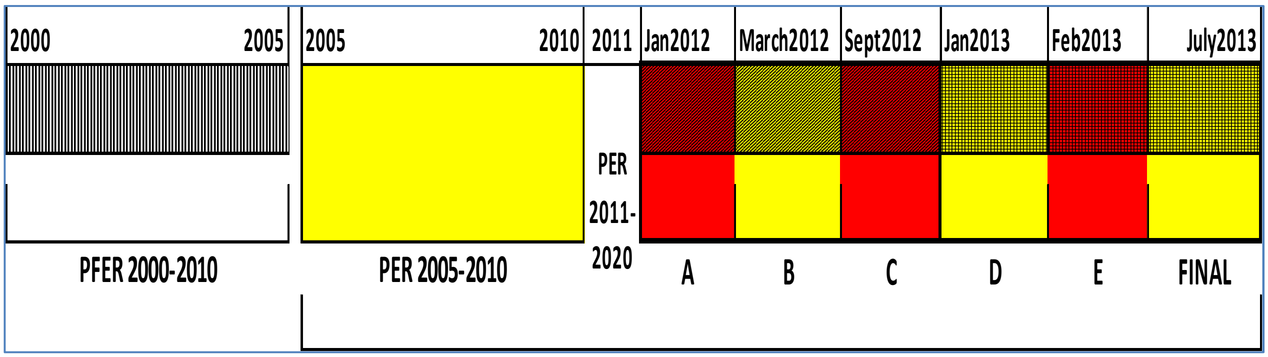


Figure 4.2. Evolution of political decisions related to RET in the last 13 years

As described in chapter 3, the PER represented the five year period where the deployment of RET was active in Spain. During this time, and including the previous RET plan, there were seven regulatory directives (three European and four national, see chapter 2 for more details) directly related to the renewable energy plans, which is shown in the table below.

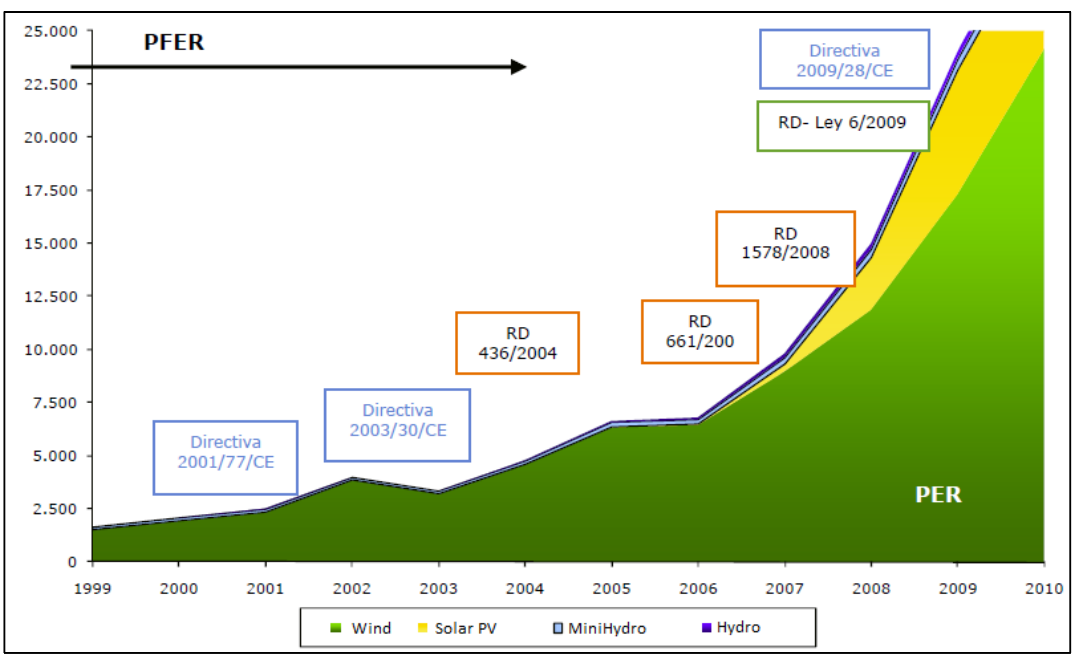


Figure 4.3. Evolution of regulations 2000-2010
Source: AEVAL report (2011)

On January 27th, 2012, the new majority conservative Government (PP) suspended subsidies for new renewable energy projects in an attempt to cut the nation's tariff deficit (this decision is considered in the design of the Business as Usual scenario). The new law put an end to subsidies for new wind, solar, cogeneration and waste-incineration plants. Existing renewable energy projects that have already been approved to receive subsidies were not affected by the new decree.

This decision attempted "to diminish the public deficit" as each year the "electricity deficit" increased between 4,000 to 5,000 million euros, with a cumulative figure of more than 26,000 million euros by the end of 2013, the so-called "financial black hole", which was owed to the electricity generators[11] (basically all Unesa members). According to the Government, this decision tried to save more than 160 million euros, but the equivalent reduction did not get to the Spanish electricity bill. The Ministry of Industry recognized ex-ante deficits until 2012 and established a 15 year maximum period to pay the debt of each year, which meant that the Spanish electricity system will finish paying the ''financial black hole'' by the end of 2027.

During February 2012 more events took place in the electricity sector in Spain. On February 22nd Endesa was fined by the Spanish Competency Board due to its dominant position in the Spanish electricity market. On February 23rd Iberdrola demanded the immediate stop of public aids for renewables as "every day the renewable bubble was increasing". The same day, Iberdrola published their 2011 financial results showing a decrease in profit of 2.3% (up to 2,805 million euros).

February 25th 2012 seemed to be the first attempt to suggest an increase in the electricity bill. This was supported by the fact that renewable energies were costing too much, and because of the debt owed to the main electricity generation companies. On February 29th 2012, Endesa publically demanded an increase of 10% in the electricity bill. The same day Endesa published a decrease in profit of 46% for 2011.

[11] Official press release from MIEYT, 2013.

On March 1st 2012, the Government of Spain was sued by the Association of Small Investors for pretending to deduct the “debt to the electricity generation companies”, arguing that it could be lethal for Spanish confidence and international investors. On March 3rd, 2012, Unesa publically claimed that “the only thing they could do was to provide their need to get paid back the debt that was owed to them”[12]. They opposed any kind of public aid since that could distort the market, and in 2012 the debt was going to increase in more than 5,000 million euros.

The same day, March 3rd 2012, Mr. Jose Folgado (board member of Fundacion Faes-PP and energy expert) was appointed new Managing Director of REE replacing Mr. Luis Atienzia (former Ministry of Agriculture and Fishing 1994-1996 with the Socialist Government).

In March 2012 (section B in Figure 4.2.) the first big cut in the RET deployment took place by reducing 1,100 million euros from electricity generation companies, 1,400 million euros from end users (electricity bill raised by 7%), and 600 million euros from adjustments in Public Organizations (CNE, REE, IDAE, etc).

In September 2012 (section C in Figure 4.2.) a new decree set new taxes on electricity generation revenues which would bring approximately 2,734 million euros, and a new 6% tax on revenue for all electricity generation technologies.

In January 2013, (section D in Figure 4.2.) a law was created that modified the remuneration system of the regulated activities and the retribution formula of the special regime´s facilities:

- Retribution was referenced to the Consumer Price Index (CPI).
- Now it was to the CPI´s constants taxes, which is, CPI less non-elaborated food and energy products. This measure was aimed at saving around 337 million euros.
- The project owner could choose between Market price+tariff or Tariff.

[12] http://www.elconfidencial.com/economia/2012/03/06/las-electricas-sin-complejos-lo-unico-que-podemos-hacer-por-el-deficit-es-cobrarlo-93840

- Now every project will have to be under the Tariff formula unless the project owner decides to receive only Market price without tariff. This measure was aimed at saving between 250 to 500 million euros.

In February 2013, (section E in figure 4.2.) an extraordinary credit of 2,200 million euros were charged to the General National budget.

On July 12th, 2013, the Government of Spain, through the Council of Minister, approved the energy reform with the aim of balancing the electricity system. This "final" reform hoped to "finally balance the electricity system, avoid new imbalances and guarantee consumer supply as cheaply and transparently as possible". According to the Government, the deficit was estimated at 4,500 million euros per year, and that now is close to 27,000 million euros.

As stated by the Government in the press release (2013), the new reform was to reduce the 4,500 million euros by 1) increasing the electricity bill by 3.2%, which will save 900 million euros, 2) reducing incentives to the electricity companies, both traditional and renewable technologies, by removing the current tariff system to renewable energies, and changing the payment system to transportation and distribution companies, which will save 2,700 million euros, and 3) obtaining 900 million euros from the General National budget (Presupuestos Generales del Estado, in Spanish).

Based on this reform, electricity companies will have to assume a loss of 2,700 million euros through modifications in the remuneration system. In particular, the reform establishes a new remuneration system for generation of renewable energy, cogeneration and waste facilities. These facilities will receive a supplement for their investment costs standards-based technologies, ensuring a "reasonable profit" [13]before taxes that, in principle, will be based on the average yield during the previous 10 years for government bonds to 10 years plus 300 basis points. This means that the tariff system developed under the PER will be abandoned and replaced by another that will try to guarantee the return on the investment at 7.5% (which is the result of adding the bond and 300 basis points). This new reform is retroactive and indicates that

[13] Official press release MIEYT, 2013.

the worse the economy gets in Spain, the better the renewables will do, and vice versa. This argument is related to the notion that this new measure is related to the risk premium of Spain which is the difference between the Spanish and German bonds to ten years.

If the Spanish economy does well, the risk will be less and the interests will also be reduced. Therefore, if the new retribution is based on the Spanish bond, if the economy does well, the RET projects will receive less. It is the opposite of believing that the "technological risk should be the one setting the business profits" and not a "reasonable profit" linked to a country's bond. It sounds like establishing a "communism for business profits".

In addition to the new retribution for RET, transportation and distribution companies will also have a new payment system which will mean a strong reduction of their revenue. Payment for distribution will consider the average yield during the previous 10 years for government bonds to 10 years plus 200 basis points (around 6.5% gross).

Finally, the Government will temporarily allow disconnecting (hibernate) some of the combined-cycle plants, which use gas to generate electricity and that in the current context of lack of demand are exploited at 10% of its capacity. The Government will allow this hibernation equivalent to 6,000 MW, a quarter of the total number of these facilities.

Up to July 2013 the electricity market in Spain suffered from a continuous trend in regulating this market in order to reduce the tariff deficit. Section 4.2. will look at the current situation of the electricity market in terms of changes and modification of regulations. The following section will look at the relationship that exists in Spain between the politicians and the electricity generation corporations.

4.1.3. The "revolving doors" effect

An important factor to consider is the "electricity connections" of politicians which has been called the "revolving doors" effect in Spain. Many of the largest Spanish electricity companies have former politicians within their advisors.

Former Socialist Prime Minister, Mr. Felipe González is an independent board member of Gas Natural Fenosa, whereas former conservative Prime Minister Mr. José Maria Aznar is an independent advisor for Endesa. He is also advisor for News Corporation, the media empire of Rupert Murdoch.

Former Minister of Economy, Ms. Elena Salgado, has recently been appointed advisor of an Endesa's subsidiary in Chile. This factor has been supported by Greenpeace Spain in its May 2013 report implicating Iberdrola at influencing the Government of Spain in almost all the decisions regarding the penetration of RET in the last decade.

Mr. De Guindos is an economist who headed Lehman Brothers in Spain from 2006 up until 2008, headed the PriceWaterhouseCoopers financial division in Spain, as well as was on the board of Endesa (with a net income of 368,400€ in 2011) until he left his positions to become the current Minister of Economy. The following table illustrates the connection of main politicians to the electricity companies.

Corporation	Name	Ocupation	Job position	Annual revenue
Endesa	Jose María Aznar (PP)	Former Prime Minister (1996 – 2004)	External advisor	200,000 euros
	Elena Salgado (PSOE)	Former Government Vicepresident of for Economic Affairs	Board member of Chilectra (Chile subsidy of Endesa)	70,000 euros
	Miquel Roca (CIU)	Former CIU MP	External independent advisor	368,000
	Luis de Guindos (PP)	Minister of Economy	External independent advisor	368,000
	Pio Cabanillas (PP)	Former Minister Speaker	Unknown	Unknown
	Rodolfo Martin Villa (PP)	Former Government Vicepresident and Home minister	Former President of Endesa	
Iberdrola	Angel Acebes (PP)	Former Government Vicepresident and Home minister	External advisor	400,000
	Ramón de Miguel	Former Secretary of	International	Unknown

		State for foreign policy and European affairs	affairs director	
	Manuel Marín (PSOE)	Former Parliament President	President of Iberdrola Foundation	
	Ignacion Lopez del Hierro (Vicepresident of PP´s Husband)		Independent advisor for Iberdrola Engineering	
Gas Natural Fenosa	Felipe González (PSOE)	Former Prime Minister	Independent advisor	126,500
	Narcis Serra (PSOE) (2009-2011)	Former Government Vicepresident and Defense minister	External advisor	126,000
Enel (Endesa since 2011)	Pedro Solbes (PSOE)	Former minister of Economy	Non executive board member	250,000
REE	José Folgado (PP)	Former Secretary of State for Energy	CEO and President	159,000
	Luis Atienza (PSOE)	Former Minister of Agriculture	Former President	Unknown
	Miguel Boyer (PSOE)	Former Minister of Economy and Taxation	Unknown	95,000
	Angeles Amador (PSOE)	Former Minister of Health		95,000
Abengoa	Ricardo Martinez	Former Secretary of State for Budgeting		
	Alberto Aza	Former Head of the King´s House		
	Jose Borrell (PSOE)	Former President of the European Parliament	Independent CEO	200,000
Acciona	Pio Cabanillas (PP)	Former Minister Speaker	General manager for corporate image and communication	Unknown
	Javier Solana (PSOE)	Former High representative of Foreign affairs for the EU	Unknown	Unknown
	Carmen Becerril (PSOE)	Former Secretary of State for Energy	Unknown	Unknown

Table 4.2. Connections of politicians and electricity generators (2013)
Source: Adapted from Greenpeace (2013)

4.1.4. Considerations of influences

As seen, and according to Bohman (1999), the more and more policies and politicians claim they are democratic governments, the more and more they become limited due to the consequences of globalization. Experiences of inadequate global governance lend credence to calls for more “cosmopolitan democracies” but such governance cannot, however, be achieved in the usual ways; there exist no institutions or set of institutions which could exercise anything like the centralized authority and capacity to command obedience analogous to the nation-state’s regulation of domestic markets or its exclusive rule of law within its territories.
According to Sterlacchini (2012) the last two decades have witnessed a staggering decline of R&D investment in the fields of energy and electricity. This widespread phenomenon is mainly ascribable to the processes of liberalization and privatization of electricity markets, which have induced electric utilities to dramatically reduce R&D expenditures.

Industry experts recommended that, to foster the development of safer, cheaper and cleaner sources of energy, the current investment in energy R&D should be increased by a factor of four in the UE (Advisory Group on Energy, 2005). Obviously, without a radical change in the behavior of electric utilities, it will be impossible to mobilize such a huge amount of funds.
The problem is that companies investing in clean energy technologies need not only generous incentives but stable ones, that is available with certainty for a long period of time. Thus, ‘‘Because the payoffs to their investments depend on the details of public policy several years in the future, private-sector actors developing low-carbon energy technologies face substantial policy risk; and this may lead to underinvestment’’(Sterlacchini 2012). TNCs, in fact, will focus on environmental technologies most likely to generate short-term profits.

TNCs are extremely effective at putting across the ‘business case’ for self-regulation both behind the scenes and in public whereas other stakeholders have considerable hurdles to overcome. It is the responsibility of international, regional and national actors, governmental and non-governmental, to ensure economic development without sacrificing common values. TNCs are unlikely to regulate themselves voluntarily to generally accepted standards of behavior.

The establishment of effective mechanisms for holding TNCs accountable may depend on the success of large-scale reforms of international institutions and the redefinition of their mandate. 'Robust' accountability mechanisms require state action, but this action is likely to remain problematic if international governance is not democratized. (Koenig-Archibugi, 2004).

For these TNCs, new technologies may not be compatible with the characteristics of the existing system, and are often handicapped in competition. Furthermore, new technologies represent a threat for the established technology and the firms that have invested in it.

RET have not undergone equivalent growth that will improve the technology and reduce their costs nor assessed with the criteria used to evaluate the old technology. All of these create challenges for policy makers interested in supporting promising new technologies. As preferences change over time, existing technology might not be able to meet the new social and market demands (i.e., environmental protection). Likewise, some negative features of the old technologies which were relatively hidden can manifest and some positive features of the new technology can be given value. These provide openings for the new technology.

Spain has been one of the most successful countries in the public promotion of electricity from renewable energy sources (RET), particularly wind electricity. Successive reforms have been the result of the imbalances between the existing regulation and a growing share of RET, the need to maintain an equilibrium between different (and sometimes conflicting) policy criteria and the interaction between stakeholders with distinct (and sometimes opposing) interests and with different negotiation power.

The Spanish case illustrates that the political commitment of all political parties to continue with the FIT scheme and the attitude of key stakeholders is a necessary factor leading to the success of the scheme. Once political commitment exists, the issue would be then how to design the system properly.

The problem of the subsidies is essentially a political problem, although it has a technical foundation. The amount of each specific subsidy is fixed according to a technical evaluation of how far the technology is from commercial maturity, and how much it needs to compensate investors. It goes without saying that many of these technical estimates for determining subsidies have gone wrong, because of the drop in cost of some critical components, like photovoltaic (PV) cells.

According to the Dean of the School of Industrial Engineers (2013), the Spanish electricity industry needs a new legal framework and economic structure, and should be based on the triple objective accepted worldwide: the security of supply; the environmental quality; the economic considerations (i.e. low costs, which are associated to a competitive sector).

The increasing participation of RET in the system is cutting down the participation of conventional power plants in matching the electricity demand, which entails that its spot price is negligible for very long periods.

It could be said that the Fossil Thermal Leg (FTL) plants have lost some weight in generating large amounts of energy (baseload) and have become back-up systems to substitute for RET when these plants are not available, either for lack of energy source or for maintenance and repairing. This is a completely new scenario that would deserve in-depth discussions about electricity policy making.

According to Tester et al (2005) enthusiasm for renewable energy is driven by three desirable characteristics: 1) Renewable energy is abundant and available everywhere, 2). It inherently does not deplete the earth's natural resources, and 3). It causes little, if any, environmental damage. Although none of these attributes is rigorously true, renewable systems, if deployed correctly, come much closer to achieving these ideals than do their fossil and fissile counterparts.

This section has outlined the main possible factors that could have influenced the design and implementation of RET and energy policies in Spain. The following section will look at some current indicators of situation of the Spanish electricity system.

4.2. Current situation of the Spanish electricity system

The data in this chapter refers to the last three years of available data (2011 to 2013), depending on the source used.

Primary energy

Several characteristics could be noted when analysing the Spanish energy system. As mentioned earlier, the first thing to be noticed is the high dependence on external resources that the Spanish energy supply system has. In 2009, 84% of the total primary energy was imported, according to the Energy´s State Secretariat (MIEYT, 2011). In addition, the Spanish system presents high energy intensity (EI), which means high energy consumption per unit of gross domestic product (GDP), when compared with other European countries.

While EI rates in half of the EU countries were descending until 2005, in Spain the rate was increasing. However, since 2005, energy demand has experienced decreases higher than GDP values and, therefore, energy intensity has declined both in primary and final energy. This effect can be related to the decline of energy consumption in the production sectors due to the economic crisis but also to an increase in energy efficiency (EE) and improvement in the transformation of primary energy into electricity through the introduction of renewable technologies and combined cycle plants (MITYC, 2010).

However, in 2008 the Spanish IE was still 19% higher than in the EU-15. This was mainly with the Spanish economic structure, which is based on high energy consumption and low value added sectors (i.e. the construction sector), and high energy consumption sectors such as the residential and the private transportation sectors (Mendiluce, 2010).

As mentioned earlier, the Spanish energy system is characterized by a high participation of fossil fuels on the primary energy share. Thus, according to data from the Energy´s State Secretariat (MIEYT, 2013) about 80% of the Spanish supply of primary energy in 2012 was of fossil sources.

According to the Ministry of Industry, Energy and Tourism (MIEYT 2011), the consumption of primary energy in Spain in 2011 was 129,339 ktoe, with a decrease of 0.6% from the 2010 value. This decrease was caused mainly due to the change of the structure in the electricity generation. Due to this, altogether, the generation in 2011 had lower performance from the previous year, in terms of primary energy, by the type of technology used. Approximately half (44.9%) of the primary energy consumed in Spain was oil-based in 2011, while coal and gas represented 9.59% and 22.28%, respectively of the primary energy consumption (Figure 4.4.).

Primary energy (ktoe)	2011
Coal	12,456
Oil	58,317
Gas	28,930
Nuclear	15,024
Hydro	2,631
Wind, Solar and Geothermal	5,226
Biomass, Biofuels and Waste	7,280
	129,864
Balance IMP-EXP electricity	-524
Total	**129,340**

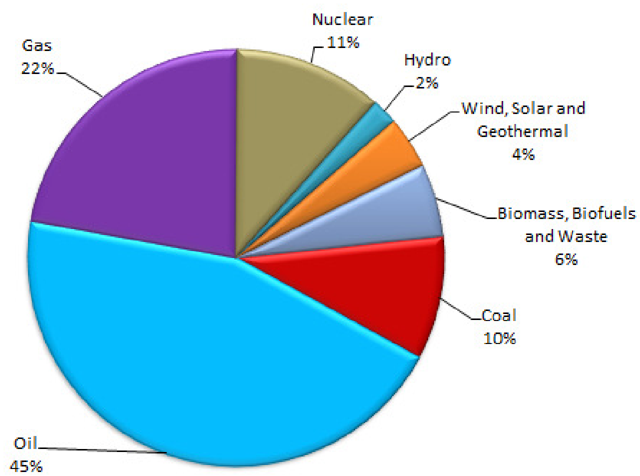


Figure 4.4. Primary energy in Spain (2011)
Source: MIEYT (2011)

Contribution of renewable energies (RET) to primary energy in 2011 was of approximately 10.4%, with a decrease of 3% from the 2010 value. The percentage contribution of each renewable source to the total of renewables in primary energy remained similar to the 2010 values. After biomass (40.6%), wind energy continues to be the second source of renewable energy, followed by hydropower, which contributed with 18%, and biofuels and solar with 9% and 8% respectively.

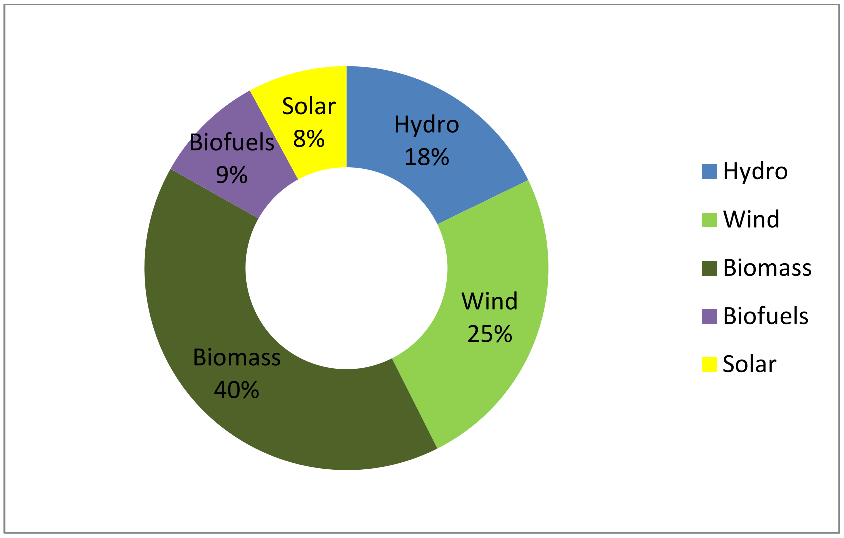


Figure 4.5. Composition of renewable energies in primary energy (2011)
Source: BP Chair (2011)

The level of energy dependency of Spain from external sources is still very high, around 84.3%, well above the European average, and continues to worsen due to the increase in the import of coal. The energy sector, and therefore the Spanish economy, is exposed to a significant risk of fossil fuel prices. Table 4.3. shows the level of dependency of external sources in 2011.

	2011
Oil	99.80%
Natural gas	99.84%
Coal	82.62%
Nuclear	100%
Renewable Energies	0%

Table 4.3. Level of dependency of external sources (2011)
Source: MIEYT (2011)

Electricity sector

Electricity demand in the Spanish system in 2013 registered its third consecutive annual decline, falling to 260,870 GWh[14], 2.3% lower than 2012. Electricity generated from RET comprised the electricity generation from hydro plants (excluding pumping), wind, solar, geothermal and

[14] Based on the preliminary report "The Spanish Electricity System preliminary report 2013" by REE (December 27th,2012)

electricity from biomass/wastes. Gross national electricity consumption comprises the total gross national electricity generation from all fuels (including auto-production), plus electricity imports, minus exports (Eurostat 2012). The electricity generated in Spain in 2013, can be seen in Table 4.4. Total generation from conventional technologies (under the ordinary regime) declined 10.45% from 2012 to a value of 168,932 GWh. Total ordinary represented around 61.7% of the total electricity generated in Spain, with Nuclear having the largest share, 20.6%, followed by Coal with 15.5%, and large Hydro and Combined cycles with 12.5% and 10.6% respectively.

Under the special regime (where RET are registered) Wind generated 54,301 GWh, a 19.8% of the total, representing an increase of 12.03% from the 2012 value. Minihydro and Solar Thermoelectric represented the bigger increases in the total generation, with 53.14% and 32.27% respectively, and with a total generation of 7,098 GWh and 4,554 GWh respectively. The only technology that declined from the 2012 values was Thermal not RET (cogeneration) with a decrease of 4.17% to an equivalent electricity generated value of 32,309 GWh. In general, electricity generated from RET (including large hydro) represented 41.5% of the total electricity generated in Spain in 2013.

Technologies	**GWh**	**%**	**Variation from 2012**
Hydroelectric	34,205	12.5%	75.8%
Nuclear	56,378	20.6%	-8.28%
Coal	42,384	15.5%	-26.5%
Fuel/Gas	6,981	2.6%	-7.43%
Combined Cycle	28,983	10.6%	-31.82%
Total ordinary regime	**168,932**	**61.7%**	**-10.45%**
Self consumption	-7,012		
MiniHydroelectric	7,098	2.6%	53.14%
Wind	54,301	19.8%	12.03%
Solar PV	8,397	3.1%	2.77%
Solar Thermoelectric	4,554	1.7%	32.27%
Thermal RE (Biogas, Biomass, etc)	5,050	1.8%	6.00%
Total RET special regime	**79,370**	**29.0%**	**14.27%**
Thermal not renewable (Cogen.)	32,309	11.8%	-4.17%
Total special regime	**111,679**	**40.8%**	**8.24%**

Total net generation	**273,598**		
Pumped storage consumption	-5,769		
Peninsula link	0		
International exchange (export)	-6,958		
DEMAND	**260,870**		**-2.3%**
BALANCE			

Table 4.4. National Electricity Balance (2013)
Source: Adapted from REE (2013)

The evolution of total electricity generated in Spain (since 2005) is shown in Figure 4.6. It shows that demand has returned to the levels of 2005, also shows the evolution of RET during the period.

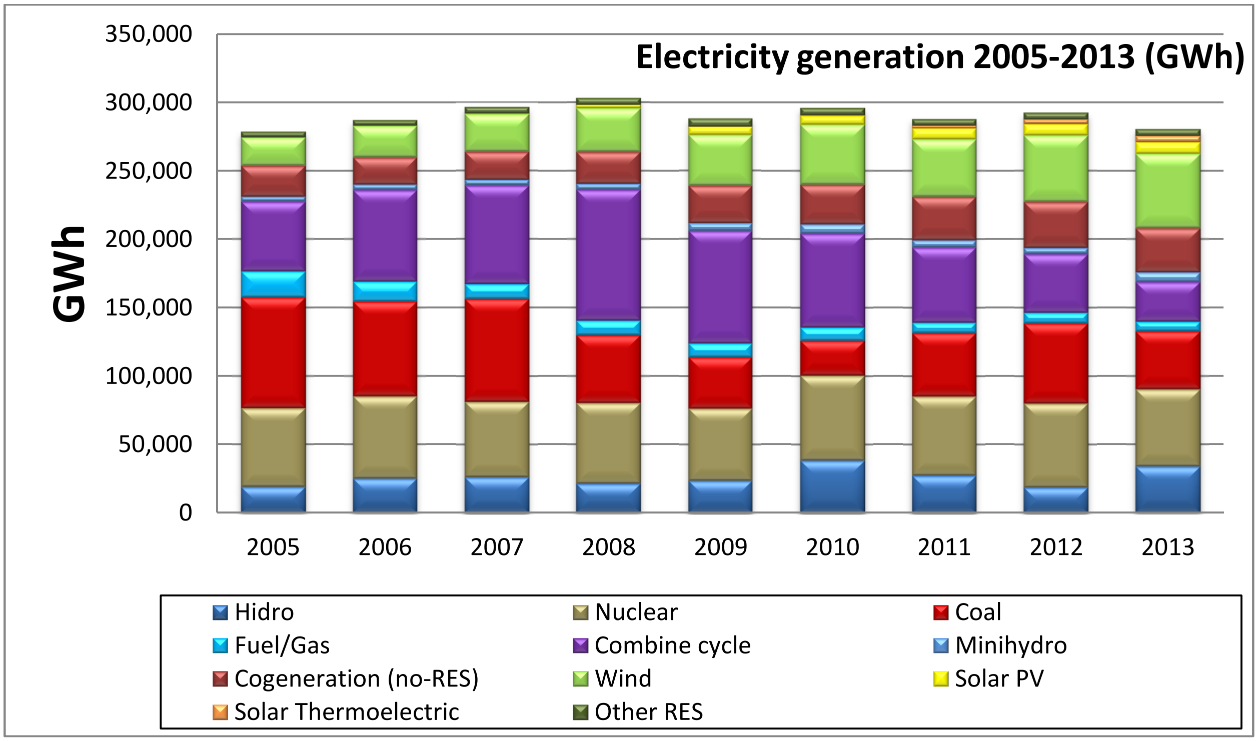


Figure 4.6. Evolution of electricity generation in Spain (2013)
Source: Adapted from REE (2013)

Table 4.4. also indicates that the electricity generated from fossil and external sources (conventional technologies), represented around 58.5% of the total net electricity generated in Spain in 2013. Figure 4.7. illustrates the evolution of the generation of electricity from conventional technologies in Spain.

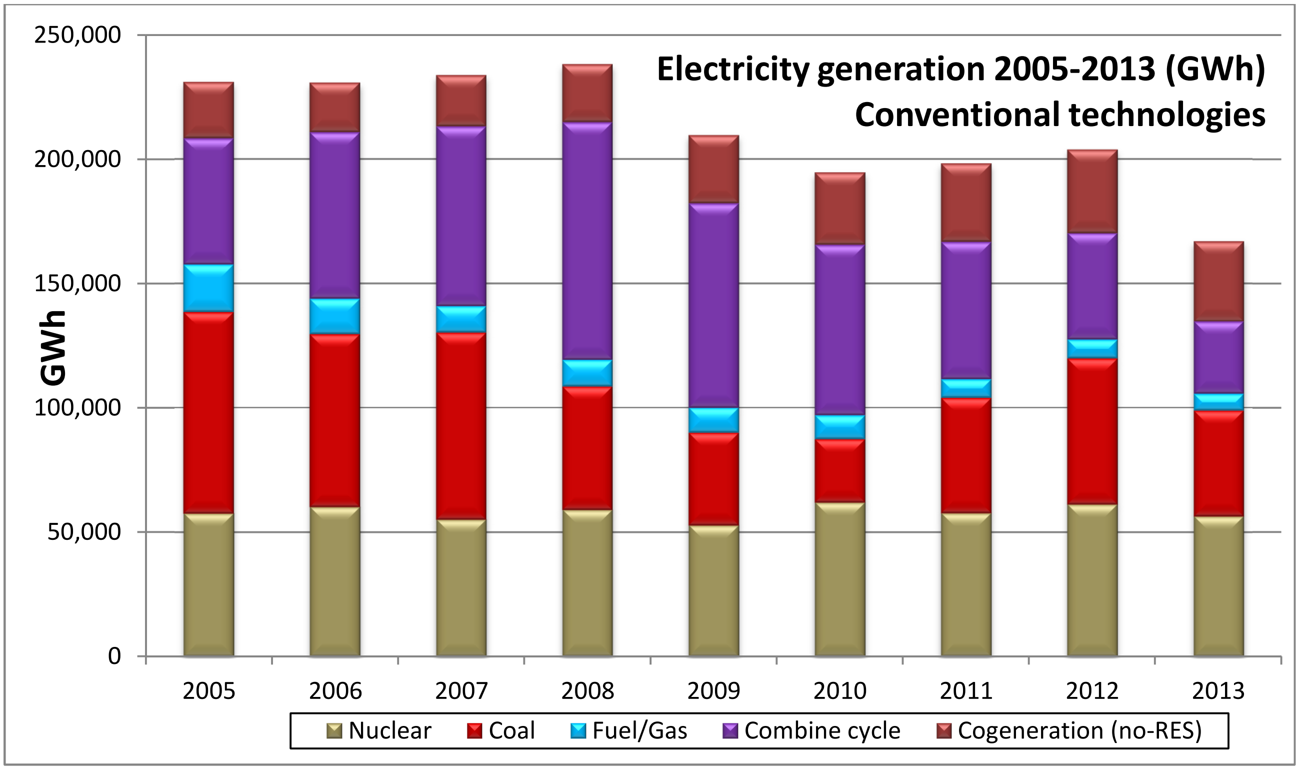


Figure 4.7. Evolution of electricity generation from conventional technologies in Spain (2013)
Source: Adapted from REE (2013)

Electricity generation from conventional technologies have declined substantially since 2005. The larger reduction comes from the combined cycle technology, which has been replaced mainly by RET. In 2005, Coal represented 29% of the total generation and in 2013 it represents only 15%, a decline on almost half (Figure 4.7.). Nuclear remains stable for the period, with around 20% of the total electricity generated, and Wind represents the highest increase in the period, going from 7% of electricity generated in 2005, to a 19% of the total electricity generated in Spain in 2013.

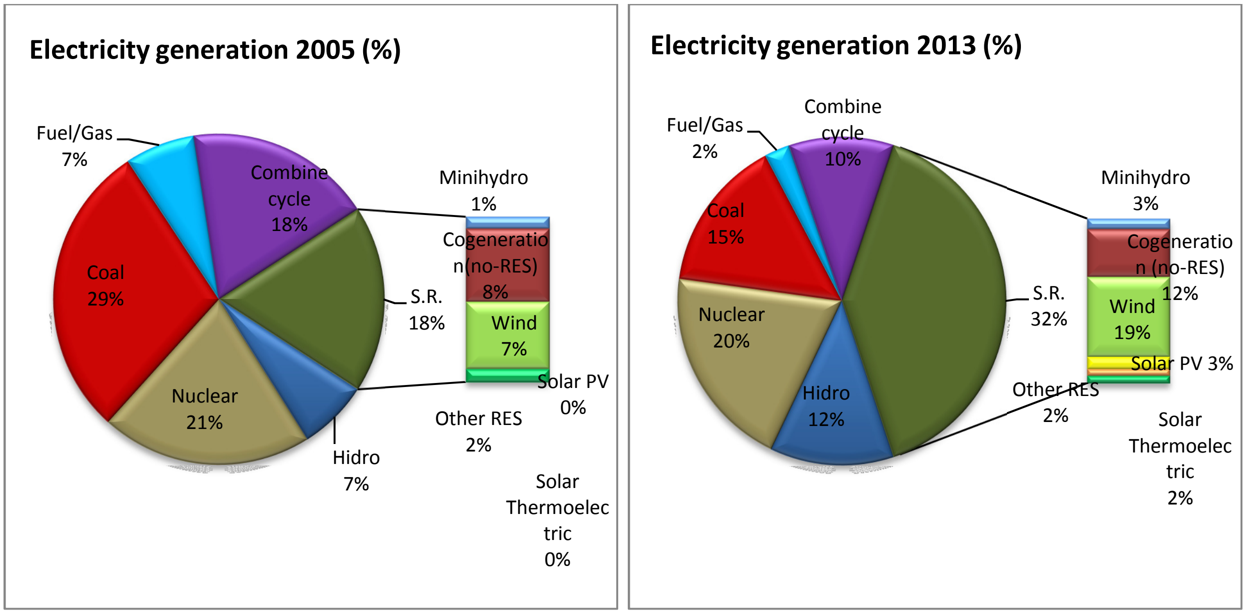


Figure 4.8. Comparison of electricity generated in Spain (2013)
Source: Adapted from REE (2013)

Spain has a good potential of renewable energies, especially wind and solar. In the last five years these technologies have experienced a huge growth in both installed capacity and electricity generation. In 2009, according to data from the European barometer of renewable energies (EurObserv'ER 2011), Spain ranked first in production of electricity from wind energy, and second in accumulated capacity, just behind Germany. The following figure illustrates the evolution of electricity generated from RET in Spain from 2005 until 2013.

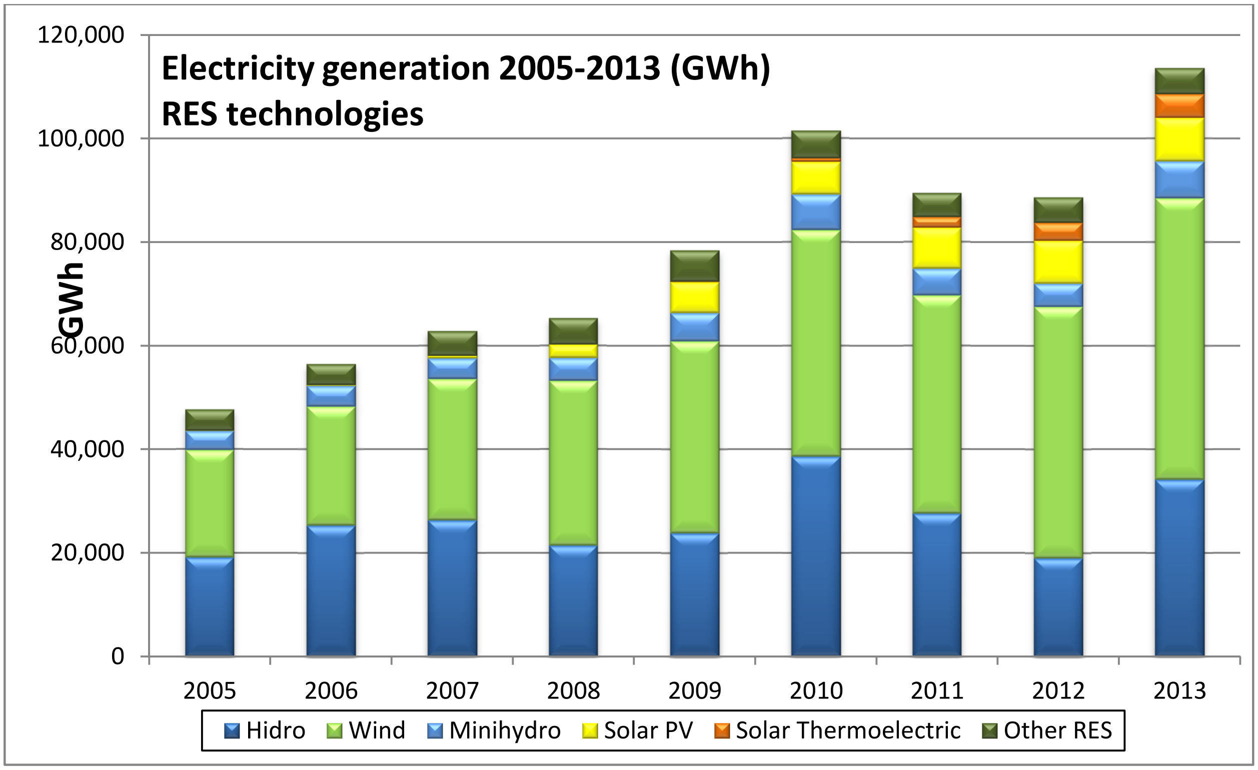


Figure 4.9. Evolution of electricity generation from RET technologies in Spain (2013)
Source: Adapted from REE (2013)

RET technologies have increased substantially since 2005. Wind becomes the first technology to show an important increased since 2005 followed by Solar PV and Solar thermoelectric, which show relevant increases after 2008 and 2011 respectively.

The installed capacity in the Spanish system closed 2013 at 102,281 MW installed, 556 MW more than in 2012. The greatest increase was recorded by Solar thermoelectric (15% or 300 MW) and Solar PV (3.3% or 140 MW). Other technologies have not experienced power variations or have been insignificant. Table 5.5. shows the installed capacity per technology in the Spanish system in 2013. Renewables (Hydroelectric + Special regime) represented more than 48% of the total power, two points more than the previous year.

