# “Investment evaluation in renewable projects under uncertainty, using real options analysis: the case of wind power industry”



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| **ARTICLE INFO** | Ioannis Kinias, Ioannis Tsakalos and Nikolaos Konstantopoulos (2017). Investment evaluation in renewable projects under uncertainty, using real options analysis: the case of wind power industry. *Investment Management and Financial Innovations*, *14*(1), 96-103. doi:10.21511/imfi.14(1).2017.10 |
| **DOI** | http://dx.doi.org/10.21511/imfi.14(1).2017.10 |
| **RELEASED ON** | Friday, 31 March 2017 |
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| **JOURNAL** | "Investment Management and Financial Innovations" |
| **ISSN PRINT** | 1810-4967 |
| **ISSN ONLINE** | 1812-9358 |
| **PUBLISHER** | LLC “Consulting Publishing Company “Business Perspectives” |
| **FOUNDER** | LLC “Consulting Publishing Company “Business Perspectives” |



| NUMBER OF REFERENCES | NUMBER OF FIGURES | NUMBER OF TABLES |
|---|---|---|
| 31 | 2 | 3 |

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# Investment evaluation in renewable projects under uncertainty, using real options analysis: the case of wind power industry


## Abstract

Investment analysis is a crucial process for any investment's success. This process can be supported by both the discounted cash flow analysis and the real options analysis. Many researchers have point out restrictions for the first one, in cases of uncertainty in the entrepreneurial environment. The main types of uncertainty, concerning the wind energy sector, include uncertainties related to the price of electriticity by RES, the public policy regulatory policies, the demand, the initial capital costs, the technological progress, the weather conditions, the political and economical situations and generally the RES market structure. In this paper, we try to find the optimal investment strategy in a liberalized global electricity market, where the price of electricity is uncertain while the other parameters are configured separately in each country. The authors consider about the factors of the time for investment and the electricity's price level, in wind energy by using the real options theory. The authors select a variety of data for the wind energy industry from different countries in several continents, and also create a model for the investment analysis in this entrepreneurial sector.


**Keywords:** real options, wind energy, uncertainty, investment analysis.
**JEL Classification:** M21.

## Introduction

Real options theory provides important ideas and appropriate techniques, modeling investment decision-making problems, in a changing environment, where instability and uncertainty are high. Yeo and Qui (2003) note that "since the early 1980s, advances in real option literature have fundamentally changed the way people think about investment opportunities". Myers (1977) was the first to use the term real options. Since then, a wide range of literature has developed regarding the evaluation of investment projects in an uncertain environment. Investments in natural resources and energy economics are admirable applications of the real options theory. Especially, in the energy sector the investments are characterized by large investment costs and uncertainty. Therefore, many researchers, such as Herbelot (1992), Kobila (1990), Salahor (1998) underlying the need using more efficient techniques for the study of this sector.

The most famous investment evaluation methods are the norm NPV and IRR that are included in the discounted cash flow analysis. Davis and Owens (2003) prove that the theory of DCF has a lot of restrictions, when considering technologies that have high technical and financial uncertainty, are ongoing. As the authors demonstrate the methods DCF seems to be outdated for the evaluation of power plants in a market that fluctuates on daily rates.

On the other hand, Schwartz (1997) points out that "the stochastic behavior of commodity prices plays an important role in the models for valuing financial contingent claims on the commodity and in the procedures for evaluating investments to extract or produce the commodity". Similarly, Hassett and Metcalf (1999) state that "the impact of uncertainty on investment depends to a large extent on the underlying stochastic process". The most commonly used stochastic process in financial theory, evaluating investment projects is the geometric Brownian motion process.

Smith and McCardle (1999) describe the relationship between pricing techniques using real options and DCF methods in real applications in oil and gas sector. Tseng and Barz (2002) estimate the value of electricity generation facilities in a liberalized market under a multistage stochastic environment, where electricity and fuel prices are uncertain. Deng and Oren (2003) try to solve the long-term asset evaluation problem with a time horizon of several years in power plants. In Brazil, Moreira et al. (2004) consider the competitiveness of thermal units in a system, characterized by low-cost production of electricity through hydroelectric plants in a highly uncertain environment. Madlener et al. (2005), Herbelot (1992), and Brekke and Schieldrop (1999), also study with real options electricity power plants with uncertainty in both oil and gas prices.

