RISK MANAGEMENT AND RESOLUTION STRATEGIES FOR ESTABLISHED AND NOVEL TECHNOLOGIES IN THE LOW HEAD, SMALL HYDROPOWER MARKET

Patrick WIEMANN(1)
Gerald MÜLLER
James SENIOR
University of Southampton, U.K.

ABSTRACT

In 2005 the market growth of small hydropower in Europe was only 0.95% from 11,535MW to 11,644MW installed power. The main obstacle to raising money for more projects in this sector is lack of investor confidence. One important reason why the low head, small hydro power market is unexploited is the perception of projects by potential lenders and investors as low-profit and risky, holding back technology development and growth. The risks affect the most important consideration for owners and operators alike: the profitability, and should be quantified and managed. Risk Management consists of three basic steps: risk identification, risk analysis and risk resolution. The unknown risks of low head, small hydropower projects are discussed following a structural approach of identification of economical, technical, socio-economic and environmental risks. Probabilistic risk analysis, although more complex and costly in terms of analysis time and effort compared to the point estimates, provides a plausible scientific tool to identify and quantify the uncertainties of risk estimates. The key to risk management is to be aware of all kinds of risk and to develop a plan to eliminate or minimise them in a cost-effective manner. A fuller understanding of the implications of the investment decision by a potential customer will lead to better decisions.

I. INTRODUCTION

According to the research company New Carbon Finance, investment in the global renewable-energy sector will top 90 Billion Dollars in 2007, a 27% increase over the previous year (Scott and Flanagan, 2007). In this fast growing market the competition for being market or technology leader, developing more efficient technologies and finding the most attractive market niches has already begun. At present, due to subsidies and beneficial electricity tariffs, wind and solar power remain the most commercially viable technologies. For example, in Germany the feed-in-tarif for wind energy and solar power are 0.082 €/kWh and 0.52 €/kWh respectively (EEG, 2004). Figure 1, however, shows that the market growth of small hydropower in Europe was only 0.95% from 11,535MW to 11,644MW installed power from 2004 to 2005 (EU, 2007).

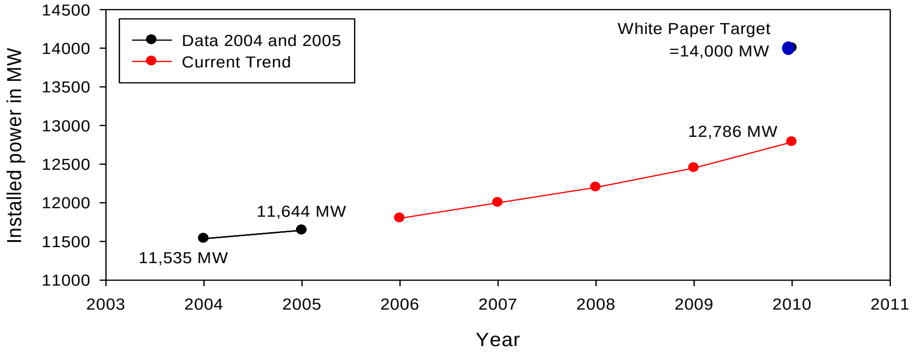

Figure 1: Market development of small hydropower

Furthermore, the European Commission`s White Paper on renewable energy sources set the goal of doubling the production of renewable energy from 6% to 12% by 2010. For the small hydropower

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[1] Corresponding author and contact address: University of Southampton, School of Civil Engineering and the Environment, Highfield, Southampton, SO17 1BJ, U.K., phone: +44 238059 4658, e-Mail: pw1105@soton.ac.uk.

market in Europe this means a target of 14,000MW installed power. This ambitious target cannot be reached with current market growth.

In Europe, the development of hydropower with installed capacities of more than 1MW and head differences of more than 5m is nearly complete (ESHA, 2005). A promising corner of the future hydropower market remains the economical and ecologically acceptable exploitation of smaller hydropower from 50 – 1,000kW with very low head differences of 0.80 to 5.00m (Müller, 2006). According to the EC’s research and development funds, Framework 7, there are technological challenges in exploiting the remaining hydropower potential, composed mainly of low-head and very-low-head sites (FP7, 2007). The currently unused low head, small hydropower potential is estimated as 500MW in Germany and around 600-1,000MW in the UK (König and Jehle, 1997; Goring, 2000). The definition of small hydropower is electricity production under 10MW, usually in the form of waterwheels, *Hydrodynamic screws* and turbines. Often conventional turbines are neither economical nor ecologically acceptable. In response to this situation, a number of novel energy converters, some of which reliant on rather unusual principles, have been proposed and developed. Wiemann et al. (2007) give a comprehensive overview of these technologies.

