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“Profitability of a wind power plant project in comparison
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1. Introduction

Since currently there are practically no or very few renewable energy sources, such as hydroelectric energy, in Croatia, great interest in constructing wind power plants has been seen in last few years. Croatia has very significant natural potentials for the development of wind power plant projects. According to the calculations of the Ministry of the Economy, Labor and Entrepreneurship, there is a minimum of 400 MW of profitable wind power plant projects.

This study compares two different projects of renewable energy: The wind power plant project and the 3E (energy, economy, ecology) project of a small hydropower plant in Croatia. The wind power plant project is a complex issue that requires many years. During this project, all the interested parties, such as project developer, investor, etc. are exposed to numerous risks, including some with potential devastating consequences. Therefore, it is very important to conduct a risk analysis in order for the investor and project developer to be able to avoid future problems. Model for qualitative and quantitative risk assessment will help us to anticipate these problems. Since the environmental impact of both projects plays an important role in their implementation, the issue of environmental impact assessment in relation with the wind power and small hydropower plant project will be examined in the present paper.

The key element of this study is the risk analysis and economic evaluation of above mentioned projects. This involves identification, measurement, valuation and then comparison of the inputs and outcomes of these two alternatives.

2. The wind power plant project in Croatia

2.1. Cost analysis

This chapter discusses the main cost categories of a wind power plant investment. The key costs of a wind power plant project can be divided into two categories:

- Capital costs, including costs of a wind power plant equipment such as wind turbine, foundation, road construction and grid connection. These costs present 80% of the total costs of the project over its whole lifetime.
- Variable costs, consisting of the operation and maintenance costs, land rental, insurance, taxes, management and administration. In comparison to other renewable energy resources, variable costs of a wind power plant project are relatively low and present about 20% of the total investment.¹

It is important to mention that the fundamental difference between electricity generated by a wind power plant and other options such as fossil fuels (coal, oil, gas), nuclear, etc. is that the wind farm fuel costs are zero. For example, concerning the gas power plant, 40 – 60% of the costs are related to fuel and O&M costs, comparing to 20% for a wind power plant.

The greatest advantage of a wind power plant project is that the generation cost is predictable, taking into account that the wind measurements have been calculated correctly. This reduces the risk of potential investors.

2.1.1. Capital Costs

As already mentioned above, the capital costs of a wind power plant can be classified in several categories:

- The costs of a wind turbine, including its all parts such as blades, transformer, etc., transportation to the location and its installation;
- The costs of a grid connection, including cables, sub – station and connection;
- The costs including the foundation of the project, road construction and buildings;

¹ Blanco: Renewable and Sustainable Energy Reviews, 2009

- Other capital costs such as development and engineering, procedures for getting license, permits, monitoring, etc.¹

The following figure shows the estimated costs of a wind power plant project:

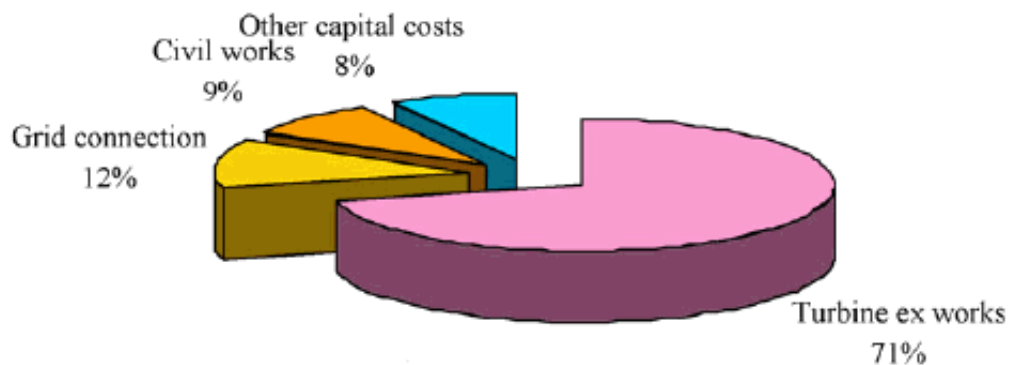


Figure 1: Estimated capital costs of a wind power plant project¹

As already mentioned, the capital costs present about 80% of the total costs of the project over its whole lifetime. The capital cost for a wind power investment in Croatia is assumed to be between 1300 €/kWh and 1500 €/kWh. As we can see in the Figure 1, the wind turbine and grid connection constitute the largest cost components. It is also necessary to mention that the capital costs depend on models of wind power plants, markets and locations.

Due to strict requirements such as environmental impact assessment, other capital costs, including land rental, taxes, licenses, permits, health and safety measures, etc. can vary and be quite high in some areas. The institutional setting, licenses and permits can have a big impact on costs.

2.1.2. Variable Costs

Variable costs have significant variations between countries, regions and locations. The key variable costs of a wind power plant project are:

- Operation and maintenance (O&M) costs, including maintenance of the electrical installation, costs for diverse repairs and spare parts;
- Land rental;
- Insurance and taxes;
- Management and administration costs, including activities of management, audits and other services.¹

The following figure shows the variable costs for a wind power plant project, distributed into different categories.

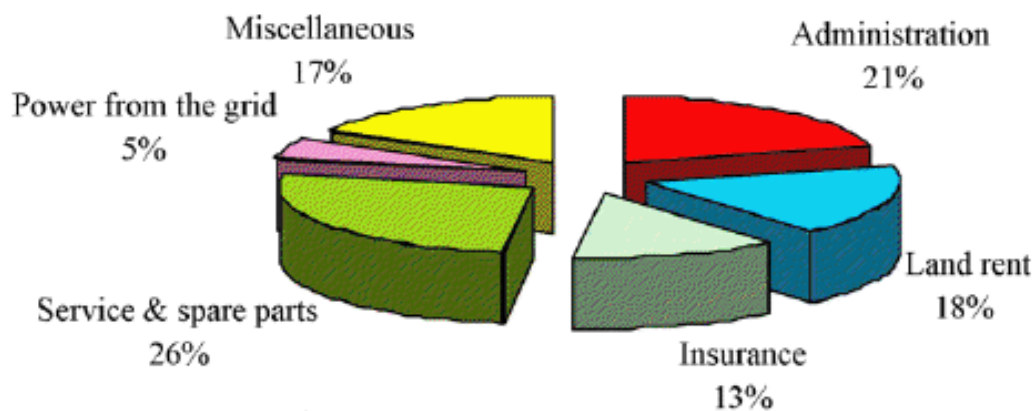


Figure 2: Variable costs for a wind power plant distributed into different categories¹

Like any other industrial equipment, wind power plants also require operation and maintenance. It is a good thing that some costs such as insurance and O&M costs can easily be estimated. O&M costs for a wind power plant project in Croatia is assumed to be between 12 €/MWh and 15 €/MWh.

On the contrary, it is more difficult to assess some costs such as costs for repair and spare parts.

2.2. Interested parties and relationships in the wind energetics market

Concerning the wind power plant project, there are three main areas of activities. Interested parties in a project of wind power plants are sometimes specialized for a certain activity and sometimes they combine several of them:

- ***The project developer*** – plays the most important role in the project. Its role is to develop the project. The activity of the project developer includes the organization of the project. It means, it is responsible for searching and selecting the right location as well as for diverse measurements and placing the plant in operation and maintenance. Since the wind energy market in Croatia is relatively new, project managers are usually involved in attracting and looking for potential investors. They are also responsible for choosing the equipment manufacturers.
- ***Equipment manufacturers*** – are usually indirectly involved in projects because they are mostly specialized in manufacturing. They sometimes also deal with the activities of the project developer. In most of the cases, it is connected with testing of equipment.
- ***Investors*** – do not exclusively need to be the ones who are involved in energetics, since the wind power projects mostly attract private capital. The usual ways of financing, such as loans from commercial banks, also function in wind power plant projects. The main problem here is that the banks are not always ready to support such projects. In countries where wind energy is not a new activity, there are certain firms that are specialized for financing wind power plant projects. Since such projects are of political and public interest in Europe which would not survive without incentives, different state and international institutions, such as the European Bank for Reconstruction and Development – EBRD, the European Investment Bank – EIB, the Global Environmental Facility – GEF, are largely involved in financing these projects.²

² Mužinić / Škrlec: Modeliranje projektnih rizika u razvoju projekta vjetroelektrane, 2007

2.3. Risk analysis

In the past several decades, the need for risk management on the market has grown. Risk management focuses on identifying what could go wrong and deals with studying risks as input data for the decision making process.

Risks are an integral part of every business and project. Therefore, they should not be ignored and should be approached in a more organized way. Organized risk management consists of the following steps:

- risk identification,
- risk analysis,
- risk response,
- risk monitoring and
- reporting.³

Risk analysis can be a complex process. It can be divided into qualitative and quantitative analysis.

2.3.1. The selected method of risk analysis

Since a risk analysis might be a pretty complex issue, it can be organized in various ways. The most widespread risk analysis methods are:

1. stress testing (the testing of extreme events),
2. scenario analysis,
3. the mean-optimistic-pessimistic case method,
4. sensitivity analysis,
5. the Value at Risk (VaR method),
6. the AS/NZS 4360 standard (Australia and New Zealand),

³ (1) Cooper / Grey / Raymond / Walker: Project Risk Management Guidelines Managing Risk in Large Projects and Complex Procurements, 2005

(2) Energetski Institut Hrvoje Požar: Strategija energetskog razvitka, u okviru projekta Strategija razvitka Republike Hrvatske – Hrvatska u 21 stoljeću, 2002

7. Project Management Body of Knowledge - PMBOK, Project Management Institute Σ PMI, USA.⁴

The methods from 1) to 4) represent the simple ones. The methods ranked from 5) to 7) are the complex ones.

The purpose of risk analysis is to give the decision maker precise information which is contained in the density of the probability distribution of the criterion variable. Additionally, risk analysis also has to provide a rigorous computer modeling process in order to get the probability distribution of the criterion variable.

The main steps of the selected process are:

1. identifying the criterion variable and relevant variables which affect the criterion variable,
2. describing the determination of the probability distribution of the relevant variables,
3. investigating and determining the connection (potential dependence) among individual variables,
4. assessing the probability distributions for all the relevant variables that affect the criterion variable,
5. determining the probability distribution of the criterion variable, using the Monte Carlo method,
6. evaluating a project using information contained in the probability distribution of the criterion variable.²

The steps from 1) to 3) represent the qualitative and steps 4) and 5) quantitative risk analysis. Step 6) shows the analysis of the results.

The following figure shows a schematic representation of the method chosen to analyze the risk of wind power plants projects in Croatia.

⁴ (1) Cooper / Grey / Raymond / Walker: Project Risk Management Guidelines Managing Risk in Large Projects and Complex Procurements, 2005

(2) Marrison: The Fundamentals of Risk Management, 2002



Figure 3: Presentation of the method chosen for the risk analysis²

2.3.2. Qualitative risk analysis

Qualitative risk analysis involves various methods for determining the significance of identified risks. The main goals of qualitative risk analysis are assessment of the risk impact on the project and the probability of risk occurrence, risk tolerance, costs, etc.

The basic classifications of the risk in wind power plant projects are:

1. project risks – are risks associated with the project. Their impact varies depending on the country, location and finally the project. However, while some political or commercial risks in certain countries or markets do not exist, the project risks are always present in all projects. It is about the risks associated with the following elements of the project:
 - a) project duration,
 - b) building,
 - c) production,
 - d) attracting capital,
 - e) location (country),
 - f) connection to the electrical energy system.⁵
2. market risks – bare mainly on the price of energy and depend on the method for encouraging the development of wind energy exploitation and formation of prices of energy gained from the wind power. When analyzing the risk of conventional power plants, the cost of fuel must be taken into account. This item does not exist for wind power plants, since the wind is free. In contrast, the price of electricity is more risky. Since the energy law regulates the price of energy produced from renewable energy sources, this is a partially regulated market.
3. technical risks – can be classified in three categories:
 - a) risks associated with the wind (wind potential) and equipment for measuring of wind potential,
 - b) risks associated with equipment for producing electricity,
 - c) risks associated with integration of wind power into the electrical energy system.⁶

Here appears a great difference in attitudes. On the one side, we have some parties who are interested in development of wind energy and tend to ignore all the dangers, and on the other side, we have former monopolists who are prone to exaggerate.

⁵ Marsh / McLennan Companies: Scoping Study Financial Risk Management Instruments for Renewable Energy Projects; Sustainable Energy Finance Initiative (SEFI) United Nations Environment Programme, 2004

⁶ Skytte / Meiborn / Uytterlinde / Lescot / Hoffmann / Del Rio: Challenges for Investment in Renewable Electricity in the European Union, Background report in the ADMIRE REBUS project, 2003

4. political risks – in Croatia should be considered as two administrative levels: state and local governments. At the state level, there is a principled stance in favor of development of wind energy based largely on the idea to follow the European trends and created as a part of EU policy.⁷ Unfortunately, the activities are quite inconsistent. A strong political wind energy development plan does not exist either. For that reason, political risks in Croatia are still quite large. One example of the instability of this policy is the adoption of Regulation on Protected Coastal Area.⁸

At the local level, risks are similar in Croatia and abroad. It means that developer should give a lot of attention to lobbying for wind energy. Any reason for skepticism of local government will have a negative impact on project.

5. administrative risks – are specific to transition countries which are still in the phase of organizing administrative and legal procedures. Many of these risks are negligible in developed countries, since administrative procedures are transparent and their duration is easily predictable. New laws regarding wind energy should accelerate an administrative process.

The most significant administrative risks are related to:

- a) spatial planning,
- b) property law questions,
- c) obtaining permits.⁹

Impact of the majority of above mentioned risks depends on the specific characteristics of the project. However, it is necessary to note that project and technical risks are common to all wind energy projects because they do not depend on the political situation. On the other hand, market and political risks are significantly different for certain countries.

The ways of classifying risks are numerous and can vary a lot. The classification of risk depends in the first place on the viewpoint from which the analysis is performed.

⁷ Energetski Institut Hrvoje Požar: Strategija energetskeg razvitka, u okviru projekta Strategija razvitka Republike Hrvatske – Hrvatska u 21 stoljeću, 2002

⁸ Vlada Republike Hrvatske: Uredba o uređenju i zaštiti zaštićenog obalnog područja mora, 2004

⁹ Škrlec / Mužinić / Maderčić: Modeliranje rizika u projektima vjetroelektrana, 2007

The way of classifying risk is not as much important as the correct allocation of the risk. The project of a wind power plant can be classified into four phases:

1. preparatory phase,
2. construction phase,
3. exploitation phase,
4. decommissioning phase.¹⁰

2.3.2.1. Risks in the preparatory phase of a project

The first phase of the project including planning, preparation of investment plan, financial analysis and measurement of wind potential is probably the most complex part of the project. Therefore, the risks can only be avoided if they are taken into account and analyzed at the beginning.