In renewable industry Venetsanos et al. (2002) highlight the importance of methodology of real options in wind power investment projects under uncertainty. They provide comparative results between


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the methods of NPV and real options, using data from the field of RES in Greece. Davis and Owens (2003) use the theory of the RO in order to assess the value of a funding program in energy production by RES. In their problem, the uncertainty in the price of conventional fuel follows the Brownian stochastic process and cost reductions in renewable energy technology due to specialized research also considered as stochastic. Their results show that the traditional NPV method underestimates the value of investments in research and development in the field of RES. Murto (2003) examines the influence of uncertainty on revenue and technology, in a wind farm, and shows the interaction between them. They also note that whenever an investor decides to implement an investment, he must take into account that the technological progress could allow him to complete the investment with a better technology and lower cost. Such a case of investments are the wind power projects.

The main types of uncertainty in the electricity sector, are related to the price of conventional fuels, the environmental regulatory policies, the demand, the initial capital costs, the technological progress and the market structure (Venetsanos et al., 2002). Regarding investments in RES, uncertainties, arising from the future technological innovations and the regulatory framework. Verra, A. (2009) also notes that renewable energy investments are capital intensive projects, characterized by low variable costs and relatively high initial capital expenditures. The uncertainty in the initial capital cost of these investments depends on the risk of exceeding the expenditure during the construction period, as well as on the increased costs in the case of delays in the investment implementation.

The stability of the regulatory framework affects the level of incomes in RES investments through the price of the produced electricity. The regulator – policy maker guarantees to the investor a certain performance for a given time period. This policy has a risk due to political uncertainty. The regulatory uncertainty stems from two sources. Firstly, the regulator may decide to alter the default policy due to factors, not related to the regulated market (inflationary pressures, budgetary and fiscal crises). This interference affects the price mechanism and reduces the efficiency of the investments. Secondly, the policy maker can decide to break his contract with companies, if there are distortions in the level of prosperity (Panteghini and Scarpa, 2003). Altug et al. (2001) examine the impact of the tax risk and political instability in an investment plan and provide the necessary conditions for the reduction of investments through an increase in tax risk. Generally, few research efforts have been made, concerning the influence of the regulatory uncertainty in investment especially in the context of electricity through renewable energy, although several articles have modeled the effects of other types of uncertainty.

In this paper we try to find the optimal investment strategy in a liberalized electricity market, where the price of electricity is uncertain, while the other parameters are configured separately in each country. We consider the problem of choosing the time and the price level for investment in wind energy by using the real options theory. We try to find the critical level of electricity prices, at which the marginal benefit is equal to the marginal present value of the investment. For this reason we try to select a variety of data for the wind energy industry from different countries in several continents.

The rest of the paper is structured as below. The next section refers to the description of the data from the global wind energy sector. Section 2 outlines the methodological issues. Section 3 presents the analysis and finally, the final section includes the main conclusions.

## 1. Wind energy sector's global overview

The record number of 51.5 GW of wind power installed in 2014, bringing the total installed global capacity to more than 369.6 GW at the end of 2014. 268.000 wind turbines are spinning around the world and 608 million tonnes of $CO_2$ emissions are avoided, globally, due to the wind energy at the end of 2014. The 3% of global electricity is supplied by wind power and the 17% of global electricity could be supplied by wind power in 2030. Concerning the employment, 601.500 people work worldwide in the wind industry, and 2.171.804 people will be employed by the wind power sector in 2030 worldwide, according to GWEC advanced scenario. About 99.5 $ billion invested in wind power globally, making it one of the fastest growing industrial segments in the world (GWEC, 2015).

According to Europe, the wind power projects were installed more than any other form of energy production in 2015. At this time, there is a 142 GW of installed wind power capacity in the EU (131 GW onshore and 11 GW offshore). Germany remains the EU country with the largest installed capacity (45 GW), followed by Spain (23 GW), UK (14 GW), France (10 GW) and sixteen EU countries that have over than 1 GW. The total capital that was invested in Europe in 2015 in wind energy projects was €26.4 billion. The EU's current wind power capacity covers 10.2% of its electricity consumption, powering over 73 million households. The 59.6% of Spain's total power demand supplied by wind power as well as 39.1% of Denmark's electricity consumption was covered by wind energy. The Danish government aims to get 50% of its electricity from wind by 2020 and 100% from renewable energy by 2050 (EWEA, 2016).