Figure 2 gives an overview of established technologies in the small hydropower sector. Furthermore, the graph highlights an interesting area of remaining hydropower potential where new technologies may emerge in the near future. Currently, the *Rotary Hydraulic Pressure Machine* appears to have development potential to fill this gap (Senior et al., 2007).

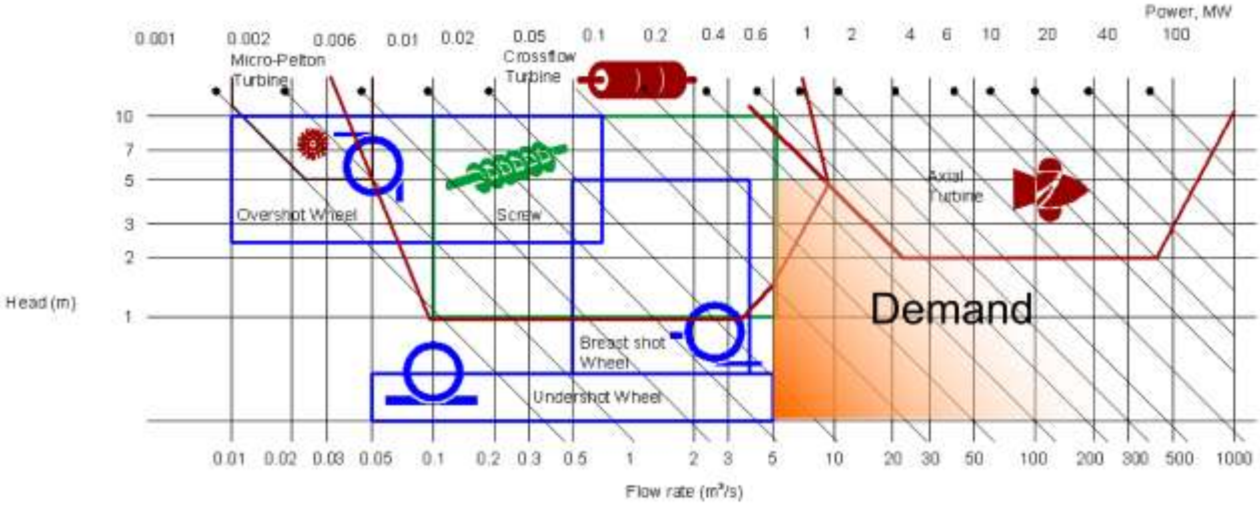

Figure 2: Operating Heads and Flows of Hydraulic machines

II. RESEARCH PROBLEM

The main problem for raising money for projects in the low head, small hydro power market is lack of investor confidence (ESHA, 2005). One important reason why this sector is unexploited is the perception of projects by potential lenders and investors as low-profit and risky, holding back technology development and growth. The risks affect the most important consideration for owners and operators alike: the profitability. Every decision for a low head, small hydropower project is made with uncertainty. Investors wishing to invest in renewable energy must be aware of all the risks to consider their effect on profitability. It is very important to consider and to be aware of the risks in low head, small hydropower projects because even relatively small changes in running hours per year or total investment cost will immediately result in significant changes in the electricity production cost per unit, as shown in Figure 3 (left) (Wiemann, 2006). For example, even small changes in water level will immediately result in significant changes in power output – whereas for larger head differences above 2m the same changes could even be ignored. Another reason is that the specific investment cost per installed kW of power for low head is significantly higher than for high head installations, as shown in Figure 3 (right) (Goldsmith, 1993). Also, often a positive view of the manufacturer/inventor will overevaluate the revenues, as well as the specific investment costs as too low, leaving potential investors with a large margin of risk.

