A RISK ANALYSIS OF SMALL-HYDRO POWER (SHP) PLANTS INVESTMENTS

Jorge Cunha[a]*, Paula Ferreira[a]

[a]Centre for Industrial and Technology Management (CGIT) – University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal

* Corresponding author and presenter: Centre for Industrial and Technology Management (CGIT), University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal, Tel.: +351 253510341, Fax: +351 253510343; e-mail: jscunha@dps.uminho.pt

ABSTRACT

The increase in electricity consumption has led to a sharp increase in energy demand which rose environmental and sustainability concerns. To address this issue, there has been an incentive to resource to renewable energy sources for electricity production. Departing from a real case study, the investment appraisal of a SHP project under the present market conditions is described, followed by a sensitivity analysis in order to identify the main sources of risk. The main results obtained showed that in the context of a regulated tariff the project is worthwhile due to a positive NPV. However, if electricity had to be sold at market prices, the project becomes unprofitable. This is an important issue because the perspectives for the future are a reduction of incentives and increased difficulties of network access for producers of electricity from renewable sources. The results put also in evidence the vulnerability of an investment of this kind to an adverse change in interest rates. Therefore, future SHP plant investments should take into account the need to operate in a free market, without special rates for renewable energy and that will have to compete with technologies based on fossil fuels or large hydro.

Keywords: Renewable energy; Small-hydropower plants; Investment risk; Sensitivity analysis

JEL classification codes: G31 - Capital Budgeting; Investment Policy; O22 - Project Analysis; Q01 - Sustainable Development; Q42 - Alternative Energy Sources

Conference topic: Energy Projects Analysis

1. INTRODUCTION

With industrial development and population and economic growth, there has been a huge increase in energy demand, which has to be met with an increase in energy production. However, given the raise of sustainable development concerns, there is the need to think about alternative sources of energy production, with a particular emphasis on renewable energy sources (RES). Apart from the need to meet the increased energy consumption, there are several reasons for the growth of RES interest (Ribeiro et al., 2011), namely: the increase in fuel prices; the concern about protecting the environment of the impact of nefarious power generation through non-renewable sources (e.g., coal and oil); and the desire to reduce dependence on traditional energy sources (e.g. thermal). It is, therefore, imperative to develop new solutions for sustainable energy production combining economic development with environmental sustainability (REN, 2006). As a manner of fact, reducing dependence on thermal energy can be achieved either by decreasing energy consumption by implementing saving programs and energy efficiency measures (both at industrial and household levels), or increasing the use of RES.

In this context, and despite the existence of some geographic and environmental restrictions, promoting the exploitation of water resources can be a viable solution for energy production. According to REN (2006), the use of thermal energy and hydropower has been implemented in the last decade and has been shown to be a viable alternative comparing with a system entirely dependent on fossil energy, since it provides greater flexibility in power management in addition to the decreased emissions of CO_2.

Water has been used for electricity production since the mid-nineteenth century as a response to the needs of factories and other human activities. In the late 1980s, small hydropower (SHP) production emerged with the publication of legislation on the establishment of the special arrangements for the production of electricity in SHP plants with installed power up to 10 MW (REN, 2006).

Notwithstanding the share of renewable energy production achieved, Portugal remains heavily dependent on imported energy sources (e.g. oil, coal and natural gas). In the particular case of hydroelectric production, it can represent almost 30% of the total electricity consumption but in dry years its contribution is even weaker (DGEG, 2012). Therefore, the continued use of renewable energy emerges as fundamental goal of the energy policy, and is a way to improve the trade balance and to contribute to energy independence. Moreover, the hydropower technology, and particularly where it is possible reservoir capacity regularization, has value added to the national grid operation, given its high availability, reliability and flexibility of operation (REN, 2006).

However, as a result of the financial, economic and political climate of the country, the risk of the investment in renewable energy has increased (Leach et al., 2011). At the same time, tends to decrease the potential interest from investors in such projects. Moreover, in addition to the factors that influence the general economic activity, investments in renewable energy are affected by many other sources of risk. Thus, there is the need to identify which factors influence those investments and understand which are perceived as risk and uncertainty drivers in these projects in order to develop strategies that help mitigate those risks and to make this type of investment as safe as possible (Agrawal, 2012).