Out of Europe, 2.472 MW of wind power were installed in Brazil in 2014. Brazil has become a leader in the South American wind energy market, in a total of more than 5.9 GW. Moreover, 110 million of Chinese houses were powered by wind energy (total capacity 114,609 MW) at the end of 2014. The annual growth of Chinese wind market was 45% in 2014 (GWEC, 2015).

Figure 1 and Figure 2 present the growth of the wind power industry, the last decade, as well as the forecast for the market's progress in the next five years. It is clear for them that there is a different behavior concerning the installed capacity by region till now and an estimate for a decrease in the growth rate for the future. Therefore, we can assume that any investor may come up against different situations, trying to invest across the world.

Kinias (2015) describes that the entrepreneurial environment in RES is developed as a sequence of national objectives, political decisions, financial tools, weather conditions, local technological situations and international factors. All these variables create a multilevel problem that may be investigated by the entrepreneur.

Weather conditions are the first crucial factor that affects the growth of this technological sector. The wind potential and the wind speed in onshore and offshore plants, in different heights, is a first important factor. Romania has the highest wind potential in South Eastern Europe and the second best place in Europe (after Scotland). In some countries the best plants are already occupied and free spaces, where companies can build, are now minimal. The next step for new installations, for countries such as Germany and Netherlands, is the coastal areas, where the wind potential is better.

Generators of electricity from renewable sources (RES-E) usually receive financial support in terms of a subsidy per kW of capacity installed, or a payment per kWh produced and sold. The most commonly used *Public Support Mechanisms* in the renewable energy industry are the Feed in Tariff (FIT), the Quota Systems, which is based on Tradable Green Certificates (TGCs), the Tax mechanism, the Tendering systems, the Net metering programs and the Self-Consumption. In the most European countries, electricity from renewable sources is promoted through the feed-in tariff and tax benefits. Table 1 presents data of public support mechanisms, from several countries. Especially, we focus on the leader European counries in RES, the mediterrenean countries and the emerging markets of the Eastern Europe trying to compare regions with so different characteristics.

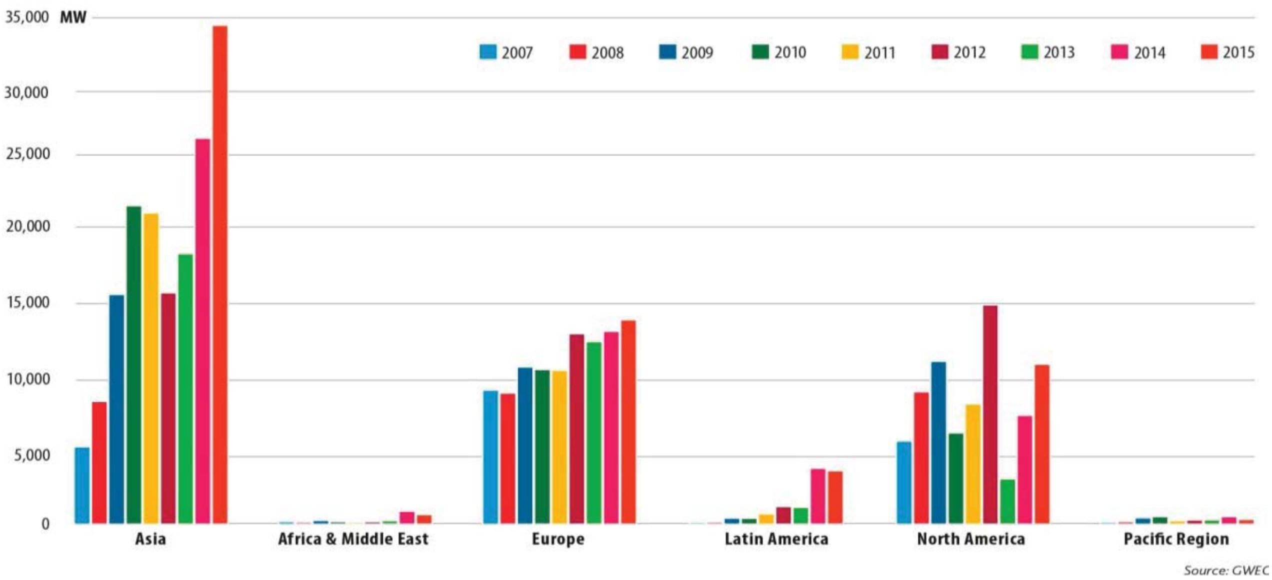
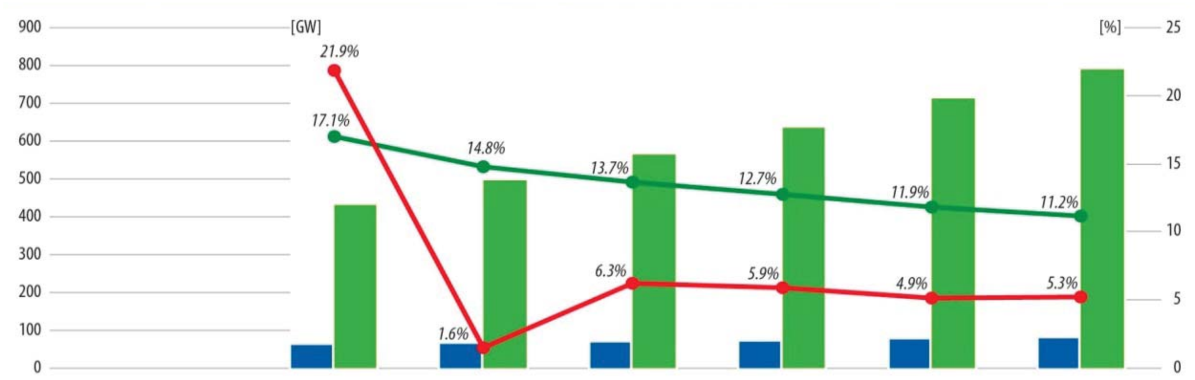



