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A risk analysis of small-hydro power (SHP) plants investments

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ABSTRACT

The increase in electricity consumption has led to a sharp increase in energy demand which has risen environmental and sustainability concerns. To address this issue, there have been incentives, in some countries, to the deployment of renewable energy sources for electricity production. Departing from a real case study, a framework for investment appraisal of a SHP project under the Portuguese present market conditions is proposed and applied. The study departed from the discounted cash-flow evaluation, complemented by both sensitivity and risk analyses, in order to identify the main sources of risk and to assess the probability and impact of each risk event. The results obtained show 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. The results put also in evidence the vulnerability of the investment to an adverse change in interest rates. Future SHP plant investments should take into account the need to operate in a free market and to compete with technologies based on fossil fuels or large hydro.

Keywords:

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

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1. Introduction

With industrial development and population and economic growth, there has been a significant increase in electricity demand and consumption in Portugal in the last decades, which has had to be met with an increase in electricity production. Table 1 shows the evolution of electricity consumption for several years since 1995. As can be seen, although there was a reduction of the consumption in 2011 and 2012, electricity consumption increased by 58% between 1995 and 2012.

However, given the raise of sustainable development concerns, there is the need to think about alternative sources of electricity production, with a particular emphasis on renewable energy sources (RES). Apart from the need to meet the increased consumption, there are several reasons for the growth of RES interest [2], namely: the increase in fuel prices (for example, from [3] one can see that the average Brent spot crude oil prices were 28.5 dollars in 2000, 54.52 dollars in 2005, 79.5 in 2010, and 111.67 dollars in 2012); the concern about protecting the environment from the negative impacts of power generation through non-renewable sources (e.g. coal and oil); and the desire to reduce dependence on traditional energy sources (e.g. fossil fuels). It is, therefore, imperative to develop new solutions for sustainable energy production combining economic development with environmental sustainability [4]. As a matter of fact, reducing dependence on fossil fuels 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. The importance of renewable energy for

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Table 1: Evolution of electricity consumption in Portugal (excluding Islands), 1995–2012.

	1995	2000	2005	2010	2011	2012
Electricity consumption (TWh)	33.34	43.54	51.73	54.86	53.46	52.78

Source: Data available from [1]).

sustainable development is well recognized in the literature (see for example [5] or [6]) and its relevance in the Portuguese electricity system is also demonstrated ([7] and [8]).

Notwithstanding the achieved share of electricity production from RES, 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 much lower. In 2010, a rainy year, the total hydropower share reached almost 30% but in 2012, an extremely dry year, the contribution of hydropower was only slightly above 12% [9]. Therefore, the continued development of renewable energy emerges as fundamental goal of the Portuguese energy policy, and is a way to improve the trade balance and to contribute to energy independence. Moreover, the hydropower technology, and particularly where regulation of the reservoir capacity is possible, adds value to the national grid operation, given its high availability, reliability and flexibility of operation [4].

In this context, and despite the existence of some geographic and environmental restrictions, promoting the exploitation of hydro resources can be an interesting solution for electricity production. According to [4], the combined use of thermal power and hydropower, in Portugal, has been implemented in the last decades 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. Hydro power can in fact have a fundamental role on the management of power systems with large RES share, allowing to better deal with the challenges related to the variability of the power output of RES plants, especially wind power. Pumped hydro storage can at least partially offset potential negative effects of fluctuating renewable on the grid, contributing to wind farms exploitation ([10], [11] and [12]).

As a result of the financial, economic and political climate of the country, the risk of the investment in renewable energy tends to increase. At the same time, the potential interest from investors in such projects tends to decrease [13]. 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 ([14] and [15]).

The main goal of this paper is to assess the viability of projects for electricity production in SHP plants in Portugal, analyzing the financial interest and the risk factors of these investments. Some studies addressed already SHP in Portugal and their environmental impacts ([16] and [17]). The economic and cost evaluation of SHP in other countries is also present in the literature ([18], [19] and [20]) However, to the best of the authors' knowledge, the topic of investment and risk evaluation of these projects in Portugal is still not explored. For this a framework for the SHP project evaluation is proposed and implemented.

The first stage of the proposed framework concerns the project investment evaluation assuming a deterministic approach. It relies mostly on information and data collected from the market and is based on a discounted cash-flow approach for analyzing the financial interest of the project. The second stage encompasses the identification of the risk factors, the assessment of the potential impact on the project and recommendation of mitigation measures. From this, it is possible to identify major sources of concern and corresponding relevant variables, using then a sensitivity analysis to evaluate the impact that possible deviations from the assumed values might have on the financial return of the project. The third stage of the framework, allows for a more elaborated analysis including not only the evaluation of the impact but also of the probability of the event or combination of events occurring.