The following table shows the risks in the preparatory phase of a project:

Table 1 – Risks in the preparatory phase		
Stage	Activities	Causes of risk
Selection of a location for measurements	Assessment of the wind conditions for the purposes of selecting locations at which measurements will be performed	<ul style="list-style-type: none"> • Quality and references of experts
	Physical planning documentation	<ul style="list-style-type: none"> • Land protection (frequently in the Republic of Croatia)
	Property – legal relations	<ul style="list-style-type: none"> • Negative attitude of the owners toward the planned project • Unreasonable demands for compensation • Unresolved property situation
	Assessment of electrical energy conditions in the network	<ul style="list-style-type: none"> • Poor network condition • Distant connection point • Necessity for upgrading the network

¹⁰ Howatson / Churchill: International Experience With Implementing Wind Energy, 2006

	Establishment of relations with the local community	<ul style="list-style-type: none"> • Opposition from the local community • Costs due to obtaining approvals
	Ecological questions	<ul style="list-style-type: none"> • The existence of protected flora and fauna • Special conditions for building on the location
	Determination of the accessibility of the location	<ul style="list-style-type: none"> • The absence of routes that would meet the requirements for the construction of a wind power plant
Measurement of wind potential	Measurement of the wind potential	<ul style="list-style-type: none"> • Poor quality measurements
	Analysis of the measured data	<ul style="list-style-type: none"> • Poor quality of measured data
Activities after the selection of the location, parallel with the measurement of the wind potential	Monitoring flora and fauna	<ul style="list-style-type: none"> • Possibility of establishing the negative impact of the wind power plant on flora and fauna
	Amendments to physical plans	<ul style="list-style-type: none"> • Unpredictable duration (a minimum of 6 months) • Investor bears the costs • Poor relations with the local self – management can result in the prolongation of the procedure • Errors during amendment
	Investigation of potential connections	<ul style="list-style-type: none"> • Requirements for financing the upgrading of the network by the operator
	Preparation of an environmental impact study	<ul style="list-style-type: none"> • Possibility of determining a negative impact upon the environment
Selection of a wind turbine (equipment)	Determination of the wind turbine	<ul style="list-style-type: none"> • Incorrect choice of any of the parameters of the wind turbine can devastate the project
	Selection of supplier	<ul style="list-style-type: none"> • The selection of a poor quality supplier
Obtaining a location permit	Preparation of the preliminary design	<ul style="list-style-type: none"> • With a quality project designer, risks are minimal • Necessary cooperation between the project designer and the author of the environmental impact study

	Assessment of environmental impact	<ul style="list-style-type: none"> • Change in the placement of the wind turbines due to the visual impact on the environment (requires changes in the preliminary design) • Requirements for amendments to the environmental impact study (long – term)
	Resolution of property – legal questions	<ul style="list-style-type: none"> • The impossibility of obtaining building rights • Requirements for unreasonable compensations
	Submitting application for obtaining a location permit	<ul style="list-style-type: none"> • Long procedure (minimum of 2 months) • Requirements for amending the preliminary design • Refusal to grant a location permit
Obtaining a building permit	Preparation of the main project	<ul style="list-style-type: none"> • Amendments to the project, depending on special conditions (HEP, the Ministry of the Interior, Croatian Waters, Croatian Forests, etc.)

Table 1: Risks in the preparatory phase²

2.3.2.2. Risks during the construction phase of a project

If the preparatory phase is performed well, we should not expect any special risks in this phase of a project. Statistics for the European Union show that the time needed for the construction of a wind power plant ranges from a half a year to a year.

The following table shows the risks during the construction phase of a project:

Table 2 – Risks during the construction phase		
Stage	Activities	Causes of risk
Construction work	Construction of routes and roads	<ul style="list-style-type: none"> • Unforeseen problems from the terrain
	Foundation construction	<ul style="list-style-type: none"> • Errors in the construction of the foundation can be fatal
Turbine installation	Equipment delivery	<ul style="list-style-type: none"> • Equipment must follow the just in time (JIT) principle because otherwise there are costs for maintaining the cranes and team on the terrain
	Installation	<ul style="list-style-type: none"> • Installation is performed by the supplier, who assumes all the risks

Table 2: Risks during the construction phase²

2.3.2.3. Risks in the exploitation phase of a wind power plant

Technical and market risks such as production and delivery of electricity mostly occur in this phase. Problems occur when a wind power plant is not operating, what leads to deficit in earnings.

The following table shows the risks in the exploitation phase of a wind power plant:

Table 3 – Risks in the exploitation phase of a wind power plant		
Stage	Activities	Causes of risk
Exploitation	Energy production	<ul style="list-style-type: none"> • Poor wind quality • Equipment breakdowns
	Participation on the energy market	<ul style="list-style-type: none"> • Reduction in incentive (energy price) below an acceptable level

Table 3: Risks in the exploitation phase of a wind power plant²

2.3.3. Quantitative risk analysis

Quantitative risk analysis is performed for risks which have been chosen by qualitative risk analysis as the most important risks for the project. Selected method of quantitative risk analysis is numerical modeling. These risks are analyzed in this part of procedure. Each risk is assigned a numerical value. Since the profitability is the most important factor for the project of a wind power plant, criterion variable is usually an economic indicator. Following methods are used for dynamic approach to the assessment of the economic contribution of a project:

1. payback period of investment,
2. method of discounted cash flows after taxation.
 - a) Internal Rate of Return,
 - b) Net Present Value.¹¹

The following figure shows the quantitative risk analysis defined by AS/NZ 4360 standard:

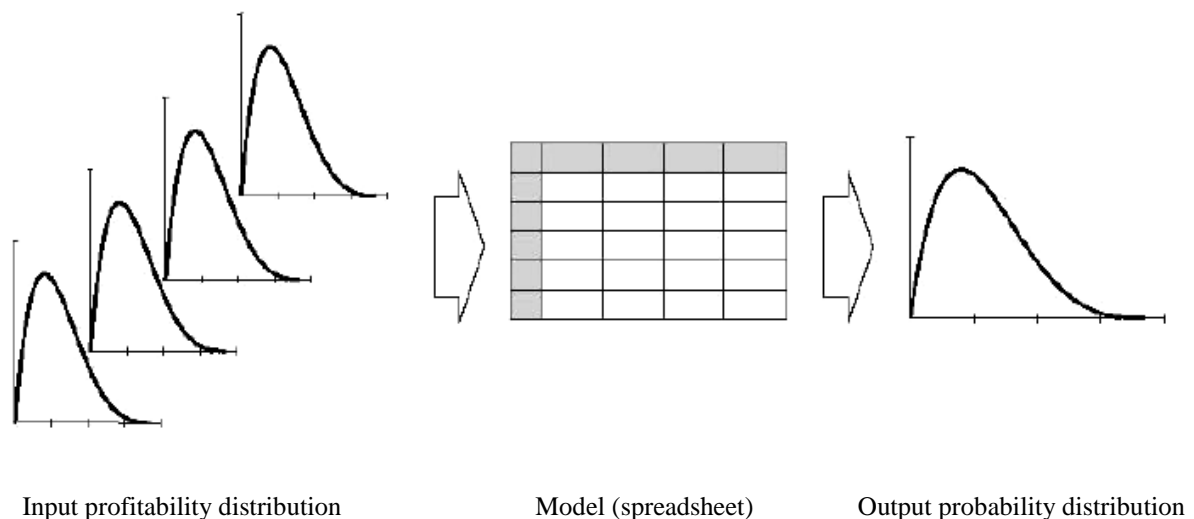


Figure 4: Quantitative risk analysis¹²

¹¹ (1) Žiković: Formiranje optimalnog portfelja hrvatskih dionica i mjerenje tržišnog rizika primjenom VaR metode, 2005

(2) Uran: Isplativost ulaganja vlastitog kapitala u projekt za zajedničku proizvodnju toplinske i električne energije, 2005

¹² Cooper / Grey / Raymond / Walker: Project Risk Management Guidelines Managing Risk in Large Projects and Complex Procurements, 2005

2.3.3.1. Model for quantitative risk analysis

The model for risk analysis for the wind power plant projects in Croatia uses Monte Carlo technique as a fundamental procedure in calculating the probability density of certain variables. This technique involves assigning probability distributions to model variables that represent risks. The next step is generation of random numbers within the framework of selected probability distributions in order to simulate future events.

The following steps show the simulation:

- definition of input variables,
- definition of input (observed) variables,
- definition of correlation coefficients (arbitrary step),
- simulation,
- result report.²

The risk analysis model for wind power plant projects in Croatia has been prepared in Microsoft Excel and has been tested on a sample of 20 wind turbines, each with 1 MW power and a lifetime of 25 years.

2.3.3.2. Definition of input variables

The input variables of the model are supposed to have an impact on the project in the future. All risks are converted into monetary units, so that their impact could be presented as changes in the financial indices of the project. Each of the above risks is assigned a probability distribution.

The input variables of the model are:

- a) annual production,
- b) measured wind potential,
- c) change in the physical plan,
- d) geodetic image,
- e) location permit,
- f) construction work,

- g) connection to the network,
- h) connection substation.

One example would be an annual production per MWh, which will later be multiplied by the price per MWh, so that the calculation could be expressed in terms of the monetary units.

The following parameters for annual production have been assumed, selected and put in the model: truncated normal distribution with an interval from 1900 MWh to 2600 MWh, mean value of 2250 ($\mu=2250$) and standard deviation of 250 ($\sigma=250$). It is assumed that the annual production should be between 1900 MWh and 2600 MWh, which characterizes a quite good location. According to world statistics, a location with over 2000 hours of operating time is considered to be very good. But, it is necessary to mention that such a location with 2000 operating hours is the lowest limit for the Croatian situation. It is not worth the investment below this limit.

The following figure shows the probability distribution of annual production variable according to the applied model on the basis of 10 000 iterations. Here, it is important to mention that the key frequency points are shown on the abscissa. Not real values of the iterative steps but the results are grouped around these key frequency points. It means that the values which are shown on the abscissa may possibly never be obtained in reality. Other input variables are determined in the same way.²

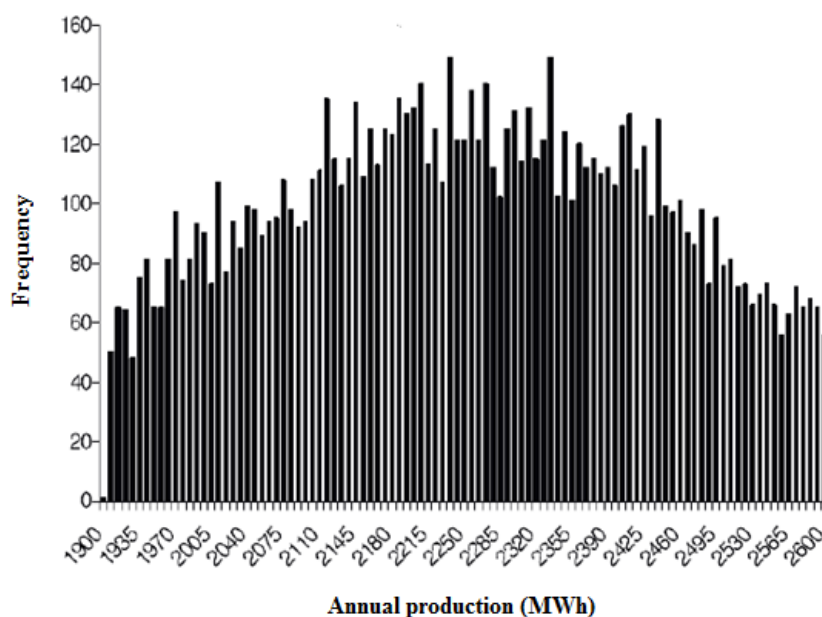


Figure 5: Probability distribution of annual production variable²

2.3.3.3. Definition of output variables

The output variables are the result of simulation of input variables. According to the model, the output variables are calculated after the random values of input variables are selected 10 000 times.

The results of simulation are used to determine the probability distribution of output variables using the Monte Carlo technique. The following output variables have been selected:

- total investment (TI),
- payback period (PP),
- net present value (NPV),
- internal rate of return (IRR).²

The net present value is calculated on the basis of cash flows after the wind power plant has been operating for 25 years.

2.3.3.4. Determination of correlations

The input variables are sometimes mutually dependent. For that reason, it is necessary to determine the correlation matrix. The correlation coefficient between -1 and 1 for any two variables are allowed in this model. At these points, the correlation between the two variables is perfect.

Two pairs of variables are correlated in this model:

- annual production and wind potential measurement are correlated with the correlation coefficient of 0,8. For example, if the costs of measurement of a wind potential increases by 10%, the annual production will increase by 8%.
- the construction work and geodetic image are correlated with the correlation coefficient of 0,5. Terrain works are the connection between these two risks. The more expensive the geodetic image is or the larger the location is, the greater construction costs are expected.²

2.3.3.5. Financial part of the model

The investment is financed from equity and loan. Ratio between the equity and loan is assumed to be 0,2 / 0,8. All investments shown in the first year are paid by equity. The equipment costs are paid by loan. The installation costs are included in the price of wind turbines, since the construction work is provided by manufacturer.

Investing in equipment is modeled as a price of 20 wind turbines, each with a 1 MW power. The price of one wind turbine is 6 570 000 HRK (900 000 €). It means, the total equipment costs are 131 400 000 HRK and they are an unchangeable variable in this model. The total investment varies depending on the location of risk.

The total location costs also include some fixed costs such wind potential measurements, geodetic image, etc. Data for loan: interest rate of 5%, payback period of 15 years, grace period 2 years. The only income is income from generated energy that varies depending on annual production. Expenditures consist of annuity, maintenance, insurance, depreciation, etc.⁹

2.3.4. Risk analysis report

2.3.4.1. Total investment

The following figure shows the probability distribution of the total investment variable. This is actually not a criterion variable for a given project but since it is interesting for the project, it will be considered in this model.

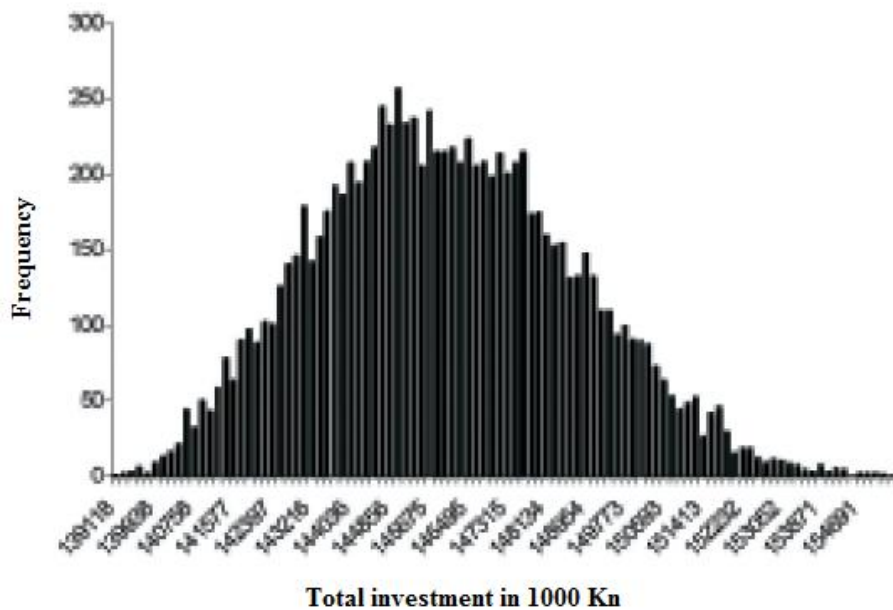


Figure 6: Probability distribution of the total investment variable²

From the above figure, we can read the following data:

Key data of the probability distribution of the total investment variable	
Data	Value in 1000 HRK
Minimum	139 118
Mean value	145 944
Maximum	155 510
Standard deviation	2 694
Range	16 392

Table 4: Key data of the probability distribution of the total investment variable²

The probability is calculated by integrating the probability density function. Integral for any value shows the probability that the finite value of the project will be lower than the given one. This information is essential for determining the risk analysis. The resulting function is a cumulative function of the variable probability. In this case, it is the value of the project.