**Fig. 1. Annual installed capacity by region 2007-2015**




| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| Cumulative [GW] | 432.9 | 496.9 | 564.9 | 636.9 | 712.4 | 792.1 |
| Cumulative capacity growth rate [%] | 17.1% | 14.8% | 13.7% | 12.7% | 11.9% | 11.2% |
| Annual installed capacity [GW] | 63 | 64 | 68 | 72 | 75.5 | 79.5 |
| Annual installed capacity growth rate [%] | 21.9% | 1.6% | 6.3% | 5.9% | 4.9% | 5.3% |

Source: GWEC

**Fig. 2. Market forecast for 2016-2020**

Table 1. Public Support Mechanisms

| Country | Support mechanisms |
|---|---|
| FRANCE | Onshore: 28-82€/MWh, Off Shore: 30-130€/MWh |
| SPAIN | Average 38-69€/MWh |
| DENMARK | Onshore: 57€/MWh, Off Shore: 66-70€/MWh |
| ROMANIA | Onshore: 63-84€/MWh |
| USA | On-Shore: 13.8 - 16.1 cents/KWh |
| ESTONIA | Average: 52€/MWh |
| GREECE | Onshore: 73-85€/MWh |
| GERMANY | Onshore: 52-83€/MWh, Off Shore: 62-91€/MWh |
| HUNGARY | Average: 95€/MWh, |
| PORTUGAL | Average: 74€/MWh |
| SLOVAKIA | Average: 55-72€/MWh |

Source: Kinias, I. (2015), Auer, H. (2008), GWEC (2015).

The installed cost of a wind power project depends on some other costs such as: a) The turbine cost (blades, tower and transformer), b) Construction costs for site preparation, buildings and the foundations for the towers; c) Grid connection costs for the connection to the local distribution or transmission network and d) Other capital costs. A typical capital cost breakdown for wind power projects fluctuates from 1.700 to 2.450 USD/kW for onshore projects, as well as from 3.300 to 5.000 USD/kW for offshore projects (Blanco, 2009).

The installed capital costs for wind power systems vary significantly, depending on the maturity of the market and the local cost structure. China and Denmark have the lowest installed capital costs for new onshore projects of between USD 1.300/kW and USD 1.384/Kw in 2010 (IEA Wind, 2011). These countries host a heavy industry of wind turbines and play a very important role as the major manufacturers of necessary components for renewable projects. The Danish wind turbine industry is the largest in the world. About 90% of national production is exported, and Danish companies represented the 38% of the global turbine market. The Spanish Gamesa is also one of the world's largest wind energy companies. In 2010 China became the world's largest maker of wind turbines, surpassing Denmark, Germany, Spain, and the United States. Furthermore there are countries with a high density of specialized institutions and universities, which play an important role in international photovoltaic research & development (R&D). All these factors can affect the final cost of investment in wind energy projects.

