STRATEGIC BUSINESS MODELLING OF RENEWABLE ENERGY INVESTMENT: A COMPREHENSIVE APPROACH

by

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Brief introduction of the candidate

Gyanendra has 10+ years of experience in teaching, research and industry. He is currently, affiliated with Amrita School of Business, Amrita University as a Faculty and University of Ghent, Belgium as a Researcher. Earlier to joining Amrita, he had been working for Birla Institute of Technology Mesra, Ranchi, RMSI Pvt. Ltd., and had been a visiting faculty lecturer at Benaras Hindu University and Jammu University. Gyanendra has worked extensively on the Department of Science and Technology sponsored project "Establishment of District Natural Resource Database Management System (NRDMS) Centre of Ranchi, Jharkhand & Creation of Geospatial Database for the Development of Spatial Decision Support System". Has presented and published a few scientific papers in conferences and journals (including Taylor and Francis group publications). He is also an editor for journals such as Acta de gerencia ciencia, Srilaka and Journal of energy & natural resources, Sciene publishing group, USA. Gyanendra also has been a guest reviewer to journals such an Applied Economics Letters and Energy Policy.

The candidate has acquired Bachelor's degree in Information Technology Applications in the years 2004 and Master'sDegree in Geoinformatics from Barkatullaha University in the year 2006. He also has a Master's in Business Administration degree. The author has full interest in academics and research and wish to take a lead in the area of renewable energy strategy and marketing.

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Abstract

The purpose of this study is two folds: to understand the drivers of the investment in solar and wind energy in the 27 states[1] of the European Union (EU), and to evaluate a renewable energy business risk through the real options approach in the framework of the thesis first part findings. The first objective is addressed through the application of panel data modelling (over the period 1995 to 2011 on three different sample sizes), henceforth finding the drivers of renewable energy (RES) investments and understanding the drivers of renewable energy investments at the macro level. It was expected that regulatory perceptions are an important determinant in the case of renewable energy investment; whereas, renewable energy generated through solar and wind impacts significantly the retail price of electricity for households and industries.

However, a macro approach does not cover the aspects and challenges of renewable energy projects' at grass root levels. These challenges are associated with the investment decisions of small entrepreneurs, medium sized businesses or industries, and renewable energy incumbents. Therefore, to understand the regulatory revision issues related to businesses at the micro level, investment decisions were evaluated through the traditional net present value and the real options approach. Second, the study seems relevant to companies/projects (associated with renewable energy generation) and investors to consider the uncertainties in changing of renewable energy support schemes with the alignment of the European Union's and its individual country's objectives. Overall, the study contributes in four ways: The first is to introduce the solar and wind investment drivers, second to determine the relationship between RES generation and electricity final prices, third understanding the variations in results because of sample sizes, and fourth is to understand the renewable energy project risk by addressing the uncertainties in the Portuguese framework of energy policies.

[1] Croatia is added recently. Now EU has 28 states.

Resumo

O objetivo deste estudo é duplo: entender os drivers do investimento em energia solar e eólica na União Europeia (UE-27) e avaliar o risco do negócio do investimento nestas energias renováveis através da abordagem de opções reais. O primeiro objetivo é prosseguido através da aplicação de modelização de dados em painel no período de 1995-2011 (em três diferentes dimensões da amostra), de modo a encontrar os "drivers" do investimento em energia renovável (FER) e compreender os fatores mais determinantes desses investimentos a nível macroeconómico. Esperava-se que o enquadramento regulatório fosse uma determinante importante no caso de investimentos em energia renovável e que a energia gerada por fontes solar e eólica afetasse o preço da eletricidade para as famílias e indústrias.

No entanto, uma abordagem macro não abrange as entidades e os desafios dos projetos de energia renovável não permitindo, portanto, uma abordagem de base. Estes desafios estão associados às decisões de investimento dos pequenos empresários, de médias empresas ou indústrias, e dos incumbentes de energias renováveis. Portanto, para entender as questões de revisão regulatória relacionados com os negócios, portanto a nível micro, a metodologia adotada foi, em primeiro lugar, a de avaliar as decisões de investimento da forma mais generalizada - pelo valor atual líquido tradicional- e posteriormente,através das opções reais. Este segundo estudo parece-nos relevante para as empresas / projetos (associados à produção de energia renovável) e investidores, especialmente por considerar as incertezas na mudança dos regimes de apoio às energias renováveis, no contexto da União Europeia e dos objetivos de cada país. No geral, o estudo contribui para a literatura de quatro maneiras: a primeira é introduzir os drivers de investimento solar e eólico; em segundo lugar, determinar a relação entre a geração de energia elétrica através das RES e os preços finais; em terceiro lugar, a compreensão das variações nos resultados causados pelas diferentes dimensões da amostra; finalmente, a compreensão do risco do projeto em energia renovável, abordando as incertezas relativas às políticas energéticas no caso português.

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Publications/Presentations from the thesis work

Journals

1. **Gyanendra Singh Sisodia** and Isabel Soares (2014). Panel data analysis of renewable energy determinants in Europe. *Applied Economics Letters* **(Taylor and Francis group publication). Journal is ISI and Scopus Indexed.**

2. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira and Sanjay Banerji (2015). Projected business risk of regulatory change on wind power project: Learning for developing nations through Spanish case. Paper accepted by *Energy Procedia,* ***Elseveir group publication***. **SCOPUS indexed**

3. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira, Dirk Vanden Poel and Sanjay Banerji (2015).Does solar and wind energy increase retail electricity price in Europe? Evidences from panel data of EU-27. Paper accepted by *Energy Procedia*, **Elsevier group publication. SCOPUS indexed**

4. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira and Sanjay Banerji (2015). Projected business risk of regulatory change on wind power project: Learning for developing nations through Spanish case. Paper accepted by ***Journal of Sustainable Energy and Environment***

5. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira, Dirk Van den Poel and Sanjay Banerji (2015). Does solar and wind energy increase retail electricity price in Europe? Evidences from panel data of EU-27. Paper accepted by ***Journal of Sustainable Energy and Environment***

6. **One more publication is expected from Conference No. 8 below.**

Conference presentation

7. **Gyanendra Singh Sisodia and** Isabel Soares (2014). Impact of solar and wind energy generation on household and industrial electricity prices in Europe. Innovation and Sustainability Conference, Porto, Dated 10-11 July 2014. Paper selected under **"Excellent"** category

8. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira and Sanjay Banerji (2015). Effect of sample size on electricity price determinants - The European Case; Paper presented in ICEE2015; a conference held at University of Minho (18-19th June 2015) in Portugal. The paper is expected to be published as a special issue by *either* ***ENERGY Journal; or Environment, development and sustainability; or International journal of sustainable planning and management***

9. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira, Sanjay Banerji and Pragya Singh (2015). Electricity price determinants over two sample sizes: A preliminary finding. A paper presented in NCARES2015, Poornima University Jaipur.
10. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira, Dirk Van den Poel and Sanjay Banerji (2015). Does solar and wind energy increase retail electricity price in Europe? Evidences from panel data of EU-27.
    Paper presented *in* ***Alternative Energy in Developing Countries and Emerging Economies (2015 AEDCEE)*** **: May 28-29, 2015: Thaksin University, Bangkok, Thailand**
11. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira, Sanjay Banerji (2015). Projected business risk of regulatory change on wind power project: Learning for developing nations through Spanish case. .
    Paper presented in ***Alternative Energy in Developing Countries and Emerging Economies (2015 AEDCEE) :*** **May 28-29, 2015: Thaksin University, Bangkok, Thailand**

Papers Communicated

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13. **Gyanendra Singh Sisodia**, Isabel Soares, Paula Ferreira, Sanjay Banerji. Effect of sample size on renewable energy investments determinants. *"Applied Economics".* **ISI Thomson Reuters/SCOPUS Indexed journal**

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List of Abbreviations

ASH-Annual Sunshine Hours

CE -Carbon Emissions (same as CO2 emissions)

DCF – Discounted Cash Flows

EG-Electricity Generation

EI-Energy Import

EPH-Retail Electricity price for Household

EPI- Retail Electricity price for Industries

EU- European Union

FIT - Feed-in tariffs

GDPG-GDP Growth rate

I/P – Input

KW- Kilo Watt

LCOE- Levelised Cost of Electricity Generation

LS-Levelised cost of electricity generation through solar technologies

LW-Levelised cost of electricity generation through wind technologies

MW – Mega Watt

NPV –Net Present Value

O & M – Operations & Maintenance

O/P – Output

PV –Photovoltaic

RE –Renewable Energy

RES- Renewable Energy Sources

RES-E Renewable Source Electricity

RES-S Renewable Energy from Solar

RES-W Renewable Energy from Wind

RG-Regulatory quality

ROA- Real Options Approach

RQ- Research Question

TOE- Tons of Oil Equivalent

TW – Terra Watt

Chapter 1

Introduction

A considerable increase in energy demand mainly in intermittent energy has been noticed since the 90's among different countries of the world, which has led to higher investments in renewables. Faundez (2008) estimated an investment of USD 16 trillion in the world energy system over the next 25 years towards fulfilling energy demand. However, the rate of growth and investments in energy depends upon the national energy policies and the financial instruments (Aguilar & Cai, 2010).

In the current trend, investments worldwide in renewable energies (RES) is dictated by several factors like availability of the technologies, legal frameworks, political will, energy demand, etc. However, UNEP Report (2009) presented two important information: first, among technologies available for the generation of renewable energy, the wind-generated electricity has attracted the highest investment of 43% followed by the solar at 23%. Second, while a very high investment growth of 123% was observed in the wind energy sector, investment through venture capitalists & private equity (USD 5.5 billion) and public markets (6.4 billion) was higher for solar energy projects.

(Hasan, 2008), analysed the solar energy industry and concluded that the solar energy would be the most profitable among renewable energy business that would attract larger investments in the future. From the similar literature on RES, it overall appears that there is a greater competition (between wind and solar) in terms of expansion, growth and investment.

1.1 Purpose of the study

The purpose of this study is two folds: the objective of the first part of the study is to understand the drivers of the investment in solar and wind energy in the European Union (EU) 27 states[2], and objective of the second part of the study is to evaluate a renewable energy project's business risk through the real options approach in the framework of the thesis first part findings.

Most of the empirical studies focus on the collective effect on RES on other economic variables such as prices, electricity demand, carbon emissions, etc. A significant research gap is observed in the RES literature pertaining to the solar and wind energy investment drivers individually. Similarly, as far as we know, there is no literature found on how solar and wind energy independently affects the electricity final prices. Thus, conducting a study on it through empirical modelling will be a contribution to the literature. In this study, a large sample of EU-27 is also compared to relatively small sample (EU-15). Results that were obtained through different sample sizes were expected to vary before study. Thus, the magnitude and direction of variations in results observed through study is interesting and contribution to the literature. Additionally, such a comprehensive study in renewable energy investment has not been previously conducted. Therefore, this dissertation will be a contribution to the existing literature.

To address the above mentioned objectives, it is important to know the investment drivers that are affecting solar and wind technologies penetration. In other words, the contribution of this study is to empirically identify the investment drivers (for solar and wind technologies), and to identify how the investment in such technologies affects electricity prices of households and industries at the macro level.

The importance of the above mentioned study is to understand the renewable energy investment from a macro level perspective. However, macro perspective does not cover the entities and challenges of renewable energy businesses at grass root level. These challenges are associated

[2] Croatia is added recently. Now EU has 28 states.

with the investment decisions of small entrepreneurs, medium sized businesses or industries, and renewable energy incumbents.

To give this study a more business perspective, an individual renewable (wind) energy generating project (50 MW) was considered for analysing the risks associated with further investments in terms of policy changes through the real options approach (in Portuguese regulatory framework). This part of the study deals with comparing a traditional and non-classical model for the business risk assessment.

Such studies (applying the real options approach) have already been conducted by researchers (for an instance, sees Burke, 2012). However, studying recent regulatory changes in Spain (described in part B) with respect to the RES policies in the Portuguese economy also intends to be a contribution to the literature. Moreover, this study leads to future research pathways to understanding how countries with developmental challenges and economic/political integration can cope with different energy and environmental objectives from business and sustainability perspectives.

The first part of the study has policy implications. The study suggests the variables that have significantly contributed to the investment in solar and wind. Determining whether wind or solar play significant roles in determining electricity prices would be of interest for economists too. If the supply through solar and wind energy increase the price of electricity, this would create further inflation by adding the cost to operations at industrial level.

Second part of the study has several managerial implications: managers who want to invest in RES would know the additional cost, loss or profits associated with delaying energy projects. In fact, the delay is one of the most critical decisions in energy business.

1.1.1 Significance of the study

Two proposed studies are significant. First, it should be clearly understood while making an investment in the RES that there are differences in renewable electricity generating technologies (example photovoltaic, concentrated solar power, hybrid systems etc.), and the final cost of investment depends on the generation of energy through these technologies (or sources). Additionally, there are different support mechanisms available in the EU context for solar and wind energy generation. Criteria that determine investment in wind could be different from that of solar. Thus, our study proposes a macro level investment criteria separately for wind and solar in the European scenario.

Second, our study analyses if renewable energy significantly increases the price of electricity. If yes, then to what extent (magnitude and direction) it increases the price of the electricity for medium size industries and households? Increasing electricity price has several other economic implications too - how those consequences would be taken into account could be a further researchable area in the European scenario.

Third, we intend to understand how energy investments project face the government policies and regulations to support the RES generation. That also means the understanding of the regulation uncertainties on the varying range of business profits. Thus, this study will be significant to RES businesses under different support schemes provided by European countries.

Further, for developing countries like India, where renewable energy generation and supply began in the late last decade, understanding the effective European RES mechanism of framework might be important. It can play a significant role in keeping up the interests of businesses to invest in RES and accelerate the adoption. The second part of the study would help developing countries to understand and realize the parameters that may stop business and investors to refrain from RES investment.

1.2 Broadly addressed research questions and contribution of this study

Markets and investors seems not to easily accommodate the growing salient and distinct energy needs of countries towards energy sustainability paths. This gave rise to many questions, some of which have been picked up by researchers. For the current study, different research questions broadly asked in the literatures, which were associated with investment in RES, were studied. Aguilar & Cai (2010) asked questions about the characteristics of potential individual sustainable energy investors. They also asked how competitively sustainable energy investments are perceived to be compared to traditional investment instruments. Examples of other interesting questions asked were: how to improve private sector's participation in electricity generation from renewable energy sources (Aslani et. al., 2012), who are the investors in renewable energy generation (Bergek et. al., 2013), and how RES investment is considered under different support schemes (Boomsma et. al., 2012). Leete et. al. (2013) asked a question related to investment barriers and incentives to RES in Europe. They proposed that the important consideration of investors in refraining from such investment is the uncertainty in policy changes and regulatory frameworks.

Further, though energy generation from traditional sources is widely accepted, but the major debate is on how to control the emissions through climate change policies- an example is Kyoto protocol. The current research on RES also recognized that increasing RES share in energy supply affects the electricity prices by indirectly passing the investment costs (to the consumers) that are incurred in RES projects (Moreno et. al., 2012; Cai et. al.,2013). However, in the long run, this could also lower the retail electricity price to the final consumers once the investment costs of RES projects are recovered (Azofra et. al., 2014). Therefore, a logical close relationship exists between the investment in RES and electricity prices. More research questions recently asked are related to the influence of biomass, solar-thermal, and hydraulic power on electricity markets, like in the case of Spain (Azofra et. al., 2014), and also on the overall renewable energy impact on electricity prices (Chattopadhyay, 2014; Darghouth, 2014).

The cost associated with RES generation is usually considered to be high. Therefore, to address this issue, regulatory frameworks are established that support the investment through feed-in-tariff (FIT), and subsidization of the levelised cost of electricity generation through different technologies for promoting the investments (Gross, 2007; VGB Report, 2011). Feed-in-tariff refers to the payment of renewable energy generator which is proportional to the quantity fed into the grid.

Through EIA Report (2013), levelised cost is described as

> *"Levelised cost of electricity (LCOE) is often cited as a convenient summary measure of the overall competitiveness of different generating technologies…. For technologies such as solar and wind generation that have no fuel costs and relatively small variable O&M costs, LCOE changes in rough proportion to the estimated capital cost of generation capacity".*

However, uncertainties concerning the policy and regulatory frameworks affect businesses associated with electricity markets in different ways. Traditional approaches like NPV and DCF have limitations in addressing uncertainties and flexibilities. Thus, strategically handling the investment projects is difficult through NPV and DCF. The real options approach takes care of the limitations of NPV and DCF method (Martinez, 2011; Kumbaroglu, 2008).

In the seminal work, Meyers in 1977 first proposed a real options framework that can assist managers and decision makers with an option to invest, grow or abandon a project subject to an arrival of revised information. Real options are referred as investment decisions that are characterized by uncertainty, the provision of future managerial discretion to exercise at the appropriate time, and irreversibility. A vast literature is available on the use of real options in several fields such as research and development projects (Schneider et. at., 2008; Eckhause et. al., 2009), information technology projects (Kumar 2002; Schwartz & Zozaya-Gorostiza, 2003), and renewable energy projects (Santos et. al., 2014; Eyre, 2013). Padhy & Sahu (2011) observed that the option to wait or to defer is embedded in most of the investment projects.

Research questions recently asked in the RES literature that used the real options approach is related to investment timing and capacity choices (Boomsma et. al., 2012). Through another question, Martinez & Mutale (2011) enquired on appropriate site selection for hydro project using real option. Additionally, renewable energy policy is also evaluated by Lee & Shih (2010) using the real options. They questioned on the level of appropriate feed-in-tariff through sensitivity analysis. However, we are not dealing with FIT in this study. The concise literature on the subject is furnished in next chapter and also followed throughout the thesis.

Therefore, in a nutshell, the broader research question that is asked through this study is: what influences the investment in RES; and what are the factors that determine electricity final price?

Thus, the overall study contributes in three ways:

-Proposing a macroeconomic model on the determinants of solar and wind investments in EU-27, EU-15 and EU-11(Top 11 EU countries having highest generation of electricity through RES) that captures the variations associated with the sample sizes.

-Determining whether solar and wind energy play significant roles in determining electricity retail prices, and

-RES investment project evaluation through real options approach by sensitivity analysis, accounting the uncertainty related to policy change in Europe or Portugal.

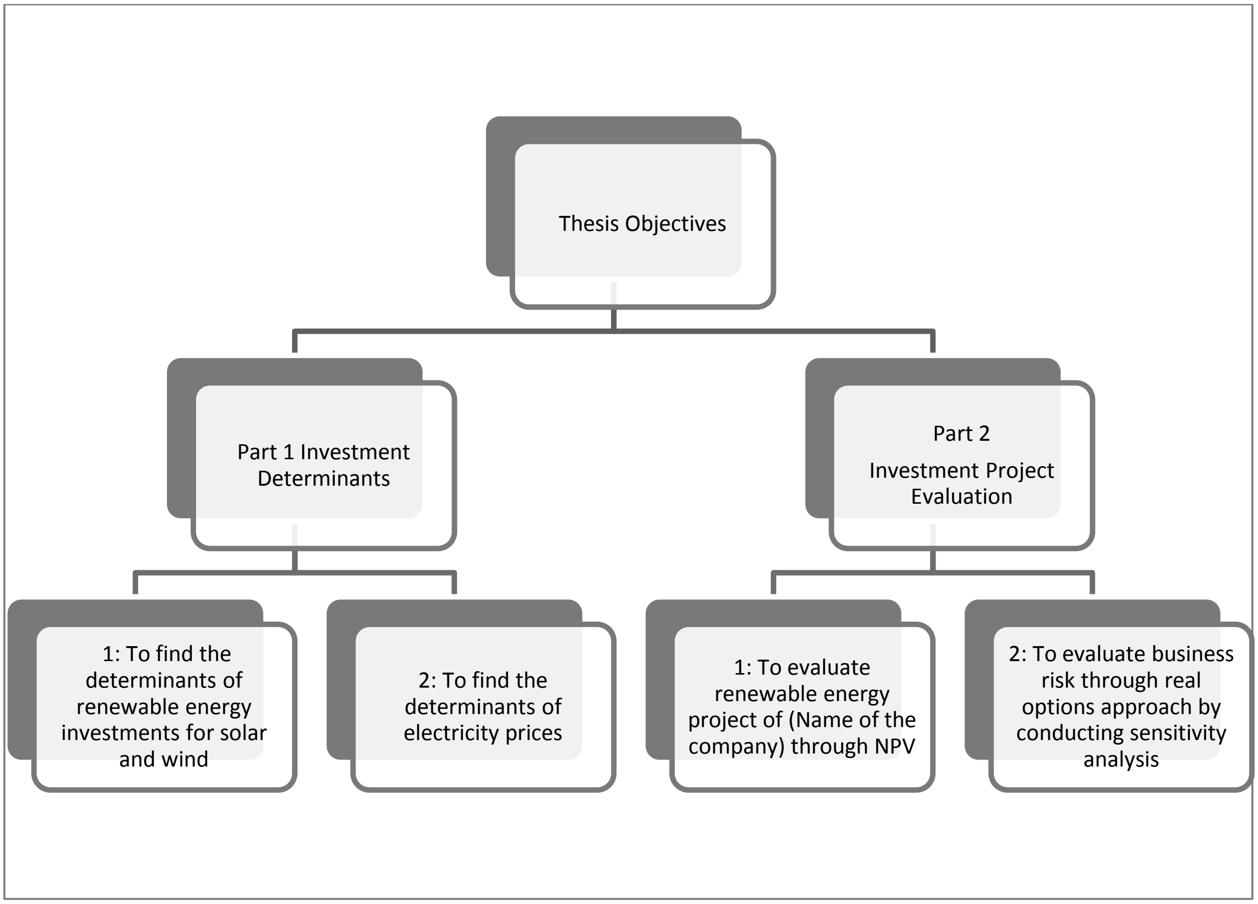
1.3 Thesis structure

The thesis is organized into two parts (Figure 1.1): Part A and Part B.

In continuation, next chapter (Chapter 2) starts with introducing the part A of the thesis, which includes research questions, motivation, etc. The third chapter targets to present a literature review of the first part of the thesis. The fourth chapter aims to describe the data used for macroeconomic modelling, overall methodology and results followed by the conclusion.

The second part of the study (Part B) starts with chapter five. The chapter five puts forth the introduction of the second part of the thesis. The sixth chapter presents a literature review on the real options approach in the project evaluation. The seventh chapter puts forth the methodology and results followed by the conclusion. Finally, the last chapter concludes both the studies.

Figure 1.1 Organization of the thesis



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PART A

Chapter 2

Macroeconomic modelling: wind and solar energy investment drivers

1.2 Objectives of the study

As mentioned in the introduction chapter, the study is broadly classified into two parts. Part A deals with two objectives and four research questions that are addressed by macroeconomic approach. The reason for conducting this study on the EU-27 sample is two folds: Europe's leading role on climate change and energy policies; and because it is the region that attracted the largest share of new renewable energy investments (UNEP and Bloomberg NEF, 2009). The sample size considered for this study was relatively large (EU-27) which includes diverse European countries.

The twin objectives of the study are towards understanding the determinants of renewable energy investment. Variations in the results were expected when compared to the smaller sample size; therefore, a large sample is also compared to relatively a small sample (EU-15).

With different sample sizes, macro econometric modelling is performed to serve the following two broad objectives.

Objective 1: To find the determinants of renewable energy investments for solar and wind

Objective 2: To find the determinants of electricity final prices for industries and households

To be more specific, the objective one compares the determinants for solar and wind investments and objective two compares the drivers of retail electricity prices for industries and households.

2.2 Research questions (RQ)

2.2.1 Solar energy investment

Market conditions in Europe for solar photovoltaic (PV) vary from country to country due to variations in government policies and support schemes (Boomsma, 2012). This difference is also observed because of the liberalization of domestic electricity markets and adoption of feed-in-tariffs. In addition to public support programs for renewable energy promotions, solar installed capacity also tripled to almost 30GW from 2008 to 2010 (Photovoltaic Energy Barometer Report, 2011; German Federal Network Agency, 2011).

Germany, Italy, France, Czech Republic, Belgium and Spain are the countries that have biggest PV market- and market is expected to grow continuously. Germany is reported to have led the market with the installation of 7.4 GW in 2010 (German Federal Network Agency, 2011). Germany introduced "Renewable Energy sources Act" in 2000 to promote solar energy. This law promoted and ensured a guaranteed returns on solar investment, provided solar installations be connected to grids. Additionally, regarding the cost reduction and efficiency enhancement in the future, it is assumed that the cost of the technology is going down each year and efficiency is increasing every year.

Contrary to the above, Carvalho et. al. (2011) studied the PV market of seven European countries and proposed that despite an active feed-in-tariff system and enough sunshine hours in Portugal, investors are not attracted to invest in solar.

Therefore, despite having a common goal of achieving a 20% of renewable electricity by each EU country by 2020, why are some countries not willing to invest in solar energy? That could also mean that investment drivers are varying for solar technologies among EU countries. Then, the research question 1 (RQ1) will be

RQ 1: Which are the determinants for solar energy investments in EU-27?

2.2.2 Wind energy investment

According to the Eurostat, among the competition between solar and wind technologies, wind is ahead in terms of investment attraction and renewable electricity generation. European wind capacity grew by 12% in 2010. Total capacity installed in Europe is estimated to be 84GW, which accounts for 6% of Europe's electricity production. German and Spanish markets represent 16 % of wind energy generation in Europe, whereas the UK and Italy have both the same share of 10% (Eurostat, 2014; Waldau et. al., 2011). According to CEER Report (2013), support schemes also vary largely for wind (just like PV) across the EU. For example, in Belgium, offshore wind farms benefit from a financial support of maximum € 25 million spread over five years. Similarly, according to Brown (2013), wind power in Germany is incentivized through government policies. Additionally, wind power also received a service bonus for maintaining frequency and voltage control. Furthermore, in Spain the market prices of wind electricity resulted in higher revenues for wind projects. Moreover, market premiums were paid to wind generators for the entire lifecycle of a project. However, with the current regulatory change, wind power generators may suffer a revenue loss (extended on the Part B).

With current trends, wind is considered to be a mature market in some of the European countries- for example, Spain stopped market premium option (from February 2013) for certain electricity projects (EDP, 2014)[3]. Projects as of now could choose either market price or fixed tariff. However, each country has deployed varying incentive drivers to meet 2020 targets. Nonetheless, incentives are considered to be just one aspect of an investment in wind technology. There are several other parameters that directly affect the investment in wind too. Therefore, the research question 2 (RQ2) will be

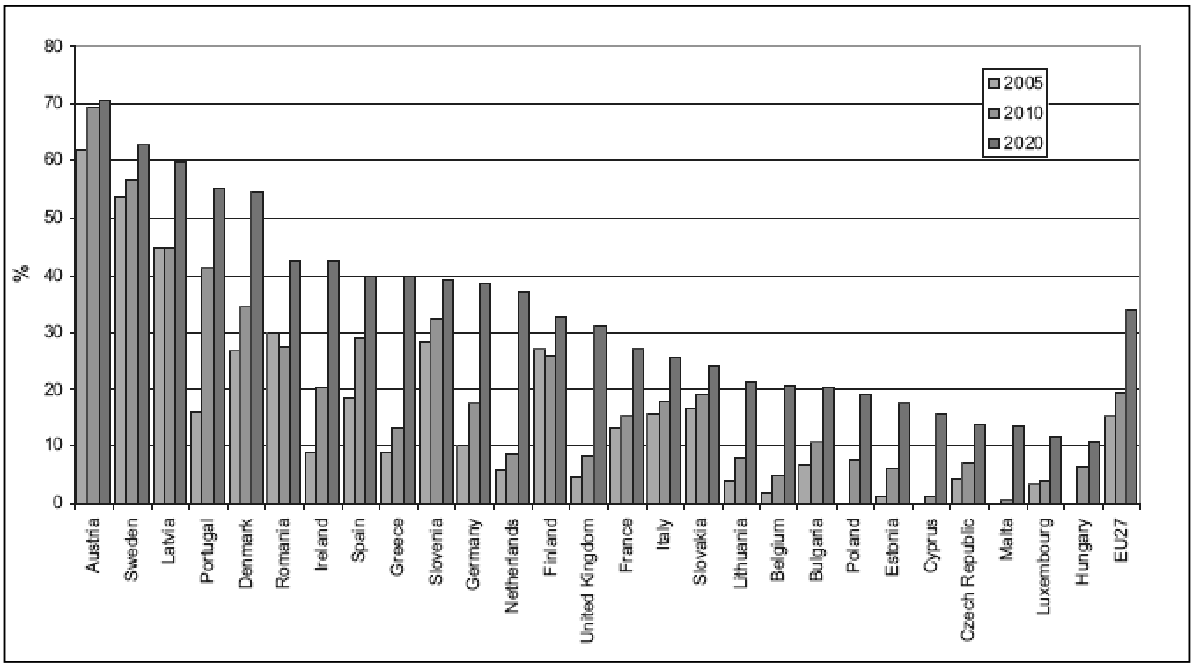
RQ 2: Which are the determinants for wind energy investment?

[3] Please refer EDP.com

2.2.3 Electricity price determinants

Renewable energy generation and supply play a higher role in increasing the total electricity production and supply of a country. There has been a shift in energy consumption in over the period 2005 -2010. Consumption figures are projected until 2020 (Figure 2.1).

Figure 2.1 RES share in electricity consumption

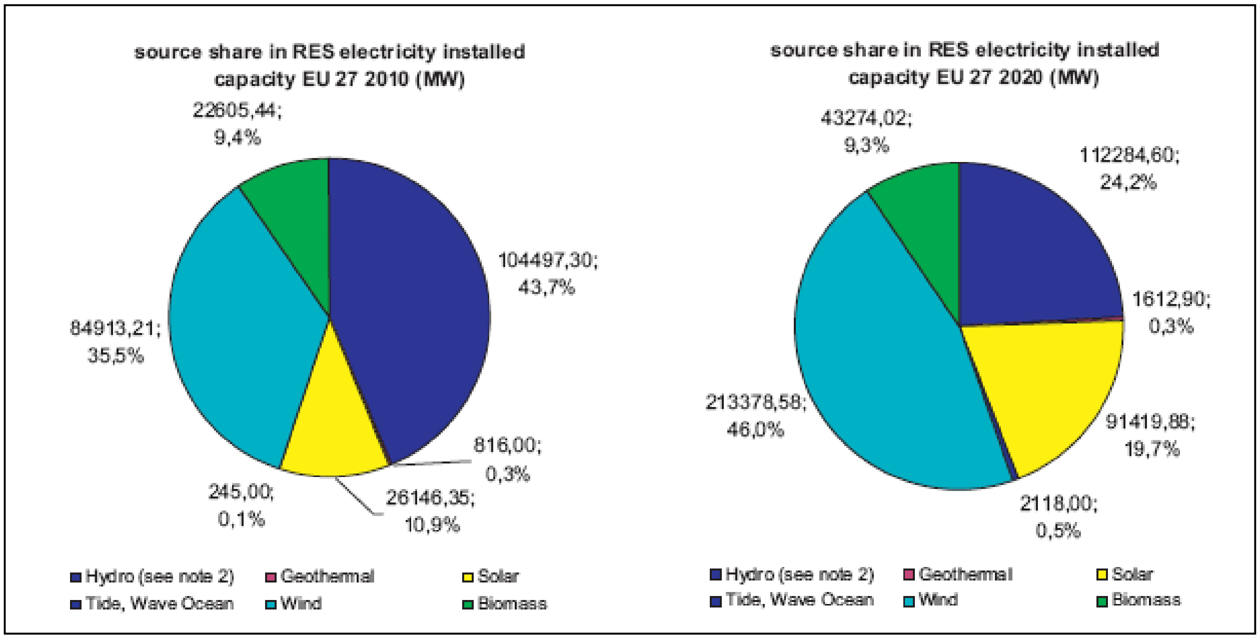


Source: Waldau et. al., 2011

Figure 2.1 shows an increase in electricity consumption for 2005, 2010 and projection for 2020. Austria, Sweden, Latvia, Portugal and Denmark are expected to consume high electricity in 2020.

Figure 2.2 depicts the change in renewable energy electricity share in 2020. On close observation, it is noticed that renewable energy's share through wind and solar are expected to dramatically rise in 2020

Figure 2.2 RES share in electricity capacities in the EU from 2010 to 2020 (projected)



Source: Waldau, 2011

Waldau et. al. (2011) mention that, due to the oil price increase in 2005, the renewable electricity demand has dramatically increased in Europe. Additionally, renewable energy production is concerned with lower safety and security concerns, promotion of energy through renewable sources has the highest (71%) approval rate (Euro Barometer Report, 2011). With the recent decline of oil prices in 2014, the scenario of renewable energy investment may change, but this is not in the scope of current study.