The aim of this paper is to assess the viability of projects for electricity production in SHP plants in Portugal, analyzing, in particular, the risk factors of these investments. Given the current situation, it is of great interest to evaluate the risks inherent in the renewables sector and, in particular, investment in projects that produce electricity in SHP plants. For this, a qualitative and quantitative analysis was undertaken in order to examine how the risk and uncertainty affect the interest of the project and its expected profitability.

The remainder of the paper is organized as follows. Section 2 presents a brief description of the Portuguese electricity sector, with a particular emphasis on RES. Section 3 describes the investment project evaluation in the case based scenario. Section 4 identifies the main sources of risk underlying the type of investment under analysis. In section 5 the results of the sensitivity analysis are presented. Finally, section 6 drawn the main conclusions of the paper and highlights future avenues of research.

2. PORTUGUESE ELECTRICITY SECTOR

The Portuguese electricity generating system presents a diversified structure including a different set of technologies. The role of the RES has been increasing over the years strongly supported by the government objectives of reducing energy importations and reducing CO_2 emissions. The Special Regime Producers (SRP) includes the small hydro generation, the production from other renewable sources and the cogeneration. These producers have priority access to the grid system under the established feed-in tariffs for the licence period. Their integration in the grid is however, dependent on the energy policy decision makers calls and on tender procedure with specific criteria.

The total installed power reached in 2011 about 18894MW, distributed between thermal power plants (coal, fuel oil, natural gas and gas oil), hydro power plants and SRP, as detailed in Figure 1. In 2011, the total electricity consumption reached 52211 GWh (DGEG, 2012).

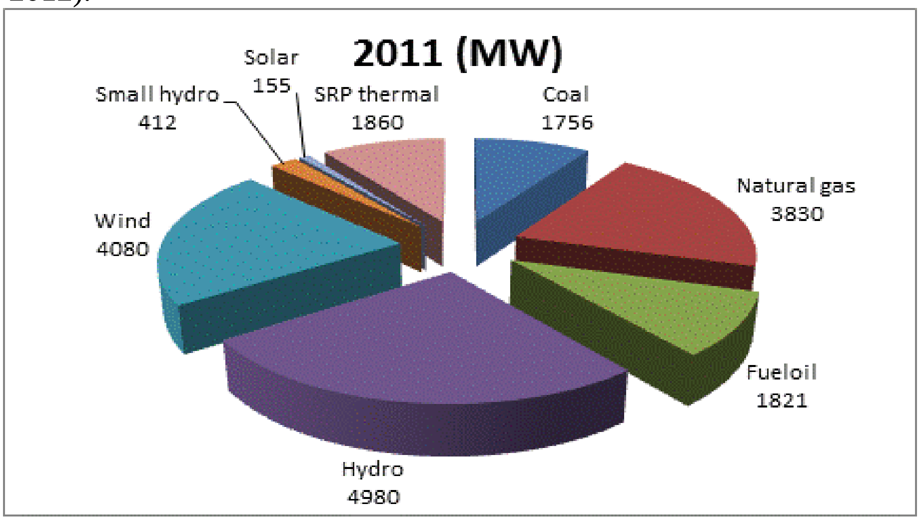

Figure 1- Distribution of the total installed power in Portugal, 2011 (Source: REN, 2012)

The future of the electricity power systems is strongly constrained by international environmental agreements, namely the Kyoto protocol and RES Directive. The Portuguese strategy for the electricity system, based on RES and natural gas growth, is fundamental to the accomplishment of these goals. The evolution of the hydroelectric sector along with the SRP is part of this strategy for the electricity system, representing a clear effort for the promotion of endogenous resources, reduction of external energy dependency and diversification of supply. The combined growth of natural gas and coal allows for a mixed thermal system and contributes to the reduction of Portugal's strong dependence on oil, although the transportation sector still plays a major role in this matter. Figure 2 presents the evolution of electricity production from RES in Portugal (excluding islands).