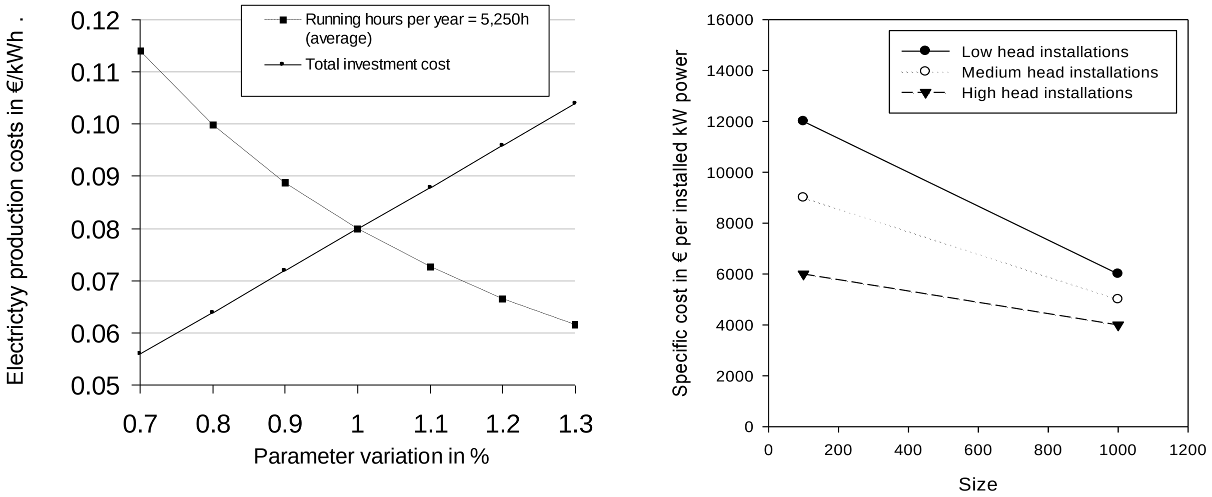

Figure 3: (left) Sensitivity of a low head, small hydropower project and (right) Specific cost/Size relationships

III. RISK MANAGEMENT FOR LOW HEAD, SMALL HYDROPOWER PROJECTS

Risk Management consists of three basic steps:

1. Risk Identification: the risks of low head, small hydropower projects are discussed following a structural approach of risk identification into economical, technical, socio-economic and environmental risks.
2. Risk Analysis: Probabilistic risk analysis, although more complex and costly in terms of analysis time and effort compared to the point estimates, provides a plausible scientific tool to identify and quantify the uncertainties of risk estimates.
3. Risk Resolution: Risk assessment including risk identification and risk analysis can be used for developing efficient resolution strategies to obtain investor confidence. Figure 4 shows the Risk-Management-Cycle which will be explained in more detail in following sections.

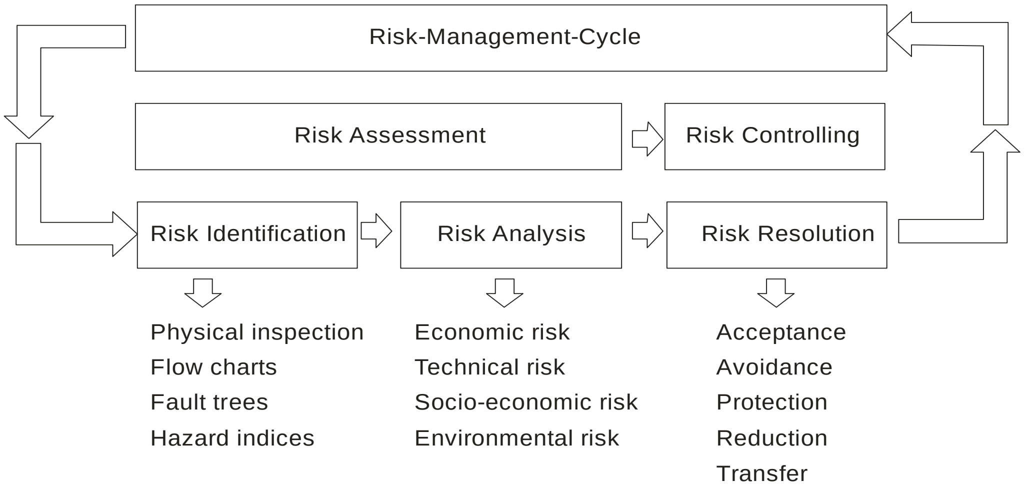

Figure 4: Process of the Risk-Management-Cycle

III.1 Risk identification

Risk identification can start with the source of the problem, or with the problem itself. There are a number of techniques which can be used to assist in the identification of risk. A short description of four typical methods is as follows (Hall, 1997):

- Physical inspection – involving an actual visit to the location of the risk.
- Flow Charts – used to describe any form of “process” within a project.
- Fault trees – diagrammatic representations of all the events which may result in loss. They also show the way in which individual events can combine together to produce potentially dangerous situations.
- Hazard indices – techniques which express the likelihood of a loss as a number, so as to allow the comparison with other similar types of risk.