The following figure shows the cumulative probability distribution of the total investment variable:

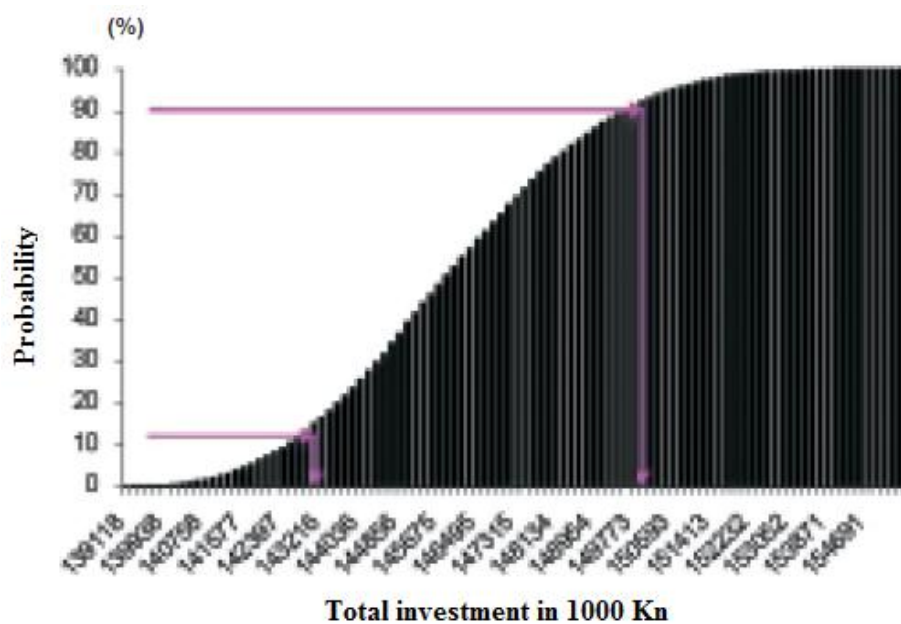


Figure 7: Cumulative probability distribution of the total investment variable²

Using the cumulative probability function, we can show some risk variable quite good. This is usually done by calculating confidence intervals of 80%. In this case, it is: 142 560 000 HRK < total investment < 149 609 000 HRK.

2.3.4.2. Payback period

The following figure shows the probability distribution of the payback period variable:

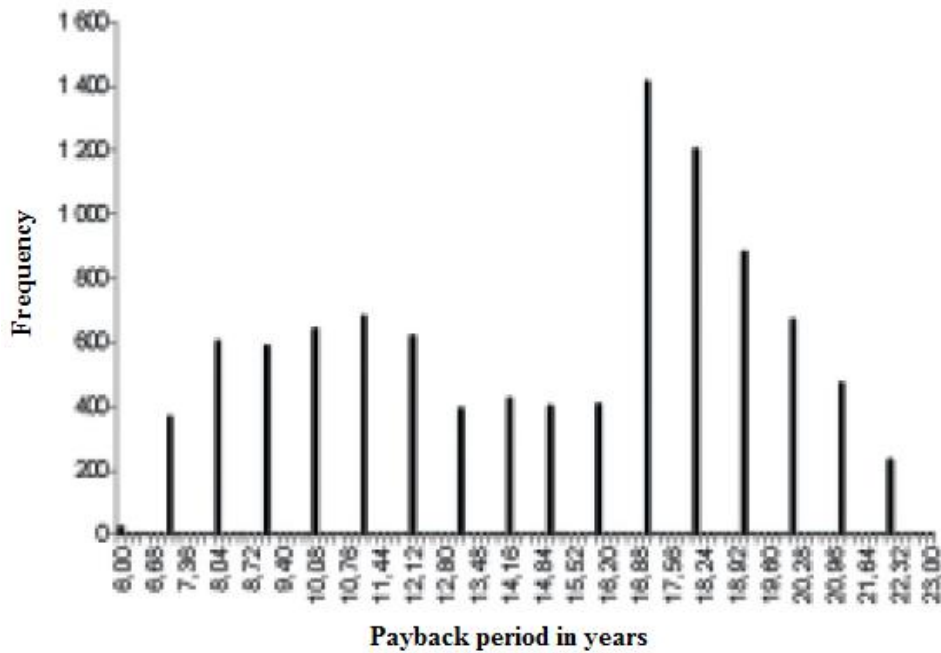


Figure 8: Probability distribution of the payback period variable²

From the above figure, we can read the following data:

Key data of the probability distribution of the payback period variable	
Data	Value in years
Minimum	6
Mean value	14,83
Maximum	23
Standard deviation	4,31
Range	17

Table 5: Key data of the probability distribution of the payback period variable²

The following figure shows the cumulative probability distribution of the payback period variable:

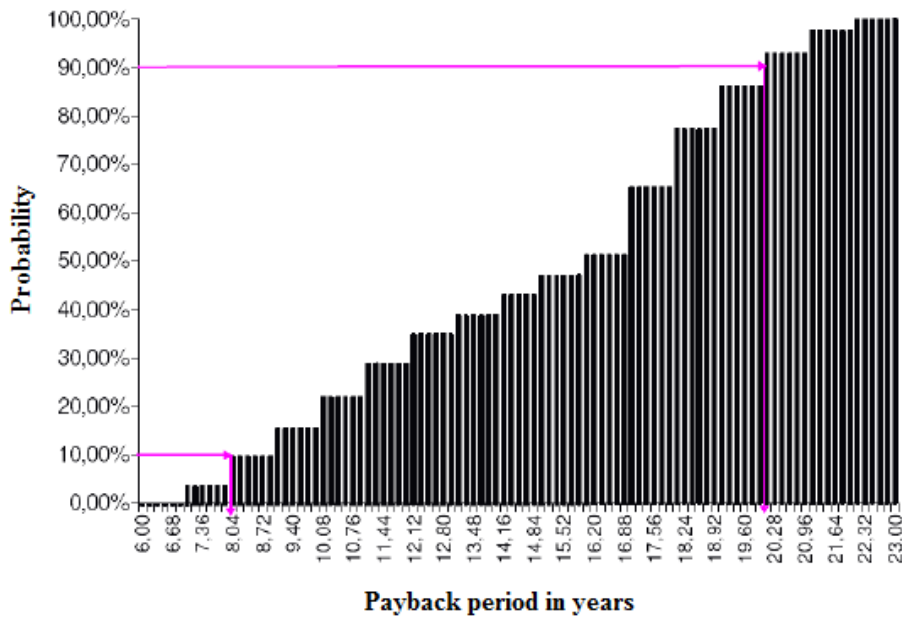


Figure 9: Cumulative probability distribution of the payback period variable²

The 80% confidence interval is 8 years < payback period < 20 years. It means, we can say with 80% confidence that the payback period will be within this interval. This is not if we take into account the mean value of probability distribution, which is about 15 years and is not a lure for investors.

2.3.4.3. Net present value

The following figure shows the probability distribution of the net present value variable:

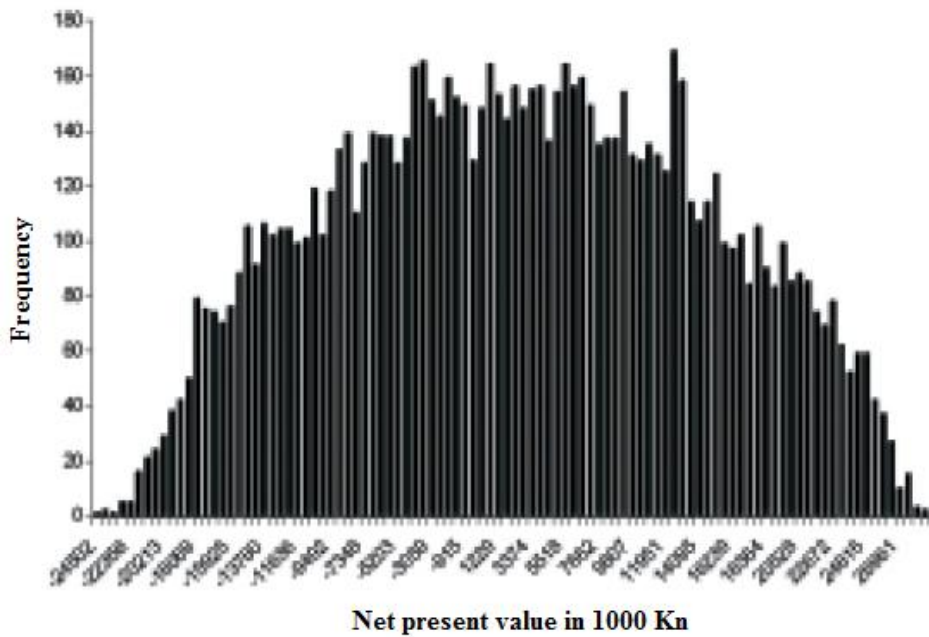


Figure 10: Probability distribution of the net present value variable²

From the above figure, we can read the following data:

Key data of the probability distribution of the net present value variable	
Data	Value in 1000 HRK
Minimum	- 24 501
Mean value	2 324
Maximum	29 105
Standard deviation	11 744
Range	53 606

Table 6: Key data of the probability distribution of the net present value variable²

The following figure shows the cumulative probability distribution of the net present value variable:

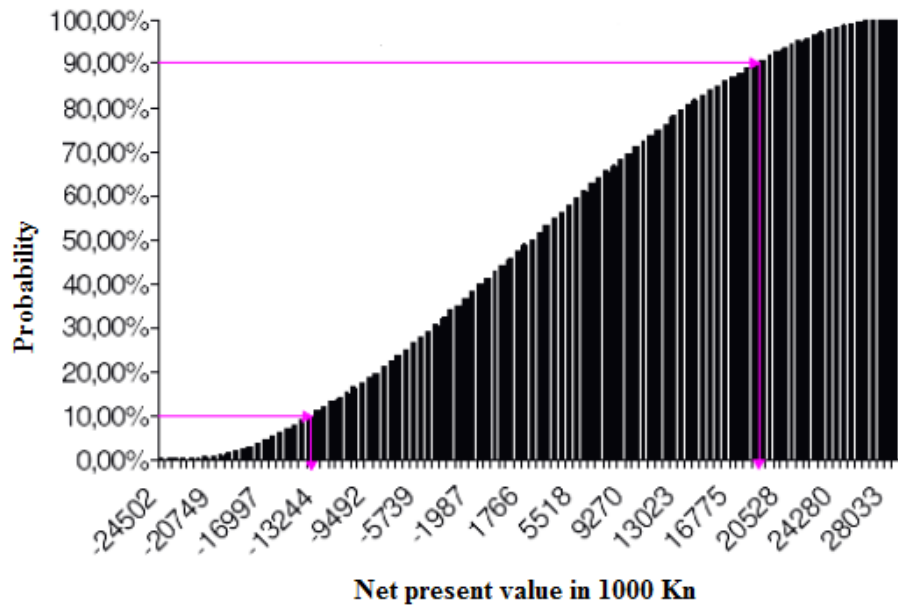


Figure 11: Cumulative probability distribution of the net present value variable²

The 80% confidence interval is $-13\,780\,460 \text{ HRK} < \text{net present value} < 18\,919\,730 \text{ HRK}$. With 80% confidence, we can not determine whether the net present value will be positive. The criterion for the assessment of the project requires that the net present value is positive. Here, we see that the positive net present value occurs at a probability above 43%. It means that the probability of a successful project is 57%.

2.3.4.4. Internal rate of return

The following figure shows the probability distribution of the internal rate of return variable:

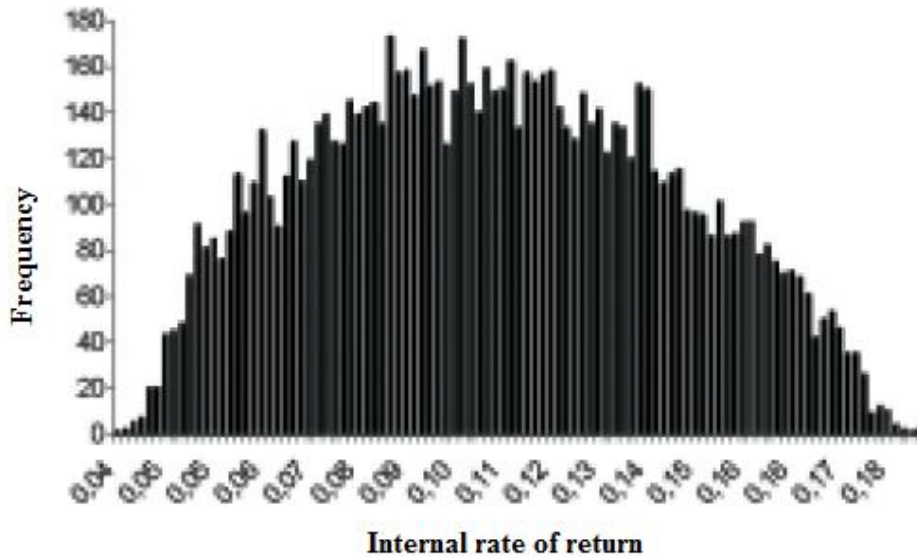


Figure 12: Probability distribution of the internal rate of return variable²

From the above figure, we can read the following data:

Key data of the probability distribution of the internal rate of return variable	
Data	Value
Minimum	0,036 122 265
Mean value	0,107 410 979
Maximum	0,189 512 628
Standard deviation	0,033 570 573
Range	0,153 390 363

Table 7: Key data of the probability distribution of the internal rate of return variable²

The following figure shows the cumulative probability distribution of the internal rate of return variable:

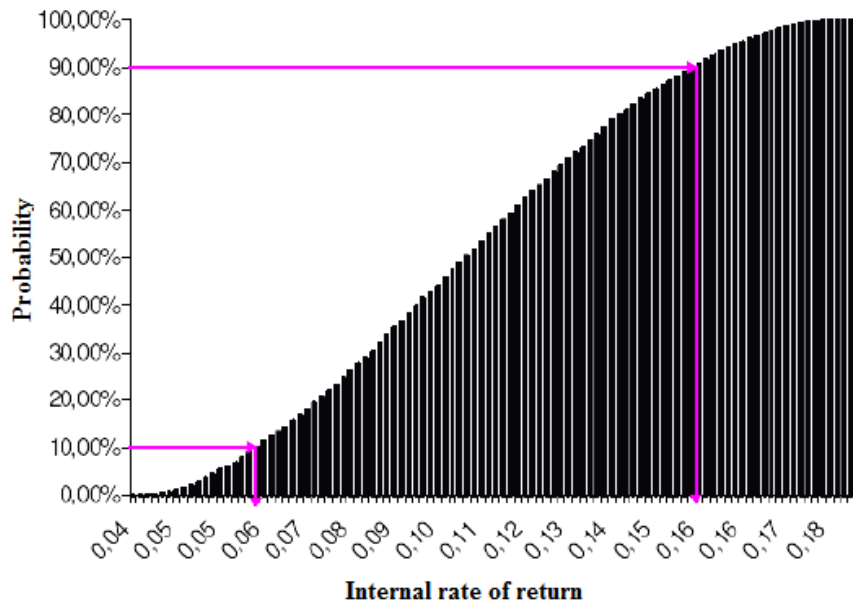


Figure 13: Cumulative probability distribution of the internal rate of return variable²

The 80% confidence interval is $0,06 < \text{internal rate of return} < 0,15$. The criterion for the assessment of the project requires that the internal rate of return is greater or equal to the given discount rate of 10%. In the above figure, we see that the discount rate of 10% occurs at a probability of 49%. The obtained value for the net present value is 43%.