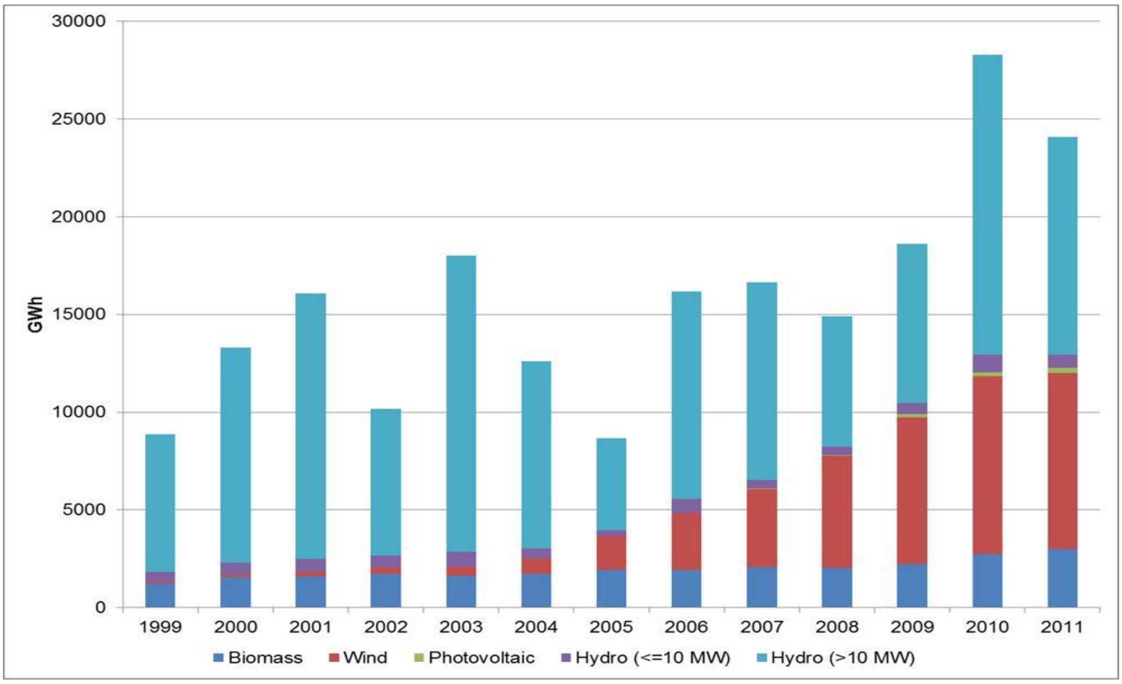

Figure 2- Electricity production from RES in Portugal (excluding islands), 1999-2011. Source: Own elaboration of DGGE (2012) data.

It has become apparent that large hydro generated electricity is the most important RES, with a contribution of 46% of the total RES production in 2011. This is closely followed by wind power production with a 37% share, biomass with 12% and small-scale hydro with less than 3%. However, the total RES production is extremely vulnerable to the rainfall conditions and in rainy years such as 2010 it becomes evident that both large and small hydro play a major role on the electricity system as a whole.

3. INVESTMENT EVALUATION

This section provides the characteristics of the project under analysis regarding the forecasted production, capital and operational expenditures. It is also shown the results of the investment appraisal.

3.1 Production and revenues

The investment refers to a project of a SHP plant and is based in a real case, although some adjustments and simplifications have been made. Given the characteristics of the location, the best alternative was a small weir with an adjacent central that has the advantage of allowing some regularization capacity. Energy production is ensured by a single generator of 1.90 MW.
To support the analysis of production and their economic valuation a study was conducted based on hydrological series of daily average flows recorded at several hydrological stations in the region, which allowed to estimate the average daily flow of the tributaries to the SHP Bayou.

Table 1 - Forecasted annual production (average hydrological regime)

Description	Value (MWh/year)
Annual production	6124

Table 2 – Estimated revenues

Description	Value	Observations
Feed-in- tariff	91 €/MWh	Determined in accordance with the currently average values.

3.2 Capital expenditures

Investment in the development and construction of a SHP power plant is conditioned by its characteristics, opportunity, choice of equipment, and ability to negotiate with suppliers. The forecasted capital expenditures are detailed in table 3. The values were obtained specifically for this project and were provided by manufacturers and installers of major equipment and construction prices were based on average market prices.