The share corresponding to RET (excluding Hydroelectric) was 31.29% of the total, with wind representing 22.17% (22,573 MW) and Solar PV representing 4.22% (4,298 MW) of the total. Renewables represented 46 % of the total power on the peninsula, two points more than the previous year

Technologies	**MW**	**%**	**Variation from 2012**
Hydroelectricity	17,766	16.43%	0.0%
Nuclear	7,866	7.27%	0.0%
Coal	11,641	10.76%	0.2%
Fuel/Gas	3,498	3.23%	2.0%
Combyne Cycle	27,206	25.15%	0.0%
Total ordinary regime	**67,978**	**62.86%**	**0.1%**
MiniHydroelectric	2,058	1.90%	0.7%
Wind	22,900	21.17%	0.8%
Solar PV	4,681	4.33%	3.2%
Solar Thermo	2,300	2.13%	15.0%
Thermal RE (Biogas, Biomass, etc)	984	0.91 %	2.9%
Total RET special regime	**31,866**	**30.44%**	
Thermal not renewable	7,248	6.70%	-1.5%
Total special regime	**39,106**	38.40%	1.4%
TOTAL	**101,828**		**0.6%**

Table 4.5. Installed capacity in Spain (2012)
Source: Adapted from REE (2013)

In terms of solar energy, Spain stood second in solar PV's cumulative capacity, and first in thermo solar energy. This positioning has also favoured the development and growth of an industry sector with great potential to be exported to countries inside and outside the EU (San Miguel G. et al., 2010). It is also worth to be mention the great insight in the system of combined-cycle natural gas plants which, in 2009, accounted for 92% of the gas plants' capacity installed.

Capacity factors in Spain

In addition to concerns on the trends in overall support costs, the system did not seem to have stimulated the efficiency of production. The capacity factor parameter has been stagnant in the case of wind energy and has declined in solar PV. In other words, it is arguable whether a FIT encourages the deployment of RET in places with low resource potential.

By taking the values for the last eight years of the electricity generated and the installed capacity in Spain, the capacity factors (CFs) can be calculated. The following table shows the evolution and average of CFs per electricity generation technology for the reference period.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	AV.
Hydro	13.14%	17.36%	18.06%	14.64%	16.35%	25.12%	18.00%	12.50%	21.98%	**17.46%**
Nuclear	83.40%	88.95%	81.52%	87.01%	78.06%	90.99%	84.65%	89.36%	81.82%	**85.08%**
Coal	77.40%	66.31%	72.17%	47.62%	35.89%	24.46%	43.41%	55.98%	41.56%	**51.64%**
Oil	23.91%	17.48%	16.20%	16.97%	19.74%	19.06%	15.76%	25.10%	22.78%	**19.67%**
Gas (CC)	44.25%	46.62%	37.29%	47.15%	38.15%	28.98%	23.18%	17.84%	12.16%	**32.85%**
Wind	23.81%	23.20%	22.13%	25.95%	22.38%	24.69%	22.99%	24.35%	27.07%	**24.06%**
Solar PV	12.72%	16.21%	9.13%	25.41%	20.32%	19.78%	22.03%	20.55%	20.48%	**18.51%**
Solar TE	0.00%	0.00%	0.00%	37.00%	4.49%	11.58%	24.41%	19.65%	22.60%	**19.96%**

Table 4.6. Evolution of capacity factors in Spain (2013)
Source: Adapted from REE (2005-2013)

Average CF for wind and solar PV in Spain resulted in 23.71% and 18.22% respectively. The highest CF´s technology in Spain was for nuclear, with 85.49%, and the lowest was for oil generation with a CF of 16.14%.

Levelized costs

The following table summarizes the value of levelized costs for key technologies in Spain.

Technology	Approximate Levelized costs
Wind	61,54 euros/MWh[c]
Solar PV	420,90 euros/MWh[c]
Solar TE through CSP	98-126 euros/MWh[c]
Biogas	80-130 euros/MWh[a]
Biomass Thermal	80-150 euros/MWh[a]
Hydro	53,50 euros/MWh[a]
Nuclear	53,84 euros/MWh[a]
Combine cycle (imported Coal)	52,03 euros/MWh[b]
Combine cycle (domestic Coal)	67,76 euros/MWh[b]
Combine cycle (domestic + CCS Coal)	69,07 euros/MWh[b]
Combine cycle (Gas)	56,10 euros/MWh[b]

Table 4.7. Levelized cost in Spain (2013)
Source: Adapted from Salvador (2010)[a], US department of Energy (2011)[b] and Ciemat (2010)[c]

Demand coverage

Regarding demand coverage on the Spanish system, nuclear headed the list covering 22.1% of demand (21% in 2011), followed by coal fired power stations that increased their contribution to 19.3% (15.4% in 2011) and wind power with a share of 18.1% (16% in 2011) (REE 2012).

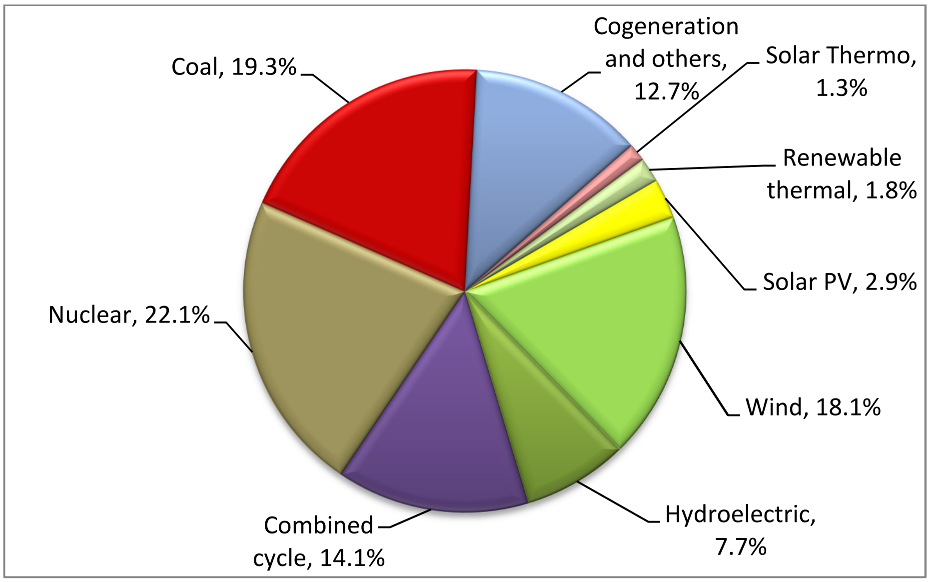


Figure 4.10. Annual demand coverage of electricity demand (2012)
Source: REE (2012)

In 2012, the whole technologies classified as renewables covered 31.8% of the demand.

According to REE (2012) the annual maximum of instantaneous, hourly and daily demand for the Spanish system again stood below the all-time maximums recorded five years ago. On February 13th at 8:21 pm there was maximum demand for instantaneous power of 43,527 MW (the all-time record of 45,450 MW was set in 2007). On the same day in February, between 8:00 pm and 9:00 pm, the maximum hourly demand was set at 43,010 MWh (the all-time record of 44,876 MWh was set in 2007). Also, on February 8th the annual maximum of daily energy of 873 GWh was reached (the all-time record of 906 GWh was set in 2007).

Figure 4.11. shows the contribution of technologies at the peak demand of 43,010 MWh. For RET, wind contributed with 20.9 % followed by Hydroelectric with 8.9 % and renewable thermal and solar thermoelectric with 1.1% and 0.6 % respectively.

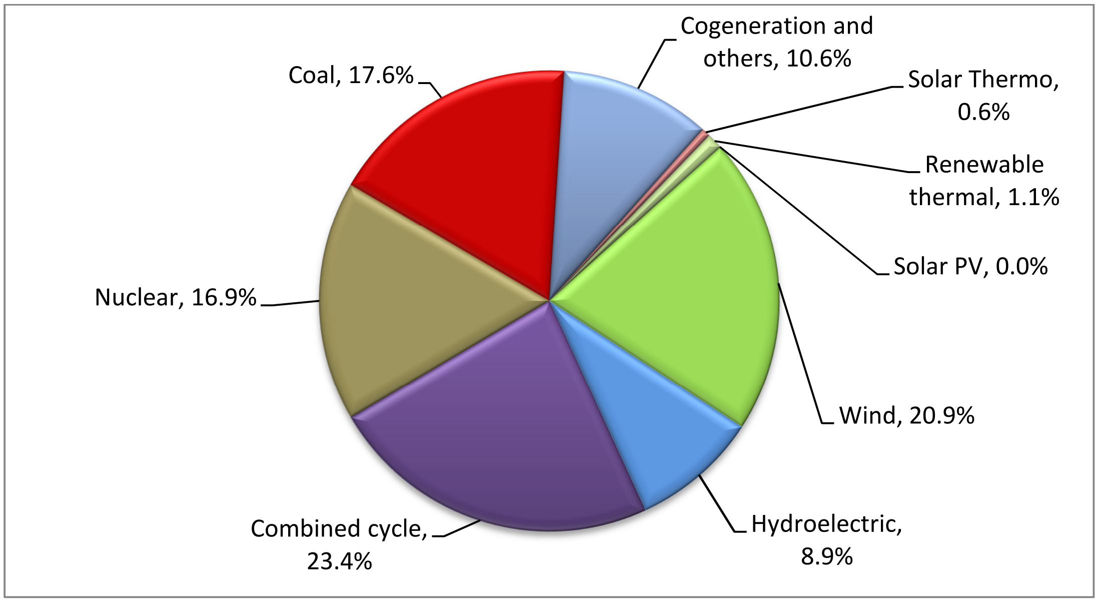


Figure 4.11. Coverage of peninsular maximum hourly demand - 13 February 2012 (9:00 pm -10:00 pm) (2012)
Source: REE (2012)

It should also be noted that the future of nuclear policy is uncertain. Although there is not a nuclear moratorium in Spain, the country does not have medium-term plan for replacing the nuclear fleet. This would lead to an abandonment of nuclear energy from fission by 2028 with the decommissioning of the last facility, without taking into account a possible lengthening of nuclear facilities or the installation of new facilities based on advanced generation.

Premium to RET

Around 39,819 million euros were paid in FIT for the special regime (Renewables + Waste + Waste treatment + CHP). Of those 39,819 million euros in FIT, around 29,110 million euros (73.10%) went to Renewables.

The special regime created 63,801 installations. Of those, 98.59% (62,906) were renewable installations. Of those 62,906 renewable installations, 95.9% (4,588 MW) were Solar PV, and 2% were Wind (22,658 MW). Solar PV generates (or sells) 4,047 GWh (9.6% of the total renewables) and Wind generates 29,564 GWh (70% of the total renewables).

The current amount delivered to RET in the form of premiums is around 39,656 million euros since the beginning of the PER. Solar PV normally receives around 33% of this amount, Wind is around 26%, and Cogeneration receives around 20% of the total. Other technologies receiving less share of this amount are: Solar Thermoelectric (7%), Waste management (5%) and Hydro and Biomass with around 3% and 3.75% respectively. The following table illustrates the evolution of the premiums since 2009 up to 2013.

	Premiums (million euros)
2009	6,521
2010	7,066
2011	6,984
2012	8,585
2013	10,500
Total	**39,656**

Table 4.8. Evolution of premiums toRES in Spain (2013)
Source: Adapted from the Dean of Spanish Industrial Engineers (2013)

Price of Electricity-End User

In Spain, electricity prices grew more than the rest of the European countries, surpassing in absolute terms the EU average, both for the residential and for the industrial sectors. The price of electricity for household consumers in 2012 was 0.177 kWh, and the price of electricity for industrial consumers during the same year was 0.116 kWh, both the third more expensive prices in the EU (Eurostat 2012). Figure 4.12. illustrates the comparison of electricity prices for residential consumers.

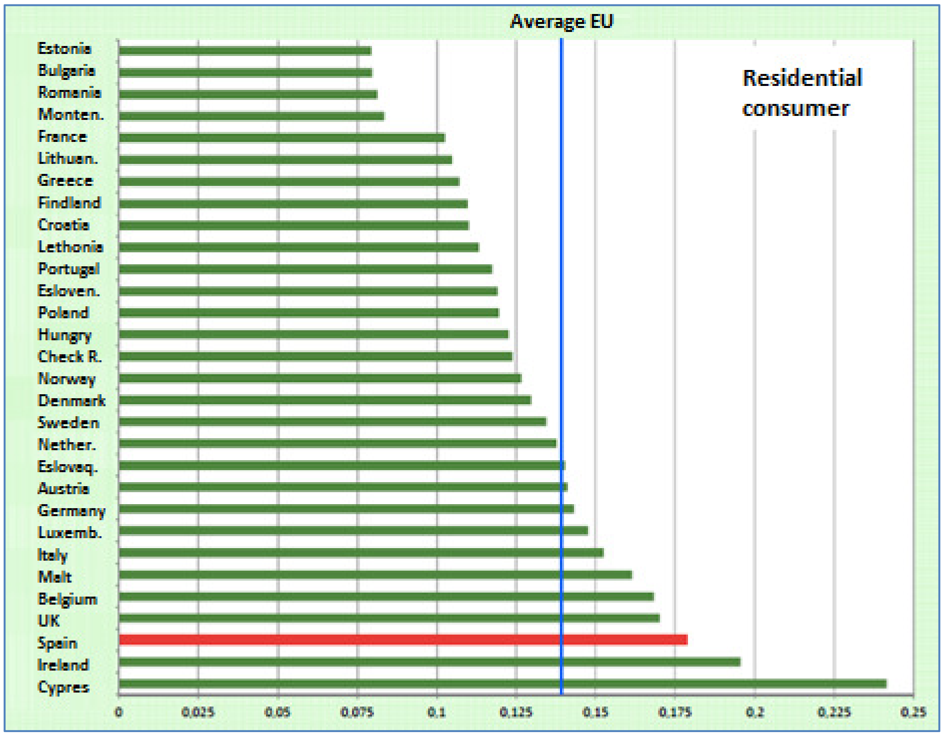


Figure 4.12. European electricity prices for residential consumers (2013)
Source: MIEYT and Eurostat (2013)

Electricity Bill

The electricity bill in Spain reflects 50% of the price of energy (set by public auctions) and the other 50% is what the Government calls the "tolls" which is controlled by the Ministry of Industry. In this 50%, the aids for RET are included along with many other concepts such as extra-peninsular expenses, transmission, distribution, taxes, etc. This is where the Government "increased" the bill. Figure 4.13. illustrates the composition of the Spanish electricity bill.

It has been argued by the RET producers that there is a need to revise the other 50% costs included in the electricity bill, the so-called "windfall profits", that are the profits that the electricity generation companies obtained for already paid off conventional plants.

The Consumers and Users Organization recently complained that the 61% increase in the electricity bill over the last five years had nothing to do with renewables aids but with "an ominous regulation for electrical companies that do not stop making money". They also argued that electricity generation companies benefit from an unfair and opaque mechanism that hides the real cost of electricity. The following figure illustrates the main breaks that compose the electricity bill in Spain.

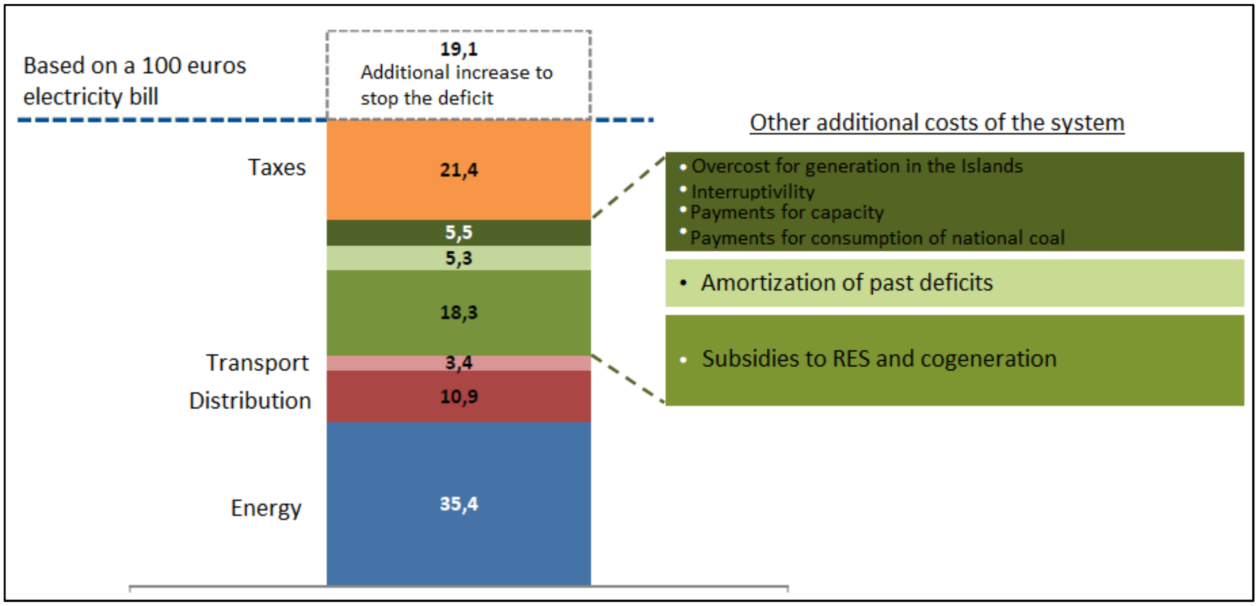


Figure 4.13. Electricity bill composition in Spain
Source: Presentation on the new electricity reform, September 2103. MIEYT (2013)

Tariff Deficit

By the end of 2013, tariff deficit in the electricity sector will reach 30,000 million euros (approximately 700 euros per person) according to the British Petroleum (BP) Chair (2012).

CO2 emissions

Following the signing of the Kyoto Protocol - protocol approved by the EU through the Decision 2002/358/EC – and the adoption of new European directives that limited GHG emissions to the atmosphere from some industrial sectors, emissions ceiling for each member country were established (Directive 2003/87/EC, Directive 2004/101/EC and recently Directive 2009/29/EC).

Following these agreements, Spain pledged not to exceed the annual CO2 emissions above + 15% compared to the base year. The figure below reflects the established emissions cap. The increase of CO2 during the last decade of the last century should be noted as the 2000 ceiling value had already doubled (in 2000 CO2 emissions reached 31% compared to the base year).

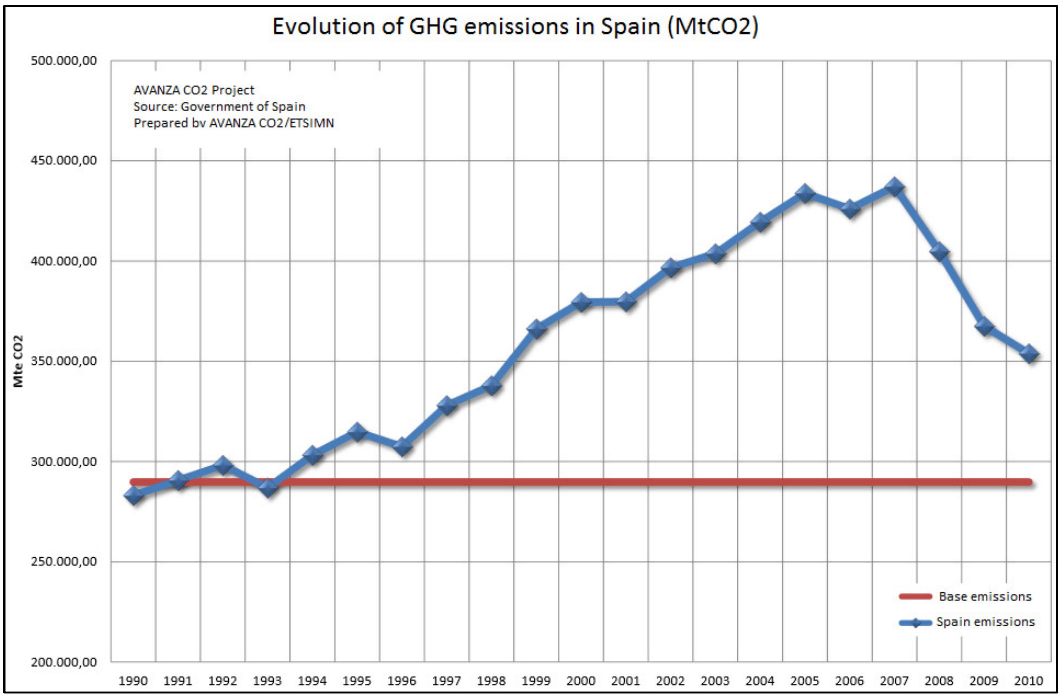


Figure 4.14. Evolution of CO2 emission in Spain

Source: REE (2012)

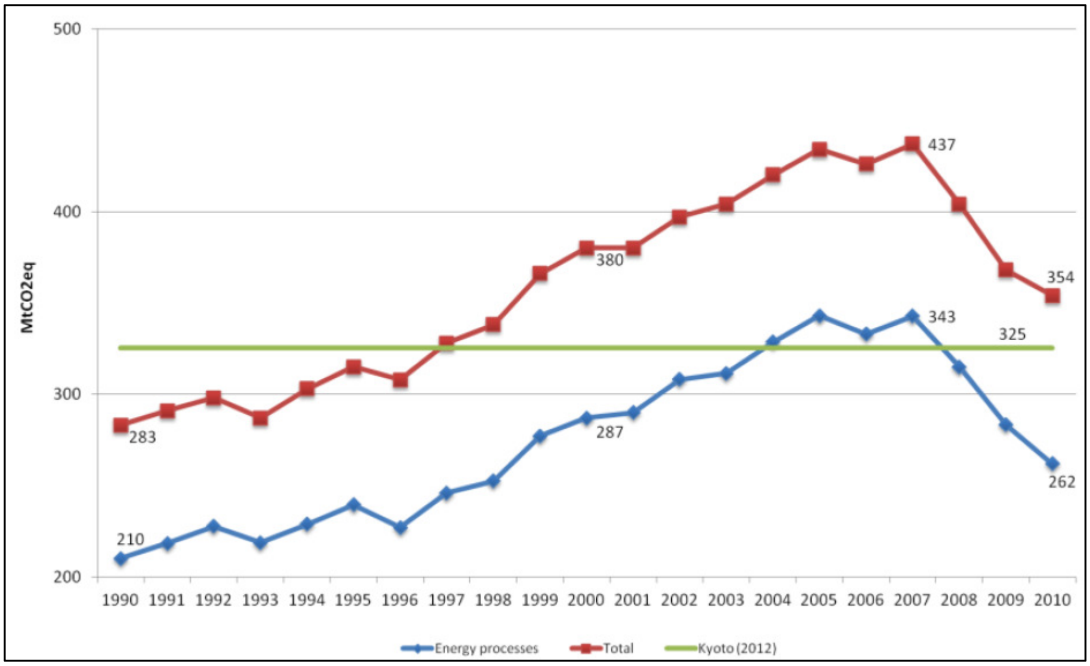


Figure 4.15. Evolution of CO2 emission from energy processes in Spain compared to total emissions

Source: Cabal H. presentation on the CO2 comet

Such growth of CO2 emissions was only truncated significantly and continuously after year 2007. Emissions for 2010 were about 353.9 MtCO2 (+22,13% compared to the base year).

The Spanish energy sector emitted 264 MtCO2 (92.9% of total CO2) in 2012. CO2 emissions from the energy system, which are 80% of the total of CO2 in Spain, rose 2% in 2011, mainly by the increase in the participation of the coal and the minor contribution of hydropower in the electrical mix compared to 2010. In Spain, the total increase of CO2 emissions in 2011 was 1.81% compared to 2010, and 8% compared to the year 2000 values. In 2012, CO2 emissions from the electricity system were estimated at 80 million tonnes, 10% higher than the previous year, which was mainly due to increased coal-fired generation (REE 2012).

The Spanish energy system generates high CO2 emissions as a direct consequence of this structure. The trend of CO2 emissions was rising in 2007 with a growth well above the committed Kyoto Protocol's target, which exceeded 51% from base year levels. However, from 2008-2010, the emissions decreased to 247 MtCO2, according to MIEYT (MIEYT, 2011).

According to the Ministry of Agriculture (Ministry of Agriculture 2013) Spain will need to purchase CO2 emission credits for a value of between 1,170 and 1,620 million euros to meet the Kyoto target. Spain can only increase their emissions by 15% in the period 2008-2012 (from the base year value in 1990) but the emissions stood at 22.8%. In particular, CO2 emissions in the industrial and energy sectors (subject to the buying/selling of rights' market) increased 9.2% in 2011 (Ministry of agriculture 2013). According to the Ministry, this 9.2% increase was mainly due to the effects that were produced by the Coal Decree, passed by the Government of Spain in 2010, to promote the domestic coal burning.

In order for Spain to comply with the first period of Kyoto (2008-2012), the country invested approximately 770 million euros to acquire carbon credits for that period (Oficina de Cambio Climático, Ministerio de Agricultura, 2012), bringing to Spain 159 MtCO2 to deduct from their emissions. According to the European Environment Agency (EEA) Spain is, together with Austria, Liechtenstein and Luxembourg, the European country that needs to buy more CO2 emission rights in proportion to its emissions. In Spain the gap between what should be reduced and the actual emissions are comparatively very large. It is 13%, when the average of European countries is 1.9%. For Spain to continually meet the Kyoto targets, the country will have to buy "significant quantities" of emission rights in the future. According to the Ministry (Ministry of Agriculture 2013) the Government of Spain will have to purchase a final 105 MtCO2 tons until 2014 in order to comply with Kyoto, which could cost between 500 and 800 million euros more.

These credits have been purchased only to cover the emissions of what is called diffuse sectors (transport, agriculture, residential and waste). The Industrial and Energy sectors, as mentioned earlier, have a buying/selling market to operate. The Industrial sector received a free allocation of CO2, but with the crisis and the decline in production, they emitted much less than expected, so they sold their surpluses in large quantities. Some companies have earned millions of euros selling what they received free; meanwhile, the Government must pay for sectors that did not receive compensations, and for which they are responsible for, and have less lowered emissions, according to the EEA (2013). Most of the reduction of CO2 emissions in Spain can be directly related to the economic crisis that the country is still in.

Summary

It can be argued that based on the information presented in this chapter, the Spanish energy system is unsustainable and there is a need for a shift to a more sustainable energy system through changes in not only supply and demand, but in the reasoning behind the design of RET plans. The following chapter introduces the model identified to be used in this document, which follows the approaches of Labriet et al. (2010).

5. Application of the TIMES-IB model to the Spanish energy system

This section examines the mathematical model proposed in chapter 1 and it will be based on the Spanish energy system.

As concluded in chapter 4, it is clear that the Spanish energy system is unsustainable and there is a need for a shift to a more sustainable energy system through changes in both supply and demand. From the demand point of view, for instance, it will be necessary to introduce efficiency and energy saving measures in all consuming sectors (residential, services, transport, industry, etc). From the supply point of view, the use of renewable energies and more efficient technologies that decrease the need for imports of fossil fuels must be promoted in order to contribute to reduce CO2 emissions and meet the required targets.

In order to deploy these changes, important investments will be required. This makes essential the need for credible and reliable prospective studies that explore possible paths to meet the targets. These studies should take into consideration the evolution of determining factors in the future demand such as the growth of the population and the growth of the economy (represented by GDP). They should also consider the current energy system and its ability to grow with all the possible technological alternatives, current and future, in a cost efficient manner, as well as complying with environmental obligations (Cabal and Lechon 2011).

Energy optimization models are tools that allow combining all these parameters in a modelling exercise and thus providing a solution as a medium to long term optimal energy system where energy demand is satisfied under certain environmental, political, technological, or economic constraints. In this document a model of this kind will be used and applies the approaches of Labriet et al. (2010) to show a possible way to achieve a more sustainable energy sector in the year 2050.

5.1. The Times model generator

An energy model is a mathematical representation of an energy system (Figure 5.1. shows a diagram overview of the development and use of a generic energy system model). There are many types of energy models but this document only considers optimization energy models that are used for the representation, optimization and analysis of energy systems. Optimization could be seen as the maximization of the total value (supplier and consumer) given the characteristics of the energy system (technologies, resources, etc) and satisfying the demand of final energy services or any other environmental (CO2 emissions), economic or political constraints (Directive 2009/28/CE).

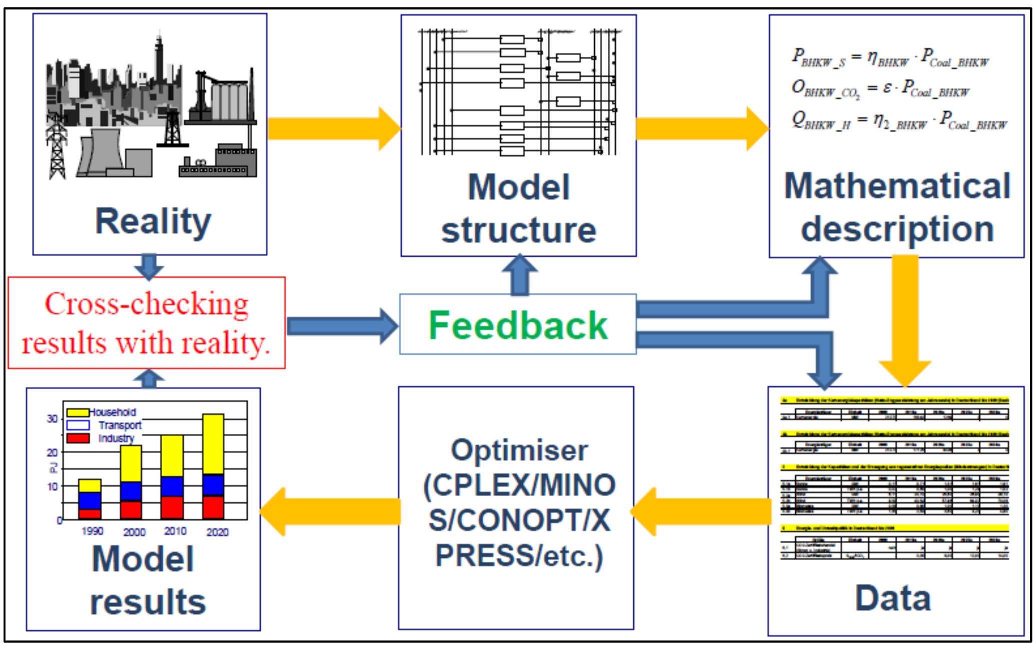


Figure 5.1. Overview of an energy system model

Source: Gargiulio, M., Universidade Nova De Lisboa, Lisboa, Portugal. 12-14 December, 2012

The TIMES model generator has been chosen for this document as a techno-economic equilibrium generated model since it provides relevant options to decision makers regarding energy systems (economically affordable, technically feasible, and environmentally sustainable), ensures that the present energy systems (in equilibrium) follows a consistent path on the long term, and determines what technologies are competitive, marginal or uncompetitive in each market, in a system view.

The Integrated MARKAL–EFOM[15] System (TIMES) is a bottom-up technology rich optimisation model using linear programming and representing the whole energy system of the region of analysis from resource extraction to final consumption. It combines advanced versions of MARKAL models and is a model generator developed by ETSAP (Energy Systems Analysis Programme)[16] which is a multilateral international agreement, promoted and sponsored by the International Energy Agency (IEA) involving national teams in nearly 70 countries.

The user provides estimates of end-use energy service demands (e.g., car road travel; residential lighting; steam heat requirements in the paper industry; etc.), estimates of the existing stock of energy related equipment in all sectors, and the characteristics of available future technologies, as well as present and future sources of primary energy supply and their potentials. Using these as inputs, the TIMES model aims to supply energy services at minimum global cost (more accurately at minimum loss of surplus) by simultaneously making equipment investment and operating, primary energy supply, and energy trade decisions, by region (Loulou et al. 2005).

The TIMES energy economy is made up of producers and consumers of commodities (energy carriers, materials, energy services, emissions, etc). and like most equilibrium models assumes competitive markets for all commodities. The result is a supply-demand equilibrium that maximizes the net total surplus (i.e. the sum of producers' and consumers' surpluses). TIMES may, however, depart from perfectly competitive market assumptions by the introduction of user-defined explicit constraints, such as limits to technological penetration, constraints on emissions, exogenous oil price, etc. Market imperfections can also be introduced in the form of taxes, subsidies and hurdle rates.

The main features of a model generated by the TIMES model generator are:

- It is a bottom-up energy model which uses an extensive economic, technical and environmental data base of hundreds of current and future energy technologies of the

[15] MARKAL (MARket Allocation model, Fishbone et al. 1981, 1983, Berger et al. 1992) and EFOM (Voort van der et al. 1984) are two bottom-up energy models which inspired the structure of TIMES.
[16] http://www.iea-etsap.org/web/index.asp

energy system (e.g., Spain's) in order to analyze this information in detail and provide a single solution.

- It provides a prospective analysis on a long term horizon (20- 50-100 years).
- It provides an optimal technology selection.
- The demand is elastic, depends on the variation of prices.
- The solution represents the simultaneous decisions on equipment investment and operation, primary energy supply and energy commodities trade, both quantities and prices of various commodities are endogenously computed such that they are in equilibrium (Labriet et al. 2010).
- The service demand considers five sectors: agriculture, commercial, residential, transportation and industry.
- The energy supply side comprises: the electricity and heat production; the high, medium and low voltage grids (included as two separated heat grids for high temperature and low temperature heat); the refineries (modelled using a generic refinery structure) and the mining and extraction of primary energy resources (modelled using cost supply curves).
- The model includes detailed information about the potential of RET and various availability factors for RET depending on the season of the year.
- The model includes CO2 emissions for all processes occurring in the energy system.
- It works based on partial and dynamic equilibrium properties. In equilibrium because the suppliers provide exactly the number of units of the processes that those consumers need (see Figure . Partial because only a part of the economy is modeled, in this case the energy sector. It is a dynamic model since it generates results for different periods of time at the same time. The perfect market involves that no participant can individually influence any power over the others and all the participants have access to information, everyone knows what the demand will be at a future time and which technologies and fuels will meet this demand.

According to Loulou et al. (2005) a supply-demand equilibrium model has as economic rationale: the maximization of the total surplus, defined as the sum of suppliers and consumers surpluses. The mathematical method used to maximize the surplus must be adapted to the particular mathematical properties of the model. In TIMES, these properties are:

- Outputs of a technology are linear functions of its inputs;
- Total economic surplus is maximized over the entire horizon, and
- Energy markets are competitive, with perfect foresight.

And as a result of these assumptions the following additional properties hold:

- The market price of each commodity is equal to its marginal value in the overall system, and
- Each economic agent maximizes its own profit or utility.

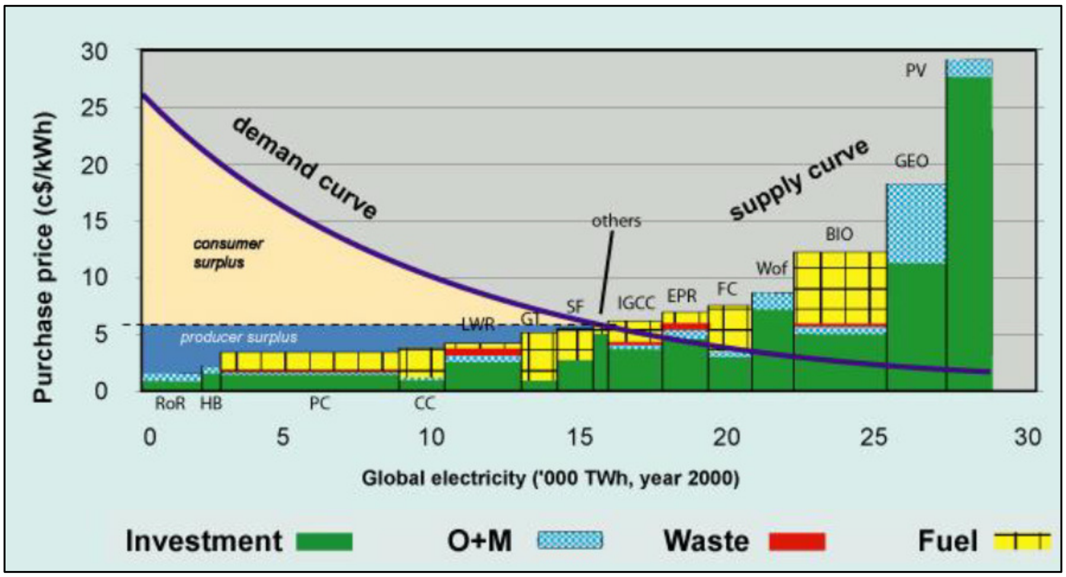


Figure 5.2. Illustration for market equilibrium.
Source: Gargiulio, M., Universidade Nova De Lisboa, Lisboa, Portugal. 12-14 December, 2012

A linear programming problem consists in the minimization (or maximization) of an objective function defined as a mathematical expression of decision variables, subject to constraints (also called equations[17]) also expressed mathematically. Very large instances of linear programs involving hundreds of thousands of constraints and variables may be formulated in the GAMS language, and solved via powerful linear programming optimizers. The linear program described in this chapter is much simplified, since it ignores many exceptions and complexities that are not essential to a basic understanding of the principles of the model (Loulou et al. 2005). An optimization problem formulation consists of three types of entities:

[17] This rather improper term includes equality as well as inequality relationships between mathematical expressions.

- *the decision variables*: i.e. the unknowns, or endogenous quantities, to be determined by the optimization,
- *the objective function*: expressing the criterion to be minimized or maximized, and
- *constraints*: equations or inequalities involving the decision variables that must be satisfied by the optimal solution

The *decision variables* represent the choices to be made by the model, i.e. the unknowns, and some of the decision variables used in the TIMES model could be summarized in: new capacity addition (investment) for technologies (*NCAP(r,v,p)*), installed capacity of processes (*CAP(r,v,t,p)*), total installed capacity of technologies (*CAPT(r,t,p)*), activity level of technologies (*ACT(r,v,t,p,s)*), the quantity of commodities consumed or produced by processes (*FLOW(r,v,t,p,c,s)*), quantity of commodities sold (exp) or purchased (imp) (*TRADE(r,t,p,c,s,imp)*), and demand for end-use energy services (*D(r,t,d)*) among a few others.
The TIMES objective function (discounted total system cost): The surplus maximization objective is first transformed into an equivalent cost minimization objective by taking the negative of the surplus, and calling this the total system cost. The TIMES objective is therefore to minimize the total cost of the system, properly augmented by the 'cost' of lost demand. All cost elements are appropriately discounted to a selected year (Loulou et al. 2005). Each year, the total cost includes some elements including *Capital Costs* incurred for *investing* into and/or *dismantling* processes; Fixed and variable annual *Operation and Maintenance (O&M) Costs;* Fixed and variable annual *Operation and Maintenance (O&M) Costs,* and *Taxes* and *subsidies* associated with commodity flows and process activities or investments among others.

According to Loulou et al. (2005) TIMES takes special to precisely track the monetary flows related to process investment and dismantling, but this tracking is complex for many factors. In addition, although these factors add precision and realism to the cost profile, also introduce complex mathematical expressions in the *objective function*. The following figure illustrates a simplified formulation that does not provide those complex expressions, limiting the description to giving general indications on the cost elements composing the objective function.

$$NPV = \sum_{r=1}^{R} \sum_{y \in YEARS} (1 + d_{r,y})^{REFYR-y} \bullet ANNCOST(r, y)$$

Figure 5.3. Simplified TIMES objective function

Source: Loulou et al. (2005)

Where:

NPV	is the net present value of the total cost for all regions (the TIMES OBJ);
ANNCOST (r,y)	is the total annual cost in region r and year y;
$d_{r,y}$	is the general discount rate;
REFYR	is the reference year for discounting;
YEARS	is the set of years for which there are costs;
R	is the set of regions in the area of study.

and

$$ANNCOST(r,y) = \sum_{p} \left\{ Annual\_Inv\cos t\_payment(r,y,p) + Fixom(r,y,p) + Varom(r,y,p) + \sum_{c} Deliv\cos t(r,y,p,c) \right\} + \sum_{c,s} \{ Trade\cos t(r,y,c) + \mathrm{Im}port\cos t(r,y,c) - Exportrevenue(r,y,c) \} + \sum_{c} \{ Emiss\_Tax(r,y,p) \} + \sum_{d} \{ DemandLoss(r,y,d) \}$$

Figure 5.4. Total annual cost simplified equation

Source: Cabal, H., (2011). Introducción a los modelos energéticos presentation

Finally, while minimizing total discounted cost the TIMES model must satisfy a large number of *constraints* which express the physical and logical relationships that must be satisfied in order to properly depict the associated energy system. TIMES constraints are of several kinds and the main ones can be listed as: *capacity transfer* (conservation of investments), *definition of process activity* variables, *use of capacity*, *commodity balance equation*, *constraints on commodities*, and *user constraints*, to name some of them.

5.2. The Times-IB model

The model used in this document is the TIMES-IB (Iberia: Spain + Portugal) model. The TIMES-IB model is a techno-economic model of the Spanish and Portuguese energy systems resulting from the interaction and participation of various European projects and entities including the CIEMAT in Spain, EU projects such as NEEDS and RES2020, and forming part of the Pan European Times (PET) model which considers the energy system of the EU27 plus Norway, Iceland and Switzerland. This model is built following the same structure of the "family of TIMES models"[18] described in the previous section, adapted to the Spanish and Portuguese energy system, and based on the parameters of the COMET project[19] (Figure 5.5. illustrates the origins of TIMES-IB).