The contribution of the work aims to be twofold: firstly, the SHP project evaluation will be analyzed in detail giving important insights for energy investors and secondly the proposed framework is expected to be a valuable evaluation approach for investor as it can be adapted to other sectors but in particular to the evaluation of other RES project.

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 base case scenario. Section 4 presents the main sources of risk for the investment under analysis. A classification for the categories of risks is proposed and the expected impact and mitigation measures are explored. In section 5 the results of the sensitivity analysis are presented. Following the outputs of both section 4 and 5, the most important risk factors are evaluated in section 6 using a probabilistic impact evaluation approach. Finally, section 7 draws 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) group includes small hydro generation, production from other renewable sources and cogeneration. These producers have priority access to the grid system under the established feed-in tariffs, for the licence period. The integration of new SRP projects in the grid is determined by public calls for each technology, depending on the energy policy priorities and according to the availability of interconnection points to the grid.

The feed-in-tariffs are defined according to Decree-Law n.° 225/2007 with subsequent legal corrections and amendments. These tariffs are specific for each technology classified as renewable SRP. The legal framework establishes then a remuneration for renewable SRP producers based on the avoided costs of the system including avoided capital costs, operational costs and environmental costs. The components related to the avoided capital and operations costs are identical for all renewable SRP technologies. The component related to the environmental costs is computed according to the avoided CO_2 emissions weighted by a factor which is specific for each SRP technology. The formula for calculating the value of feed-in-tariffs in each year also takes into account the inflation rate through the consumer price index.

As for the total installed power of the electricity system in Portugal (excluding islands), it reached about 18.5 GW in 2012, distributed between thermal power plants (coal, fuel oil, natural gas and gas oil), hydro power plants and SRP, as detailed in Figure 1. In 2012, the total electricity consumption reached 52, 8 GWh [9].

The composition of the Portuguese electricity sector has been influenced by international environmental agreements, namely the Kyoto protocol and RES Directive. The evolution of the hydroelectric sector along with the SRP is part of the 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 fossil fuel power production mainly relies on natural gas and coal, both of them coming from external suppliers, as Portugal does not have own fossil fuel reserves. Figure 2 presents the evolution of electricity production from RES in Portugal (excluding islands).

The importance of the large hydropower sector is evident. The electricity production form these plants represented 46.2% of the total RES production in 2011 and 30.2% in 2012. However, wind power is becoming increasingly relevant and in this last year it even surpassed hydro power due to the reduced precipitation levels. In 2012, the share of electricity from wind

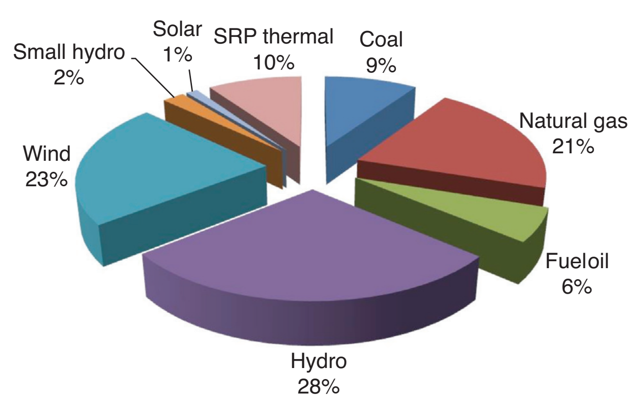

Figure 1: Distribution of the total installed power in Portugal, 2012 (Source: [21]).