The identification activities are critical, for any risks that are not discovered are risks accepted. The risk identification process is sufficient when it uncovers the risks and its sources while there is time to take action (Hall, 1997).

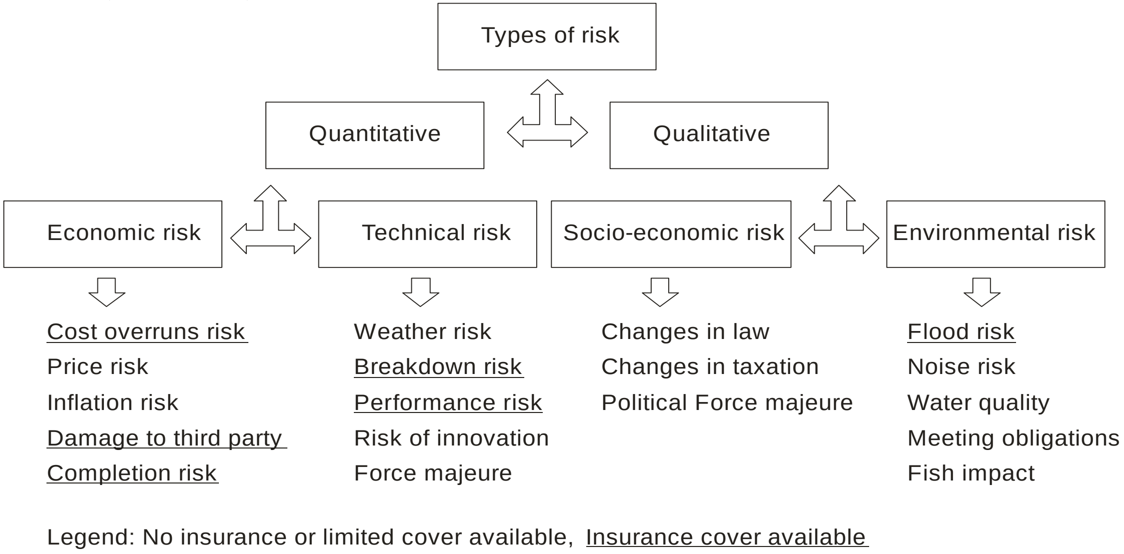

Figure 5: Classification of risk

There are many different risks existing which should be subdivided into tangible (quantitative) and intangible (qualitative) features. Typical tangible features are costs and benefits because they can be expressed in monetary terms. Intangible features cannot be readily valued in money, for example socio-economic and environmental risks (Goldsmith, 1993). Figure 5 shows the classification of risks and it is important to mention that this is a selection – and not a complete list – of possible risks facing a low head, small hydropower project. The importance and emphasis of every kind of risk depends on the target group, the technology, the potential site and the stage for an implementation of a hydropower plant. The following scenario describes some risks in different stages of a hydropower project.

At project selection stage concern lies with the reliability of feasibility studies, economic forecasts and environmental impacts, for example flood risk, noise risk, water quality issues or fish impact. In the financing stage the risks are political and economic stability, government commitment to policy, reliability of cost estimates and revenue projections; and financial measures, for instance currency and interest rate. After a low head, small hydropower project has obtained the necessary permissions for development there are further risks during the construction period including completion risk, cost overruns risk, meeting environmental obligations, political and other forces majeures, changes in taxation and in law.

In the operation and maintenance stage, risks include weather risk, for example the availability of water, price risk, breakdown risk, inflation risk, changes in taxation and in law, political and other forces majeures, technical performance risk, damage to third party, risk of innovation and finding costs higher than planned. To sum up, it is important to consider risks through all stages of the product life-cycle.

III.2 Risk analysis

After the risks are identified they must be individually assessed as to their potential probability and consequence (Borge, 2001). If historical data is available, the projections made are more likely to reflect what could actually happen. However, it is important to handle this information with care, as many forecasts based solely on past data have been inaccurate or inadequate. If there is no historical information, estimates must be based on experience, knowledge or comparisons with similar cases, or effort must be expended to increase the certainty of the information (Vose, 1996).