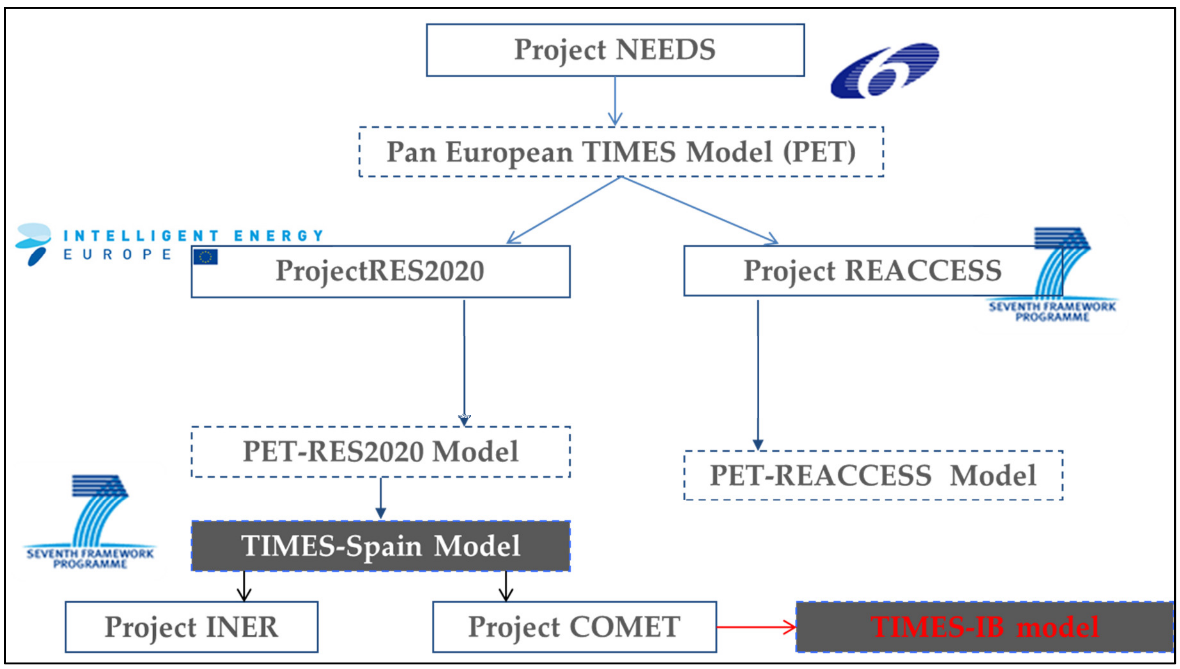


Figure 5.5. Origins of Times-IB.
Source: Cabal, H. presentation. ETSAP workshop, Cape Town 22nd June 2012.

The model was developed for the project COMET (Integrated infrastructure for CO2 transport and storage in the west Mediterranean – a join research Project co-financed by the European

[18] As discussed earlier in this document, the family of times models were developed over a long period of time by several experts, and for this thesis, the TIMES-IB model has been accommodated in order to address the research questions raised in chapter 1.
[19] http://comet.lneg.pt

Seventh Framework Programme (FP7)), and considered the significant role for carbon capture and storage (CCS) technologies, and was based on four main conditions (Boavida et al. 2011):

1. CO2 capture technology will be available in the model;
2. The option will be competitive;
3. Sufficient and suitable underground storage capacity will be available, and
4. CO2 transport infrastructure is available or construction of such an infrastructure can be built within the near future.

Figure 5.6. illustrates the high level block diagram (Reference Energy System) of the national TIMES model.

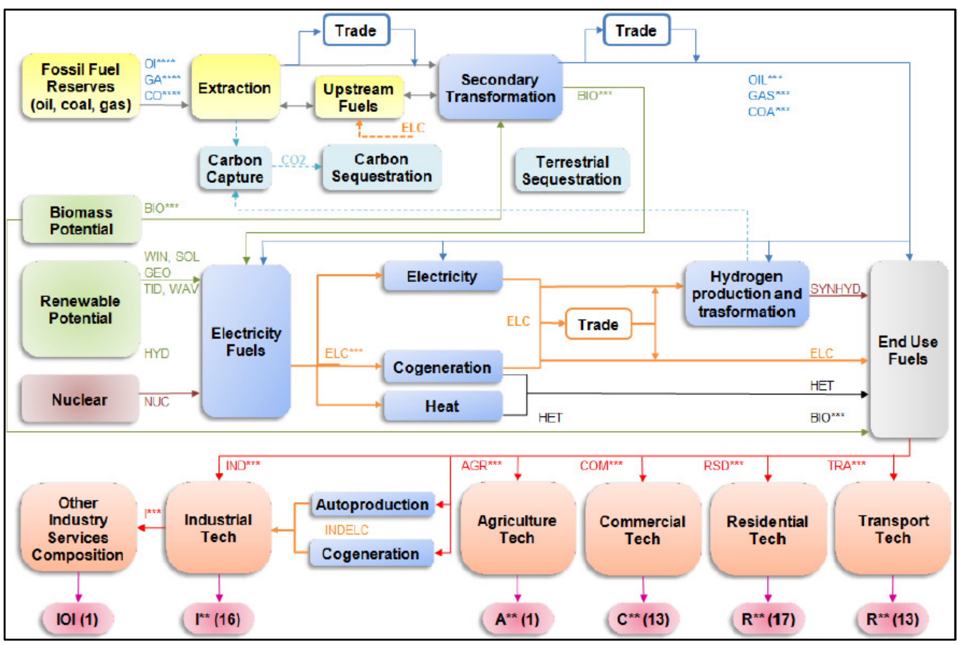


Figure 5.6. Single region reference energy system.
Source: Cabal, H. et al. presentation. CO2PipeHaz - COCATE, Lisbon, December 12, 2012.

In addition, the model runs for the period 2000–2050 in 5-year intervals. It is calibrated for the years 2000 and 2005 to the energy balances of the two countries available in the Eurostat database provided by the Statistical Office of the European Communities, completed by other sources when required, such as the US Energy Information Administration, the Energy Council, the Eurelectric and the OPTRES forecasts, etc.

The objective function computes a supply-demand equilibrium that maximizes net social surplus. By giving the model the technology data, the end-use demands, the world crude oil price, the supply curves, the emission constraints, and other parameters such as discount rates, time period definition and time slice definition, the model will provide the technology investments, technology activities, emission trajectories, final fuel market share, adjusted demands, marginal energy prices, imports/exports, permit trading, and total system cost, among others. In order to provide all that information, the model requires additional tools to support the process. Figure 5.7. illustrates these additional tools.

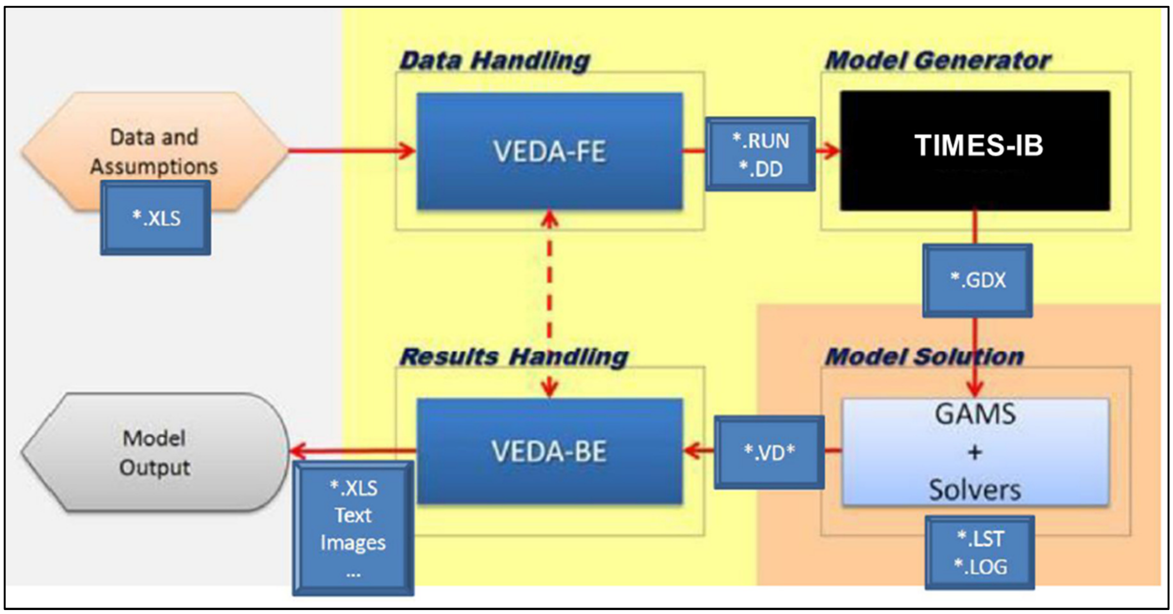


Figure 5.7. Model requirements.
Source: Gargiulo, M. presentation. VEDA-TIMES Training Course, Lisbon 12-14 December 2012.

The Database and Assumptions are collected in .xls files and are the responsibility of the analyst. The Shell tools interpret the data input and output. The Shell interfaced used in this document is the VEDA user interface (VEDA-FRONT END and VEDA-BACK END). Then, the model generator processes the data files from the model and generates a matrix (GAMS) - mathematical programming problem). VEDA-BE collects the results from the model generator and it is used to analyze the results.

In more detail, VEDA-FE handles the model input data. It has a highly modular design and is heavily reliant on flexible excel workbooks integrated with a core database viewable via a browser with a navigator to oversee the management of the excel workbooks. It has powerful filters and search facilities with Reference Energy Systems (RET) diagramming and commodity/process masters with data views. It also incorporates a case manager for composing and submitting model runs.

VEDA-BE is a powerful results analysis system with flexible features including the user's definition of sets and tables, unit conversions, dynamic pivot tables (cubes) to visualize the model results, grouping tables into reports, exporting the cubes to excel files, and automatic updating of workbooks with new model run results. The runs performed for this document using VEDA-FE and the results visualized using VEDA-BE can be seen on appendix A.

TIMES systems are very complex model and it required groups of experts in many countries to develop them. Intensive training is required to be able to use and understand the TIMES system and the VEDA interfaces, as well as to understand and design new scenarios and technologies. The author of this document participated in a three days training session on December 12-14, 2012, at the Faculdade de Ciências e Tecnologia, Universidade Nova De Lisboa, in Lisbon, Portugal, for this purpose. The three days agenda for this training course can be seen in appendix G as well as the Certificate in appendix H.

5.3. Scenarios

Taking into account the dependence on primary energy sources from external sources, the scarcity of fossil resources, the uncertainties about the nuclear future, the potential of RET and the maturity of some of these technologies in Spain, three scenarios were defined for this document in order to examine the potential of RET to substitute fossil resources for electricity generation by 2050. These three scenarios do not represent a perfect final description of the Spanish energy/electricity system and will be only used to obtain results and draw preliminary conclusions of the situation by 2050. The definitions and assumptions of the three scenarios are as follows:

Business as Usual (BaU) scenario:

The base year is 2005 (IEA, Eurostat, and national data) with all considerations of the Spanish energy system, including new solar thermo electric plants.

Nuclear energy: nuclear phase out after the decided decommissioning time of this technology, which for Spain it will be around the year 2028 (this technology is not allowed after the life of the existing ones).

Renewables: the support mechanisms modeled are investment subsidies and FIT in Spain. This scenario also includes the decision of the Government of Spain in January 2012 to suspend the FIT from that moment on. Further explanations about this mechanism are provided in the following pages.

European Union targets: it enforces the targets for the penetration of RET set by the EU (Directive 2009/28/EC), where 20% of the final energy consumption and a 10% of final consumption of energy in transport by 2020 have to come from RET. This path is implemented as a lower bound in the model solution. Also, the corresponding targets for CO2 emissions in 2020 are enforced, where they should be 20% below 1990 emissions by 2020.

Prices of fossil fuels: the prices used are those of the World Energy Outlook 2008[20], published by the IEA in November 2008, and estimated to $100\$_{2007}$/barrel in 2010. These prices have been updated for the 2010 values.

CO2 tax: the Kyoto targets or the post-Kyoto targets set by the 2007 European Spring Council are not imposed as a bound. It is assumed that the current Emissions Trading Scheme (ETS) operates at a clearing price of 20euros(2005)/tonCO2 in 2010. For the post-Kyoto period, carbon prices increase smoothly to 24euros(2005)/tonCO2 in 2030 and this price applies to the current ETS sectors.

Demographic: the population projection is according to Eurostat.

Macroeconomic outlook: the GEM-E3 model is used to quantify the national sectorial figures of economic and GDP growth.

[20] World Energy Outlook, November 2008, IEA, http://www.worldenergyoutlook.org/

Emissions: only CO2 emissions are taking in mind in the implementation of the emissions limits. The approach is that ETS sectors can full trade CO2 emitted, and non-ETS sectors have an imposed upper bound in the emissions of CO2 according to the Directive proposal for non-ETS emissions.

All these assumptions remain constant until the end of the modeling period, 2050[21].

Feed-In-Tariff (FIT) scenario:

This scenario is based on the same hypotheses as the BaU scenario but with an extension of the Spanish FIT for the renewable technologies as described in the PER. The results of this scenario will be compared with the results from the BaU scenario.

High Fossil fuel prices (HFOSPRI) scenario:

This scenario is based on the same hypotheses as the BaU but with an increase in prices of imported fuel by 10% of the reference prices as a way to explore energy security scenarios. The results of this scenario will be compared with the results from the BaU scenario.

The model follows the FIT program outlined in chapter 3 of this document (also known as the PER), and were based on the fact that project developers should choose one of the following options (RES2020 2010):

- Transfer electricity to the system through the transport or distribution grid, therefore being paid a FIT for it, unique for all the programming periods.
- Sell the electricity on the wholesale electricity market. In this case, the electricity sale price is the hour price resulting in the wholesale market supplemented if any, with a premium. In this last case, a new feature is introduced for some technologies, a higher and a lower limit (cap and floor).

[21] A detailed description of the data and mechanisms using in the model for Spain can be found in the "Reference Document on Renewable Energy Sources Policy and Potential" on the RES2020 project website (http://www.cres.gr/res2020/).

The titleholders of the facilities may choose the most suitable sale options for periods no shorter than a year. Nevertheless, the participation in the market is encouraged as it is deemed that in this way. Figure 5.8. illustrates the most relevant FIT prices considered in the model.

			Feed in tariff	**Feed-in premium**		
	Capacity (MW)	Life (y)	Feed in tariff (c€/kWh)	Reference feed-in premium (c€/kWh)	Upper limit (c€/kWh)	Lower limit (c€/kWh)
Biomass						
Energy crops	≤ 2	0-15	15.889	11.5294	16.6300	15.4100
		>15	11.7931	0		
	> 2	0-15	14.659	10.0964	15.09	14.27
		>15	12.347	0		
Agricultural residues	≤ 2	0-15	12.571	8.2114	13.31	12.09
		>15	8.4752	0		
	> 2	0-15	10.754	6.1914	11.19	10.379
		>15	8.066	0		
Forest residues	≤ 2	0-15	12.571	8.2114	13.31	12.09
		>15	8.4752	0		
	> 2	0-15	11.8294	7.2674	12.26	11.44
		>15	8.066	0		
Landfill biogas		0-15	7.992	3.7784	8.96	7.44
		>15	6.51	0		
Biogas from digesters	≤ 0.5	0-15	13.069	9.7696	15.33	12.35
		>15	6.51	0		
	> 0.5	0-15	9.68	5.7774	11.03	9.55
		>15	6.51	0		
Manure		0-15	5.36	3.0844	8.33	5.1
		>15	5.36	0		
Agricultural industry residues	≤ 2	0-15	12.571	8.2114	13.31	12.09
		>15	8.4752	0		
	> 2	0-15	10.754	6.1914	11.19	10.379
		>15	8.066	0		
Forest industry residues	≤ 2	0-15	9.28	4.9214	10.02	8.79
		>15	6.51	0		
	> 2	0-15	6.508	1.9454	6.94	6.12
		>15	6.508	0		
Black liquor	≤ 2	0-15	9.28	5.1696	10.02	8.79
		>15	6.51	0		
	> 2	0-15	8	3.2199	9	7.5
		>15	6.5080	0		
MSW			5.36	2.3		
Other renewable						
Solar PV	< 0.1	0-25	44.0381			
		> 25	35.2305			
	0.1-10	0-25	41.7500			
		> 25	33.4000			
	> 10	0-25	22.9764			
		> 25	18.3811			
Solar thermal		0-25	26.9375	25.4000	34.3976	25.4038
		> 25	21.5498	20.3200		
Wind	Onshore	0-20	7.3228	2.9291	8.4944	7.1275
		> 20	6.1200	0.0000		
Geothermal, tide, ocean		0-20	6.9800	3.8444		
		> 20	6.5100	3.0600		
Hydro	< 10	0-25	7.8000	2.5044	8.5200	6.5200
		> 25	7.0200	1.3444		
	10 - 50	0-25	6.60+1.20*[(50-capacity)/40]	2.1044	8.000	6.1200
		> 25	5.94+1.08*[(50-capacity)/40]	1.3444		

Figure 5.8. FIT values in the model.
Source: RES2020 (2010).

According to RES2020 (2010) the premium to be paid every hour was calculated as follows:
a) For values of the reference market price plus the reference premium lower or equal to the lower limit, the premium value to be paid shall be the difference between the lower limit and the daily market hourly price at that hour.

b) For the reference market price values plus the reference premium included between the higher and the lower limits, established for a given group or subgroup, the value to be paid shall be the reference premium for this group or subgroup, at that hour.

c) For the reference market price values included between the higher limit and minus the reference premium and the higher limit, the value of the premium to be paid shall be the difference between the higher limit and the reference market price at that hour.

d) For the reference market price values higher or equal to the higher limit, the price of the premium to be paid shall be zero at that time.

The amounts of tariffs, premiums, supplements and cap & floor limits will be annually updated having the consumer price index (CPI) as a reference minus 0.25 until the 31st of December 2012 and minus 0.5 since then.

The following chapter will present the results of the runs for the three scenarios, and the analysis of these results.

6. Results

This chapter shows the results from the runs made for each of the three different scenarios described in chapter 5. The processing time for each scenario took approximately six minutes. A graphical description of the process to run the scenarios and display the results can be found in appendix A. Also, for a better interpretation of the results, the main technologies of the energy system have been coded with the same color for all the results, thus providing consistency in the view of these results. The following table illustrates the color coding of the results.

Wind	Solar	Hydro	Ocean	Oil	Gas	Coal	Geo	Biofuel

Table 6. Color coding for main technologies.

6.1. Primary energy

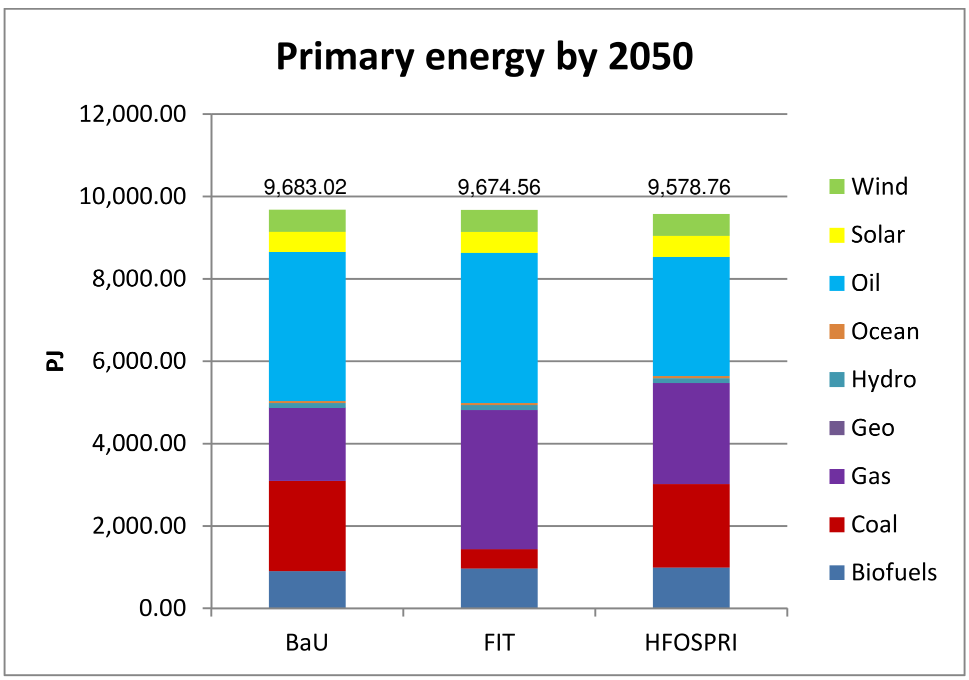


Figure 6.1 Primary energy consumption in the three scenarios.

The evolution of the total value of the primary energy shows a constant trend of consumption on primary energy by 2050 in the three scenarios. The total final primary energy consumption for the BaU scenario shows that by 2050 Oil and Coal will be the two alternatives leading the share, followed by Gas. These three alternatives represent more than 78% of the primary energy consumption by 2050. Based on this result, the evolution of the primary energy in Spain without the FIT incentives (BaU) clearly indicates an increase in coal as the alternative (see appendix B for more details). This alternative will be used for electricity generation and will use CCS technologies as a reference. This can be seen when looking at the results of the electricity generated from fossil fuels.

The results for the FIT scenario show that by 2050 Oil remains as the main source of primary energy with 37.72% of the share (see table 6.1. for more details) but in this scenario, the second alternative is no longer Coal but Gas, with an important increase in the share, up to 34.98% in comparison to the 18.25 % that had under the BaU. Coal becomes a smaller alternative with only 4.83 % of the share, and allowing Biofuels to become the third alternative of the share. It seems strange that reintroduction of the FIT incentive produces tiny increases in RET (mainly bio and solar), together with a big switch from coal to gas. The small extra RET is intermittent (solar is, but not bio) and requires backup which is provided by gas. This gives added value to gas, which tips the economic balance away from coal (with carbon capture) towards gas.

	BaU	FIT	HFOSPRI
Biofuels	9.35%	9.97%	10.32%
Coal	22.65%	4.83%	21.22%
Gas	18.25%	34.98%	25.56%
Geo	0.01%	0.01%	0.01%
Hydro	1.21%	1.21%	1.22%
Ocean	0.49%	0.49%	0.50%
Oil	37.33%	37.72%	30.28%
Solar	5.18%	5.25%	5.31%
Wind	5.53%	5.53%	5.59%

Table 6.1. Share of primary energy per scenario in 2050

In the high fossil fuel price scenario (HFOSPRI), which considers no FIT incentives after January 2012 and an increase of fossil prices in 10% cumulative over the period, results indicate that Oil decreases to a share of 30.28% of the primary energy consumption in 2050 and Gas and Coal remain as second and third alternatives respectively. In the event of an increase of fossil prices, the system reduces the dependency on Oil but it is still dependent on Coal and Gas, with the addition of Biofuels in this scenario.

The contribution of RET (mainly Wind and Solar) to the primary energy consumption seems to stay constant in the three scenarios. A very slight increase can be observed in the HFOSPRI scenario and it is due to the increase of the fossil prices and the need for the system to find cheaper alternatives. It does not show, however, a clear intention to switch to RET, in comparison to other options such as Coal, Gas or Biofuels. The small increase in RET, in spite of very high fossil fuel prices, is due to other constraints in the model that prevented much additional RET, and in due to the support that the Government of Spain provides to the generation of electricity from domestic coal.

For the three scenarios, the year 2015 seems to be the year when RET begins to have a significant share in the primary energy consumption evolution (see figures B.1., B.2. and B.3. on appendix B). In terms of the other alternatives, by 2020 under the BaU scenario Coal is practically irrelevant until 2035, when it increases again until its share of 22.65% in 2050. This is due to the penetration of coal with CCS. This is of special relevance since it means a possible competitive alternative to RET, and it can explain the reasons for RET not to share a bigger portion in the supply mix. In addition, this CO2 is stored in Spain and the Coal used is not national but imported, representing a negative result for the potential of RET.

In the case of the FIT scenario, 2020 is the year when Coal practically disappears from the supply mix and keeps that trend until 2050. Gas is the alternative that replaces Coal in the final mix. Finally, under the HFOSPRI scenario, the year 2040 seems to be the year when coal is back to the mix with CCS, but not as strong as in the BaU scenario, mainly due to the increase of the price of fossil fuels enforced in this scenario. Gas begins to increase by 2040 as well, and keeps its increase constant up to 2050.

Based on these results, RET seems to be an unclear alternative for any of the scenarios, and not a clear alternative to replace fossil fuels by 2050. However, it does show an important increase from 2015 to 2050 and become steady for the remaining of the period. This could be interpreted that under a more drastic increase in the price of fossil fuels, RET could be an alternative to fossils, but CCS will remain as a competitive alternative to RET.

6.2. Final energy consumption

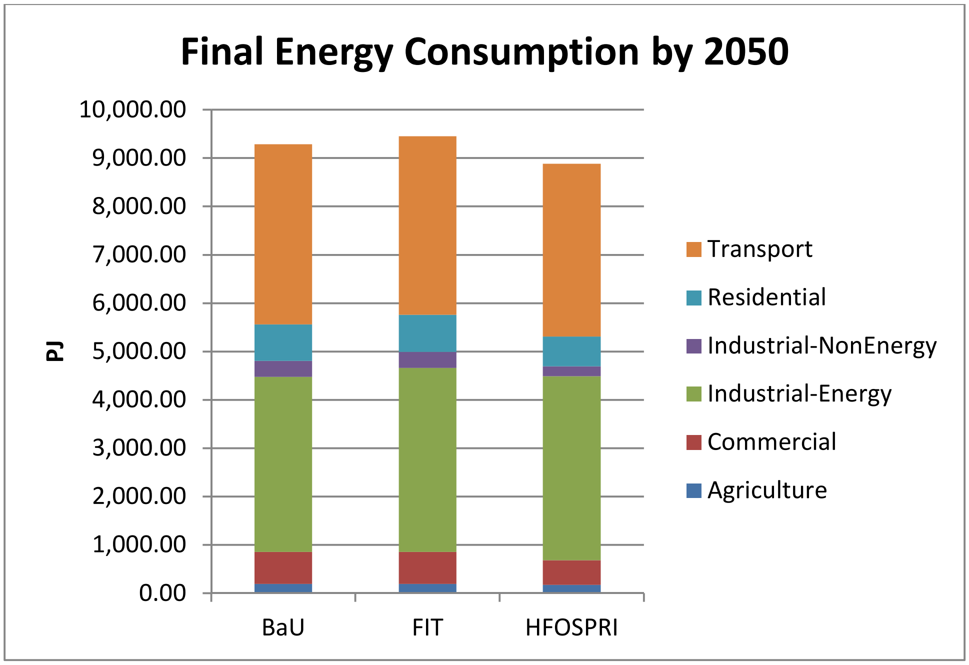


Figure 6.2. Final energy consumption in the three scenarios.

The evolution of the total values for final energy consumption show a small increase of the FIT scenario (over the BaU) and a decrease of the HFOSPRI scenario (compared with the BaU). This is probably due to the maintenance of the FIT incentives under the FIT scenario and the perception of a reduction in the cost of imported resources, which could lead to an increase in consumption. On the other hand, and due to the enforcement of high fossil prices and the perception caused by not having incentives to RET, a decrease in consumption could occur.

Transport and Industrial-Energy related sectors represent more than 80% of the consumption in the three scenarios. This is in line with all the studies and conclusions outlined in previous chapters, and indicate that these two sectors will be the sectors that will need more considerations when designing policies for energy efficiency (EE) or savings in energy consumption.

6.3. Primary energy-Imports

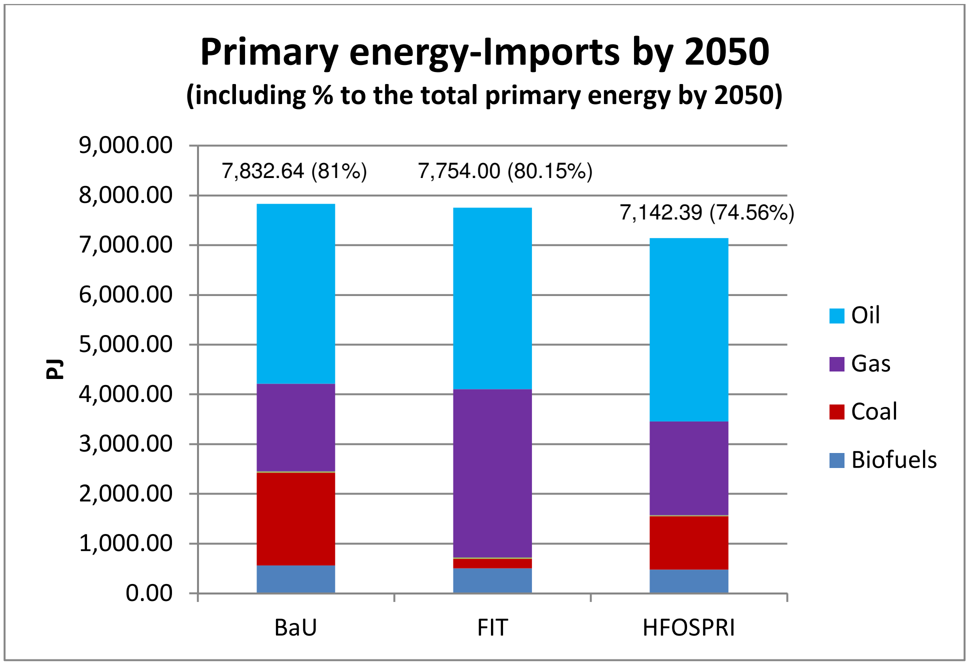


Figure 6.3. Comparison of primary energy import results per scenario in 2050 (PJ)

As an immediate consequence of a situation with steady final energy consumption (previously analyzed), imports remain in the same trend as demand (see appendix C for more details), since neither energy efficiency nor any other enforcement were considered for the three scenarios. Primary energy imports for the BaU represents 81% of the total primary energy by 2050 with Oil as the main alternative, followed by Coal and Gas respectively. For the FIT scenario, imports represent 80.15% of the total primary energy, with just Oil and Gas as clear alternatives. Under the HFOSPRI scenario, imports represent around 74.56% of the total primary energy, proving that under a situation with high fossil prices, imports decline.

	BaU	FIT	HFOSPRI
Biofuels	7.18%	6.49%	6.70%
Coal	23.81%	2.49%	15.00%
Electricity	0.30%	0.31%	0.33%
Gas	22.56%	43.65%	26.39%
Oil	46.15%	47.06%	51.57%

Table 6.2. Share of primary energy imports per scenario in 2050

The evolution of imports from 2005 to 2050 also show that 2015 and 2040 are the years when both Coal and Gas change their participation in the supply mix. This is consistent with what it was seen for the results of primary energy consumption. The evolution of imports per year, as well as the final share of each alternative can been seen in appendix C.

6.4. Electricity generation

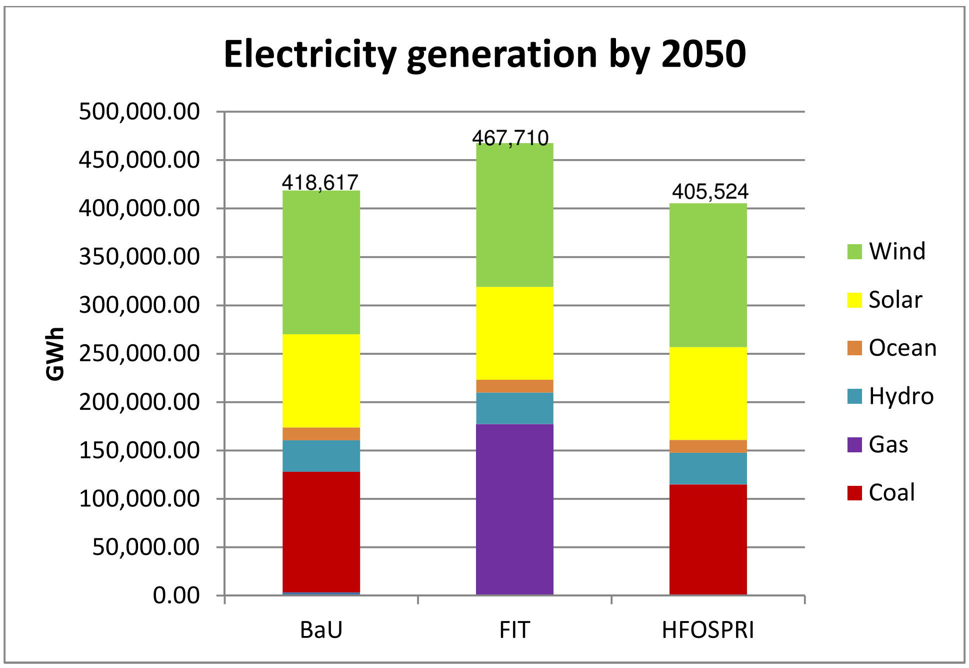


Figure 6.4. Comparison of electricity generation results per scenario in 2050 (GWh)

The evolution of the total values for electricity generation is not steady for the three scenarios. Under the FIT scenario there is an increase in electricity generation, and under the HFOSPRI scenario there is a decrease in electricity generation, when compared to the BaU scenario. These variations can be related to the cost of electricity during the period of analysis. Under the BaU scenario, Wind and Solar represent more than 58% of the total electricity generated, followed by Coal with 29.78%. Under the FIT scenario, Wind and Solar represent around 52% followed by Gas with 37.89%. Finally, under the HFOSPRI scenario, Wind and Solar represent more than 60% of the generation mix, followed by Coal with 28.34%. In 2013, the generation of electricity from Wind technologies was 19.8%, from Solar PV was 3.1% and Solar Thermoelectric 1.7%

(Table 4.4., section 4.2.). This is in line with the analyses for the primary energy consumption and proves that by 2050 RET are a real alternative for the Spanish electricity system. It can be seen that under the BaU scenario, the non-RET technology to accompany RET in the mix would be Coal, whereas with FIT incentives in the system, the chosen non-RET technology would be Gas. Under no FIT incentives and with high fossil prices, the chosen technology is Gas, with more share for Hydro. Table 6.3. shows the share of electricity generation per scenario in 2050.

	BaU	FIT	HFOSPRI
Gas (CHP)	0.80%	0.00%	0.00%
Coal	29.78%	0.00%	28.34%
Gas	0.00%	37.89%	0.00%
Geothermal	0.04%	0.05%	0.04%
Hydro	7.77%	6.92%	8.02%
Ocean	3.16%	2.83%	3.26%
Solar	22.94%	20.53%	23.68%
Wind	35.51%	31.78%	36.66%

Table 6.3. Share of electricity generation per scenario in 2050

The evolution of electricity generation also shows (see appendix D) the decline of Coal generation by 2025 in all scenarios, but a recovery on this technology is due to the introduction of carbon capture and storage (CCS) technologies by 2040 in both the BaU and HFOSPRI scenarios. In the same year, both in the FIT and HFOSPRI scenarios, Solar becomes a new alternative in the share, whereas Wind is been deployed in all three scenarios. It is not until 2035 when Solar becomes a key alternative under the BaU scenario.

6.5. Electricity generation-fossil resources

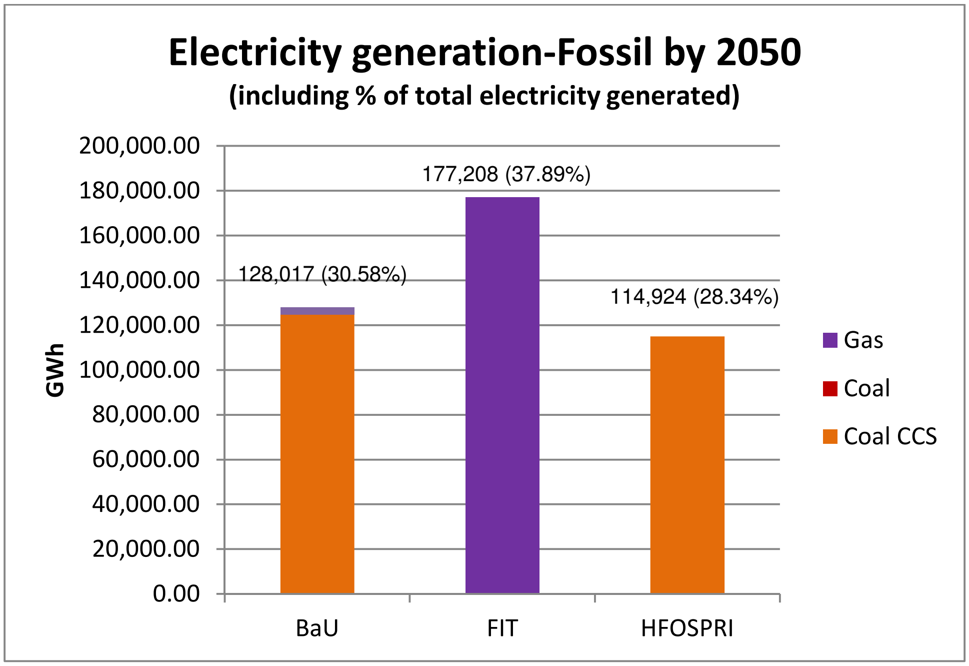


Figure 6.5. Comparison of electricity generation from fossil resources results in 2050 (GWh)

The evolution of the total values for electricity generated from fossil resources by 2050 is in line with the total electricity generated. Under the BaU, the generation of electricity from these sources represents around 30.58% of the total, 37.89% of the total for the FIT scenario, and 28.34% of the total under the HFOSPRI scenario. The reference technology under BaU is Coal CCS, with almost 98% of the fossil generation, and only 2.62% for Gas (CHP). With FIT incentives in place, 100% of the generation of electricity from fossil resources comes from Gas plants by 2050, and under high fossil prices, the chosen alternatives is Coal CCS by 2050. Table 6.4. shows the share of electricity generated from fossil resources per scenario in 2050.

	BaU	FIT	HFOSPRI
Coal CCS	97.38%	-	100.00%
Coal	-	-	-
Gas	-	100.00%	-
Gas (CHP)	2.62%	-	

Table 6.4. Share of electricity generation from fossil resources per scenario in 2050

The year 2020 can be seen as the year of change in all three scenarios. This makes sense due to the enforcement of the EU targets by 2020. Under the BaU scenario, 2020 is the year when almost all electricity generated from fossil resources is produced from Gas plants and it is not until 2040 when Coal CCS penetrates into the mix and displaces Gas by 2050. Under the FIT scenario, 2020 becomes the year when Gas plants are the main source of electricity from fossil resources, and remains in this position until 2050. Finally, under the HFOSPRI scenario, it is again 2020 the year when Gas plants are the main producers of electricity under this category. But it is in 2035, earlier than in the BaU scenario, and due to the increase of prices in fossil resources, when Coal CCS enters the generation mix, displacing Gas plants completely by 2050. (see appendix E).

It can be seen that the suspension of FIT incentives did not affect or impact in great detail the final generation mix in 2050. However, it did contribute to support one or another selected alternative technology, whereas under a non-FIT situation (BaU and HFOSPRI scenarios) the chosen technology was Coal CCS, representing a threat to RET, or under a FIT scenario, the chosen technology was Gas.

In any case, if RET were to replace the technologies that use fossil resources, under a non-FIT situation, the amounts of electricity to be replaced would be approximately 128,000 GWh, and under a FIT and high fossil prices would be approximately 177,000 GWh and 115,000 GWh respectively.

6.6. CO2 emissions

CO2 emissions under the three scenarios remain substantially high, with the FIT scenario being the least CO2 emitter of the three. This is in line with all the analyses performed in this chapter since both the BaU and the HFOSPRI scenarios consider Coal as an alternative for both primary energy and electricity generation. It has already been explained that for Spain to meet the Kyoto targets, the only way was to buy carbon credits from other surrounding countries. In addition, the only reason why Spain reduced the emission of CO2 was because of the economic crisis that affected the country (section 4.2.). The CO2 emission trend based on the results of this model show that CO2 emissions will be in the order of 415-430 MtCO2 unless a FIT plan is deployed, more strategies of the penetration of RET are design, or other alternatives such as CCS are in place during the period of the analysis. It can also be seen that the two main CO2 emission sectors are the Transport and Industrial sectors, with a relaxation on these values under the HFOSPRI scenario, due mainly to the increase in the prices of these resources (see appendix F).

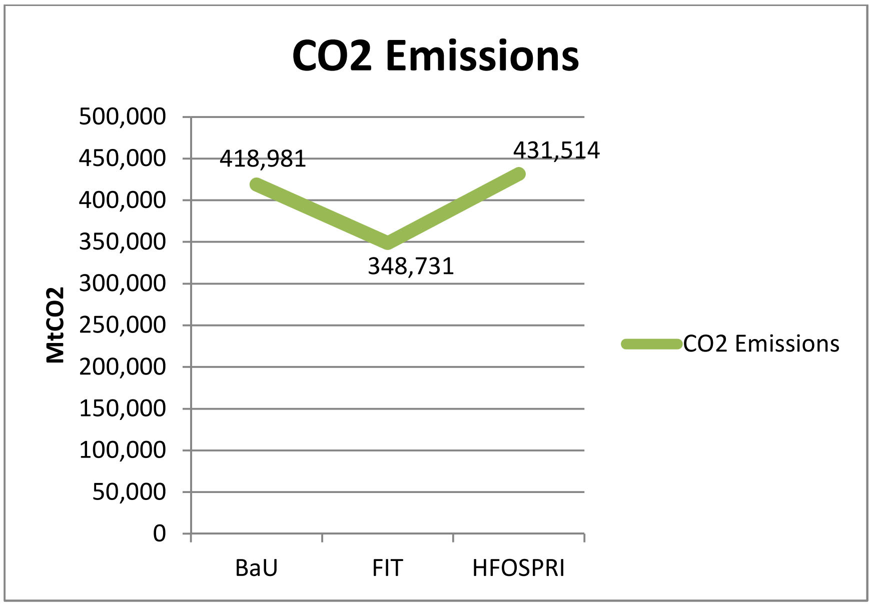


Figure 6.6. Comparison of CO2 emissions before CCS results per scenario in 2050 (MtCO2)

6.7. Summary

In the BaU scenario, primary energy (PE) was dominated by Oil, followed by Coal, Gas and Biofuels. PE imports was dominated by Oil (46%), Coal (24%), and Gas (23%). For the generation of electricity, electricity generation was led by Wind (35%), followed by Coal (30%) and Solar PV (23%), and electricity generated from fossil fuels was dominated by Coal CCS (96%). CO2 emissions were of the order of 418.98 MtCO2.