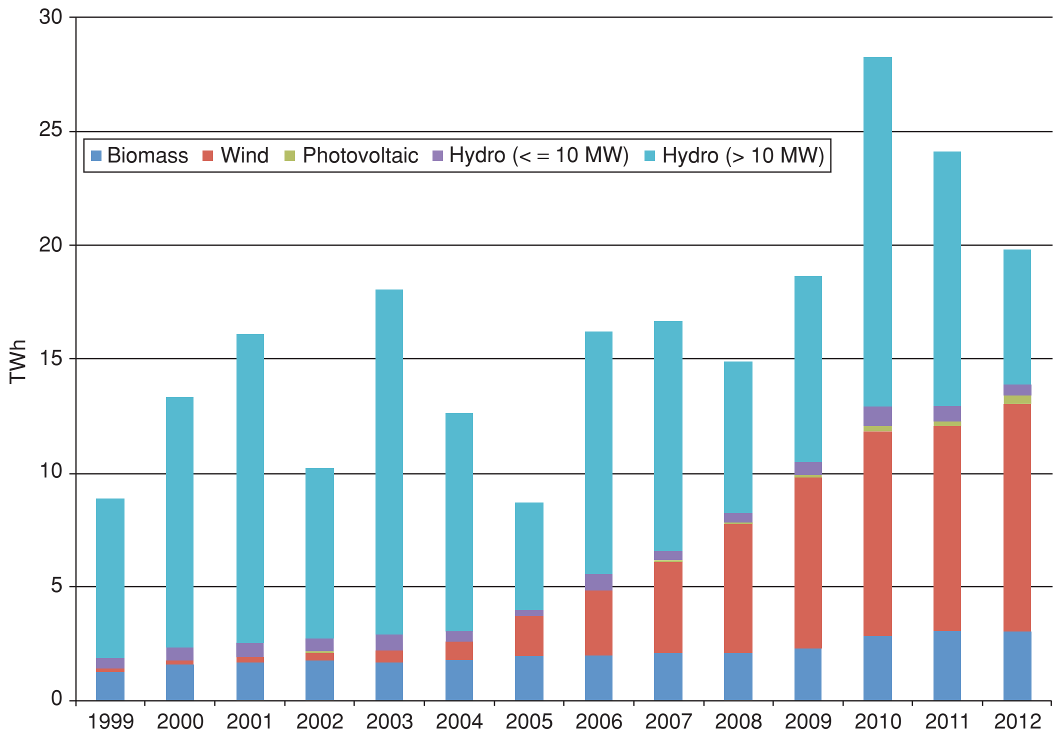

Figure 2: Electricity production from RES in Portugal (excluding islands), 1999–2012. Source: Own elaboration of [9] and [22] data.

power reached 50.5% of the total RES production, followed by large hydropower with 30.2%, biomass with 15.2%, small scale hydropower with 2.3% and solar with 1.8%. Particularly interesting is the comparison between 2005 and 2012. In fact, both these years were extremely dry but in 2012 the wind power production allowed to compensate the low hydropower availability.

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.

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. The project is expected to be implemented in a small river in the central region of Portugal. Given the characteristics of the location, the best alternative was a run of river plant with a small weir which has the advantage of allowing some regulating capacity. No pumping storage capacity is foreseen in the project.

The project considers the use of a Kaplan reaction turbine, the electricity production is ensured by a single generator of 1.90 MW and the reservoir size is 0.5 hm^3. The head height is 12.5 m and the project was designed for a flow rate of 18 m^3/s.

The plant will be owned by private investors, whose remuneration will come from the established feed-in-tariff for this SHP sector and no additional support mechanism are to be considered.

3.1. Production and revenues

The expected annual power production was calculated from daily data of the inflows, obtained from information collected by the river hydrological stations during a 10 years period. From this series, the expected average monthly output was obtained for a typical year on that location. Figure 3, presents this expected average monthly electricity generation demonstrating that the production is highly seasonal, with the highest values achieved during the winter.

Table 2 shows the forecasted annual electricity production to be considered for the computation of the financial revenues for the investor.

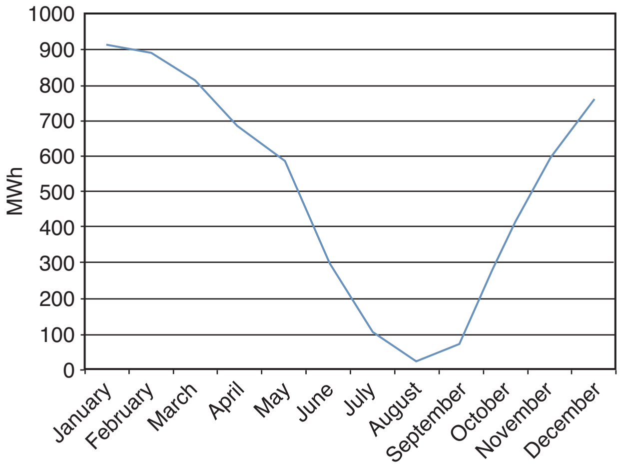

Figure 3: Estimated monthly electricity generation for the SHP project.

The feed-in tariff is presented in Table 3. This value defined according to Decree-Law n.º 225/2007 as described previously, amended by Decree-Law 126/2010 specific for SHP. This last document also established that this remuneration will be maintained for 25 years starting from the beginning of the project operation.

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 4. The values were obtained specifically for this project and were provided by manufacturers and installers of major equipment. Construction costs were based on average market prices. A straight line depreciation of the equipment was assumed according to its lifetime.

Table 2: Forecasted annual production (average hydrological regime).

Description	Value (MWh/year)
Annual production	6,124

Table 3: Estimated revenues.

Description	Value
Feed-in- tariff	91 €/MWh

Table 4: Estimated capital expenditures.

Description	Value (k€)	Depreciation
Infra-structures Building	1,350	30 years
Hydromechanical equipment	544	16 years
Electromechanical equipment	1,120	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 represent a small portion of the total costs, but should also be properly identified and taken into account in the economic study for the investment evaluation. Those costs were identified and valued according to information provided by companies operating similar facilities. The costs included general and administrative expenses; monitoring and first level surveillance; technical support; scheduled maintenance or maintenance on failure; other service supplies, communications and energy; administrative charges (e. g. water and energy); insurance; and major maintenance or replacement needs. Tables 5 and 6 show these values grouped in main categories.