The operation license and the connection with the distribution grid is another serious aspect for the sector. There are big differences among the countries in the duration for these processes, as well as in the number and the level of the responsible administrative authorities.

Concerning the projects funding, Central Banks supports renewable energy projects, both in Europe and America. Moreover, in most of countries, the funding will be implemented in collaboration with national Comercial Banks, as well as Independant State Organizations, with several programs and enormous capitals. One parameter for banks is the challenge to finance these projects with unattractive returns, especially when you consider the high borrowing costs, such as India, combined with the fact that foreign banks may consider the market too immature and risky for such low returns. On the other hand, there are many cases, where borrowers are not being able to pay back the loans due to the FITs cut. Finally, in many countries there are also public subsidies for the projects' capital that range from 30% to 60%.

Risk-free interest rate is the theoretical rate of return of an investment with no risk of financial loss. This is another very important factor for the investment's evaluation due to represent the interest that an investor would expect from an absolutely risk-free investment. On the other hand, taxation is the other crucial factor that can reduce the profitability of investments and by this way many projects may not be able to meet the terms of the payment in their debts.

Finally, the global financial crisis has affected many countries, especially in South Europe. This had a big effect in feed in tariffs, and many countries made important discounts in these tariffs. It inevitably led to massive losses in revenue for RES projects owners and damaged heavily investors' confidence. These decisions have also led to major job losses in the sector. The above mentioned cuts of in feed-in tariffs, not only in mature markets (Germany, Spain, France, Italy), but also in emerging markets(Czech Republic, Greece and Bulgaria), forced the investors to look for new opportunities in South-East European (SEE) nations. Romania is presenting such a very interesting investment alternative.

Table 2 presents the fluctuation of interest rates in several countries in the last decade.

Table 2. Interest rates

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| Australia | 5.99 | 5.82 | 5.04 | 5.37 | 4.88 | 3.38 | 3.70 | 3.66 | 2.71 |
| Canada | 4.27 | 3.61 | 3.23 | 3.24 | 2.78 | 1.87 | 2.26 | 2.23 | 1.52 |
| Denmark | 4.29 | 4.28 | 3.59 | 2.93 | 2.73 | 1.40 | 1.75 | 1.33 | 0.69 |
| Euro area (19 countries) | 4.33 | 4.36 | 4.03 | 3.78 | 4.31 | 3.05 | 3.01 | 2.28 | 1.27 |
| France | 4.30 | 4.23 | 3.65 | 3.12 | 3.32 | 2.54 | 2.20 | 1.67 | 0.84 |
| Germany | 4.22 | 3.98 | 3.22 | 2.74 | 2.61 | 1.50 | 1.57 | 1.16 | 0.50 |
| Greece | 4.50 | 4.80 | 5.17 | 9.09 | 15.75 | 22.50 | 10.05 | 6.93 | 9.67 |
| Hungary | 6.74 | 8.24 | 9.12 | 7.28 | 7.64 | 7.89 | 5.92 | 4.81 | 3.43 |
| Japan | 1.67 | 1.47 | 1.33 | 1.15 | 1.10 | 0.84 | 0.69 | 0.52 | 0.35 |
| Mexico | 7.79 | 8.31 | 7.96 | 6.90 | 6.67 | 5.60 | 5.68 | 6.01 | 5.93 |
| Portugal | 4.42 | 4.52 | 4.21 | 5.40 | 10.24 | 10.55 | 6.29 | 3.75 | 2.42 |
| Russia | 6.72 | 7.52 | 9.87 | 7.83 | 8.06 | 8.15 | 7.33 | 8.46 | 10.89 |
| Slovak Republic | 4.49 | 4.72 | 4.71 | 3.87 | 4.42 | 4.55 | 3.19 | 2.07 | 0.89 |
| South Africa | 7.99 | 9.10 | 8.70 | 8.62 | 8.52 | 7.90 | 7.72 | 8.25 | 8.17 |
| Spain | 4.31 | 4.36 | 3.97 | 4.25 | 5.44 | 5.85 | 4.56 | 2.72 | 1.74 |
| United States | 4.63 | 3.67 | 3.26 | 3.21 | 2.79 | 1.80 | 2.35 | 2.54 | 2.14 |

Source: OECD (2016).