Jensen et al. (2000) presented a selection of diverse methods of risk analysis which can be classified as follows**:**

1. *Intuitive approach:* Add an item for "unforeseen costs" (the traditional approach for accounting risk)
2. *Sensitivity analysis* (probably the most common way of handling project risk in practice)
3. *Statistical methods*, for example probabilistic risk analysis using the Monte-Carlo Simulation (MCS) method.

The obvious disadvantage of the *"Intuitive approach"* is that the estimate depends solely on subjectivity and refers to just one item which is inaccurate. The disadvantages of the second approach *"Sensitivity analysis"* are the assumption of linearity and the limitation of modelling dependency and interactions. An advantage is that the analysis shows easily those items which may strongly affect the profitability of the project or not. On the other hand, the different parameters or assumptions are treated one by one but the sum of effects is seldom considered (Vose, 1996). In contrast, the third approach *"Statistical methods"* is able to resolve the shortcomings of the sensitivity analysis by the joint consideration of a series of possible variations for each and every variable that affects the profitability. White et al. (1998) stressed that this approach gives a measure of the variability around the investment outcome based on the expected cash flow, which is an important consideration in the comparison of alternative investments. Furthermore, they stated that the use of probability distribution assuming uncertainty approximates the "real world" conditions better rather than just the single-estimate approach, which implies that conditions of certainty exist.

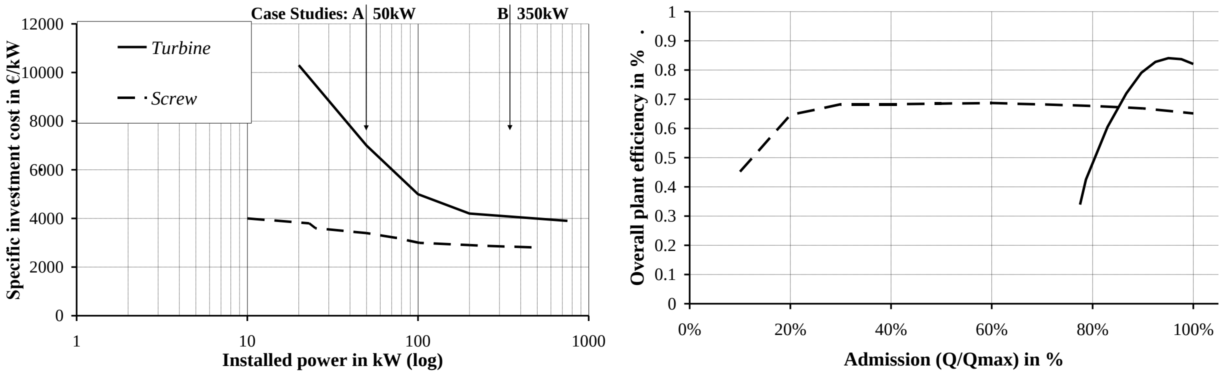

Figure 6: (left) Specific investment cost per kW and (right) Overall efficiency curves for *Turbine* and *Screw*

As shown in Figure 2, the profitability of the hydropower plant is highly sensitive regarding the running hours per year and the total investment cost. These factors both depend on the availability of water. Therefore, we focus on weather risk through variation of rainfall and the choice between alternative technologies, for example *Turbine* and *Screw*, regarding their specific cost per installed kW power. Figure 6 (left) shows these specific investment cost for two possible alternative technologies in low head, small hydropower installations. Figure 6 (right) shows the relationship between the turbine efficiency and the flow rate; the *Turbine* efficiency curve is very tight around maximum efficiency value of 85% while the *Screw* has a very flat efficiency curve with a maximum efficiency value of around 70%. The data for investment cost and efficiency curves are approximated by using textbooks from Giesecke and Mosonyi (2005) and Kaltschmitt et al. (2006). Figure 6 (left) also shows the two cases: A, for a 50kW installation and B, for a 350kW installation. The cases A and B will be considered under low flow volatility, which means relatively low weather risk, and under high flow volatility, which means relatively high weather risk. It is important to mention that this paper considers only qualitative results of the four cases and that quantitative results under several uncertainties is part of further research. Therefore, the aim of this case study is to give some interesting insights without being accurate in a quantitative way.