Table 5: 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 6: 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

3.4. 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%. The annual discount rate comprises two components: the risk-free rate of return and the risk premium.

The risk free rate was considered to be 3.41% [23] and the risk premium was considered to be 6.60%, computed as the average yield to maturity rate of the 10 years Portuguese treasury bond from daily values between November 2012 and November 2013 obtained from [24]. 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 electricity produced is received in full by the grid operator and there is a fixed payment per MWh, as set in Table 3. A conservative approach was assumed regarding revenues and expenditures' growth over the investment horizon. Through the Portuguese 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 slightly 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 7 presents the main results.

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 [25]. In this sense, it is important to identify the main sources of uncertainty and risk associated with such investments. In fact, as emphasized by [25], risk analysis is an essential part of project development.

Table 7: Investment appraisal indicators.

Net present value (NPV), thousand €	984.24
Internal rate of return (IRR), percentage	13.17
Payback period (years)	7.8
Discounted payback period (years)	15.2

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 ([26], [14], [27], [13], [28], [29] and [30]). Thus, the following types of risks were considered to be relevant for the project: construction/completion, technological, geological, hydrological, economic, financial, political, environmental, external events, 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 electricity 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 electricity 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 electricity 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. The SRP return highly depends on the existence of feed-in-tariffs. Changes on the economic conditions of the country may force policy decision makers to reduce these values or even eliminate this option by new regulatory impositions. Although this tends to affect mostly new projects, the Climate Policy Initiative report already called attention to the retroactive policy risk referring to policy or regulatory changes which adversely affect the financial viability of RES projects [31]. In the case of a SHP investment, under an extreme scenario of terminating feed-in-tariff, the risk would derive mainly from the uncertainty about the price of electricity in a liberalized market. In addition, mismanagement of the project, increasing operating costs, among other factors should also be considered as important risk 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. In the case of RES projects this political risk is highly related to the economic risk as described previously.

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. Sociocultural 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.

4.11. Risks summary

Table 8 attempted to summarize the identified risk, proposing a classification, defining each of them, identifying the major source of risk and possible impacts for the project and recommending mitigation measures.

Although the provided list focuses mainly on the SHP project, most of the information can easily be transpose to other RES investments. All these are investments strongly dependent on the policy and legal environment and frequently prone to some social opposition. For some of the RES technologies, the learning curve experience effect is still very much relevant and cost reductions can be foreseen ([32], [33] and [34]) which represents an additional risk factor for investors facing the possible lower costs for the future competitors. Also, RES electricity power output is frequently difficult to forecast as it largely depends on uncontrollable external factors such as rainfall, wind speed or solar radiation. In fact, these investments require long payback period and the historic data about the availability of the resources may not be informative enough about the future.

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 [25]. Therefore and taking into account the availability of data, a sensitivity analysis was undertaken, 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 a change in the price at which the electricity produced would be sold instead of a fixed feed-in tariff guaranteed to the SHP investor. 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 4.

One concludes that the NPV reaches a value of zero for a price decrease of 20.43%, which means a tariff of 72.41 €. Given that the average market price of electricity is around 50 €, 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, a sensitivity analysis regarding what happens if there is a delay in starting electricity production was undertaken. From the analysis of Figure 5 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.

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 6.

Table 8: Summary of categories of risks, their impact and mitigation measures for the SHP project.

Type of risk	Definition	Source of risk	Impact on the project	Mitigation measures
Construction or Completion	Possibility of the project is not timely concluded/completed	Unexpected delays in the schedule Underestimation of construction costs Inaccuracies in the initial project design Failure in supplies Contractual problems Unexpected rise in inflation	Unfeasibility of the project Increased costs Increased time to complete the project	Detailed budgeting Efficient management of the project Stipulation of deadlines with penalty clauses for non-compliance
Technological	Technology becomes obsolete very soon or performs below their specifications throughout the project life	Early obsolescence of equipment Equipment performance below expectations	Reduced yields Capital loss for the company	Implementation of appropriate maintenance plans
Geological	Dependent on the construction site of the dam	Uncertainties in the impact of sediment in the reservoir Geological conditions of the surface Seismic activity	Delay in construction period Increased costs	Detailed geological study
Hydrological	Electricity production will depend on the river water supplied	Meteorological and hydrological instability	Decrease in the amount of electricity produced Decrease in revenue generated	Detailed hydrological study Careful analysis of the historical local meteorological conditions
Economic	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	Rising costs of operation Variation in market price of electricity Changes in demand Delays in receiving money from clients Poor project management	Cash flow problems Not fully recovery of investment expenses Increased operating costs	Use of contracts that allow the transfer of risk with penalties for non-compliance Efficient management of the project Implementation of policies and processes for measuring and managing risk

(Continued)

Table 8: Summary of categories of risks, their impact and mitigation measures for the SHP project (Continued).