However, there could be another consequence of increasing renewable share in electricity supply on retail electricity prices. Azofra et. al. (2014) studied the impact of biomass, solar thermal and mini hydro power on electricity prices. They used an artificial intelligence method to model the data, and outcome shows a negative relationship between prices of electricity and power generation. Similarly, Darghout et. al. (2014) studied the long-term effect of residential PV on electricity prices. Results suggest that in the long term, investments in solar PV can save up to 47% of electricity bills.

Contrary to the above, Cai et. al. (2013) found that despite the promised and fixed rates of returns in feed-in-tariffs, higher solar installation (rooftop) leads to increasing of electricity prices. They simulated the study and captured the feedback effects between the PV adoption and electricity prices. Similarly, Dinica (2011) puts forth that the operational cost of producing electricity through renewable energy sources vary with geography, infrastructural, institutional and resource factors. Finally, increased operational cost is passed on to consumers, thereby increasing the electricity prices. However, other than the production cost, other factors such as-market drivers, regulatory quality, corruption, environmental pollution, etc. can also influence the final prices of electricity (Kema Consulting, 2014).

Final electricity prices in EU countries for households and industries vary depending upon regulation, distribution, technological cost and the different needs of the two sectors[4]. Therefore, we assume that the price determinants for households and industrial electricity are different that can be further tested and compared empirically. In the light of this, research questions 3 & 4 (RQ 3 & RQ 4) are:

RQ 3: Which are the determinants of retail household electricity prices?

RQ 4: Which are the determinants of retail industrial electricity prices?

2.3 Conclusion

This chapter has described the basic introduction to the first part of the thesis. The goal of this chapter was to present the aim of the study. To address the two objectives, four research questions were formulated. Next chapter covers the literature review and conceptual framework for this part of the thesis.

[4] Please refer Eurostat 2011 through http://ec.europa.eu/energy/doc/2030/20140122_swd_prices.pdf

Chapter 3

Survey of the literature and framework

3.1 Introduction

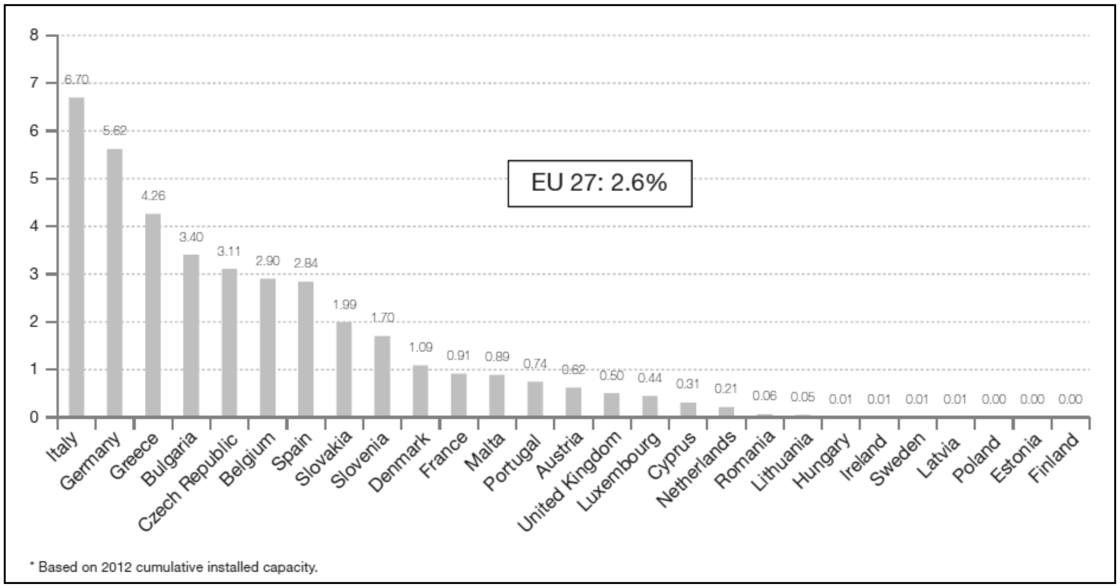
The aim of this chapter is to put forth a broad and critical review of the literature. This chapter presents the addressing of several related research questions that have already been addressed in the literature and the different methodologies that have been adopted to address such research questions empirically.

To be established as self-dependent on energy needs, and reducing carbon footprints, the European Union (EU), became the first in the world to implement policies related to renewable energy use and thus constructed several renewable energy projects. However, an effective legal framework may be required for further sustainable adoption of the renewable energy systems. Implementing the RES technologies individually by households and industries may be expensive because of substantial installation costs associated with wind and solar RES. To avoid high investments, most of the EU countries have efficiently adopted the feed-in tariff system for production and supply of renewable energy, and hence increased the generation of renewable energy (Eurostat).

Carvalho et. al.(2011) point out that the EU is not only the first, but also the world's leader in the photovoltaic (PV) sector. However, because of the high installation rate, lesser investors prefer RES generation through PV.

According to the major findings presented in European Photovoltaic Industry Association (EPIA) 2013 report the world's total PV capacity was 31.1GW in 2012, whereas Europe (not EU) accounts for 17.2 GW which is almost 55% of the total PV installation in the world. Germany is the top market with a PV installation of 7.2 GW. However, the generation of energy through PV is the third in choice after hydro and wind respectively. In the electricity market, PV accounts for 2.6% of total demand (Figure 3.1) whereas, during peak, the demand raises up to 5.2%.

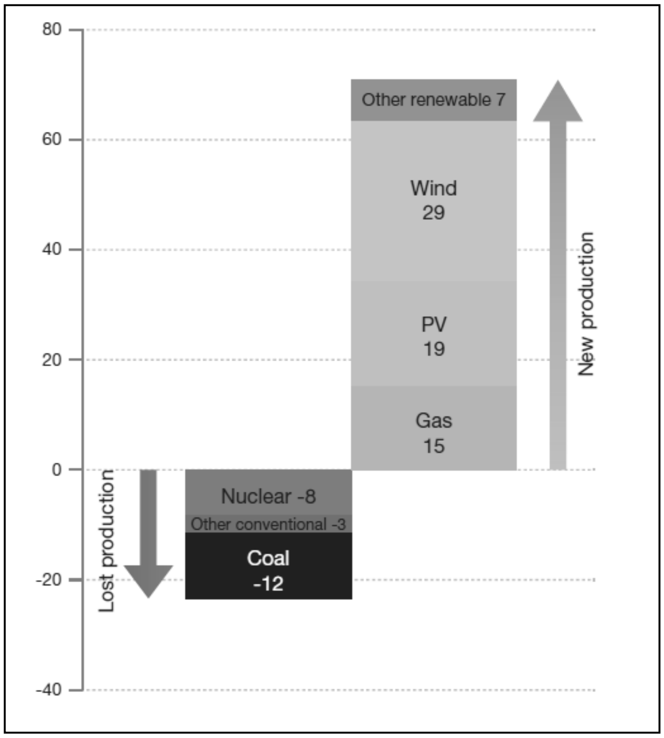
Figure 3.1 PV contribution to the electricity demand in the EU 27 in 2012* (%)



Source EPIA 2013

Additionally, PV is the second choice after wind because of the reduced operating hours (Figure 3.2). However, during the whole year (in 2012 compared to 2011), PV could provide 19TWh of electricity compared to 29TWh produced by wind.

Figure 3.2 Theoretical balance of electricity production in EU 2012 (TWh)



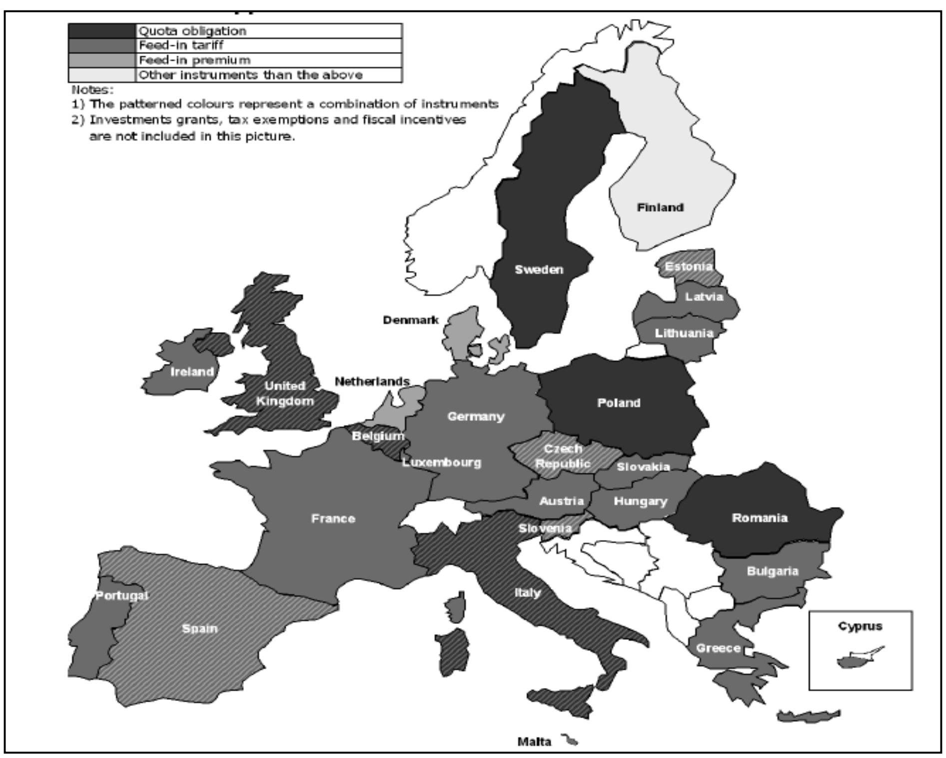
Source-EPIA report 2013

Further, at country level, Kost et. al. (2013) analysed the Spanish market for concentrated PV, where investment decision is not only relied upon the capacity installation, but also on the storage capacity of the plant. They analysed the economic value of concentrated PV in Spanish market under wholesale market price and local FIT. In the Spanish market, there is a limited incentive for storage (also for the thermal power). They developed a framework that gives optimal layout decision and the operation of CSP plants. In another recent study, Avila-Marin et. al. (2013) analysed different renewable energy plants for their cost effectiveness. Specifically for solar plants, they mention that the larger plant size can be cost effective through improved economies of scale.

A higher installation and more energy generation has proved to be a cost effective measure (Menanteau et. al., 2003; Qiu & Anadon, 2012). Among EU states, not all states are able to exploit the solar energy for higher use. However, Germany, a rather cold country (with annual sunshine of 1200 to 1650 hours annually), has been able to make tremendous progress in solar installations of 7.6 GW in 2012. On the other hand, with Portugal's geography (with annual sunshine ranging between 2200 to 3000 hours), and with the enforcement of several policies and self-support mechanisms, Portugal has not made a remarkable progress in the generation of solar energies (LNEG, 2013). There could be several reasons behind it; the major reason could be either the lack of effective dissemination of price protection policy or the higher cost of PV technology.

Under RES framework, renewable energy distribution in Europe is mainly through the FIT distribution of the energy (Figure 3.3). Almost 13 countries out of 27 have adopted FIT in 2010 (figure 3.3), whereas only three countries, Sweden, Poland and Romania have implemented Quota obligation.

Figure 3.3 Current applied schemes for the support of electricity from RES in the EU-27 countries



Source Klein et. al. (2010)

Couture and Gagnon (2010) have studied the different types of FIT policies which are broadly classified as policies with remuneration and policies without remunerations. They have also examined the FIT models- and presented design options that are beneficial for consumers and investors too. Finally, they conclude that fixed FIT can help lower the investment risks; whereas premium price policy can help market integration of RES sources by generating incentives.

3.2 Influence of renewable energy directives on investments

Policies associated with regulatory frameworks play a vital role in positively or negatively affecting the businesses and investments (Saltari & Travaglini, 2011; Schmit & Conrad, 2011). Renewable energy sector is dynamic fields, companies or an individual see investment in this sector as an input to fetch returns.

European countries are considered as favourite destinations for RES investments research. According to Lux research (2011), Portugal should be the second top priority for the investors of solar energy after New Jersey. Other destinations for investment are Australia, Italy and India. This interest is shown by the companies because of the steadily rising internal rates of returns (IRR), which are expected to bring an opportunity of 400MW business every year. On the contrary, as reported by Leete et. al. (2013), investment in the energy sector in the UK is declining. The investors who had invested in the renewable energy business now show less interest in investing further because of the unattractive regulatory policies and increased waiting time for investment returns.

More recently, Boomsma et. al. (2012) adopted an approach for analysing the duration and time of an investment in renewable energies under various support schemes mainly FIT and RE trading certificates. They have considered uncertainties in the model and reported the investment decisions. In their baseline scenario, they mention "*taking the fixed feed-in tariff as a base, the revenue required to trigger the investments was 61% higher with renewable certificates*".

However, they have had certain assumptions on capital costs, which display economies of scale, and a total annual production as a function of the capacity installed.

In other research, Fernandes et. al. (2011), investigated real options theory approach in the energy sector investment. Copeland and Antikarov (2003) defined real option "*as a right, but not the obligation, to take an action (e.g., deferring, expanding, contracting or abandoning) at a predetermined cost, called the exercise price, for a predetermined period – the life of the option".* This theory has been widely accepted in the energy sectors from generation to evaluation of policies.

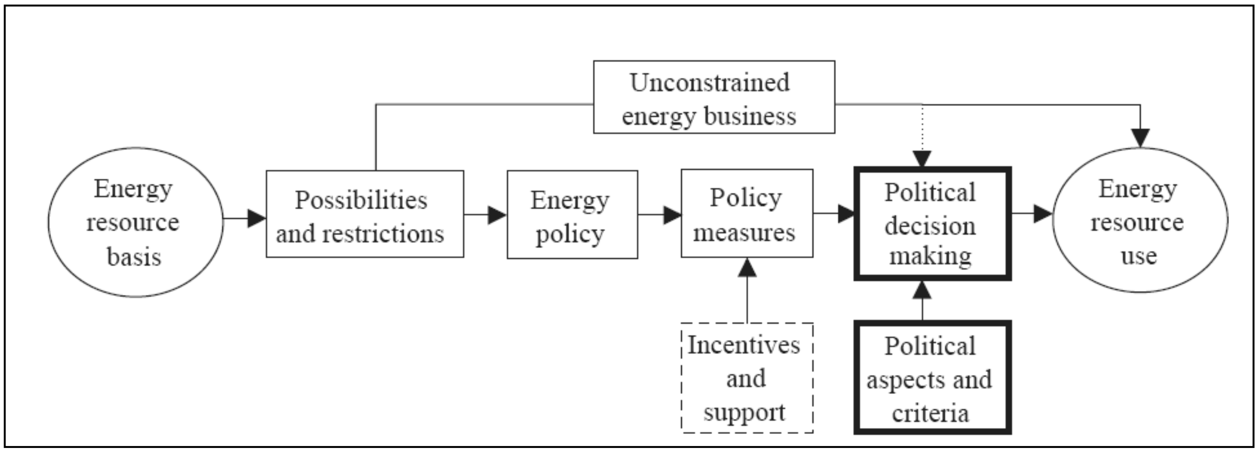
Furthermore, observing the cases from non-EU countries, Aslani et. al. (2012) studied the prime criteria for private sector participation in renewable energy investment in the Middle East. They cite that for private firms the driving force for investment is friendly government policies along with consumer markets.

3.3 Political desire and investment in renewable energy

In the Policy-Driven scenarios presented in an EPIA 2013 report, it mentions that the introduction of adequate support along with a strong political desire will be required to consider PV as a major power source in the coming years. To achieve this, there is a need to reduce unimportant administrative barriers for streamlining the grid connection procedures. However, the market might not pickup if there is an inadequate support mechanism.

Jacobsson and Laura (2006) in their study found that the policy instrumentation and political desire played an important role in the implementation of the renewable energy technologies. They mentioned that the regulatory framework was made after fighting a battle with the political leaders who were in power and were interested in nuclear and coal-based energy. Similarly, Lund (2007) noticed the non-alignment of political parties' agenda and future energy options in Finland. Despite the huge risk, the interest and focus were on nuclear energy rather than wind or solar. He presented the political decision-making framework through this study, and observed that the political decision-making in terms of renewable energy setup is a complex and critical environment. He also described the variables on which the decision on renewable policies framing and implementation is based upon. For the current study, it is assumed that regulatory policy change is a part of political intervention.

Figure 3.4 Political decision framework



Source: Lund (2007)

More recently, Biresselioglu and Zengin (2012) through econometric analysis found that the alignment of political parties in favor of renewable energy support policies led to greater consumption of renewable energy by local consumers. They found significant positive correlation between government's will power for renewable energy implementation and energy consumption. Literature available on the relationship between political desire on renewable energy and consumption is less available in the scientific database and might constitute a good future research options.

3.4 European Union’s strategy with regards to RES

To meet the EU’s 2020 goals, higher energy generation from RES is required. The higher generation needs higher investments. Therefore, this section of the literature is also quite important in this part of the thesis. Nagy & Kormendi (2012) proposed a detailed strategy for Europe to meet its 2020 targets. They presented the literature from Laurell (2011) who mentioned that the smart grids are the main requirements for heavy wind power installation, small-scale local electricity power production, intensive use of electrical cars, and energy storage systems.

However, they mentioned the following five priorities and the requisite actions to accomplish the priorities

Priority 1: Achieving an energy-efficient Europe.

Action -Reinforcing efficiency in energy supply

Priority 2: Building a pan-European integrated energy market

Action -Establishing a blueprint of the European infra- structure for 2020–30

-Streamlining permit procedures and market rules for infrastructure developments

Priority 3: Empowering consumers and achieving the highest level of safety and security

Action -Continuous improvement in safety and security

Priority 4: Extending Europe’s leadership in energy technology and innovation

Action - Implementing the SET Plan without delay

-The Commission will be launching four new large-scale European projects

- Ensuring long-term EU technological competitiveness

Priority 5: Strengthening the external dimension of the EU energy market

Action 3 - Promoting the global role of the EU for a future of low-carbon energy.

3.5 Conceptual framework and formulation of hypotheses

This brief literature review also reveals that there are still many unanswered questions about solar and wind energy investment and electricity retail price determinants in EU-27. Examples of these questions are

-Does a regulation perception impacts solar and wind investments individually?

-Do annual sunshine hours impacts solar and wind investments individually?

-Does solar or wind individually impact electricity prices of households and industries?

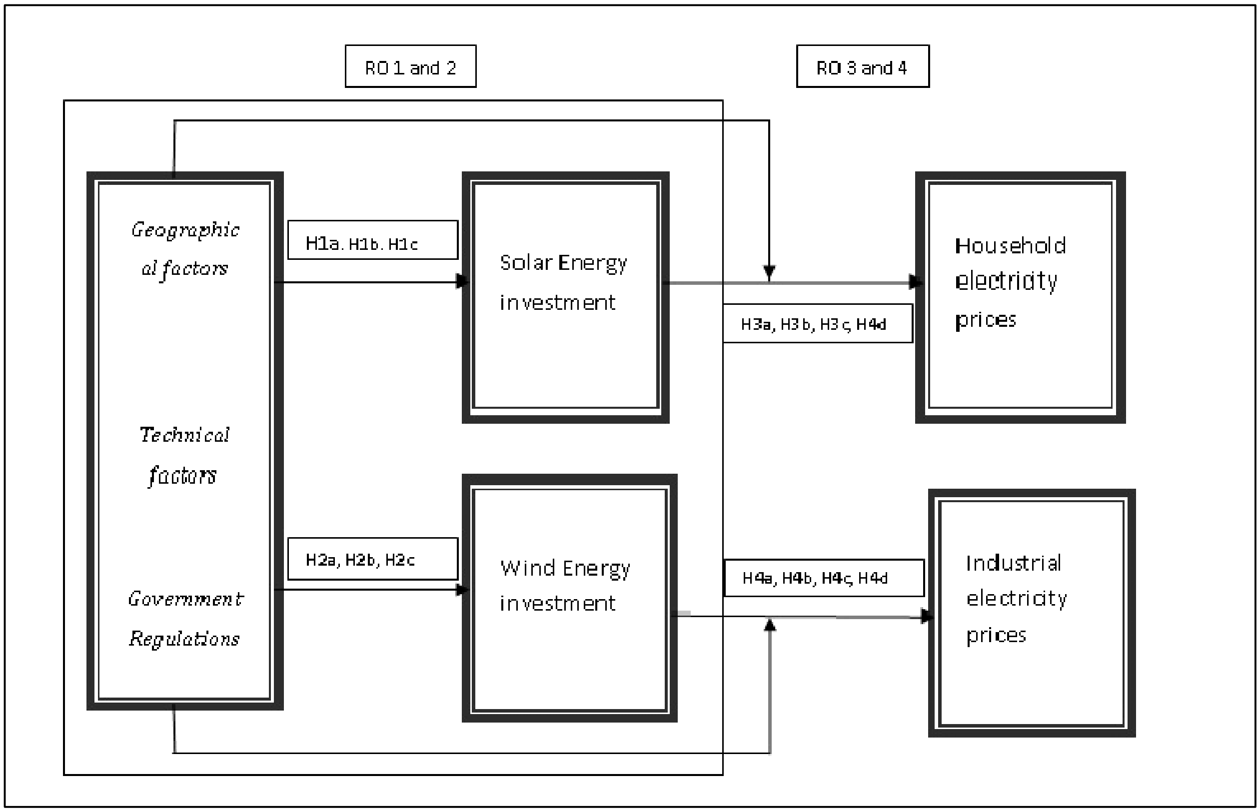
-Does regulation perception impact electricity prices of household and industries?

-Is carbon emission an important factor to be considered for an investment in the current European scenario?

-How important are the geographical factors in terms of renewable energy generation through solar or wind?

This section presents a conceptual model (Fig. 3.5) and hypothesis formulation for the study

Figure 3.5 Conceptual framework for macroeconomic modelling



Source: developed by author

3.5.1 Geographical condition for solar and wind as a factor of investment

Electricity can be generated through solar energy during the day when the sun shines. Selected geology and geography for the plant installation could play a significant role in the generation of solar energy. Uyan (2013) has used the potential of Analytical Hierarchical Process (AHP) for mapping the potential of solar energy in Turkey through geospatial technologies and has proposed four classifications of the solar sites, namely, “best-suitable”, “suitable”, “moderate” and “low-suitable”. He has used the economic and environmental factors to model the map. The

AHP provides a flexible and easy way of analysing complicated problems. It uses multiple criteria decision-making techniques to be considered in the decision-making process (Saaty, 1980). In another example, Polo et. al. (2015) have used satellite maps along with atmospheric data and annual sunshine hours to model the sites for the installation of CSP and PV plants.

Thus, assuming an unlimited capacity, the electricity generated through solar energy could be considered to be directly proportional to sunshine hours. By this logic, the countries like Portugal and Spain with average annual sunshine of 2781 and 2691[5] hours respectively could frame their policies that are favourable to solar energy production. Moreover, countries such as Germany and Netherlands with low annual sunshine of 1650 and 1580 hours respectively could frame policies favouring wind energy production if geographical conditions permit. However, through academic and non-academic literature, it is observed that Germany being one of the coldest countries with considerably lower average annual sunshine hours is a world leader in producing electricity through solar energy (Eurostat). Therefore, it would be interesting to know whether investment in wind or solar energy is dependent upon geographical location in terms of reception of sufficient solar irradiances or blowing of the wind.

H1a: Higher sunshine hours lead to higher electricity generation through solar

H2a: Lower sunshine hours lead to higher electricity generation through wind

3.5.2 Electricity from solar and wind

Electricity prices are highly volatile and it cause a high risk to potential investors in solar power generation markets (Coulon et. al., 2015). Investment cost of setting up a renewable energy plant includes high fixed cost and variable cost. These costs along with returns are to be recovered over a period. Thus, the cost involved in setting up of the plant, its operations and energy distribution is passed on to the consumers thereby increasing the price of electricity (Shin et. al., 2014). However, over a period, when these costs are recovered, the electricity prices might

[5] The annual sunshine hours data is taken from climatedata.eu

become cheaper (Darghout et. al., 2014). The argument is that in the long run prices should become cheaper as solar and wind plants do not consume fuels, unlike conventional energy plants. Although, through the study conducted by Spiecker & Weber (2014) mention that in a short run the prices of energy increase if the renewable share is high, however, in the long run prices could reduce. Hypothesis test this relationship on diverse samples: EU-27 (also EU-15 and EU-11) for solar and wind generated electricity.

As explained in the formulation of research questions that, the determinants of household and industrial prices are expected to be different, we propose separate hypotheses for households and industrial prices.

H3a: Higher share of electricity generated through solar leads to higher electricity prices for households

H3b: Higher the share of wind-generated electricity in supply, the higher is the electricity prices for households

H4a: Higher share of electricity generated through solar leads to higher electricity prices for industries

H4b: Higher the share of wind-generated electricity in supply, higher are the electricity prices for industries

3.5.3 Carbon emissions

Incentives given towards the adoption of green technology are supposed to be one of the instruments of climate change policies, which ultimately aim to reduce the carbon emissions. A higher investment in renewable energy sector has been suggested by several researchers, and ultimate goal is to reduce the carbon footprints. For instance, see Shawhan et. al. (2015). That also means that countries with higher carbon emissions should invest more in wind and solar technologies (or biomass, hydro etc.) to meet its 2020 targets (specific to EU context). However, wind and solar plant may play less importance in controlling the carbon emissions when policy support might be given to another renewable technology example (hydro or biomass). Hypotheses H1c and H2c test the dependency on solar and wind energy investment in controlling carbon emissions.

H1c: Higher carbon emissions lead to higher investment in solar

H2c: Higher carbon emissions lead to higher investment in wind

Through panel data analysis, Alshehry and Belloumi (2014) concluded that energy price is the crucial indicator for the economic development and they have proposed a high installation of clean energy generating sources for the controlling of carbon emissions. However, there also exists a cost associated with reducing carbon emissions. Marcatonini & Ellerman (2013) calculated the abatement cost of solar and wind to be Euro 537/t CO_2 and 43/t CO_2 Euro respectively. Thus, clean energy supply is expected to have an impact on retail electricity price. H1c and H2c test the underlying relationship.

H3c: Cleaner energy supply leads to higher electricity prices for households

H4c: Cleaner energy supply leads to higher electricity prices for industries

3.5.4 Regulatory framework

Since the technology is expensive (KEMA Consulting, 2014), a regulatory framework that could subsidize the investment cost could play a significant role in the adoption/rejection of technology by prosumers and/or incumbents for investing in the clean electricity. The policies towards adoption of renewable energy still exert uncertainty at the regulatory level (details are in Part B), and could change with political intervention. Currently, there are two kinds of support methods. The first is the indirect support, which includes research and development funds, cost of technology adaptation, grid access, renewable energy dispatch priority, net metering, etc. On the other hand, there are direct supports too, such as investment supports like capital funding, tax exemption, operating support mechanism, etc. Direct support scheme mechanism includes feed-in tariffs, feed-in-premiums[6], investment incentives and financial incentives such as loans that are below the market interest rate.

Strong regulation is also perceived as more formalities, higher paperwork, more licenses, and higher taxes. Thus, strong regulations are expected to require long time for taking the permission from related authorities to invest in renewable business. However, more positively, stronger regulation would also control the environmental degradation factors, which could include the policy related to the adoption of technologies that emit less carbon.

A recent study conducted by Sas (2015) mentions that in Romania a majority of regulations in favour of generation of renewable energy has increased the price of electricity for industries and households. Higher price of electricity for industrial consumers has increased the price of final goods that made industries uncompetitive. Therefore, investors tend to invest in alternative project with higher support scheme. H1b and H2b would be tested to address the RQ 1

H1b: Strong regulation perception leads to higher investment in solar

H2b: Strong regulation perception leads to higher investment in wind

In the same way, strong regulation is also expected to be associated with strictness of authorities in terms of energy distribution, supply, energy audit, etc., which could also increase the operating cost of regulatory authority, and subsequently increase the tax levied on consumers.

H3d: Stronger regulation perception leads to higher electricity price of households

H4d: Stronger regulation perception leads to higher electricity price of industries

[6] Feed-in-premiums (FIP) are payments guaranteed to RES-E generators on top of existing electricity market prices

Note: Although interest rates, the rate of economic growth, fuel prices and the rate of population growth are important parameters, seem irrelevant to the nature of the current study because of the following reasons. Interest rates in energy projects are not as important as in other investments, as most of the energy projects are financed by government or by banks; but, due to subsidies in investment and to the feed-in tariffs the financial risk is relatively low. Therefore, to determine the final cost of capital, the regulatory framework is important. However, we are not considering it, as our goal is to broadly understand the effect on investment, and not to do a detailed analysis of regulation. Similarly, the rate of economic growth impacts demand and demand is a regulatory parameter. The scope of the present study does not extend to understand how demand will eventually impact RES investments. In the same way, the rate of population growth indirectly affects the demand. However, the results of it are not straight forward, because we can have high population growth but GDP might be slowing down. Similarly, fuel prices have an effect on RES investment, but the impact is not visible in the short run. The scope of the study is limited to carefully observing the results in a short run, and broadly in the long run.

3.6 Conclusion

This chapter presented the literature review for the study including the growth of the renewable energy, regulation, European strategy to meet 2020 targets, etc. The aim of this chapter is to present the conceptual model of the study. We conceptualized the study and were able to formulate the hypotheses that will be tested in the next chapter. In order to take this study further, the next chapter presents the data, detailed methodology and results of the study.

Chapter 4

Methodology, data analysis and results

4.1 Introduction and short critical review of existing panel data studies

This chapter explains the methodology adopted to obtain the results empirically from modelling an EU-27 sample data concerning the factors that affect wind and solar energy generation. This study uses the panel data methodology for addressing the research questions and hypotheses. Menegaki (2011) adopts similar kind of approach for empirical understanding the causal relationship between economic growth and renewable energy through panel data over the period 1997-2007 in EU-27, using random effect modelling. Observation suggests that there is no relationship between RES consumption and economic growth. More recently, Lee (2013) used a fixed effects panel data model to investigate the contribution of foreign direct investment (FDI) net inflows on clean energy use, carbon emissions, and economic growth using a panel data of G20 countries over the period 1971-2009. He observed that FDI plays a positive role in economic development, whereas it leads to higher carbon emissions. Similarly, Chakraborty & Mukherjee (2014) studied a 10 years panel data (2000-2010) on 114 countries to understand the relationship among environmental performance index, export and FDI. Export and FDI were observed to be negatively associated with an environmental performance index. Thus, the study revealed a serious concern on the nexus between environmental sustainability and economic growth.

Cambini & Rondi (2009) investigated the relationship between investment and regulation through panel data of EU-27. The outcome shows that the regulation is negatively associated with private and public firms' incentives to invest. However, instead of ordinary least square method they have used two-stage least squares (TSLS) and generalized method of movements

(GMM). Two-stage least squares is widely used in econometrics to estimate parameters in systems of linear simultaneous equations and to solve problems of omitted-variables bias in single-equation estimation (Angrist & Imbens, 1995); whereas, the GMM estimator is typically used to correct for bias caused by endogenous explanatory variables (Xang & Fan, 2003).

Another empirical study by Sadorsky (2012), related to modelling of renewable energy company risk, suggested a negative association of sales growth to business risk. This study used panel data on 52 companies over the period 2001-2007. In another study, Ni et. al. (2014) conducted a panel data study over the period 1990-2009 to understand the competitiveness among 25 cities in China. The objective of the study was to put forth the policy perspective concerned with the economic development of China. The result suggests that cities situated in the north of China are developing at a faster pace.

Saenz de Miera (2008) has empirically studied the interaction of RES in electricity and electricity price of wind energy in the electricity market like Spain and found that lot of wind energy is fed into the grid, which finally reduced the final price to end consumer.

On the other hand, Moreno et. al. (2011) studied the panel data of European country over the period 1998-2008 and proposed that the renewable share of electricity supply significantly increases household price to final consumers. Additional variables for determining the electricity price of household were carbon emissions: they mentioned that cleaner the energy is, higher would be the price of electricity because technological, operation and regulatory cost is involved in the production of green energy. In the more recent article, Del Rio & Tarancon (2012) have analysed the features of econometric research on RES determinants (articles published from 2006 to 2010). The main objective of their study is to find the relationship between administrative barriers and onshore wind investments.

Methodological approach to addressing the current study is in line with the above literature. Questions asked for the current study can be answered by understanding a trend of RES and associated variables on EU-27. Data over a relatively long period was required to understand the trend and relationships among variables. In the current situation, panel data modelling is found and considered suitably fit among the other choices of methodologies available. Thus, it should be noted that the aim of this thesis is to conduct the original research (ideas) using the existing methodologies.

The explicit research questions (RQ) formulated were the following:

RQ1: Which are the determinants of solar energy investment?

RQ2: Which are the determinants of wind energy investment?