2.4. Environmental impact of a wind power plant

Like any other project, this project also has a certain impact on the environment. This chapter describes the environmental impacts of wind power plants and suggests some measures for reducing their impact. The environmental impact of a wind power plant is classified in three phases:

- during the construction phase,
- during the operation time,
- during dismantling of a wind power plant.

Special attention is directed towards the visual impact and effects of flicker, shadows and noise.

2.4.1. Environmental impact during construction¹³

2.4.1.1. Flora and Fauna

Flora - In general, impacts on flora and vegetation during construction of a wind power plant is reflected in the reduction of natural habitats and diversity of these habitats and as well as diversity of plants associated with these habitats. However, based on existing information, a negative impact on flora is not expected. The proposed project locations are generally rocky areas with limited vegetation, where endemic species are not found.

Impact on forests is mainly reflected in permanent loss of forest land as a result of construction of wind turbines and associated works. Although the proposed location is classified as a forest land, existing vegetation is very limited and consists mainly of low brushwood. Removal of vegetation has a local character and lasts only during installation of a wind turbine and other equipment.

Fauna – Concerning large mammals, fauna is not affected during the construction phase. Impact on animals is associated only with a temporary displacement caused by the presence of workers and machines as well as of noise, vibration, explosion, exhaust gases and dust due to

¹³ Exergia – IHGF: Prethodna procjena uticaja na okoliš za projekat izgradnje vjetroelektrane Msihovina, 2009

construction works. Such effects are temporary and reversible. It means that the animals will return after the construction works are completed.

Impact on ornithofauna is associated with direct loss of a bird habitat during the construction phase of a wind turbine. There is also a possibility that this affects their temporary abandonment of this area. As in the case of large mammals, the potential impacts on ornithofauna are also only temporary.

2.4.1.2. Geomorphology

Limited impact on the geomorphology of the area is expected during the phase of construction, mainly regarding the installation of a wind turbine as well as the reconstruction of roads and electric energy infrastructure.

These effects are limited because the size of construction works does not cause changes in general morphology of the area.

2.4.1.3. Air quality

Earthworks lead to dust emissions, especially in the phases of excavation and cleaning of location. The presence of machines on these locations also has a negative impact on the air quality. Similar effects also occur during the construction of access roads and transport of equipment. In any case, these impacts have a short and limited character and do not have significant effects on air quality in the area.

2.4.1.4. Ground water and surface water

During the construction phase, a negative impact on water bodies can be caused by inappropriate handling of liquid waste caused by workers. If we suppose that there is no surface water in the area of construction works, construction works can only affect the groundwater as a result of uncontrolled discharge of contaminated wastewater from sanitary

facilities. The more significant issue is spilling of oil, hydraulic fluid and fuel. This issue requires special attention because of the high porosity of soil.

2.4.1.5. Landscape

Some visual effects are also expected in the construction phase. Such impacts are limited in duration and space, since they are connected with the presence of machines.

The visual impacts of a wind power plant during construction are temporary and last as long as construction works. They are only visible closest inhabited places.

Any changes in the landscape as a result of construction works such as excavation will be returned to its original condition after completion of construction works. This involves removing the construction or excavated materials and planting vegetation.

2.4.1.6. Noise

During the construction phase, there is a relative increase in current level of noise caused by construction works and vehicle movements. The impact of noise is generally temporary and fully reversible after completion of works. Additionally, since the closest inhabited place is in the worst case at least a few hundred meters away from the location of construction works, noise does not affect the people. Certain measures should also reduce the level of noise:

- The movement of heavy vehicles should be planned in cooperation with the local police, especially in terms of passing through some inhabited places.
- The movement of heavy vehicles should completely be avoided near schools, hospitals and other sensitive areas.
- Works which produce noise should be suspended for holidays.

2.4.1.7. Climate

Negative impacts on the climate are not expected in the construction phase of wind power plants.

2.4.1.8. Infrastructure

Positive impacts on the local infrastructure are expected during construction. Due to the needs of the project, improvement of road and infrastructure in the area will be done. As previously mentioned, parts of existing road infrastructure will need reconstruction in order to allow passage of heavy vehicles.

2.4.1.9. Socio - economic impacts

Some limited impacts are expected due to changes in land use on the proposed locations, since the forest land will get converted into construction land. However, since this land is not used, such impact is insignificant.

It is necessary to mention that the wind power plants require large areas of land depending on the installed capacity, but since the turbines are installed at a considerable height, they cover less than 1% of the total area.

From the economic point of view, we expect positive effects because the construction works will make job opportunities. It is expected that the local labor will partly carry out works, especially those works that do not require qualifications. This will reduce unemployment and provide support to the local economy.

In case that it is necessary to hire workers from other parts of the country or abroad, there will still be a need for accommodation, food supply, etc. which will again be provided by the local community.

2.4.2. Environmental impact during operation¹³

2.4.2.1. Flora and Fauna

Operation of wind turbines generally has a negligible impact on flora and fauna, except on bird population. When the turbines are put into operation, they may cause negligible discomfort to the vertebrates and large mammals that inhabit that area or use it as a feeding or migratory path.

Regarding the impact on birds, there are data on birds that have died due to collisions with turbine blades. These types of collisions are statistically very rare and the number of birds which have died that way is much smaller than the number of birds that have died due to other human activities such as illegal fishing and collisions with high-voltage electric transmission lines.

Studies done in Germany, the Netherlands, Denmark and the UK have shown that the total number of died birds per year due to collisions with wind turbines is only 20 (regarding the installed capacity of 1000 MW), while the number of died birds due to illegal fishing is 1500.¹³

The risk of collision with wind turbines depends on many parameters such as types of birds, their number in that area, flight mode, food availability, weather conditions, topography and characteristics of a wind farm.

2.4.2.2. Geomorphology

Negative impacts on the geomorphology are not expected during operation of a wind power plant.

2.4.2.3. Air quality

Since there are no pollutant emissions during operation of a wind power plant, negative impacts are not expected on the air quality.

2.4.2.4. Ground water and surface water

Since wind power plants do not produce liquid waste, there are no negative impacts on the ground and surface water. In case of turbine maintenance and use of lubricants, oil and its derivatives, disposal of waste should be done carefully.

2.4.2.5. Landscape

Generally, wind power plants are dominant structures that are visible from big distances because of their size. Wind farms create a "technological" landscape that is not pleasing many people, although this is a very subjective thing. All in all, impacts on the landscape can be negligible.

2.4.2.6. Noise

Modeling has shown that the noise is always within allowed limits. The level of noise that is heard in the nearest inhabited places is very low, such as an everyday noise in the workplace.

Therefore, special measures for controlling noise levels are not provided, except the selection of modern equipment which possesses advanced new technologies for noise emission control.

2.4.2.7. Climate

Negative impacts on the climate are not expected during operation of a wind power plant.

2.4.2.8. Infrastructure

In the operation phase, wind power plants can cause interference with the transport of electromagnetic waves that are used in telecommunications, radio navigation or transmission of TV signals. These problems may occur because of the position of wind turbines towards existing stations. If a wind power plant is placed between the transmitter and receiver, it causes signal fluctuation and problems with electromagnetic waves. This problem has been

expressed by previous generations of wind turbines which have had metal blades. Modern wind turbines have blades which are made from synthetic materials that have a minimal impact on the transmission of electromagnetic waves. Besides, the emission of electromagnetic waves of a wind turbine is particularly weak during its operation. It is also retained only in the vicinity of housing and does not affect the environment.

2.4.2.9. Socio - economic impacts

It is expected that the social impacts resulting from changes in land use are not significant and are related only to irreversible loss of land occupied by wind power plants. The real land use is only a restricted area occupied by wind power plants, while the rest of land is practically unchangeable.

On the other hand, significant positive effects are expected from the economic point of view. These effects are associated with the production of electricity, stabilization in local power supply network and supply a larger number of people with electricity. Since the electricity generation in most of the areas is entirely based on hydropower plants, the proposed project should increase the production of electricity, which will enable better supply response to increased demand, strengthen the economy and technological advances and generally improve the quality of life in these areas.

2.4.3. Environmental impact during dismantling

Significant impact on the environment as a result of project termination due to the nature of project and materials used for making turbines is not expected. Dismantling requires the removal of turbines and processing of waste materials. Recycling techniques should be conducted in accordance with appropriate legislation.

Besides, it is necessary to mention that the life time of a wind power plant is 25 years and it may be extended if a regular maintenance is performed.

2.4.4. Cumulative and secondary impacts

Cumulative and secondary impacts are not expected during construction and operation of a wind power plant.

3. The small hydropower plant project in Croatia

3.1. Financial analysis

There is no standard answer to the question how much the construction of a small hydropower plant costs. From the financial point of view, the hydropower plants differ from other sources of electrical energy because they are characterized by high initial specific investments (per kW of installed power) and low operating costs because expenditure on fuel does not have to be considered.¹⁴ In general, by using current technologies, the total costs can range from 1500 \$ to 2500 \$ per kW of installed power. It all depends on system capacity and location.¹⁵ Large hydropower plants have little difficulties in competing with other conventional production of electricity but small hydropower plants can normally compete where the charges for external costs associated with fossil fuels and nuclear energy are introduced.¹⁶ In addition, part of the costs as well as a high proportion of benefits from the small hydropower plant is achieved through the future time. For that reason, financial analysis requires assigning time dimension. This time period is usually determined by the whole lifetime of a small hydropower plant. Since the lifetime of a small hydropower plant is supposed to be 30 years, the financial analysis should be conducted for that period of time.¹⁷

In order to carry out any analysis, it is necessary to develop a preliminary design of a small hydropower plant which includes key elements of a hydropower plant schema. On the basis of such scheme, it is possible to determine the approximate costs of equipment and materials as well as the assessment of the total cost of a small hydropower plant.¹⁴ This certain price is only guideline but satisfies the purpose of estimating an initial financial analysis of project feasibility. The actual price should be determined after the design and collection of accurate and detailed data. Finally, the financial analysis boils down to comparing the costs and benefits which is achieved by construction of a small hydropower plant.¹⁷

¹⁴ Micro - Hydropower Systems: A Buyer's Guide, 2004

¹⁵ European Small Hydropower Association – ESHA: Guide on How to Develop a Small Hydropower Plant, 2004

¹⁶ Energetski institut Hrvoje Požar: Male hidroelektrane
(http://www.eihp.hr/hrvatski/projekti/see_ener-supply/pdf/5_Mahe.pdf)

¹⁷ Tomišić: Značaj i uloga malih hidroelektrana u elektroenergetskom sustavu, 2009

3.2. Cost Analysis

The cost analysis includes the initial (investment) costs and annual costs. The initial costs include:

- preparation costs and the costs of construction works,
- costs of hydro-mechanical equipment,
- costs of electrical engineering equipment,
- costs of connecting to the network,
- other unexpected costs such as (purchases, wages and compensations, studies, project implementation, supervision, etc.).

The annual costs include:

- operation and maintenance costs,
- depreciation costs,
- cost of capital,
- profit tax.¹⁵

Figure 14 shows the distribution of project costs:

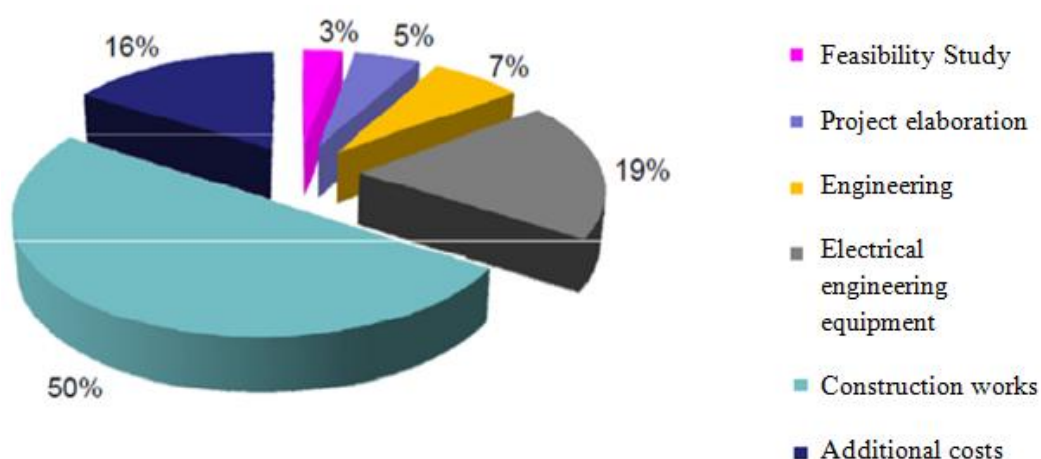


Figure 14: Distribution of project costs for a small hydropower plant¹⁸

¹⁸ Car: Obnovljivi izvori energije, 2009

3.2.1. Investment costs

The required initial investment for a small hydropower plant depends on effective fall, water flow, geological and geographical features, equipment (turbines, generators, etc.), construction works and the continuity of flow. By using existing dams, bulkheads, reservoirs and lakes, the environmental impact and costs can significantly be reduced. Hydropower plants with a small drop height and large water flow require greater initial investment because construction works and turbine machinery must be able to handle larger water flow. Assuming the same installed power, the price for a larger drop height is also lower because the required dimensions of the appropriate equipment are smaller.

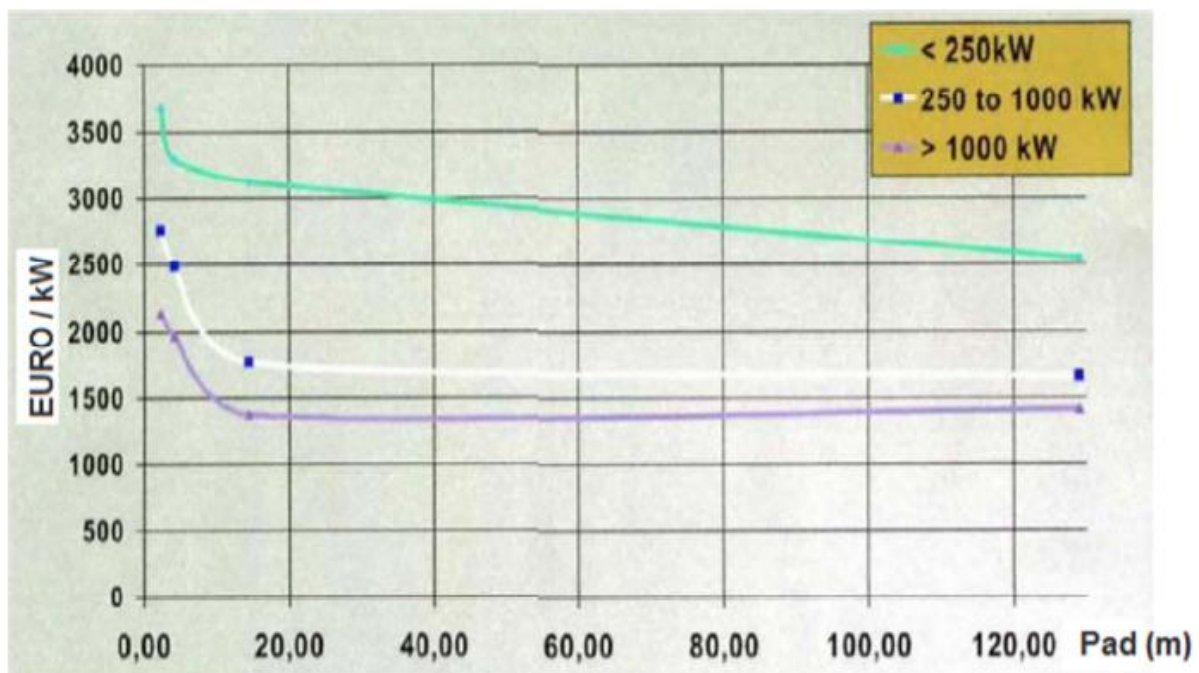


Figure 15: Specific investment costs of a small hydropower plant depending on drop height and installed capacity¹⁹

¹⁹ Elektrotehnički fakultet Osijek: Male hidroelektrane
(http://www.etfos.hr/upload/OBAVIJESTI/obavijesti_dodiplomski/2243.DIE_MHE.pdf)

According to the Figure 15, we can conclude that the hydropower plants with installed capacity of less than 250 kW and a drop height of less than 15 m have the highest average costs. Figure 16 shows the total costs of a small hydropower plant in a wide range and minimum and extreme values respectively.