Type of risk	Definition	Source of risk	Impact on the project	Mitigation measures
Financial	Arises from external factors to the project and can significantly affect its financial condition	Difficulties in obtaining financing Changes in exchange rates Changes in interest rates	Cash flow problems	Use of derivative financial instruments that allow the transfer of risk
Political or Legal	Is related to changes in legislation about the energy sector	Unexpected changes in current legislation Political instability	Increased uncertainty among potential investors Uncertainty about the viability of the project Cost overruns	Study of the political environment
Environmental	Occurs when the effects of the project on the environment cause delays in their development or even a change in the initial design	Misinterpretation of environmental legislation Changes in legislation Legal obstacles raised by environmental groups	Increased costs Changes to the initial project Delays in project implementation	Detailed environmental impact study Study of the environmental legislation Strict monitoring of environmental requirements
Other external events	Is characterized by the occurrence of a particular event that prevents the normal operation of the project	Technical failures Fires Strikes Earthquakes Other natural disasters	Increased costs Preventing the normal operation of the project Reduction in revenue	Insurance policy
Sociocultural	Arises from social and cultural differences between the promoters of the project, local authorities and workers	Complaints and grievances of the populations concerned with the implementation of the project	Increased costs Abandonment of the project Reputation damage of promoters and investors Loss of revenue Consumer boycott	Studies on the social impacts Looking for a good public image Promote social acceptance of the project since its inception Establish local forms of compensation

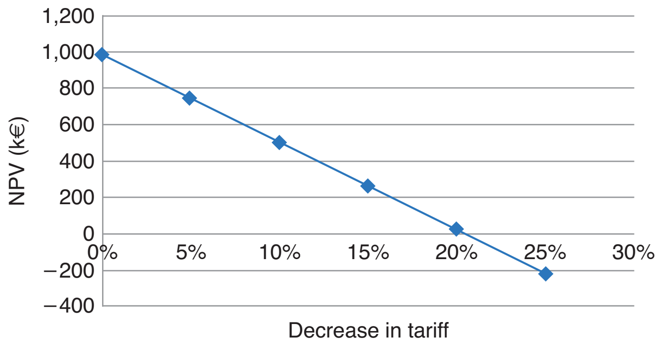

Figure 4: Electricity tariff change impact on NPV.

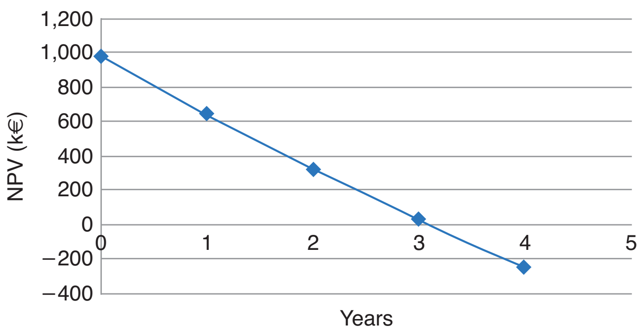

Figure 5: Impact of project delay on NPV.

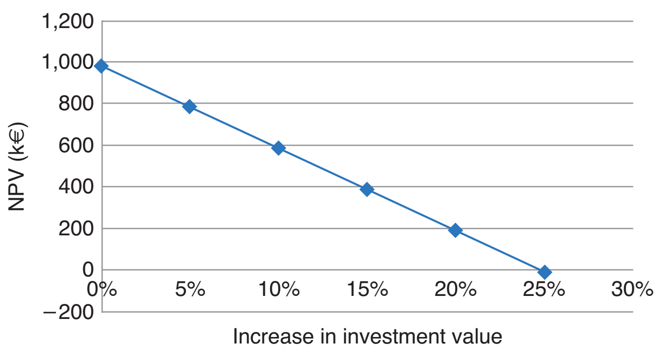

Figure 6: Impact of investment increase on NPV.

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 € to 4,962,000 €, i.e. an increase of about 1,000,000 €, which seems to be very implausible.