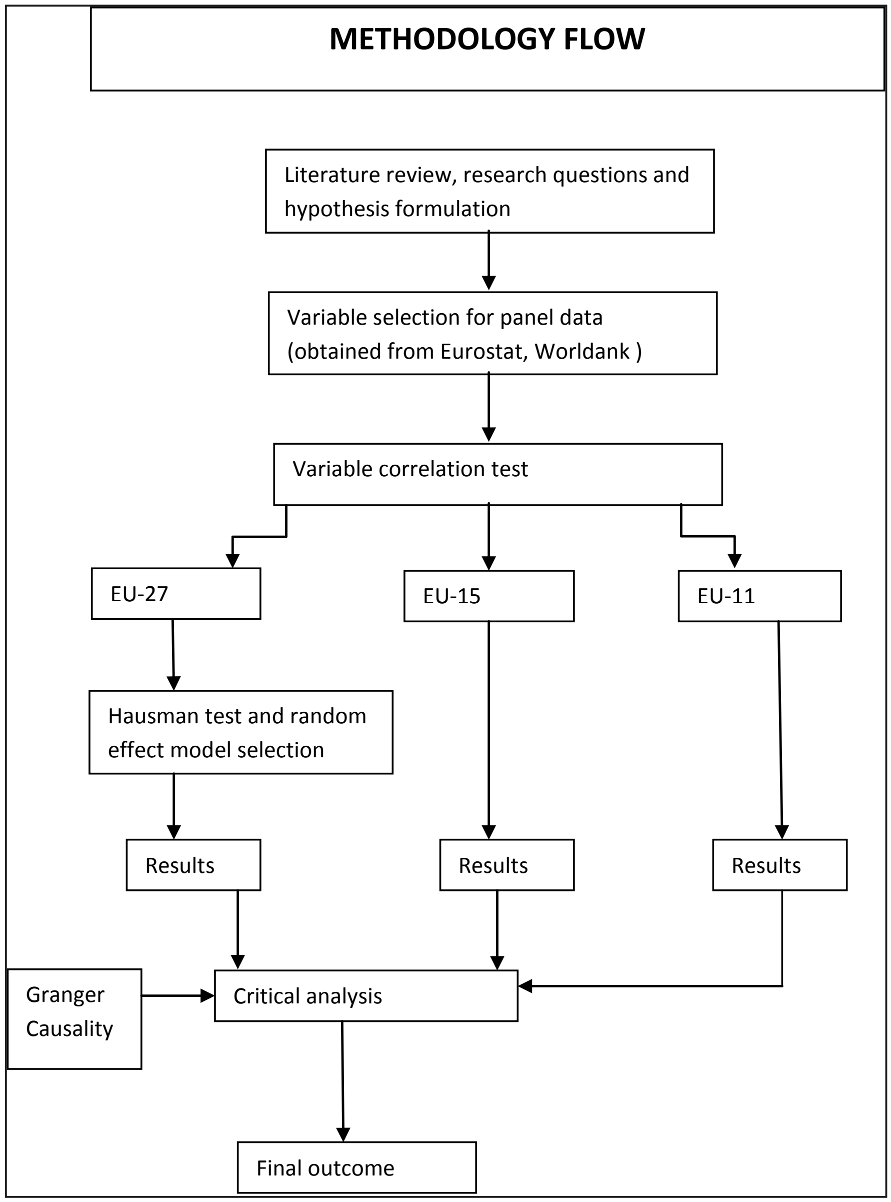
RQ3: Which are the determinants of electricity prices for households?

RQ4: Which are the determinants of electricity prices for industries?

Hypotheses were formulated, to address the above questions, which were answered through empirical models. Data used was taken from Eurostat and World Bank. Finally, the results were critically analysed and compared with relatively smaller samples.

Figure 4.1 presents the methodology flow of the first section of the thesis

Figure 4.1 Methodology flow Chart



Source: Designed by the author

4.2 Sample and data collection

EU-27[7] consists of 27 European countries. Given that Europe is the first union of nations to implement renewable energy projects, and considering the diverse settings of regulatory systems, economic framework and geographical factors, this sample finds importance in understanding the causal relationship between determined independent variables and solar & wind energy generation. Also, another goal of this research was to analyse how solar and wind energy generation impact the electricity prices of both households and industries.

According to the United Nations Framework convention on climate change, Kyoto protocol - an international agreement on emissions reduction and allowing for carbon emissions trading was established in 1997. However, Europe had already started its movement towards controlling emissions and thus initiated RES investment much before the formation of the Kyoto protocol. For instance, Eurostat[8] mentions that in 1990, the gross inland supply, transformation and consumption of EU-28 was 71,189.1 TOE. During the same year renewable energy consumption was highest in France (15,219.5 TOE), followed by Finland (11,530.3 TOE), Italy (6,352 TOE), Spain (6,202 TOE) and Germany (5,313.4 TOE). It should be noted that the Kyoto Protocol was introduced in 1997, however, we have observable renewable energy investment data available for 1990.

In the accordance with this, annual data from 1995 to 2011 was obtained from the World Bank and Eurostat database for EU-27 countries. The World Bank and Eurostat databases are scientifically considered as reliable source of information. The availability of the data concerning solar and wind energy for the countries in the sample dictated our preference for the period chosen for the study.

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[7] EU-27 consists of 27 European countries (see annex 2). Given that Europe is first mover in implementing renewable energy projects, and the diverse settings of regulatory systems, economic framework and geographical factors- this sample finds importance in understanding the causal relationship between determined independent variables and solar & wind energy generation.
[8] Example is taken from content of Eurostat database no. nrg_107a

Few of the variables that were directly used also have random missing values, which were taken care by the random effect panel data model (see Dragsat, 2009; Wang & Lee, 2013; Hedeker & Gibbons, 1997).

Table 4.1 presents the statistics of variables (both dependent and independent) used in the model

Table 4.1 Descriptive statistics of variables used

	Mean	Median	Maximum	Minimum	Std. Dev.	Observations
CE	0.348445	0.308683	0.940093	0.126268	0.140781	267
EPH	0.101005	0.0967	0.1712	0.03615	0.028763	267
EPI	0.07421	0.07185	0.18	0.0306	0.02307	267
EG	9610.728	4377	45780.2	138.3	11959.18	267
EI	51.95402	57.34226	99.65426	-65.7408	32.52008	267
GDPG	2.494271	3.10143	12.23323	-17.955	3.846123	267
LS	569.4855	615.98	934.63	388.14	93.10623	267
LW	186.0761	194.74	229.27	122.04	42.67863	267
RG	3.781111	3.76976	4.576635	2.709352	0.377051	267
RES-S	4.107228	0.260146	86	0	15.64139	267
RES-W	5.050694	1.200358	40.31746	0	7.947742	267
ASH	0.595506	1	1	0	0.491716	267

Source: compiled by author

Abbreviations: CE represents carbon emissions (same as CO2 emissions); EPH-retail electricity price for household; EPI- retail electricity price for industries; EG-electricity generation in total; EI-energy import; GDPG-GDP growth rate; LS-levelised cost of electricity generation through solar technologies; LW-levelised cost of electricity generation through wind technologies; RG-regulatory quality; RES-S –solar energy generation on total renewable energy; RES-W- wind energy generation on total renewable energy; ASH-annual sunshine hours

One of the stated goals of this study was to find the RES-E generating drivers. For the current study, the scope is limited to solar and wind energy generation. In fact, for most of the European countries, those energy sources are dominant in the renewable share of electricity portfolio. They are also the main renewable energy supported by the European Union fund and national support schemes (see Brown, 2013; Council of European Energy Regulators, 2013).

Renewable energy from other sources like biomass, hydro, geothermal, nuclear, etc. are not taken into account. Wind and solar technologies being competitive (Fraunhofer, 2013) to each other are the main reason for eliminating other renewable energy sources.

Another reason for only choosing wind and solar is because of the policies and frameworks such as feed-in-tariffs are most used, allowing for a reduced market risk and assuming a reasonable pay back to those projects. Additionally, in the last years, the European regulation called the attention to an important concept: the prosumers (consumers are RES generators too). Prosumers can generate electricity through solar PV and supply it back to the grid at an agreed tariff (Aspinwall, 2012).

4.3 Dependent variables

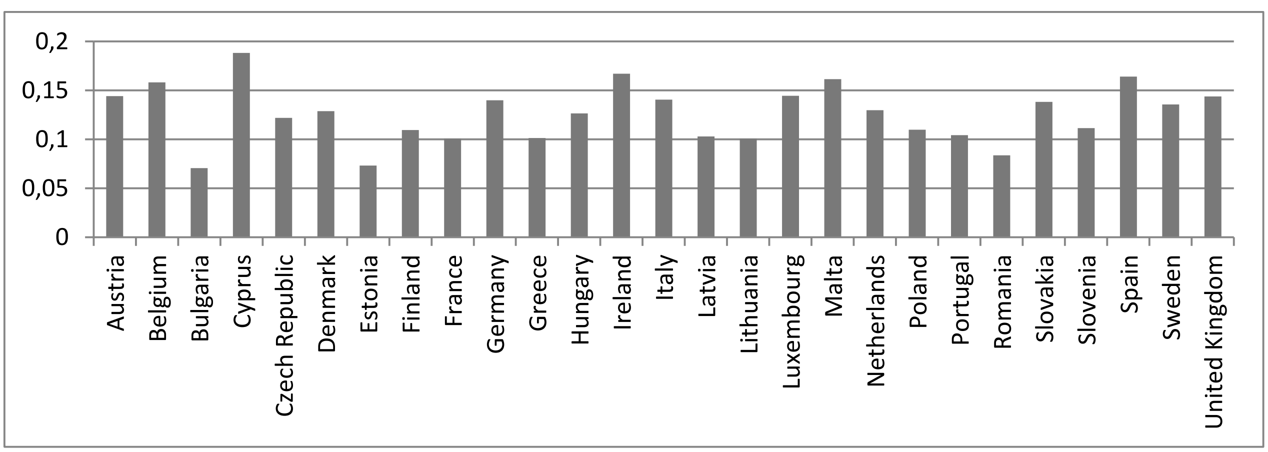
To answer the major research questions, we used dependent and independent variables. Four dependent variables were chosen, and four major versions of the econometric model were proposed. Since EU-27 is a large sample, to better understand the variation in the EU-27, a small, traditionally used sample (EU-15 and EU-11) was also used. This smaller sample of EU-15 corresponds to the 1995 enlargement of the European Union. The EU-11 sample consists of top 11 countries high on the ranking in generating RES electricity.

Outcomes from EU-27, EU-15 and EU-11 model versions were compared and analysed. Therefore, in total (4 x 3 =12) twelve sub-versions of the model were proposed. For the first two models, percentage of solar energy generation over total RES and percentage of wind energy generation on total RES respectively were considered to be dependent variables. RES generation is assumed to be linked to RES installed capacity. It is assumed that for higher generation of RES-E, larger investment might be required for either expansion or setting up a new power plant. Therefore, since the above mentioned two variables were interchangeable, they are also referred as an investment in solar and wind. In other words, RES through wind and solar were used as proxies for investment in wind and solar energy respectively. For solar investment modelling, we have not considered the energy generation from passive solar, whereas for wind, only onshore wind is considered.

Through versions 3 and 4, this study aims to identify the main drivers associated to the retail electricity prices for households and industries. Data was identified in Eurostat for both the variables. Each one has six monthly data available. An average of two six monthly data was taken into account, to match the dependent variables with other independent variables. Following the model adopted by Moreno et. al. (2012), we preferred to use logarithmic values for retail electricity prices of household and industry instead of using direct available values. Given the high variation of taxes among countries, net electricity price before taxes was considered.

For the current study, medium sized households and medium sized industries were considered following the data from Eurostat. In the case of household electricity consumption, prices were measured as an average national price in Euro per KWh without taxes for the average of first & the second semester of each year for medium size household consumers (Consumption Band DC with annual consumption between 2500 KWh and 5000 KWh) (Figure 4.2). This variant was also studied by Soares & Sarmento (2009) and Moreno[b] (2013).

Figure 4.2 Retail electricity prices of household (Euros/KWh) before taxes for 2011.

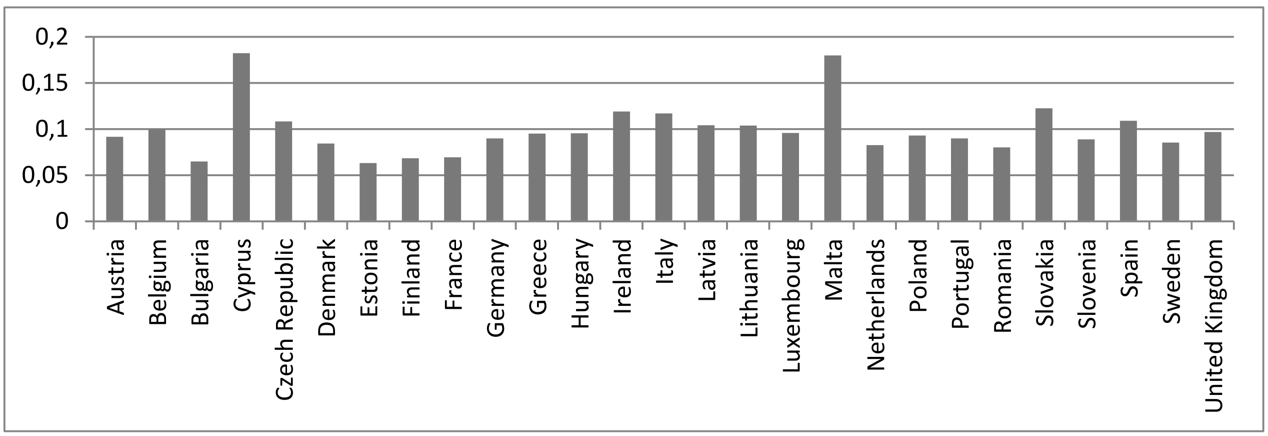


Source- compiled by the author through Eurostat

General electricity prices for household consumers across the Europe were higher than that of industrial electricity consumers. For example, see the instances of Germany, Netherlands, United Kingdom, Sweden, Finland, France, etc.

For industrial electricity, prices were measured as an average national price in Euro per KWh without taxes for the average of first & the second semester of each year for medium size industrial consumers (Annual consumption: 2000 MWh; maximum demand: 500 KW; annual load: 4000 hours) (Figure 4.3).

Figure 4.3 Retail electricity prices for the industry (Euros/KWh) before tax for 2011



Source- compiled by the author through Eurostat

Moreno et. al. (2012) have considered four economic variables (including RES) to propose empirical models. However, Moreno et. al. (2012) used aggregated RES instead of separating its sources (as solar or wind). Additionally, they did not consider levelised costs of electricity generations. Levelised cost associated with electricity generation (although it may be subsidized) is an important consideration in the model of an empirical investment. This is particularly significant as businesses looking to make an investment in the electricity sector are also looking at levelised costs of available options (e.g., wind, solar, biomass, nuclear) (see Gross, 2007 & VGB Report, 2011). Therefore, the present study is an attempt to develop a revised model that can give more information on other associated variables through panel data modelling. Thus, it intends to contribute to the body of current scientific knowledge on the solar and wind energy investment drivers.

4.4 Independent variables

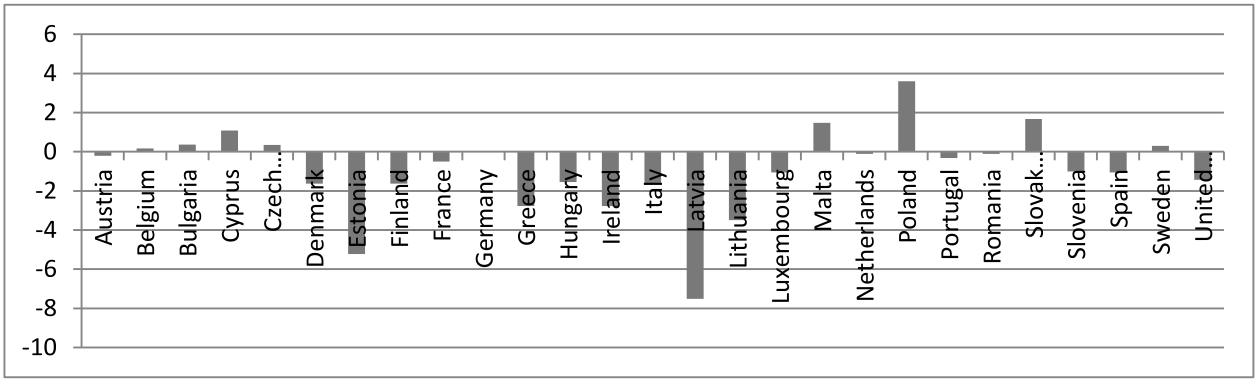
At the start of this study, almost 17 variables were considered. However, variables are prioritized and shortened to 12 because of multicollinearity. However, for testing hypotheses, and in the process of developing empirical models, independent variables were further reduced to follow the rules of Econometrics (see Arceneaux & Huber, 2007). Variations in the results were examined for EU-15 & EU-11 sample too. Independent variables chosen for model versions 5, 6, 7, 8 and 9,10,11,12 were similar to model versions 1, 2, 3 and 4. Also, taking small sample bias into consideration, larger sample use in panel data modelling also avoids individual heterogeneity of EU-27 (see Cho et. al., 2013). Furthermore, this also helped in comparing and contrasting the results obtained from two sample sizes. Howie & Kleczyk (2007) proposed the use of larger sample size for panel data modelling that result in reliable parameter estimation. Independent variables were broadly classified as price variables, economic variables and other variables. “Price variables” consists of the levelised cost of electricity generation for wind (LW) and solar (LS) and electricity prices before taxes for households (EPH) and industries (EPI); Whereas, “economic variables” were clubbed as CO_2 emissions (CE), energy imports (EI), GDP growth rate (GDPG), electricity generation (EG), RES through solar (RES-S) and wind (RES-W). A third broad section, namely “other variables” - consists of annual sunshine hours (ASH), and regulatory quality (RG).

Levelised cost of electricity generation through wind and solar were taken from World Energy Outlook. According to EIA (2013), levelised costs are associated with competitiveness of generating electricity from different sources. The main input to calculate the levelised cost is overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs and an assumed utilization rate for each plant type. Levelised cost is considered to be an important factor in investment decisions associated with the implementation of the renewable energy project (Gross et. al., 2010; Hernandez & Martinez, 2013), because generation of energy from renewable sources is considered to be an expensive operation for businesses (Borenstein, 2011). Levelised cost of electricity generation has been also used as an input variable by Ohunakin (2013) for energy modelling.

EPH and EPI price to final consumers before taxes were taken from Eurostat database. Prices are influenced by local and national circumstances of electricity market regulations. Therefore, the implemented prices are not homogeneous in nature. For formulating model versions 3 and 4, both of these variables were considered to be dependent variables. Additionally, RES also has an impact on prices. These impacts were presented in the RES literature for a long and short runs (See, for instance, Hughes & Barnett, 2012).

Economic variables such as GDP growth (Figure 4.4) and CO_2 emissions (Figure 4.5 & 4.6) are variables that are used by several authors for empirical studies (Kayhan et. al., 2010; Silva et. al., 2012; Kulionis, 2013). Kayhan et. al. (2010) studied the relationship between energy consumption and economic growth. Studies suggest that GDP growth is associated with electricity consumption. In another multivariate framework, Kulionis (2013) examined the causal relationship among renewable energy consumption, GDP and CO_2 emission in Denmark on time series data from 1972 to 2012. The results of this study reveal that there is no statistically significant relationship between economic growth and renewable energy consumption. However, Silva et. al. (2012) observed opposite effects. They examined the effect of GDP and CO_2 on an increasing share of renewable energy on electricity. Results indicate that the renewable energy share has an economic cost on GDP; however, increased share of RES-E has decreased CO_2 emissions per capita.

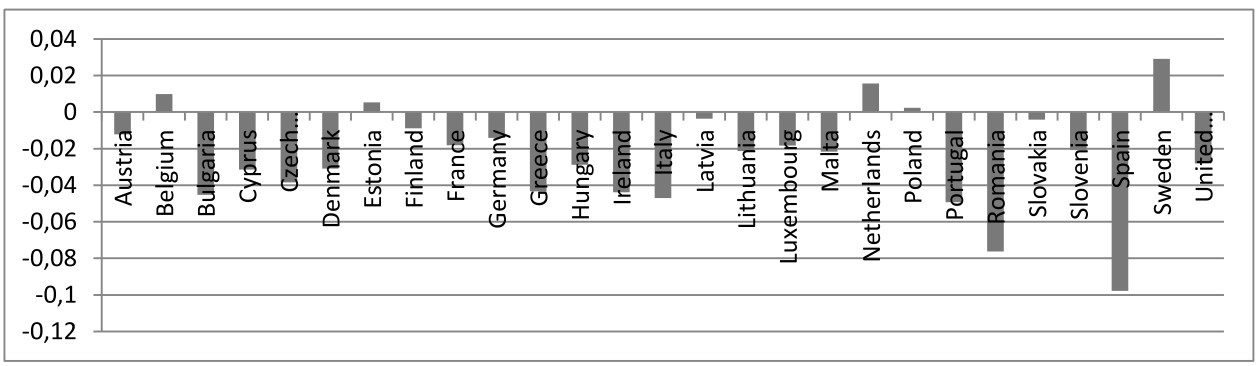
Figure 4.4 Average of GDP growth rate from 2008 to 2010



Source: compiled by author through World Bank database

An overall positive relationship between GDP growth and CO_2 growth can be observed through Figure 4.4 & 4.5. A positive effect in the short run has been tested recently in two studies (Victor, 2012; Narayan & Narayan, 2010).

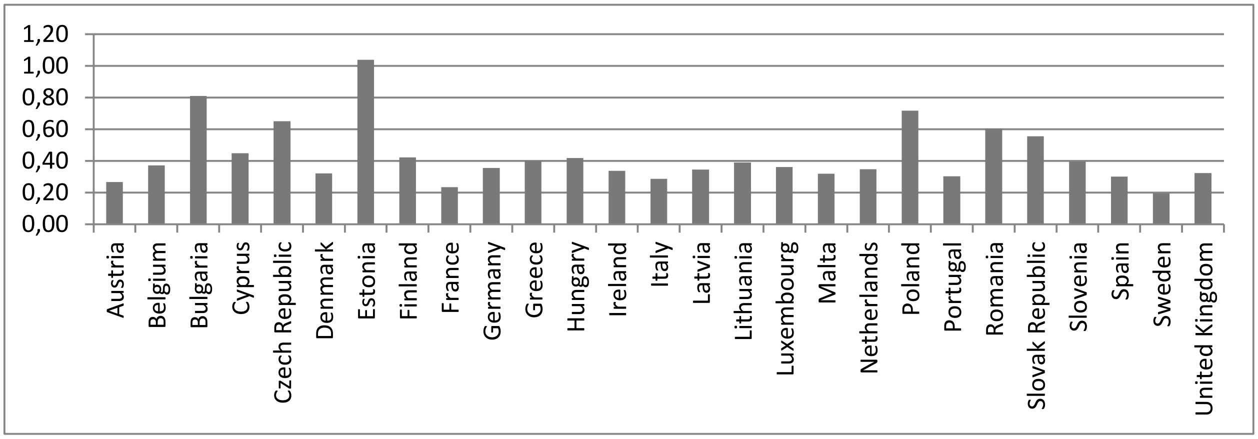
Figure 4.5 Average of CO2 growth rate from 2008 to 2010



Source: compiled by author through World Bank database

A very clear observation of the overall positive relationship was observed for Austria, Belgium, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Poland, Portugal, Spain, Sweden, and UK (Figure 4.4 & 4.5). A correlation was expected between GDP and CO_2 growth. Therefore, CO_2 emissions (see Figure 4.6) were chosen to be one of the independent variables for the current study.

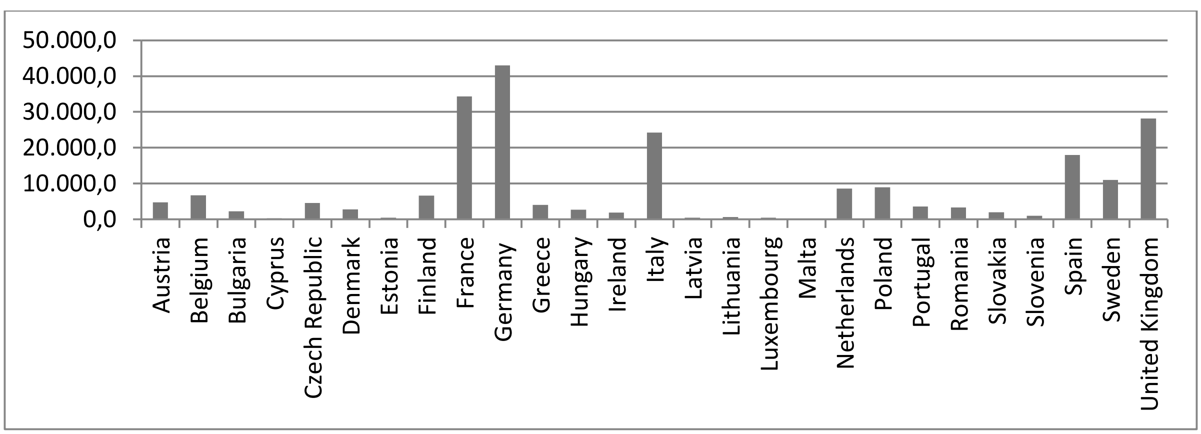
Figure 4.6 Average CO2 emissions (Kg per PPP $ of GDP) from 1995 to 2010



Source: compiled by author through World Bank database

According to Eurostat[9], 11 % of the greenhouse gases emitted each year worldwide come from within the European Union. However, Europe has been able to control its emissions over a long period. According to Figure 4.6, Bulgaria, Estonia, Poland, Romania, etc. are the countries that are observed to be high on their average emissions. Whereas more developed countries such as France, Germany, Italy, Sweden, etc. are able to control emissions over the same period.

Figure 4.7 Average electricity generation from 1995 to 2011



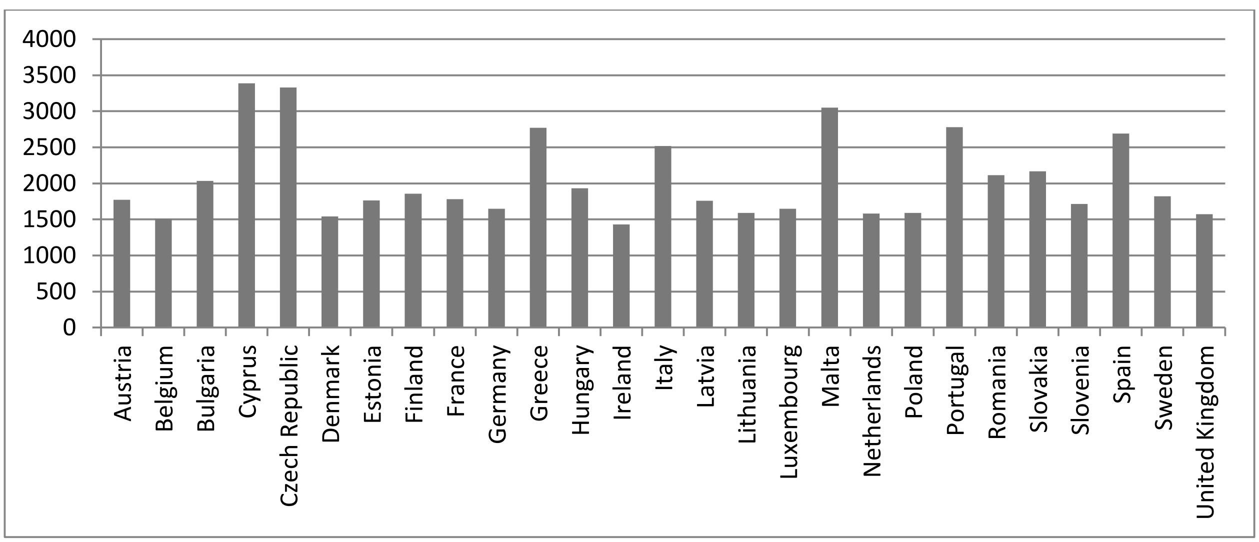
Source: compiled by the author from World Bank database

[9] Source: Eurostat (see EU greenhouse gas emissions and targets http://ec.europa.eu/clima/policies/g-gas/index_en.htm)

Kyoto protocol[10] also allowed countries jointly to fulfil their commitments and thus referred to it as a burden sharing within the group of countries. Figure 4.7 suggests the high electricity production (through all sources) is high in Germany, France, United Kingdom, Italy and Spain; whereas electricity generation is less for Latvia, Lithuania, Cyprus, Estonia, Malta and Slovakia.

Annual sunshine hours (ASH) is assumed to play a critical role in the generation of solar power. The energy generated is obviously related to ASH of each country of the sample. Given the geographical diversities in EU-27, it was expected that the variable would play a significant role in the study. In the current sample that includes 27 countries; 17 countries have annual sunshine hours above 1650 hours; 10 countries have annual sunshine hours less than 1650. Germany was kept as a reference, as it is a country where a solar PV generation is higher, although it has only around 1650 hours of ASH. This cut-off was established to help understand why countries with lesser sunshine hours may invest more on solar energy. However, limitation with using ASH data as a variable is that, it doesn't change dramatically from year to year, and hence, constant values were chosen for the study. Data on ASH was taken from climatedata.eu (Figure 4.8).

Figure 4.8 Average annual sunshine hours



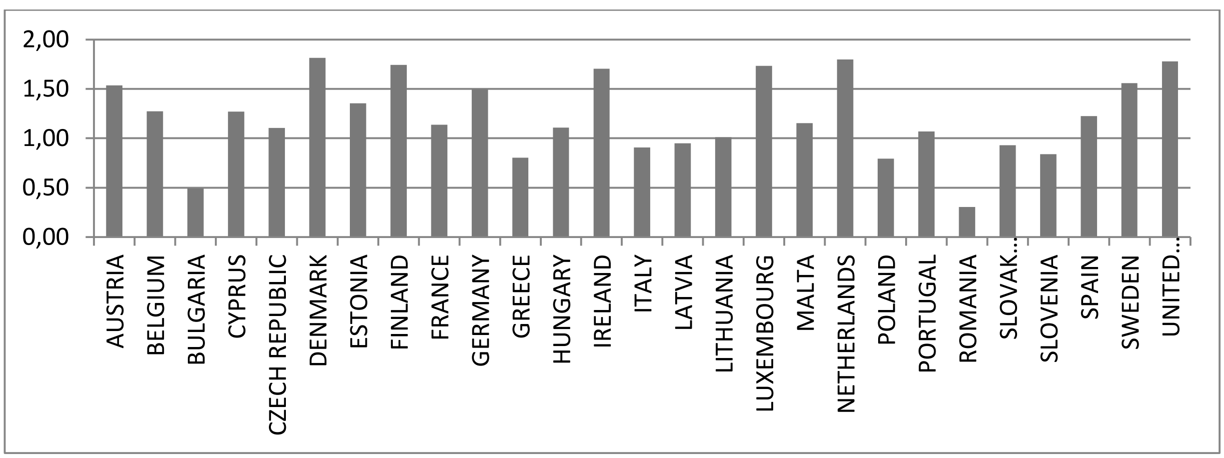
Source: compiled by author from data available at http://www.climatedata.eu/

[10] See Climate Action http://ec.europa.eu/clima/policies/g-gas/kyoto/index_en.htm

Regulatory quality (RG) is a world governance indicator taken from World Bank database. It reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Originally, estimation of governance perception ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance. To make the values positive without effecting the scale, a value 2.5 was added, such that -2.5 becomes (-2.5+2.5=0) zero, and +2.5 becomes (+2.5+2.5=5) five. Thus, the scale is re-stretched from 0 to 5 (weak to strong) to avoid negative values in it. RG was expected to play a positive role in the investment. RG was also expected to be associated with corruption. Although corruption control as a variable was not directly used in the model, but may have an explanation on the results associated with RG.

It is assumed that electricity market regulation is a subset of overall regulation perception. Therefore, RG is considered to be a proxy of electricity regulation perception.

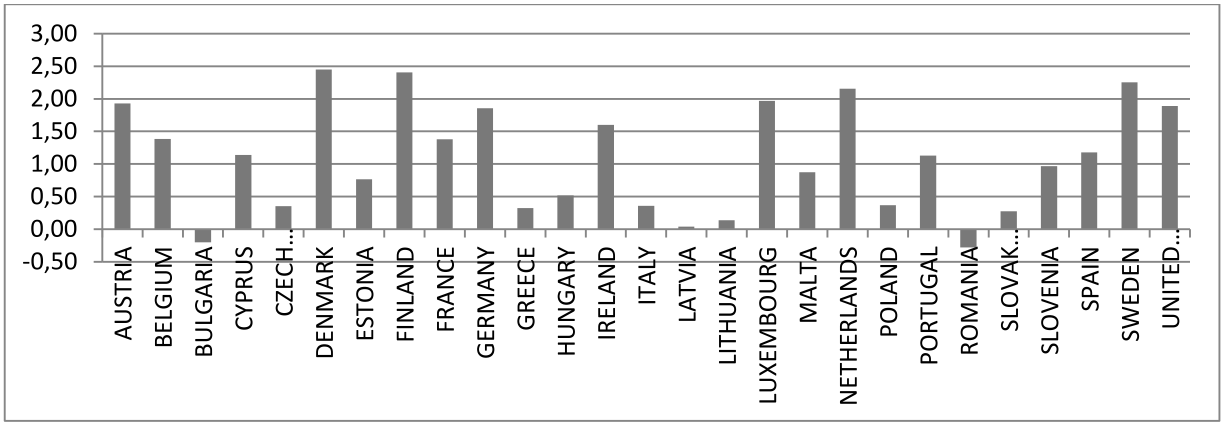
Figure 4.9 Average regulatory quality perceptions 1996 to 2011



Source: compiled by author from World governance indicators. Higher values determine strong regulatory quality

Strong regulatory quality plays a major role in supporting structural reforms of countries (OECD Report, 2010). In other words, strong regulation can be a proxy to strong, consistent and stable public policy and management. Figure 4.9 suggests Romania and Bulgaria are countries that have weak regulatory perceptions. Whereas Denmark, Netherlands, Finland, Ireland, United Kingdom has strong regulatory perceptions.