Table 3- Estimated capital expenditures

Description	Value (k€)	Amortisation
Infra-structures Building	1350	30 years
Hydromechanical equipment	544	16 years
Electromechanical equipment	1120	16 years
General electrical installations	365	16 years
Auxiliary equipment	60,5	16 years
Interconnection line	62,5	20 years
Acquisition of land	169	-
Studies and projects	127,1	3 years
Audit and consulting	161,5	3 years
Licensing	10	3 years

3.3 Operational expenditures

The operational expenditures of a SHP plant involve a limited number of factors, some of which are characteristic of the plant itself and others that are conditioned by the potential for exploiting the investor's synergies. Although, they represent a small portion of the total costs, these expenditures should be properly identified and taken into account in the economic study for a correct investment evaluation. Those costs were identified and estimated by comparing the known costs of similar facilities and some examples are: general and administrative expenses; monitoring and first level surveillance; technical support; scheduled maintenance or maintenance on failure; supplies, communications and energy; administrative charges (e. g. water and energy); insurance; and major maintenance or replacement needs. Tables 4 and 5 show these costs grouped in main categories.

Table 4- Estimate of annual Operation and Maintenance (O&M) costs

Description	**Value (k€/year)**
General and administrative	11
Operation and maintenance	21,5
Insurance	10
Contingencies	1,5

Table 5- Major maintenance costs forecasted

Description	**Value (k€)**
Revision turbine and alternator (after 15 years)	25
Review and partial replacement of equipment (after 15 years)	60

3.5 Investment appraisal

The analysis of the project was undertaken considering an investment horizon of 25 years, current prices, a discount rate of 10.3%, and an income tax rate of 25%. For simplicity it was assumed that investments values were paid completely at time zero. Moreover, the analysis was conducted in the context of a regulated tariff (feed-in), which means that the energy produced is received in full by the grip operator and there is a fixed payment per MWh, as set in Table 2. A conservative approach was assumed regarding revenues and expenditures' growth over the investment horizon. Through the consumer price index (excluding housing) of the last five years, it was possible to calculate an estimate for the tariff's value growth rate of 1.92%. On the other hand, given that in the last two years the average rate of inflation was a little more than 3%, it was assumed that operational expenditures increased at this rate. To assess the economic viability of the project the following indicators were computed: net present value (NPV); internal rate of return (IRR); simple payback period (PBP) and the discounted payback period (DPBP). Table 6 presents the main results.

Table 6- Investment appraisal indicators

NPV	984.240,25 €
IRR	13,17%
PBP (years)	7,8
DPBP (years)	15,2

As can be seen in the table, the investment is recovered in 15 years, with a positive NPV of € 948,240 and an IRR of 13.2% (higher than the discount rate of 10.3%). Therefore, one may conclude that this is an economically viable investment project under the assumed conditions.

While in this baseline scenario, the investment is attractive, this type of investment is subject to a number of risks that may restrict its profitability. Project risks involve the likelihood and degree of unacceptable deviations from predicted characteristics that are the basis for the investment decision (Kurowski and Sussman, 2011). In this sense, it is important to identify the main sources of uncertainty and risk associated with such investments. In fact, as emphasized by Kurowski and Sussman (2011), risk analysis is an essential part of project development.

4. IDENTIFICATION OF RISKS

In this section the major potential risks associated with investments in these SHP plants were identified according to a literature review (Carneiro and Ferreira, 2012, Agrawal 2012, Cucchiella et al. 2012, Leach et al. 2011, Nikolic et al. 2011, Rangel 2008, and Cleijne and Ruijgroks 2004). Thus, the following types of risks were considered to be relevant for the project: construction/completion, technological, geological, hydrological, economic, financial, political, environmental, nature, and sociocultural. These risks are briefly described in what follows.

4.1 Construction/Completion Risk

The possibility of construction delays, increased costs relative to expected, and the overall quality of the project should be analyzed together with their respective impacts. Thus, this type of risk corresponds to the possibility of the project is not concluded, and this can be due to monetary or technical reasons. The monetary reasons include the underestimation of construction costs, unexpected rise in inflation, unexpected delays in the schedule, among others. With regard to the technical reasons they are related to inaccuracies in the initial project design, failure in supplies (e.g. materials), and contractual problems.