5.4. Financial risk

This risk can be measured by a change in the discount rate (or cost of capital) used to calculate NPV. In fact, capital intensive projects are very sensitive to a change

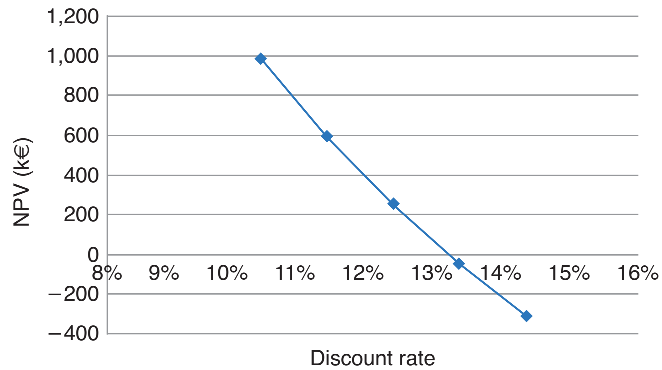

Figure 7: Impact of a change in the discount rate on NPV.

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 7.

As expected, given the nature of the investment, the project's NVP decreases sharply for each percentage point increase in the discount rate.

6. Probabilistic risk analysis

In the previous section, the sensitivity analysis demonstrated that the project viability can be very much sensitive to variations of variables related to investment, tariffs and discount rate. This previous study was based on a deterministic approach and each variable was analyzed independently, evaluating its impact on the project viability. Following this initial approach, a probabilistic risk analysis technique will now be used to assess both the impact and probability of the events.

The relevant variables were randomly generated using a Monte Carlo simulation and from these values the annual cash-flow was estimated in order to calculate the expected NPV and its probability distribution. Firstly an independent evaluation of each variable was conducted but the main goal was to obtain a combined analysis, allowing to evaluate both the impact and probability of different scenarios characterized by a mix of random events.

Software @Risk was used for the distribution fitting of the data used in this analysis and for the Monte Carlo simulations.

Table 9: Summary about the variables considered for the risk simulations.

Variable	Distribution	Assumptions
Investment cost	Triangular	Maximum value = 226% × Mode Minimum value = 54% × Mode
O&M cost	Triangular	Maximum value = 195% × Mode Minimum value = 62 % × Mode
Discount rate	Triangular	Maximum value = 171 % × Mode Minimum value = 76% × Mode
Tariffs (market values)	Normal	Expected value = 46.96 €/MWh Standard deviation = 14.80 €/MWh
Tariffs (feed in values)	Normal	Expected value = 91.00 €/MWh Standard deviation = 28.68 €/MWh

Table 9 summarizes the variables considered for the risk simulations, the assumed distribution and the parameters used.

6.1. Investment and O&M costs

For the investment costs, the mean value of each category was assumed equal to the base case scenario. The maximum and minimum values were based on the expected investment costs range for large dams in Portugal computed against the mean. This information was obtained from the technical document [35]. The same goes for the O&M costs. Figures 8 and 9 present the results of these two simulations for the NPV computation.

For both cases, although the NPV mean is lower than the base case scenario (especially for the investment risk), it is still positive and the probability of having a positive NPV is around 56% even for the investment simulation.

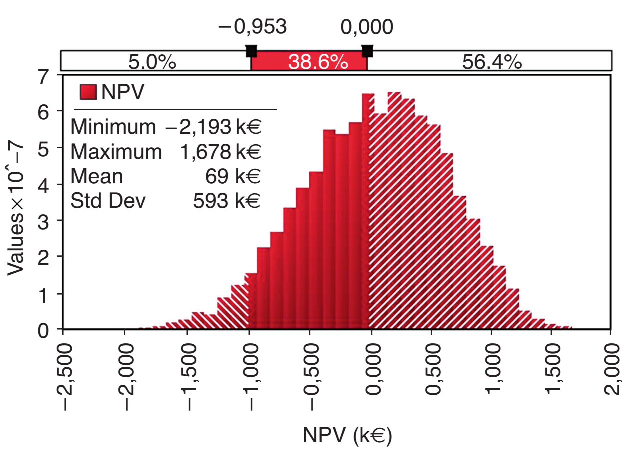

Figure 8: Probability density graph for investment risk.

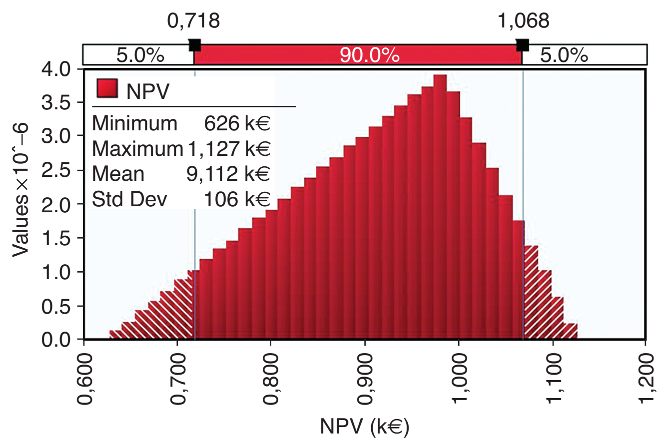

Figure 9: Probability density graph for O&M cost risk.