## 2. Methodological issues

The annual income I(t) of a wind energy producer is given by

$$I(t) = Pe \times Qe - Ce,$$

where *Pe* (Euro/MWh) is the price at which he sells electricity, *Qe* (MWh/year) the expected annual production of wind energy and *Ce* (Euro) is the annual operating cost of the plant.

For research needs we suppose that the price of electricity follows the stochastic process Return to Medium – GMR. So, the change of the future price of electricity, in a small period, can be written as follows:

$$dP = \xi(\theta - P)\,dt + \sigma P dz,$$

where $\xi$ counts the return speed in the middle from the current $Po$ to the long balance point $\theta$, as well as $\sigma$ is the annual variation. The final part $dz = \varepsilon_t \sqrt{dt}$ follows a standard Wiener process, where $\varepsilon_t$ is a random variable that follows a normal distribution with mean zero and standard deviation equal to one. Therefore, the deviations of the price from the balance point $\theta$ are corrected with rate $\xi$, as well as influenced by random changes $\sigma Pdz$.

*Qe* is a power factor depends on the wind data of each area as well as the penetration of wind power in the energy mix of each country. The quality of the wind resource (taller wind towers and longer and lighter blades) can affect the performance of wind turbine, and therefore the cost of the wind electricity.

According to implemented methologies in the literature (Venetsanos et al., 2002; and Kjærland, F., 2007) we set specific values in the above-mentioned variables for the purposes of this study. So, we firstly set *Qe* = 30% that means a production of 2.628 MWh/year for a wind energy established capacity of 1MW.

The economic life of the wind farm is considered to be equal to 20 years with no residual value. Additionally, the risk-free interest rate r is determined by the 10-year state bond of each country. According to the OECD data in Table 2, we set r = 3%.

Regarding the investment capital *K* for the creation of a wind power plant, it is clear that high investment funds and small variable costs are required. The cost of installing a wind farm retreats with the advancement of technology. According to the European Commission in the Renewable Energy Roadmap (2016), the cost of wind power plants was 948 €/KW in 2005 with a provision for 826 €/KW in 2020 and 788 €/KW in 2030. For the purposes of this study we set the investment cost K =850 €/KW.

The operating cost OC of the investment includes variable costs, such as the maintenance of equipment and the fee that the investor returns on local communities in the area of the wind farm. A representative value for the maintenance cost might be 6% of the investment capital per year and for the return tariff for local communities 4%. So, for the purposes of this study we set a total annual operating costs OC= 10% of the investment cost.

Another feature, we also consider, is the grant in the investment costs E that the investor may take by the state. The amount of this grant varies from country to country and from period to period, depending on the policy pursued by each country. In this study, we set the level of subsidy as E =40% of the investment cost.

For the modeling of the long-term electricity prices θ and the variance parameter $\sigma$ we make the following assumptions. In some countries, such as Greece there is no long-term market electricity prices, but a regulated energy pricing system. In other markets like German, which is considered as one of the largest energy markets in Europe, there are data for both the average long-term energy price and the relevant variation. Seifert and Marliese Uhrig – Homburg (2007) trying to model the variations in electricity prices resulting in the determination of the standard deviation $\sigma$ = 20%. According to values of the Phelix Baseload Year Future of the German energy market, as well as the data of Table 1, we set $\theta = 70$ €/MWh and $\sigma = 0.20$ (Seifert – Marliese, 2007).

Finally, the rotation speed to the mean $\xi$, from the current price level in the long term price level, in a market of electricity, can affect the critical point, above which an investment plan will be undertaken. The increase of the parameter $\xi$ encourage the investment by reducing the level of critical value, above which the project will be implemented. Verra (2009) tests the value from 0 to 0.08 for the parameter $\xi$. Therefore, we set the value $\xi = 0.04$.

## 3. Analysis

Through a sensitivity analysis we examine, how the degree of uncertainty in electricity prices $\sigma$, the size of grants in the cost of capital *E*%, the speed of return to the mean $\xi$, the long-term price level $\theta$, and the interest rate *r* affects the optimal investment rule. The optimal price of electricity *P**, which the potential investor will invest, is sensitive in changes of all the above mentioned parameter values. The results of this analysis are presented in the following Table 3.