The impact underlying this type of risk can vary from moderate to high depending on the extent of the consequences of delays or cancellation of the project itself. The delay of construction may increase the risk of the project, the cost can increase significantly and the project economic viability can be strongly affected.

4.2 Technological Risk

This risk occurs when the technology becomes obsolete very soon or performs below their specifications throughout the project life. In fact, this risk can be a major threat in the design of a hydroelectric plant, given that even a small percentage reduction in yield of a turbine may represent a large capital loss over the life of the project. Moreover, although the hydro technology is well established in Portugal, in recent years there has been a significant development of other renewable technologies for energy production, which may represent a risk for this type of investment competing in the same market segment.

4.3 Geological risk

The geological risk will depend on the construction site of the dam. This must be able to accommodate a reservoir and a power station generation. A detailed study is vital to know the geological conditions of the site. Flaws in the underlying rock structure may cause problems in construction, leading to an increase of the estimated costs if not previously identified. The risk of seismic activity should also be considered.

4.4 Hydrological risk

The hydrological risk must also be considered because the energy production will depend on the river water supplied, which will be unpredictable as well as environmental conditions and precipitation. Problems of water loss by evaporation or leakage from the reservoir must also be considered. Therefore, a detailed study about their existence and of the water availability is essential, in order to estimate the amount of energy produced, and take into account, also, other parameters that will influence the viability of the project (e.g. the rate of precipitation and evaporation in the region and the flow of water from tributaries).

4.5 Economic Risk

This type of risk arises from the possibility of a poor economic performance of the project, even if the project is underpinned in good technology and operating at normal load. In this case, the revenue generated, while being able to cover operating costs, may not be sufficient to cover the initial investment cost, preventing the recovery of the investment and achieving the required rate of return. In the case of a SHP investment, this risk derives from the uncertainty about the price of electricity in a liberalized market, mismanagement of the project, increasing operating costs, among other factors.

4.6 Financial Risk

Financial risk arises from external factors to the project and can significantly affect its financial condition. This risk may be related to difficulties in obtaining financing, uncertainty regarding interest rates and exchange rates.

4.7 Political or Legal Risk

The political and/or legal risk arises from unexpected changes in current legislation, particularly in the energy sector, which might favor investments in other than hydro technologies. Thus, due to possible changes in government regulations (or policies), the economic viability of a project, initially profitable, might be compromised. Although the new legislation usually applies to projects that have not yet been submitted, if this does not occur, these changes can have a major impact on the initial investment and revenue. On the other hand, if there are frequent changes in legislation, this can cause uncertainty among possible investors.

4.8 Environmental Risk

This risk occurs when the effects of the project on the environment cause delays in their development or even a change in the initial design. Since an investment in hydroelectricity means that the production of electricity uses a natural resource, the existence of environmental risk is inevitable. Some problems that can arise are related to the deterioration of water quality; impact on flora and fauna; emission of greenhouse gases; relocation of inhabitants of their areas of residence and occupation of agricultural land by the water.

Environmental risk may be enhanced by the action of groups of people (e.g. residents of the affected area, environmentalists, etc.), which might have slight consequences, such as making a small change in the project, or severe consequences, such as the cancellation of the project. In order to mitigate this risk and allow the implementation of the project is necessary to develop studies of environmental impact assessment in order to comply with the regulations.

4.9 Risk of other external events

The risk of external events is characterized by the occurrence of a particular event that prevents the normal operation of the project. In the case of hydroelectric plant this risk may be associated with technical failures, fires, and strikes or even due to external causes such as earthquakes or other natural disasters.

4.10 Socio-cultural Risk

This type of risks arises from social and cultural differences between the promoters of the project, local authorities and workers. This type of risk is generally considered very important by the promoters and funders of the investment, as they can be translated into a large increase in costs as a result of complaints and grievances of the populations concerned. Some of the most common effects of this type of risk relates to abandonment of projects, reputation damage of promoters and investors, loss of revenue, consumer boycotts, among others.

5. SENSITIVITY ANALYSIS

From the risks discussed in the previous section, a sensitivity analysis was developed. This procedure is a way of analyzing the effects of changes in selected project variables that might have major implications for project profitability and associated risk (Kurowski and Sussman, 2011). Therefore and taking into account the availability of data, a sensitivity analysis was undertake, regarding the following types of risks: political risk (value of the tariff); completion risk (a delay in the starting of electricity production); economic risk (an increase in the initial investment amount); and financial risk (the cost of capital).