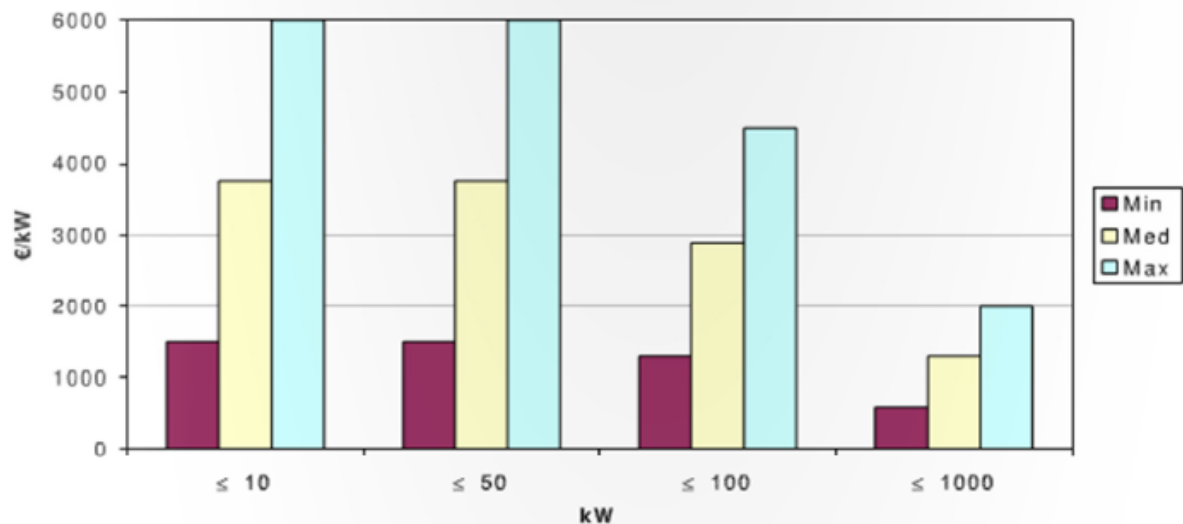


Figure 16: Total investment costs (turn-key principle)¹⁵

In order to reduce costs, the conclusion would be that the implementation of a small hydropower project needs to achieve lower administration costs and to use mostly local labor and local materials for construction. With this approach, it is possible to achieve savings for the transport of materials and equipment as well as labor cost savings. In the context of small hydropower plants, expensive and often unnecessary technical expertise and supervision should also be avoided.

The size of hydropower plant is an influential parameter that affects the unit price of hydropower plant in such a way that the specific investment costs (per kW of installed power) are greater for small hydropower plants. In comparison to large hydropower plants, specific investments for small hydropower plants are more than 25% greater and can reach three times larger value. The annual costs for small hydropower plants are significantly lower than the equivalent costs for large hydropower plants. Unlike other energy sources, costs of a small hydropower plant largely depend on locational conditions. Locational conditions determine about 75% of the price of a small hydropower plant and make so-called variable costs. Only about 25% of the price is relatively fixed.¹⁷

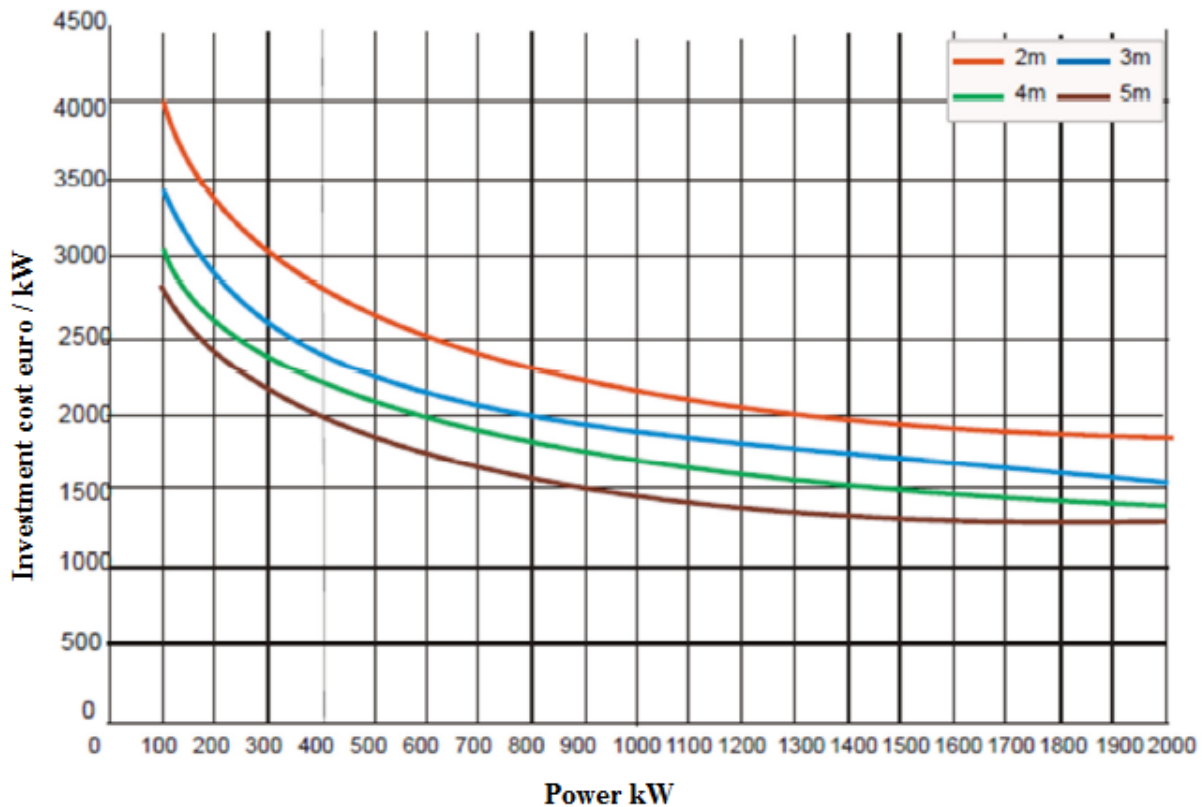


Figure 17: Specific investment costs depending on capacity of hydropower plant and drop height¹⁵

The value of total investments based on average investments derived from certain study analysis of small hydropower plants for the sites on the territory of Croatia is,

- 100 kW of installed capacity makes the average investment of 600 000 \$,
- 500 kW of installed capacity makes the average investment of 2 400 000 \$,
- 1500 kW of installed capacity makes the average investment of 4 350 000 \$,
- 3000 kW of installed capacity makes the average investment of 4 800 000 \$.²⁰

By making “the cadastre of small water capacities in Croatia”, it was determined that for 63 streams (of 134 analyzed) there exist 699 possible locations that could be used for the plant construction of capacity of 5 MW. Pricing criteria and criteria for allocation of small hydropower plants to one of the following categories depend on effective fall, flow, geological and geographical features, equipment (turbines, generators, etc.), construction works and the continuity of the flow. Taking into account the characteristics of the locations in Croatia, the estimated prices would be,

²⁰ Franjić: Analiza isplativosti izgradnje malih hidroelektrana u Hrvatskoj, 1997

1. Types of watercourses (108 locations) of mean value of $H = 16,62$ m, $Q = 8,04$ m³/s, $P = 791,3$ kW – up to 2500 €/kW
2. Types of watercourses (244 locations) of mean value of $H = 5,33$ m, $Q = 9,81$ m³/s, $P = 247,35$ kW – 2500 €/kW – 4500 €/kW
3. Types of watercourses (231 locations) of mean value of $H = 3,11$ m, $Q = 6,69$ m³/s, $P = 95,47$ kW – 4500 €/kW – 6000 €/kW
4. Types of watercourses (111 locations) of mean value of $H = 0,99$ m, $Q = 13,08$ m³/s, $P = 73,53$ kW – above 6000 €/kW¹⁹

The price of a small hydropower plant ranges from 2500 to 3000 \$ per installed kW for the higher capacities and a record high of 10 000 \$ per installed kW for the smaller ones (less than 500 kW). Figure 18 shows the dependence of the specific investment costs on capacity of a small hydropower plant. According to the literature, a typical price of a small hydropower plant ranges from 1000 to 2000 € per kW of installed capacity.

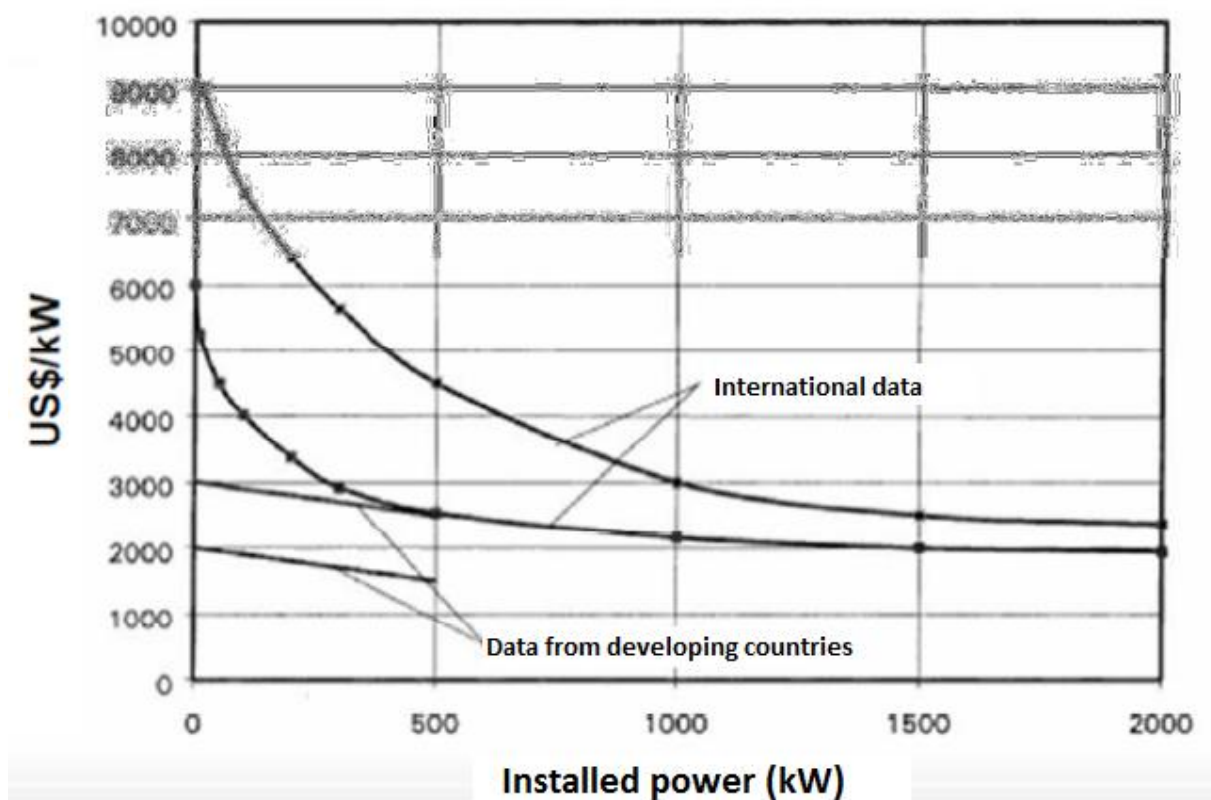


Figure 18: The range of project costs for small hydropower plants in the world¹⁷

3.2.2. Costs of components

The share of construction costs in the total investment ranges from 40% to 70%. It is obvious that the largest share of investment goes to construction works. It is clear, therefore, that it is necessary to build small hydropower plants in conjunction with other commercial facilities that require similar construction requirements such as facilities for flood control, irrigation, water supply in cities, etc. In this way, by using a common infrastructure for several activities, the investments can be shared and the required investments for a small hydropower plant can be greatly reduced.

Quantities of construction materials and works for some parts of the plant can be roughly determined according to the installed flow. Initial construction consists of low threshold, input device, grid, precipitator, flushing channel and proper closures. Depending on the type of procedure, the dimensions of these components can be put into the functional dependence of the flow. From this dependence, it is possible to determine the costs of each type. The flume as well as the volume of excavation and embankment and surface coating can be put in relation to the flow which makes possible to determine the costs of each flume. To sum up, the costs of hydromechanical equipment can be set as a functional dependency on the installed flow and range from 1 to 2% of total investments.

The costs of electrical engineering equipment depend on the applied type of aggregate, type of its installation, applied turbine and voltage regulation, method of electric power transmission (cable or transmission line), distance of hydropower plant and consumption, auxiliary power supply, transport costs, necessity for access roads, etc.

In doing so, the costs of certain equipment and services such as costs of control system, measurement, synchronization, protection, regulation of the turbine and generator, auxiliary power sources and construction can be considered as fixed costs. On the other hand, costs for the turbine, generator, transformer and their supporting equipment are changeable. The price of these components is often not available in the market but determined on the basis of other parameters such as the strategic interests of equipment producers, number of ordered units, etc. A very influential factor on the price of electrical engineering part of a small hydropower plant is the gearbox which is used for providing speed and torque and is not necessarily required. Its installation should be avoided because it has a significant impact on the price of electrical engineering part of a small hydropower plant. The costs of electrical engineering

equipment range from 20% to 40% of total investments of a small hydropower plant. When considering the price of a small hydropower plant, special attention should be directed to the costs of connecting to the electrical grid and all equipment and works which need to be done in order to enable this connection. The costs of connecting to the electrical grid can vary and reach up to 20% of total investments. They depend on the voltage level, power of a small plant, geographical conditions and the length of the connecting line. It is estimated that other costs (purchases, wages and compensation, studies, project implementation and supervision) range from 50 to 10% of the total investment.¹⁷

3.2.3. Annual costs

Operating costs consist of a lubricant, salary costs of staff, expenditure of own consumption, various regular duties, fuel for the diesel generator (if installed) used for bringing the hydroelectric generating station into operation, etc. while maintenance costs consist of repairs, reconstruction costs, technical monitoring, etc. Depreciation is a major part of the annual costs. Description of fixed assets is determined by using a method of linear depreciation of tangible and intangible assets or more exactly, by using a method of annual depreciation rate of 4% for buildings, 5% for equipment and 20% for intangible investments. Costs of capital are perceived through annuity loan repayments which realize an investment of a small hydropower plant. Income tax in Croatia is calculated at a rate of 35% of determined tax base. It is also important to mention the fees. When it is about fees associated with hydroelectric facilities, it refers to the following fees:

- fee for use of location (over 500 kW of installed capacity),
- water use fee,
- fee for water catchment,
- water protection fee,
- concession fee for use of water and public water resources,
- public utility rates,
- fee for use of the maritime domain.¹⁷

The maximum annual operating and maintenance costs can be estimated as 25% of annual revenue.