Figure 4.10 Average corruption control perceptions 1996 to 2011.



Source: compiled by author from world governance indicators. Higher value determines higher control of corruption

Corruption of control (Figure 4.10) is associated with regulation quality. Close observations of Figure 4.9 and 4.10, countries that have high scores on corruption control, also have high scores on regulation quality. For instance, see the case for Denmark, Finland, Luxembourg, Netherlands and Sweden. Although, corruption control variable is not used directly in empirical testing, some of the results were expected to be explained using this variable.

4.5 Understanding the effects of independent variables

As stated, EU-27 has diversity in various forms; each country also has its structured energy policies. Literature suggests that each country is free to develop any source of RES to meet its 2020 targets (see Saraiva et. al., 2011; EREC Report, 2013). That means RES support policies would vary from country to country. Therefore, local and international circumstances influence the electricity markets. Since the implementation results are different for each country, panel data technique in this context fits well to understand and report the results of testing.

For empirical modelling, fixed panel regression was done on four dependent variables, followed by random panel regression with white periods. White periods were used to control heteroskedasticity (see Stock & Watson, 2008). Hausman test was performed to decide between choosing fixed or random panel data modelling. Menegaki (2011), Lee (2013), Moreno (2012) have used Hausman test to identify between fixed and random panel data modelling choice. The null hypothesis is to choose a random effect model. Results of Hausman tests are not significant, so it was decided to use random effect panel data modelling. Granger causality test was also performed to support the outcome of the model (in the long run).

In each case, correlation and heteroscedasticity were tested. We have also applied unit root testing. Correlated and insignificant variables were dropped (for modelling) to keep up with statistical relevance for obtaining the proposed model. Results were checked for relevance and were backed up by existing literature to understand the existing theories from the obtained results. Finally, twelve model versions were proposed; out of which four models were proposed to examine the results for EU-15 sample, and other for presents the outcome of EU-11.

4.6 Underlying assumptions for the model

The following assumptions were made while developing the versions of the model as they represent the actual European framework.

1. Price of solar PV and wind technology has been decreasing over a period due to the technology life cycle.

2. The goals of energy policy in Europe are towards a strict environmental concern (green energy).

3. There are no significant problems concerning grids (transmission and distribution).

4. Time for building wind and solar energy plant is relatively short (Armaroli & Balzani, 2013). Therefore, a time lag of "zero" was considered for solar and wind energy generation. In other words, investments on solar and wind each year were considered to be uninfluenced by previous year(s) investments in the short run.
5. Most of the countries follow feed-in-tariff models and electricity generated through RES is 100% supplied to the grid.

4.7 Empirical models

This section deals with modelling and empirical results. Once more, a survey of the literature on econometric associated with renewable energy was considered. Results obtained in previous studies were considered to back up the findings. However, counter relationships were also observed. The possibility of such variations could be because of the large sample size considered in this study.

Further, hypotheses were formulated to answer major research questions. In the light of this, empirical models were developed. Independent variables that were used are mentioned in Table (4.1). RES-S, RES-W, EPH, EPI were considered to be dependent variables.

Electricity prices are understood as an outcome of supply and demand, investment in electricity generation, business competition, regulatory quality and political intervention. Notwithstanding, in the short run, higher prices of electricity could mean that there is a higher demand, which in turn leads to higher production or import of electricity. RES adds to the production of energy, but in the short run, increased energy production through RES could increase the price in two ways. First, the energy production with lower CO_2 emission has a cost; second, the cost of investment in RES plants are also passed to electricity consumers (see Silva et. al., 2012). Nonetheless, in the long run, after investment costs are recovered, and the RES plant uses freely available solar radiations and wind for electricity generation, the electricity prices are expected to get lowered (Felder, 2011).

Finally, the cross-correlation was performed among variables to decide the final variables used in model building. It was found that electricity prices for households and industries were highly correlated with each other by a factor of 0.74. So, in the modelling process, swapping was done between both variables to avoid collinearity (see Resende, 2013; Ni et. al., 2014). In earlier panel studies, electricity prices were used in logarithmic transformation (Aiube et. al., 2013; Serati et. al., 2008).

Table 4.2: Table showing a correlation matrix of dependent and independent variables

	CE	**GDPG**	**EPH**	**EI**	**LS**	**LW**	**RG**	**RES-S**	**RES-W**	**ASH**	**EPI**
CE	1.00	0.21	-0.47	-0.19	-0.06	-0.11	-0.37	-0.01	-0.31	0.07	-0.39
GDPG	0.21	1.00	-0.29	0.00	0.05	0.09	-0.08	0.00	-0.21	0.06	-0.29
EPH	-0.47	-0.29	1.00	0.28	0.10	0.07	0.28	0.13	0.35	-0.27	0.74
EI	-0.19	0.00	0.28	1.00	-0.16	0.08	-0.11	0.32	-0.09	0.30	0.33
LS	-0.06	0.05	0.10	-0.16	1.00	0.29	0.07	-0.14	0.01	-0.15	0.07
LW	-0.11	0.09	0.07	0.08	0.29	1.00	-0.33	-0.21	-0.22	0.25	0.02
RG	-0.37	-0.08	0.28	-0.11	0.07	-0.33	1.00	0.02	0.39	-0.52	0.06
RES-S	-0.01	0.00	0.13	0.32	-0.14	-0.21	0.02	1.00	-0.06	0.16	0.39
RES-W	-0.31	-0.21	0.35	-0.09	0.01	-0.22	0.39	-0.06	1.00	-0.36	0.29
ASH	0.07	0.06	-0.27	0.30	-0.15	0.25	-0.52	0.16	-0.36	1.00	-0.09
EPI	-0.39	-0.29	0.74	0.33	0.07	0.02	0.06	0.39	0.29	-0.09	1.00

Source: compiled by author

With the current scope, the following four OLS regression models were used to understand the effects of independent variables.

$$\textbf{Yit(RES-S)} = \beta_0 + \beta_1\text{*LS} + \beta_2\text{ *CE} + \beta_3\text{* ASH} + \beta_4\text{*RG} + \text{Uit} \tag{4.1}$$

$$\textbf{Yit(RES-W)} = \beta_0 + \beta_1\text{*LW} + \beta_2\text{ *CE} + \beta_3\text{* ASH} + \beta_4\text{*RG} + \text{Uit} \tag{4.2}$$

$$\text{Log Yit (EPH)} = \beta_0 + \beta_1\text{*LS} + \beta_2\text{ *LW} + \beta_3\text{* Lag 1*EPH} + \beta_4\text{*CE+ }\beta_5\text{*EG+ }\beta_6\text{*RES-S} + \beta_7\text{*RES-W+ }\beta_8\text{*ASH} + \beta_9\text{*RG} + \text{Uit} \tag{4.3}$$

$$\text{Log Yit (EPI)} = \beta_0 + \beta_1\text{*LS} + \beta_2\text{ *LW} + \beta_3\text{* Lag 1*EPI} + \beta_4\text{*CE+ }\beta_5\text{*EG+ }\beta_6\text{*RES-S} + \beta_7\text{*RES-W+ }\beta_8\text{*ASH} + \beta_9\text{*RG} + \text{Uit} \tag{4.4}$$

where i = 1,.,27, t = 1995,.,2011, and β_0 parameters denote country effects which are included in the model in order to take account of any possible country-specific factors that may have an influence on prices beyond the explanatory variables included. The disturbance of this model is denoted by Uit and is assumed to be independent and identically distributed random variables with mean zero and variances σ^2u.

Further, RES market is considered to be a dynamic market in the current context with several new businesses enter in and increase the competition in the sector (Peter, 2013). Investment in RES in a particular year may not be dependent on investment in the previous year. In order to understand which panel model is suitable for data modelling, Hausman test was performed. P value in our case was higher than 0.5, which suggested that a random effect model (over the fixed effect model) is a choice for the study.

4.8 Results: A critical analysis

The results of the study are shown in table 4.3. To check the diverse effect of relatively large sample of EU-27, the results are compared with EU-15 sample. A major consideration for the analysis is the determination of coefficient values and levels of significance. In our analysis, we observe low R-squared (for Model version 1 & 2). However, model correctness is not always associated with high R-square; increasing the independent variables in a regression increase the value associated with R-square, and in some cases lower R-square indicates greater selectivity (Ahimud & Goyenko, 2013).

Table 4.3 Results of model versions (MV)

		EU-27								**EU-15**							
		RES-S MV 1		**RES-W MV 2**		**Log (EPH) MV 3**		**Log (EPI) MV 4**		**RES-S MV 5**		**RES-W MV 6**		**Log (EPH) MV 7**		**Log (EPI) MV 8**	
	LS	-0.002				0.000		0.000		0.000				0.000		0.000	
	LW			-0.044	*	0.000		0.000				-0.042	***	0.000		0.000	
	Lag EPH (-1)					0.879	*							0.920	*		
Price variables	Lag EPI (-1)							0.847	*							0.923	*
	CE	-1.513	*	-9.748	*	-0.109	**	-0.174	*	-6.236	*	-49.688	*	-0.172	**	-0.177	**
	EG					0.000		0.000	**					0.000		0.000	
Economic	RES-S					0.000	***	0.002	***					0.003		0.003	
variables	RES-W					0.000		0.002	**					0.001	***	0.001	
Other	ASH	8.129	*	-6.699	**	-0.007		-0.009		-0.175		-9.150	*	-0.001		0.003	
variables	RG	-0.916	***	-2.231		0.017		-0.035		-1.285	***	-3.463		0.042	**	0.046	**
R-squared		0.034		0.128		0.918		0.863		0.238		0.455		0.918		0.918	
Adjusted R-squared		0.021		0.116		0.915		0.859		0.220		0.443		0.913		0.913	
F-statistic		2.685		11.261		315.98		176.37		13.632		36.531		203.01		195.539	
Prob(F-statistic)		0.032		0.000		0.000		0.000		0.000		0.000		0.000		0.000	

*significant at 1% level
**significant at 5% level
***significant at 10% level

In the model version 1, we found solar investments are not significantly affected by electricity prices of either household or industries. However, carbon emissions and regulatory quality negatively affect investment in solar with a factor of -1.5 and -0.91 respectively, and are highly significant at the 5 % level. Literature suggests that the electricity market is highly sensitive to regulatory policies; higher regulatory quality is perceived to have higher formalities and higher taxes, which can be offset in the short run by giving bribes and saving money (World bank report, 1997; Johnson et. al., 1998). To more recent, Cambini & Rondi (2009), also studied the relationship between regulatory regimes and investment through panel data modelling and found a negative relationship between regulations and investments. It could also give us the logic to believe that businesses want to save money on taxes and also want to avoid the tedious formalities leading to bribes.

Another perspective is that, lower quality of regulation can be associated with fewer formalities because of which businesses feel comfortable to invest. Furthermore, possibility of higher investment in countries that have a high regulatory quality could also be due to their stringent environmental policies. Such stringent environmental policies give the business opportunity to align with the aim of government; and they might tend to invest more. For example Germany, Denmark, the Netherlands and Sweden have the highest perception of regulatory quality and investment in solar is also higher than that of other countries.

However, observation on EU-27 and EU-15 is not enough to conclude the negative association of RES-S with regulation and emissions. Therefore, to check the variability, top 11 EU countries in terms of RES-E generation were considered. The countries included in the sample were Austria, Denmark, Finland, France, Germany, Italy, Netherland, Poland, Italy, Spain and Sweden. Regression model version 1 was used to check for the result (see equation 1). Results obtained for 11 selected countries suggest that the regulation has no significant effect on solar energy investment. In other words, regulation has no role to play in solar energy investment in countries that are considered high on solar energy generation.

Nonetheless, carbon emissions were found to have negative association and were significant at the 5 % level. Further, the association was checked using the Granger causality test. Granger causality test was done (using two lag periods) to find a long run relationship between RES-S and CE; indicates there is no relationship in the long run.

The rationale for the above-mentioned conclusion is that in the long run, European countries are able to control the emissions. Therefore, the emission curve might be stagnant or falling down for the majority of the countries, thus might be less significant in terms of solar investment.

On the other hand, ASH is positively and significantly (at the 1 % level) associated with RES-S. That means higher the ASH is, the higher is the attraction for investment in solar energy.

Model version 2 explains the determinants of investments in wind. Although, levelised cost of electricity generation through wind (LW) is highly subsidized (Lazard Report, 2013), still the effect is observed for wind investment due to the continuously dropping prices of wind technology (Ernst & Young Report, 2012). That means the lower the LW is, the higher the investment (in wind) would be. This was found significant at the 1 % level. On the other hand, CO_2 emissions (CE) were observed to be highly significantly and negatively associated with wind investment by a factor of -9.74. A negative association of CE raises new questions, such as, does model explain that the countries that can reduce carbon emissions give higher incentives and opportunities to invest in wind power? Or, it is a consequence of investing in RES-W over a long time?

To answer the above questions, again regression using model version 2 was performed in countries with high investment in RES-E (top 11 countries in terms of RES-E were selected). The results suggest (table 4.4) that the regulation has no significant relationship with an investment in the wind sector; whereas, carbon emission was still negative and significantly associated with RES-W. To further check this negative association in the long run, Granger causality test was performed.

Table 4.4 Model versions depicting results from EU-11 sample (countries include Austria, Denmark, Finland, France, Germany, Italy, Netherland, Poland, Italy, Spain, Sweden)

		RES-S		RES-W		Log(EPH)		Log(EPI)	
		MV-9		**MV-10**		**MV-11**		**MV-12**	
Price variables	LS	0.000353							
	LW			-0.01275		0.000234		5.67E-05	
	Lag EPH (-1)					0.915618	*		
	Lag EPI (-1)							0.830227	*
Economic variables	CE	-3.00529	**	-19.5562	*	-0.10086	**	-0.21309	**
	EG					-9.25E-07	***	-1.46E-06	**
	RES-S					0.013537	*	0.016705	
	RES-W					2.87E-05		0.000805	
Other variables	ASH	-0.6623	**	-9.01976	*	-0.01882		-0.03119	
	RG	-0.65391		-2.32685		0.007107		-0.04458	
R-squared		0.106959		0.216815		0.925574		0.845201	
Adjusted R-squared		0.075897		0.189574		0.919737		0.832302	
F-statistic		3.443377		7.959074		158.5622		65.52011	
Prob(F-statistic)		0.010701		0.000011		0		0	

*significant at 1% level
**significant at 5% level
***significant at 10% level

The result suggests that in the long run there is no significant relationship between RES-W and CE. However, ASH is negative with a coefficient of -6.7 and is significant at the 5 % level. This also means that lower ASH leads to higher investment in wind energy.

In model version 3, wind and solar energies were expected to influence the prices of households. However, it is observed that the RES-S and RES-W do not play a significant role in determining household electricity retail prices. Electricity generated through RES-S and RES-W is sold in the electricity market at wholesale price. Later electricity is redistributed by suppliers through networks to households. Therefore, variations between wholesale and retail prices might not be explained thoroughly in the model.

Nonetheless, lag (1 year) electricity price of household play significant (at 1%) and critical role in determining the electricity price of households by a coefficient of 0.87. Furthermore, no significant relationship is observed for LS, LW, EG, ASH, RES. However, a statistically significant (at the 5 % level) and negative relationship with a coefficient of -0.1 is observed for carbon emissions- which also signifies that the cleaner the energy is, the higher the price customers have to pay in the short run. Additionally, no significant variations are observed over EU-15 (model version 7), except for regulatory quality (RG). RG was found to be positive by 0.04 and significant at the 5 % level- which explains that over a large sample, the effect of RG on EPH is not observable.

In model version 4, electricity prices for industry (EPI) were found to be insignificant for LW and LS; CE is negative with a factor of -0.17 and significant at the 1 % level. The results obtained are similar to results obtained by Paul et. al. (2013) and Mulder et. al. (2013). They found a positive relationship between electricity prices and RES generation; this reinforces that the cleaner the energy is, the higher the price customers have to pay in the short run.

However, the portrayed effects are already known. Probably what is less known is the effect of solar and wind energy in the increase of EPI. Effects of solar and wind are found to be positive and significant; however, values of coefficients are not significant. ASH is not found to be significant for EPI.

Similarly for EPH, RG was found to be positive by a factor of 0.04 and significant at 5% for EU-15. This means that a large sample is not able to capture the effect of RG on EPI.

Table 4.5 Consolidated results of hypothesis tests

Research Question	**Hypothesis**	**EU-27**	**EU-15**	**EU-11**	**Granger causality at lag 2 (EU-27)**
RQ1: Which are the determinants of solar energy investment?	H1a: Higher sunshine hours lead to higher electricity generation through solar	Do not reject	No significant relationship	Reject	No relationship
	H1b: Strong regulation perception leads to higher investment in solar	Reject	Reject	No significant relationship	No significant relationship
	H1c: Higher carbon emissions lead to higher investment in solar	Reject	Reject	Reject	No significant relationship
RQ2: Which are the determinants of wind energy investment?	H2a: Lower sunshine hours lead to higher electricity generation through wind	Do not reject	Do not reject	Do not reject	No significant relationship
	H2b: Strong regulation perception leads to higher investment in wind	No significant relationship	No significant relationship	No significant relationship	No significant relationship
	H2c: Higher carbon emissions lead to higher investment in wind	Reject	Reject	Reject	No significant relationship
RQ3: Which are the determinants of electricity prices for households?	H3a: Higher share of electricity generated through solar leads to higher electricity prices for households	Do not reject	No significant relationship	Do not reject	Significant relationship
	H3b: Higher share of electricity generated through wind leads to higher electricity prices for households	No significant relationship	Do not reject	No significant relationship	Significant relationship
	H3c: Cleaner energy supply leads to higher electricity prices for households	Do not reject	Do not reject	Do not reject	Significant relationship
	H3d: Stronger regulation perception leads to higher electricity price of households	No significant relationship	Do not reject	No significant relationship	Significant relationship

RQ4: Which are the determinants of electricity prices for industries?	H4a: Higher share of electricity generated through solar leads to higher electricity prices for industries	Do not reject	No significant relationship	No significant relationship	Significant relationship
	H4b: Higher share of electricity generated through wind leads to higher electricity prices for industries	Do not reject	No significant relationship	No significant relationship	No significant relationship
	H4c: Cleaner energy supply leads to higher electricity prices for industries	Do not reject	Do not reject	Do not reject	No significant relationship
	H4d: Stronger regulation perception leads to higher electricity price of industries	No significant relationship	Do not reject	No significant relationship	No significant relationship

Source: Developed by the author

The table has presented the consolidated hypotheses testing results for EU-27, EU-15 and EU-11. For few of the hypothesis we obtained consistent testing results (e.g. H1c, H2a, H2b, H2c, H3c, H4c); whereas, for few of the hypothesis, contrasting results were observed in the short and long run (e.g. H4c).

4.9 Conclusion

In the framework of RES investment and the RES effect on the real prices in the liberalized electricity market, this section of the thesis explored the impact of several variables on solar and wind generation; and the impact of solar and wind generation on electricity prices for households and industries. Specifically, we used set panel data provided by Eurostat that covered EU-27 countries during the period 1995 to 2011.

With liberalization, the electricity market has gone through significant changes. RE coming from different sources such as wind, hydro, biomass and PV is expensive to produce and supply;

RE is integrated with the system and is controlled and financed by electricity markets; and finally, the expenses are transferred to end users. However, along with changing the way earlier markets used to operate, reforms gave birth to new business. Electricity started selling at wholesale prices and finally distributed to end customers through distributors and retailers. This brought an organized supply chain in the electricity market.

Despite the reform in the energy market, the quantitative results show that when proportion of renewable energy through wind or solar increases in conventional energy supply there is no significant increase and decrease of energy prices for domestic and industrial customers respectively. However, if solar and wind is not playing a significant role, then which kind of renewable energy leads to increased electricity price could be a question for future research.

Literature suggests that the main reasons for increased electricity prices, when RE is supplied, is due to the system cost that is required to develop the RE plants. It takes time for RE incumbents to recover the money invested in setting up a plant. However, in the long run, given other economic variables remain constant, prices are expected to drop down, as fixed cost would come down after the recovery period.

The most relevant reason that could explain the drop in renewable energy price (through wind) in the future on industry prices, could be because of the continuous electricity that could be supplied to industries round the clock, without requiring energy storage, which significantly raises operation costs. Another important reason would be that industrial needs are higher than domestic needs; therefore, supply to industries would favour the economies of scale, which would lead to decrease the energy price for industries, whereas it would be perhaps the reverse for household prices.

Further, as stated earlier, the macroeconomic model does not take care of the details of the individual renewable energy projects. Therefore, to understand the phenomenon from micro level perspective, a 50 MW wind power project was evaluated using NPV and the real options method. Both the studies were important to understand the investments from different perspectives and thus complement each other.

PART B

Chapter 5

Introduction: renewable energy project evaluation and business risk

5.1 Background and connection with the first part of the thesis

Regulatory risk is commonly accepted as one of the most important risks in the energy business, particularly renewable energy. However, in general, renewable energy can be freely generated from solar, wind, biomass, etc.; the adoption of it at a large scale may be still difficult. The renewable share of electricity has considerably increased in previous years for different EU states (Eurostat). As an example, in Germany the wind capacity has increased to four folds (6GW to 27 GW) over the period 2000 – 2010, and solar capacity has increased to 20 folds (76MW to 17GW) over the same period (Marcatonini & Ellerman, 2013). Thus, with the current estimates for the EU, it appears that in the next few decades, renewable energy will replace a significant part of fossil fuels. For instance, Denmark has a policy goal to supply 100% of renewable electricity by 2050 (Lund, 2012). However, achieving this might still be far from reality until several policy instruments are played effectively. Investment support policies are expected to positively influence the renewable energy generation and business. It has been observed that investment and adoption have two-way relationship; that means investments lead to adoption (Miguel, 2012), and adoption leads to investment (Gordon & Loeb, 2012). The current study is focused on the modelling of business risk associated with the renewable energy investments in the Iberian market due to the current policy changes in Spain.

The first part of the thesis explores the mechanism of the renewable energy investment from a macro perspective. However, macro level study does not cover the details and challenges of renewable energy businesses at individual level. These challenges are associated with the investment decisions of small entrepreneurs, medium sized businesses or industries, and renewable energy incumbents. In another aspect, first part of the thesis has demonstrated the relationship of regulation perceptions to renewable energy generation and the electricity prices. Thus, regulatory revisions can significantly affect the energy generation businesses. This part of the thesis considers a special case of Iberian market where the regulations are revised recently. Therefore, to understand issues related to businesses at micro level, a 50MW wind project is carefully reviewed and investment decisions are evaluated through traditional NPV and real options approach.

Owen (2006) stated *"evaluation is a generic process defined at its most general level as the systematic investigation of the worth or merit of an object. It can be applied at the level of policy, program and project. At the project level, evaluation can be seen as the processes of:*
• Negotiating an evaluation plan with stakeholders;
• Identifying, collecting and analysing evidence to produce findings; and
• Disseminating the findings to identify audiences for use in:
- Describing or understanding the project and/or
-Making judgements and/or decisions related to the project."

An investment project evaluation refers to a cost-benefit analysis a firm does before undertaking, rejecting or delaying any project. Details of investment project evaluation pertaining to this study are mentioned in chapter 7.

As micro and macro aspects of an economy are intertwined, this part of the thesis aims to:

1. Complement the macroeconomic study with a business approach
2. Achieve a detailed understanding of the variables and drivers that impact a renewable energy project

Furthermore, related studies for understanding the uncertainties (in higher detail) will be carried out after completion of doctoral work.

Note: It should be noted that second part of the study is complementary to understand the specific case of Iberian market and it should not be misunderstood as a separate thesis work. We have considered only the major details to execute the study.

5.2 Current changes in the Spanish regulation and objective of the study

In June 2014, Spanish government announced the revised renewable electricity regulations in accordance with the Royal Decree Law no. 413/2014. Several revisions[11] have been introduced to the Spanish electricity market, namely: first, the regulation period is reduced to 6 years; second, remuneration for the first regulatory period is 7.4% (pre-tax), while the third relates to pool prices. The latter means investors are eligible for the subsidy only if standard production is maintained between caps and floors. EDP Renewables, one of the world's largest renewable energy generating and supplying companies has estimated a loss of 30million Euros with the revised regulatory framework.

The Iberian Electricity Market (MIBEL) was initiated in 2001, but started to operate regularly only in 2007. In order to implement MIBEL, the Government of Portugal and Spain chose to agree on a plan for regulatory harmonization. That means the revision of regulations in one market may also largely affect another market. In the current regulatory revision, a simulation study on energy investment uncertainty in the Portuguese framework is a fresh idea and contribution to the literature.

Thus, in the current context, there are two broad objectives of the study-

Objective 1: To find out the renewable energy investment decision through NPV

Objective 2: To find the renewable energy investment decision and business risk through real options by performing sensitivity analysis

[11]Details are available on EDP renewables website http://www.edpr.com/

5.3 Research question (RQ)

Several factors, namely: government policies, friendly business environment, competition, production, consumers, suppliers, etc., usually dictate investment in the business. Renewable energy market is considered to be a dynamic place (Tappesar, 2011) where demand and supply are expected to be dependent upon several factors such as change is government policies, targets, business profits, etc.

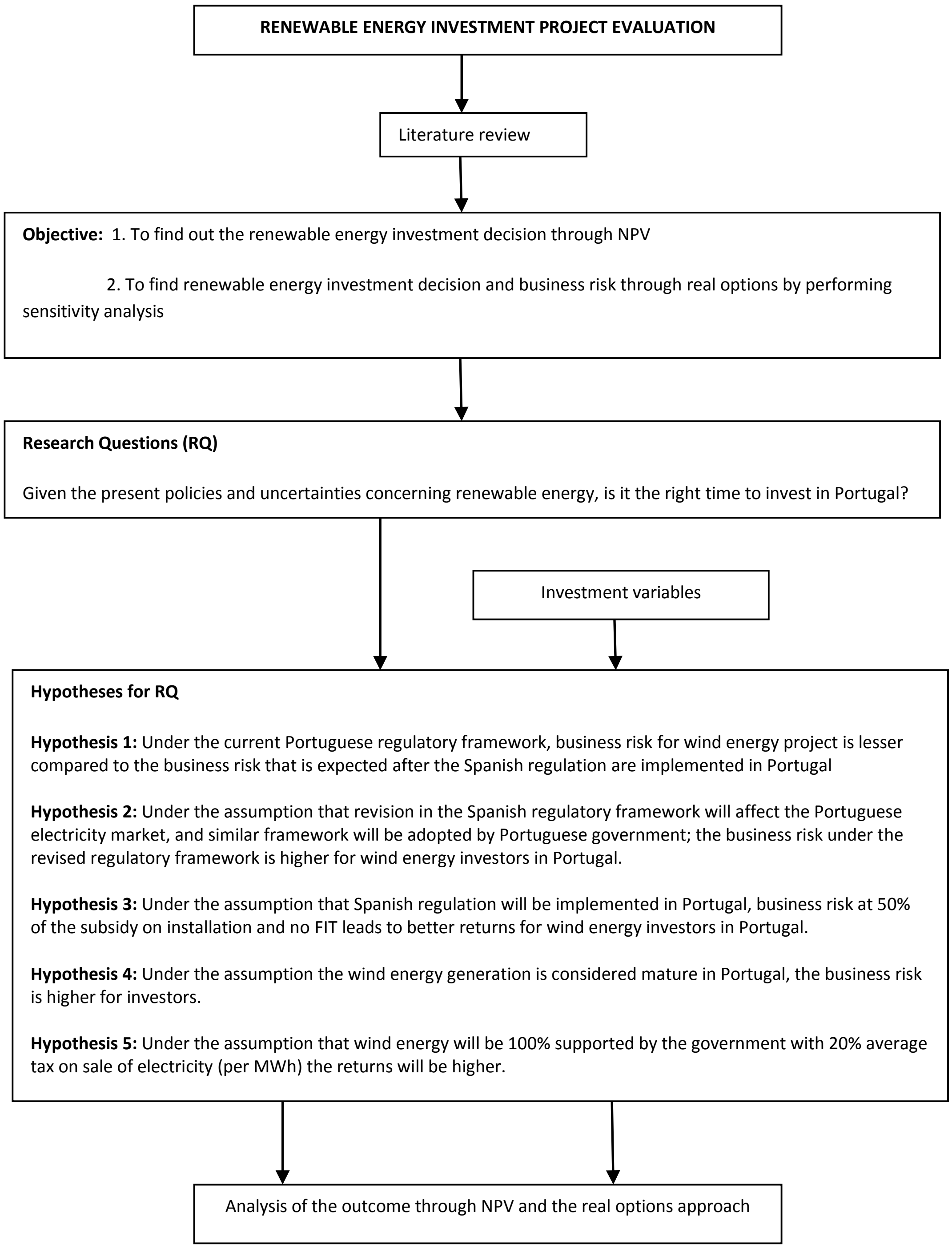
Uncertainties with the revision of regulations, laws and policies are expected to affect the profits of business companies. The more crucial is the transition of ongoing project from one policy framework to another. Therefore, it is reasonable for a business to delay an investment until new information related to government policy arrives. Moreover, policies may also target a specific project size; it is important to consider the size of a plant while evaluating a project.

Within the current scope of the study, following research question is addressed in this part of the thesis-

RQ 1: Under an assumption that Spanish regulations will affect the Portuguese electricity market; Given the present policies and uncertainties, is it reasonable to delay an investment project in Portugal?

Figure 5.1 represents the study flow designed to address the objectives and research question of this part of the thesis.

Figure 5.1 Study flow of second part of the thesis



Source: Designed by the author

5.4 Conclusion

The profit of a business depends upon several factors such as investment costs and incoming cash. Uncertainties in regulation framework are one of the key variables affecting the capital budgeting and return of investment. This chapter dealt with the short introduction of the second part of the thesis. We briefly described the objectives and the connection to the first part of the study. A brief study flow chart was also presented diagrammatically.

The chapter arrangement is continued from part A. Next chapter (Chapter 6) refers to the survey of the literature and the methodologies for evaluation of the renewable energy projects; it describes the traditional and non-traditional approaches to project evaluation. Chapter 7 presents the methodology and results of Part B of the thesis; whereas, chapter 8 concludes the thesis.

Chapter 6

Literature review: the real options approach to project evaluation

6.1 Introduction

According to project guidelines provided by the New York University[12], project evaluation refers to *a methodology for assessing the economic, social, environmental and financial impact of proposed capital projects.* Project evaluation can be done by various techniques. Remer & Nieto (1995) proposed 25 techniques and methods to assess the economic value of the projects. These 25 methods are classified into five categories: *net present value (NPV), internal rate of return (IRR), ratio return, payback and accounting method*. Details of these methods are found in the later sections. Above mentioned methods are also used to conduct sensitivity and scenario analysis. For an instance, Borgonova & Peccati (2004) used NPV and IRR methods to perform sensitivity analysis to understand the business risk (in terms of varying cash flows) of a power generation company. Further, Dey (2006) proposed multiple criteria evaluation using analytical hierarchical process (AHP) to understand the pipeline project from marketing, social and environmental perspectives. He performed a sensitivity analysis using AHP and concluded that model facilitates communication among stakeholders in a structured way. The AHP provides a flexible and easy way of analysing complicated problems. It uses multiple criteria decision-making techniques to be considered in the decision-making process (Saaty, 1980).

Researchers have used several methods for the evaluation of business projects and also have compared the traditional and non-traditional methods (Santos, 2014). However, in different scenarios and various projects within an energy domain, different authors have applied varying methodologies to address the project risk. Fagiani et. al. (2013) presented the application of

[12] Project evaluation guidelines, Queensland treasury 1997 , New York University, Stern
http://people.stern.nyu.edu/adamodar/pdfiles/eqnotes/PROJGUID.PDF

system dynamics method for evaluating the renewable energy support schemes (mainly feed in tariffs and renewable energy certificates). The objective of this study was to compare the economic efficiency of two support systems. The outcome of the study suggested that the feed-in tariff is better to stimulate the market at initial level. However, renewable certificates increase the share of renewable energy in the electricity market if the perceived risk of the investment is moderate. One of the important observations presented by them is related to the indicator for evaluating the cost efficiency of support schemes. It is mentioned that this indicator can be obtained by dividing total policy cost by quantity of renewable electricity generated (also see Miera et. al., 2008). Support schemes cost can be calculated by benchmark cases in which renewable energy is presented as unsubsidized option.