In the FIT scenario, PE was dominated by Oil (38%) and Gas (35%) with an important reduction of Coal (5%). PE imports were dominated by Oil (47%), and Gas (44%). Electricity generation was led by Gas (38%) and Wind (32%), followed by Solar (20%) and Hydro (7%), and the

electricity generated from fossil fuels was 100% produced from Gas. CO2 emissions were of the order of 348.73 MtCO2, a reduction of around 16.79% from the BaU.
In the HFOPRI scenario, PE was dominated by Oil (30%) and Gas (26%) and Coal (21%), and PE imports were dominated by Oil (51%), Gas (26%) and Coal (15%). The generation of electricity was led by Wind (37%) and Coal (28%), followed by Solar (24%) and Hydro (8%). Electricity generated from fossil fuels was 100% produced from Coal CCS. CO2 emissions were of the order of 431.51MtCO2, around 3% more than the BaU scenario.

RET behaviour in the three scenarios

It can be noted that RET (mainly wind and solar) behaves in similar ways in the scenarios. This is probably due to the restrictions in the model related to the technical potential of each technology. Each technology has a limit that cannot be surpassed (in terms of energy produced) and they are specific for each country (in this case for Spain). For instance, for the RET behaviour in the three scenarios, these limits are related to the localization of facilities (using GIS information), wind data, irradiation (for Solar PV), and that they have exhausted the best available wind land resources, among others. Therefore the model chooses from other alternatives. In addition, the model uses, among other parameters, the predefined capacity factors per technology to choose between the best and the more efficient options.

The increase in demand in the FIT scenario is probably due to environmental constraints. These constraints allow gas to be chosen as an alternative technology under the FIT scenario. This also implies that with fewer emissions the electricity generated is “cleaner” and the model chooses to shift from energy produced with coal to electricity from renewable and gas, especially in the industry sector. This can be understood when under the FIT scenario, the model chooses the most efficient and cleaner alternatives such as electric ovens and generators; and therefore increasing electricity demand. The model does not look at where the monetary resources for a FIT incentive comes from; this is not consider from the demand side since the model does look at the overall cost of the system and not at who it affects. With this in mind, it can be argued that these constraints on RET could be violated in the real world but only if the technical potential is improved. Therefore, if RET had the potential to replace the technologies that use fossil resources, the amounts of electricity to be replaced would be approximately 128,000 GWh (BaU), 177,000 GWh (FIT) and 115,000 GWh (HFOSPRI), although even more fossil fuels than the model suggests could be replaced by RET.

If the worst case scenario was to be considered, 177,000 GWh would be used to analyse the potential of RET. With the possibility of violating in the real world the constraints mentioned earlier, the following considerations would apply:

With capacity factors of 24.06% for Wind, 19.96% for Solar TE, 18.51% for Solar PV, and 17.46% for minihydro, and considering that Wind represents 19.80% of the total electricity generated in the Spanish system in 2013, Solar PV represented 3.10%, Minihydro represented 2.6% and Solar TE represented 1.70%, a preliminary total amount of capacity to be installed by 2050 using these four technologies would be of the order of around 90,840MW, where Wind technology would need around 61,100MW installed, Solar PV would need around 12,440MW installed, Minihydro technology would need around 11,000MW installed, and Solar TE would need an additional 6,300MW installed.

However, although the nature of RET resources could be considered unlimited, they are limited by technical potential and unless these limitations are overcome, the replacement of 100% by RET will not be possible. Large improvements in the efficiency of RET technologies through the capacity factor of each RET technology will be needed in order to replace the generation of electricity from fossil resources by RET by 100%. This will be one of the few options, since in Spain, the availability for the best land has already been exhausted.

7. Analysis

This chapter continues with the analysis of the Spanish electricity system from the perspective of the evolution of the PER and the electricity system in order to complement the analysis of the period under description (2005-2050). First, a review of the evaluation report of the PER carried out by the Government of Spain will be discussed. This information will be combined with a more comprehensive analysis of the current situation of the Spanish electricity system, including the tariff deficit, influences of corporations and politicians, and the CO2 emissions, among others.

7.1. Analysis of the PER

The objective of the evaluation report (AEVAL 2011) was to determine the degree of implementation and success achieved in the execution of the PER's objectives. The evaluation aimed to consider the peculiarities of the different dimensions and levels involved in the promotion of renewable energies such as the European dimension (EU Directives), the national dimension (the Government of Spain as being the one in charge of the planning), the provincial dimension (the AACC had the competences to authorize the RET installations) and the local dimension (they could/couldn't the installation of generation facilities from RET).

According to the report, one of the most complex issues for the evaluation process was to establish a clear way to unify the results. The data was so disperse and sometimes not available until the end of the period. The unsustainability of the energy existing model based on fossil fuels dependency was at the heart of the development of the PER. The transition to an energy model more energetic, environmentally and economically sustainable required the definition of different supply and demand policies as well as new technologies based on the use of RET with new generation, distribution, transmission and consumption guidelines, that were less wasteful and more efficient.

The PER had three main targets and only one was fulfilled, and not to the full extent. Analysis and evaluations of the results have shown the complexity of the deployment of these kind of plans and the evidence that there is still much to do in terms of RET, not only in Spain but elsewhere. The efficiency of the public aids – mainly the premiums by unit of installed power – indicated that the less was the index the more was the efficiency. The thermoelectrical area proved to be the most efficient. The economic yield of the premiums had undergone remarkable variations from the 27 euros per KW of the hydro to the 413 euros of the photovoltaic.

Based on the results of the PER for primary energy, at a hypothetical five years period path set by the PER, the European directive target[22] could have been met. Unfortunately, and after the decision of the Government of Spain (January 2012) to suspend the premiums for RET projects in an attempt to cut the nation's budget deficit (the tariff deficit), and after the analysis of the three scenarios in the model, this target will not be met unless other type of incentives are designed and properly implemented.

The great differences in investments and premiums cashed between different RET were never addressed in the PER. The plan allowed that Solar PV installations represented 94% of the total RET recorded and 67.5% of the total premium cashed during the period 2005-2010. By reviewing the results and the current data, targets were met to some degree by putting large amounts of resources (mainly monetary) into the lower capacity factor technological areas and development (i.e. Solar PV). Figure 7.1. illustrates the unbalanced achievement of installed capacity based on the targets of the PER. (see chapter 3 for more details).

[22] For Spain, the path for the renewable energy targets stated with a share of 8.7% in 2005, and a growth to 11% in 2011-2012, 12.1% in 2013-2014, 13.8% in 2015-2016, 16% in 2017-2018, and 20% in 2020.

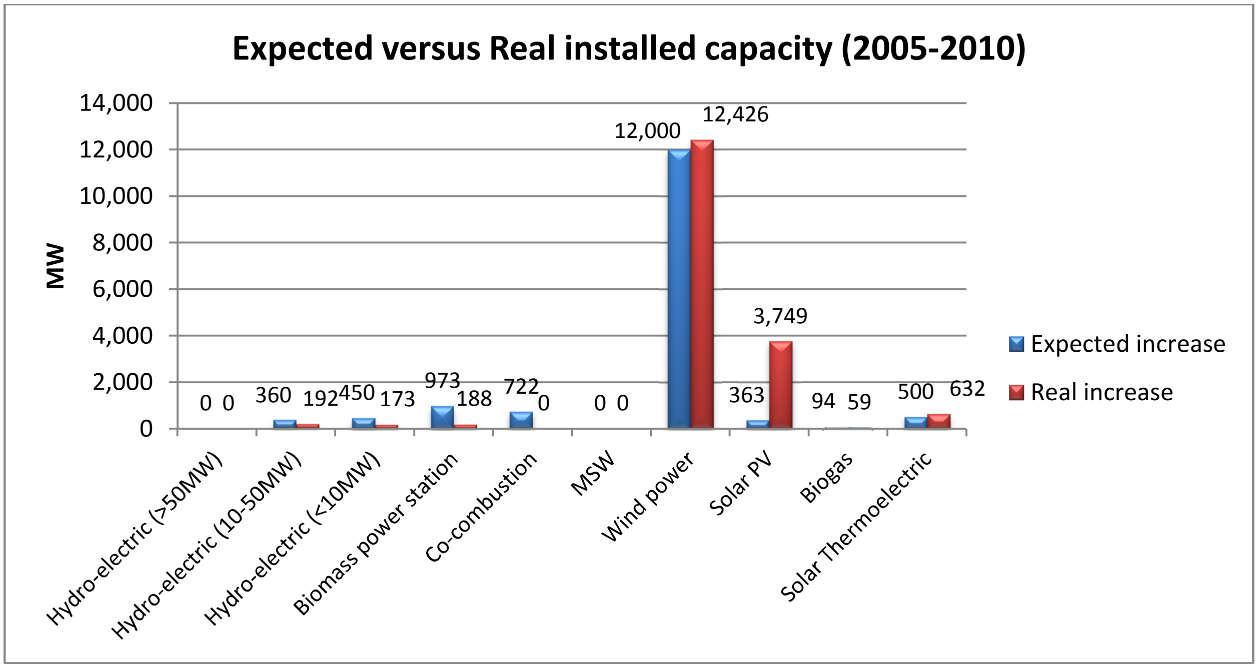


Figure 7.1. Expected and real installed capacity of the PER.
Source: Adapted from AEVAL (2011).

The public aids system used in the PER demonstrated its effectiveness with respect to other stimulus tools and systems in other countries. It seems adequate that the premiums have facilitated the creation of a flow of income/returns on the generation side that contributed to the amortization of investments with sufficiently positive results for the adequate repayment of the yield expectations from the investors. However, this is only valid for the wind, Solar PV and thermoelectrical areas.

When the results are evaluated from the performance of the overall system, the PER created huge inequities across technology sectors; wind versus solar, and so on. For a technology like Solar PV, with a lower capacity factor, around 18%, and high levelized cost, around 420 euros/MWh, its impact on the overall energy mix was trivial and it came at a very large cost. This situation drove down more promising options that could have achieved its fuller potential but it could not be done due to the tax and financial incentive, that were so heavily targeted on one technology to another.

The PER did not reflect the value (real) to the consumer and to the system. When looking at the performance of a system, using appropriate methodologies to evaluate the cost and benefits of RET is more efficient than allocating large monetary resources into the system. Questions arising as a result of this could be related to questioning what could have happened if the same amount of these resources would have been allocated in other RET with different capacity factors and levelized costs (see Tables 4.6. and 4.7. for a comparison of these values in the Spanish electricity market). These questions were not clearly analyzed nor considered in the design and deployment of the PER. The political game could have been to assume that capacity factors are high in order to drive down the advertised levelized cost, so it can be more competitive than it actually is.

According to Joskow (2010) solar technology may have a higher levelized cost than wind technology, but it may produce much more valuable electricity (during peak time); arguing that levelized costs calculations might hide important factors. Paying less for a project that only supplies power during off peak periods could be a very inefficient choice if a more costly alternative when a more economically attractive output profile is available. Traditional levelized cost comparisons fail to consider that the value to the system varies widely over the course of the year thus appropriate methods to evaluate the costs and benefits of renewable generating technologies should be assessed for future PER plans.

Calculations of Pearson correlation for wind contribution to demand during the most electricity demanding month (February 2012) showed that almost half of the month were negative correlation of around -0.7 factor, indicating that energy from wind was not produced at the time it was needed. (Appendix I contains the data for these calculations and data for the month of February 2012).

The argument of the Government of Spain to suspend premiums in order to reduce the tariff deficit is not easy to understand since there was no clear relationship between one and the other. Saenz de Miera et al. (2008) argued that renewables are expensive but failing to consider the social benefits provided by electricity from RET, including environmental and socioeconomic ones. Their study pointed out that there is another neglected benefit: the reduction in the wholesale price of electricity as a result of more electricity from RET being fed into the grid. This also indicates that the increase in the cost of electricity from RET support may be offset by the short/medium term reduction in the wholesale price, leading to a reduction of retail electricity prices, which does not seem to happen in the Spanish market.

But this benefit does not seem to pass along to consumers nor to the system's value. This could be a result of what it was proved by Linares et al. (2008) where the Spanish market was a concentrated market, with two large firms covering almost 80% of the generation market and only four more other small firms with only some generation capacity.

This supports the idea that any plan, model or quantitative prediction should always consider aspects such as the strategies of dominant firms and the level of public support for RET. Therefore, these two aspects will be critical in any future development of a RET plan.

Substituting natural gas by RET will imply a substantial saving and benefits due to increases of the price of this resource. With the initial goal of saving money in the national budget (by suspending the premium to RET) consumers will be paying more, through the electricity bill, and to countries and firms that do not invest in Spain nor looking into the best value for the system and the consumer. Former executives of the Spanish Energy Secretariat already admitted that the tariff deficit debt to the electricity generators will take 20 to 30 years to be paid off, and it will be the next generations who will pay for it[23]. It seems that Spain is not only locked into a very expensive form of electricity generation, but has put the country in a trajectory that there is no easy exit.

Although the deployed investment of the plan surpassed the forecast, great differences between different technological areas were observed. While the co-combustion area had 0% of development, the Solar PV area reached an annual percentage of almost 1000% (in 2007). It is necessary to remember that the plan was not provided with review mechanisms based on the degree of fulfillment of the targets (AEVAL 2011). This mechanism would have allowed the correcting of excesses before it happened, as the case of Solar PV, where Solar PV installations

[23] http://www.abc.es/economia/20130507/abci-deficit-tarifa-explicacion-201305061845.html

represented 94% of the total registered RET producers, and 67.5% of the total premiums cashed in the period of the plan.
The plan's capacity to attract investments could be considered a success for technologies such as Solar PV, biofuels, biogas, wind, thermoelectric and hydro (for more than 10MW), and a failure for the mini-hydro, solar thermoelectric and in particular, biomass.

A further analysis of the review of the evaluation report indicated that the implementation of the PER was difficult in its deployment due to a lack of articulation between supply and demand offers in designing, implementing and monitoring, and between the public agents involved in its management and implementation. The analysis of the results indicated that the plan was conceived as a Governmental commitment and designed as a national policy. Thus, the real implementation of the plan happened to be more a departmental deployment than a national program probably due to the limitations in departmental competencies. This same limitation was identified within the intervention of the Autonomous Communities (AACC) in areas such as the industrial developments, territory zoning or local energy policies (AEVAL 2011).

Based on the analysis of the targets, the PER did not consider in depth the penetration of RET in other sectors such as transportation, domestic and services neither the difficulties to penetrate RET in these sectors. The initial design of the objectives was based on a period of time that considered the maturity of some technologies but, as results showed, not all technologies matured at the same pace. The time frame of the PER should have considered the maturity of technologies and perhaps this time frame should have been extended or reduced based on the evolution of the technologies.

During the period of the PER, the evaluation report (AEVAL 2011) considered other important aspects:

- There was a lack of coordination between the AACC, the National administration, and the Regulator agents.
- The PER was configured as an aids plan and system rather than an "integral" RET plan.

- There was a huge unbalanced commitment between sector's departments in the definition, fulfillment and monitoring of the objectives and measures of the PER.
- The initial planning process had little or none external participation and lack of debate about the contents of the PER.
- The PER did not have any information and participation mechanisms neither accountability mechanisms. This reflected a lack of accountability to the society in general.
- Absence of commitment in the PER, clearly identified due to the absence of territorial targets.
- Lack of monitoring and evaluation mechanism in place for the follow up of the targets.
- Lack of appropriate indicators associated to the development of each type of energy source in order to observe the evolution of the implementation of the RET.
- The National administration lacked on necessary resources to be able to stop irregularities in time.
- The PER was conditioned by permanent activities incorporating regulations that have altered the plan's objectives (around 30 Royal Decrees were passed in the period of the PER).

The economic impact measured in terms of GDP growth and job creation was described by the report as positive. In terms of job creation, 50% of jobs were created within the wind energy area, followed by far by the Solar PV area, and even further, by the solar thermoelectric.

The results for R&D impact considered in the PER shown an evolution of inventions and patents related to RET, and presented a spectacular increase, especially in the areas of wind and solar PV, being registered primarily by companies. It is a believed that there is still room for innovation in the fields of the third generation of wind turbine generators, large scale storage technologies, distributed generation systems, and smart grids technologies.

Finally, the environmental impacts of the PER were associated to the CO_2 emissions avoided by the installation of RET. This measure was fulfilled by the plan's objectives since the avoided amount of CO_2 emissions was about 93.6 $MtCO_2$.

7.2. Understanding the Spanish electricity system

After reviewing and analyzing the results of the latest RET plan in Spain (the PER) it is worthwhile to analyze the current situation of the Spanish electricity system based on the information provided in chapter 4.

The first thing to consider in the Spanish electricity system is the uncontrolled investment in new generation plants. As shown in figures 4.7. and 4.9. (chapter 4), the generation of electricity using natural gas (combine cycle) was declining while the special regime (renewable and cogeneration) continued to grow. Also, the electricity companies continued to construct gas-fired stations at the same time as wind farms and solar thermoelectric plants during the same period. in In recent years, and as seen in chapter 4, only gas stations, wind farms, solar PV farms (especially after 2007) and solar thermoelectric plants (especially after 2009) were built while the tip (peak demand) of the system (the parameter that should guide the investment in new plants) was constant for six years. Figure 7.2. shows the maximum hourly and daily demand in Spain for the last five years.

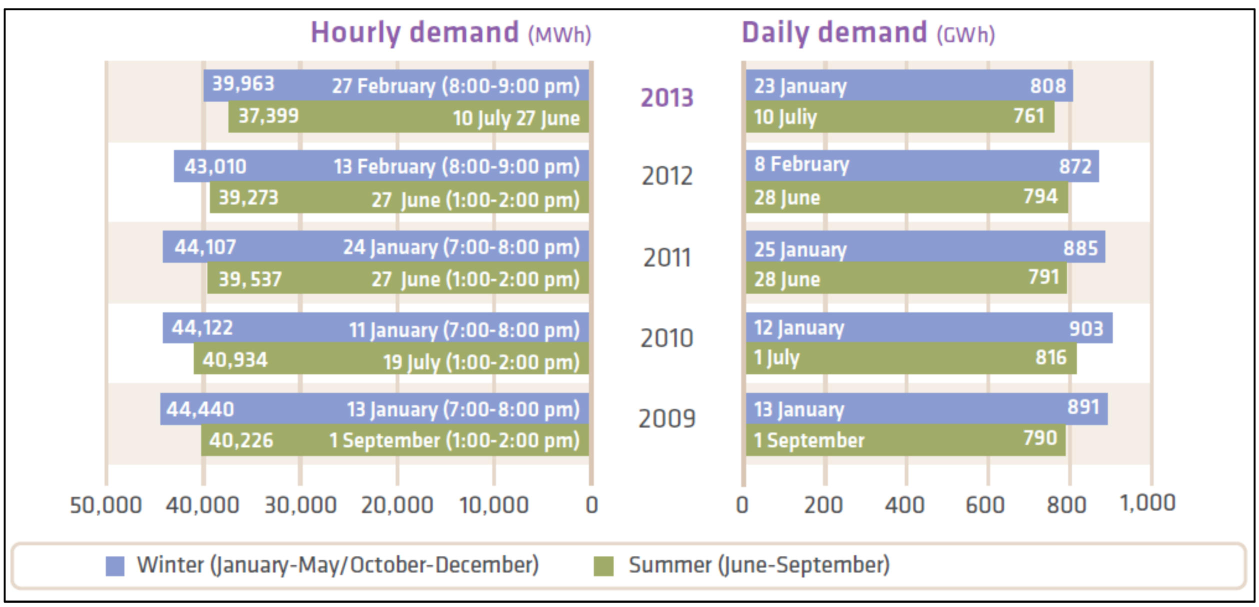


Figure 7.2. Maximum hourly and daily demands in Spain.
Source: REE (2013).

Since the process of liberalisation of the market began in 1998 (see chapter 2 for more details), the wholesale market rules remained unchanged. As previously discussed, the cornerstone of the the electricity market, is the "pool" where all the vendors and buyers come to negotiate up to 7 times a day the energy for every hour. The market operator, OMEL, adds the curves for supply and demand and calculates the price that corresponds to each hour, that is, for the entire market, the most expensive offer needed to meet demand (marginal market). In practice, even at times of higher demand (as shown in the figure below which corresponds to one day in winter), most of the energy is acceptance-price, in both the supply and the demand side, so just a few power plants set the price for the entire market.

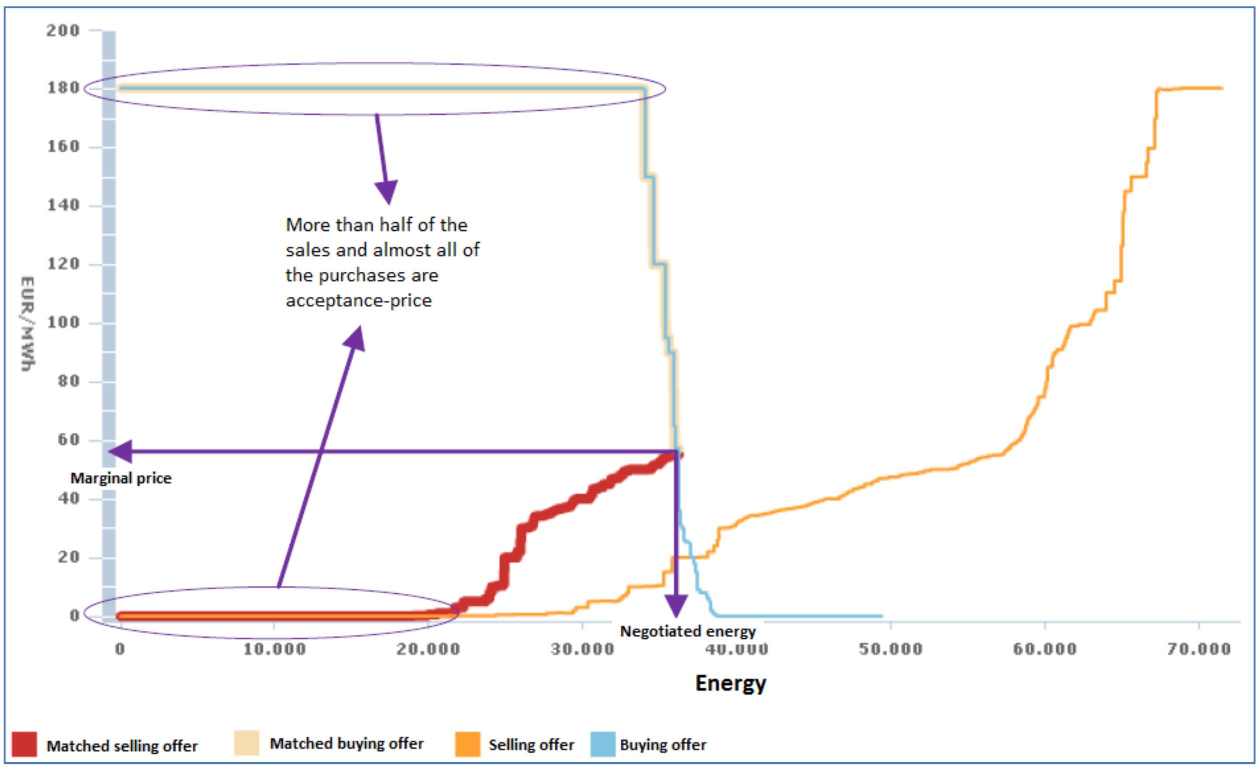


Figure 7.3. Supply and demand aggregated curves.
Source: OMEL (2011).

According to Morales (2011), demand is acceptance-price because it is inelastic. The acceptance-price offer has its origin in nuclear power plants (which for these plants is cheaper to produce at any price than to stop) and in special regime facilities, mainly wind farms, solar and cogeneration plants, which are forced to offer at zero price.

Demand coverage for the previous situation indicated that only around 30% of the generation came from gas stations, which are the ones where agents can operate with a higher degree of competition. This shows that power plants that were built in a fully regulated system in which there was no competition, are not benefiting from liberalised prices that are much higher than what was guaranteed when they were built. This situation applies mainly to nuclear and large hydroelectric dams. The market signal is inefficient for these technologies simply because there is no agent that can construct similar plants in order to compete.

According to data from the Spanish Nuclear Industry Forum (2008) "in Spain the operating cost for generating the nuclear kWh generation has remained stable, reaching a value of 12.9 euros per net MWh, of which 9.5 euros correspond to the costs of operation and maintenance, and 3.4 euros per MWh to the cost of the fuel". The price of the pool in Spain has been around 45 euros/MWh in recent years. Ignoring the payments for capacity that nuclear plants receive, which in 2010 was an additional 3 euros/MWh and subtracting from this value the 12.9 euros/MWh of cost, margins of around 35 euros/MWh are obtained, which would have been used to finance the investment. The average margin is 2,000 million euros[24] annually, which divided by the installed nuclear power, provides an annual margin of around 0.25 million euros/MW.

According to the Forum, the cost of investment for a new generation nuclear plant is about 3 million euros/MW. Therefore, at the current rate, a new nuclear plant would be amortized in a period of about 12 years. Taking into account that the Spanish nuclear system has an average life time of 25 years, it is surprising that the electricity generation companies intend to argue that the plants are not yet depreciated. It can be seen then that, without taking into consideration other externalities, the construction of new nuclear plants under the current market model would not lead to a lower cost to the consumer, but to an increase in the benefits of its promoters.

Regarding large hydroelectric power plants, its use as a large scale energy storage is crucial for the setting of the market price. Since their ownerships are highly concentrated in just a few companies, its market influence is very high (Morales 2011).

[24] Based on data from OMEL, REE and the Nuclear Forum.

Through discussions within this document , it was noted that these technologies had over costs for the last decade of more than 39,000 million euros in premium to the generation from RET, and more than 39,000 million euros in investments. In addition to these over costs, the current pool had a second effect: RET were favouring significant drops in prices which, paradoxically, translated into an increase of these over costs that then customer perceives.

RET produced savings to the electricity system of 6,576 million euros, 620 million higher than the premiums received by its generation of electricity. If these savings were not taken into account, the tariff deficit at the end of 2012 could have been of 5,639 million euros higher than the current situation. In addition, RET avoided the importation of 13.480.857 toe of fossil fuels, with economic savings equivalent to 2,429 million euros in 2012, and avoided the emission into the atmosphere of 36.7 MtCO2, producing a savings of 270,8 million euros. The reduction in the cost of energy in the daily market (OMEI) due to the penetration of RET, was 4,056 million euros (APPA 2012).

However, RET are largely subsided and all facilities, regardless of its remuneration scheme, sell its power in the pool (offered at zero price) and subsequently they deal with the CNE (depending on their corresponding remuneration scheme) to get paid whether the difference between the set tariff and what they have gained in the pool (the so-called equivalent premium), or the premium. Therefore, the lower the market price is the higher the RET over costs are (the sum of premium and equivalent premiums) that the market perceives. While the volume of RET was small, its influence on the pool price was minimal; but with this changing situation, the influence is obviously very different.

The coal mining industry has been considered strategic in Spain for a long time and enjoys a great social impact, employing around 8,800 workers. Since 2010, utilities have been generating electricity from natural gas and not from coal since gas is more profitable and therefore more natural gas capacity has been installed. As an immediate consequence, they stopped buying domestic coal, which had a strong social impact in the areas of extraction. The solution adopted by the Ministry of Industry was to establish a new concept in the wholesale price of electricity called "technical restriction for security of supply"[25] that is paid by all consumers. In practice, a selling price has been set for all coal plants so that if the pool does not reach the price, deficit is compensated. The measure has been justified by the need to secure an indigenous energy supply, which is contradictory with the decision to extract coal, reducing its strategic reserve nature.

Nevertheless, the main problem of the electricity system in Spain is the so-called "tariff deficit", which is currently of more than 27,000 million euros. Its origins are very simple: the political inconvenience of applying the increases in the costs of the electricity services to end customers. The Government of Spain has acknowledged that the electricity bill has increased by more than 71% over the last 11 years[26] and yet these increases have not been enough to cover the regulated costs of the system. The following figure shows the evolution of the tariff deficit.

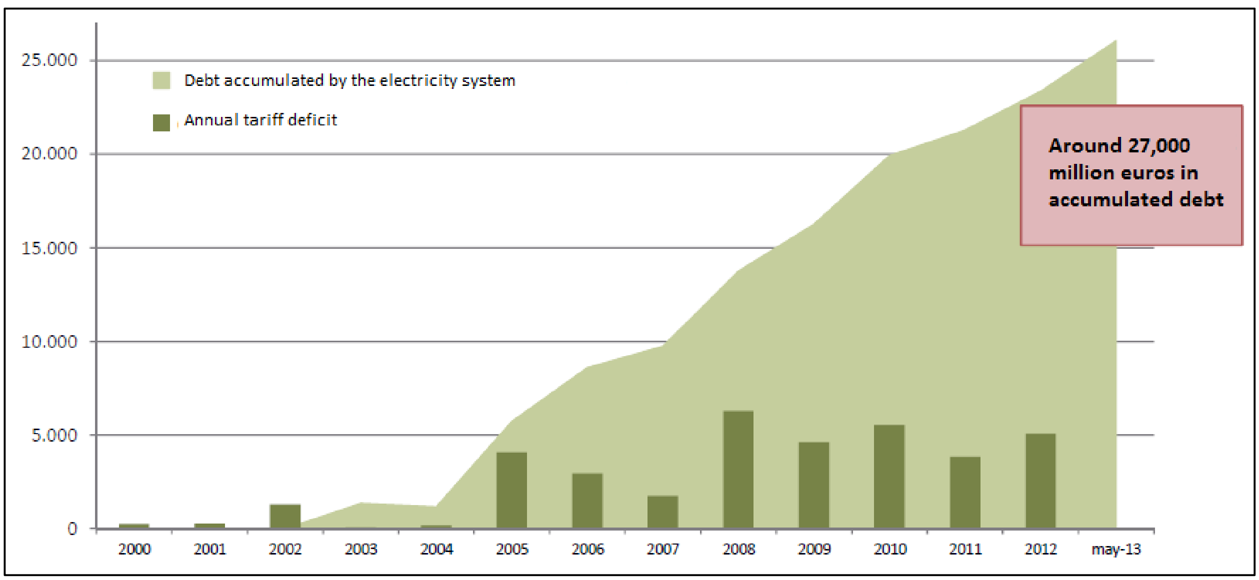


Figure 7.4. Evolution of the tariff deficit in Spain (2013).
Source: MIEYT (2013).

In order to prevent the bankruptcy of the system, the difference between revenue and recognised costs has been long-term funded (more than 10 years). In order to reduce the complete deficit, an increase of 68% in the end customer prices would be required if the deficit would be liquidated in a single year. Quotas to meet long-term financing are already about 10% of the costs of the

25 http://www.boe.es/buscar/act.php?id=BOE-A-2010-3158
26 http://www.elconfidencial.com/empresas/2013-09-18/el-gobierno-admite-que-el-recibo-de-la-luz-aumento-un-71-en-la-ultima-decada_29569/

service in Spain. The deficit problem has worsened during recent years due to the difficulties of financing it in international markets, so it has remained in the balance of the electricity companies. The endorsement of the State was required in order to securitize this debt and move it in international markets (started in 2011) (Matea Rosa 2013).

As far as recognized costs, there are two main components: the price of energy and the tolls. While the price of energy is set by the market, the tolls are decided administratively. The price of energy is the result of free negotiation between the ones selling the energy (the producers) and those who buy it (commercialization companies and direct consumers).

This market has rules that are supposed to ensure the transparency and independence of those acting. However, it is subject to strong distortions, which makes the resulting price not credible[27]. For instance, some producers offer their energy at prices that do not include all the costs[28]. Another problem for the market is that some of the companies that sell and buy energy are the same (the big electrical five members of Unesa), giving them a competitive edge and market power, resulting in prices beneficial to the interests of its parent company.

In addition, the aggravating factor seems to be that large buyers are those five companies in their role of last resort tariff commercials, who have to sell their electricity at the price of the last resort tariff that is set by the Government. That tariff, which electricity companies considered insufficient as long as the tariff deficit exits, has the price of energy as one of its two main components the price of the energy resulting from the market in which those same companies have so much influence.

If changes to the tolls were to be reduced, there are many concepts on which to act. In doing so, it would have to take into account the extent to each of those costs, as well as the returns to society, both economic and others. In the case of the RET charges, the incentives received are justified, among other reasons, by the need, as indicated by the European and international

[27] http://www.libremercado.com/2013-12-20/la-factura-de-la-luz-bajaria-hasta-un-65-eliminando-los-costes-politicos-1276506940/

[28] http://www.europapress.es/economia/energia-00341/noticia-economia-energia-ceaccu-dice-invalidacion-subasta-electrica-pone-evidencia-manipulacion-precio-20131220135103.html

commitments, to promote new technologies that do not emit CO2, or escalating nuclear danger, or increasing the external dependency.

However, the last reform of the Government of Spain (July 2013) to solve the deficit was not only left in an increase in prices: it abolished the "special regime" and added retroactive effects with seemingly discriminatory measures, virtually ending with the Spain branding for RET. This reform did not address the real problems and contributed to more confusion. It can be argued that the problem was not the RET but the premium.

The Royal Decree 9/2013, acknowledged that this rise of the premium has soared as a result of that "during the first quarter of 2013 have been a series of events that have changed the assumptions on which the forecasts was done"[29]. Apparently, the premium increase could be due to the errors in the Government forecast. These deviations, always according to the Government, were motivated by the fact that atypical weather conditions occurred in the first months of 2013. This situation created a collapse in the price of the daily market up to minimum levels of 18.17 euros/MWh in April, resulting in an average 37 euros/MWh in the first six months of 2013 which did not reach the expected 51,19 euros/MWh. Therefore, the market failed to reward RET with 51,19euros/MWh and only paid 18.17 euros/MWh[30]. Since the premium is the difference between the market price and the supplement that is paid within the fee to pay the price of RET, the tariff deficit seems to be a “forecasted problem” and therefore could be seen more as an accounting problem, rather than an economic problem.

The tariff deficit was created by the regulator, both PP and PSOE political parties, which is the entity who decides what costs should be regulated and how. The tariff deficit is still growing because the regulator seems to want to continue subsidizing natural gas, for instance. The Secretary of State for energy, Mr. Alberto Nadal, confirmed in July 2013[31] that combined cycles will continue receiving the so-called investment incentives (non-recovery grants) during the next 20 years at a rate of 10,000 euros per installed megawatt per year. The PSOE established the

[29] http://blogs.lavanguardia.com/diario-de-futuro/las-energias-renovables-el-chivo-expiatorio-del-deficit-de-tarifa-60414

[30] http://www.nuevatribuna.es/opinion/ladislao-martinez/ha-resuelto-ahora-problema-deficit-tarifario/20130724112047095040.html

[31] http://www.energias-renovables.com/articulo/quien-tiene-la-culpa-del-deficit-20130715

incentive in 2007 (20,000 euros per megawatt per year and for ten years) and PP, although it extends the term of the payment, respects the amount carefully. This represented more than 2,500 million euros in the last five years that electricity companies perceived to build the plants, not by the kW to be generated in the future (RET get paid per kilowatt generated; gas gets paid just to be there).

The tariff deficit is still growing because the regulator allowed the large electricity companies to get 3,000 million euros via the CTC process and none of the Ministers and officials involved (Mr. Sebastian, Mr. Soria and Mr. Nadal) were unwilling to claim the refund of that amount.

The tariff deficit seems to be consented because the regulator does not seem to want to contain the profits that the large electricity corporations obtain with nuclear and hydroelectric generation, and does not seem to want to change them into the reasonable profits that RET have been imposed by successive regulations, therefore balancing the structural deficit evaluated at around 4,500 million euros for 2013. For the last five years, and due to the market rules being accommodated to the large electricity companies, nuclear and hydroelectric generation have obtained returns of up to 2,200%. This surplus was identified as more than 14,000 million euros in the five-year period 2008-2012.

Reactions to these markets situations have happened from different stakeholders but with no reaction from the regulator. For instance, the CNE warned the Governments in more than 14 reports of the 'holes' distorting auctions that the system did not work and it was essential to correct it. Minority political groups have submitted proposals to investigate the privatization process of the electricity sector which occurred during the first PP Government (1996-2000). Sadly enough, in July 2013, 300 of the 323 Members of Congress did not vote in favor for a proposal by another minority political group to carry out an energy audit to the energy system and the electricity companies in order to find out how much each concept of the electricity bill was related to and where they can save money to consumers. Although voting against this proposal, some Members of Congress acknowledged that "the problem of the deficit is in the regulation and not in the generation" [ergo not in RET][32].

[32] http://www.energias-renovables.com/articulo/trescientos-diputados-paralizan-la-auditoria-energetica-20130703

The latest events occurred in December 2013 in the Spanish electricity market were:

- The electricity bill in Spain will increase by a total of 2.3% by January 1st, 2014.
- The association of consumers denounced the Government in Brussels for breaching the European electricity directive.
- The Government suspended the implementation of the CESUR auction due to "atypical circumstances" in the auctioning prices, in order to avoid an increase of 11% in the electricity bill and to “work on a new system of pricing the energy”.
- The Spanish High Tribunal supports that the deficit tariff has to be financed temporally by the five members of Unesa.

For CO_2 emissions, the energy sector is primary responsible for almost all the emissions, which accounted for 78% of the total in 2012. The most important emissions are due to electricity generation and road transport. The rest corresponds to ten oil refineries, energy consumption of industry, air transport, and residential uses and services (especially heating and domestic hot water) (BP Chair 2012).

Emissions from electricity generation grew by 25.4% between 1990 and 2012, representing 23.5% of the total in 2012, still in the electricity sector where there are more possibilities of reducing emissions and at a lower cost. Renewable energies in Spain have prevented the issuance of 38 million tons of CO_2, and about 200 million tonnes of CO_2 over the period 2008-2012 in 2012. -Primarily wind power - renewable energy contribution to this result of emission reduction is very important, as they covered 31.2% of electricity generation in 2012, well above what brought nuclear. On the opposite side, the generation of electricity is coal, which grew 35.2% in 2012, and that explains the increase of emissions in the sector of electricity generation of 8 million tons of CO_2 in 2012 compared to 2011 (REE 2012). It was estimated that this increase was due to the decree which promotes the consumption of coal and low prices of CO_2 emissions in 2012. The following table shows the CO_2 emissions in Spain for the last four years as a consequence of the electricity system.

	MtCO2	Variation from previos year
2013	61.4	- 23.1%
2012	80	+ 10%
2011	73	+ 25%
2010	58	- 21%

Table 7.1. CO_2 emissions from the Spanish electricity sector
Source: Adapted from REE (2013)

Finally, the following table summarizes some key values that could be used to define the Spanish electricity and energy systems.

	Value	Units	Source
CO2 emissions from Energy Sector (2012)	264	MtCO2	BP
CO2 emissions from Electricity sector (2013)	61.4	MtCO2	REE
Dependency from external sources (2012)	84.3 %	-	MIEYT/BP
Cost of electricity – Households (2012)	0.177	kWh	EUROSTAT
Cost of electricity – Industrial (2012)	0.116	kWh	EUROSTAT
Increase of cost of electricity (2003-2012)	71 %	-	GOS[33]
Total installed capacity (2013)	108,148	MW	REE
Installed capacity RET (2013)	50,689 (46.87%)	MW	REE
Installed capacity Wind (2013)	22,900 (21.17%)	MW	REE
Installed capacity Solar PV (2013)	4,681 (4.33%)	MW	REE
Installed capacity Solar Thermoelectric (2013)	2,300 (2.13%)	MW	REE
Total net electricity generation (2013)	273,598	GWh	REE
Total Wind electricity generation (2013)	54,301 (19.8%)	GWh	REE
Total Solar PV electricity generation (2013)	8,397 (3.1%)	GWh	REE
Total Solar thermoelectric (2013)	4,554 (1.7%)	GWh	REE
Average Capacity Factor Wind (2005-2013)	24.06%	-	Adapted from REE
Average Capacity Factor Solar PV (2005-2013)	18.51%	-	Adapted from REE
Average Capacity Factor Solar Thermoelectric (2008-2013)	19.96%	-	Adapted from REE

[33] Government of Spain

Annual coverage demand – Wind (2012)	18.1%	-	REE
Annual coverage demand – Solar (2012)	2.9%	-	REE
Peak demand (2012)	43,010	MW	REE
Contribution of RET to peak demand – Wind (2012)	20.9%	-	REE
Investment in RET (PER 2005-2010)	39,237	Million euros	AEVAL
Premium to RET (2005-2012)	39,656	Million euros	CNE, DIE[34], MIEYT
Wind installed capacity by the PER	12,426	MW	AEVAL
Solar PV installed capacity by the PER	3,749	MW	AEVAL
Total electricity generated by the PER (2010)	34,340	GWh	AEVAL
Wind electricity generated by the PER (2010)	24,137 (70.28%)	GWh	AEVAL
Solar PV electricity generated by the PER (2010)	6,261 (18.23%)	GWh	AEVAL
Tariff deficit (cumulative to 2013)	26,759	Million euros	MIEYT
Tariff deficit (annual)	4,000 – 5,000	Million euros	MIEYT
Base load price for electricity – annual pool (2013)	44,64	euro/MWh	OMEL
Peak load price for electricity – annual pool (2013)	51,94	euro/MWh	OMEL

Table 7.2. Values for the Spanish electricity and energy systems (2012-2013)

[34] Dean of industrial engineers

8. Conclusions and recommendations

8.1. Conclusions

It is clear that Spain is in a transition stage in the history of RET support. As well, the history of the Spanish electricity system suggests the need for a new era of conceiving the development of having the country linked to their long term energy planning. The description of the electricity system has shown that the Spanish FIT scheme functioned relatively well when a take-off of the RET sector was required and when it had a small weight in the total electricity generation. However, this is no longer the case. The sector today is mature, has strong implications for the economy as a whole, and should be seen with huge potential for future growth.