3.3. Environmental impact analysis

3.3.1. Water management strategy²¹

According to Water Act, the use of water considers abstraction and the use of surface and groundwater for different purposes, where a drinking water supply for population is a public interest and takes precedence over the use of water for other purposes that is primarily economic interest, which is influenced by market (electricity generation, irrigation, fish farming, navigation, the abstraction of geothermal and mineral water, water use for sport and recreation, etc.).

Hydropower facilities and installations usually have a multi-character with the broader social and water management significance (flood protection, ensuring water supply, electricity generation, provision of water for irrigation, small water regulation regime, sport and recreation, etc.).

The use of water power for electricity generation provides one-third of the total energy production in Croatia. The available water resources and remaining water potential are strategically important for the country because it is about own and renewable energy which is environmentally friendly. Strategy of energy announces a rise in interest for the construction of hydropower as well as increase in price of fossil fuel. In general, we are talking about multi-purpose projects, which can be a significant initiator of local and regional development. Water management interest is to participate in the realization of such projects, ensuring the efficient use of available water resources (multi-purpose solutions) and the sustainability of the water regime (securing ecologically acceptable flow, improvement of small water, etc.).

Water protection includes the principles of sustainable development and unity of the water system because of ensuring an adequate water regime (quantity and quality of water), which is based on regulations of Water Act, National Water Protection Plan, water protection against pollution and other documents such as Law on Nature Protection, Law on Physical Planning and Construction, Physical Planning Strategy of the Republic of Croatia, Law on Environmental Protection, National Environmental Strategy and National Environmental Action Plan, Public Utility Act. In protection of water, it is important to respect the

²¹ <http://narodne-novine.nn.hr/clanci/sluzbeni/340787.html>

international agreements which the Republic of Croatia signed and ratified in the ratification procedures which refer to implementation of measures and construction of facilities for water protection.

Energy Strategy of the Republic of Croatia gives a great importance to hydroenergetics as the most important renewable and environmentally friendly energy source. It is estimated that new plants can be built on medium and large rivers in Croatia which would produce an annual average of 3.0 TWh of additional electricity. In the period until 2020, the construction of several new hydropower plants is planned. Hydrologic and topographic characteristics of some small streams are also suitable for the construction of small hydropower plants. The development of hydroelectric must be accommodated to protect the environment and nature, flood, public water supply, irrigation, inland waterways, etc. Hydropower plants which are placed on the border and trans-boundary rivers must be in accordance with bilateral agreements with neighboring countries due to cross-border impacts. Development plans for the energy sector and water management will be harmonized by taking into account the requirements of other users of water.

3.3.2. National Environmental Strategy and National Environmental Action Plan²²

The main objective of this strategy is the preservation of the environment of the Republic of Croatia on the principles of sustainable development through the achievement of the following steps:

- Improving the legal, financial and institutional framework for environmental management at local and national level, including strengthening of human resources, taking into account the convergence in the EU,
- Integrating environmental protection into other sectors (agriculture, forestry, tourism, energetics, industry, mining, transportation, etc.) to reduce environmental pollution and sustainable use of natural resources,

²² (1) <http://narodne-novine.nn.hr/clanci/sluzbeni/308683.html>

(2) <http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/358127.htm>

(3) <http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/358123.htm>

- Establishment of a comprehensive monitoring and unified information system,
- Enhancing public awareness and public participation in decision-making process and implementation measures.

The energetics sector was designated as one of the primary sectors in which it is necessary to include the requirements of environmental protection as an integral part of the strategy and policy development, especially in the case of building new energy facilities.

The goals of environmental protection or the energy sector include the following:

- Changing technologies for the production of energy in a manner that it will be acceptable for the environment,
- The strategy is outlined to achieve the goals of energy development. Special attention should be paid to the evaluation of energy efficiency and developing new and renewable sources. It is also necessary to take into account the economic and state factors as well as requirements arising from the environment.

3.3.3. Strategy and Action Plan for Biological and Landscape Diversity of the Republic of Croatia²³

Strategy and Action Plan for Biological and Landscape Diversity of the Republic of Croatia is a fundamental document for protection of nature, which sets long term goals and the objectives of preserving biological and landscape diversity and protected natural values as well as ways of its enforcement in accordance with economic, social and cultural development of the Republic of Croatia.

Impacts of hydropower plants on water and aquatic ecosystems may be multiple. It could lead to changes in water regime, reduction in quantity of sediment, what can lead to erosion and deepening of the riverbed (the river of Drava, Sava, etc.). Water accumulations can cover valuable natural areas and dams can be barriers to movement of fish and other organisms. In karst regions, the construction of water tunnels and water transmission through the karst drainage basins are associated with hydroelectric facilities. This can lead to disturbances of the groundwater regime in the wider area.

²³ <http://narodne-novine.nn.hr/clanci/sluzbeni/378092.html>

The construction of hydropower plants and water retention ponds substantially changes the natural flow of rivers which negatively affects the whole range of habitats and associated benthic communities. The river basin contains a range of different aquatic and wetland habitats of unique dynamics (river banks, wetlands, wet meadows and riparian forests). Therefore, the preservation of the natural river flow is a condition of maintaining the diversity of these habitats and the diversity of plant and animal species. For programs and implementation plans for energy development strategy (in development), it is necessary to develop a strategic environmental assessment including the assessment of sustainability in order to determine which of the planned hydropower plants have a significant adverse impact on species and habitats in the area of ecological networks. When planning the hydropower plant project, it is necessary to go through the process of environmental impact assessment.

3.3.4. The strategy of energy development in the Republic of Croatia²⁴

The aim of this strategy is the system construction of balanced development of security of energy supply, competitiveness and environmental protection which will provide Croatian citizens and economy a safe, affordable and adequate energy supply. This energy supply is a prerequisite for economic and social progress.

The Republic of Croatia has good natural resources for exploitation of renewable energy sources. Renewable energy sources are domestic energy sources and their use is a means for improving security of energy supply, an impetus to development of domestic production of energy equipment and services and a way to achieve environmental objectives.

The Republic of Croatia will maximally stimulate renewable energy source. But firstly, it is necessary to set the following strategic goals:

- The Republic of Croatia will fulfill the obligations proposed by the European Union Directive on stimulation of renewable energy sources, also including large hydropower plants, in gross final energy consumption of 20%,
- The Republic of Croatia will fulfill the obligations under the Directive of the European Union on the share of renewable energy sources of 10% in final transport energy consumption in the period until 2020,

²⁴ http://narodne-novine.nn.hr/clanci/sluzbeni/2009_10_130_3192.html

- The Republic of Croatia sets a goal that the share of electricity production from renewable energy sources, including large hydropower plants, stays at level of 35% in total electricity consumption in the period until 2020.

The exploitation of renewable energy sources makes a domestic opportunity of technology development favorable. Therefore, the Republic of Croatia will encourage investments in research and development as well as their implementation. Opportunities for development of technology for the use of biomass, use of wind energy in wind power plants, use of distributed power generation and small hydropower plants are good. The total technically exploitable hydro potential in hydropower plants in the Republic of Croatia is estimated at 12,45 TWh / year. The power plants are currently using 6,13 TWh / year or 49,2% of this potential. The potential of small rivers is about 10% of total potential (about 1 TWh / year). The research potential of small streams in Croatia has been conducted through the preparation of the Cadastre of small hydropower (up to 5 MW). Based on the Cadastre of a small hydropower, the Cadastre of small hydropower plants with 67 potential sites for small hydropower plants is made but due to various constraints this number was reduced to 18 sites. According to available sources, it would be possible to produce the total amount of 125 MW from hydropower plants of 5 to 10 MW but due to additional researches, it is expected that this number will decrease.

The Republic of Croatia has set the goal of producing at least 100 MW from small hydropower plants by year 2020.

Due to the high specific investments and restrictions related to the impact on the environment, protection of cultural and historical heritage and landscapes, it will be very difficult to achieve that goal. In order to achieve the objectives set by the strategy, the Republic of Croatia will encourage the study of the remaining water flows to determine the exact location and resources for building of hydropower plants, facilitate the administrative procedure to acquire licenses (especially for hydropower plants producing less than 5 MW) and harmonize the energy and water management legislation.

3.3.5. Strategy for Sustainable Development of the Republic of Croatia²⁵

Sustainable Development has a task of achieving three general goals: a stable economic development, social equity and environmental protection. Taking into account the responsibility of the state for global issues at the international level, these objectives can only be done in a joint collaboration of all stakeholders. In order to achieve these goals, it is necessary to protect the earth's capacity to sustain life in all its diversity, respect the existing limitations in the use of natural resources, ensure a high level of protection and improvement of environmental quality, prevent and reduce environmental pollution and promote sustainable production and consumption so that economic growth would not necessarily mean degradation of the environment. Renewable energy sources do not an appropriate share and position in the Croatian energy sector, although they have a great importance and availability (especially solar energy, wind energy, biomass and water).

Activities or measures for achieving the main goal:

- a) Increasing the share of renewable energy (excluding hydropower plants which produce more than 10 MW) in total energy consumption up to 20% by 2020,
- b) Providing 12% of the average energy consumption and 21% of electricity consumption from renewable sources by 2010 and increasing their share up to 15% by 2015.

3.3.6. Regulations of the Republic of Croatia

3.3.6.1. Water Act²⁶

This Act regulates the legal status of water, water goods and water structures, managing water quality and quantity, protection from flooding, public water and drainage supply activities, special activities of water management, institutions which are responsible for performing these activities and other issues related to water and water goods.

Water structures and devices for electricity generation must be designed and constructed in such a way:

²⁵ http://narodne-novine.nn.hr/clanci/sluzbeni/2009_03_30_658.html

²⁶ <http://www.zakon.hr/z/124/Zakon-o-vodama>

1. to allow returning of water to streams and other water bodies,
2. not to reduce the extent of use of water supply and irrigation and not to prevent the use of water for other purposes in accordance with this Act,
3. not to reduce a degree of protection from flooding and not to hinder the implementation of such protection measures,
4. not worsen the health situation and not to adversely affect the water status,
5. not to threaten life and health, not to cause damage to water, water environment, other components of environment and environment in general,
6. not to impede pedestrian, road and rail traffic and inland waterway navigation.

3.3.6.2. Environmental Protection Act²⁷

This Act regulates the principles of environmental protection and sustainable development, protection of environmental components, documents of sustainable development and environmental protection, environmental protection instruments, environmental monitoring, information system, providing access to environmental information, public participation in environmental issues, ensuring the right of access to justice, responsibility for damage, financing instruments and the general environmental policy, administrative and inspection bodies.

Environmental objectives in creating the conditions for sustainable development are:

- protection of life and health of people,
- protection of flora and fauna, biological and landscape diversity and preservation of ecological stability,
- protection and improvement of quality of individual components of environment,
- protection of the ozone layer and mitigation of climate change,
- protection and restoration of cultural and aesthetic values of landscapes,
- prevention of major accidents involving dangerous substances,
- preventing and reducing environmental pollution,
- permanent use of natural resources,
- rational use of energy and encouraging use of renewable energy sources,

²⁷ <http://narodne-novine.nn.hr/clanci/sluzbeni/329475.html>

- addressing the consequences of environmental pollution,
- improving of disturbed natural balance and re-establishment of its regeneration ability,
- achievement of sustainable production and consumption,
- replacement of hazardous and noxious substances,
- sustainable use of natural resources without greater damage and threats to the environment,
- ensuring a healthy environment.

Water protection includes measures to protect water and improve water quality for the purpose of avoiding or minimizing adverse effects on human health, freshwater ecosystems, quality of life and the environment in general. Protecting water from pollution is carried out in order to preserve life and health of people and environment as well as to ensure sustainable, harmless and free use of water for different purposes.

3.3.6.3. Regulation on strategic environmental impact assessment of plans and programs²⁸

Strategic assessment is a procedure that assesses significant environmental impacts that may arise from the implementation of plans and programs. This process involves determining the content of strategic studies, preparation of strategic studies and evaluation of integrity and competence of strategic studies, particularly in relation to variant solutions of plans and programs. It also involves the procedure of issuing an opinion of the commission, specially designated people, territorial (regional) governments and other bodies. This process includes the results of transboundary consultations, information and public participation, the process of issuing an opinion of the ministry which is responsible for environmental protection and reporting after the adoption of plans or programs.

²⁸ <http://narodne-novine.nn.hr/clanci/sluzbeni/339665.html>

3.3.6.4. Regulation on environmental impact assessment of hydropower plant constructions²⁹

The environmental impact assessment is conducted for

- plants for the generation of electricity, steam and hot water of capacity greater than 1 MW by using of
 - a) fossil and solid fuels,
 - b) renewable energy sources (water, sun, wind, biomass, biogas, geothermal energy, waves, tides, etc.).

3.3.6.5. Nature Conservation Act³⁰

Objectives and tasks of the Nature Conservation Act are

- to preserve and to restore the existing biological and landscape diversity to the natural state of balance and harmonized relationships with human activities,
- to establish and to monitor the state of nature,
- to ensure the protection system of natural values for their permanent preservation,
- to ensure the sustainable use of natural resources without damaging the essential parts of nature and with the least possible disruption of its components,
- to help to preserve soil, quality, quantity and availability of water, atmosphere, production of oxygen and climate,
- to prevent harmful human activities and natural disturbances as a result of technological development and activities,
- to ensure citizens' right to a healthy life, leisure and entertainment in nature.

Interventions in nature are planned in such a way to avoid or to minimize damage to the environment. During performing the procedure, the holder is obliged to act in such a way to harm the environment as less as possible. Upon completion of the procedure, state of the environment in the operating region should not be worse than it was before the procedure.

²⁹ <http://narodne-novine.nn.hr/clanci/sluzbeni/339664.html>

³⁰ <http://narodne-novine.nn.hr/clanci/sluzbeni/288893.html>

3.3.6.6. Regulation on proclamation of the ecological network³¹

The ecological network is a system of interconnected or spatially close ecologically important areas, which significantly contribute to the preservation of natural balance and biodiversity. Its parts are connected by natural or artificial ecological corridors.

According to the EU ecological network NATURA 2000, ecological networks in the Republic of Croatia are divided into internationally important area for birds and other areas important for wild species and habitat types.

An ecological network of the Republic of Croatia covers 47% of land and 39% of marine territory of Croatia.

3.3.6.7. Regulation on Appropriate Assessment of plan, program and project of ecological network³²

Appropriate Assessment of plan, program and project which can have a significant impact on goals of preserving and integrity of the ecological network is obligatory.

3.3.6.8. Regulation of habitat types, habitat maps, endangered and rare habitat types and measures to maintain habitat³³

These regulations prescribe the types of habitat, form, content and the use of habitat map, endangered and rare habitat types, measures for the conservation of endangered and rare habitat types and keeping them in favorable conditions.

³¹ <http://narodne-novine.nn.hr/clanci/sluzbeni/329431.html>

³² http://narodne-novine.nn.hr/clanci/sluzbeni/2009_09_118_2915.html

³³ http://www.dzrp.hr/dokumenti_upload/20100311/dzrp201003111026000.pdf

3.3.6.9. Regulation of strictly protected and protected wildlife species³⁴

These regulations designate wild species as “strictly protected” and “protected” based on the Red list of threatened species of animals, plants and fungi of the Republic of Croatia, expert assessment of the State Institute for Nature Protection and obligations under international agreements.