However, in recent days, the real options method is widely used in investment project for business risk evaluation. The real options method is referred to an appropriate method in dynamic markets like renewable energy (definition, details and references can be found in further sections).

Further, there is still a debate on considering renewable energy to be competitive with conventional sources of energy, and the referred significant barrier constitutes a higher investment cost (Menegaki, 2008). To overcome this obstacle, adequate government support schemes play a significant role in making it competitive and increasing its share of electricity production (Haas et. al., 2011). On the other hand, it is also reported in the literature that support schemes are just one way of trying to bring renewable energy as a source of mainstream energy generation; and in order to increase the production of electricity through these sources, it is necessary to understand and model the uncertainties of government support schemes (Munoz et. al., 2011).

Traditional approaches like NPV and DCF have limitations in addressing uncertainties and flexibilities. Therefore, understanding project decisions strategically that makes it profitable is difficult with NPV and DCF. The real options approach takes care of the limitations of NPV and DCF methods (Martinez, 2011; Kumbaroglu, 2008).

6.2 A traditional approach

6.2.1 Project and risk evaluation

Karmperis et. al. (2011) mention that IRR method is based on discounted cash flows and it is widely used for evaluating a project and a business risk during the initial stage. They developed an algorithm for analysing environmental project using IRR and Monte Carlo simulations. The primary aim of the study was to provide decision makers a support to choose a project with maximum profit.

Driver & Whelan (2001) put forth four categories of theories that are associated with capital investments under risk. These four categories are 1) Non-linearities, 2) Rationing disequilibrium, 3) Risk attitude, and 4) Dynamics and irreversibility.

Furthermore, under the renewable energy framework, European regulations have encouraged the energy efficiency projects in the EU building sector. This encouragement is regarded as one of the components towards meeting EU 2020 targets (Chachoua, 2013). In addition, a healthy relationship was also found between reduction of carbon emissions and energy efficiency. Institute for Building Efficiency Report (2013) mentions, "*Energy or carbon reduction targets correlate strongly with more action on energy efficiency".* In the same lines, Mills et. al. (2006) broadly identified five areas of risk associated with energy efficiency investments (Table 6.1). Each of these areas has intrinsic (controllable) and extrinsic (uncontrollable) aspects. Economic zone includes factors such as energy-cost volatility, tariff structures, tariff levels, and labour costs. Whereas, contextual risks include the quality and completeness of the information on the plant layout, services and environmental conditions (For example, weather patterns, energy service levels and changes in occupancy). Other examples of technology risk comprise of equipment performance and technology shift. Examples of operational risks include degradation of energy savings over time due to poor maintenance, revisions in baselines due to changing operating hours, peak loads (or average load), etc. Risks associated with the measurement and verification of savings vary from simulation and metering accuracy to measurement bias. To model the uncertainties created through multiple variables, Monte Carlo[13] techniques are also widely used for energy efficiency measurements (Laurikka & Kolijonen, 2006).

Table 6.1 Matrix of risks associated with energy-efficiency projects

	Intrinsic factors	Risk management	Extrinsic factors	Risk management
Economic			Fuel costs	Hedges; fixed-price contracts
			Demand charges	Hedges; fixed-price contracts
			Cost of capital	Risk-based rates
			Exchange rates	Hedges
			Labour costs	Fixed-price contracts; inflation bonds (dirty hedges)
			Equipment costs	Fixed-price contracts; inflation bonds (dirty hedges)
Contextual	Information on facility	Due diligence; surveys	Environment	Pre-project data analysis, weather Hedges
	Applicability/feasibility	Careful design	Energy service levels	Contractual exclusions/ adjustments
Technology	Equipment performance	Design, specification, measurement; ESI; stipulated savings	Equipment lifetime	Careful design; specification; contractual exclusions
	System performance	Measurement		
	Equipment sizing	Design		
Operational	Degradation of savings	Monitoring and diagnostics	Persistance	End-user training and information; contractual exclusions; occupant incentives
	Baseline Adjustments	Contractual adjustments		
	Indoor environmental quality	Liability insurance		
Measurement and verification	Data quality	Engineering review		
	Modeling errors	Model validation		
	Energy power (kWh,therms,etc.)	Adequate measurement plan and equipment		
	Metering precision/ accuracy	Proper metering specification/procurement/ testing		

Source: Mills et. al. (2006)

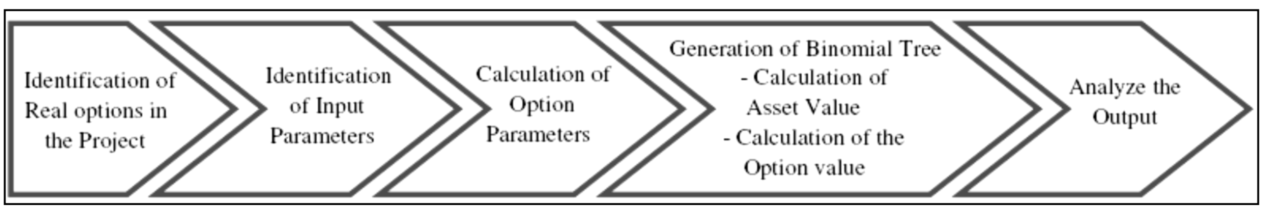
[13]Monte Carlo simulation method is a problem solving technique used to approximate the probability of certain outcomes by running multiple trial runs, called simulations, using random variables.

6.3 A non-classical perspective: Real options (RO)

6.3.1 Application of real options

Meyers (1977), first proposed a real options framework that assists managers and decision makers with the options to invest, grow or abandon a project with the arrival of revised information. A vast literature is available on the use of real options in several fields. Examples of such areas are: research and development projects (Schneider et. at., 2008; Eckhause et. al., 2009), information technology projects (Kumar 2002; Schwartz& Zozaya-Gorostiza, 2003), renewable energy (Santos et. al., 2014; Eyre, 2013), etc.. Padhy & Sahu (2011) proposed that option to wait or defer is embedded in most of the projects. Figure 6.1 put forth the procedure for determining the values of real options.

Figure 6.1 Procedures for determining real options valuation of projects



Source: Padhy & Sahu (2011)

Some authors suggest the use of decision tree analysis (for instance, see Matsubara, 2001). The decision tree enables to choose nodes (cases) with maximum values which can further be enhanced by real options (Copeland & Antikarov, 2001). Wagner et. al.(2014) studies 21 supply chain projects that faced numerous risk and resource constraints; introducing the real options approach to addressing uncertainty and flexibility in project scheduling.

In another study, Maklan et. al. (2005) used real option in addition to the discounted cash flow method to model the investment and business risk associated with customer relationship management. The outcome of the study suggests that the discounted cash flow method is not enough to account for the long-term investment. Under high uncertainty, real option is a better approach to understanding the avoidance of high market risk with the option of investing later.

6.3.2 Real options theory

Investment analysed with errors, which are unstructured and not planned strategically could bring in loss to the project values and could lead to a bankruptcy of an enterprise. Therefore, for long-term success of a firm, a good financial management along with strategic capital investment is required (Bennouna, 2010).

NPV and DCF methods are used worldwide to take the investment decisions (Graham & Harway, 2002; Ryan & Ryan, 2002). However, in today's scenarios where businesses are dynamic, the risk and uncertainty associated with business could be unpredictable. NPV and DCF do not take into account the irreversibility and uncertain risks into account. Additionally, these two methods also do not have an explanation of deferring now and taking up the project later when market conditions are appropriate to it (Dixit & Pindyk, 1994).

Therefore, business can always seek a value by having an option that would have an opportunity to invest in later stage, or flexibility to expand (Fernandes et. al., 2011), or simply not invest (Dixit & Pindyk, 1994). "Real Option", the term was first coined by Meyer (1977). Trigeorgis (2000) also supported Meyer by stating

> *"An options approach to capital budgeting has the potential to conceptualize, and even quantify, the value of options for active management. This value is manifest as a collection of corporate real options embedded in capital investments opportunities...".*

Unlike NPV and DCF, real options theory provides a support to managerial flexibility that addresses decisions under different scenarios and account for the high level of uncertainties. This theory is a modern approach to risk evaluation of a project (Marreco & Carplo, 2006).

Real options is also considered to be an extension of the theory of option-pricing. The concept arises from financial option, and it was developed by Black & Scholes (1973). Options pricing considers both kinds of options (real and financial) for investments.

6.3.3 Real options definitions

There are a few definitions of "real options" available in the literature.

According to Kogut & Kulatilaka (2001), real options are defined as *"an investment decision that is characterized by uncertainty, the provision of future managerial discretion to exercise at the appropriate time, and irreversibility"*.

Copeland & Antikarov (2003) define a real option "*as a right, but not the obligation, to take an action (e.g., deferring, expanding, contracting or abandoning) at a predetermined cost, called exercise price, for a predetermined period – the life of the option"*.

Thus, investment opportunity is referred as a call option. In other words, a firm that wants to invest money or exercise price has an option to invest now or in the future. Table 6.2 suggests the analogy of the call options and the project characteristics.

Table 6.2 Analogy of the call option and the project characteristics

Project characteristics	Call option
Present value of expected cash flows	Stock price
Present value of investment outlays	Exercise price
Length of deferral time	Time to maturity
Time value of money	Risk-free rate
Volatility of project's returns	Variance of stock returns

Source: Fernandes et. al. (2011)

6.3.4 Financial call options

Black & Scholes (1973) mention *"An option is a security giving the right to buy or sell an asset, subject to certain conditions, within a specified period".* Broadly, there are two kinds of options. First, it gives a right to call (or buy) an asset at exercised price in a particular estimated time (or time of maturity). Second, it gives a right to put (or sell) an asset in specified time (time of maturity). Thus, Fernandes et. al. (2011) mentions that when the choice to exercise price is less than the current price of the asset (for a call option), or more than the current price of the asset (for a put option), the option is said to be "in the money"; Otherwise, it is "out of the money".

Options can be of two natures- either European or American. An option that can be exercised only on the maturity that option is designated to be a "European option"; whereas, the option that can be exercised at any time before maturity, is called an "American option".

6.3.5 Types of real options

In this subsection, a summary of the types of real option is presented. Major real options mentioned by Trigeorgis (2000) are related to deferring, time-to-build, alter operating scale, abandon, and switch and growth options.

Defer refers to the ability of an investor to wait for pre-specified time and exercise an option when maximum profits are expected from the market changes. In other words, the investor has a choice to invest now or wait for further information related to uncertainty to invest later (Dixit & Pindyk, 1994). These options are commonly exercised on projects related to mining, farming, and real estate development. However, in another kind of industries such as pharmaceutical, energy, construction, etc., the long-term capital investment returns can be received only after a project completes. This option refers to time-to-build (Trigeorgis, 2000). Kudankulam nuclear power plant (in India) could explain better the consequence of exercising such kind of an option in particular situations. The project started in 2002 and was formally commissioned in 2013 after six years from the scheduled date. Main reason quoted for this delay was the people's protest against safety concerns (Press Trust of India, 2013). However, the return on investment in such kind of a project is also delayed, finally bringing in the loss to the business in the short run.

Whereas, in another kind of real option related to scale of operation, investor is offered a flexibility to expand it if market conditions are expected to be favourable, and to reduce the level of production if market situation is bad (Trigeorgis, 2000). Examples of such industries are natural resource industries, manufacturing industries, construction industries, facility planning and commercial real-estate firms.

In situations, when the market shift informs adverse conditions to the project, there is an option for an investor to sell the available assets. This might be important to avoid further losses in the investment on the project. Real option gives a choice to the decision maker to abandon such projects if unfavourable information related to a project arrives (Majd & Pindyk, 1997). This option might be sometimes important in capital intensive industries like railroads, airlines, financial services, introduction of a new product, etc. (Meyers & Majid, 1990).

Further, when there is a sudden shift in the demand function of an industry, the firm can have the option to produce similar kinds of products from the same machineries (changing the output). On the other hand, using varying raw materials, a firm can produce the same product (changing inputs). These options are referred to as "Option to switch", as they offer a greater flexibility to an investor (Trigeorgis, 2000; Kulatilaka & Trigeorgis, 1994). Another referred option is "growth". In strategic industries like R&D, high-tech, pharmaceuticals, etc., the option for acquiring necessary capabilities can be exercised by strategic acquisitions that can offer firm an advantage to grow in the future (Kulatilaka & Perotti, 1984).

6.3.6 Value of the real options

Within a specified time, if the option can be strategically considered, it is expected to have a value. The values of such options depend majorly on six variables (Copeland & Antikarlov, 2003). The first is related to the value of an asset: if the value of asset increases, the value of an option also increases. The second is associated with an exercised price: value of exercised price is inversely associated with the value of an option. That means if exercised price increases, the value of an option decreases. The third is related with time: whether the value of an option increases with time. Whereas, fourth is linked to the uncertainty: if the managerial decision has flexibility, the value of an option increases with increasing uncertainty. The fifth is associated with a risk-free rate of interest: if risk-free interest goes high, the value of an option enhances. The sixth and final variable is related to dividends: an increase in the amount of dividend paid would increase the value of an option.

Post identification of variables, the valuing of real option could be possible. Amram & Kulatalika (1999) suggested four-step solutions related to (i) better frame the application of real options, (ii) identifies the inputs and the valuation models, (iii) provide benchmarks for interpreting results, (iv) implementation of the options valuation model and to review the results and the redesign if required.

First step reflects the framing and timing of possible decisions to be made. Chorn & Shokhor (2006) studied the policies related to investment in the petroleum industry. They understood and framed the problems, and used these problems as an option for development of policies. Further, they considered real options to address the uncertainty. Similarly, in different studies related to energy, real options are used to address the uncertainty (Yang & Blyth, 2007; Blyth & Yang, 2006).

In the second step, for realizing the values of real options, it is important to express it mathematically. Black & Scholes (1973) proposed the mathematical formulation of such problems and later the formulation was applied by authors like Amram & Kulatalika (1999) and Merton (1973). Cortazar et al. (1998) proposed a model that mathematically explains the proper time of an investment (in environmental technologies) by the firm. Description of how future payoffs are influenced by current decisions is also explained mathematically.

The third step proposed by Amram and Kulatilaka (1999) is the review of the results, such as discounted cash flow. The fourth step proposes the redesign. D'souza (2002)[14] mentions *"redesigning the project enables managers to learn more about the market at an earlier stage, thereby creating an opportunity to modify the marketing plan and increase the chance of market success".* Besides the Amram and Kulatilaka (1999) approach, other authors (e.g., Copeland & Antikarov, 2003; Dixit & Pindyck, 1994) also presented real options valuation processes.

6.4 Real options applications in the energy sector

Since 1970, the worldwide energy market has gone through deep changes in terms of regulation, technology, distribution, etc. (Fernandes et. al. 2011). With the dynamic shifts across the market, other changes within the market such as increased competition, government intervention and uncertainty have also been observed (Awerbuch, 1996). Tappesar (2012) reinforces it and mentions that the renewable energy market would soon become uncontrollable with present regulatory conditions in Europe. An uncontrollable movement of the electricity market would also account for an uncertainty.

Real options approach addressed various issues related to the energy industry. In the early phase of renewable energy development, Brennan & Schwatrtz (1985) studied and evaluated the irreversible nature of natural resources in Chilean copper mines using options pricing methods. Paddock et. al. (1988) and Ekern (1988) used the real options method to evaluate investments in the oil industry.

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[14]Redesign definition is taken from Harvard Business School archive Putting Real Options to Work to Improve Project Planning - Project Analysis? Climb the Decision Tree

The academic use of real options approach seems to increase over the period 1990-2000. In line, Dixit & Pindyk (1994), Trigeorgis (1996) and Amran & Kulatikala (1999) published books containing cases related to the use of real options in energy.

Felder (1996) and Ghosh & Ramesh (1997) noted that the power sector reform are subjected to market risk and proposed an options pricing method for future electricity markets. They also noted the constraints associated to power sector planning, operationalisation, distribution requirement. Moreira et. al. (2004) studied the investment attractiveness for power generators in Brazil using real options, whereas Hlouskova (2005) investigated the optimal value of operating electricity generating turbines in electricity markets.

In another type of studies related to energy policies and climate change, Blyth & Yang (2006) quantified the effect of climate change policy on investment in the power sector. To model the price uncertainty and market risk, they used the real options approach. Similarly, Chorn & Shokhor (2006) addressed the application of real options valuation for framing policy guidelines in the energy sector. This article was also the first in the literature that mathematically demonstrated the use of real option and the Bellman equation[15]. Further, Marreco & Carpio (2006) applied the real options theory to understand the operational flexibility in the complex Brazilian Power System. The methodology proposed by them is expected to compute the fair values that could be paid to thermal power generators.

Moreover, more recently Abadie (2009) valued the long-term investment in renewable energy company assets through real options. Additionally, to address the expansion of a project, Bonis et. al. (2009) used real options approach in the Latin-American market.

Further, the details of literature that are reviewed for the purpose of the current study are mentioned in Table (6.3 & 6.4)

[15] Belman equation is a dynamic programming equation. For details see http://www.princeton.edu/~moll/ECO521Web/Lecture4_ECO521_web.pdf

6.5 Application of real options is renewable energy

Venetsanos et. al. (2002) used real option to evaluate a wind power project. To evaluate the project they applied following four steps. First, identified the risks and uncertainty related to the power production through wind energy. Secondly, they figured out the options that are relevant to the project. Next, using the Black and Scholes model, they estimated the project through real options approach. Finally, they compared the outcome of the evaluation to traditional method (DCF). Outcome through NPV was negative, that suggested a negative return; whereas, outcome of the real options approach suggested the positive return.

Munoz et. al. (2009) proposed a model for evaluation of wind power projects. Using a stochastic model, they suggested the probabilities to invest, wait or abandon the project. This model was applied in a few investment cases. Similarly, Kjarland (2007) and Bockman et. al. (2008) followed Dixit & Pindyck's (1994) framework to apply the real options approach to evaluate a large and small hydro power plant respectively. For renewable energy generation projects, Cesena & Mutale (2011) proposed an advanced real options method. In one of the hydro power project evaluation, they demonstrated that the real optionss approach based results show higher profits compared to the outcome of the traditional method.

Further, Lee & Shih (2010) put forth a policy evaluation model applying real options pricing technique that considered uncertainty and risk factors as a barrier to developing renewable energy policy. Their framework also allowed assessing volatility, uncertainty, and managerial flexibility information of policy planning.

Table 6.3 Reviewed articles that used real options in the energy sector (Non-renewable)

Authors	**Year**	**Application area**	**Method used**
Siegel et al.	1987	Oil industry	Pde
Paddock et al.	1988	Oil industry	Pde
Ekern	1988	Oil industry	Binomial option valuation
Dixit and Pindyck	1994	Book: case studies in energy sector	
Trigeorgis	1996	Book: case studies in energy sector	
Amram and Kulatilaka	1999	Book: case studies in energy sector	
Felder	1995	Power generation	Binomial option valuation
Ghosh and Ramesh	1997	Energy market	Pde
Hsu	1998	Power generation	Pde
Deng et al.	2001	Energy market	Pde
Frayer and Uludere	2001	Energy market	Pde
Moreira et al.	2004	Power generation	Dynamic programming
Armstrong et al.	2004	Oil industry	Pde; Monte Carlo simulation
Madlener et al.	2005	Power generation	Dynamic programming
Hlouskova	2005	Power generation	Monte Carlo Simulation
Van Benthem et al.	2006	Power generation	Dynamic programming
Laurikka and Koljonen	2006	Impact of emission policy	Pde; Monte Carlo simulation
Blyth and Yang	2006	Impact of climate change policy	Monte Carlo simulation; dynamic programming
Chorn and Shokhor	2006	Policies study	Dynamic programming

Marreco and Carpio	2006	Power generation	Pde
Deng and Xia	2006	Energy market	Dynamic programming; Monte Carlo simulation
Botterud and Korpas	2007	Energy market	Dynamic programming
Prelipcean and Boscoianu	2008	Energy market	Dynamic programming
Bonis et al.	2009	Energy market	Pde
Abadie	2009	Energy market	Pde
Ucal and Kahraman	2009	Oil industry	Pde
Fuss et al.	2009	Impact of climate change policy	Pde; Monte Carlo simulation
Fleten and Nasakkala	2010	Power generation	Pde
Fan and Zhu	2010	Oil industry	Pde
Fernandes et. al.	2011	Energy market	Review

Source: Revised from Fernandes et. al (2011)

Table 6.4 Reviewed articles that used real options in renewable energy sector

Authors	Year	Resource	Application area	Method used
Venetsanos et al.	2002	Wind energy	Power generation	Pde
Davis and Owens	2003	Renewable energy technologies	R&D program	Pde
Yu et al.	2006	Wind energy	Policy evaluation	Pde
Siddiqui	2007	Renewable energy	R&D investments	Pde; dynamic programming
Kjarland	2007	Hydropower	Policy evaluation	Pde
Kumbaroglu et al.	2008	Renewable energy technologies	Policy evaluation	Dynamic programming
Bockman et al.	2008	Hydropower	Power generation	Pde; dynamic programming
Mu.noz et al.	2009	Wind Energy	Power generation	Dynamic programming
Lee and Shih	2010	Renewable energy	Policy evaluation	Pde; dynamic programming
Siddiqui and Fleten	2010	Renewable energy technologies	Policy evaluation	Pde; dynamic programming
Martinez-Cese.na and Mutale	2011	Hydropower	Power generation	Dynamic Programming; Monte Carlo Simulation
Cheng et. al.	2011	Renewable energy	Expansion strategy	Binomial model
Huges & Barnett	2011	Wind energy	Policy evaluation	Review

Leet et. al.	2013	Hydropower	Investment uncertainty	Dynamic programming
Detert & Kotani	2013	Renewable energy	switching of technologies	Monte Carlo
Santos et. al.	2014	Wind energy	Investment uncertainty	Decision tree

Source: Revised from Fernandes et. al (2011)

6.6 Important case studies applying real options approach

This section explains in depth the application of real options approach applied to renewable energy project evaluations. The mathematical frameworks explained by Black & Scholes (1973) and used by Santos et. al. (2014) is presented in this section, represents the fundamental framework that we have used in our study.

6.6.1 Deferring an investment as an option

Santos et. al. (2014) studied mini hydropower investment project of 500 MW capacity and compared the outcome of traditional NPV method with real options approach to finding out whether deferring a project would be better?

Study was completed in several stages. 1) They studied Black & Scholes and binomial tree models. Black & Scholes developed equilibrium model that comprised of risk-free portfolios on the following fundamental assumptions.

1.) The risk-free rate is known as constant over time; 2.) The asset pays no dividends; 3.) The option can only be exercised at the maturity date; 4.) There are no transaction costs when buying or selling an asset or derivate; 5.) It is possible to invest any fraction of assets or derivate *to the risk-free interest rate; 6.) There are no penalties when short-selling is made; 7.) The model is developed from the concept that an options asset price has a continuous stochastic behaviour, which is defined by the Geometric Brownian Motion (GBM) which is given by the following equation:*

[16] $dS/S = \mu dt + \sigma dz$ (6.1)

where dS represents the variation of the underlying asset price (S) at time dt, μ is a mathematical expectation of the instantaneous return rate related to the underlying asset, s is the instantaneous standard deviation of the underlying asset return, and dz is a standard process of Gausse Wiener[17].

The Black Scholes equation for a European call option is mentioned by

$C=SN(d1)-K\exp^{-rt}N(d2)$ (6.2)

where,

$d1=[\ln(S/K)+(r+(\sigma^2/2)\tau]/\ \sigma\ \tau$ (6.3)

$d2=d1-\ \sigma\ \tau$ (6.4)

In the previous equations, N(d) represents the normal cumulative distribution function, S represent stock price, K refers to the exercise price, r gives the time to expiration, and s signifies the volatility associated with the underlying asset. For the European put options, they can be easily subtracted from the previous equation by put-call parity. Put-call parity takes a form when a portfolio composed of a unit of the underlying asset in a longer position. On the one hand, call

[16] Equations 1 to 10 are Black & Scholes derivation quoted by Satntos et. al. (2014)

[17] This is taken from Santos et. al.(2014). A stochastic processWt = {W(t); t >= 0},defined in a probability space (Ω, F,P)
is a Wiener process if: for s >= 0 and t > 0, the random variable Wt+s -Ws has a normal distribution N(0,t); for n >= 1 and 0 <= t0 <=…..<= tn, the random variable Wtr – Wtr-1 is independent; W0 = 0; Wt is continuous for t >= 0.

option in a short position and on the other hand, a pull option in a long position may have the same value of the exercised price at the maturity time, despite the price of the underlying asset. Therefore, in the absence of arbitrage chances, the portfolio worth is equal to the exercise price, which is discounted by the risk-free interest rate, at any time.

Therefore, if p is the put option's value of an asset (at time t), a European put option can be worked out as:

$$p = K\exp^{-rt}N(-d2) - SN(d1) \tag{6.5}$$

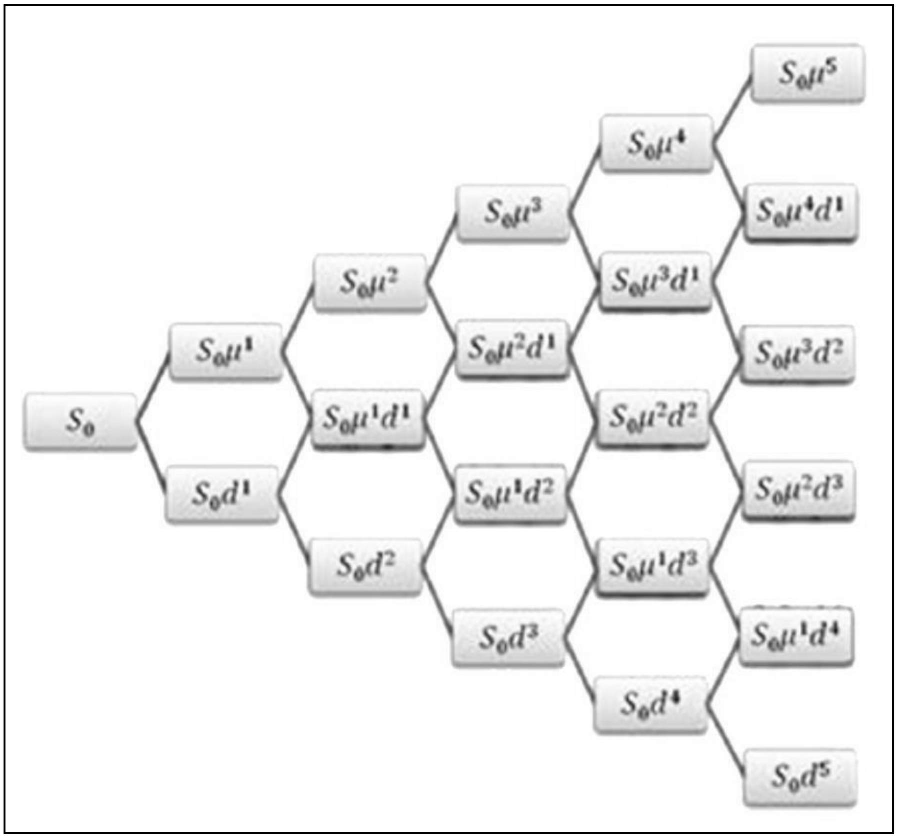
However, Santos et. al. (2014) also mention that American options and as well as European options need numerical methods to evaluate projects. The binominal tree developed by Cox, Ross and Rubinstein (1979) is an example of such evaluation method. According to the authors, this efficient and simple method permits the holder of an option to pick whether it is most beneficial to exercise the option or to wait until its maturity period. The model also assumes that the maturity date of an option can be divided into periods (dt). Further, the prices of the underlying assets are subjected to a given behaviour and it would be multiplied at each period (dt) by a random coefficient m or d.

Just to define, random coefficients are the price variation rates of the underlying assets. Since this rate can be descending (d) or ascending (μ), specifying the favourable or unfavourable energy market conditions, these factors are dependent on the length of the periods (dt) and volatility (σ). Binominal tree for the underlying assets and illustration of its price evolution are mentioned (Figure 6.2). The nodes at the right side represent the distribution of possible opportunity values for the underlying asset. The multiplicative factors (μ) and (d) are represented by:

$$\mu=\exp^{\sigma\sqrt{(dt)}} \tag{6.6}$$

$$d= \exp^{-\sigma\sqrt{(dt)}} \tag{6.7}$$

Figure 6.2 The binomial tree used for the evolution price of the underlying asset



Source: Santos et. al (2014)

A risk-neutral measure gives the probability of the stock price to increase or to decrease. Therefore, the stock price increases with a probability equal to:

$p=(\exp^{rfdt}-d)/(\mu-d)$ (6.8)

and decreases with a probability given by

$q=1-p$ (6.9)

The options value can be derived through a binominal tree after determining the parameters. In Fig.6.2 each gain obtained for stock price is represented. Santos et. al (2014) also mention that *in the case of a call option, this value is represented by the max (S-K, 0), that is, maximum* *difference between the value of the underlying asset and its exercise price, and zero; Whereas, in the case of a put option, the value corresponds to the maximum difference of the exercise price and its stock price, and zero, that is max (K-S, 0). Through the option values represented by the nodes at the right of the tree, it is feasible to calculate the other related values by applying the neutral probability on each pair of vertically adjacent values.*

They are mathematically represented by the following equation:

$$C_t = \left[pC_\mu^{t+1} + (1-p)C_d^{t+1}\right]/exp^{rt} \tag{6.10}$$

When stock price is determined, different trajectories are followed by price until the maturity date can be defined. For estimating the options value, a reverse route from the right to the left is adopted which is based on prices defined in each node.

Few of the characteristics of a mini hydro (as inputs to the model) such as turbine type, number of turbines, generator types, transformers, capacity, etc. were determined. In evaluating the project through NPV method, they made few assumptions such as

-Plant will produce at full capacity and all energy will be sold during the project lifetime

-Energy remuneration is constant during the project's lifetime (50 years)

-Discount rate of 10% and an inflation rate of 3% is considered

The major assumptions made for evaluating project through real options are-

-all data provided by traditional evaluation methods are considered. Possible corrections are difficult to be made, since the necessary data is unavailable

-operational costs of the power plant are not affected by

-prices considered in this study were the electricity prices of long-term contracts high levels of uncertainty

With NPV method, a positive value suggests that the project is viable and should be taken up. However, outcome of real option advises that the project value with deferral option is higher than NPV. Therefore, the project should be delayed until further information is received. Binomial decision trees were used in both the methods.

6.6.2 Investment timings and capacity options

Boomsma et. al. (2012) conducted a study to evaluate the renewable energy investments in wind farms under two support schemes (feed-in-tariffs and renewable energy certificates. Time required for setting up a renewable energy plant is relatively shorter than that of conventional energy plant, therefore, it is justified to defer a project until the investments funds and market information is justified. This refers to a value of waiting. Thus, considering deferral option as a perpetual is referred to as a standard assumption in real options method, and this helps in deriving an analytical solution.

Choice to scale the wind power production depends on the owner/investor. Therefore, it is assumed in this case that the power generation choice is unrestricted to quantity generated and generation can start immediately after the plant is setup. Another assumption is that the plant has a life time of 20-25 years. However, uncertainties in the energy market such as subsidy change, capital cost, electricity prices etc. could witness in future. Therefore, allowing for possible uncertainties and considering assumptions, a risk neutral model was presented for various cases applying partial differential method (PDE). However, in the current study we have used an assumptions made by Monjas-Barroso & Balibrea-Iniesta (2013).

Fabrizio (2012) investigated the investment patterns in renewable energy and mentions that the firms that expect the change in regulation policies might alter their responses to current policies, which would delay the investment in electricity industry. In other word, the perceived regulation instability would lead to deferring of an investment.

Barradale (2010) put forth the specific examples related to wind energy in Denmark and Germany. In Germany, wind power industry suffered a downturn in renewable electricity investment with a change in regulation policy that added a biennial review process. As a consequence of this, the feed-in-tariff laws were also changed. Overall, because of the uncertainty, investors would not know how the changes in regulation policy would affect their profits. Therefore, it would be obvious for them to wait until appropriate information is arrived.

6.6.3 No subsidy as an option

Renewable energy businesses in most of the cases are subsidized by the government to accelerate its adoption in the energy market and increase the share of renewable electricity. As mentioned earlier, in Europe, most of the renewable energies are supported by government. However, it is uncertain to say when the government policy changes regarding the provision of subsidy. In few cases, government has considered the wind to be a mature technology and stopped subsidizing it (Example is Spain). Under the certain conditions, over a period, wind energy has become most economic technology to produce electricity, which includes advanced technology, mature supply and lesser supply delays (IRENA Report, 2012).