Based on the results of the model, the electricity generated from fossil fuels by 2050 was 128,000 GWh for the BaU scenario, 177,000 GWh for the FIT scenario, and 115,000 GWh for the HFOSPRI scenario. As outlined earlier, it can be concluded that RET have the potential to replace fossil fuels by 2050, but the sustainability of this transition will have to be seriously addressed and calculated. In particular, the efficiency of RET will have to improved and the influence of organizations and corporations in the design and implementation of RET plans will have to be reduced.

Although final numbers for investment and premiums for RET were described in this document, calculations for final investment and support to RET for the capacity to be installed (90,840MW) have not been done due to the need of reviewing the appropriateness of applying those values to the result. The cost of installing this capacity will have to be evaluated with different approaches and calculations, which it is not covered in this document.

It can also be concluded that with this installed capacity RET will have the potential to reduce CO_2 emissions by 2050. This reduction will be achieved in the same order that the PER itself indicated, which had a rate of 93.6 $MtCO_2$ every five years, if RET were to be installed at the same pace.

This document attempts to describe how the Spanish electricity system has evolved and can evolve with the current measures and policies in what was called the Business as Usual scenario, as well as possible ways to achieve a system with more RET in the future.

The suggested additional scenarios have shown different results, especially in the electricity generated by 2050. Wind and Solar contributed in a similar way in all three scenarios. The FIT incentives, in principle, were supposed to promote RET, but based on the conditions of the model, these incentives were probably not very profitable and not enough to push RET more into the system, bringing gas and coal as the alternatives.

In order to achieve the RET target suggested in this document, or any other document of its kind, reviews of the latest RET plan should be considered in order to understand and learn more from the past. In this regard, no matter how ambitious the targets of a plan of any kind can be, no policy will be deployed successfully unless fundamental and structural changes happen.

Spain embraced a more ambitious plan for RET. The plan for technologies in terms of installed capacities was a stable plan and set targets for decarbonizing the Spanish energy system and the economy by providing huge incentives to meet specific targets for installation.

What happened was that targets for installed capacity were met by huge margins, particularly for the installation of solar PV, and this was achieved by financial incentives greater than ten times what it was planned. Although the electricity generation from RET target was met, it was only by adding large costs to the system.

While comparing the overall performance of the overall system the PER created huge inequities across technology sectors, wind versus solar, and so on. For a technology like solar, with low capacity factors (CF), its impact on the overall energy mix was insignificant but it came at a very large cost driving other more promising options away from achieving its fuller potential because tax and financial incentives are so heavily targeted to one technology or another.

Based on the comprehensive description of both the designed scenarios and the current data, even after all investments, the system is still dependant on fossil fuels and RET have really not made any substantial meaningful impact in the Spain electricity system with the cost of electricity being one of the most expensive in Europe and with a huge deficit of around 27,000 million euros (see chapter 4 for more details).

Spain was the world's second largest producer of wind energy (MIEYT 2013). The success in the development of wind power in Spain has been accompanied by the creation of competitive companies now active in international technology markets. As a developed country, the design and development of the PER in Spain should have never let the lack of information and participation to happen. The PER did not have any information and participation mechanisms neither any accountability mechanisms. The political responsibilities inherent to this kind of plan makes it essential to substantially improve the accountability mechanisms by means of establishing official and national debates at parliamentary levels regarding the state, progress and future of RET.

Based on the information outlined in this document, future sustainability targets for the Spanish energy model should be based on a combination of energy efficiency and savings policies, and promotion, development and penetration of RET, with a progressive decarbonisation of the supply mix. All these targets should be included in one consistent plan. Linares et al. (2008) suggested that the highest priority should be to focus on policies towards the reduction of demand, ahead of RET promotion policies and carbon reduction policies.

The new Spanish RET plan 2011-2020 was passed in November, 11th, 2011. On January 27th, 2012, the new majority conservative Government (elected November 20th, 2012) suspended the premiums for new renewable energy projects in an attempt to cut the nation's tariff deficit. The new law put an end to premiums for new wind, solar, cogeneration and waste-incineration projects. Existing RET projects that were already approved to receive premiums were not affected by the law.

The current Government's energy policy seems to be characterized by dismantling RET, by the slowdown of RET, by keeping coal subsidy and a lack of encouragement for energy saving, Spain has not implemented serious emission reduction policies, but maintained support for the consumption of coal and gas, which has increased significantly by the transport of goods by road, has encouraged the use of private transport, has increased exponentially high capacity routes, and has built homes (of which there are 3.1 million empty) without criterion.

The energy policy in Spain has not really supported RET effectively due to the continuance of uncertainty in the regulatory legal framework of the system and its lack of setting regulations in the polluting sectors.

Energy is fundamental to the development of the economy and ensuring the social welfare of a country. The energy system should be compatible with sustainable development, i.e., respectful with the environment, while ensuring a security in supply, and contributing to increasing the competitiveness of the economy. With this in mind, Spain has an irrational supply mix that bases generation on expensive and low efficient technologies, which is a real problem for a country whose industry is intensive in electricity use: automobile, cement or ceramic enterprises.

As stated, the cost of the Spanish system is unsustainable due primarily to the tariff deficit. The large electricity generators (the Unesa members) claim to the Government a cumulative amount of around 30,000 million euros which represents the tariff deficit. This debt is in the hands of the financial sector: 20,000 million is the hands of the Spanish banking sector, and around 10,000 million euros in the hands of funds and banks in other countries.

In this last decade, the large electricity corporations have grown and increased their political power and influence with the various Governments of Spain, power which has also spread to the autonomous communities. Former political leaders and Prime ministers have, and still do, belong to the Board of Directors of the four big electricity generators. This is known in Spain as the “revolving doors” effect, whereas politicians move back and forth from their political responsibilities into the large electricity corporation responsibilities. These political influences have been reflected in the regulations approved by Governments, which favors its business model. Examples were payments for capacity and availability, or Royal Decrees – law 1/2012 and 2/2013.

Spain has a surplus of energy and demand has declined due to the economic crisis. Spain is an energetic island and due to this surplus of energy, the service is more expensive. What Spain produces has to be consumed it the country. The whole electricity system should then be restructured.

In recent years, the electricity sector has been treated as a financial sector. The technical and security of supply aspects have been forgotten completely. Energy policies in all the countries of the world are supported by three well-known principles: security of supply, economic issues and environmental issues. In Spain, since 2004, the focus has been on environmental issues, and the security of supply and the economic issues seems to have been forgotten.

In this regard, the EU has no competences in the field of energy, although it does have an interest to do so. What the EU does do is regulates energy and electricity issues through the Ministries of environment, agriculture and competition, although not many countries have followed these directives as strongly as Spain. EU members have handed over sovereignty in monetary policy, movement of people or services, environment, agricultural policy, etc but have not done so in energy.

Unless the Government of Spain decides to have energy and electricity planning as a core activity for the development of the country and the future generations, no plan of any kind will be effective in achieving its targets, no matter how ambitious these targets are.

8.2. Recommendations

It has been concluded that RET has the potential to replace the generation of electricity from imported fossil fuels in Spain. Therefore, in order to move towards this potential situation for the electricity system, some recommendations can be formulated:

- The promotion of RET, both in terms of economic support and availability, should be put in place again and be strengthened. It has been proved repeatedly (e.g. Menanteau et al. 2003) that FITs are the most effective instrument in promoting RET development, but they should be fine-tuned, first, to reflect the different cost of different sites (levelized costs), and second, to reflect the contribution of RET to the value of the technology to the system (capacity factors). These two could be accomplished by starting a gradual implementation of smart grids and more investment in storage technologies so RET is less dependent on their intermittency.

- With the current demand shown in the results from the model, the development of more RET alternatives will not be feasible unless the efficiency of the technologies improved (through the capacity factors of the RET alternatives). More R&D for the efficiency of RET could be considered.

- The description of the electricity system has shown that the electricity prices do not include the real cost of electricity. Investigations should be carried out in order to find out how to incorporate in the electricity prices the full cost of electricity generation, so real prices can reach final consumers.

- Considerations should be made in order to remove from the "electric pool" the nuclear and hydroelectric technologies since these technologies are paid the highest cost of all combined cycles.

- To investigate how to achieve a higher degree of penetration of RET in sectors such as transport and construction (housing). These sectors have suffered a lack of a subsidy return system able to stimulate them, in the same way that the electricity generation sector had.

- To investigate a quicker development of distributed generation. This type of generation, produced on small scale and near demand points, favors the reduction of energy losses in the network and the reduction of the needs of investments in transport and distribution infrastructures, as well as environmental benefits.

- To support regulation for self-consumption of clean energy that facilitates that all people can exercise, in favorable conditions, their right to produce and consume their own energy.

- As described in this document, Spain has invested more than 80,000 million euros in RET. After this investment, it is hard to find the value to the system: Spain has more than 100,000 MW of Power installed, for a peak demand of 43,000MW; the model, at current costs and availabilities, does not offer any other alternatives but to continue with fossil fuels and with the current renewable energy technologies available. Further investigations could be carried out in order to assess the potential of other RET with better capacity factors such as geothermal, minihydro, and wind-offshore. In addition, studies could be developed in order to start facilitating new storage and smart grid technologies to support RET plans.

- National Governments should be constantly searching for the true value of the systems and the consumers. The Government of Spain should make energy a priority for the country's future development. The two largest political parties in Spain should collaborate in making this a priority.

- The whole energy structure could be reviewed in depth by the Government of Spain, and assess the importance and influence of all the stakeholders in the energy system.

- To investigate hot to put in place a separation between the companies who own the transmission networks and electricity distribution and those having the power generation.

- To adapt the Law of incompatibilities in order to put control measures in place to reduce or eliminate the controversial influences of people who have held positions of responsibility in the public administration and later exercise these influences in their positions within the large energy companies and vice versa.

- To provide the experiences of RET plans in Spain to other jurisdictions so they can learn from the “Spanish experience”.

9. Further work

Following is a list of suggestions to build on this research:

1. Use the model to study the claims of lobby groups (ie. Nuclear, Renewable, think tanks, etc).

2. Look at the demand side of the equation from an "income group" perspective instead of a "service group".

3. Incorporate future new renewable energy technologies in the model for the same time horizon.

References

AEVAL, 2011, Evaluación del Plan Español de Energías Renovables 2005-2010, Agencia Estatal de Evaluación de las Políticas públicas y la Calidad de los Servicios, Ministerio de Política Territorial y Administración Pública. <http://www.aeval.es/es/difusion_y_comunicacion/publicaciones/Informes/Informes_de_Evaluacion/Evaluaciones_2010/E24.html>

APPA (Association of Small Renewable Producers), 2010, Study of the impact of macroeconomic impact of renewable energies in Spain, <http://www.appa.es/descargas/Informe_2012_Web.pdf>

Batlle, C., Pérez-Arriaga, I.J., Zambrano-Barragán, P., 2012, Regulatory design for RET-E support mechanisms: Learning curves, market structure, and burden-sharing, Energy Policy 41, 212-220.

Boavida, D. et al., 2011,Integrated infrastructure for CO2 transport and storage in the west Mediterranean Energy Procedia 4, pg 2440-2447.

Boavida, D., Carneiro, J.F., Ramírez, A., Martinez, R., Czernichowski-Lauriol, I., Tosato, G., Rimi, A., Zarhloule, Y. Simões, S., and Cabal, H., 2011, Integrated infrastructure for CO2 transport and storage in the west Mediterranean. Energy Procedia 4. 2440–2447.

Bohman, J., 1999, International regimes and democratic governance: political equality and influence in global institutions. International Affairs. Volume 75, Issue 3, 499–513.

Brown, S.P.A., and Huntington, H.G., 2008, Energy security and climate change protection: Complementarity or tradeoff?, Energy Policy 36, 3510-3513.

BP Chair - British Petroleum Chair for Energy and Sustainability, 2012, Informe sobre energía y sostenibilidad en España 2012. Universidad Pontificia de Comillas, Madrid.

Burgos-Payan, M., et al, 2013, Costs and benefits of the renewable production of electricity in Spain. Energy Policy 56. 259-270.

Cabal, H., 2011, Introducción a los modelos energéticos presentation. Herramientas para el análisis de la sostenibilidad de sistemas energéticos, Universitat Jaume I – Castellón, 11-12 Julio 2011.

Cabal, H., Lechon, Y., Garcia, D., Labriet, M., Tosato, G., Gargiulio, M. and Kanudia, A., 2012, TIMES-Spain model and scenarios presentation. ETSAP workshop, Cape Town 22nd June 2012.

Cabal H. and Lechon, 2011, Escenarios energéticos sostenibles a medio y largo plazo. Revista ambienta. Secretaría General Técnica Ministerio de Agricultura, Alimentación y Medio Ambiente 96.

Cabal, H., Labriet, M., Lechón, Y., Fortes, P., Gouveia, J., Seixas, J., Kanudia, A., Gargiulo, M., and Tosato, G., 2012, The TIMES-COMET Energy-Transport Technical-Economic Model: Purpose, Description, Functionalities, and Results presentation. COMET – CO2PipeHaz - COCATE. Bridging the Gap in CCS Infrastructure: Results from European Projects. Lisbon, December 12, 2012.

Calvo Silvosa, A. et al., 2011, Policy paper on renewable energy and energy efficiency of residential housing – Spain. Expert Evaluation Network. Task 1.

Casey, J., 1999, Non-government organizations as policy actors. Doctoral Document, Universitat Autònoma de Barcelona, Spain.

Ciarreta, A., Gutierrez-Hita, C., and and Nasirov, S., 2011, Renewable energy sources in the Spanish electricity market: Instruments and effects. Renewable and Sustainable Energy Reviews. Volume 15, Issue 5, 2510–2519.

Coleman, D., 2003, The United Nations and Transnational Corporations: From an Inter-nation to a ‘‘Beyond-state’’ Model of Engagement. *Global Society*, Vol. 17, No. 4.

Cossent, R., Gómez, T., and Olmos, L., 2011, Large-scale integration of renewable and distributed generation of electricity in Spain: Current situation and future needs. Energy Policy 39. 8078-8087.

Del Río González, P., 2008, Ten years of renewable electricity policies in Spain: An analysis of successive feed-in tariff reforms. Energy Policy 36. 2917-2929.

Del Río, P., and Unruh, G., 2007, Overcoming the lock-out of renewable energy technologies in Spain: The cases of wind and solar electricity. Renewable & Sustainable Energy Reviews 11. 1498-1513.

Del Río, P., 2009, Interactions between climate and energy policies: the case of Spain. Climate Policy 9. 119.

Dinica, V. , 2008, Initiating a sustained diffusion of wind power: The role of public– private partnerships in Spain. Energy Policy 36. 3562-3571.

Dinica, V. , 2011, Renewable electricity production costs - A framework to assist policy-makers' decisions on price support. Energy Policy 36. 4153-4167.

ENDESA corporation, 2012, Corporate website. Governing bodies <http://www.endesa.com/en/aboutEndesa/OrganosdeGobierno/Paginas/OrganosdeGobierno.aspx>

EurObserv'ER, 2011, 10th report on “The State of Renewable Energies in Europe”.

European commission, 2009, Directive 2009/28/EC on the Promotion of the use of energy from renewable energy sources. Official Journal of the EU.

European commission, 2003, Directive 2003/87/EC, 2003. Official Journal of the EU.

European commission, 2004, Directive 2004/101/EC, 2004. Official Journal of the EU.

European commission, 2009, Directive 2009/29/EC, 2009. Official Journal of the EU.

European Environmental Agency, 2013, Annual report.

Eurostats, 2012, Prices of electricity - Main tables for Energy <http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables>

Fishbone L G, Giesen G, Hymmen H A, Stocks M, Vos H, Wilde, D, Zoelcher R, Balzer C, and Abilock H. (1983), "Users Guide for MARKAL: A Multi-period, Linear Programming Model for Energy Systems Analysis", BNL Upton, NY, and KFA, Julich, Germany, BNL 51701.

Foidart, F., Oliver-Sola, J., Gasol, C.M., Gabarrell, X., and Rieradevall, J., 2010,How important are current energy mix choices on future sustainability? Case study: BelgiumandSpain—projections towards 2020–2030. Energy Policy 38. 5028-5037.

Fuller, D., 2008, Market equilibrium models with continuous and binary variables. Department of Management Sciences, University of Waterloo.

Gargiulio, M., 2012, Introduction to the TIMES model generator presentation. VEDA-TIMES Training course. Universidade Nova De Lisboa, Lisboa, Portugal. 12-14 December, 2012.

Gil, H.A., Gomez-Quiles, C., and Riquelme, J., 2012, Large-scale wind power integration and wholesale electricity trading benefits: Estimation via an ex post approach. Energy Policy 41. 849-859.

Greenpeace Spain, 2012, Corporate website. Achievements. <http://www.greenpeace.org/espana/es/Por-dentro/Nuestras-victorias/>

Greenpeace Spain, 2013, Iberdrola, empresa enemiga de las renovables report. <http://www.greenpeace.org/espana/es/reports/Iberdrola-empresa-enemiga-de-las-renovables/>

Haas, R. et al, 2004, How to promote renewable energy systems successfully and effectively. Energy Policy 32. 833-839.

Hernández, A., 2009, Director General for Energy Policy and Mines, presentation of the "Estudio Macroeconómico del Impacto del Sector Eólico en España, Madrid, METER WEB

Iberdrola corporation, 2012, Corporate website. International panorama <http://www.iberdrola.es/webibd/corporativa/iberdrola?IDPAG=ENWEBCONEMPGINT>

IDAE, 2005, Plan de Energías Renovables en España 2005–2010. Institute for Diversification and Saving of Energy, Ministry of Industry,Tourism and Trade.

Iglesias, G., Del Río, P., and Dopico, J.A., 2011, Policy analysis of authorisation procedures for wind energy deployment in Spain. Energy Policy 39. 4067-4076.

International Energy Agency, 2008, Deploying renewables, Principles for effective policies. Paris.

Jamasb, T., and Pollin, M., 2005, Electricity market reform in the European Union: Review of progress towards liberalization & integration. The Energy Journal. European Energy Liberalisation Special Issue 11-41.

Joskow, P., 2010, Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies. A joint Center of the Department of Economics, MIT Energy Initiative, and Sloan School of Management.

Katzenstein, W., Fertig, E., and Apt, J., 2010, The variability of interconnected wind plants. Energy Policy 38. 4400-4410.

Klessmann, C. Held, A. Rathmann, M. Ragwitz, M., 2011, Status and perspectives of renewable energy policy and deployment in the European Union—What is needed to reach the 2020 targets?. Energy Policy 39. 7637-7657.

Klessmann, C., Nabe, C., and Burges, K., 2008, Pros and cons of exposing renewables to electricity market risks - A comparison of the market integration approaches in Germany, Spain,and the UK. Energy Policy 36. 3646-3661.

Koenig-Archibugi, M., 2004, Transnational Corporations and Public Accountability. *Government and Opposition Ltd*. Published by Blackwell Publishing.

Komor, P. and Bazilian, M., 2005, Renewable energy policy goals, programs, and technologies. Energy Policy 33. 1873–1881.

Labriet, M., Cabal, H., Lechón, Y., Giannakidis, G., and Kanudia, A., 2010, The implementation of the EU renewable directive in Spain. Strategies and challenges. Energy Policy 38. 2272-2281.

Law 54/1997for the Electrical Sector, 1997. November 27th.

Lewis, D. and MacLeod, S., 2004, Transnational Corporations: Power, Influence and Responsibility. Global Social Policy.

Lewis, J. I. and Wiser, R. H., 2007, Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms. Energy Policy 35. 1844–1857.

Linares, P., Santos, F.J., and Pérez-Arriaga, I.J., 2008, Scenarios for the evolution of the Spanish electricity sector: Is it on the right path towards sustainability?. Energy Policy 36. 4057-4068.

Linares, P., Santos, F.J., Ventosa, M., and Lapiedra, L., 2006, Impacts of the European Emissions Trading Scheme Directive and Permit Assignment Methods on the Spanish Electricity Sector. The Energy Journal 27. 79-98.

Loulou, R., Remne, U., Kanudia, A., Lehtila, A., and Goldstein, G., 2005, Documentation for the TIMES Model, Part I, Energy Technology Systems Analysis Programme. <http://www.etsap.org/tools.htm >

Matea Rosa, M., 2013, El fondo de titularización del déficit del sistema eléctrico, Boletín económico del ICE, Nº 3039, Bank of Spain. Del 1 al 31 de Mayo de 2013.

Martínez, I. Díaz, P., Martínez, I., and Ruiz, P., 2009, Renewable Sustainable Energy Rev 13.

Mendiluce, M., Perez-Arriaga, I., and Ocaña, C., 2010, Comparison of the evolution of energy intensity in Spain and in the EU15. Why is Spain different?. Energy Policy 38. 639-645.

Menanteau, P., Finon, D., Lamy, M., 2003, Prices versus quantities: choosing policies for promoting the development of renewable energy. Energy policy 31. 799-812.

MITYC, 2009, La energía en España 2009. Secretaría de Estado de Energía, Ministerio de Industria, Turismo y Comercio.

MITYC, 2010, La energía en España 2010. Secretaría de Estado de Energía, Ministerio de Industria, Turismo y Comercio.

MIEYT, 2011, La energía en España 2011. Secretaría de Estado de Energía, Ministerio de Industria, Energía y Turismo.

MIEYT, 2013, Reforma del sistema eléctrico: una reforma necesaria. Ministerio de Industria, Energía y Turismo. 24 de Septiembre de 2013.

Ministerio de Medio Ambiente (MMA), 2007, Spanish Strategy for Climate Change and Clean Energy (Horizon 2007–2012–2020). Approved by Council of Ministers, 2 November 2007.

Ministerio de Agricultura, 2013, Informe de las evoluciones de las emisiones de CO2 en España.

Moreno, F., and Martínez-Val, J. M., 2011, Collateral effects of renewable energies deployment inSpain: Impact on thermal power plants performance and management. Energy Policy 39. 6561-6574.

Morales, J., 2011, Diez claves para entender el sistema español. Fundación ciudadanía y valores.

Oficina de cambio climático, Ministerio de agricultura, 2012, <http://www.magrama.gob.es/es/cambio-climatico/temas/organismos-e-instituciones-implicados-en-la-lucha-contra-el-cambio-climatico-a-nivel-nacional/oficina-espanola-en-cambio-climatico/>

Ortega, M., Del Rio, P. and Montero, E., 2013, Assessing the benefits and costs of renewable electricity. The Spanish case. Renewable and Sustainable Energy Reviews 27. 294-304.

REE-Red Electrica de España, 2013, The Spanish Electricity System preliminary report 2013. <http://www.ree.es/sites/default/files/downloadable/preliminary_report_2013.pdf>

REE-Red Electrica de España, 2013, El sistema eléctrico español 2012. <http://www.ree.es/en/publications/2013/10/spanish-electricity-system-report-2012>

REE-Red Electrica de España, 2010, El sistema eléctrico español 2010. <http://www.ree.es/en/publications/2013/09/spanish-electricity-system-report-2010 >

RES2020, 2010, Reference document on renewable energy sources policy and potential. RES2020: Monitoring and Evaluation of the RET directives implementation in EU27 and policy recommendations for 2020. <http://www.cres.gr/res2020/files/fs_inferior01_h_files/pdf/deliver/RES2020-D22-D23_Reference_Document_on_Renewable_Energy_Sources_Policy_and_Potential.pdf> pages 92-111.

Resch, G., Faber, T., Ragwitz, M., Held, A., Panzer, C., and Haas, R., 2008, 20% RET by 2020—A balanced scenario to meet Europe's renewable energy target. Project futures-e, Intelligent Energy—Europe (IEE), ALTENER.

Rivier Abbad, J., 2010, Electricity market participation of wind farms: the success story of the Spanish pragmatism. Energy policy 38. 3174–3179.

Sáenz de Miera, G., Del Río González, P. and Vizcaíno, I., 2008, Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain. Energy Policy 36. 3345-3359.

San Cristobal, J.R., 2012, A goal programming model for environmental policy analysis: Application to Spain. Energy Policy 43. 303-307.

San Miguel, G., Del Rio, P., and Hernandez, F., (2010), An update of Spanish renewable energy policy and achievements in a low carbon context. Journal of Renewable Sustainable Energy 2, 031007.

Sensfuss, F., Ragwitz, M. and Genoese, M., 2008, The merit order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany, Energy Policy 36. 3086-3094.

Schallenberg-Rodriguez, J., and Haas, R., 2012, Fixed feed-in tariff versus premium: A review of the current Spanish system. Renewable and Sustainable Energy Reviews 16. 293-305.

Sterlacchini, A., 2012, Energy R&D in private and state-owned utilities: An analysis of the major world electric companies. Energy Policy 41. 494-506.

Tester, J.W. et al, 2005, Sustainable Energy: Choosing among options. The MIT Press.

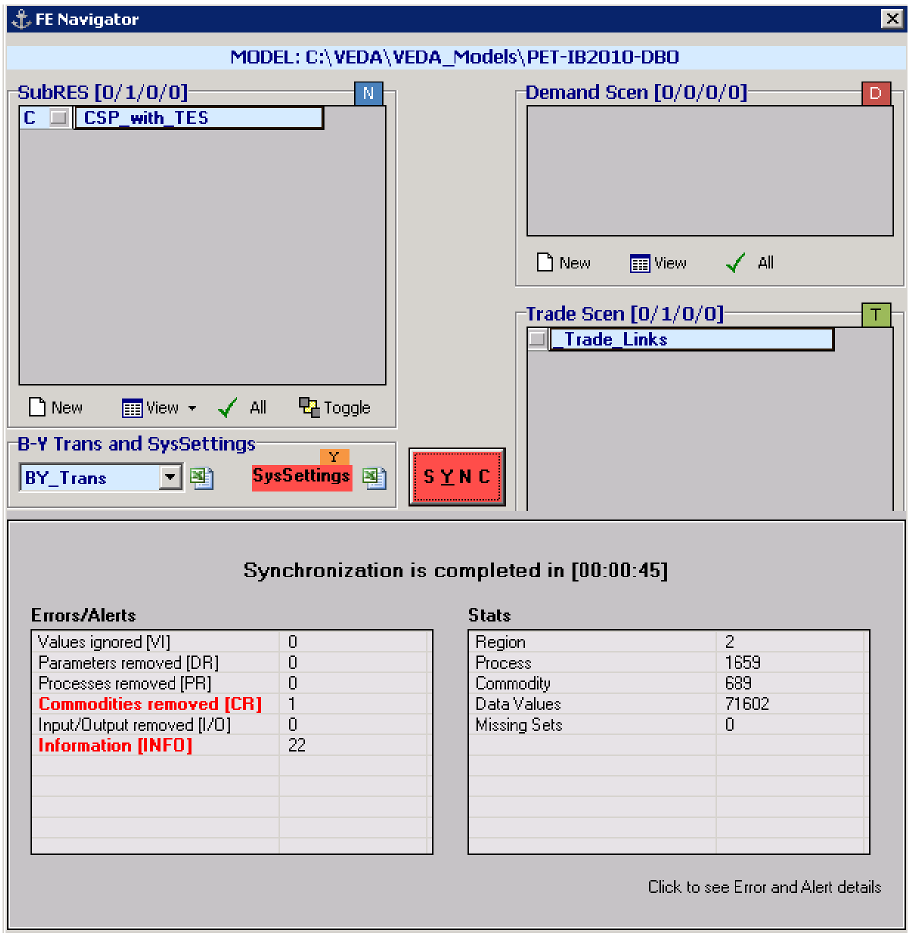
US Department of Energy, 2011, Strategic Plan.

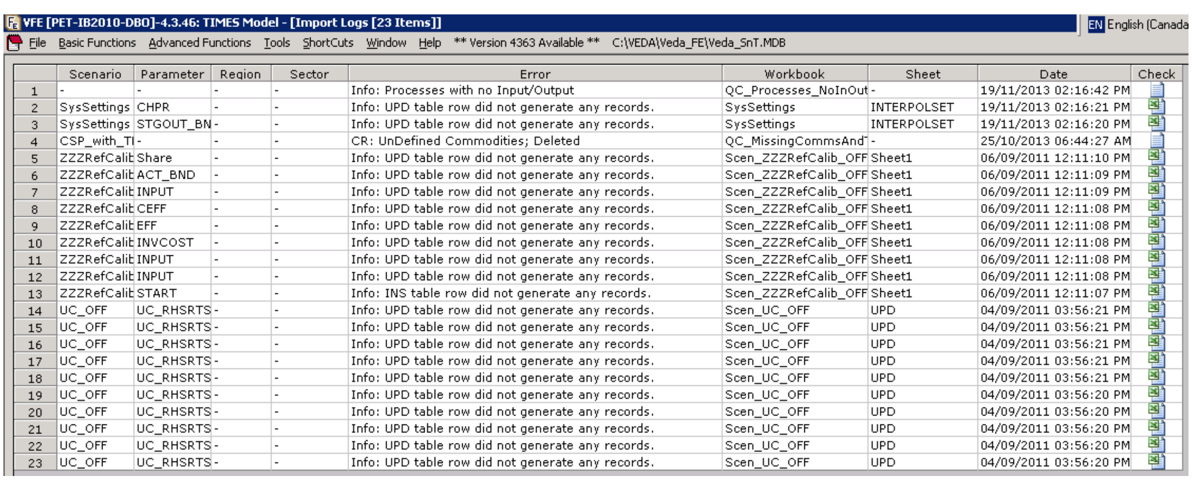
Voort, E. van der, Donni, E., Thonet, C., Bois d'Enghien, E., Dechamps, C. & Guilmot, J.F. 1984. Energy Supply Modelling Package EFOM-12C Mark I, Mathematical description. Louvain-la-Neuve, Cabay: Commission of the European Communities.

Zubi, G., Bernal-Agustín, J.L., Fandos Marín, A.B. , 2009, Wind energy (30%) in the Spanish power mix - technically feasible and economically reasonable. Energy Policy 37. 3221-3226.

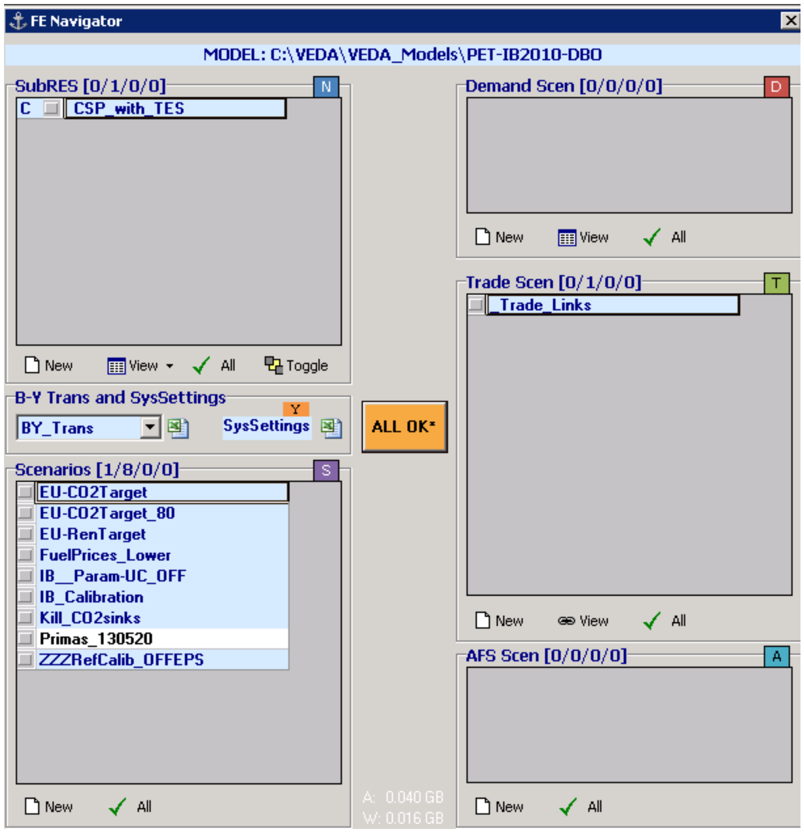
Appendix A – Shell interface

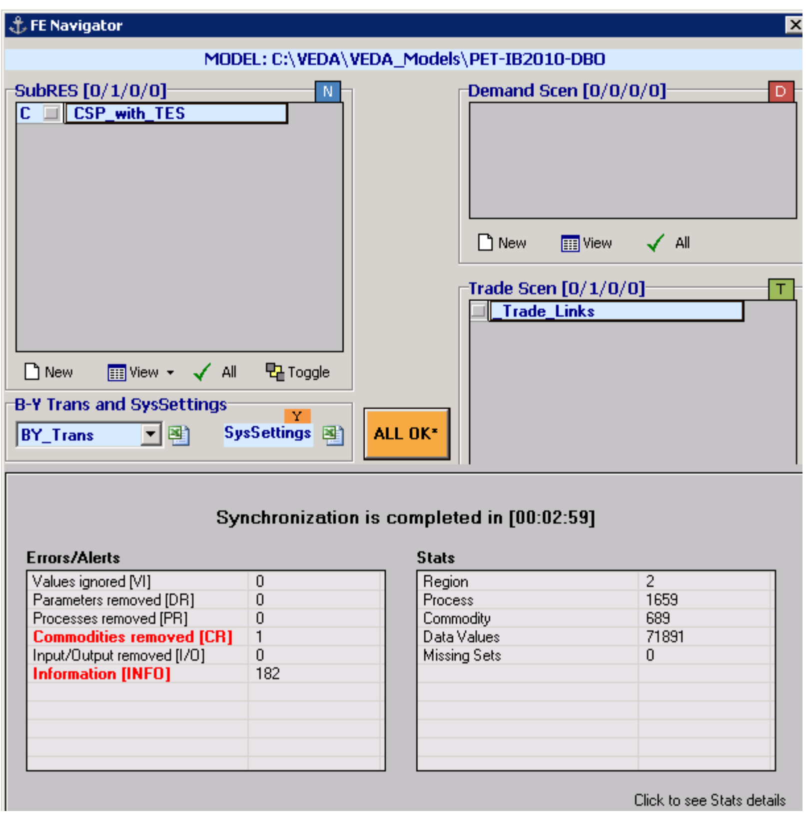
VEDA-FE

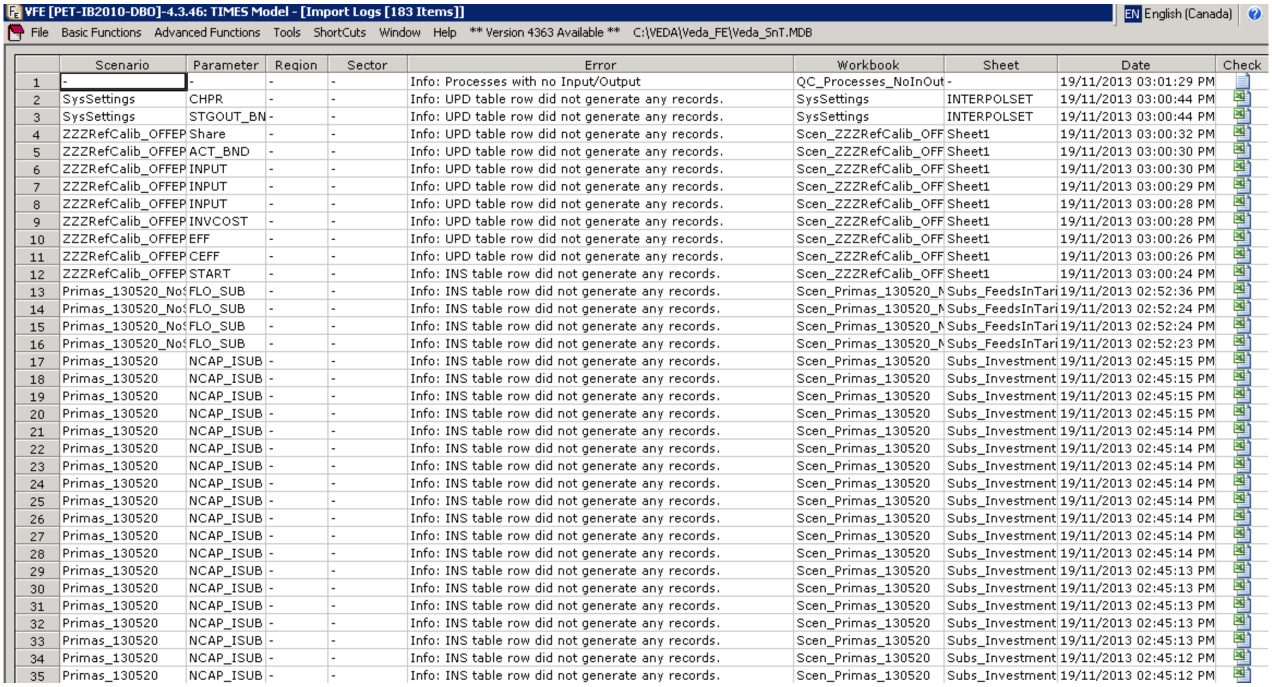




	Scenario	Parameter	Region	Sector	Error	Workbook	Sheet	Date	Check
1	-	-	-	-	Info: Processes with no Input/Output	QC_Processes_NoInOut	-	19/11/2013 02:16:42 PM	
2	SysSettings	CHPR	-	-	Info: UPD table row did not generate any records.	SysSettings	INTERPOLSET	19/11/2013 02:16:21 PM	
3	SysSettings	STGOUT_BN	-	-	Info: UPD table row did not generate any records.	SysSettings	INTERPOLSET	19/11/2013 02:16:20 PM	
4	CSP_with_TI	-	-	-	CR: UnDefined Commodities; Deleted	QC_MissingCommsAnd	-	25/10/2013 06:44:27 AM	
5	ZZZRefCalit	Share	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:10 PM	
6	ZZZRefCalit	ACT_BND	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:09 PM	
7	ZZZRefCalit	INPUT	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:09 PM	
8	ZZZRefCalit	CEFF	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:08 PM	
9	ZZZRefCalit	EFF	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:08 PM	
10	ZZZRefCalit	INVCOST	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:08 PM	
11	ZZZRefCalit	INPUT	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:08 PM	
12	ZZZRefCalit	INPUT	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:08 PM	
13	ZZZRefCalit	START	-	-	Info: INS table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	06/09/2011 12:11:07 PM	
14	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:21 PM	
15	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:21 PM	
16	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:21 PM	
17	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:21 PM	
18	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:21 PM	
19	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:20 PM	
20	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:20 PM	
21	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:20 PM	
22	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:20 PM	
23	UC_OFF	UC_RHSRTS	-	-	Info: UPD table row did not generate any records.	Scen_UC_OFF	UPD	04/09/2011 03:56:20 PM	


FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
Trade Scen [0/1/0/0]
_Trade_Links
B-Y Trans and SysSettings
BY_Trans
SysSettings
ALL OK*
Scenarios [1/8/0/0]
EU-CO2Target
EU-CO2Target_80
EU-RenTarget
FuelPrices_Lower
IB__Param-UC_OFF
IB_Calibration
Kill_CO2sinks
Primas_130520
ZZZRefCalib_OFFEPS
AFS Scen [0/0/0/0]
New
View
All
Toggle