When using a risk analysis method with the Monte-Carlo-Simulation (MCS), it is possible to take interdependency into account. Before the simulation can be carried out the analyst must make a model of the project. This model must include all relevant cost and revenue items and their interdependency. The real problem is to assess the expected value and probability distribution of each item, and to evaluate their interdependency. In our case study, we assume that all variables are independent.

The three steps of probabilistic risk analysis using the MCS method are as follows:

1. Identification of the variables that determine profitability. In the case of the qualitative consideration of investing in small, low head hydropower project, the key variable is the weather risk measured as variability around the mean value of the flow data, as shown in Figure 7 (left).
2. Calculation of the probability functions of the aforementioned variable. In our case, we begin with available historical flow data and describe the flow variation by using the log-normal or the Gumbel distribution, as shown in Figure 7 (right).
3. Starting the Simulation: A risk analysis model provides information on the relationship between the parameters, showing the distributions of possible outcomes by using randomly selected sets of values as input parameters to simulate possible outcomes. In our case, the result is the density function of the profitability or expected Net Present Value via the probability of each profitability value, as shown in Figure 8. The result of the qualitative case study will be presented in section 4 on the next page.

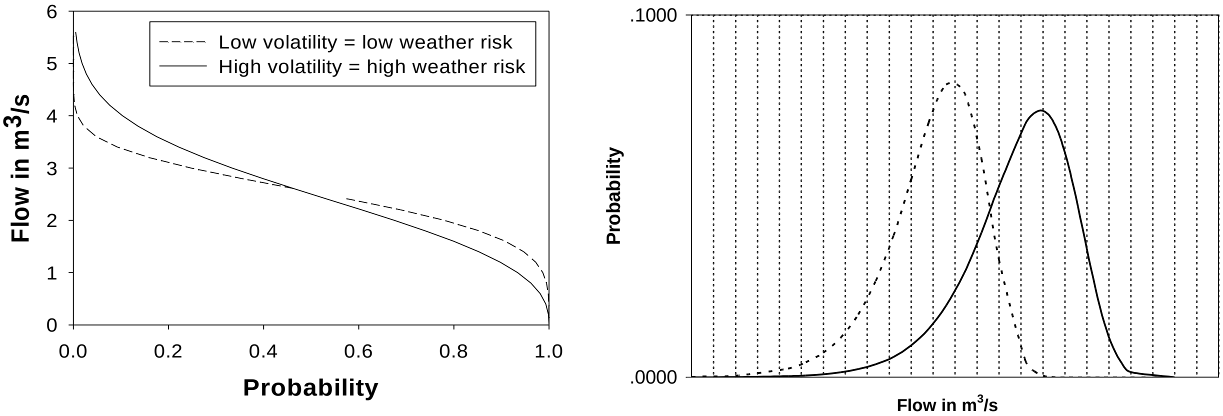

Figure 7: (left) Flow duration curves as probability density and (right) probability function(Gumbel distribtution)

III.3 Risk resolution

Once the risks have been identified and analysed, a decision needs to be taken as to how they are to be controlled. Possible courses of action to reduce risk should be identified along with the benefits and costs of each course of action. Hall (1997) introduced several risk resolution strategies including risk acceptance, avoidance, reduction, research and transfer. Enzensberger et al. (2002) described a couple of applications of the aforementioned strategies. As an example for risk transfer, which is a strategy to shift the risk to another person, group, or organization, they explained that construction risks can best eliminated by a *`fixed timescale turnkey contract`*. Another strategy is risk reduction through mitigation, prevention, or anticipation. In the case of low head hydropower projects the risk of price uncertainty can be reduced through power purchase agreements, for example the feed-in tariff (EEG) in Germany reduces risk and stimulates development. Further, Enzensberger et al. (2002) found that dynamic performance risk can be mitigated by analysing the present performance of previous projects of a chosen project developer. This risk strategy is called risk research which helps to obtain more information through investigation.

As shown in Figure 5, some of the risks facing a low head, small hydropower project can be resolved through insurance cover. However, for weather risk is no insurance cover available. Therefore, it is important to analyse and to reduce this type of risk by an accurate planning process.