Another alternative that government could choose in the future is to subsidize only a small part of the project. Such kind of uncertainties (if not manageable) could lead to project failures and lowering of profits, or sometimes investor may face a loss. Thus, to handle no support scheme choice, Boomsma et. al. (2012) proposed a mathematical solution to handle uncertainty in investing in wind power that is associated to steel price and electricity spot prices.

Whereas in our study, we have studied five scenarios that have options as FIT, subsidy and combination of both.

6.7 Conclusion

This chapter has briefly dealt with the literature review for the second part of the thesis. It explains the difference between the traditional and modern approach. The chapter also described the types of real options available and their applications in several areas and energy sectors. In the current context, Portugal economy expects a change in regulation framework. Thus, deciding upon whether the investment should be made now or investor should wait until more information arrives, “delay” option is most appropriate for the present studies. The next chapter describes the data, methodology and results of the study.

Chapter 7

Methodology, data analysis and results

7.1 Brief of project: data and assumptions

This chapter explains the methodology, the data used and the results of the second part of the thesis.

For the current study, a 50 MW wind power project was considered. A 50 MW plant consists of 39 units of 1.3 MW wind towers. It is assumed that the towers were mounted at optimal location where they could receive required wind speed for electricity generation. The installation cost of the project may vary due to several factors such as labour cost, steel cost, availability of suitable land onshore where acceptable wind speed is available throughout the year (with slight deviations), etc. In the optimistic and pessimistic situations, per megawatt installation cost considered in the study were 1200 Euros/KWh and 1800 Euros/KWh respectively, whereas, in the most likely situation, per megawatt installation cost of 1500[18] Euros was considered. This cost is also assumed to consist of labour cost and other costs, including official/regulatory formalities. It is assumed that four years are required to start a project and project once taken is irreversible in nature. Project life is assumed to be 25 years, and it is assumed that there will be no salvage value at the maturity of the project.

Leasing the land on which project will start is assumed to cost Euros 1,00,000 per year with 10% of the increment after every fifth year for 25 years. Operations and maintenance cost is estimated to be in the range of 12.51 to 17 Euros per MWh. However, in most likely situation

[18] The prices range considered were influence from IRENA.Org report downloaded from http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-WIND_POWER.pdf

13.91 Euros/MWh is accounted in the study. Staffing and insurance are assumed to be 305,932 Euros per year with the increment of 10% after every fifth year. Present value (PV) factor ranging from 2-5% are considered; in the most likely case PV factor of 2.5% is taken. Monjas-Barroso & Balibrea-Iniesta (2013) also made similar kinds of assumptions for the valuation of wind power projects in Denmark, Finland and Portugal.

The average market price of electricity over the two years (2012 and 2014) for Portugal and Spain were obtained from MIBEL[19] data. The two years average prices and standard deviations observed over the periods were 46.84 and 17.08 respectively for Portugal, and 46.16 and 16.715 respectively for Spain. However, Portuguese prices are considered for modelling and analysis in the scope of the current study.

Table 7.1 A table showing the major inputs to the project

Variables	Value
Total investment estimation without subsidy (Euros)	(75000000)
Installation cost Euros per MWh	1500000
Capacity in MW	50
PV factor	2.50%
Project life time	25yrs
O & M per MWh	13.91
Volatility	20%
Risk-free rate	5%
Dividend rate	4%
Leasing per year in Euros per year @10%increment after every 5th year	100000
Staffing and insurance per year @10%increment after every 5th year (Euros)	305932
Energy produced MWh per year	100000
Electricity selling price Euros per MWh with standard deviation of 17.08 Euros per MWh	46.84
Selling price with subsidy Euros per MWh	75

Source: compiled by the author

[19] http://www.mercado.ren.pt/EN/Electr/MarketInfo/MarketResults/OMIE/Pages/Prices.aspx

7.2 Methodology

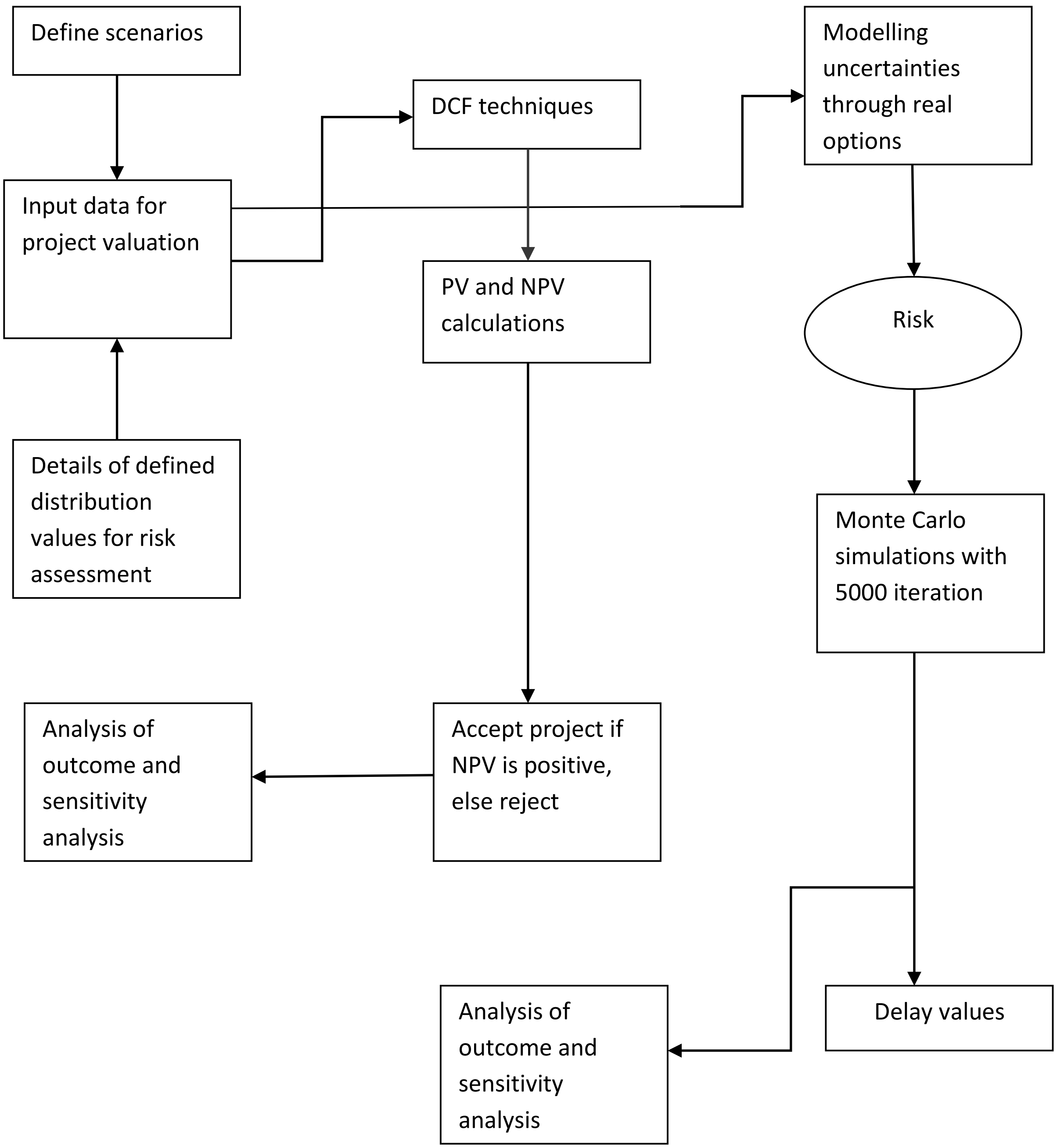
With the above-mentioned data and assumptions, five scenarios (mentioned in the subsection of methodology) of the project are evaluated through this study. The project is evaluated through NPV with risk factors and through a real options approach with "delay" option. The detailed methodology for the study is mentioned in a methodology flow chart (Figure. 7.1).

Equations derived by Black and Scholes (1973) and applied by Santos et al. (2014) & Boomsma et. al.(2012) were applied to address this study. Various range of input values with varying risk parameters (under assumptions) were used for the modelling. For the modelling purpose, a trail version of @Risk software developed by Palisade (2000) was used.

Instead of directly using the DCF method to determine the NPV in the deterministic case, NPV with risk values was calculated for each scenario by applying Monte Carlo simulations. We have used triangular distribution in most of the cases for data input variables. Thus, different ranges of output for varying levels of inputs were observed and analysed.

Under the real options method, we chose to take up and study the "delay" option. Delay option was most appropriate as regulatory changes (under our assumption) are in a transition stage. The range of values for volatility, risk-free rate, and deviation in cash flows were given as inputs; and delay values received as outcome was analysed. The five scenarios were analysed in this study. The proposed methodology can be seen in Figure7.1

Figure 7.1 Flow chart of the methodology of the second part of the thesis



Source: developed by the author

7.2.1 Scenario 1[20] (Base Scenario)

Different support schemes in renewable energies expose investors with various risks. The FIT since long time has been termed to induce the renewable investments through price protection (Butler and Neuhoff, 2008). The FIT also requires less direct support and provides an attractiveness to investors because of less risk (Kitzing, 2014).

Under the current Portuguese regulatory framework, Portugal supports renewable electricity generation through feed-in-tariff rate of 75 Euros/MWh (including premium for generating clean energy) for upto 33GWh/MW or upto the maximum of 15 years. Assuming that a generator can utilize maximum capacity and can sell 100% of generating electricity at FIT rates for 15 years. An electricity generated per year is derived as 110,000 MWh (=33GWh/15 years). However, in the realistic case wind can stop blowing sometimes or the plant may have a technical problem because of which it may not generate the electricity to the desired level. Therefore, the range of electricity generation from 90,000-1,10,000 MWh is considered; in the most likely situation, plant can produce 100,000 KWh annually. However, it is assumed that after 15th years, the generator is not eligible for FIT benefits. Nonetheless, the generator is assumed to be able to sell complete electricity after the 15th year at wholesale market prices without paying any tax to the government.

Hypothesis 1: Under the current Portuguese regulatory framework, business risk for wind energy project is less compared to the business risk that is expected after the Spanish regulation are implemented in Portugal

7.2.2 Scenario 2 (Spanish renewable electricity regulatory changes)

In several countries the change in regulatory policies have affected the energy investments. For instance, in April 2012, the FIT rate was revised for UK. Muhammad-Sukki (2013) conducted

[20] Scenario 1 is considered as a base case and rest of the four scenarios are compared to it in every case.

a simulation study to account for the regulatory impacts on the investments. They found that the revised rates of FIT has lowered the profits, lowered the return on investment and increase the payback period. This revised policy has reduced the acceleration of solar investments in the UK.

Similarly, scenario 2 is based on the current regulatory changes that have been introduced in Spanish market in June 2014. Under this scenario, the project was evaluated under the assumption that soon these regulations will be implemented in Portugal too. According to the new Spanish regulations, FIT is reduced to 6 years. To be eligible for FIT, generators have to produce renewable electricity in the pre-established slabs. It is assumed that for six years generators will be able to produce electricity, such that they are eligible for the FIT benefits. FIT benefits include 50% of benefits on the market price of electricity at per MWh. In this scenario, it is further assumed that generators do not pay taxes on selling electricity after 6th years. Therefore, a standard FIT of 75 Euros/MWh is not considered in this scenario. Details of current regulatory changes are described in the introduction chapter.

Hypothesis 2: Under the assumption that revision in the Spanish regulatory framework will affect the Portuguese electricity market and similar framework will be adopted by the Portuguese government; the business risk under the revised regulatory framework is higher for wind energy investors in Portugal.

7.2.3 Scenario 3 (50% subsidy and no FIT)

The effect of subsidy has been recently studied in the many areas of social sciences. For instance, see Black et. al. (2014), Anderson et. al. (2015) and Hong et. al. (2014). Zhang et. al. (2014) observed that in the long run and short run the financial performance of wind power companies. Similarly, the effects of incentives and taxes have been studied by Black[b] et. al. (2014). They observed that the reduced incentives on wind generation has resulted in the reduced tax revenues and has ultimately reduced the total income of the Idaho state. Thus, it is observed that subsidies or incentives when increased has positive effect on economic development, whereas, the effect is negative when incentives are reduced.

This scenario assumes the direct subsidy of 50% on installation cost whereas there is no support scheme in the form of FIT. It was expected in scenario 2 that with the current Spanish regulatory changes (which partially assumed wind power to be a mature technology), generators may not be able to maintain the sufficient levels of profits. Therefore, other scenarios were considered that can be profitable to the industry as a whole. In this scenario, 50% subsidy on installation cost along with no FIT was considered. That means a wind generator is eligible to claim direct 50% of the installation cost (including leasing cost over the installation period of 4 years without interest). However, generators are assumed not to be eligible for any other support scheme, except they are not liable to pay taxes on selling of electricity at the market price.

Hypothesis 3: Under the assumption that Spanish regulation will be implemented in Portugal, business risk at 50% of the subsidy on installation and no FIT leads to better returns for wind energy investors in Portugal.

7.2.4 Scenario 4 (No subsidy and no FIT)

According to the European commission[21] report it is mentioned the technology prices are continuously falling and therefore they should be exposed to market prices, which means, the support system is proposed to be completely removed. It is also mentioned that the financial support should be kept minimum which could ultimately lead to the lower investments.

The current regulatory changes in Spanish market can be assumed to signal that sooner or later the renewable energy will be considered as fully mature technology like traditional technologies, and governments will offer no support schemes. In such scenarios, subsidies and incentives from the government would not be expected- generators will have to rely on market electricity prices. However, by further lowering down of the electricity prices in a long run may further affect the

[21] http://europa.eu/rapid/press-release_IP-13-1021_en.htm

profitability of the project. Thus, regulatory uncertainties that consider wind power generation as fully mature, are accounted in scenario 4.

Hypothesis 4: Under the assumption the wind energy generation is considered mature in Portugal, the business risk is higher for investors.

7.2.5 Scenario 5 (100% subsidy and no FIT @ 20% tax on the sale of electricity)

This scenario is very hypothetical in nature. The assumption in this scenario is that only selected investors (or public enterprise fully funded and owned by the government) would qualify for such projects. Consequently, from scenario 4, it was expected that business would not be able to make profits. It would have to operate on a loss or will have to close the operations. An alternative scenario with 100% subsidy allocation on installation cost was assumed (scenario 5) to account for low risk. However, taxes in the range 15-25% per MWh were assumed on selling of electricity in the open market; the most likely tax rate of 20% was considered in the current study. A 20% tax rate is assumed to be applicable on the sale of electricity (per MWh). It is also assumed that the 100% electricity generated by project is supplied to the grid.

Hypothesis 5: Under the assumption that wind energy will be 100% supported by the government with 20% average tax on sale of electricity (per MWh), the returns will be higher.

To address the above five scenarios, financial modelling approach to understanding the profitability of the project is applied through two ways. First, by understanding the profitability through NPV method; and second, is to understand the value of delaying the project through real options method. Understanding the value of delay is important, because policy transitions market can fluctuate in several ways, which can ultimately account for business losses. In such situations, it is suggested to wait for the further information. However, loss of cash flow (on delaying the project) also needs to be accounted while considering the delay option.

7.3 Analysis and results

7.3.1 Project risk evaluation through NPV

In this section, the five scenarios will be analysed by the NPV risk method. Basic criteria to understand the project risk is through sensitivity plots and tornado diagrams. Values that were considered for modelling were generated through Monte Carlo simulations with 5000 iterations.

For calculating the NPV of the project, the following model was applied:

$$\mathrm{NPV}\{t = 0, N\} = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

Where, t represents time, R_t represents cash flow at time t, N means project life in years, and i represents discounted rate of interest.

7.3.1.1 Base Scenario (Scenario 1)

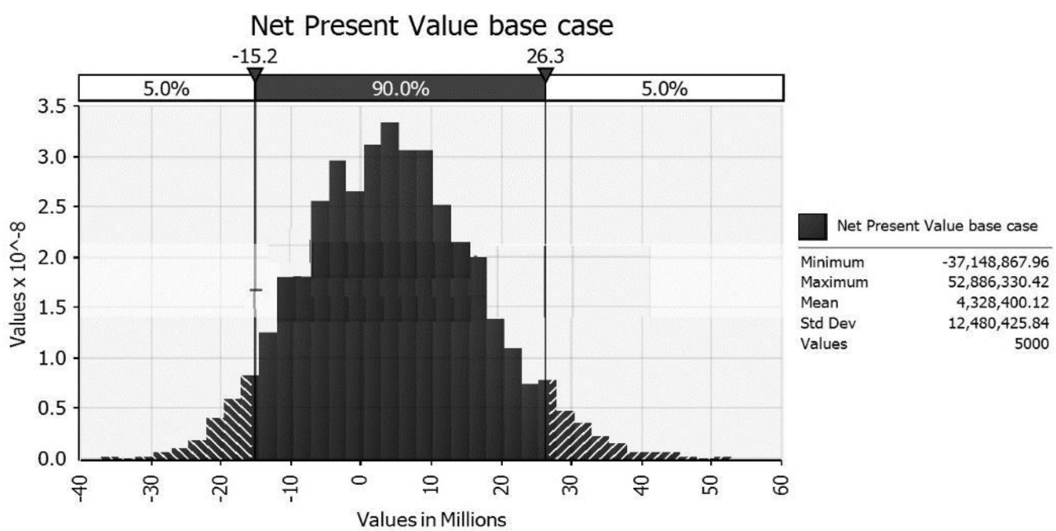
With Monte Carlo simulations of 5000 iterations, a normal distributed graph was obtained. Nonetheless, probability to obtain a positive NPV is higher as it is obvious from the fig.7.2 & 7.3. Electricity sale at a higher price range can generate up to 20 million of NPV. Whereas in lower price cases, NPV can significantly slash down to -11million, in which it may not be advisable to take up the project.

The second important variable observed was an installation cost. Higher installation cost can significantly reduce the NPV of the project. In this model, the higher values of installation cost can reduce NPV by around 5millions of Euros. On the other hand, lesser installation cost can significantly improve the NPV by around 14 million Euros. PV factor is also determined to be an important variable in the current modelling process. Increase in inflation can result in drastic changes in NPV. However, it depends on several factors and can be accounted as uncontrollable variable. Nonetheless, it can affect the NPV by lowering it to around 4.3 million Euros in extraordinary circumstances.

As it is stated above in the last section, electricity fluctuation depends on several controllable and uncontrollable parameters. Reduction in electricity produced per MWh per years can also substantially lead to lower the NPV by around 2 million Euros; whereas, keeping the electricity generation constant at 1,00,000 MWh/year, the NPV can be considerably positive.

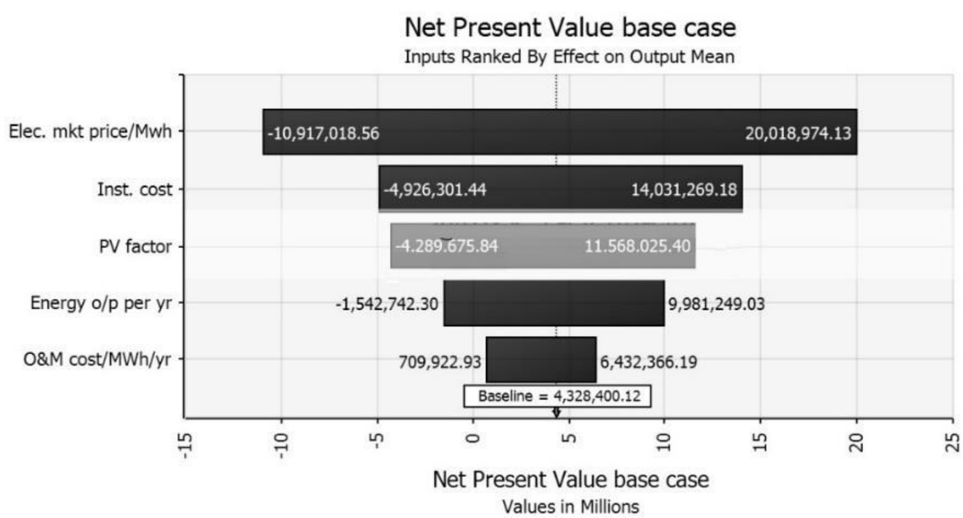
Overall, in the deterministic case, average NPV observed is positive. Therefore, through NPV method, the project can be taken up. The correlation between the variables and fluctuation in NPV can be observed through fig. 7.4 and 7.5 respectively.

Figure 7.2 Normal distribution of NPV (in Euros) values for scenario 1 from Monte Carlo simulations



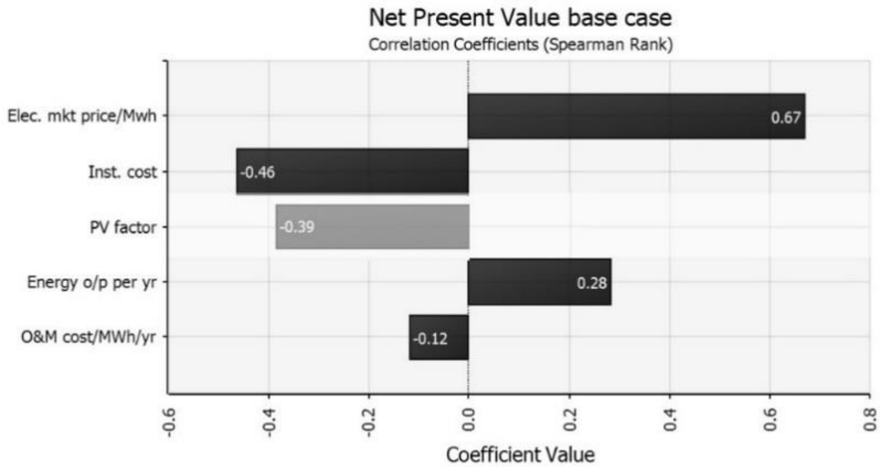
Source: generated by the author

Figure 7.3 Tornado showing the sensitivity of variables to NPV (in Euros) in scenario 1



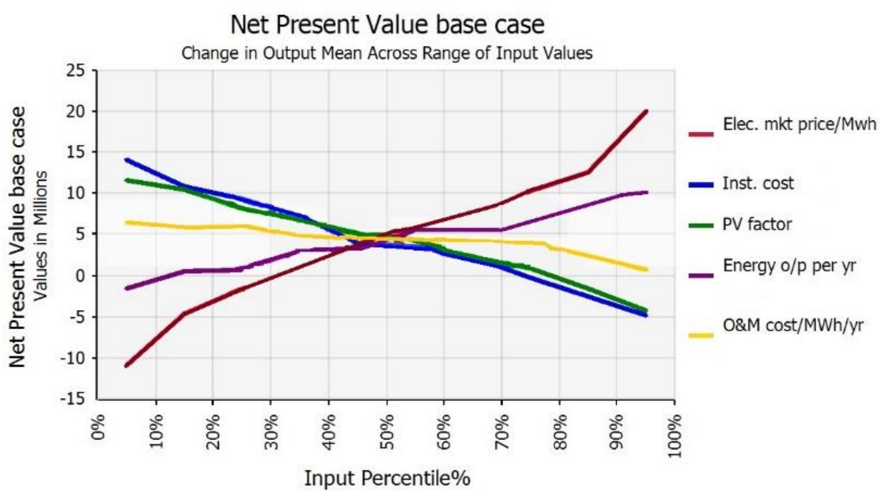
Source: generated by the author

Figure 7.4 Tornado graph showing the Spearman coefficients variables for scenario 1



Source: generated by the author

Figure 7.5 Sensitivity of input variables to NPV (in Euros) for scenario 1



Source: generated by the author

Table 7.3 A table showing the lower and upper values (in Euros) of important variables affecting the model of scenario 1

Change in Output Statistic for Net Present Value base case			
Rank	Name	Lower	Upper
1	Electricity selling price	(11,279,571)	20,198,510
2	Installation cost Euros per MWh	(5,729,344)	14,624,274
3	PV factor	(4,348,833)	11,678,483
4	Energy produced MWh per year	(2,127,131)	11,378,786
5	O & M per MWh	1,069,464	7,085,465

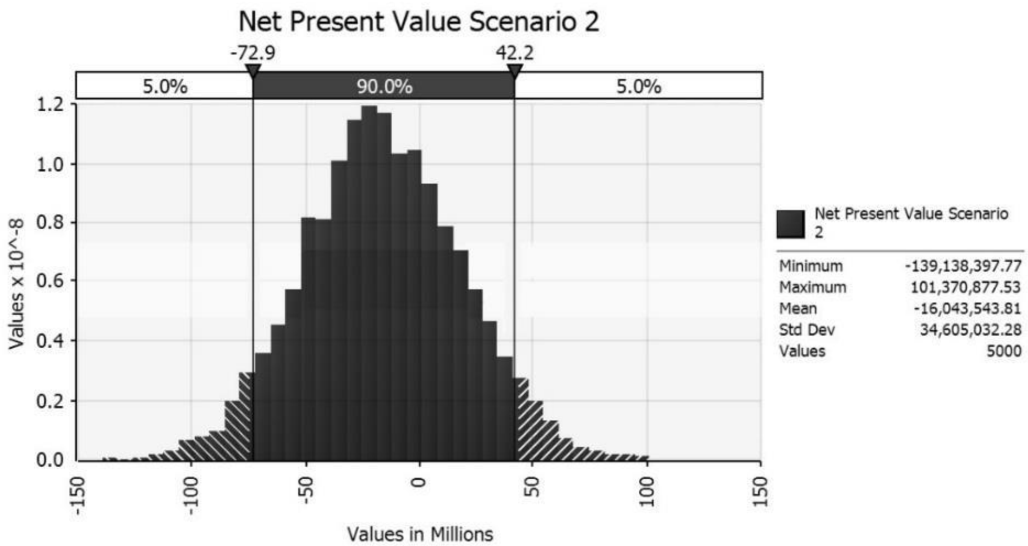
Source: generated by the author

7.3.1.2 Scenario 2 (Spanish Regulation)

This was the most important scenario considered by the current study. Since Spain and Portugal operate under the Iberian market, the regulatory change in one country can significantly affect the decision of another. In the analysis of this scenario, FIT rates and market price of electricity were taken as mentioned in the methodology section. Most of the simulated NPV values fall under the negative category with a mean of around -16 million Euros (fig. 7.6& 7.7). This regulatory change may not be seen as a good scenario for investors. Through tornado plot (fig. 7.7), it is observed that the condition of NPV to yield positive and profitable result depend highly on electricity price. Variation in electricity price towards a higher range can generate a positive NPV of around 43 million Euros. On the other hand, there are equal chances of getting considerably low NPV too. In the case, if the electricity price per MWh falls below the most likely case, the NPV can fall upto -74 million Euros (table 7.4). Other factors such as installation cost, PV factor and electricity production per annum are less sensitive compared to electricity prices.

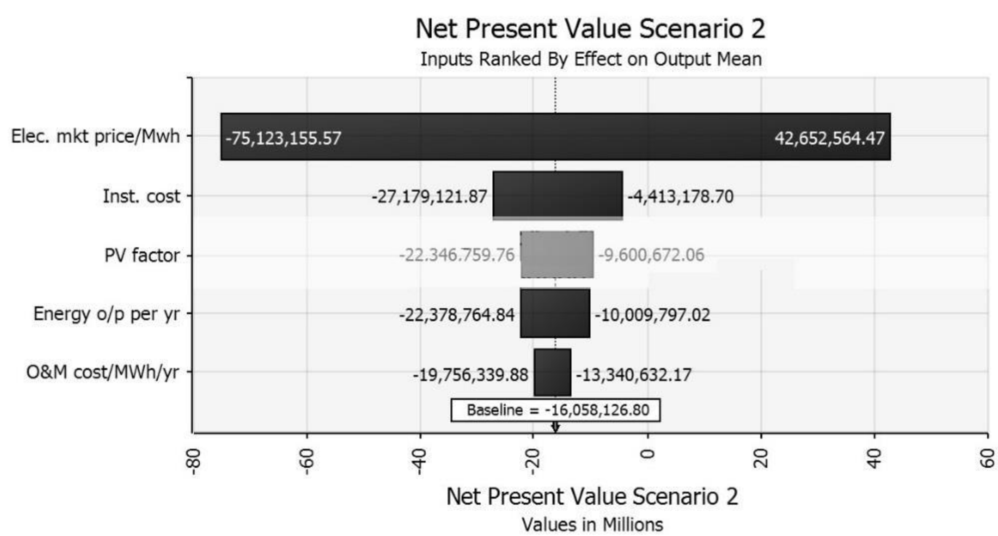
Overall, the execution of a project under this condition appears to be highly risky, and NPV method does not suggest taking up the project because of its unprofitable nature. The correlation between the variables and fluctuation in NPV can be observed through fig. 7.8 and 7.9 respectively.

Figure 7.6 The simulated NPV (in Euros) distribution for scenario 2



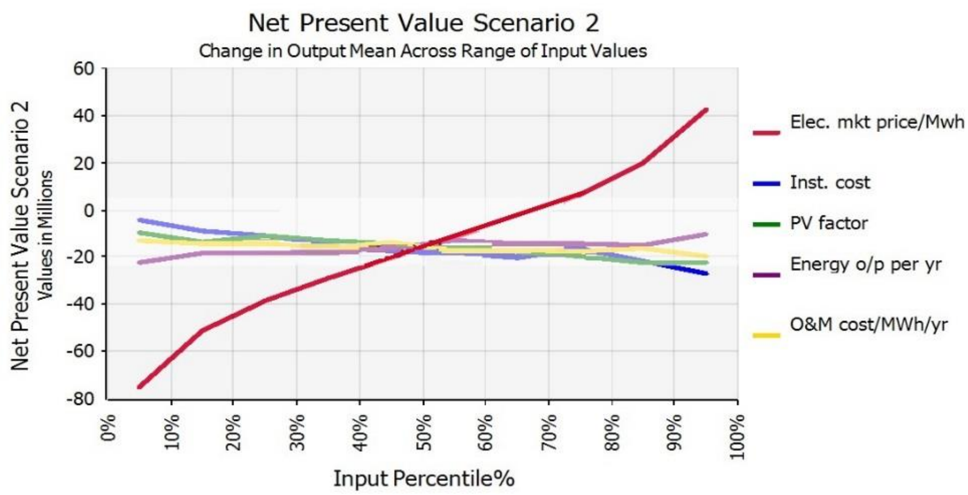
Source: generated by the author

Figure 7.7 Sensitivity of variables to NPV (in Euros) in scenario 2



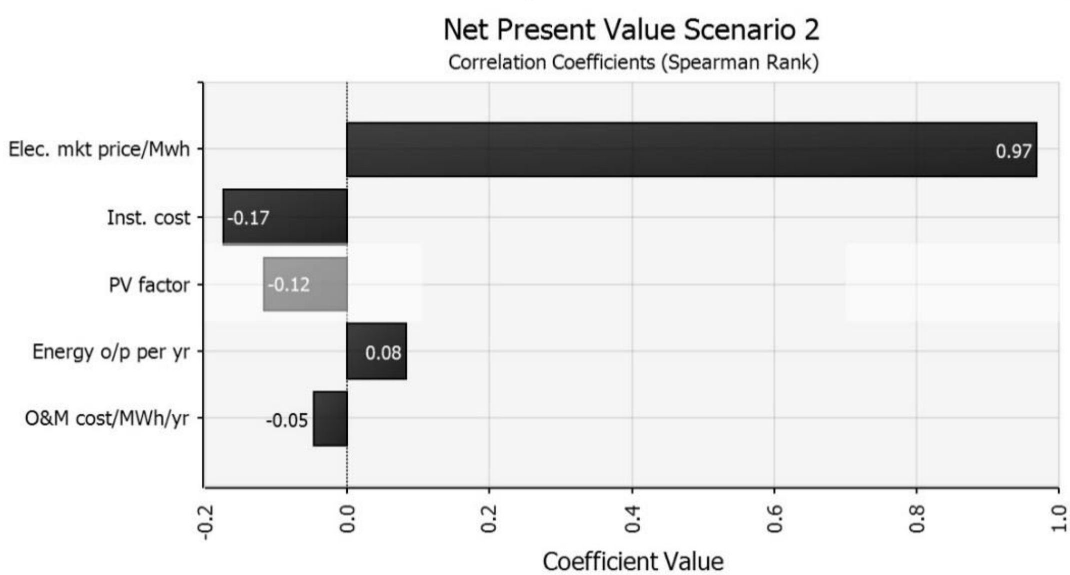
Source: generated by the author

Figure 7.8 Sensitivity of input variables to NPV (in Euros) for scenario 2



Source: generated by the author

Figure 7.9 Spearman coefficients variables for scenario 2



Source: generated by the author

Table 7.4 Lower and upper values (in Euros) of important variables affecting the model of scenario 2

Change in Output Statistic for Net Present Value Scenario 2			
Rank	Name	Lower	Upper
1	Electricity selling price	(74,963,658)	43,109,790
2	Installation cost Euros per MWh	(26,927,398)	(6,573,186)
3	PV factor	(24,949,907)	(7,940,729)
4	Energy produced MWh per year	(21,108,511)	(10,702,882)
5	O & M per MWh	(18,682,091)	(12,615,327)

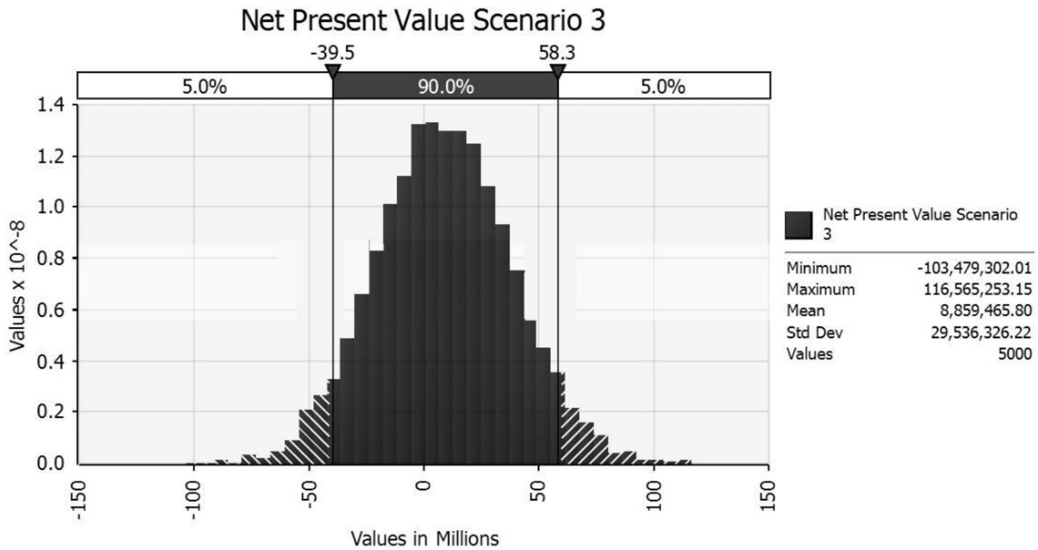
Source: generated by the author

7.3.1.3 Scenario 3

This scenario assumes a 50% subsidy on installation cost and no FIT benefits to the generators. In this case, NPV values generated through Monte Carlo simulations have a higher occurrence (more than 50%) in the 90% confidence interval of the normal distribution. However, in this situation, it may not be so straight to mention whether the project should be taken or not to be taken.