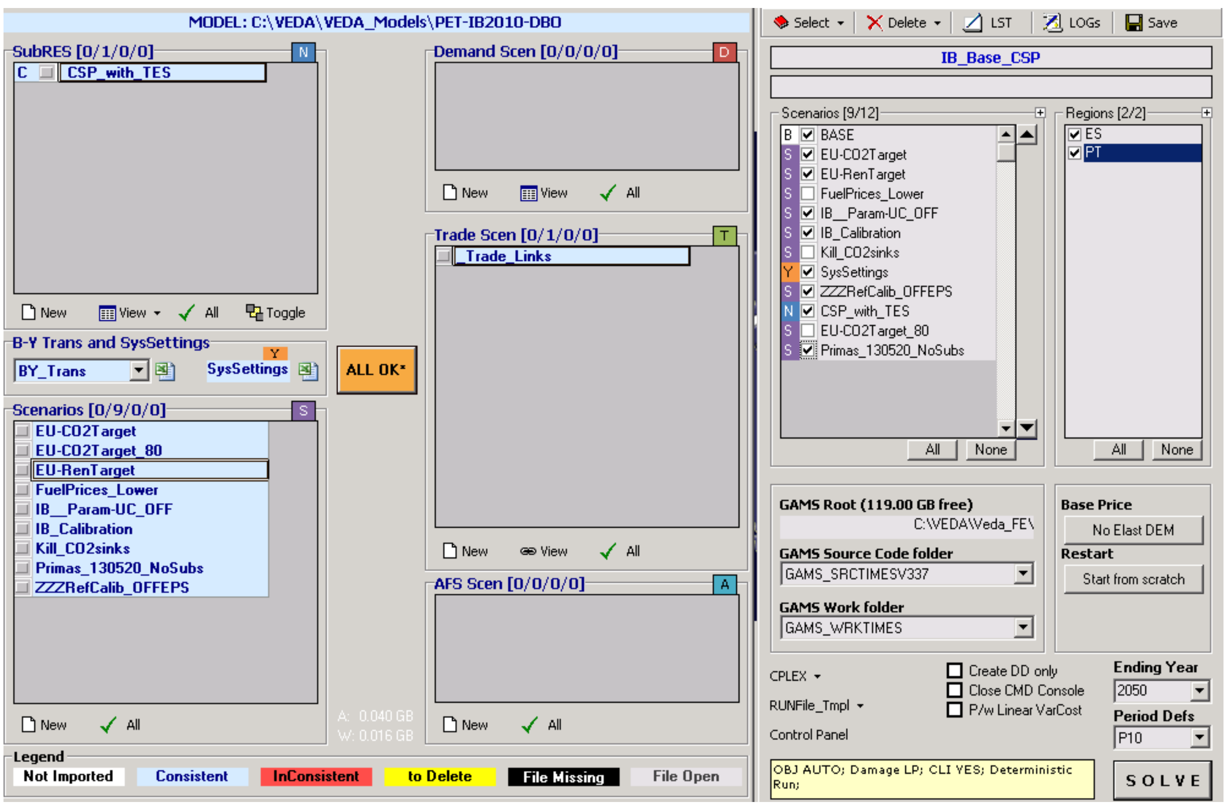

FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
Trade Scen [0/1/0/0]
_Trade_Links
B-Y Trans and SysSettings
BY_Trans
SysSettings
ALL OK*
Synchronization is completed in [00:02:59]
Errors/Alerts
Values ignored [VI] 0
Parameters removed [DR] 0
Processes removed [PR] 0
Commodities removed [CR] 1
Input/Output removed [I/O] 0
Information [INFO] 182
Stats
Region 2
Process 1659
Commodity 689
Data Values 71891
Missing Sets 0
Click to see Stats details

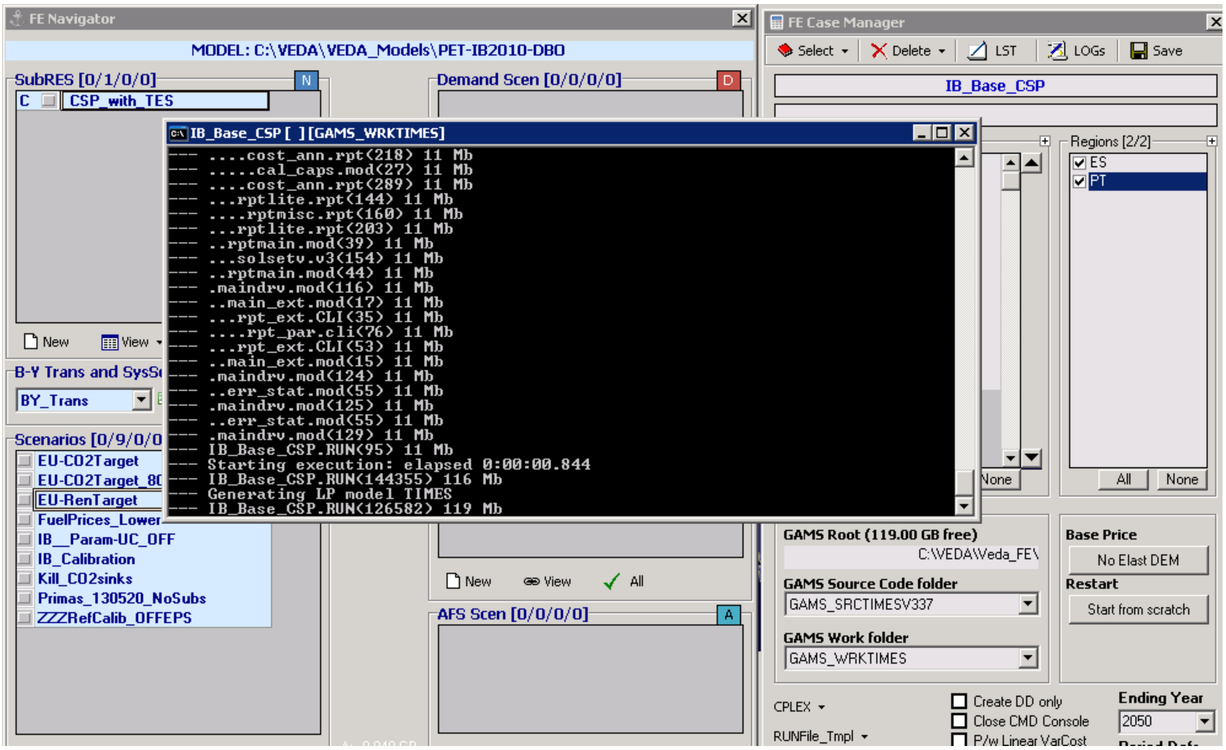


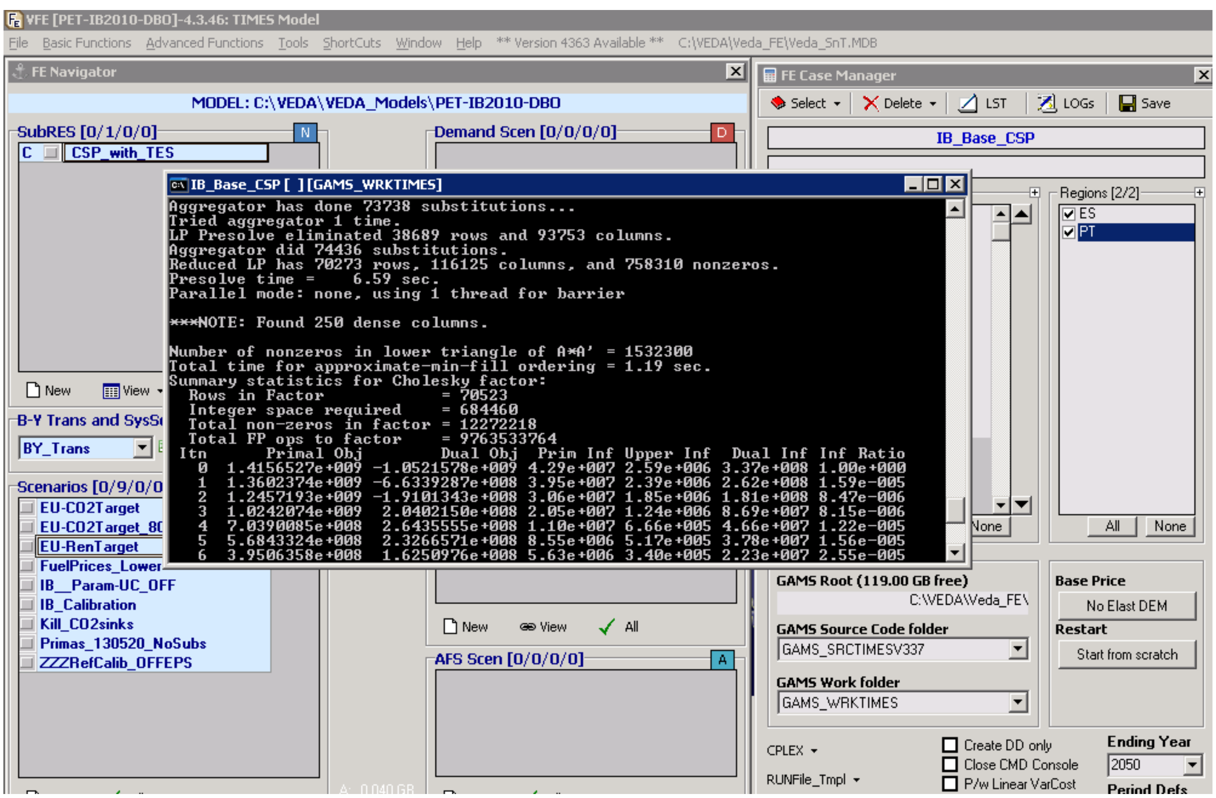
VFE [PET-IB2010-DBO]-4.3.46: TIMES Model - [Import Logs [183 Items]]

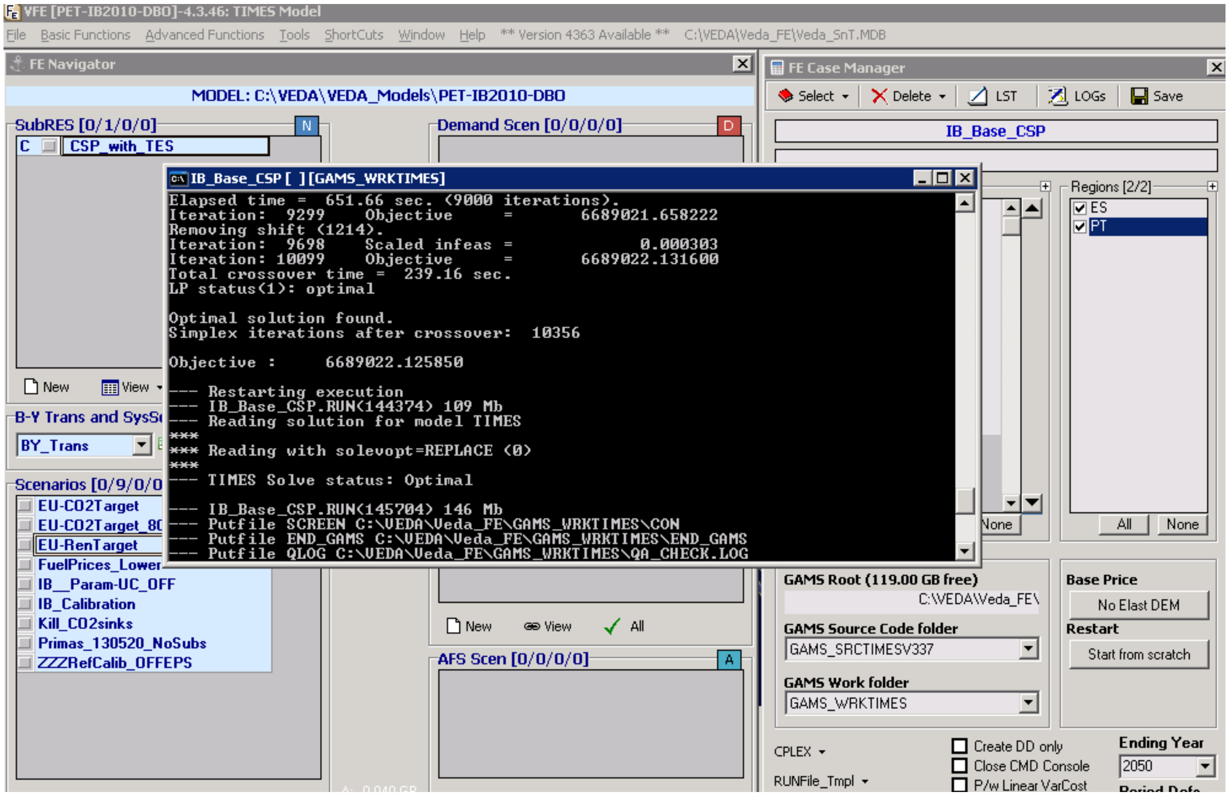
File Basic Functions Advanced Functions Tools ShortCuts Window Help ** Version 4363 Available ** C:\VEDA\Veda_FE\Veda_SnT.MDB

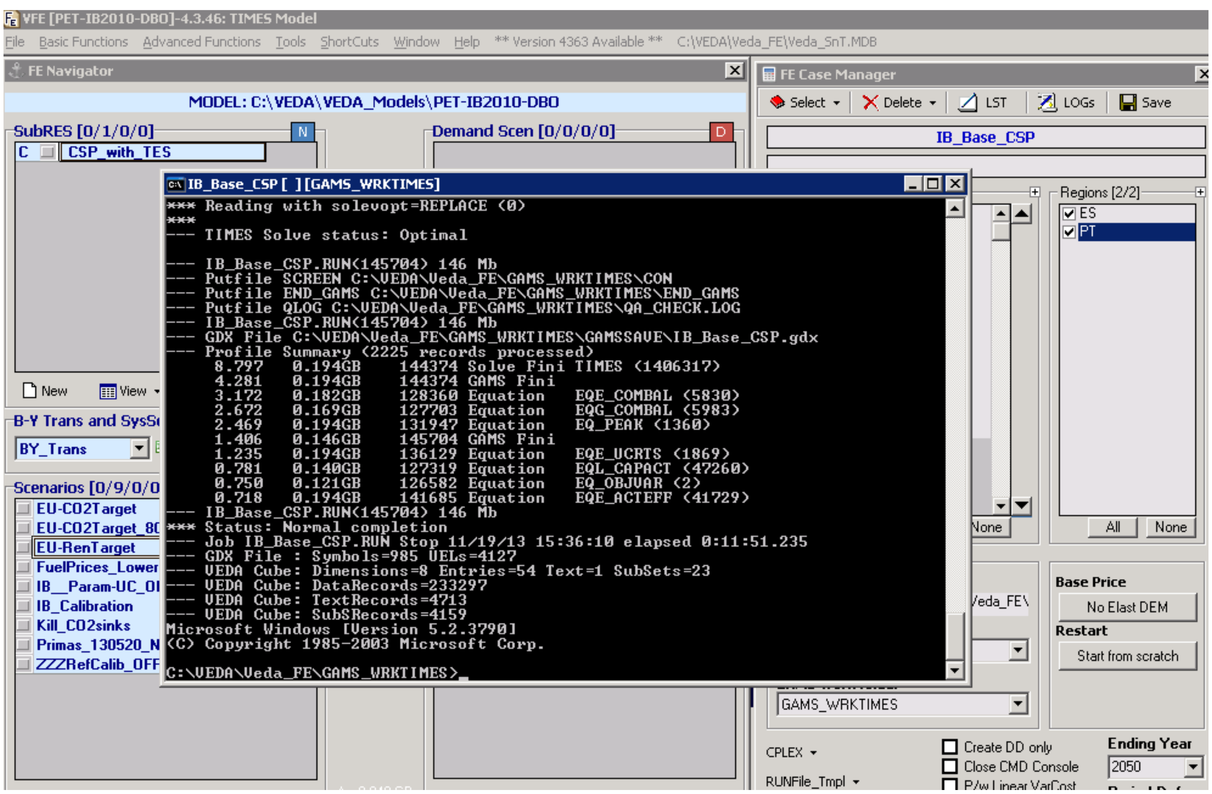
	Scenario	Parameter	Region	Sector	Error	Workbook	Sheet	Date	Check
1	-	-	-	-	Info: Processes with no Input/Output	QC_Processes_NoInOut	-	19/11/2013 03:01:29 PM	
2	SysSettings	CHPR	-	-	Info: UPD table row did not generate any records.	SysSettings	INTERPOLSET	19/11/2013 03:00:44 PM	
3	SysSettings	STGOUT_BN	-	-	Info: UPD table row did not generate any records.	SysSettings	INTERPOLSET	19/11/2013 03:00:44 PM	
4	ZZZRefCalib_OFFEP	Share	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:32 PM	
5	ZZZRefCalib_OFFEP	ACT_BND	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:30 PM	
6	ZZZRefCalib_OFFEP	INPUT	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:30 PM	
7	ZZZRefCalib_OFFEP	INPUT	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:29 PM	
8	ZZZRefCalib_OFFEP	INPUT	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:28 PM	
9	ZZZRefCalib_OFFEP	INVCOST	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:28 PM	
10	ZZZRefCalib_OFFEP	EFF	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:26 PM	
11	ZZZRefCalib_OFFEP	CEFF	-	-	Info: UPD table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:26 PM	
12	ZZZRefCalib_OFFEP	START	-	-	Info: INS table row did not generate any records.	Scen_ZZZRefCalib_OFF	Sheet1	19/11/2013 03:00:24 PM	
13	Primas_130520_No	FLO_SUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520_N	Subs_FeedsInTari	19/11/2013 02:52:36 PM	
14	Primas_130520_No	FLO_SUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520_N	Subs_FeedsInTari	19/11/2013 02:52:24 PM	
15	Primas_130520_No	FLO_SUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520_N	Subs_FeedsInTari	19/11/2013 02:52:24 PM	
16	Primas_130520_No	FLO_SUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520_N	Subs_FeedsInTari	19/11/2013 02:52:23 PM	
17	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:15 PM	
18	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:15 PM	
19	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:15 PM	
20	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:15 PM	
21	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
22	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
23	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
24	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
25	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
26	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
27	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
28	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:14 PM	
29	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:13 PM	
30	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:13 PM	
31	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:13 PM	
32	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:13 PM	
33	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:13 PM	
34	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:12 PM	
35	Primas_130520	NCAP_ISUB	-	-	Info: INS table row did not generate any records.	Scen_Primas_130520	Subs_Investment	19/11/2013 02:45:12 PM	

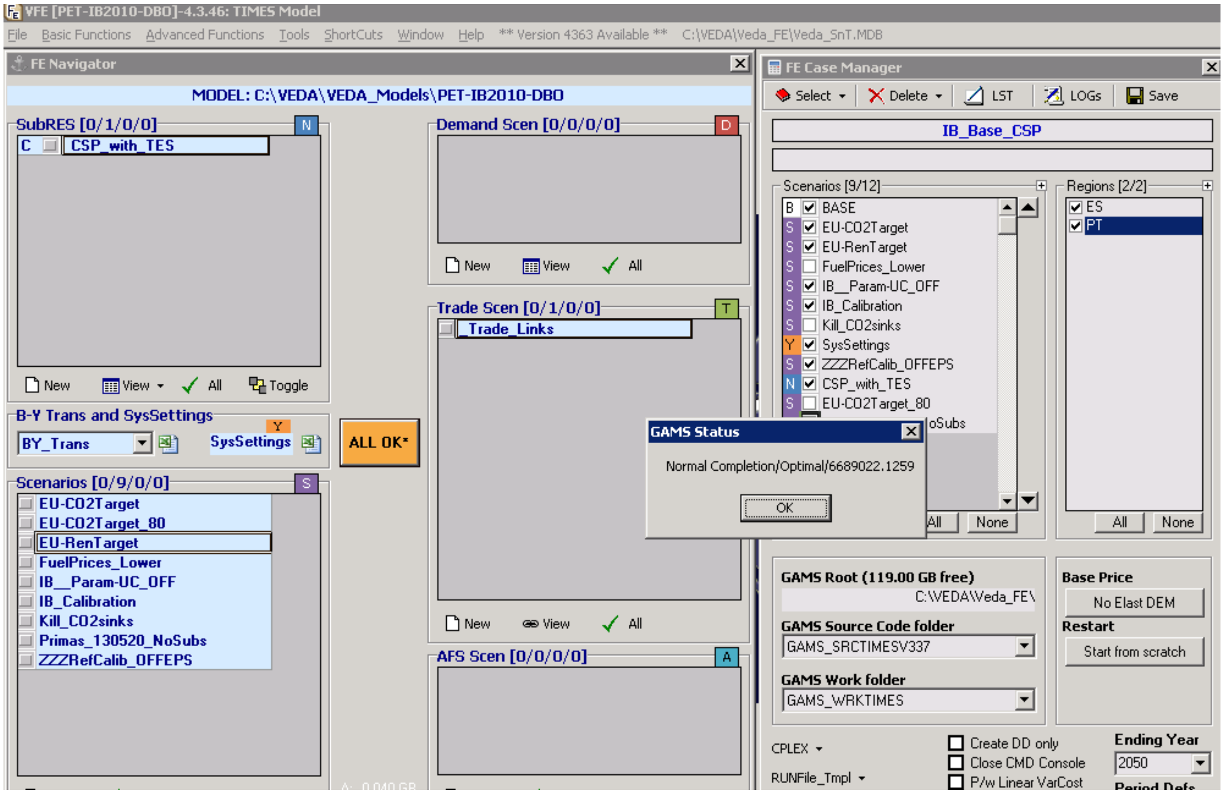



FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
IB_Base_CSP [ ] [GAMS_WRKTIMES]
--- ....cost_ann.rpt(218) 11 Mb
--- .....cal_caps.mod(27) 11 Mb
--- ....cost_ann.rpt(289) 11 Mb
--- ...rptlite.rpt(144) 11 Mb
--- ....rptmisc.rpt(160) 11 Mb
--- ...rptlite.rpt(203) 11 Mb
--- ..rptmain.mod(39) 11 Mb
--- ...solsetv.v3(154) 11 Mb
--- ..rptmain.mod(44) 11 Mb
--- .maindrv.mod(116) 11 Mb
--- ..main_ext.mod(17) 11 Mb
--- ...rpt_ext.CLI(35) 11 Mb
--- ....rpt_par.cli(76) 11 Mb
--- ...rpt_ext.CLI(53) 11 Mb
--- ..main_ext.mod(15) 11 Mb
--- .maindrv.mod(124) 11 Mb
--- ..err_stat.mod(55) 11 Mb
--- .maindrv.mod(125) 11 Mb
--- ..err_stat.mod(55) 11 Mb
--- .maindrv.mod(129) 11 Mb
--- IB_Base_CSP.RUN(95) 11 Mb
--- Starting execution: elapsed 0:00:00.844
--- IB_Base_CSP.RUN(144355) 116 Mb
--- Generating LP model TIMES
--- IB_Base_CSP.RUN(126582) 119 Mb
B-Y Trans and SysS
BY_Trans
Scenarios [0/9/0/0
EU-CO2Target
EU-CO2Target_80
EU-RenTarget
FuelPrices_Lower
IB__Param-UC_OFF
IB_Calibration
Kill_CO2sinks
Primas_130520_NoSubs
ZZZRefCalib_OFFEPS
New
View
All
AFS Scen [0/0/0/0]
FE Case Manager
Select
Delete
LST
LOGs
Save
IB_Base_CSP
Regions [2/2]
ES
PT
None
All
GAMS Root (119.00 GB free)
C:\VEDA\Veda_FE\
GAMS Source Code folder
GAMS_SRCTIMESV337
GAMS Work folder
GAMS_WRKTIMES
Base Price
No Elast DEM
Restart
Start from scratch
CPLEX
RUNFile_Tmpl
Create DD only
Close CMD Console
P/w Linear VarCost
Ending Year
2050

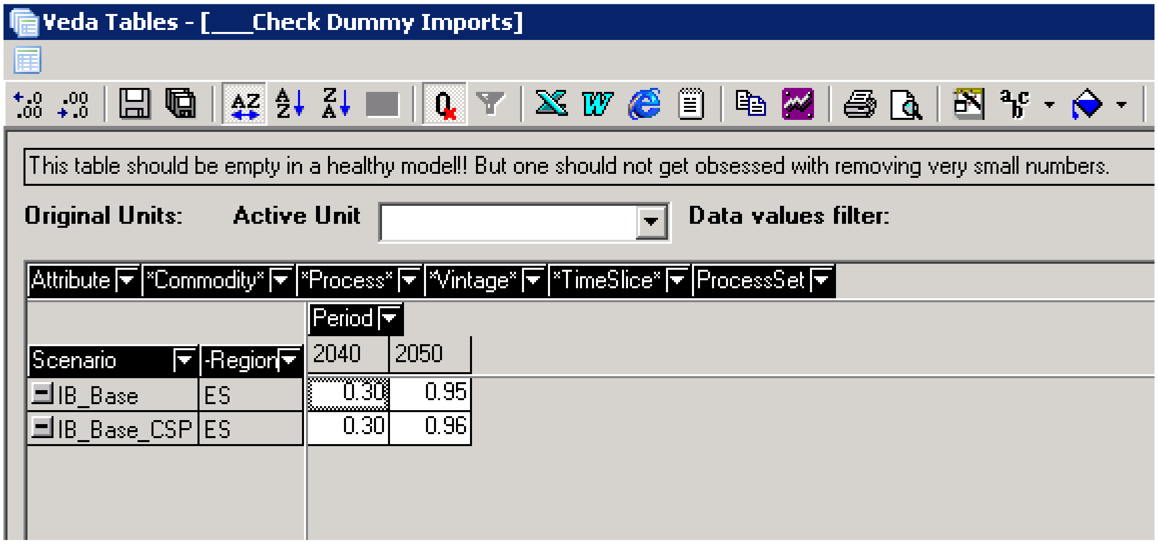

VFE [PET-IB2010-DBO]-4.3.46: TIMES Model
File Basic Functions Advanced Functions Tools ShortCuts Window Help ** Version 4363 Available ** C:\VEDA\Veda_FE\Veda_SnT.MDB
FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
IB_Base_CSP [ ] [GAMS_WRKTIMES]
Aggregator has done 73738 substitutions...
Tried aggregator 1 time.
LP Presolve eliminated 38689 rows and 93753 columns.
Aggregator did 74436 substitutions.
Reduced LP has 70273 rows, 116125 columns, and 758310 nonzeros.
Presolve time = 6.59 sec.
Parallel mode: none, using 1 thread for barrier
***NOTE: Found 250 dense columns.
Number of nonzeros in lower triangle of A*A' = 1532300
Total time for approximate-min-fill ordering = 1.19 sec.
Summary statistics for Cholesky factor:
Rows in Factor = 70523
Integer space required = 684460
Total non-zeros in factor = 12272218
Total FP ops to factor = 9763533764
Itn Primal Obj Dual Obj Prim Inf Upper Inf Dual Inf Inf Ratio
0 1.4156527e+009 -1.0521578e+009 4.29e+007 2.59e+006 3.37e+008 1.00e+000
1 1.3602374e+009 -6.6339287e+008 3.95e+007 2.39e+006 2.62e+008 1.59e-005
2 1.2457193e+009 -1.9101343e+008 3.06e+007 1.85e+006 1.81e+008 8.47e-006
3 1.0242074e+009 2.0402150e+008 2.05e+007 1.24e+006 8.69e+007 8.15e-006
4 7.0390085e+008 2.6435555e+008 1.10e+007 6.66e+005 4.66e+007 1.22e-005
5 5.6843324e+008 2.3266571e+008 8.55e+006 5.17e+005 3.78e+007 1.56e-005
6 3.9506358e+008 1.6250976e+008 5.63e+006 3.40e+005 2.23e+007 2.55e-005
B-Y Trans and SysS
BY_Trans
Scenarios [0/9/0/0
EU-CO2Target
EU-CO2Target_80
EU-RenTarget
FuelPrices_Lower
IB__Param-UC_OFF
IB_Calibration
Kill_CO2sinks
Primas_130520_NoSubs
ZZZRefCalib_OFFEPS
New
View
All
AFS Scen [0/0/0/0]
FE Case Manager
Select
Delete
LST
LOGs
Save
IB_Base_CSP
Regions [2/2]
ES
PT
None
All
GAMS Root (119.00 GB free)
C:\VEDA\Veda_FE\
GAMS Source Code folder
GAMS_SRCTIMESV337
GAMS Work folder
GAMS_WRKTIMES
Base Price
No Elast DEM
Restart
Start from scratch
CPLEX
RUNFile_Tmpl
Create DD only
Close CMD Console
P/w Linear VarCost
Ending Year
2050
Period Defs

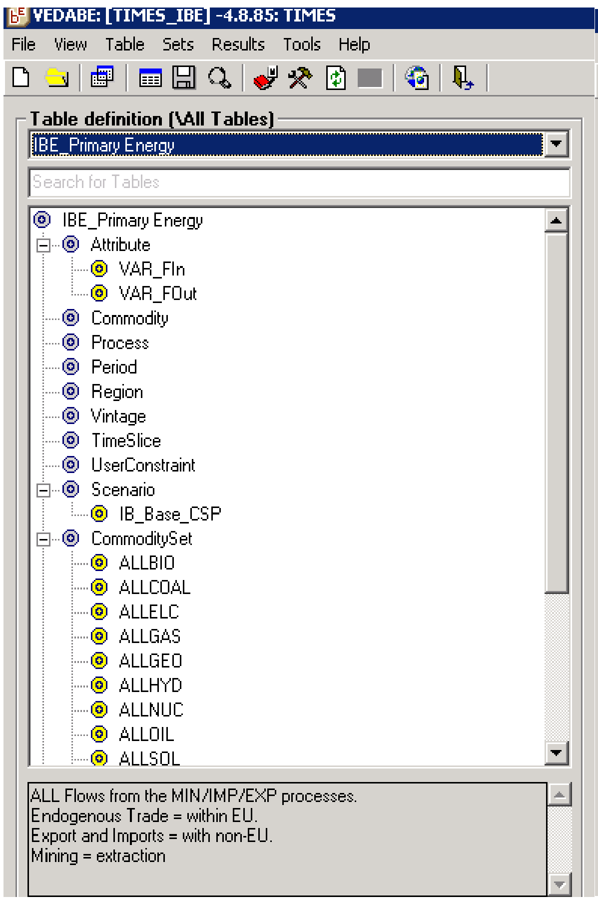

VFE [PET-IB2010-DBO]-4.3.46: TIMES Model
File Basic Functions Advanced Functions Tools ShortCuts Window Help ** Version 4363 Available ** C:\VEDA\Veda_FE\Veda_SnT.MDB
FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
FE Case Manager
Select Delete LST LOGs Save
IB_Base_CSP
IB_Base_CSP [ ] [GAMS_WRKTIMES]
Elapsed time = 651.66 sec. (9000 iterations).
Iteration: 9299 Objective = 6689021.658222
Removing shift (1214).
Iteration: 9698 Scaled infeas = 0.000303
Iteration: 10099 Objective = 6689022.131600
Total crossover time = 239.16 sec.
LP status(1): optimal
Optimal solution found.
Simplex iterations after crossover: 10356
Objective : 6689022.125850
--- Restarting execution
--- IB_Base_CSP.RUN(144374) 109 Mb
--- Reading solution for model TIMES
***
*** Reading with solevopt=REPLACE (0)
***
--- TIMES Solve status: Optimal
--- IB_Base_CSP.RUN(145704) 146 Mb
--- Putfile SCREEN C:\VEDA\Veda_FE\GAMS_WRKTIMES\CON
--- Putfile END_GAMS C:\VEDA\Veda_FE\GAMS_WRKTIMES\END_GAMS
--- Putfile QLOG C:\VEDA\Veda_FE\GAMS_WRKTIMES\QA_CHECK.LOG
Regions [2/2]
ES
PT
All None
New View
B-Y Trans and SysS
BY_Trans
Scenarios [0/9/0/0
EU-CO2Target
EU-CO2Target_80
EU-RenTarget
FuelPrices_Lower
IB__Param-UC_OFF
IB_Calibration
Kill_CO2sinks
Primas_130520_NoSubs
ZZZRefCalib_OFFEPS
New View All
AFS Scen [0/0/0/0]
GAMS Root (119.00 GB free)
C:\VEDA\Veda_FE\
GAMS Source Code folder
GAMS_SRCTIMESV337
GAMS Work folder
GAMS_WRKTIMES
Base Price
No Elast DEM
Restart
Start from scratch
CPLEX
RUNFile_Tmpl
Create DD only
Close CMD Console
P/w Linear VarCost
Ending Year
2050

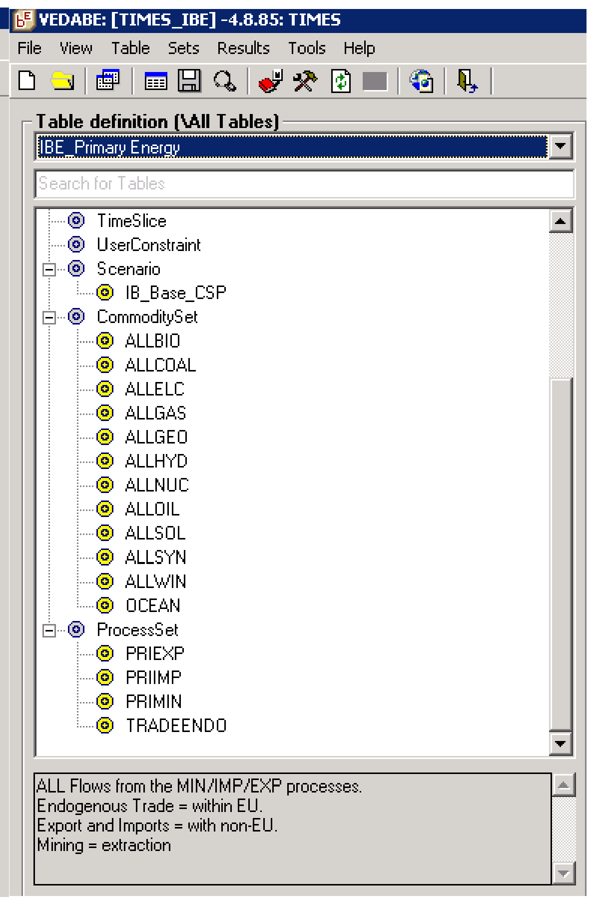

VFE [PET-IB2010-DBO]-4.3.46: TIMES Model
File Basic Functions Advanced Functions Tools ShortCuts Window Help ** Version 4363 Available ** C:\VEDA\Veda_FE\Veda_SnT.MDB
FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
FE Case Manager
Select Delete LST LOGs Save
IB_Base_CSP
IB_Base_CSP [ ] [GAMS_WRKTIMES]
*** Reading with solevopt=REPLACE (0)
***
--- TIMES Solve status: Optimal
--- IB_Base_CSP.RUN(145704) 146 Mb
--- Putfile SCREEN C:\VEDA\Veda_FE\GAMS_WRKTIMES\CON
--- Putfile END_GAMS C:\VEDA\Veda_FE\GAMS_WRKTIMES\END_GAMS
--- Putfile QLOG C:\VEDA\Veda_FE\GAMS_WRKTIMES\QA_CHECK.LOG
--- IB_Base_CSP.RUN(145704) 146 Mb
--- GDX File C:\VEDA\Veda_FE\GAMS_WRKTIMES\GAMSSAVE\IB_Base_CSP.gdx
--- Profile Summary (2225 records processed)
8.797 0.194GB 144374 Solve Fini TIMES (1406317)
4.281 0.194GB 144374 GAMS Fini
3.172 0.182GB 128360 Equation EQE_COMBAL (5830)
2.672 0.169GB 127703 Equation EQG_COMBAL (5983)
2.469 0.194GB 131947 Equation EQ_PEAK (1360)
1.406 0.146GB 145704 GAMS Fini
1.235 0.194GB 136129 Equation EQE_UCRTS (1869)
0.781 0.140GB 127319 Equation EQL_CAPACT (47260)
0.750 0.121GB 126582 Equation EQE_OBJVAR (2)
0.718 0.194GB 141685 Equation EQE_ACTEFF (41729)
--- IB_Base_CSP.RUN(145704) 146 Mb
*** Status: Normal completion
--- Job IB_Base_CSP.RUN Stop 11/19/13 15:36:10 elapsed 0:11:51.235
--- GDX File : Symbols=985 UELs=4127
--- VEDA Cube: Dimensions=8 Entries=54 Text=1 SubSets=23
--- VEDA Cube: DataRecords=233297
--- VEDA Cube: TextRecords=4713
--- VEDA Cube: SubSRecords=4159
Microsoft Windows [Version 5.2.3790]
(C) Copyright 1985-2003 Microsoft Corp.
C:\VEDA\Veda_FE\GAMS_WRKTIMES>_
Regions [2/2]
ES
PT
All None
New View
B-Y Trans and SysS
BY_Trans
Scenarios [0/9/0/0
EU-CO2Target
EU-CO2Target_80
EU-RenTarget
FuelPrices_Lower
IB__Param-UC_OI
IB_Calibration
Kill_CO2sinks
Primas_130520_N
ZZZRefCalib_OFF
GAMS_WRKTIMES
Base Price
No Elast DEM
Restart
Start from scratch
CPLEX
RUNFile_Tmpl
Create DD only
Close CMD Console
P/w Linear VarCost
Ending Year
2050

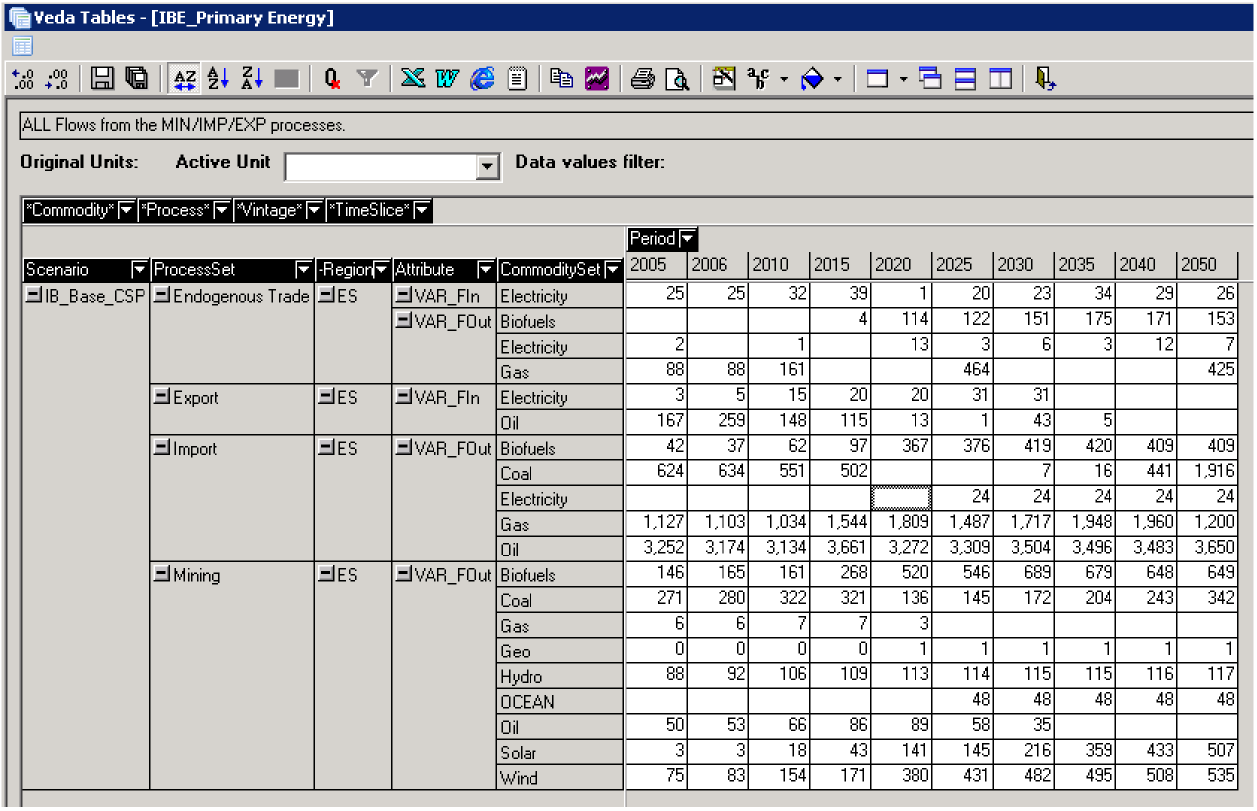

VFE [PET-IB2010-DBO]-4.3.46: TIMES Model
FE Navigator
MODEL: C:\VEDA\VEDA_Models\PET-IB2010-DBO
SubRES [0/1/0/0]
CSP_with_TES
Demand Scen [0/0/0/0]
Trade Scen [0/1/0/0]
Trade_Links
B-Y Trans and SysSettings
BY_Trans
SysSettings
ALL OK*
Scenarios [0/9/0/0]
EU-CO2Target
EU-CO2Target_80
EU-RenTarget
FuelPrices_Lower
IB__Param-UC_OFF
IB_Calibration
Kill_CO2sinks
Primas_130520_NoSubs
ZZZRefCalib_OFFEPS
AFS Scen [0/0/0/0]
FE Case Manager
IB_Base_CSP
Scenarios [9/12]
BASE
SysSettings
Regions [2/2]
ES
PT
GAMS Status
Normal Completion/Optimal/6689022.1259
OK
GAMS Root (119.00 GB free)
C:\VEDA\Veda_FE\
GAMS Source Code folder
GAMS_SRCTIMESV337
GAMS Work folder
GAMS_WRKTIMES
Base Price
No Elast DEM
Restart
Start from scratch
Create DD only
Close CMD Console
P/w Linear VarCost
Ending Year
2050

VEDA-BE

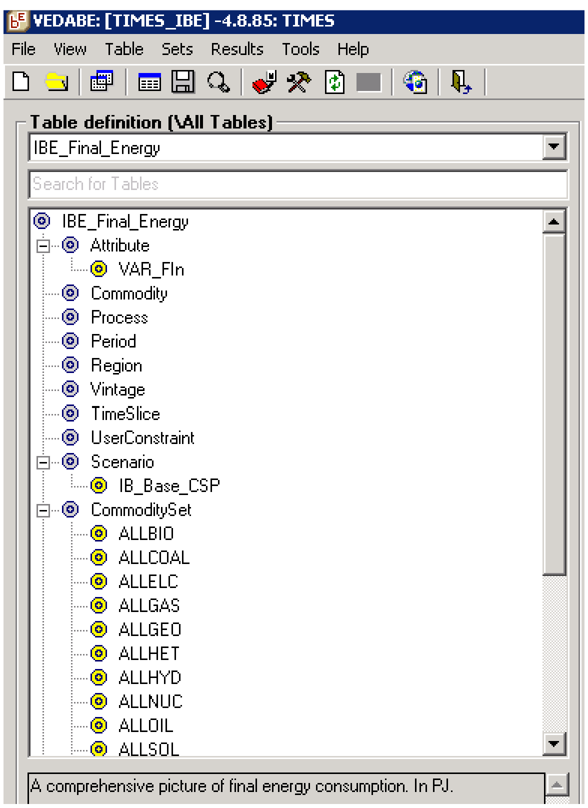

Veda Tables - [___Check Dummy Imports]
This table should be empty in a healthy model!! But one should not get obsessed with removing very small numbers.
Original Units:
Active Unit
Data values filter:
Attribute
Commodity
Process
Vintage
TimeSlice
ProcessSet
Period
Scenario
-Region
2040
2050
IB_Base
ES
0.30
0.95
IB_Base_CSP
ES
0.30
0.96