5.1 Political risk

This risk was proxied by the change in the value of the tariff charged. Although, the investment in a SHP as in this case is protected by a fixed feed-in tariff, the liberalization trend of the electricity market can open way in the future to fully competitive RES market. It is then interesting to see what would happen in terms of the economic viability of the project if the electricity produced was sold at market prices. Since these prices are below the regulated tariff, it was simulated the effect of a tariff decrease on the project's NPV, and the results are shown in Figure 3

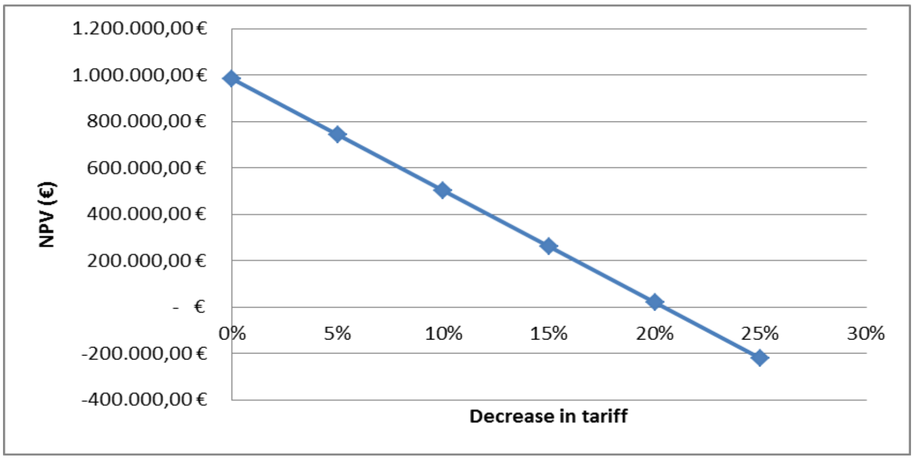

Figure 3- Electricity tariff change impact on NPV

One concludes that the NPV reaches a value of zero for a price decrease of 20.43%, which means a tariff of 72.41 euros. Given that the average market price of electricity is around fifty euros, this means that an investment with these characteristics outside the Special Regime Production (SRP) would not be economically viable.

5.2 Completion risk

To assess the impact of this risk, it was undertaken a sensitivity analysis regarding what happen if there is a delay in starting electricity production. From the analysis of and Figure 4 it is seen that the project presents some robustness in this context, for only after three years of delay in the start of production the project would become unviable. However, one must take into account either that the regulatory/legal framework in which the project takes place or the market conditions can change and could undermine its profitability.

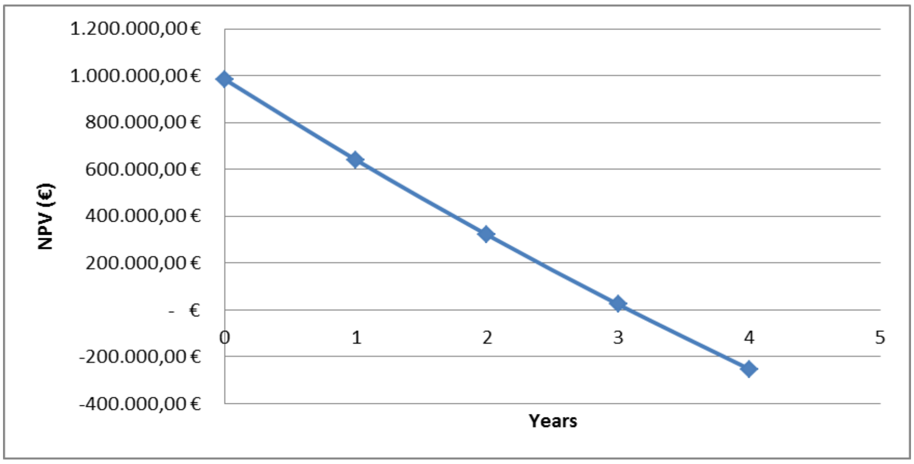

Figure 4- Impact of project delay on NPV

5.3 Economic risk

Although, the economic risk could be measure in several ways, in this study it was proxied by an increase in the initial investment amount, given that in this type of project, the major component of total investment is capital expenditures. Therefore, it is reasonable to think that an unexpected increase in these expenditures would have an effect on the investment's profitability. The impact of changes in this variable can be seen in figure 5.