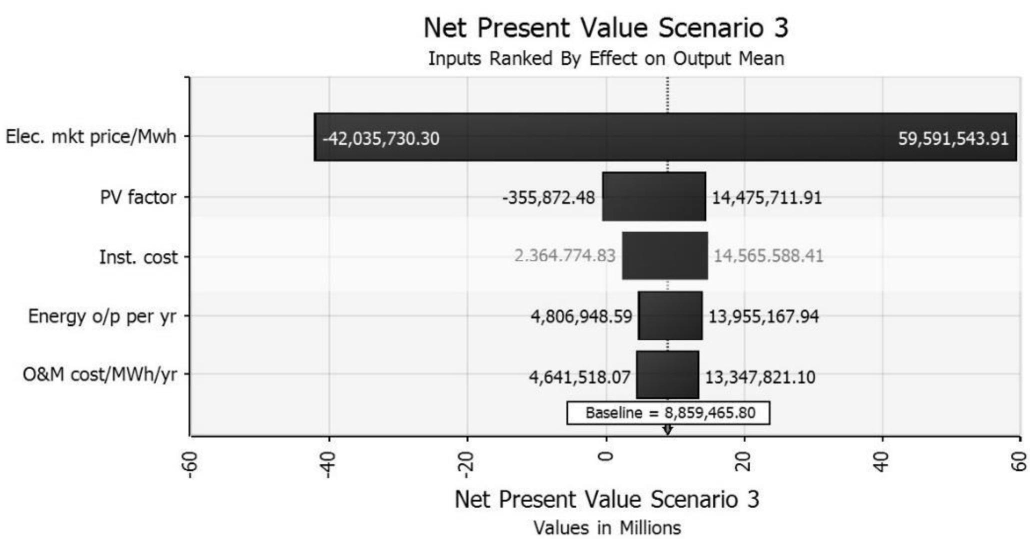
The observed results of this simulation are very similar to the previous scenario. In this scenario too, the electricity selling price appears to be the most important factor on which the NPV values depend. In the lower range of electricity price in the market, the NPV can significantly fall by around -42 million Euros; Whereas, on the other extreme case when the price can go up, the NPV can attain a considerable high positive value of around 60 million Euros. PV factor also plays an important role, but relatively very less when compared to electricity price. Other factors such as installation cost, O & M cost, etc. does not seem to affect the NPV significantly. Concisely, taking up the project through NPV method may not be advisable. The correlation between the variables and fluctuation in NPV can be observed through fig. 7.11 and 7.12 respectively.

Figure 7.10 Normal distribution of NPV values (in Euros) from Monte Carlo simulations for scenario 3



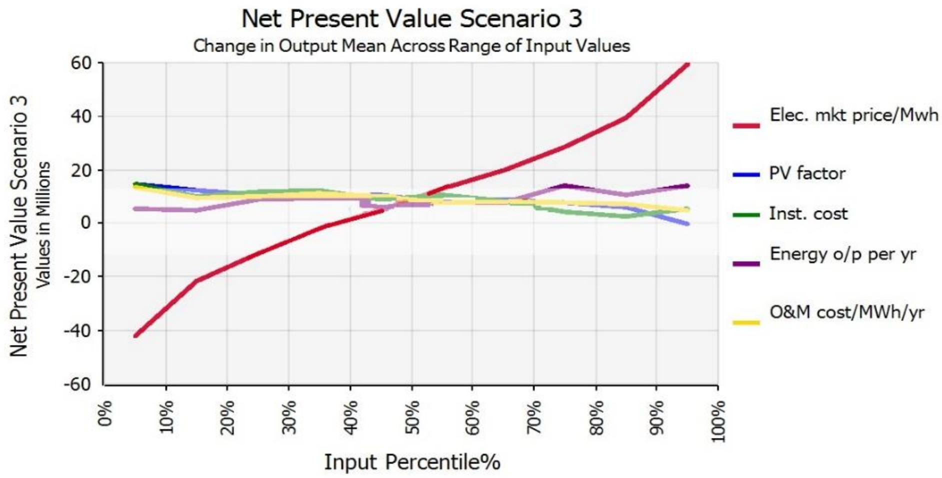
Source: generated by the author

Figure 7.11 Sensitivity of variables to NPV (in Euros) in scenario 3



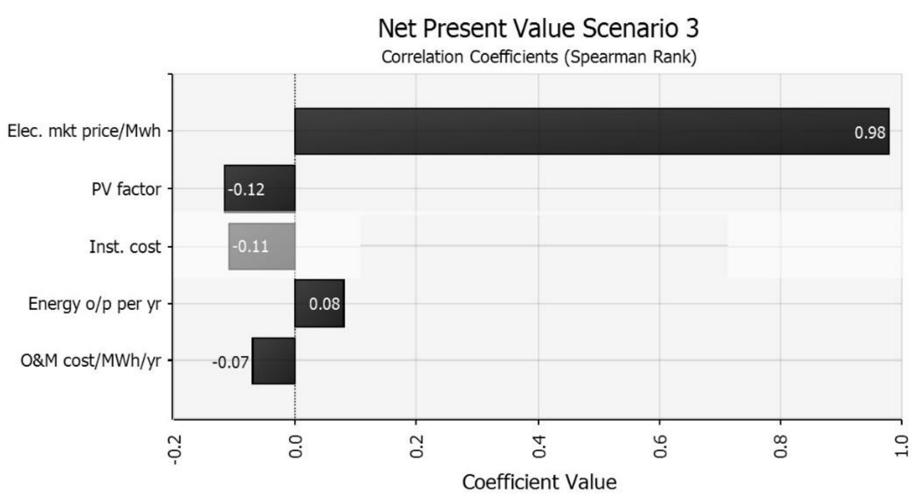
Source: generated by the author

Figure 7.12 Sensitivity of input variables to NPV (in Euros) for scenario 3



Source: generated by the author

Figure 7.13 Spearman coefficients variables for scenario 3



Source: generated by the author

Table 7.5 Lower and upper values (in Euros) of important variables affecting the model of scenario 3

Change in Output Statistic for Net Present Value Scenario 3			
Rank	Name	Lower	Upper
1	Electricity selling price	(42,288,139)	59,966,303
2	PV factor	982,400	13,402,433
3	Installation cost Euros per MWh	3,831,618	15,067,438
4	O & M per MWh	4,935,761	13,553,829
5	Energy produced MWh per year	5,521,433	12,302,839

Source: generated by the author

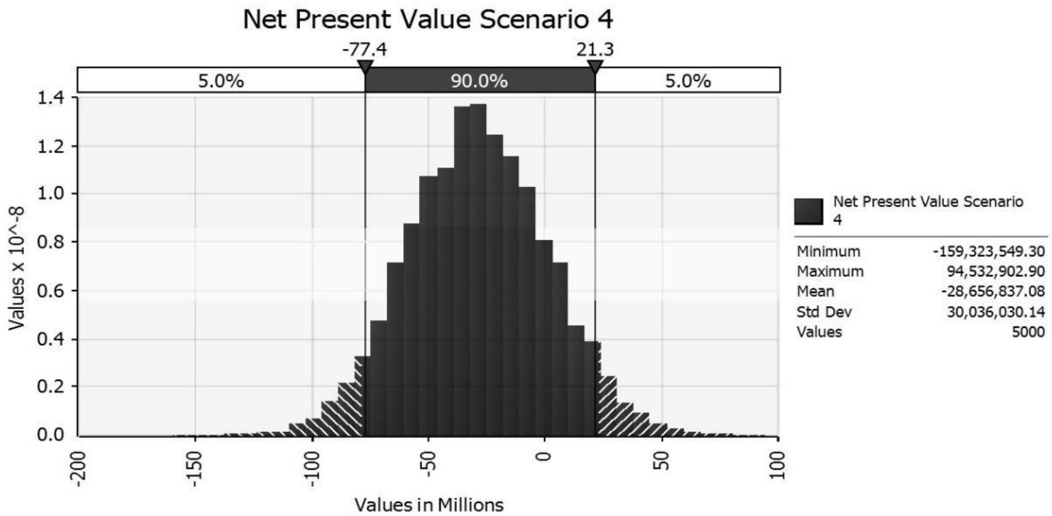
7.3.1.4 Scenario 4

Uncertainty accounted through this scenario may appear to be the risky for new investors, as this situation considers the market to be mature, offers no subsidies on installations and provides no incentives. However, taxes on selling electricity at market price in the open market are not considered in this scenario.

As it is observed through NVP simulation (fig. 7.14), the probability of getting negative NPV is higher with the mean of -28 million Euros. Through the NPV method, this project might not be advisable to be taken up by an investor.

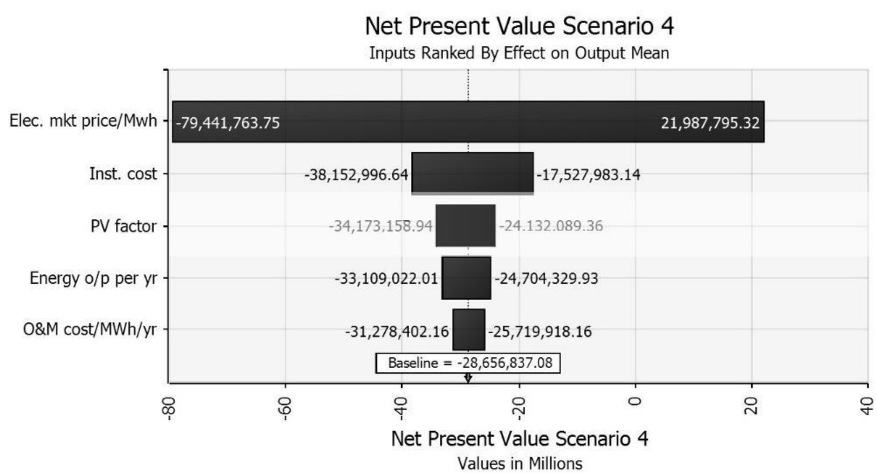
Similar to the previous scenario, this model also heavily relies upon electricity selling prices in the open market (fig. 7.15), which largely brings the NPV values in the range between -79 million to around +22 million Euros. Also, with all the input ranges of installation cost, the NPV is observed to be negative in every case. Other variables also influence NPV negatively. The correlation between the variables and fluctuation in NPV can be observed through fig. 7.16 and 7.17 respectively.

Figure 7.14 Normal distribution of NPV values (in Euros) through Monte Carlo simulations for scenario 4



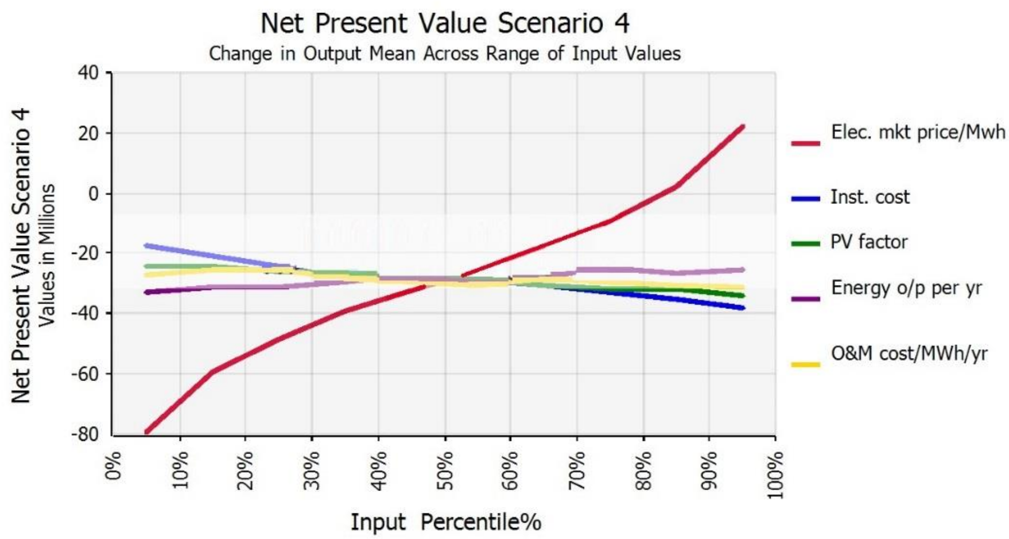
Source: generated by the author

Figure 7.15 Sensitivity of variables to NPV (in Euros) in scenario 4



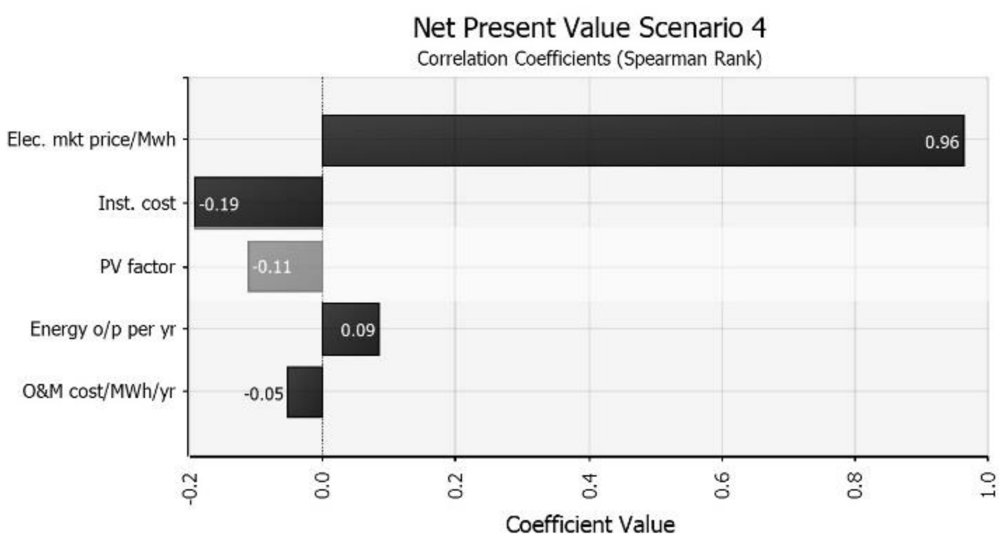
Source: generated by the author

Figure 7.16 Sensitivity of input variables to NPV (in Euros) for scenario 4



Source: generated by the author

Figure 7.17 Spearman coefficients variables for scenario 4



Source: generated by the author

Table 7.6 Lower and upper values (in Euros) of important variables affecting the model of scenario 4

Change in Output Statistic for Net Present Value Scenario 2			
Rank	Name	Lower	Upper
1	Electricity selling price	(74,963,658)	43,109,790
2	Installation cost Euros per MWh	(26,927,398)	(6,573,186)
3	PV factor	(24,949,907)	(7,940,729)
4	Energy produced MWh per year	(21,108,511)	(10,702,882)
5	O & M per MWh	(18,682,091)	(12,615,327)

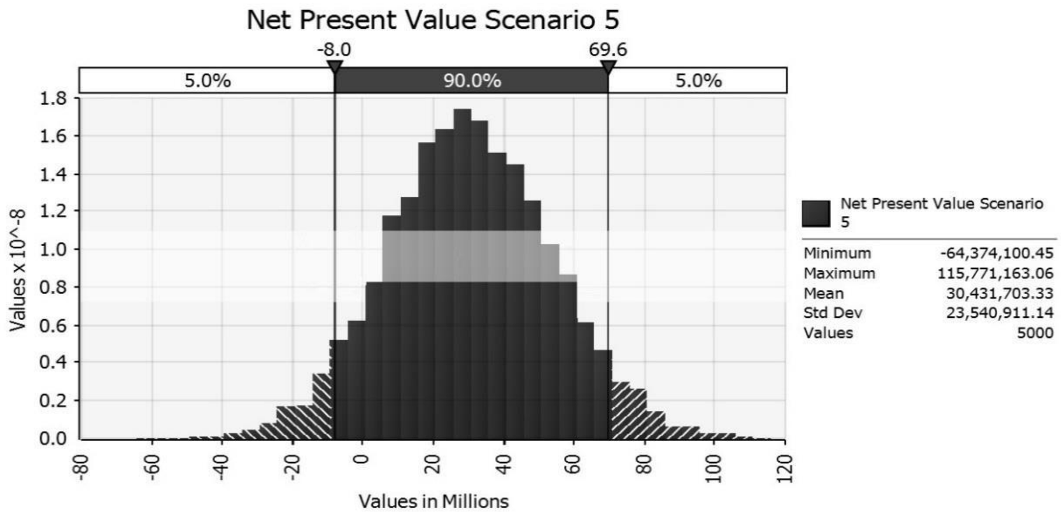
Source: generated by the author

7.3.1.5 Scenario 5

This scenario assumes a 100% subsidy on the installation cost and the selling of the electricity at market price with tax on electricity sales in the range 15-25%. As it is observed through simulated NPV distribution graph (fig. 7.18), the NPV in most of the cases is positive with a mean NPV of around 30 million. Based on the NPV logic, the project has higher positive value, and it can be considered viable.

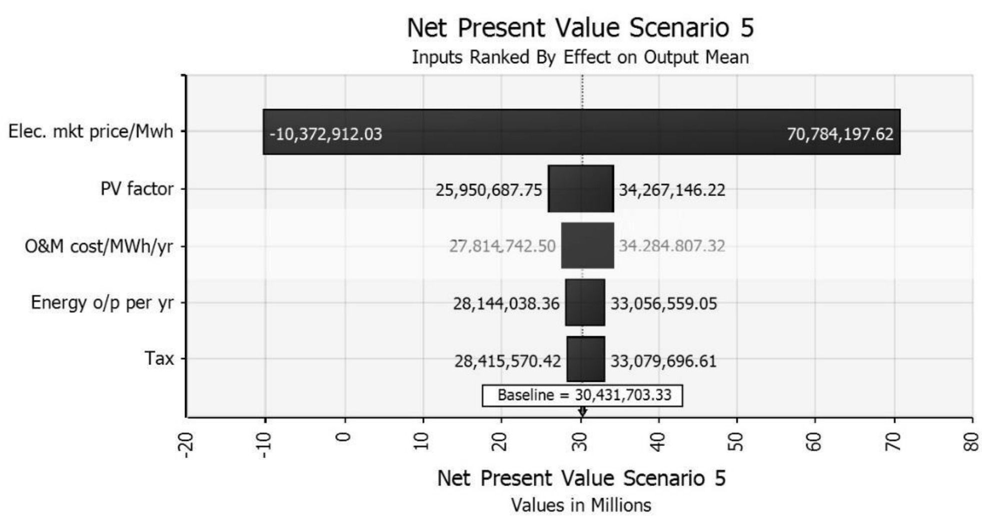
However, similar to previous scenarios, this scenario also exhibits greater sensitivity to electricity prices. The fluctuation in NPV and correlation between the variables can be observed through fig. 7.19, 7.20 and 7.21 respectively.

Figure 7.18 Normal distribution of NPV (in Euros) values through Monte Carlo simulations for scenario 5



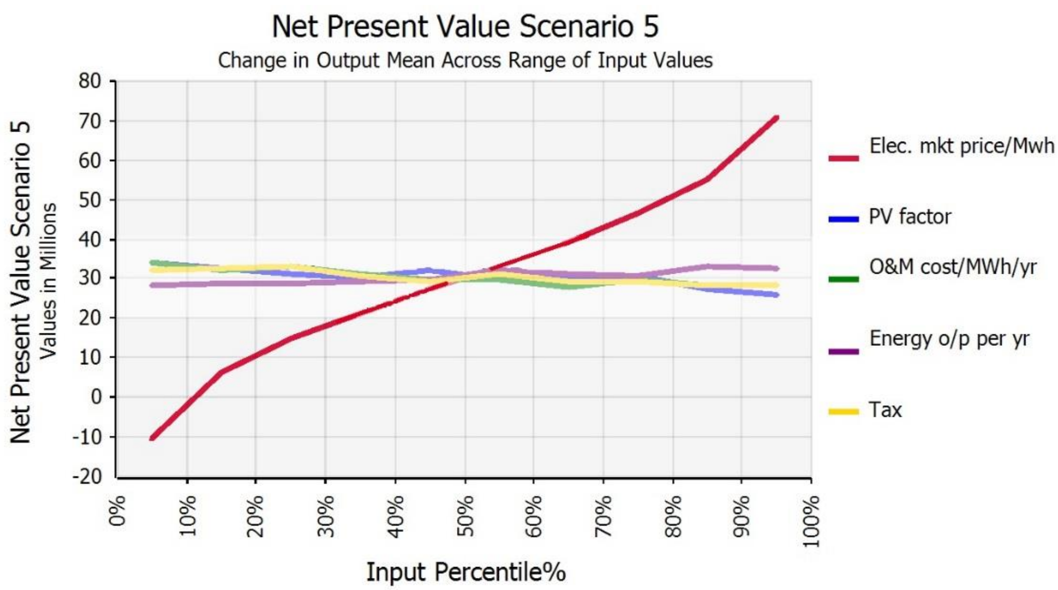
Source: generated by the author

Figure 7.19 Sensitivity of variables to NPV (in Euros) in scenario 5



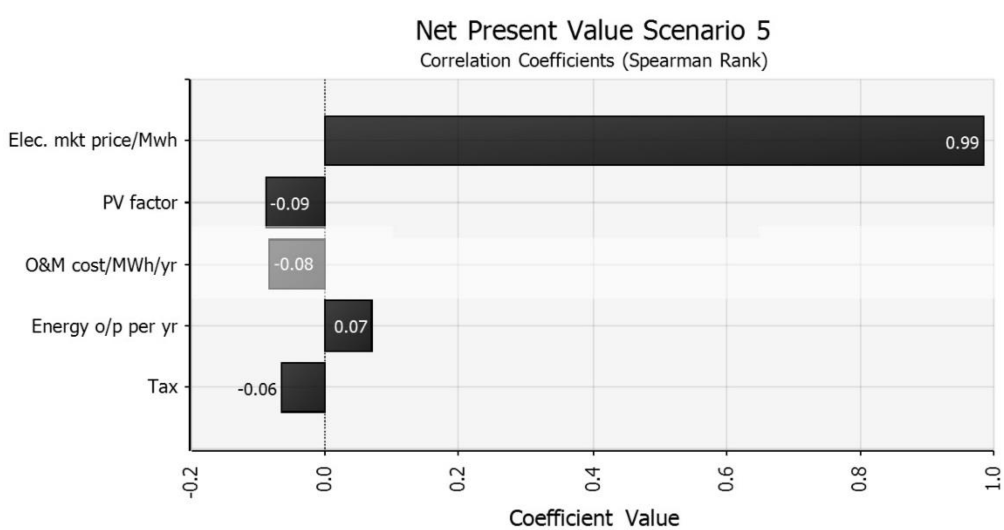
Source: generated by the author

Figure 7.20 Sensitivity of input variables to NPV (in Euros) for scenario 5



Source: generated by the author

Figure 7.21 Spearman coefficients variables for scenario 5



Source: generated by the author

Table 7.8 Lower and upper values (in Euros) of important variables affecting the model of scenario 5

Change in Output Statistic for Net Present Value Scenario 5			
Rank	Name	Lower	Upper
1	Electricity selling price	(10,211,830)	70,686,937
2	PV factor	27,193,461	33,775,048
3	Energy produced MWh per year	27,482,517	33,673,360
4	O & M per MWh	27,284,956	32,980,716
5	Tax @	28,675,682	33,014,917

Source: generated by the author

7.3.2 Project analysis through real options “delay values”

Further, for delay value calculations, following Black and Schole’s model was used:

$$\text{Delay Value} = [\left(e^{-\delta * t}\right) * S * N(d1) - S * (e^{-r*t}) * N(d2)]$$

Whereas,

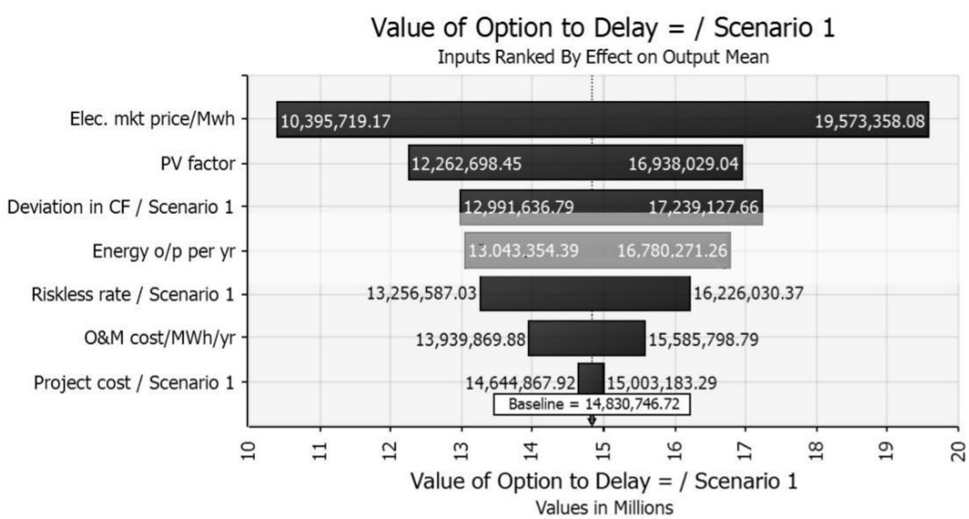
$$d1 = \frac{[\ln\frac{S}{E} + (r + \delta + \left(\frac{v}{2}\right) * t)]}{\sqrt{v} * \sqrt{t}}; \quad \text{and} \quad d2 = d1 - [\sqrt{v} * \sqrt{t}];$$

v represents variance = σ^2, N(d) represents the cumulative normal distribution

7.3.2 .1 Scenario 1

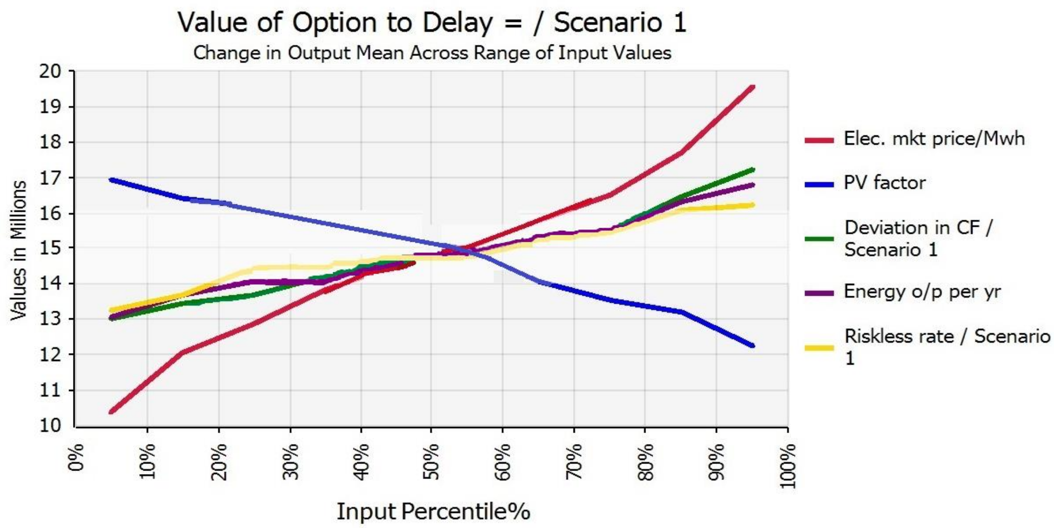
The mean value observed for this delay option is around 114.8 million Euros (fig. 7.22). Variations in Electricity price have high sensitivity to delay value ranging from 10.3 to 19.5 million Euros. PV factor and deviation in cash flow is another risk factor. Variations in cash flows appear to affect the value of delay - as low as 12.9 million Euros, and as high as around 17.29 million Euros. Another factor that affects significantly is a riskless rate. It affects delay value in the range 13.2-16.2 million Euros. The project cost is also observed to affect delay value to the least in this scenario. The fluctuation in NPV and correlation between the variables can be observed through fig. 7.23 and 7.24 respectively.