IV. CASE STUDY RESULTS

Table 1 summarises a qualitative comparison of hydropower sites with 50kW and 350kW installed power under consideration of weater risk regarding which low head technology is favourable. To sum up, it is interesting to note that the overall result of technical choice under weather risk differs from the obvious plant construction point of view, which would indicate the *Turbine* for low volatility and the *Screw* for high volatility, because of their specific efficiency curves.

Cases	Qualitative results
Case A: Low Volatility and 50kW installed power, as shown in Figure 8 (left).	It is better to use the *Screw*, because although the course of water is of regular nature (low volatility), which is the preferred choice for the *Turbine*, the advantage of significantly less investment costs compared to the *Turbine* determines the choice for the *Screw* at this particular hydropower side with 50kW installed power. The efficiency advantage of the *Turbine* is less important than the cost advantage of the *Screw* .
Case B: High Volatility and 350kW installed power, as shown in Figure 8 (right).	It is better to use the *Turbine*, because although the course of water is of unregular nature (high volatility), which is the preferred choice for the *Screw*, the advantage of significantly higher energy outputs through higher efficiency of the *Turbine* determines the choice. In this particular case of installed 350kW power, the cost advantage of the *Screw* is less important than the higher efficiency advantage of the *Turbine.*

Table 1: Qualitative comparison of different combinations of installed power and flow volatility

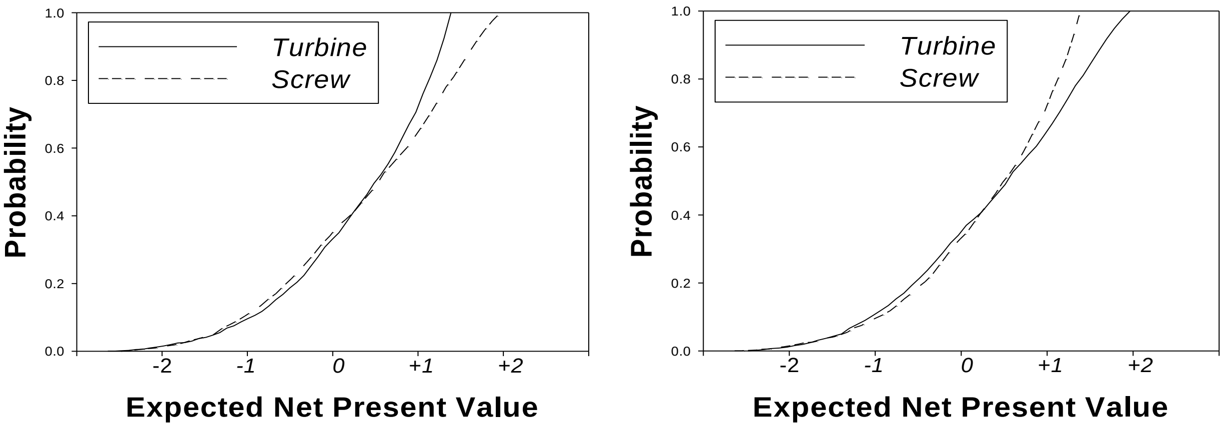

Figure 8: (left) Case A: Low volatility and 50kW and (right) Case B: High volatility and 350kW

V. CONCLUSIONS AND DISCUSSION

The low head, small hydro power market is unexploited as a result of the lack of understanding of risk, holding back technologies development and growth because of low investor confidence. The risks affect, what is most important to owners and operators alike, the profitability. This is based on the main variables, cost and revenue. Both are dependent on the quality of site surveys and machine selection. This includes accurate hydrological data, installation efficiency, power purchase agreements, environmental obligations, etc. Due to the fact that these factors may have a great influence on uncertainty they must be properly identified and their influence estimated.

It seems clear that statistical simulation methods are better suited to analyse risks of low head, small hydropower projects as they allow us to calculate the density function of profitability directly from the probability distributions for historical flow data. To sum up, this method provides comprehensive knowledge on the projects; improve the quality of the decisions that are made and increase confidence in the decision. The case study provides some interesting insights into the importance of considering risk from the beginning of a low head, small hydropower project. However, further research will aim for quantitative results under a combination of several uncertainties and their influence on the technical selection process.

The key to risk management is to be aware of all kinds of risk and to develop a plan to eliminate or minimise them in a cost-effective manner. The major premise of risk analysis is the belief that a potential customer can make better decisions when provided with a fuller understanding of the implications of the investment decision.

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