3.3.6.10. Water Framework Directive³⁵

Further integration of protection and sustainable water management in other areas of community policy such as energy, transport, agriculture, fisheries, regional policy and tourism is necessary to be done. This directive should provide a basis for continued dialogue and strategy development for further integration of different policy areas.

The aim is sustainable water management and achievement of a good ecological status of all water within 15 years after the directive enters into force.

It is necessary to identify all the river basins, to conduct an analysis of the characteristics of water, to assess the impacts of human activities on water, to conduct an economic analysis of water use and to register areas which require special protection.

On the basis of an analysis, it is necessary to adopt a management plan and program of measures for each river basin.

Measures proposed by the river basin management plan should:

- prevent deterioration, enhance and restore the initial state of surface waters, reach a good chemical and ecological status of water and reduce pollution from wastewater discharges and emissions of hazardous substances,
- protect, enhance and restore the initial state of the groundwater, prevent pollution and deterioration of groundwater and ensure a balance between abstraction and recharge of groundwater,

³⁴ <http://narodne-novine.nn.hr/clanci/sluzbeni/125901.html>

³⁵ Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (<http://www.voda.hr/Default.aspx?sec=194>)

- preserve protected areas.

3.3.7. Impact on the environment

The role of small hydropower plants includes sudden interventions in a particular area (for example, in case of failure of other conventional energy resources which are responsible for that area). Considering the installed capacity of small hydropower plants, their relative impact on the environment is much greater than the impact caused by large hydropower plants.¹⁵

Each small hydropower plant is unique and, therefore, its effects vary depending on the ecosystem and location. Besides, a way of managing hydropower plants is very important to minimize the negative impacts.¹⁵ Any changes to the hydromorphological characteristics have an impact on the environment. How intense the effect is depends on the type of a plant, extent of other existing works and ability of the entire system to minimize the negative impacts.³⁶

Studies have shown that not all hydropower plants have the same impact on the environment. On the contrary, the size plays an important role in this regard. The size of impact depends on ecosystem, basin characteristics and how the plant is projected. One of the most critical impacts of small hydropower plants is on aquatic species.

Small hydropower plants do not affect only fish but also other species that live in rivers in terms of mortality, migration, changes in conditions and quality of their habitat.¹⁵ The consequences can sometimes be very negative for some disappearing species and others come because of morphological changes of the river basin and/or changes in composition of water due to thermal pollution, increased turbidity and nutrient exchange. In some cases, strong variations in flow can destroy fish eggs. Besides these problems, there is a problem of sedimentation of materials, for example, sand which affects the disappearance of plant and animal species. Figure 19 shows the changes and other impacts caused by construction of a small hydropower plant.

³⁶ http://www.esha.be/fileadmin/esha_files/documents/SHERPA/Environmental_Barometer_SHP.pdf

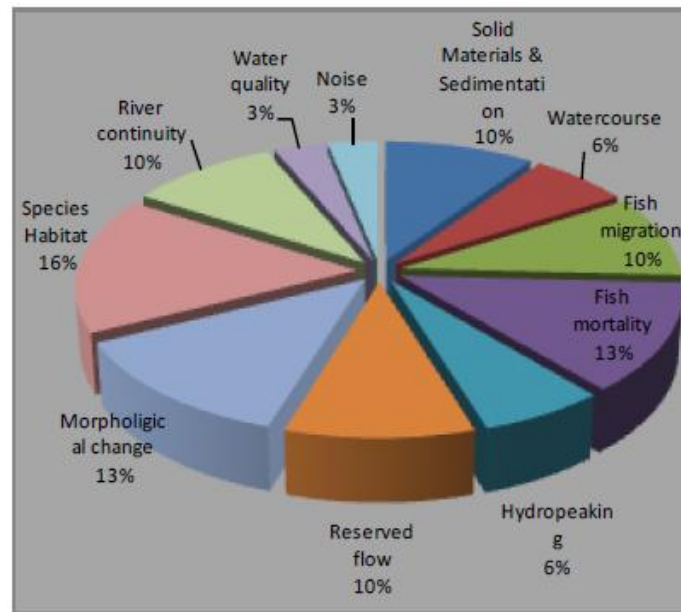


Figure 19: Identified hydropower impacts³⁶

The remainder of this paper is the analysis of adverse and favorable impact of small hydropower plants on the environment.

3.3.7.1. Adverse effects on the environment

The impact of a small hydropower plant is largely determined by location and applied technology of a small hydropower plant. Redirecting the watercourses from its natural riverbed is a major problem because it changes the river ecosystem and there is a great danger for the population due to the sudden change in flow. Adverse impact on fish populations may be of such magnitude that their aquatic habitat can completely be lost. Habitats are also being changed to such an extent that they become unsuitable for the life of certain plant and animal species.

3.3.7.2. Impact on the environment during construction

As shown in Table 8, realized projects enabled rough estimates of the impact of a small hydropower plant during the construction phase.

Activities during construction	Affected by activity	Impact manifested through	Importance (priority)
Geological research	Living world	Noise	Low
Vegetation cutting	Forestry	Habitat change	Medium
Earthworks	Geological changes	Soil stability	Low
Tunnel excavation	Hydrogeological changes	Changes of groundwater circulation	Low
Pit backfilling	Geological changes	Soil stability	Low
Embankment construction	Flora and fauna, hydrogeological changes	Changes of riverbed	Medium
Formation of permanent earth structure	Geological changes	Soil stability	Low
Temporary relocation of people, roads and electric lines	General public		Negligible
Implementation of roads	Living world, general public	Visual changes, disruption of habitat	Low
Establishment of a watercourse	Aquatic ecosystem	Habitat change	Medium
Temporary river diversion	Aquatic ecosystem	Habitat change	High
Use of excavators, trucks, helicopters and cars	Living world, general public	Noise	High
Human presence during works	Living world, general public	Noise	Low

Table 8: Impact assessment during the construction of a small hydropower plant

Construction of a small hydropower generally leads to throwing the material and dust waste into the water what can result in sedimentation and initial habitat loss. In addition, the equipment used in performing the work emits specific pollutants that can affect the living world.

Small hydropower plants generally do not have big accumulation reservoirs. Because of that, large-scale works during the dam construction are avoided as well as their impact on the environment. But in case that accumulation reservoirs are built, the impact on the environment caused by construction of a small hydropower plant is the same as the one caused by construction of a large hydropower plant. This impact is manifested through loss of land, construction of access roads, excavation works, mining and sometimes concrete construction.¹⁵ Physical and chemical conditions such as temperature, amount of oxygen, sediment accumulation, from upstream to downstream flow, etc. are also changing. Unlike large hydropower plants, which often adversely affect the geological and pedological characteristics of the land where they are constructed, the impact of small hydropower plants is quite smaller due to less accumulation.³⁶

The impact of input devices, open channel, pressure piping and sewer is manifested through noise which affects the habits of animals, danger of erosion caused by loss of vegetation during excavation works, turbidity of water, etc. In order to avoid these impacts, it is advisable to perform excavation works in the season of low water levels and faster return of excavated soil to its original position. In terms of preventing erosion, it is also advisable to restore vegetation on river banks with indigenous species that thrive best and best fit into natural environment. It is also necessary to consider the influence of workers and their needs and habits of life in uninhabited areas.

3.3.7.3. Impact on the environment during operation

Table 9 shows the impacts during operation of a small hydropower plant.

Activities during operating	Affected by activity	Impact manifested through	Importance (priority)
Production from renewable sources	General public	Emission reduction	High
Rearrangement of watercourse	Aquatic ecosystem	Habitat change	High
Permanent works in the riverbed	Aquatic ecosystem	Habitat change	High
Redirection of watercourse	Aquatic ecosystem	Habitat change	High
Pipeline	Living world	Visual changes	Medium
New electrical lines	Living world, general public	Visual changes	Low
	Aquatic ecosystem, general public	Habitat change, visual changes	Low
Embankments	Aquatic ecosystem, general public	Habitat change, visual changes	Low
Change on river flow	Fishes	Habitat change	High
	Plants	Habitat change	Medium
	General public	Change of recreational activities	
Noise due to electromechanical equipment	General public	Change in quality of life	Low
Removal of deposited material	Aquatic ecosystem, general public	Increase in water quality	High

Table 9: Impacts during operation of a small hydropower plant

3.3.7.4. Noise impact on the environment

Noise impact of a small hydropower plant on the environment and permissible level of noise depend on position of a small hydropower plant depends on proximity of residential or natural protected areas (Law against noise). Regulation on maximum permitted level of noise in an environment where people work and live prescribes noise emissions of 55 dB (day) and 40 dB (night) in the zone intended for housing and residence. The noise is caused by system for cleaning the protective grid, generators, multipliers, turbines and transformers. The noise is to the maximum extent caused by use of units and multipliers. The noise level can be reduced to 70 dB inside the engine room and almost to zero outside the engine room by using a modern technology. Applied measures so far in terms of reduction of noise level consist of:

- applying small tolerances in the production of multiplier,
- applying sound covers over turbines,
- applying water cooled generator instead of air cooled generator,
- careful construction of auxiliary systems,
- applying sound insulation in buildings (walls) such as glass wool and some other special materials which lead to reduction of noise level outside the engine room,
- delivery of turbine, multiplier and generator, etc. in a common housing which insulated from noise impact.³⁶

3.3.7.5. Visual impact on the environment

The problem of visual impact of small hydropower plants on the environment is expressed in two extreme cases:

1. at locations where small hydropower plants are now faced with the pristine nature (for example, in high mountain regions) and
2. in urban areas that affect the living environment of local population which is often very sensitive to changes in its environment.¹⁵

Each of the structures of a small hydropower plant (canal intake, sedimentation basins, engine room, pressure pipe, inlet, outlet, etc.) may cause a change in the landscape in terms of changes of form, line, color or material.



Figure 20: Visual impact on the environment of a small hydropower plant³⁷

Most of these structures, even the largest ones can be masked by use of appropriate methods for adjustment to the landscape and planting appropriate vegetation. By use of non-contrasting color and non-reflective material, a high degree of adjustment to the landscape can be achieved.

The best way to reduce the visual impact of the engine room is to bury it. This solution is expensive and often makes the whole project of a small hydropower plant unprofitable. The cheaper way is to use locally available materials such as stone, soil, vegetation, appropriate colors or landscape textures.

Pressure pipe is usually the biggest problem in the context of visual impact and obstacles in life of wild animals. Therefore, if we want to achieve integration into the existing landscape, the best way to do it is to bury a pipeline although this solution is more expensive and less favorable in terms of maintenance. For this reason, by applying modern methods and technologies, buried pressure pipelines were developed. They almost do not even require the maintenance for several decades. The great advantage of such pressure pipeline is that the original soil excavated for the burial of a pressure pipeline is returned back to its original

³⁷ <http://www.sswm.info/sites/default/files/toolbox/FAO%202010%20Overview.png>

position and does not create obstacles in life of wild animals. Canals may also pose a barrier to the free passage for animals. In order to avoid this, the canals are nowadays completely buried and sometimes revegetated so that they represent a minimal impact on the environment. If they are not buried or covered, it is advisable to build the support structures which allow animals to escape from these canals in case that they fall into them.¹⁵

Access to the building can sometimes have a significant impact on the environment, particularly in terms of visibility. This applies particularly to the construction of roads because even a very carefully constructed road represents landscape degradation.

Electrical lines that are used for connecting small hydropower plant to the network may also have a negative impact on the environment.

It can be concluded that the small hydropower plants can be in such way designed to be fully integrated into the landscape and to reduce visual pollution to the minimum.

3.3.7.6. Impact on the living world

The small hydropower plants with have accumulation basins have a special impact on plant and animal life. In such schemes, during lower demand for electricity, there is a problem for fish that live there since the downstream flow falls significantly. Large changes in flow regimes that vary from large flow to the extremely low can also seriously harm the living world. Therefore, a minimum amount of flow which should always be satisfied should be defined.

Accumulation may have an impact on the living world that lives in the upstream flow or accumulation. Accumulated water can get stratified so that the warmer water collects on the surface and colder water in the depth. In this way, the cold water is isolated from the air and causing the loss of oxygen. Such conditions prevent the life of certain fish species that inhabit in the depth.

Fish populations are highly susceptible to influences of environment in which they live, especially migratory fish populations which require a large diversity of habitats in its life cycle in order to meet their basic needs such as finding food or breeding. Construction of the dam jeopardizes the migration which is necessary for the survival of these fish species.

Therefore, during the construction of a small hydropower plant, it is also necessary to consider the construction of structure of the fish passes that would enable these migrations. When considering fish passes, it is necessary to distinguish between those passes which are adapted for fish which move downstream and those adapted for fish which move upstream. The amount of water needed to achieve the fish pass is dependent on the type and size of the system: the greater a system is, the greater amount of water is needed. Depending on the size of an average flow, a rough estimate gives results between 1% and 5% of an average flow which is needed for fish passes.³⁸

Although various technologies for construction of the fish passes have been developed so far, their price can have a significant impact on the overall costs of a small hydropower plant. Therefore, when building fish passes, it is necessary to find a certain solution that reduces costs. Price of a fish pass varies considerably ranging from 1% to 10% of the total costs of a small hydropower plant.

1. Fish passes which are adapted for fish which move upstream are made in a few basic types: fish ladders, lifts or pumps. The most frequently used form of fish runs consists of overflow pools with openings through which the water overflows. Pools are used to slow down the water. The most frequently used three basic types are:
 - slotted bulkheads through which fish and sediments can pass,
 - bulkheads with openings at the bottom which are large enough for passage of fish,
 - bulkheads with vertical slots and openings at the bottom.¹⁵

³⁸ Frequently Asked Questions on Small Hydropower, 2007 (<http://www.esha.be>)



Figure 21: A fish ladder³⁹



Figure 22: A fish lift⁴⁰



Figure 23: A fish pump⁴¹

³⁹ <http://chrisnbecky.com/pictures/ainsworthimages/FishLadder.jpg>

⁴⁰ <http://www.dnr.sc.gov/news/Yr2006/feb20/fishlift.jpg>

⁴¹ <http://www.nj.gov/dep/fgw/images/fishpump.jpg>

Bulkheads with openings at the bottom are applicable only to fish that swim along the bottom. Bulkheads with rectangular slits represent the oldest type. This type of fish runs is not adaptable to changes in water level. Fish runs have to be designed in such a way that they allow unobstructed passage of fish in all flow regimes. Very good results are achieved with bulkheads with vertical slots and openings at the bottom.