6.2. Discount rate

The discount rate maximum and minimum variations were obtained according to the yield to maturity rate of the 10 years Portuguese Treasury bonds. A daily series (2008–2013) was used to compute the mean value and to check the maximum and minimum variations against the mean (data available from [24]). The same variation range was used for the project under analysis, assuming the base case scenario as the expected discount rate. Figure 10 presents the results of this simulation for the NPV computation.

Also for the discount rate, the NPV mean is much lower than the base case scenario but it is still positive. The probability of having a positive NPV is 72% but a negative NPV is possible if an increase of the discount rate is experienced.

6.3. Electricity tariffs

Finally, for the values of the tariffs, market values were used according to the MIBEL spot prices for the period

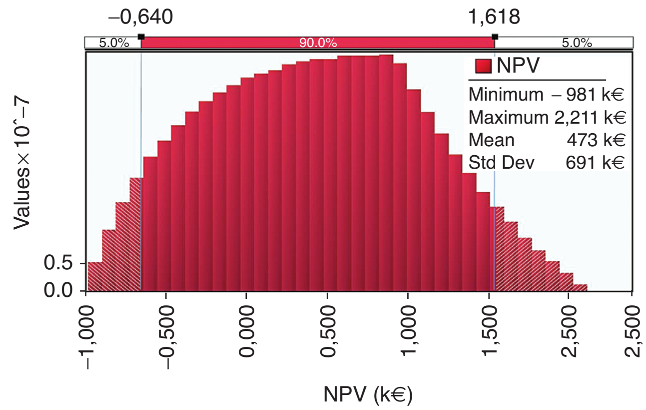

Figure 10: Probability density graph for discount rate risk.

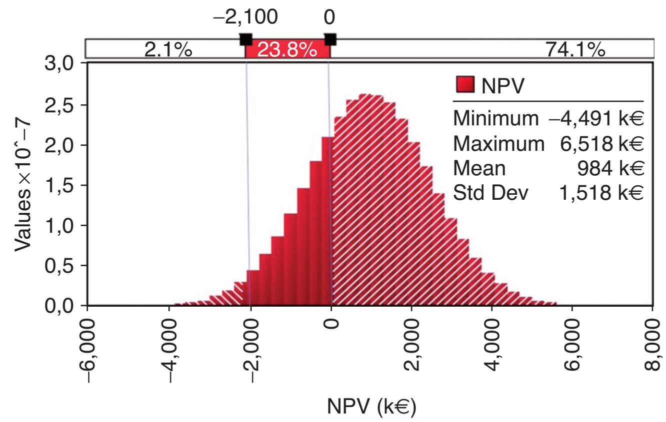

Figure 12: Probability density graph for feed-in-tariffs.

2010–2013. A normal distribution was assumed with the expected value and standard deviation directly obtained from the time series. Recognizing that this can severely threaten the return of the project, in a second approach the time series were corrected according to the feed-in-tariff assumed under the base case scenario. This would mean that the investor return would still depend on the market variations but an average higher tariff would be ensured. Figures 11 and 12 present the results of these two simulations for the NPV computation.

The obtained results demonstrate the importance of the feed-in-tariffs for these projects. In fact, if the project is operating under market conditions the viability of the investment is much doubtful as the possibility of having a positive NPV only slightly surpasses 4.3%. On the other hand, under the assumed feed-in-tariff regime subject to market variations, the mean is positive and the probability of having a positive NPV is more than 74%.

6.4 Combined risk analysis

The risk evaluation must go beyond the analysis of each variable independently. In fact, much of the uncertainty of the NPV output comes from the combination of several random events. The final and fundamental simulation combines now the different variables distributions giving rise to the expected NPV at risk. Figures 13 and 14 present the results of this simulation for the NPV computation, assuming a feed-in-tariff scenario subject to market variations.

The combined risk evaluation leads to a less positive view of the project return. The possibility of having a positive NPV is only 36% and the expected value is negative. The tornado chart puts in evidence the importance of the feed-in-tariffs, the discount rate and the initial investment.

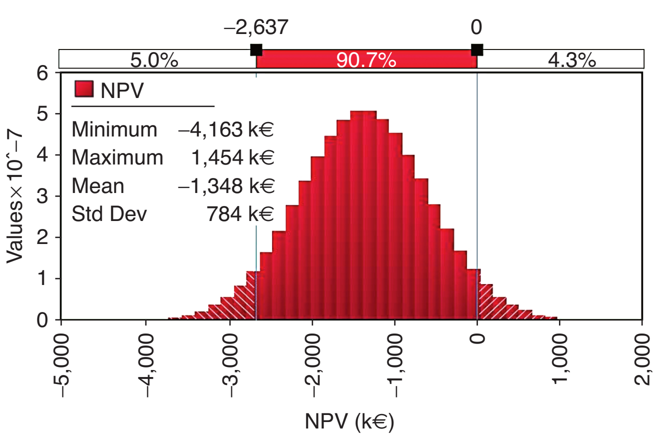

Figure 11: Probability density graph for market tariffs.