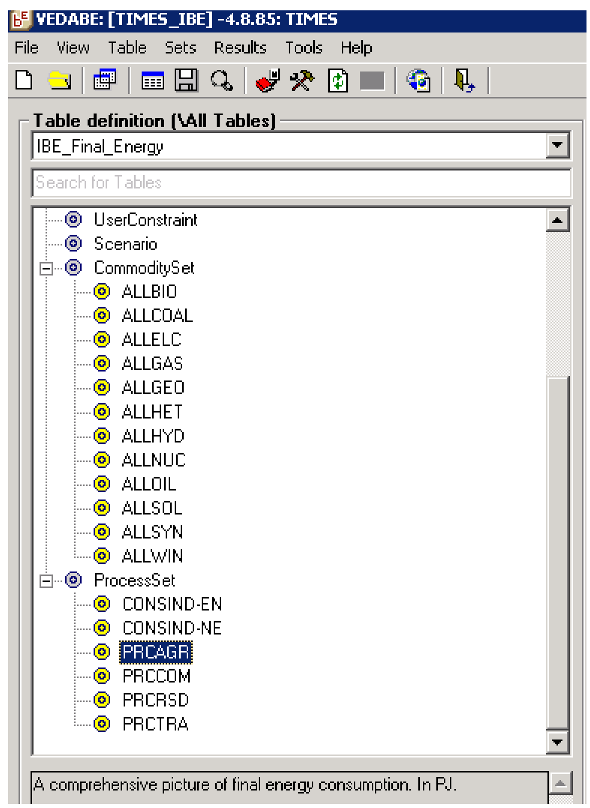

VEDABE: [TIMES_IBE] -4.8.85: TIMES
File
View
Table
Sets
Results
Tools
Help
Table definition (\All Tables)
IBE_Primary Energy
Search for Tables
IBE_Primary Energy
Attribute
VAR_FIn
VAR_FOut
Commodity
Process
Period
Region
Vintage
TimeSlice
UserConstraint
Scenario
IB_Base_CSP
CommoditySet
ALLBIO
ALLCOAL
ALLELC
ALLGAS
ALLGEO
ALLHYD
ALLNUC
ALLOIL
ALLSOL
ALL Flows from the MIN/IMP/EXP processes.
Endogenous Trade = within EU.
Export and Imports = with non-EU.
Mining = extraction


VEDABE: [TIMES_IBE] -4.8.85: TIMES
File
View
Table
Sets
Results
Tools
Help
Table definition (\All Tables)
IBE_Primary Energy
Search for Tables
TimeSlice
UserConstraint
Scenario
IB_Base_CSP
CommoditySet
ALLBIO
ALLCOAL
ALLELC
ALLGAS
ALLGEO
ALLHYD
ALLNUC
ALLOIL
ALLSOL
ALLSYN
ALLWIN
OCEAN
ProcessSet
PRIEXP
PRIIMP
PRIMIN
TRADEENDO
ALL Flows from the MIN/IMP/EXP processes.
Endogenous Trade = within EU.
Export and Imports = with non-EU.
Mining = extraction



Scenario	ProcessSet	Region	Attribute	CommoditySet	2005	2006	2010	2015	2020	2025	2030	2035	2040	2050
IB_Base_CSP	Endogenous Trade	ES	VAR_FIn	Electricity	25	25	32	39	1	20	23	34	29	26
			VAR_FOut	Biofuels				4	114	122	151	175	171	153
				Electricity	2		1		13	3	6	3	12	7
				Gas	88	88	161			464				425
	Export	ES	VAR_FIn	Electricity	3	5	15	20	20	31	31			
				Oil	167	259	148	115	13	1	43	5		
	Import	ES	VAR_FOut	Biofuels	42	37	62	97	367	376	419	420	409	409
				Coal	624	634	551	502			7	16	441	1,916
				Electricity						24	24	24	24	24
				Gas	1,127	1,103	1,034	1,544	1,809	1,487	1,717	1,948	1,960	1,200
				Oil	3,252	3,174	3,134	3,661	3,272	3,309	3,504	3,496	3,483	3,650
	Mining	ES	VAR_FOut	Biofuels	146	165	161	268	520	546	689	679	648	649
				Coal	271	280	322	321	136	145	172	204	243	342
				Gas	6	6	7	7	3					
				Geo	0	0	0	0	1	1	1	1	1	1
				Hydro	88	92	106	109	113	114	115	115	116	117
				OCEAN						48	48	48	48	48
				Oil	50	53	66	86	89	58	35			
				Solar	3	3	18	43	141	145	216	359	433	507
				Wind	75	83	154	171	380	431	482	495	508	535





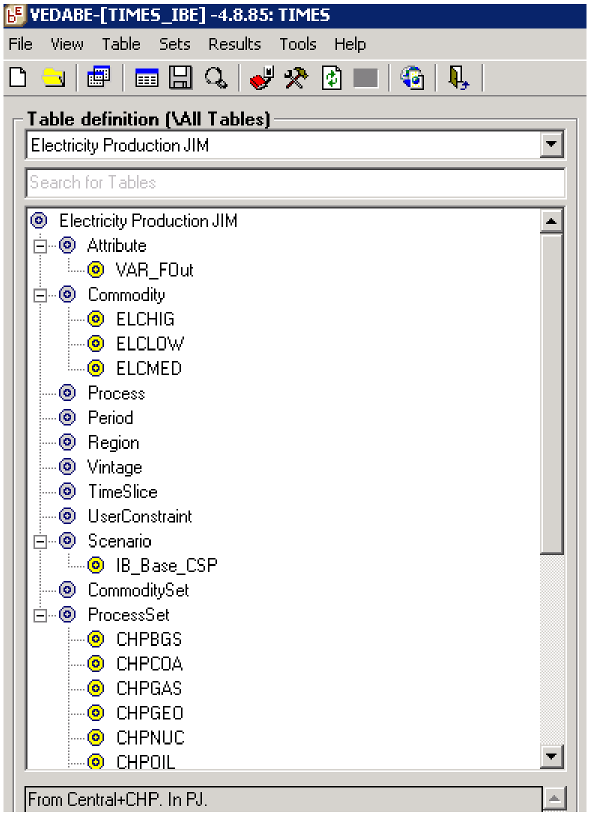
Veda Tables - [IBE_Final_Energy]

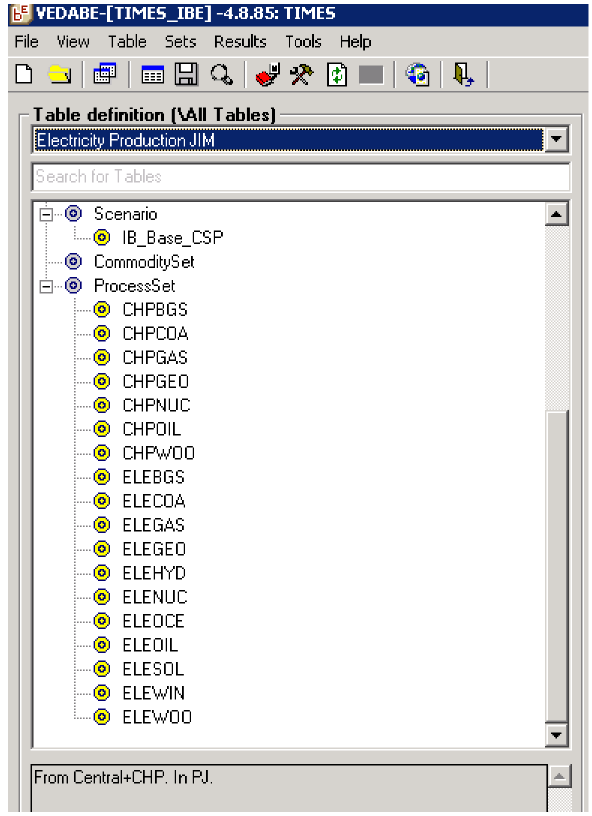
A comprehensive picture of final energy consumption. In PJ.

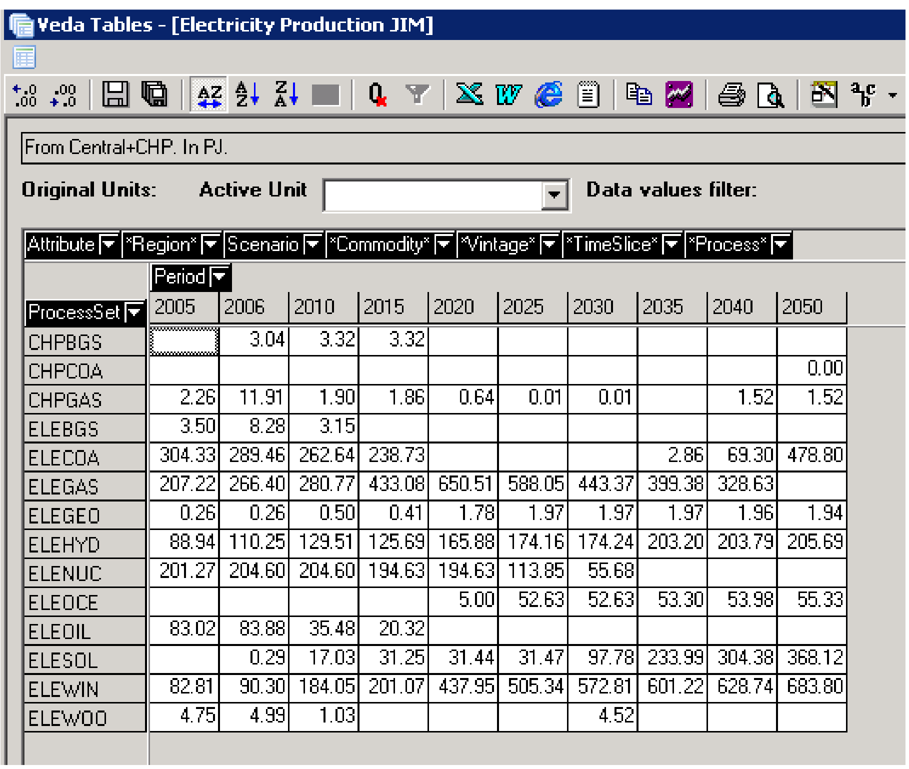
Original Units: **Active Unit** **Data values filter:**

Attribute | *Commodity* | *Process* | -Region- | *Vintage* | *TimeSlice*

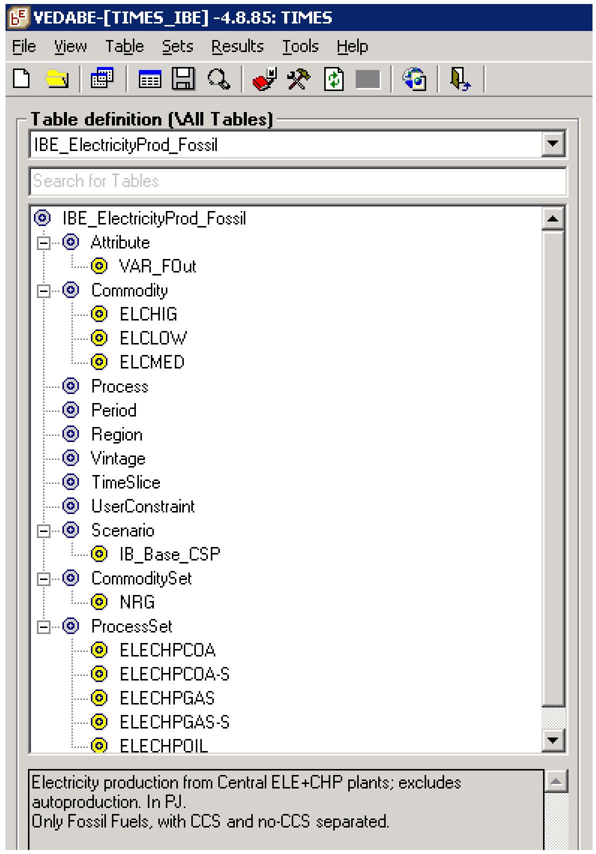
Scenario	ProcessSet	CommoditySet	2005	2006	2010	2015	2020	2025	2030	2035	2040	2050
IB_Base_CSP	Agriculture	Biofuels	1	1	1	1	1	1	1	1	1	1
		Electricity	19	19	18	20	83	43	23	24	24	26
		Gas	16	16	15	17	9	16	19	20	20	21
		Geo	0	0	0	0	0	0	0	0	0	0
		Oil	93	93	90	99	53	93	113	116	119	125
		Total	129	128	125	137	146	153	157	161	164	173
	Commercial	Biofuels	3	3	3	38	136	139	153	139	141	145
		Electricity	225	215	200	219	247	253	247	270	285	321
		Gas	30	32	34	37		6	15	16	17	19
		Geo	0	0	0	0	0					
		Heat									1	1
		Oil	89	94	99	84						
		Solar	1	1	0	0	13	15	17	19	21	26
		Total	348	345	337	378	396	412	433	444	465	512
	Industrial-Energy	Biofuels	81	50	39	111	231	213	358	271	293	368
		Coal	97	232	233	266	112	84	159	154	227	402
		Electricity	254	328	345	405	459	506	566	617	653	745
		Gas	710	553	591	643	773	958	884	1,146	1,270	1,446
		Heat	0		0							
		Hydro	18	18	18	18			1		0	
		Oil	236	119	112	117	115	114	112	110	82	92
		Wind	0	0	0	0	0	0				
		Total	1,396	1,300	1,339	1,560	1,691	1,874	2,081	2,298	2,526	3,052
	Industrial-NonEnergy	Gas	20	20	18	20	21	22	23	24	25	26
		Oil	133	130	124	135	143	149	156	162	169	182
		Total	153	150	142	155	164	172	179	186	193	209
	Residential	Biofuels	85	85	84	85	25	25	25	25	26	26

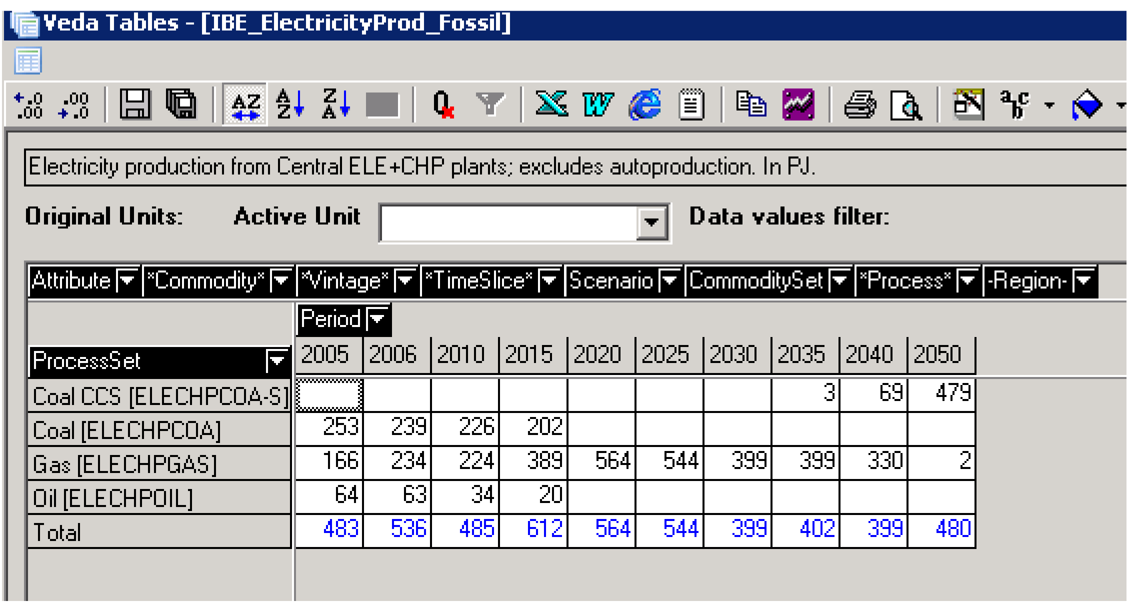






ProcessSet	2005	2006	2010	2015	2020	2025	2030	2035	2040	2050
CHPBGS		3.04	3.32	3.32						
CHPCOA										0.00
CHPGAS	2.26	11.91	1.90	1.86	0.64	0.01	0.01		1.52	1.52
ELEBGS	3.50	8.28	3.15							
ELECOA	304.33	289.46	262.64	238.73				2.86	69.30	478.80
ELEGAS	207.22	266.40	280.77	433.08	650.51	588.05	443.37	399.38	328.63	
ELEGEO	0.26	0.26	0.50	0.41	1.78	1.97	1.97	1.97	1.96	1.94
ELEHYD	88.94	110.25	129.51	125.69	165.88	174.16	174.24	203.20	203.79	205.69
ELENUC	201.27	204.60	204.60	194.63	194.63	113.85	55.68			
ELEOCE					5.00	52.63	52.63	53.30	53.98	55.33
ELEOIL	83.02	83.88	35.48	20.32						
ELESOL		0.29	17.03	31.25	31.44	31.47	97.78	233.99	304.38	368.12
ELEWIN	82.81	90.30	184.05	201.07	437.95	505.34	572.81	601.22	628.74	683.80
ELEWOO	4.75	4.99	1.03				4.52			





ProcessSet	2005	2006	2010	2015	2020	2025	2030	2035	2040	2050
Coal CCS [ELECHPCOA-S]								3	69	479
Coal [ELECHPCOA]	253	239	226	202						
Gas [ELECHPGAS]	166	234	224	389	564	544	399	399	330	2
Oil [ELECHPOIL]	64	63	34	20						
Total	483	536	485	612	564	544	399	402	399	480