Table 3. Investment evaluation

| K (€/MWh) | Subsidy (%*K) | σ | r% | θ (€/MWh) | ξ | P* (€/MWh) $C_F$ = 32% | P* (€/MWh) $C_F$ = 28% |
|---|---|---|---|---|---|---|---|
| 0.85 | 40 | 0.2 | 3 | 70 | 0.04 | 42.742 | 52.499 |
| 0.85 | 40 | 0.3 | 3 | 70 | 0.04 | 64.113 | 78.748 |
| 0.85 | 40 | 0.4 | 3 | 70 | 0.04 | 85.484 | 104.997 |
| 0.85 | 40 | 0.2 | 3 | 80 | 0.04 | 36.636 | 44.998 |
| 0.85 | 40 | 0.3 | 3 | 80 | 0.04 | 54.954 | 67.497 |
| 0.85 | 40 | 0.4 | 3 | 80 | 0.04 | 73.272 | 89.996 |
| 0.85 | 40 | 0.2 | 3 | 60 | 0.04 | 48.848 | 59.998 |
| 0.85 | 40 | 0.3 | 3 | 60 | 0.04 | 73.062 | 89.236 |
| 0.85 | 40 | 0.4 | 3 | 60 | 0.04 | 97.696 | 119.996 |
| 0.85 | 40 | 0.2 | 3,5 | 70 | 0.04 | 49.865 | 61.248 |
| 0.85 | 40 | 0.2 | 4,0 | 70 | 0.04 | 56.988 | 69.997 |
| 0.85 | 30 | 0.2 | 3 | 70 | 0.04 | 56.137 | 69.362 |
| 0.85 | 20 | 0.2 | 3 | 70 | 0.04 | 68.395 | 83.998 |

## Conclusions

Firstly, it is clear that when the fluctuation in the prices of futures contracts $\sigma$ increases, then the uncertainty increases. So, the investor requires higher P value to offset the effect of the volatile environment. Hassett and Metcalf (1995) have also writen for this impact of the uncertainty in parameter σ to the optimal investment behavior.

Secondly, regarding the long-term energy price θ, a high value of the parameter θ has a positive effect on the level of investment by reducing the critical value P over which the investor is best to implement the investment project. Overall, a high long-run average price level is a good sign for an investor who wants to invest capital in a project with high yields.

Regarding the effect of the return to the mean $\xi$, we concluded that there is a positive effect on the investment, both in the short and long-term investment projects. The parameter $\xi$ is inversely related to the optimum critical level value *P*. This effect has been analyzed by Sarkar (2003), as well as by Metcalf and Hassett (1995), who had concluded that a higher value of the parameter ξ implies lower price for the systematic risk, which reduces the value of options and increases value of the investment plan by exercising a positive effect on the level of investment. Generally, when the return to the mean $\xi$ increases on a high level of long-term values $\theta$, then the probability of the investment also increases.

Additionally, as higher is the percentage of the grant E%, provided by each government, as lower will be the critical price level *P* and therefore the probability of acceptance of the project will be higher. On the other hand, regarding the interest rate r, any increase of this increases respectively the critical level value *P* and ultimately reduces the likelihood of investment.

Moreover, in the case that a government wants to strengthen the implementation of investments, especially in a region with a low level wind potential, it ought to provide a higher price of electricity. Policy makers should be aware, because the uncertainty in the formulation of this policy leads to the fluctuation of the electricity price. This can increase the investment risk for the investors and finally can affect their business behavior. So, a pricing policy regardless of the energy potential of each region creates a disincentive for a large number of investors in wind power plants. This disadvantage in policy can be treated by the diversificationsin subsidies that governments offer according to the data of each region.

Therefore, it is finally clear from all the above considerations that the existence of a stable and predictable investment environment can reduce the uncertainty and encourages the investments in wind power plants.

## Acknowledgements

This paper is part of a research project, in the context of a Post-doctoral Research that takes place at the University of the Aegean and funded by the-Greek State Scholarship Foundation (IKY).