Figure 7.22 Sensitivity of variables to delay value (in Euros) in the scenario



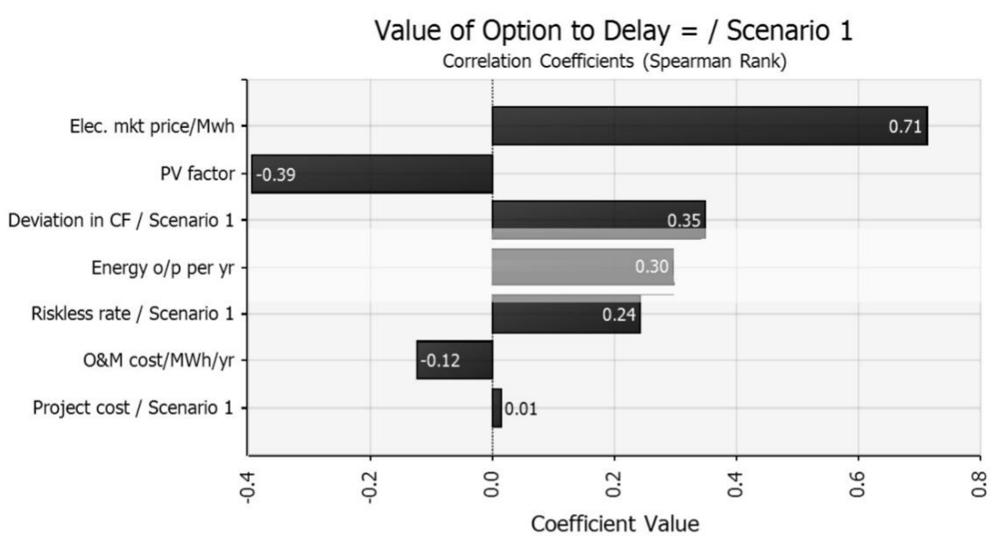
Source: generated by the author

Figure 7.23 Sensitivity of input variables to delay (in Euros) for scenario 1



Source: generated by the author

Figure 7.24 Spearman coefficients variables for scenario 1



Source: generated by the author

Table 7.9 Lower and upper values (in Euros) of important variables affecting the model of scenario 1

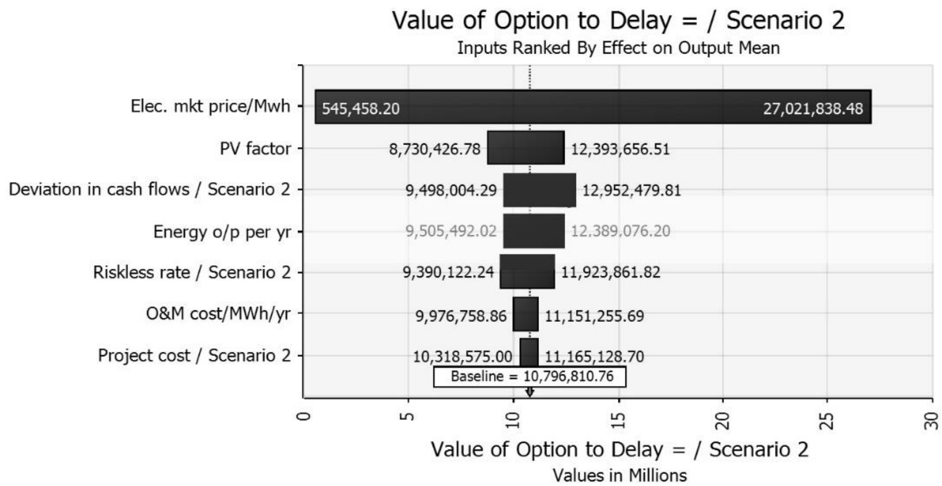
Change in Output Statistic for Value of Option to Delay = / Scenario 1			
Rank	Name	Lower	Upper
1	Elec. mkt price/MWh	10,518,021.68	19,500,499.85
2	PV factor	12,171,559.40	16,976,220.57
3	Deviation in CF / Scenario 1	12,831,057.26	17,320,046.23
4	Energy o/p per yr	13,054,133.62	16,619,586.95
5	Riskless rate / Scenario 1	13,422,121.58	16,417,266.95
6	O&M cost/MWh/yr	13,898,081.17	15,525,705.80
7	Project cost / Scenario 1	14,664,551.95	15,033,685.94

Source: generated by the author

7.3.2.2 Scenario 2

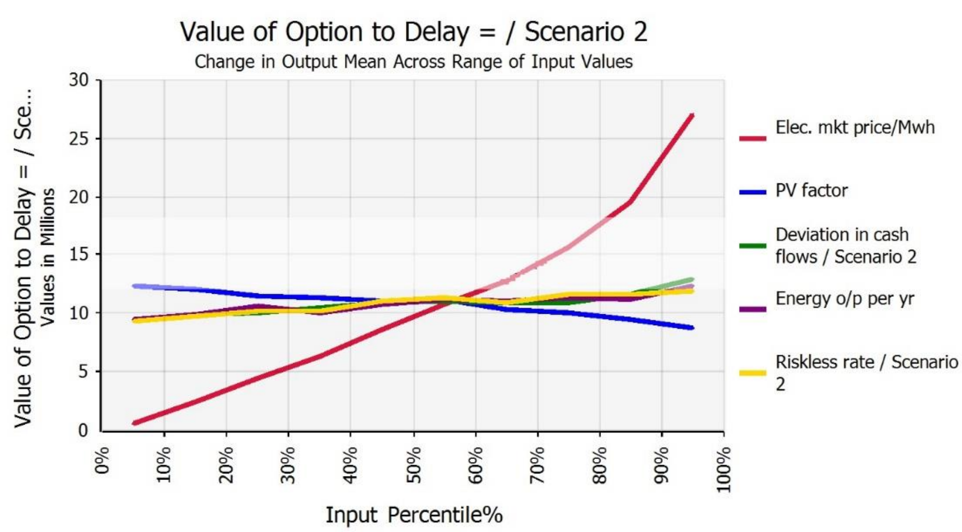
The mean delay value observed for this scenario is around 10.79 million Euros (fig. 7.25). High sensitivity towards the market price of electricity is observed within the range of 0.5 to 27 million Euros. In addition, sensitive variation is noticed in the delay with the deviation of cash flows (9.4 to 12.9 million Euros). However, with the varying riskless rate, the delay value can range from 9.3 to 11.2 million Euros. The project cost is not observed to have affected delay value to high level. The American and European option value in this scenario is 25.43 and 15.98 Million Euros respectively. The fluctuation in NPV and correlation between the variables can be observed through fig. 7.26 and 7.27 respectively.

Figure 7.25 Sensitivity of variables to delay value (in Euros) in scenario 2



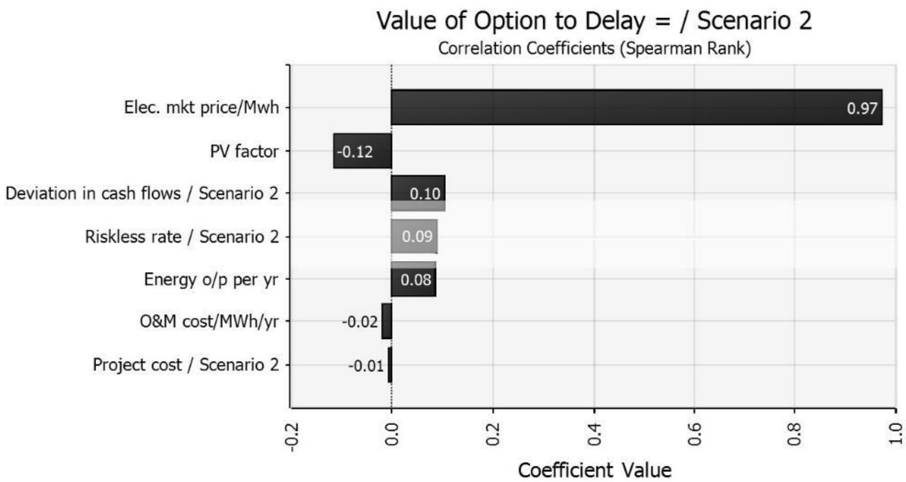
Source: generated by the author

Figure 7.26 Figure showing sensitivity of input variables to delay (in Euros) for scenario 2



Source: generated by the author

Figure 7.27 Spearman coefficients variables for scenario 2



Source: generated by the author

Table 7.10 Lower and upper values (in Euros) of important variables affecting the model of scenario

Change in Output Statistic for Value of Option to Delay = / Scenario 2			
Rank	Name	Lower	Upper
1	Elec. mkt price/MWh	515,851.46	26,845,742.34
2	Deviation in cash flows / Scenario 2	8,810,869.90	12,771,640.19
3	PV factor	8,753,248.55	12,607,116.02
4	Energy o/p per yr	9,823,228.77	12,553,420.25
5	Riskless rate / Scenario 2	9,431,496.55	12,154,101.24
6	Project cost / Scenario 2	9,796,825.86	11,654,467.24
7	O&M cost/MWh/yr	10,029,326.79	11,667,725.18

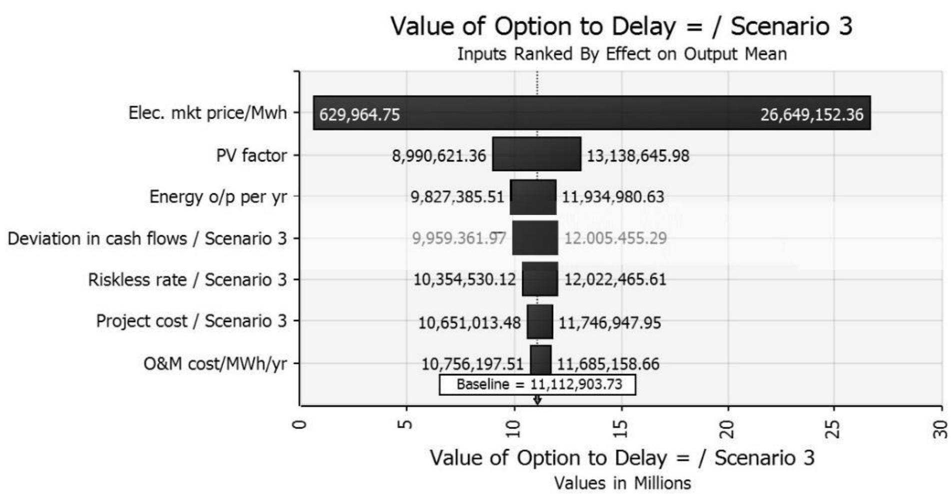
Source: generated by author

7.3.2.3 Scenario 3

The value of the mean delay in this scenario is around 11.14 million Euros (fig. 7.28) with lower and higher ranges of 3.4 to 47 million Euros. Deviation in electricity price and PV factor has a major impact on delay values. Deviation in the other variables such as PV factor and energy output plays a relatively less role in the variation of delay values.

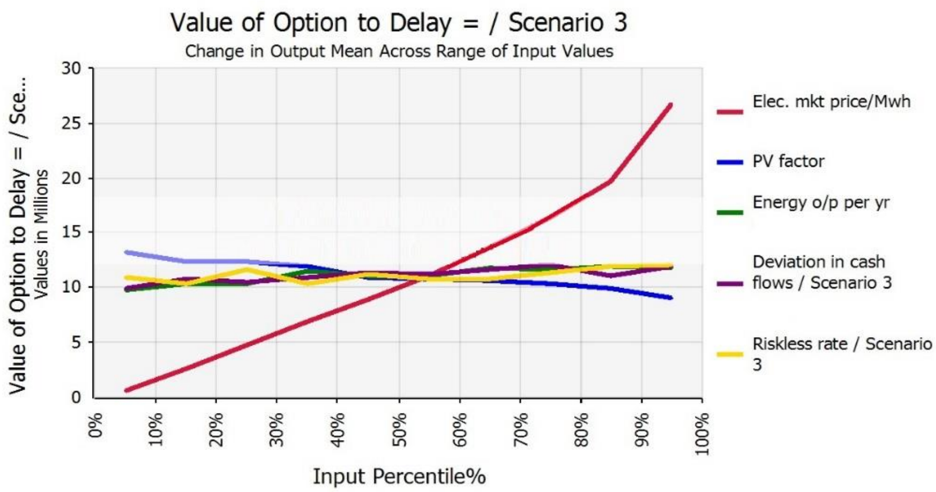
The American and European option observed for this valuation are 17.9 and 10.63 million Euros respectively. The fluctuation in NPV and correlation between the variables can be observed through fig. 7.29 and 7.30 respectively.

Figure 7.28 Sensitivity of variables to delay value (in Euros) in the scenario 3



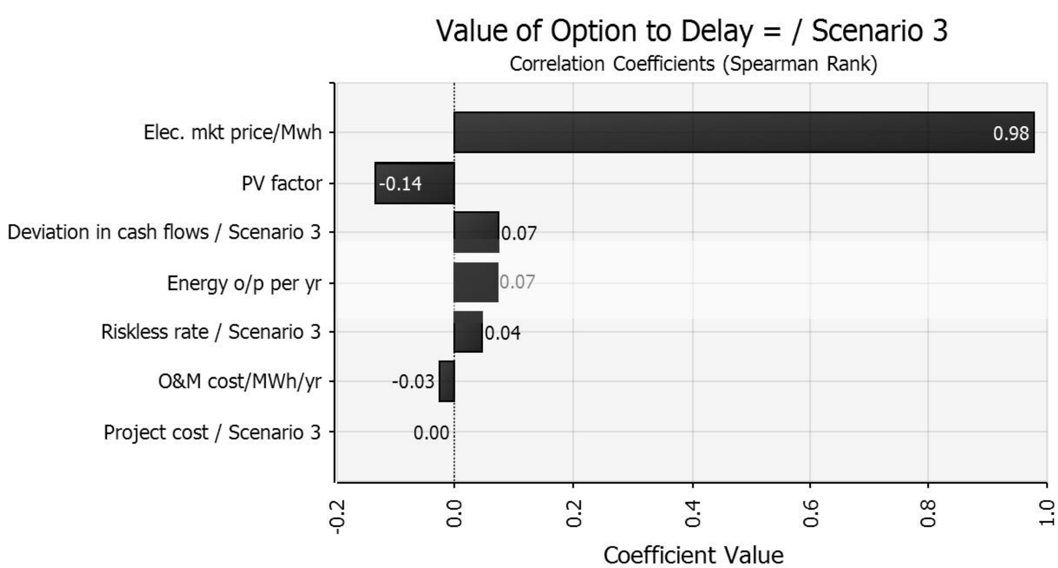
Source: generated by the author

Figure 7.29 Sensitivity of input variables to delay value (in Euros) for scenario 3



Source: generated by the author

Figure 7.30 Spearman coefficients variables for scenario 3



Source: generated by the author

Table 7.11 Lower and upper values (in Euros) of important variables affecting the model of scenario

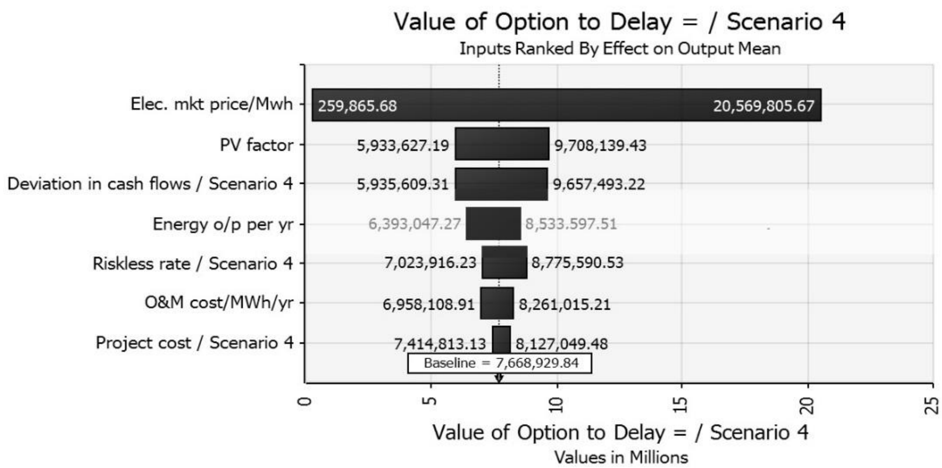
Change in Output Statistic for Value of Option to Delay = / Scenario 3			
Rank	Name	Lower	Upper
1	Elec. mkt price/MWh	641,750.18	26,810,466.03
2	PV factor	8,813,812.68	12,835,835.47
3	O&M cost/MWh/yr	10,019,863.58	12,197,081.96
4	Energy o/p per yr	10,116,205.37	12,275,139.10
5	Deviation in cash flows / Scenario 3	10,299,079.85	12,161,291.34
6	Riskless rate / Scenario 3	10,286,594.89	12,101,980.00
7	Project cost / Scenario 3	10,500,473.45	11,792,582.57

Source: generated by the author

7.3.2.4 Scenario 4

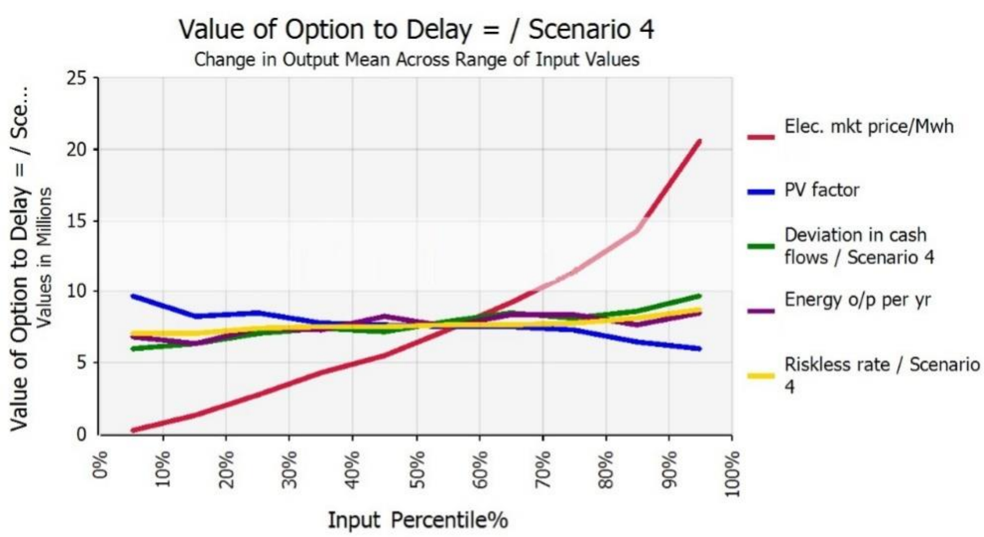
The mean delay value observed for this scenario is 7.6 million Euros (fig. 7.31). A trend observed from the tornado graph is similar to the previous scenario. Deviation in cash flows can vary the delay value from 0.2 to 20 million Euros. PV factor affects delay value in the range of 5.9 to 9 million Euros. Both riskless rate and deviation in cash flows is observed to affect the delay value from 7 to 8 million Euros. The American and European options' values are observed to be 8.7 and 6.6 million Euros respectively. The fluctuation in NPV and correlation between the variables can be observed through fig. 7.32 and 7.33 respectively.

Figure 7.31 Sensitivity of variables to delay value (in Euros) in scenario



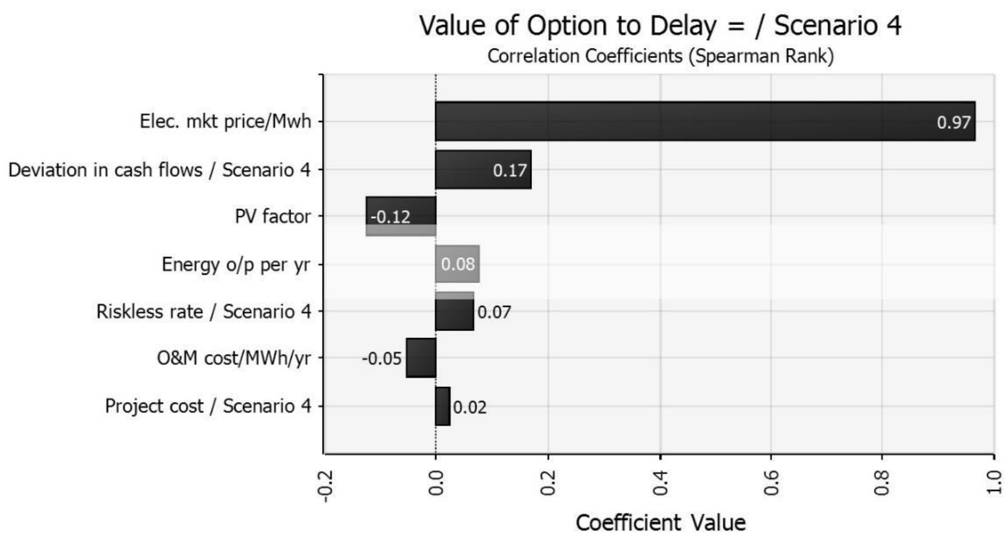
Source: generated by the author

Figure 7.32 Sensitivity of input variables to delay value (in Euros) for scenario 4



Source: generated by the author

Figure 7.33 Spearman coefficients variables for scenario 4



Source: generated by the author

Table 7.12 Lower and upper values (in Euros) of important variables affecting the model of scenario

Change in Output Statistic for Value of Option to Delay = / Scenario 4			
Rank	Name	Lower	Upper
1	Elec. mkt price/MWh	253,991.06	20,310,682.05
2	Deviation in cash flows / Scenario 4	6,282,906.62	9,613,455.39
3	PV factor	6,028,329.98	9,128,001.72
4	Riskless rate / Scenario 4	6,852,119.82	8,514,908.56
5	Project cost / Scenario 4	6,879,093.94	8,425,898.91
6	O&M cost/MWh/yr	6,951,983.66	8,295,295.86
7	Energy o/p per yr	7,171,482.51	8,147,671.09

Source: generated by author

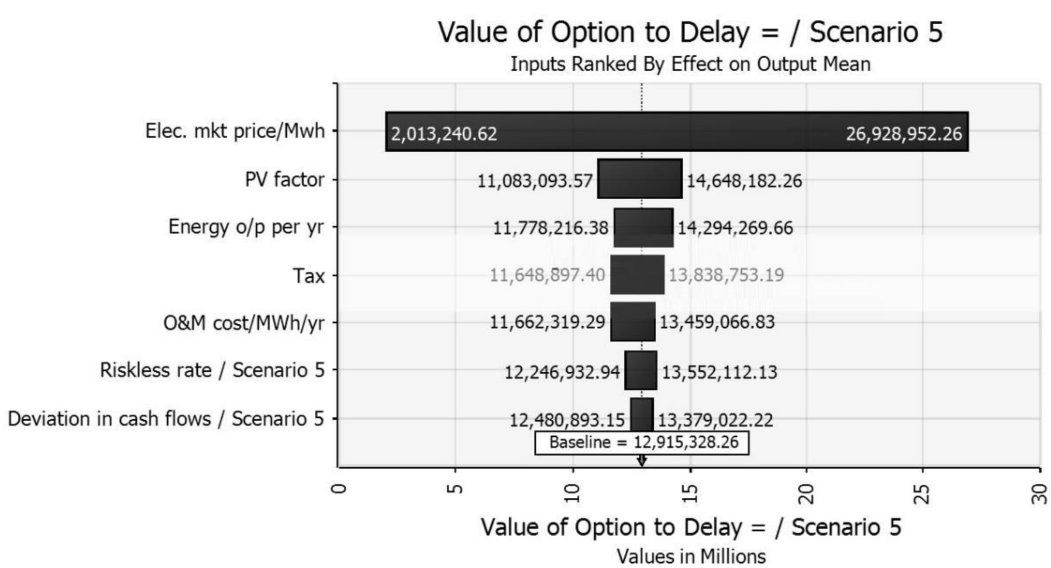
7.3.2.5 Scenario 5

The value of the mean delay in this scenario is around 12.9 million Euros (fig. 7.34). There is very less deviation in cash flows because 100% subsidy is considered. This scenario largely depends on the output of energy generated and market electricity price. However, overall, tax rate also does not seem to affect the value to a larger extent

O&M cost and riskless rates seem to affect the delay value to a great extent. The observed values for both variables are around 12 to 13.5 million Euros.

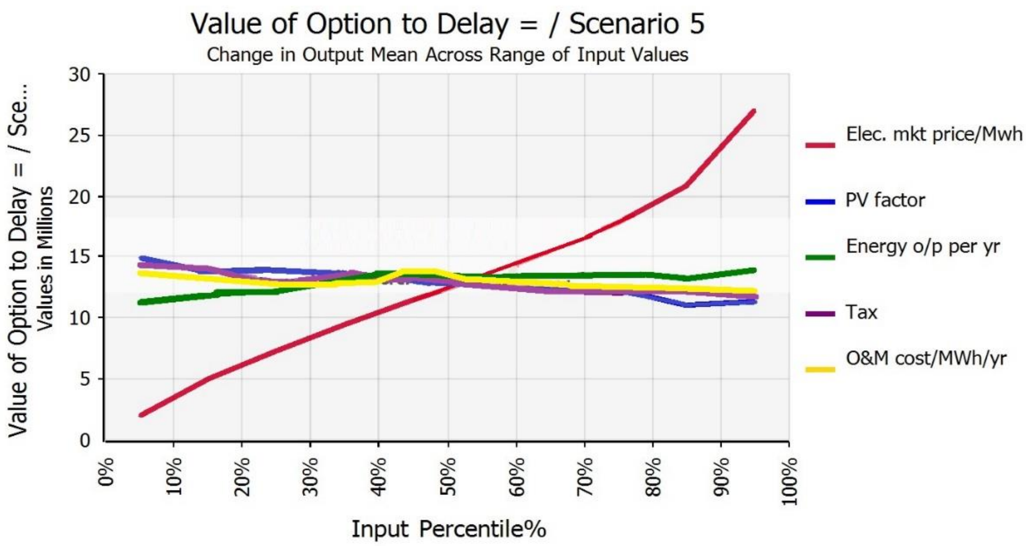
The American and European option observed for this valuation are 34.2 and 12.59 million Euros respectively. The fluctuation in NPV and correlation between the variables can be observed through fig. 7.35 and 7.36 respectively.

Figure 7.34 Tornado graph showing the sensitivity of variables to delay value (in Euros) in the scenario



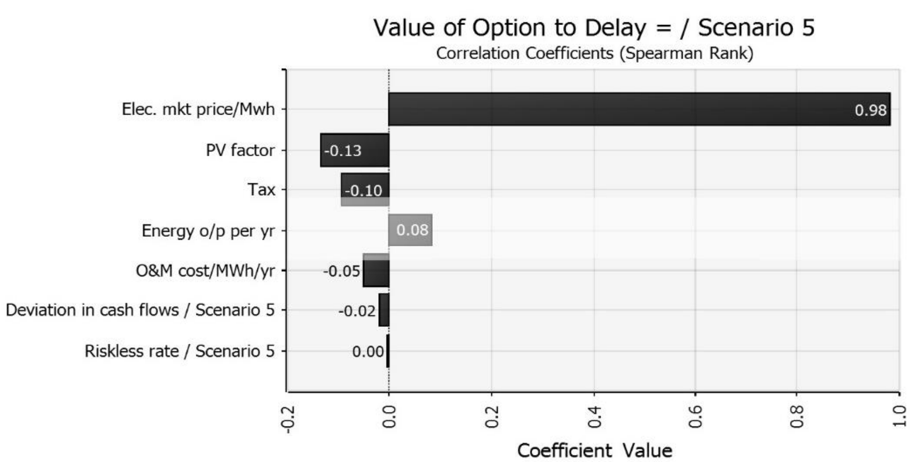
Source: generated by the author

Figure 7.35 Sensitivity of input variables to delay value (in Euros) for scenario 5



Source: generated by the author

Figure 7.36 Spearman coefficients variables for scenario 5



Source: generated by the author

Table 7.13 Lower and upper values (in Euros) of important variables affecting the model of scenario

Change in Output Statistic for Value of Option to Delay = / Scenario 5			
Rank	Name	Lower	Upper
1	Elec. mkt price/MWh	2,023,082.24	26,565,088.60
2	Energy o/p per yr	11,494,029.25	14,510,994.35
3	PV factor	11,255,315.56	14,087,765.03
4	Tax	11,763,209.61	13,633,126.02
5	O&M cost/MWh/yr	12,238,279.72	13,577,999.13
6	Riskless rate / Scenario 5	12,402,645.85	13,417,041.21
7	Deviation in cash flows / Scenario 5	12,457,655.06	13,466,849.59

Source: generated by author

The overall output statistics and output of project are summarized in Table 7.14

Table 7.14 Summary of the project evaluation (Unit is Million Euros)

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
	15 yrs FIT @ 75 Euros/MWh generation and no subsidy	**6 yrs FIT @ market price plus benefit in Euros/MWh generation and no subsidy**	**50% subsidy on installation cost and No FIT**	**No subsidy on installation cost and No FIT**	**100% subsidy on installation cost and No FIT and tax @ 20%**
PV in Euros	86.08	64.25	51.37	51.37	34.24
NPV in Euros	10.68	-11.14	13.47	-24.02	33.84
Delay value Euros	15.95	9.75	10.53	6.49	12.59
American options value	25.43	14.33	17.92	8.71	34.24
European options value in Euros	15.98	9.75	10.63	6.61	12.59
Black & Scholes call options value in Euros	15.95	9.75	10.53	6.49	12.59
Black & Scholes put option in Euros	5.77	7.60	2.38	9.08	0.00

Source: generated by author

A comparative summary of the scenarios is shown through the Table 7.14. The delay values in scenario 2 and 4 are much higher than that of scenario1 and 5. According to this study, it is suggested that project should not be taken under scenario 2 and 4. However, scenario 3 and 5 are relatively better, having higher NPV values.

7.4 Contribution to the literature

The study evaluates a 50MW wind project and presents the effect of recent regulatory changes introduced in the Iberian market. The revisions in Spain would significantly affect the regulations in Portugal too, as they operate under a same market regime.

To the best of our knowledge, the scientific literature is not available for Portuguese framework under recent regulatory revision in Spain. Therefore, presenting the results of financial evaluation through NPV and Real Options Approach for a wind power project in the Portuguese framework is a contribution to literature. Furthermore, the context itself is very novel, and according to our best understanding has not been studied previously. Additionally, the scenarios that have been studied in this part of the thesis use absolutely different input values (and combination of variables) that were not seen in the previous literature.

7.5 Conclusion

Through our study, we have tried to show that uncertainties in the regulatory framework may affect business investments, as the possibility of getting returns on investments may vary with regulations. In conducting the study, we took 50 MW wind power project. Since the aim of the study was to understand the profit/loss variations in the NPV and real options values, we tried to maintain the simplicity in considering the data and therefore avoided the micro level data. The results obtained from NPV and Real options values were compared. In the overall study, the main scenario (scenario 2) was found to be the riskiest. The delay value in this case was considered to be higher. Therefore, from a business point of view, taking up such project, until more information arrives, may not be advisable.

Further, the variables like steel cost, fluctuations in the land leasing prices, project operation failures, strikes, natural calamities, changes in the labour markets, etc. were not considered in the evaluation of the project. Secondly, it was assumed that there is no competition in the market.

Further, it is well documented in the literature that the ROA has advantage over NPV. However, ROA calculations start by analysing NPV. Therefore, evaluating project through ROA complements traditional NPV method. Nevertheless, there could also be other methods for evaluating energy projects, but considering the irreversibility and flexibility; ROA may be a better option to analyse business risk in the current condition. Thus, ROA may be better and more realistic for the decision-making process.

Chapter 8

Concluding remarks

Through this dissertation, we tried to understand the investments in the renewable energy from macro and micro perspective. The purpose of this study was twofolds: to understand the drivers of the investment in solar and wind energy in the European Union (EU) 27 states[22], and to evaluate a renewable energy company business risk through real option approach in the framework of the first part of the thesis.

Despite the higher number of annual sunshine hours, in most of the European countries, the generation of electricity through solar is not yet picked up. Rather, wind is perceived as the preferred source of electricity generation with huge investment in the sector.

This study seems relevant to companies (associated to renewable energy generation) and investors to consider uncertainties in changing of renewable energy support schemes with the alignment of European Union's and its individual country's objectives. For example, Spain considers wind to be a mature technology and recently reformulated the regulations to subsidize it. Investment in renewable energy is relevant as it is one of the key instruments that increases the renewable energy share and helps achieving energy independence and reduce the carbon footprints. Another purpose of the study was to understand the effect of increasing renewable energy share on the retail electricity price. With the investment in renewable energies, the cost incurred in project implementation is passed to the customers. Furthermore, the importance of the latter was to understand the investment from a macro level perspective.

The investment in renewable energy (RES) remains one of the drivers in increasing the share of clean energy supply; there has been a lot of research conducted in Europe Union that connect RES generation to policy frameworks. However, research on how a particular technology is

[22] Selection of countries were dictated by the availability of data and period of our study

seen by investors is underdeveloped. This research postulated the effects of different variables (regulation perception, carbon emissions etc.) on investment in solar and wind at macro level.

The research used macroeconomic modelling through panel data over the period 1995 to 2011. Data was taken from Eurostat and World Bank databases. The first contribution of this study is to introduce the solar and wind investment drivers, second contribution is to determine the relationship between RES generation and electricity final prices.

Taking European Union countries as a sample seems obvious and useful, as EU was the earliest mover in terms of framing and implementing renewable energy policies. EU-27 represents a very large sample with heterogeneous group of countries, therefore it seems adequate to apply model to a smaller sample of 15 countries (EU-15[23]). Thus, the EU-27 sample was also compared to EU-15 to understand the variations in results. This is another contribution to the literature on this subject.

However, a macro approach does not cover the entities and challenges of renewable energy businesses at individual root level. These challenges are associated with the investment decisions of small entrepreneurs, medium sized businesses or industries, and renewable energy incumbents. Therefore, to understand issues related to businesses at micro level, details of RES project were carefully considered, reviewed and investment decisions were evaluated through traditional net present value and the real options approach. Thus, both sections of this study were complemented and connected to each other. As this study is performed on project that dealt with uncertainty and irreversibility, we used real options approach to address our study.

Additionally, to give this thesis a business perspective, a 50 MW wind power project was analysed using real option approach. Sensitivity analysis was performed to identify the level of business risk, under uncertainties in the RES framework.

[23] EU-15 is old group of 15 Western European states including Sweden and Finland (year 1995)

In the second part, a real option approach, developed by Black and Scholes in 1973, was used to measure the business risk of company under uncertainties. Although, this method to address the renewable energy project evaluation is not widely used in practice.

Addressing the issue in current policy framework within specific geography (Portugal) is also an interesting, and is an important contribution to existing knowledge. Moreover, this study can also be effectively replicated by other developing and developed nations to evaluate the RES investment projects particular to their situation. Additionally, this study could also help managers to take expansion decisions related to renewable energy projects.

The proposed methods to model the investments are based on certain assumptions and study serves as a comprehensive approach. Thus, it does not cover the micro level details in our modelling approach, which serves as a limitation of the study. A strategic formulation and recommendations in the form of publishable article will be published after the doctoral work. A case study on wind power companies from Spain and Portugal that involves qualitative and quantitative methods is proposed after the completion of doctoral work. Results arrived from this thesis would be explored in different conditions and in different geographies. We also propose to study the existing grid quality of developed/developing nations that has lot to do with Renewable energy generation and supply. It is also expected that we will conduct an economic survey and research on the renewable energy consumerism (demand side) using big data through geospatial technologies. Such a research will be useful in understanding the consumers' perspectives and their contribution to meeting European 2020 clean energy targets.

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