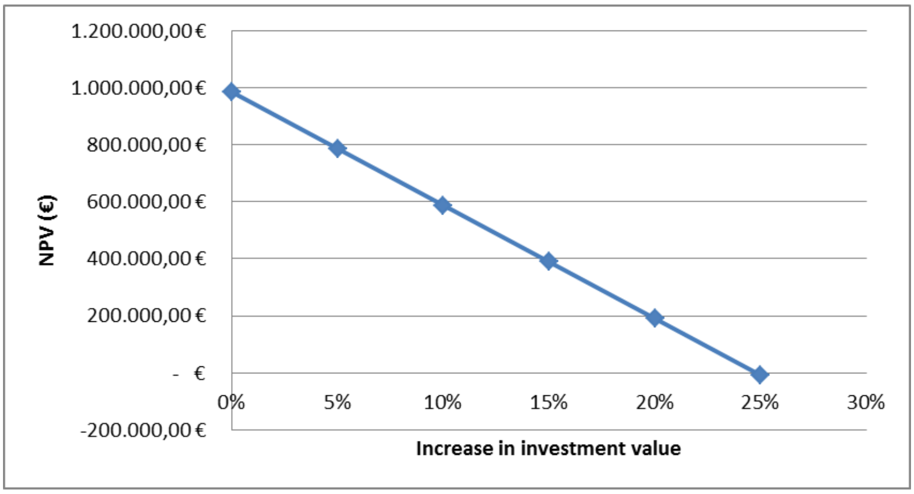

Figure 5- Impact of investment increase on NPV

As can be seen, it would be required an increase of almost 25% in the initial investment amount to reach a zero NPV for the project. The initial value of the investment would have to grow from 3,969,600 euros to 4,962,000 euros, i.e. an increase of about one million euros, which seems to be very implausible.

5.4 Financial risk

This risk can be measure by the cost of capital used to calculate NPV. In fact, capital intensive projects are very sensitive to a change in the discount rate. This change can be due, for example, to an increase in the country risk premium component of the cost of capital, as has been the case for Portugal in the last years as a result of the profound economic crisis and the difficulties in obtaining finance either by the government, financial institutions or private investors. Therefore, it should be recognized the importance of changes in the cost of capital and its impact over the project´s NVP is shown in figure 6.

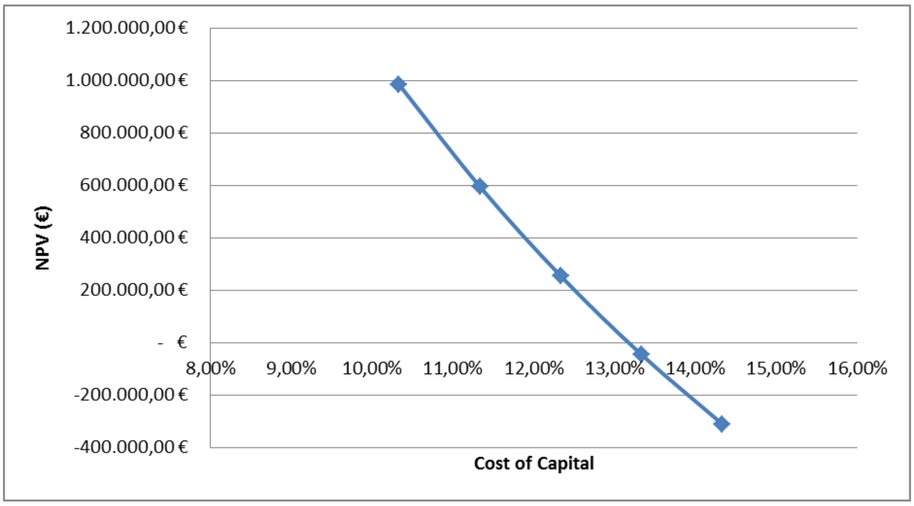

Figure 6- Cost of capital impact on NPV

As expected, given the nature of the investment, the project´s NVP decreases sharply for each percentage point increase in the cost of capital.