## References


1. Altug, S., Demers, F., and Demers, M. (2001). The impact of Tax Risk and Persistence on Investment Decisions. *Economics Bulletin, 5,* 1-6.
2. Auer, H. (2008). Overview of the main RES – E support schemes for wind energy in the EU-27 Member States, September 2008.
3. Blanco, M. (2009). The economics of wind energy. *Renewable and Sustainable Energy Reviews, 13*(6-7), 1372-1382.
4. Brekke, K. A., Schieldrop, B. (1999). Investment in flexible technologies under uncertainty. In M.J.Brennan and L. Trigeorgis, eds., *Project Flexibility, Agency and Competition: New Developments in the Theory of Real Options* (pp. 34-49), Oxford University Press, New York.
5. Davis, G., Owens, B. (2003). Optimizing the level of renewable electric R and D expenditures using real options analysis. *Energy Policy, 31*(15), 229-263.
6. Deng, S-J., Oren, S. S. (2003). Incorporating operational characteristics and startup costs in option-based valuation of power generation capacity. *Probability in the Engineering and Information Sciences, 17*(2), 155-182.
7. EWEA (2016). *Wind in power 2015 – European statistics.* THE EUROPEAN WIND ENERGY ASSOCIATION, February.
8. GWEC (2015). GLOBAL WIND REPORT – ANNUAL MARKET UPDATE. *Global Wind Energy Council – GWEC.*
9. Hassett, K. A., Metcalf, G. E. (1995). Investment under alternative return assumptions: Comparing random walks and mean reversion. *Journal of Economic Dynamics and Control, 19,* 1471-1488.
10. Hassett, K. A., Metcalf, G. E. (1999). Investment with uncertain tax policy: Does Random Tax Policy discourages investment? *The Economic Journal, 109,* 372-393.
11. Herbelot, O. (1992). Option Valuation of Flexible Investments: The case of environmental investments in the electric power industry. *MIT Press, PhD Thesis.*
12. IEA (2011). IEA WIND2011 Annual Report, July 2012.
13. Kjærland, F. (2007). A real option analysis of investments in hydropower: The case of Norway. *Energy Policy, 35*, 5901-5908.
14. Kinias I. (2015). *Renewable Energy Sources. Europe vs BRICS*, 16th International Conference of the Global Academy of Business & Economic Research (GABER), 22-42, New York, USA.
15. Kobila, T. (1990). The choice between hydro and thermal power generation under uncertainty. O. Olsen and J. Vislie, eds., Recent modeling approaches in applied energy economics, *International Studies in Economic.*
16. Madlener, R., Kumbaroglu, G., Ediger, V. S. (2005). Modeling technology adoption as an irreversible investment under uncertainty: the case of the Turkish electricity supply industry, *Energy Economics, 27,* 139-163.
17. Moreira, A., Rocha, K., David, P. (2004). Thermopower generation investment in Brazil-economic conditions, *Energy Policy, 32*(1), 91-100.
18. Murto, P. (2003). *Timing of investment under technological and revenue related uncertainties*. Helsinki University of technology, E11.
19. Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics, 5*(2), 147-175.
20. OECD (2016). Annual Statistics 2016.

21. Panteghini, P. M., Scarpa, C. (2003). *Irreversible Investments and Regulatory Risk.* CES Working Paper 934.
22. Renewable Energy Roadmap (2016). Roadmap for a Renewable Energy Future, International Renewable Energy Agency, 2016 Edition.
23. Salahor, G. (1998). Implications of outputs price risk and operating leverage for the evaluation of petroleum development projects. *The Energy Journal, 19*(1), 13-46.
24. Sarkar, S. (2003). The effect of mean reversion on investment under uncertainty, *Journal of Economic Dynamics and Control, 28,* 377-396.
25. Schwartz, E. (1997). The stochastic behavior of commodity prices: implications for valuation and hedging. *Journal of Finance, 52,* 923-973.
26. Seifert, J., Marliese Uhrig – Homburg (2007). Modeling jumps in electricity prices: theory and empirical evidence. *Review of Derivatives, 10*(1), 59-85.
27. Smith, J., McCardle, K. (1999). Options in the real world: lessons learned in evaluating oil and gas investments, *Operations Research, 47*(1), 1-15.
28. Tseng, C., Barz, G. (2002). Short – term generation asset valuation: a real options approach. *Operations Research, 50*(2), 297-310.
29. Yeo, K. T., Qui, F. (2003). The value of management flexibility – a real option approach to investment evaluation. *International Journal of Project Management, 21,* 243-250.
30. Venetsanos, K., Angelopoulou, P., Tsoutsos, T. (2002). Renewable Energy Sources project appraisal under uncertainty: the case of wind energy exploitation within a changing energy market development. *Energy Policy, 30,* 297-307.
31. Verra, A. (2009). *Modeling the income uncertainty using the real options theory: the case of renewable energy industry.* PhD Thesis, UoA.