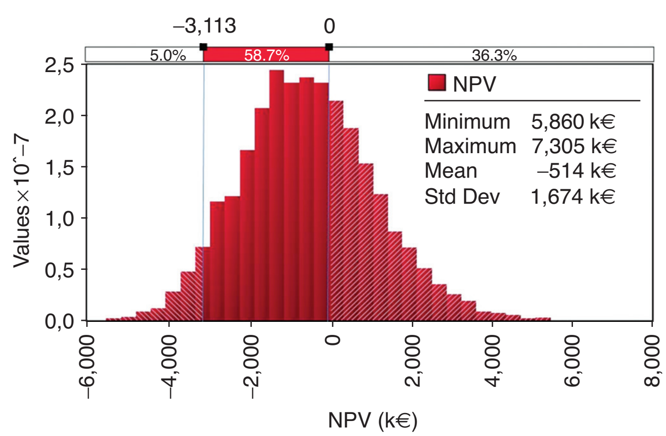

Figure 13: Combined probability density graph

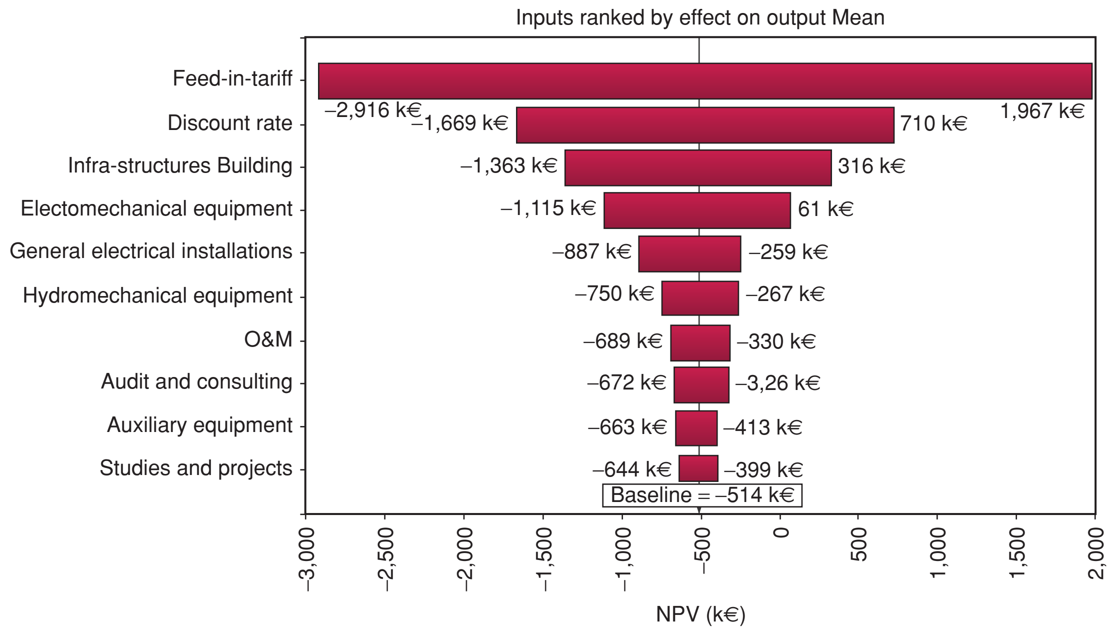

Figure 14: Tornado chart for NPV

7. 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 and a probabilistic risk 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.

As for the risk evaluation, although the independent analysis of each variable showed that the project could be interesting with positive mean values, the possibility of having a negative outcome was evident for the investment costs, discount rate and feed-in-tariffs variables. On the other hand, the results of the combined analysis are much less optimistic demonstrating that even under regulated tariffs the probability of having a negative NPV largely surpasses the probability of obtaining a positive value. This demonstrates the need to implement mitigation measures related to these variables, supported on the establishment of long term contracts and careful project management and budgeting.

It should be underlined that the analysis was conducted for a particular project based on SHP technology but the possibility of reducing risk based on a diversified portfolio must be also considered. In fact, from the investor point of view the ownership of a project mix with different technical characteristics, supported on different resources and operating in different market segments (free market and feed-in-tariff protected market) represents one of the most valuable strategies to reduce the risk.

Finally, the framework proposed in this paper can be adapted and used in other sectors as a risk evaluation methodology. In particular, its use was demonstrated with the SHP but most of the conclusions can easily be transpose to other RES projects also characterized by high investment costs, high dependence on fixed government set feed-in-tariffs and often facing delays and social opposition.

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