6. CONCLUSIONS

Given the growing concerns with sustainable electricity production, small hydroelectric power plants emerge as an interesting alternative, especially as it refers to renewable energy sources. However, it is advisable to develop a thorough identification of the risks associated with this investment, since they range from completion to technological risk, from hydrologic to environmental impact, and from political to sociocultural risk.

In this paper, departing from a real case study, the investment appraisal of a SHP project was described under the present market conditions followed by a sensitivity analysis in order to identify the main sources of risk.

The results obtained showed that in the context of a regulated tariff, as was the case-base scenario, the project is worthwhile due to a positive NPV. However, if electricity had to be sold at market prices, the project becomes unprofitable. This is an important issue because the perspectives for the future is a reduction of incentives (especially feed-in tariffs) and increased difficulties of network access for producers of electricity from renewable sources. In fact, the possibility of reducing these rates or being replaced by other incentive systems seems to be an increasingly likely possibility. Countries such as Belgium, Sweden and Italy have opted for implementing quota systems for green certificates at the expense of special fixed tariffs. In the limit, the need to operate in a free market, without special rates for renewable energy and that will have to compete with technologies based on fossil fuels or large hydro, should also be considered.

The sensitivity analysis put also in evidence the vulnerability of an investment of this kind to an adverse change in interest rates. This is not an unexpected outcome given the nature of RES projects, characterized by large investment values and reduced O&M costs. In fact the present market conditions giving rise to high capital costs along with the liberalization trend of the tariffs represent important risk elements that can easily lead to a reduction of the investors' interest on these projects.

Evidently, this was an exploratory study that aimed to provide the necessary inputs for an in-depth risk analysis of the SHP investments. Future research is expected to address the use of different tools able to incorporate a formal risk analysis procedure on project evaluation, namely the application of real options approach, multi-criteria decision methods in order to take into account different perspectives on the decision-making process and a probabilistic assessment of the risk factor impacts.

Acknowledgements

This work was financed by: the QREN – Operational Programme for Competitiveness Factors, the European Union – European Regional Development Fund and National Funds- Portuguese Foundation for Science and Technology, under Project FCOMP-01-0124-FEDER-011377 and Project Pest-OE/EME/UI0252/2011.

REFERENCES

Agrawal, A., 2012. Risk mitigation strategies for renewable energy project financing. Strategic Planning for Energy and the Environment, 32(2), 9-20.

Carneiro, P., and Ferreira, P., 2012. The economic, environmental and strategic value of biomass. Renewable Energy, 44, 17-22.

Cleijne, H., and Ruijgroks , W., 2004. Report of the project Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in a Dynamic European Electricity Market: Modelling Risks of Renewable Energy Investments.

Cucchiella, F., and D'Adarno, I., 2012. Feasibility study of developing photovoltaic power projects in Italy: An integrated approach. Renewable & Sustainable Energy Reviews, 16(3), 1562-1576.

DGEG, 2012. "Renováveis, Estatísticas Rápidas"; 2012; www.ren.pt (in Portuguese).

Kurowski, L. and Sussman, D., 2011. Investment project design. John Wiley & Sons, New Jersey.

Leach, A., Doucet, J., and Nickel, T., 2011. Renewable fuels: Policy effectiveness and project risk. Energy Policy, 39(7), 4007-4015.

Nikolic, D. M., Jednak, S., Benkovic, S., and Poznanic, V., 2011. Project finance risk evaluation of the Electric power industry of Serbia. Energy Policy, 39(10), 6168-6177.

Rangel, L.F., 2008. Competition policy and regulation in hydro-dominated electricity markets. Energy Policy, Volume 36, Issue 4, 1292-1302.

REN, 2006. Potencial Hidroeléctrico Nacional: importância sócio-económica e ambiental do seu desenvolvimento. (in Portuguese)

Ribeiro, F., Ferreira, P., and Araujo, M. (2011). The inclusion of social aspects in power planning. Renewable & Sustainable Energy Reviews, 15(9), 4361-4369