Appendix B – Primary energy additional graphs

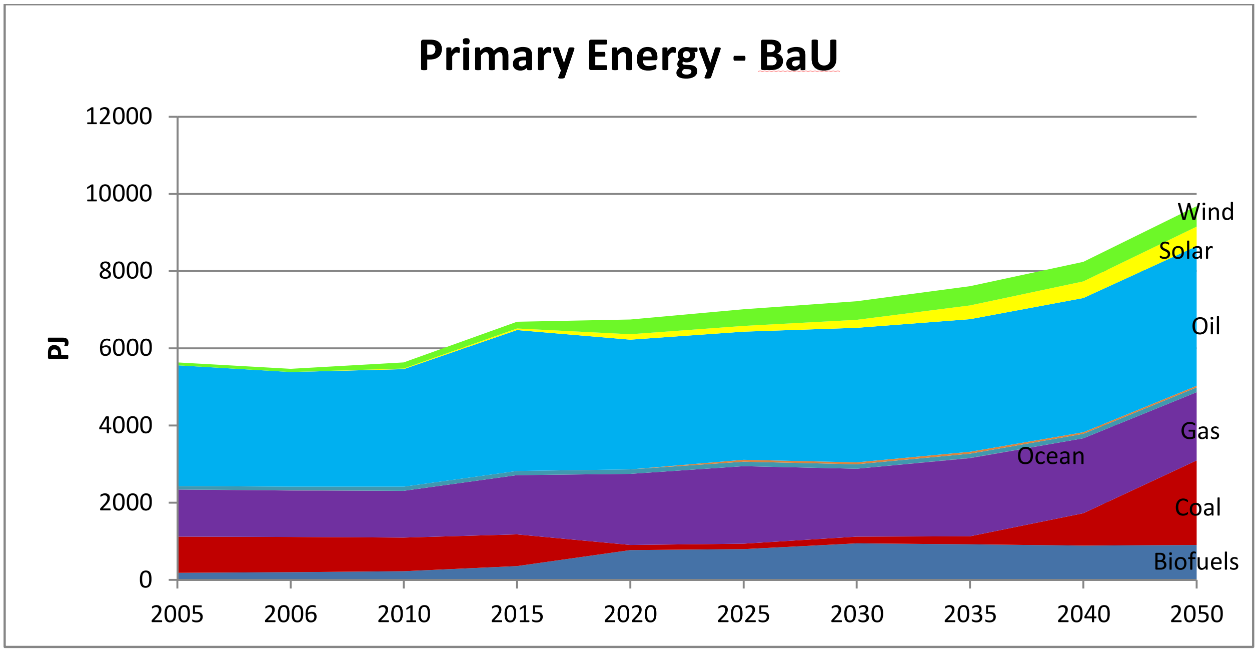


Figure B.1 Evolution of primary energy – BaU

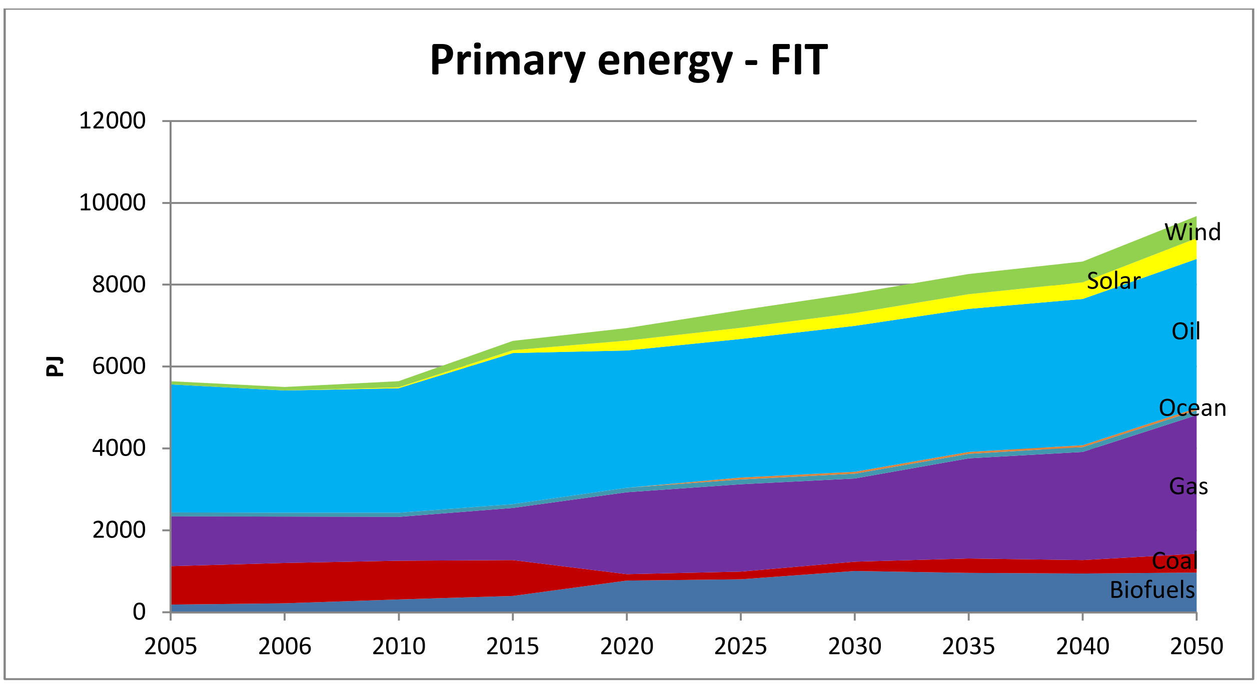


Figure B.2. Evolution of primary energy – FIT

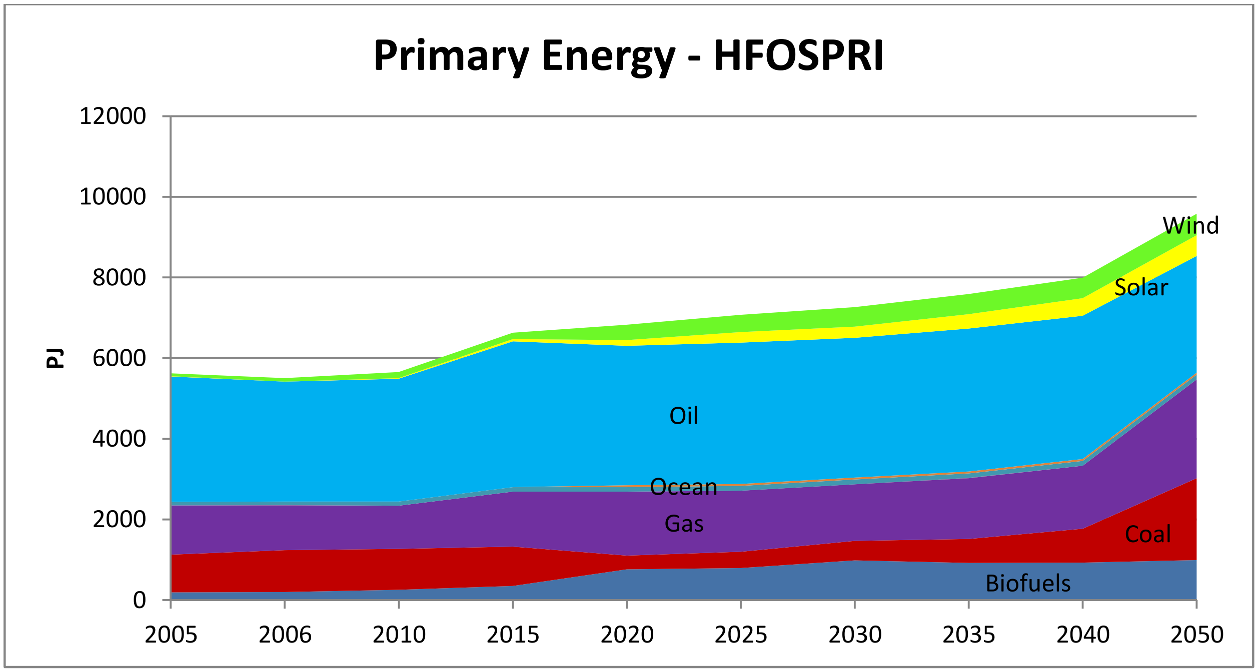


Figure B.3. Evolution of primary energy – HFOSPRI

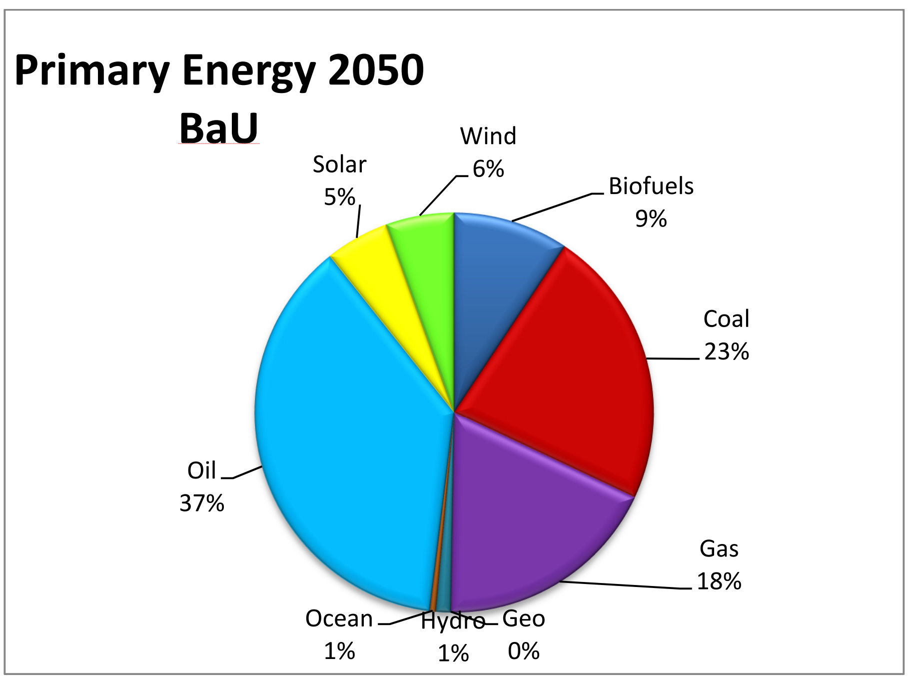


Figure B.4. Primary energy share by 2050 – BaU

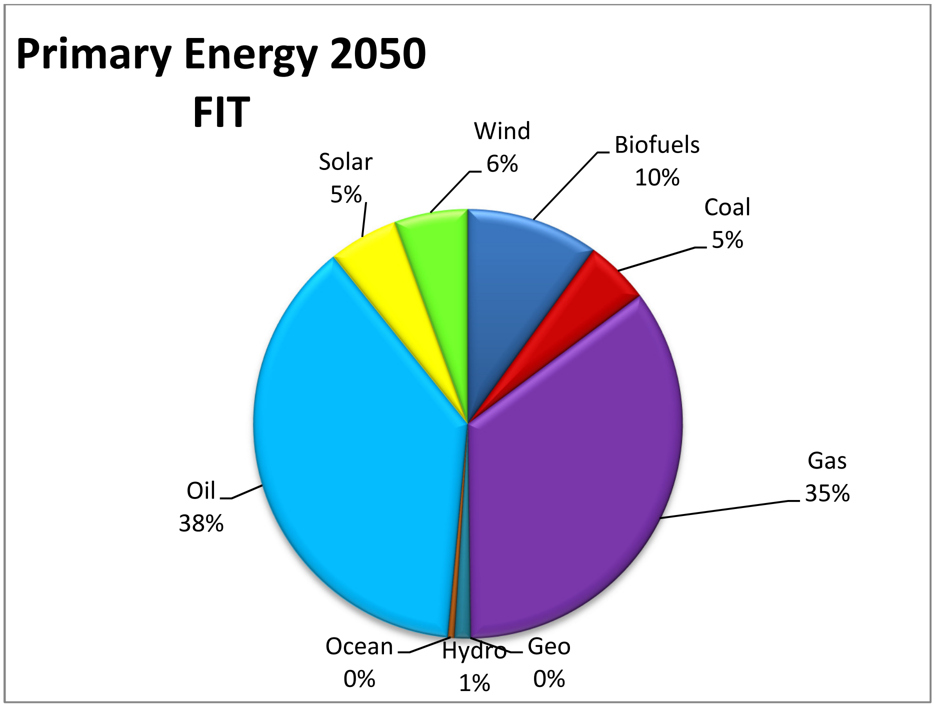


Figure B.5. Primary energy share by 2050 – FIT

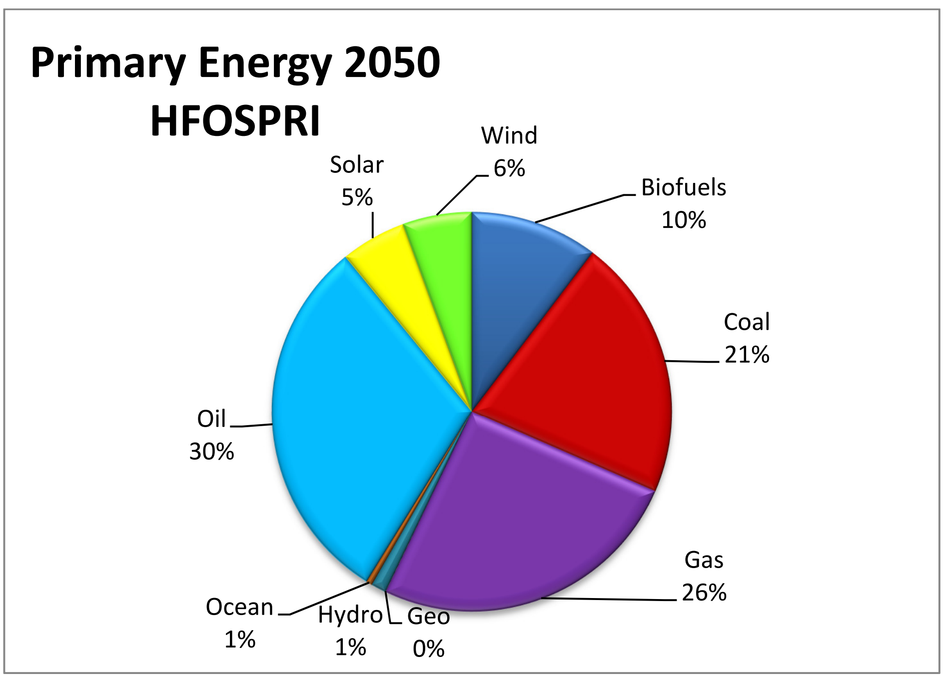


Figure B.6. Primary energy share by 2050 – HFOSPRI

Appendix C – Primary energy imports additional graphs

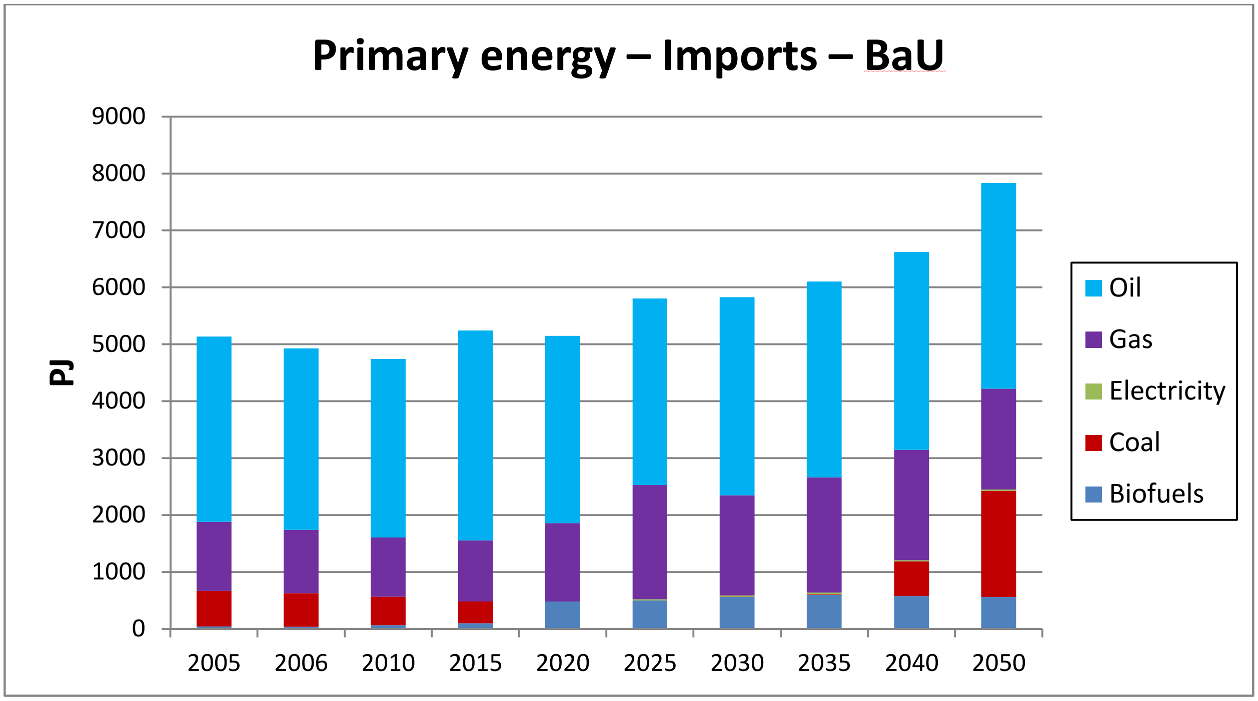


Figure C.1. Evolution of imports on primary energy – BaU

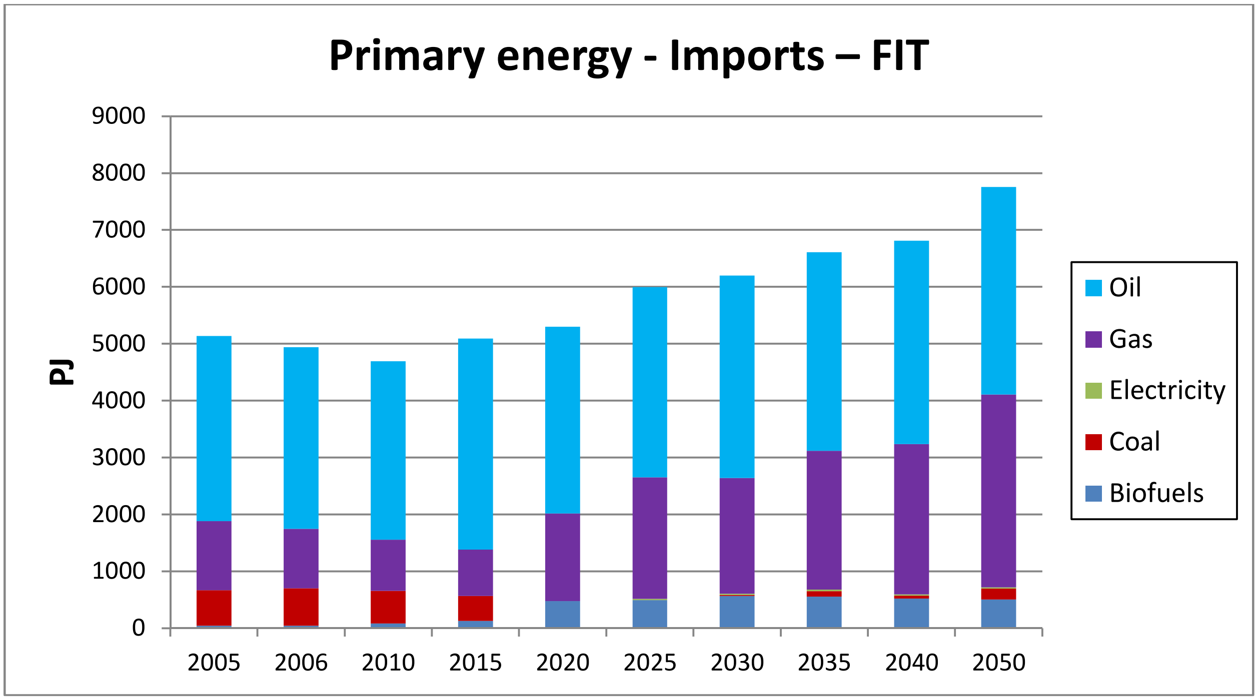


Figure C.2. Evolution of imports on primary energy – FIT

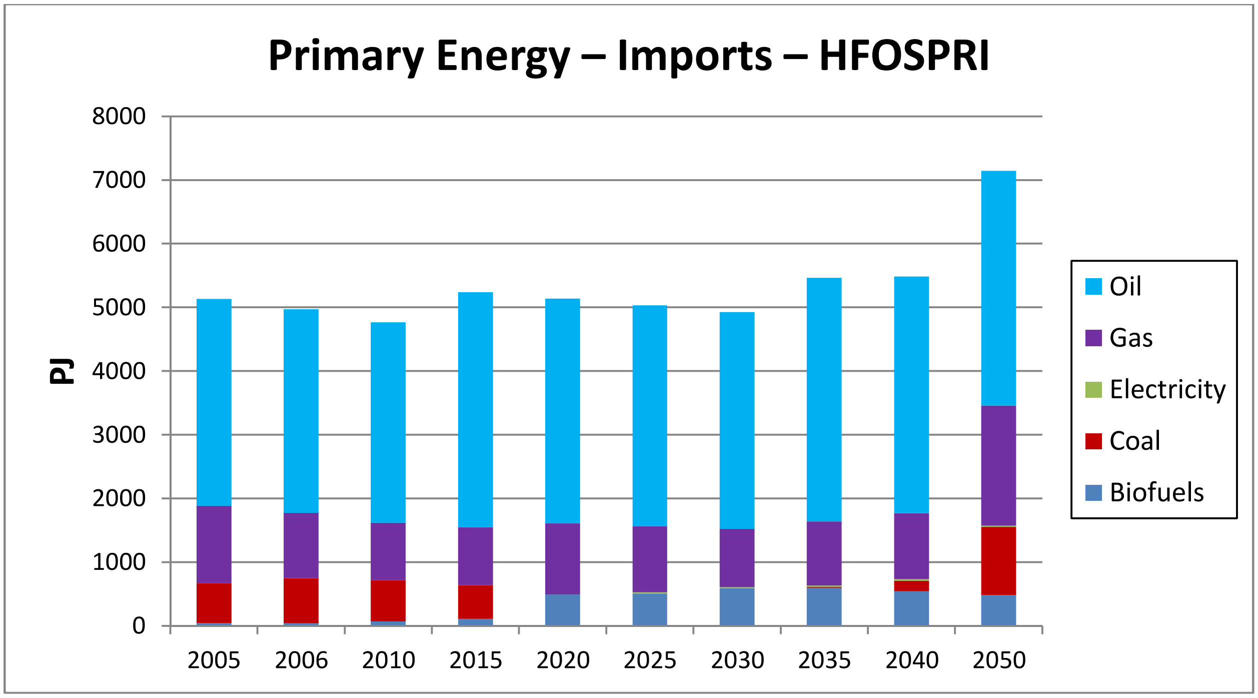


Figure C.3. Evolution of imports on primary energy – HFOSPRI

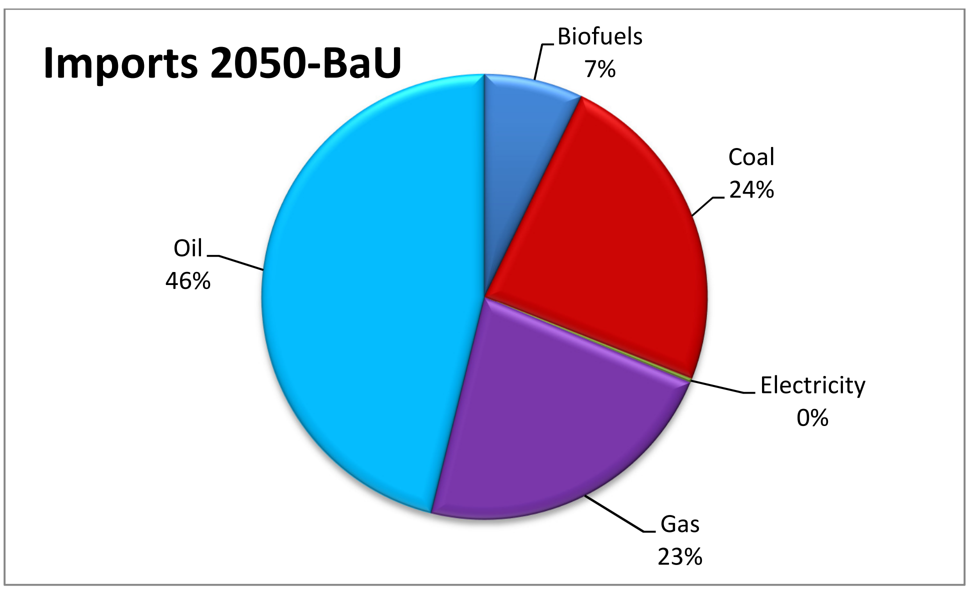


Figure C.4. Imports share on primary energy by 2050 – BaU

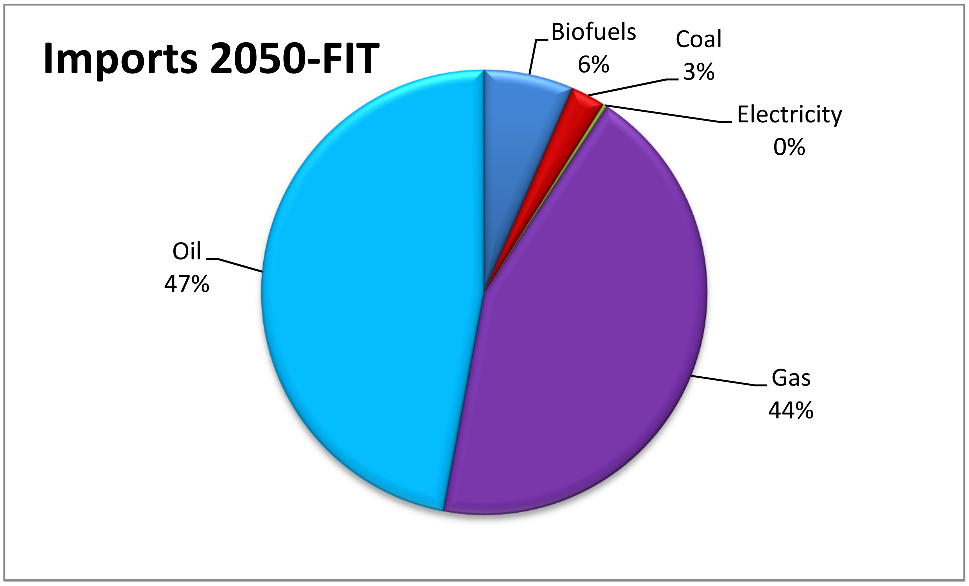


Figure C.5. Imports share on primary energy by 2050 – FIT

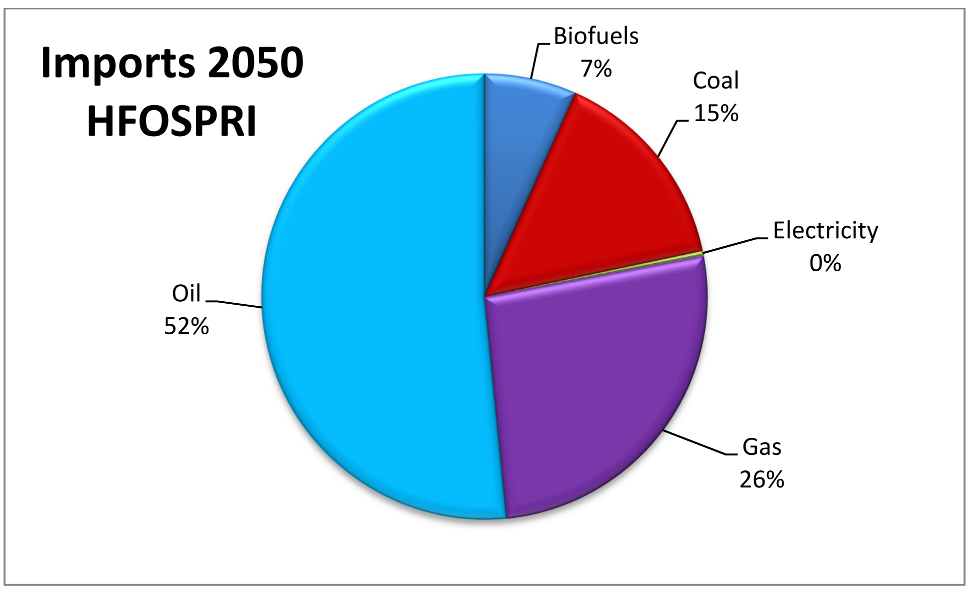


Figure C.6. Imports share on primary energy by 2050 – HFOSPRI

Appendix D – Electricity generation additional graphs

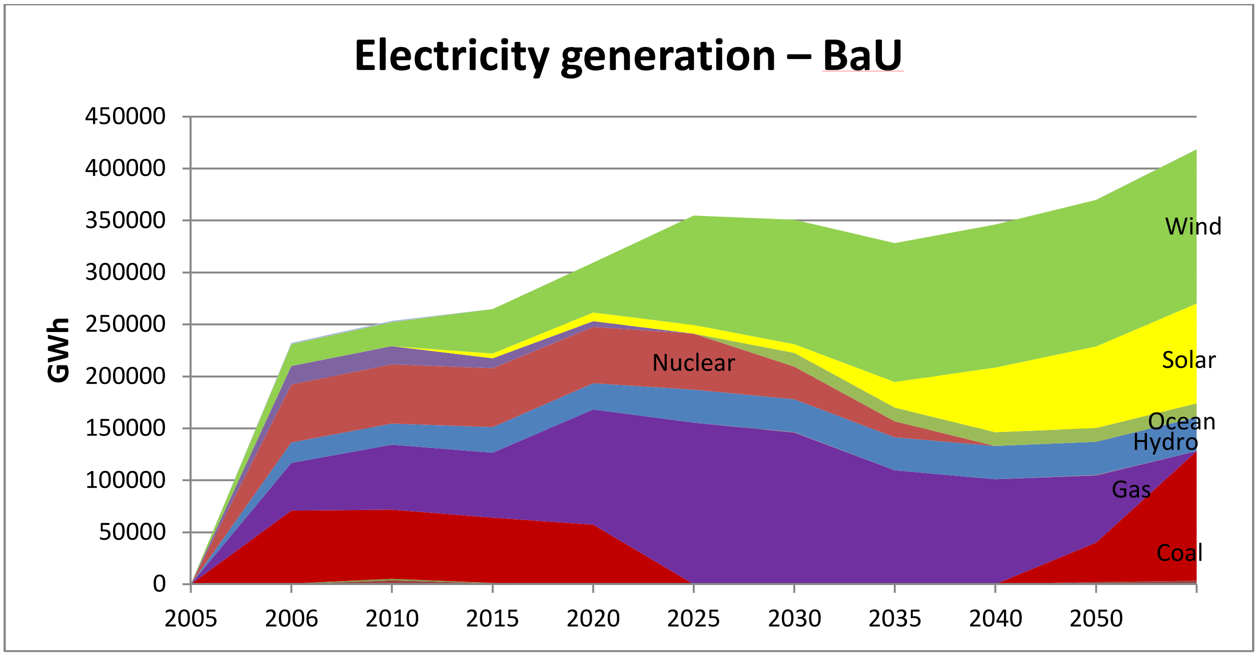


Figure D.1. Evolution of electricity generation – BaU

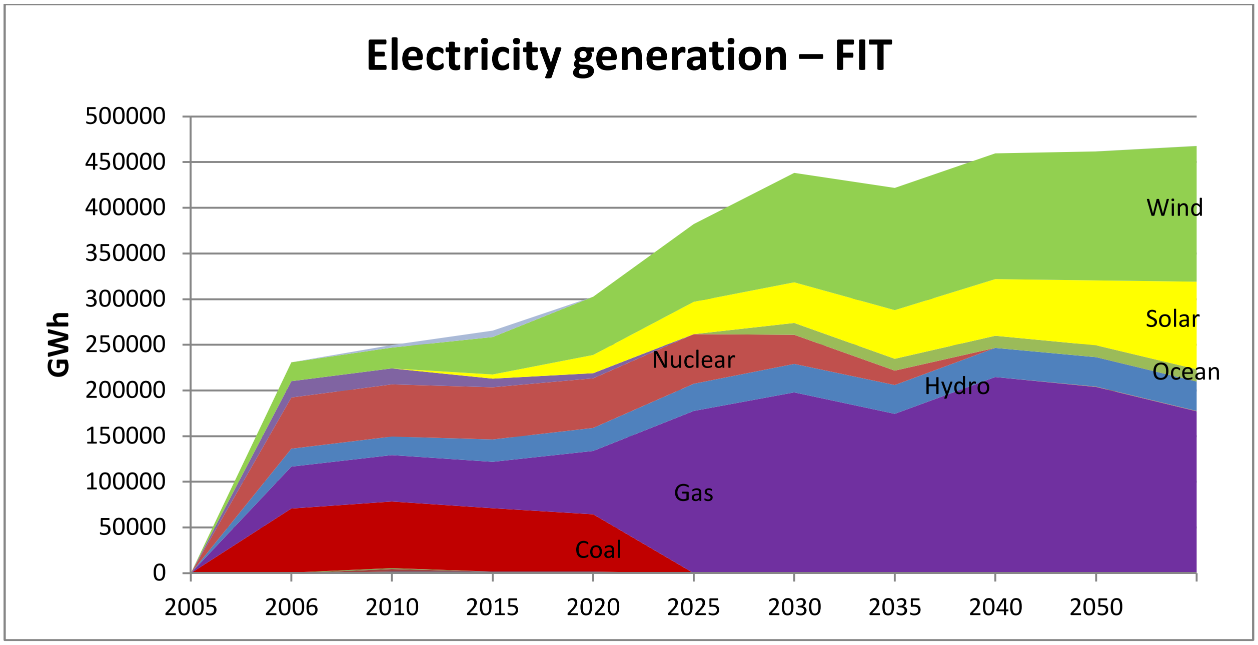


Figure D.2. Evolution of electricity generation – FIT

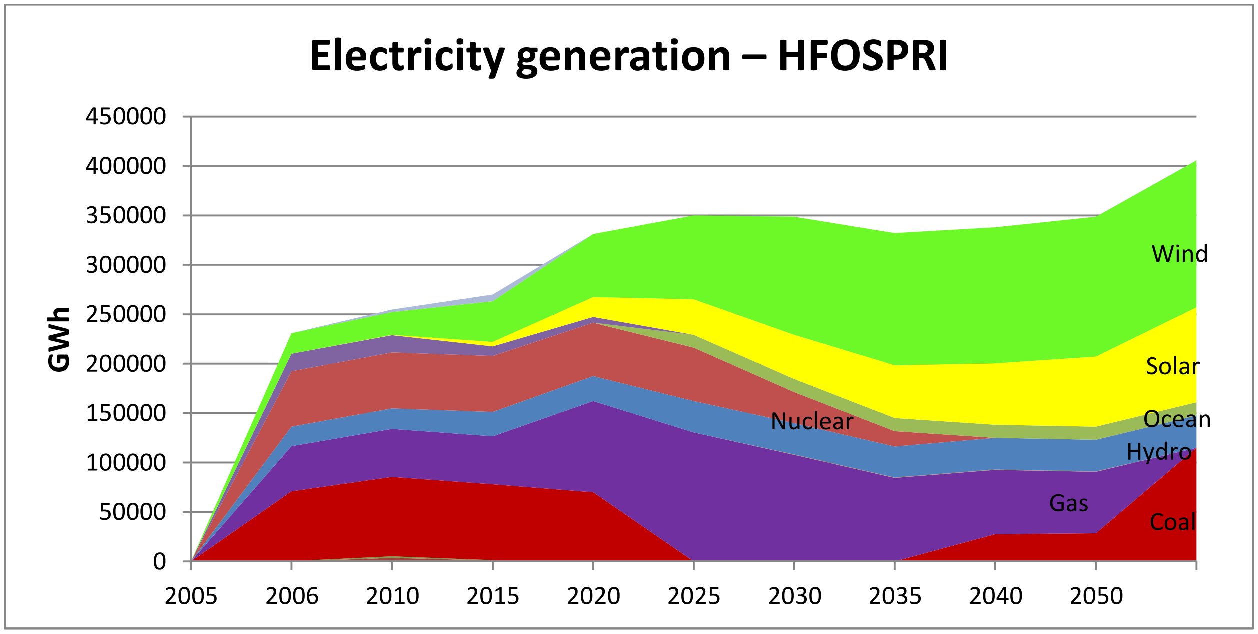


Figure D.3. Evolution of electricity generation – HFOSPRI

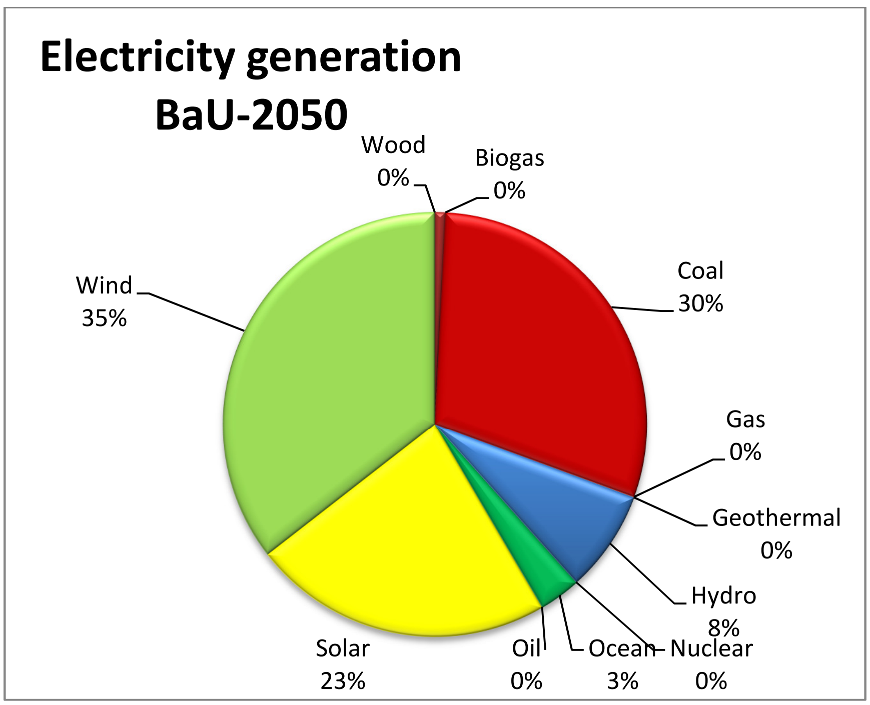


Figure D.4. Electricity generation share by 2050 – BaU

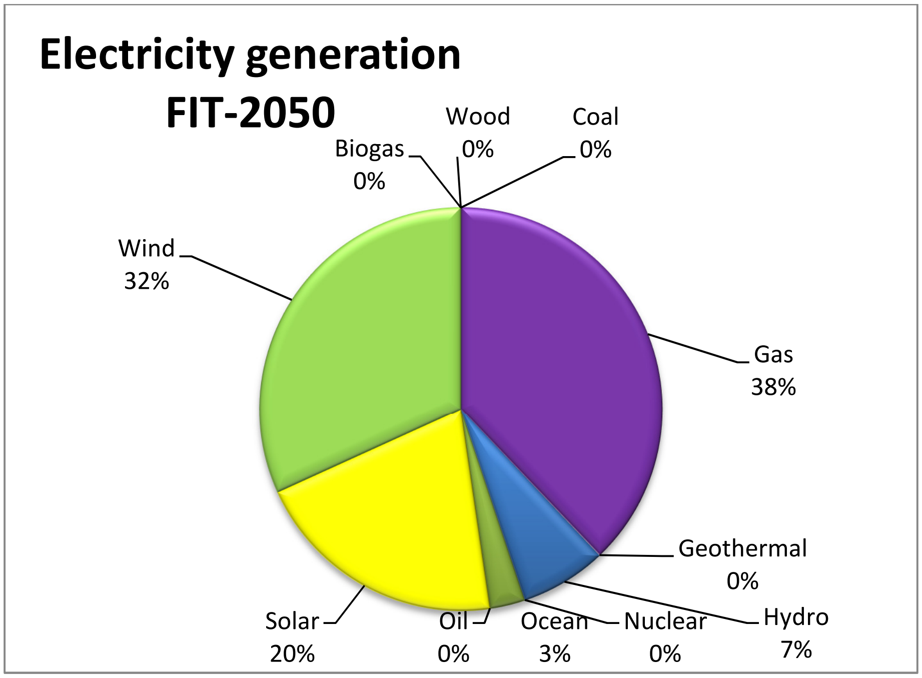


Figure D.5. Electricity generation share by 2050 – FIT

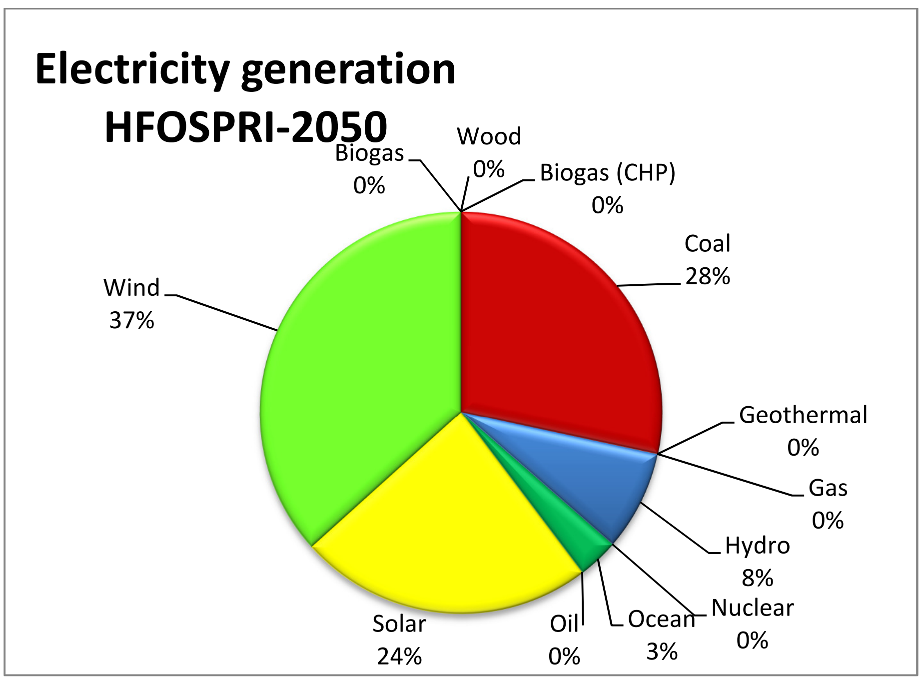


Figure D.6. Electricity generation share by 2050 – HFOSPRI

Appendix E – Electricity generation from fossil additional graphs

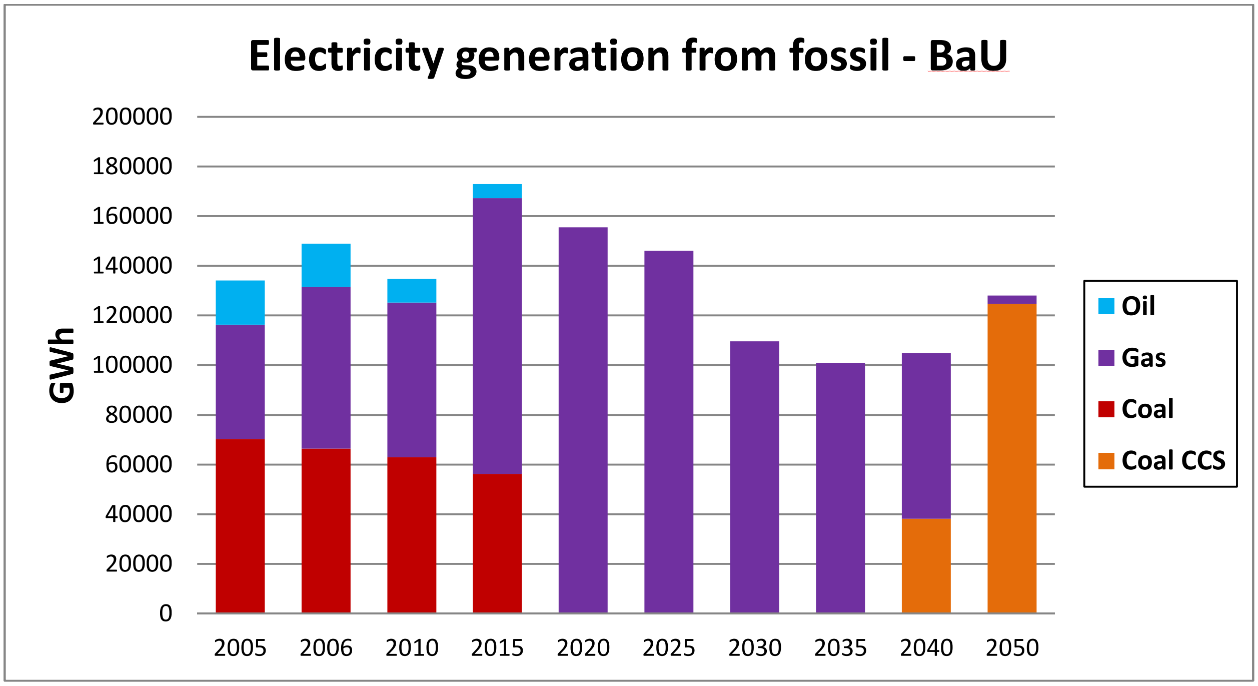


Figure E.1. Evolution of electricity generation from fossil resources – BaU

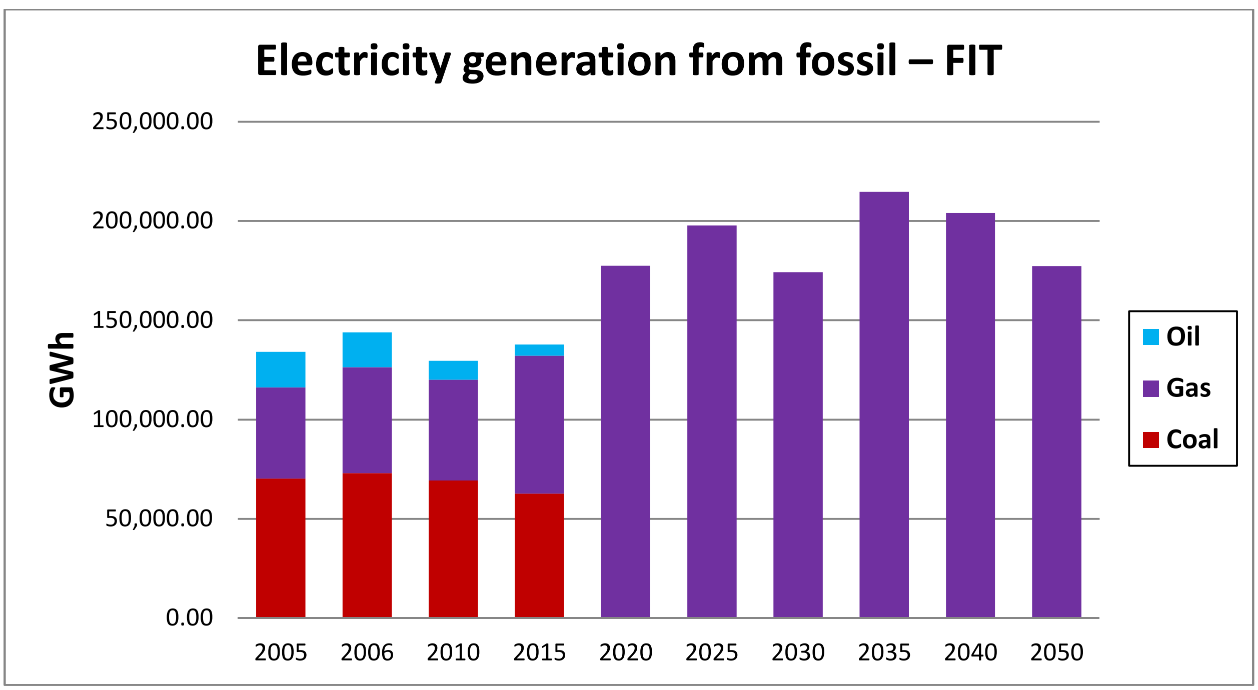


Figure E.2. Evolution of electricity generation from fossil resources – FIT

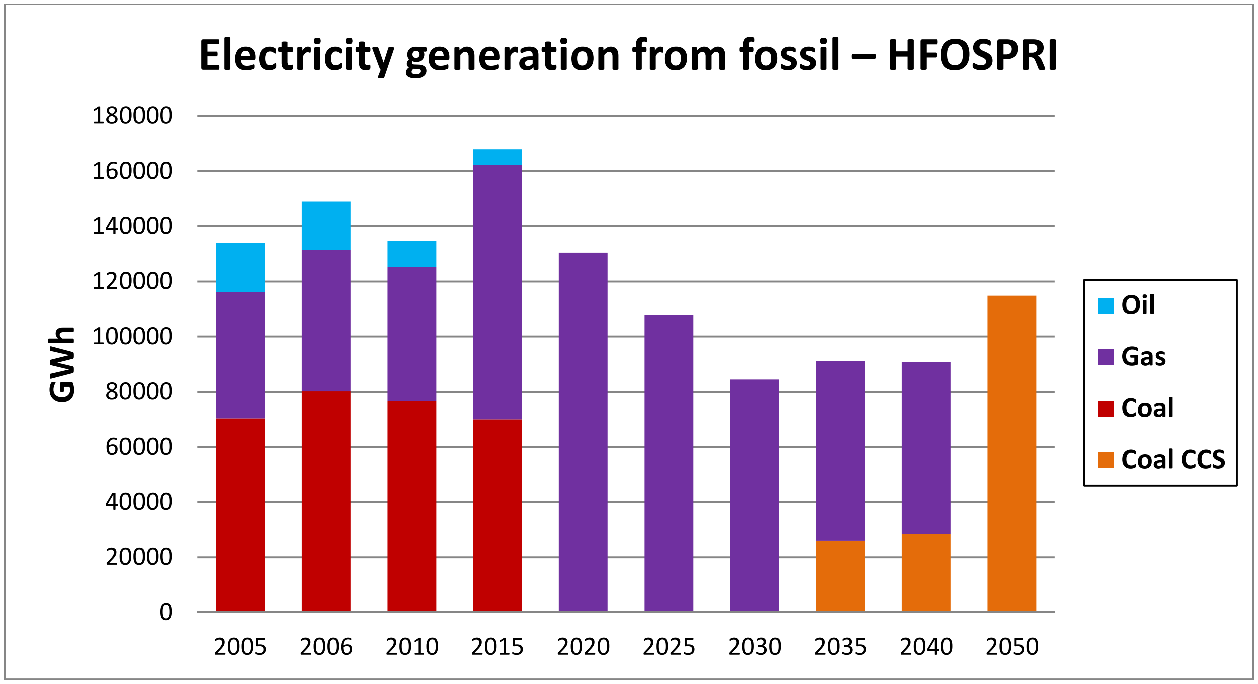


Figure E.3. Evolution of electricity generation from fossil resources – HFOSPRI

Appendix F - CO2 emissions additional graphs

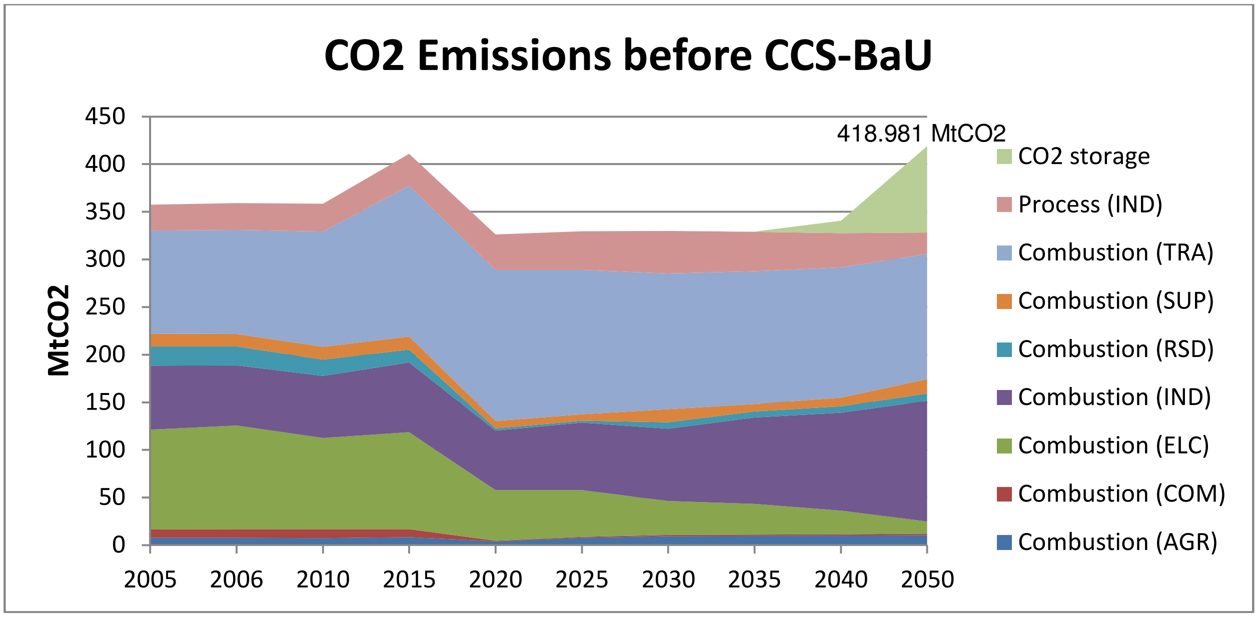


Figure F.1. Evolution of CO2 emissions before CCS – BaU

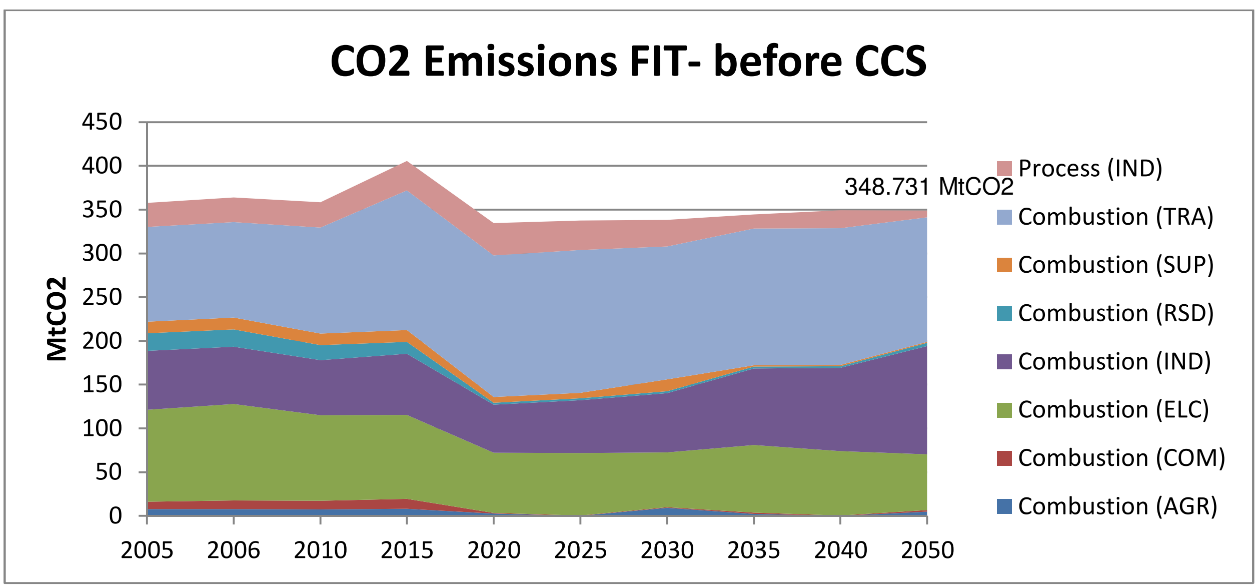


Figure F.2. Evolution of CO2 emissions before CCS – FIT

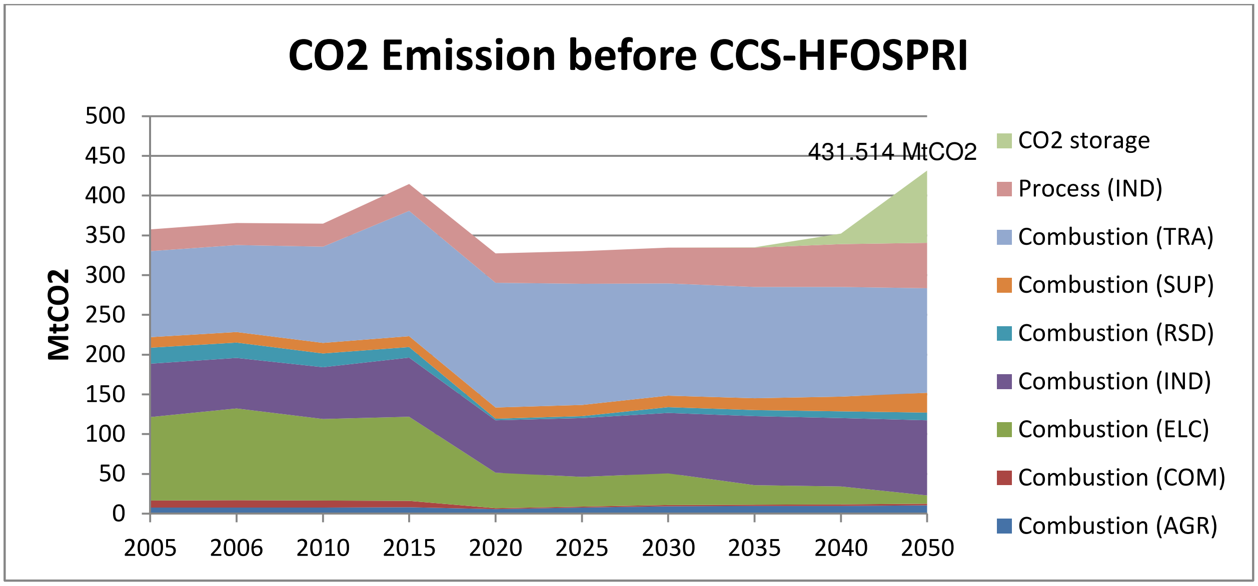


Figure F.3. Evolution of CO2 emissions before CCS – HFOSPRI

Appendix G - VEDA training course agenda

Wednesday, December 12, 2012 TIMES basics 1: The tutorial model

9.00-9.15	All participants	Presentation of the program and round table
9.15-10.15	Presentation:	Elements of Energy Technology Systems Analyses
10.15-11.00	Presentation:	Linear Economic Models
11.00-11.30	Coffee break	
11.30-13.00	Presentation: Hands-on:	Overview of a simple TIMES model Building a tutorial TIMES model from scratch with VEDA-FE
13.00-14.00	Lunch break	
14.00-15.30	Hands-on:	Results analysis with VEDA-Back End
15.30-15.50	Coffee break	
15.50-16.30	Hands-on:	Building scenarios for the tutorial TIMES model Scenario results analysis with VEDA-Back End
16.30-17.15	Hands-on: Hands-on:	Use of VEDA-TIMES to build the 2-region tutorial model Results analysis with VEDA-BE
17.15-17.30	Open questions	

Thursday, December 13, 2012 TIMES Basic 2: The DEMO model

9.00-9.30	TIMES documentation:	Users' Guide, Tutorial, The VEDA-TIMES support web-site
9.30-10.00	Presentation:	From an energy balance to final consumption split by end-use
10.00-11.00	Presentation:	The VEDA-TIMES DEMO description and analysis by VFE browse
11.00-11.30	Coffee break	
11.30-13.00	Hands-on:	The BaU scenario with the VEDA-TIMES DEMO
13.00-14.00	Lunch	
14.00-15.30	Hands-on:	How to run build alternative scenarios with the VEDA-TIMES DEMO
15.30-15.50	Coffee/tea break	
15.50-17.00	Hands-on:	How to run and analyse results for the VEDA-TIMES DEMO
17.00-17.30	Open questions	

Friday, December 14, 2012 TIMES Basic 3: How to

9.00-11.00	How to do.... (time slices, simple/standard user constraints, …)
11.00-11.30	Coffee break
11.30-13.00	How to do.... (cont.)
13.00-14.00	Lunch
14.00-15.00	Modelling tips with VEDA-FE and VEDA-BE
15.00-15.30	Questions – Answers
15.30-16.30	Feedbacks – Conclusion

Appendix H - VEDA training course certificate

ETSAP ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAM

CERTIFICATE OF ATTENDANCE

This is to certify that ***Mr Javier I. Millan***, of **University of Waterloo** has attended the **"VEDA-TIMES Basic Level Training Course"** that was held on 12-14 December 2012 in Lisbon Portugal, under the auspices of the ***Energy Technology Systems Analysis Programme Implementing Agreement*** of the International Energy Agency.

Dr George Giannakidis

On behalf of the Operating Agent of ETSAP

Appendix I – Wind data

Day	Wind load MW	Increment load (MW)	Demand load MW	Increment load (MW)	Average Wind Contribution to Demand (MW)	Average Wind load (MW)	Average Demand (MW)	Relationship with wind installed power	Maxium contribution to demand coverage	Correlation
1	164,801	5,529	819,068	-65	20.16%	6,866.71	34,127.83	54%	32%	0.468745
2	274,259	675	841,334	1,204	33.28%	11,427.46	35,055.58	64%	41%	0.6569237
3	301,087	1,434	848,505	392	36.23%	12,545.29	35,354.38	66%	46%	0.6083277
4	268,743	-3,993	777,966	-1,022	35.34%	11,197.63	32,415.25	61%	44%	-0.3434127
5	252,150	3,019	726,882	-1,426	34.79%	10,506.25	30,286.75	62%	41%	0.7428009
6	256,488	-1,538	822,385	672	32.40%	10,687.00	34,266.04	59%	45%	-0.129291
7	269,334	1,965	828,842	727	33.02%	11,222.25	34,535.08	63%	40%	0.6035436
8	251,916	-5,274	854,417	1,411	30.80%	10,496.50	35,600.71	61%	46%	-0.4729617
9	159,284	1,183	860,722	-61	18.86%	6,636.83	35,863.42	41%	24%	0.3550262
10	208,134	-129	844,688	-377	25.22%	8,672.25	35,195.33	47%	33%	0.0820826
11	211,457	1,020	751,366	-2,127	28.47%	8,810.71	31,306.92	49%	33%	0.5147364
12	252,948	1,148	709,050	224	36.13%	10,539.50	29,543.75	60%	42%	0.4782031
13	209,475	#REF!	849,819	2,210	26.03%	8,728.13	35,409.13	50%	40%	-0.643433
14	233,463	-244	856,530	-417	27.85%	9,727.63	35,688.75	59%	36%	0.3628842
15	193,551	2,418	838,652	-394	23.32%	8,065	34,943.83	50%	30%	0.5448943
16	216,391	-2,453	827,714	-445	26.92%	9,016	34,488.08	49%	36%	-0.546305
17	126,744	-5,803	812,014	-579	16.56%	5,281	33,833.92	36%	29%	-0.718687
18	56,493	1,639	727,600	-2,390	7.79%	2,354	30,316.67	18%	12%	0.36671
19	132,006	4,348	662,071	-544	19.82%	5,500	27,586.29	40%	27%	0.6642252
20	148,992	-3,331	781,122	2,196	20.28%	6,208	32,546.75	38%	33%	-0.86724
21	48,633	-3,177	799,699	224	6.72%	2,026	33,320.79	20%	14%	-0.8277201
22	60,602	3,458	803,961	274	7.44%	2,525	33,498.38	24%	15%	0.5330084
23	92,955	-340	792,116	-963	12.10%	3,873	33,004.83	24%	17%	-0.3570696
24	62,097	-3,023	769,533	-516	8.50%	2,587	32,063.88	20%	16%	-0.7728726
25	51,367	4,342	688,354	-2,120	7.16%	2,140	28,681.42	28%	20%	0.6774713
26	173,789	2,504	623,202	-1,485	28.10%	7,241	25,966.75	40%	32%	0.5245989
27	124,968	-3,555	728,595	1,856	18.31%	5,207	30,358.13	40%	33%	-0.7586615
28	57,668	-3,502	730,687	-108	8.43%	2,403	30,445.29	21%	16%	-0.7990733
29	27,546	-355	736,613	88	3.87%	1,148	30,692.21	7%	6%	-0.5204568