One of the most famous passes is the Denil fish pass, which consists of baffles as illustrated in Figure 22. These baffles dissipate the energy and provide a low-velocity flow through which the fish can easily ascend. This characteristic allows Denil fish pass to be used with a big slope up to 1:5. They also produce turbulences which are very attractive to fish species.¹⁵

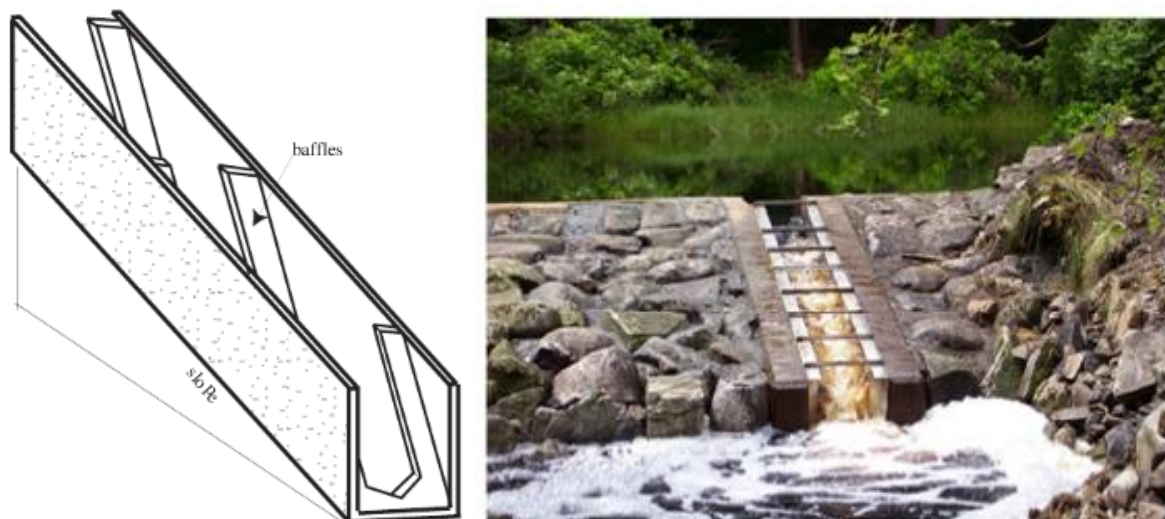


Figure 24: Samples of a Denil Fishpass¹⁵

Another example of a fish pass is the Borland Lock. It is a relatively cheap solution for transferring fish from the tailrace to the forebay. The fish climb a ladder to the bottom chamber. Then the bottom chamber gets closed and filled with the water from the top chamber. When it gets filled, the fish get close to the forebay level into which they can swim.

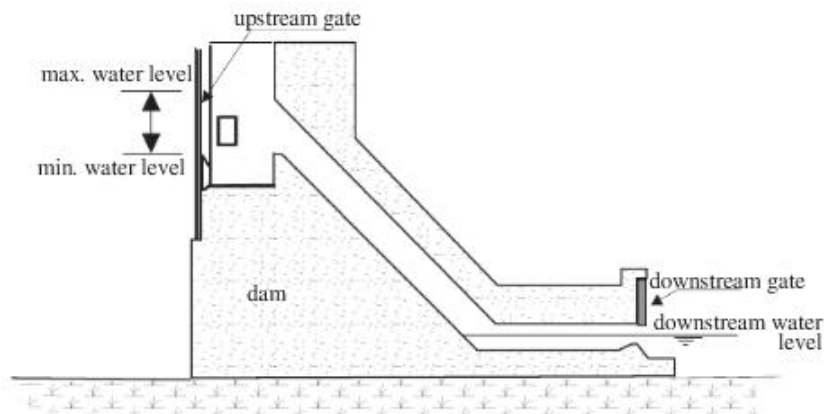


Figure 25: Section through Borland Lock¹⁵

2. In the past the fish passed through the turbine during their downstream migration. The mortality of fish at that time varied from a few percent to more than 40% depending on the design of turbine and more importantly on the peripheral speed of impeller. Due to structural characteristics, Francis turbines cause higher mortality than Kaplan turbines. Bulb turbines reduce mortality to less than 5%.¹⁵

Studies have shown that fish injuries occur due to the increase of pressure, rapid decrease in pressure, cavitation, strokes, kneading, cutting and turbulence.¹⁵ At the present time, a series of studies on the development of new types of turbines (for example, fish friendly turbines) is carried out. Their use should reduce fish injuries. Small hydropower plants use traditional wood or in recent times metal impellers and Archimedean screw. These turbines are robust and slow, do not require a protective grill and do not jeopardize fish.



Figure 26: Archimedean screw and impeller¹⁵

For fish protection, new innovative self-cleaning intake screens, which do not need power, have been developed. They are cleaned by the water that passes through. This screen is called Coanda screen and provides protection for the turbine. The water flows to the system through the screen slots. Fish and 90% of solid particles are not able to pass through these slots. The smooth screen provides a great passageway to a fish bypass. A disadvantage of this type of screen is that it loses about 1 – 1,20 m of height which can be uneconomic.

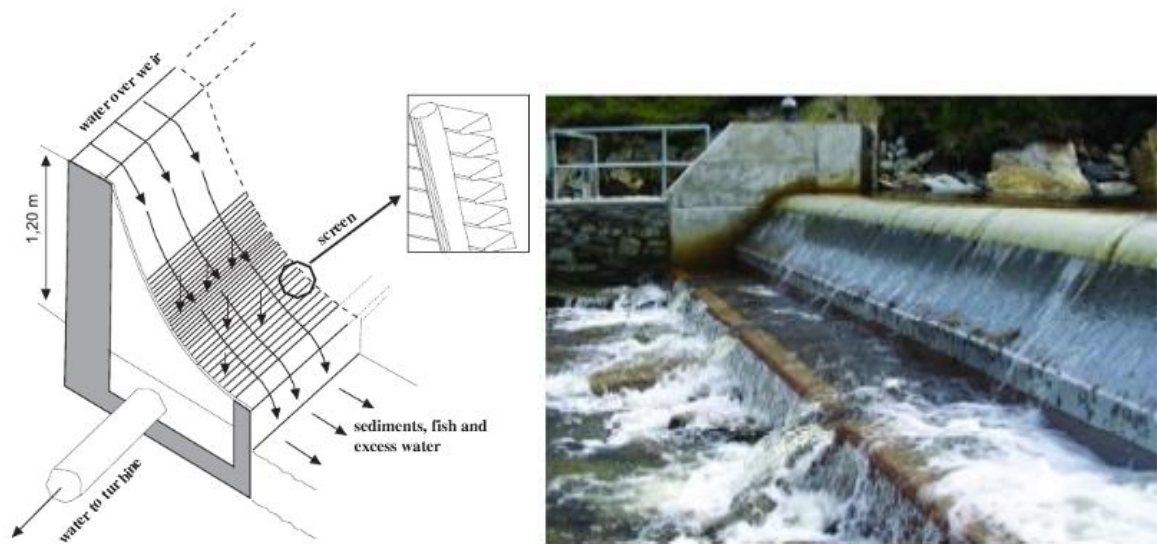


Figure 27: Coanda screens¹⁵

3.3.7.7. Positive impact on the environment

The main advantage of a small hydropower plant compared to conventional sources of electricity in the context of environmental impact is reflected in the fact that its work does not cause the emission of greenhouse gases in the atmosphere. The Republic of Croatia has ratified the Kyoto Protocol committed itself to reducing greenhouse gas emissions by 5% in the period from 2008 in comparison with the level of emissions from the base year. The aim of the European Union is to reduce emissions compared to the year 1990 by 20% or 30% if other countries accept certain obligations (especially China, India, and Brazil). It is necessary to reduce emissions of SO_2 and NO_x because the Republic of Croatia emits 4.82 g / kWh of SO_2 , 1.36 g / kWh of NO_x and 0.78 kg / kWh of CO_2 from thermal power plants. It is estimated that a small hydropower plant of 5 MW replaces through its work 1400 tons of fossil fuel yearly and reduces emissions of 16,000 tons of CO_2 and 1100 tons of SO_2 in

comparison with fossil fuel plants which produce the same amount of electricity per year. Unlike large hydropower plants, small hydropower plants often do not produce emissions. Small hydropower plants use small dams and the water that passes through the intake screen such as Coanda screen does not change its content. Emissions occur, of course, in the stage of material production and construction of a small hydropower plant.

A positive impact of a small hydropower plant on the environment should be emphasized in the watercourse regulation and flood protection. This is manifested through construction works including expansion of embankments on the river banks what results in a larger flow of a river that the river bed can accept. Another method of flood control is the construction of the storage pool (reservoirs) that allows receiving large amounts of water.¹⁵

4. Economic evaluation of wind power and small hydropower plant project

4.1. Revenue Analysis

Revenue consists of so-called direct revenue, which is generated through sales of electricity and indirect revenue. Indirect revenues are settled through positive impacts on other activities. Since the greatest return on investment is achieved through sales of electricity, it is very important for investors of small hydropower plants to know that the tariffs for sale of electricity are clearly defined, known and stable. According to the decision of the Governing Board of the Croatian electric power industry, the redemption price of electricity which is sold to the electric power system is determined for the production from small hydropower plants of capacity up to 500 kW at 75% of the average selling price, and small hydropower plants of capacity over 500 kW at 65% of the average selling price respectively.⁴²

Indirect revenues consist of the positive impact of small hydropower plants on the environment, flow regulation and flood control, irrigation, fish farms, camps, recreation centers, etc. Any revenue arising from above mentioned sources which is other than normal business activity (sale of electricity) is called indirect revenue.⁴³

Earnings from the reduction of greenhouse gas emissions are calculated according to the generated electric power and the total amount of CO₂ that a small hydropower plant saves. The amount of compensation for the reduction of emissions is 18 HRK (about 2,38 Euros) per ton of CO₂ with a growth rate of 20% during the duration of compensation. The duration of compensation is 35 years. The income is generated through the production of clear energy. The production cost is 0.34 HRK (about 0,05 Euros) per kWh of produced electricity.⁴⁴

⁴² Tomišić: Značaj i uloga malih hidroelektrana u elektroenergetskom sustavu, 2009

⁴³ Hosseini / Forouzbakhsh / Rahimpour: Determination of the optimal installation capacity of small hydropower plants through the use of technical, economic and reliability indices, 2004

⁴⁴ Narodne Novine (<http://narodne-novine.nn.hr/clanci/sluzbeni/298715.html>)

4.2. Investment profitability index

Decision on the implementation of certain energy efficiency measures is made on the basis of evaluation of its effectiveness. This chapter gives us the basics of economic evaluation of the project.

Economics basics of project

Economic parameters

Each profitability assessment requires the following input data:⁴⁵

- a) Investment I_0 [HRK]

The investment includes all project costs including project implementation procurement of equipment, installation of equipment, value added tax (VAT), other taxes, etc.

- b) Annual savings V [HRK/year]

Annual savings represent the total savings on an annual basis established by the project. They are easy to calculate.

$$V = W \times e$$

where,

W – annual energy savings [kWh],

e – energy price [HRK/kWh].

The equation should also include some other savings if they are applicable to a given project such as fee reduction for committed electrical power, reduction in the environmental fee, operating and maintenance cost reduction, etc.

- c) Time of effectuating

⁴⁵ FER: Ekonomija u energetici - Ocjena isplativosti investiranja u energetici, 2008/2009

The technical lifetime of some equipment includes the time period in which the technical equipment is functioning properly, while the economic lifetime is the period after which existing equipment should be changed. If the equipment is replaced due to obsolescence, technological progress, changes in standards and regulations, etc., economic life is shorter than the technical. The best example for it is computer - their technical lifetime is from 7 to 10 years, but their economic life is 3 years because after that they should be replaced by the ones with a newer technology. It should be noted that the economic lifetime of equipment is used in economic assumptions. This economic lifetime of the project is called as period of effectuating. During this period, an investment project generates profits and cash flows that can be treated as its contribution for increasing the present value of companies or investors.

d) Inflation rate i [%]

Inflation is defined as the average annual price increases of goods and services.

e) Discount rate k [%]

The discount rate is a measure of the time value of money and bringing future cash receipts to present value. The discount rate of a company is determined by using the company's cost of capital but in fact, it shows the interest rate at which the company (an investor) is willing to invest. We should distinguish between nominal and real discount rate. The real discount rate is a nominal rate adjusted according to inflation rate, relative price increases of energy and other possible relevant price increases. This is an extremely important parameter to assess the profitability of the project but at the same time, it is difficult to determine it accurately.

The price of energy is a very important parameter in energy efficiency projects because viability of the project depends on how big net annual savings are. As the energy price increases, the energy efficiency project becomes financially more attractive.

4.2.1. Time value of money

Money does not have the same value over time. An idea is that money is today not as much worth as it will be in the future. In this so - called time preference of money, we distinguish two processes; compounding and discounting.

Compounding refers to generating earnings from previous earnings.⁴⁶

$$V_t = V_0(1 + r)^t$$

Discounting is multiplying an amount by a discount rate to compute its present value.⁴⁷

$$V_0 = \frac{V_t}{(1 + r)^t}$$

4.3. Project profitability index

There are a number of methods used to assess the profitability of investments. In what follows, commonly used methods will be clarified. We distinguish static and dynamic methods.

4.3.1. Period of return

Payback period is the simplest criterion of making financial decisions on investments. It refers to the period of time required to recover the cost of an investment. The return period criterion can mathematically be written in the following way:

$$I_0 = \sum_{t=1}^{T_p} V_t$$

Investment costs represent an initial investment (building, hydromechanical and electrical engineering equipment) and net annual savings represent the amount of money realized from sales of electricity minus the annual costs. Changes in the value of money are not considered here. Those solutions which result in a shorter return period are considered better. In order to accept a project acceptable, the return period should be no longer than 7 years.⁴⁸

⁴⁶ <http://www.investopedia.com/terms/c/compounding.asp#ixzz1jZjPHgCC>

⁴⁷ <http://www.businessdictionary.com/definition/discounting.html#ixzz1jZm4khg6>

⁴⁸ Tomišić: Značaj i uloga malih hidroelektrana u elektroenergetskom sustavu, 2009

4.3.2. Payback period of investment

This method is used to determine the length of time that will be needed to recoup the initial amount of money invested on a project.

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Periodic Cash Flow}}$$

Quick estimates of net profits of a certain project can be made by use of this method. It can also provide a good basis for comparing several different alternatives. This method, like the previous one, ignores the changes in time value of money.⁴⁷

4.3.3. Discounted payback period

Discounted payback period is the return period which seeks to eliminate the lack of not taking into account of time value of money. This method calculates the time required to equalize the discounted cash flows with investment costs of the project.

In discounted payback period, we firstly need to calculate the present value of each cash inflow. In order to make it much easier to understand, we will use the following example with random numbers.

An initial investment of 40 000 000 HRK is expected to generate 10 000 000 HRK per year for 6 years. Management sets a discount rate of 11%.

In Step 1, we calculate discounted cash flow of each year by multiplying the actual cash flows by present value factor in order to get cumulative discounted cash flow.

Year n	Cash Flow (Kn) CF	Present Value Factor $1/(1+i)^n$	Discounted Cash Flow CF x PV	Cumulative Discounted Cash Flow
0	-40000000	1	-40000000	-40000000
1	10000000	0,900900901	9009009,009	-30990990,99
2	10000000	0,811622433	8116224,332	-22874766,66
3	10000000	0,731191381	7311913,813	-15562852,85
4	10000000	0,658730974	6587309,741	-8975543,104
5	10000000	0,593451328	5934513,281	-3041029,824
6	10000000	0,534640836	5346408,361	2305378,537

Step 2: Discounted Payback Period = $5 + | - 3\,041\,029,824 | / 5\,346\,408,361 \approx 5,56$ years.

We accept the project if discounted payback period is less than the target period. The criterion of financial decision making is, of course, possibly faster discounted payback period. However, this method contains a basic lack of payback period because it does not take into account the effects of projects after paying off the costs of investment.⁴⁷

4.3.4. Net present Value

As already said, the money does not have the same value at different points in time. It means that 1000 HRK, for example, will not have the same value in 2011 and in 2012 because of inflation. This property of money must be applied to evaluating energy efficiency projects. In order to summarize the discounted value of annual cash flows, it is necessary to define the reference year, which refers to all investments and savings. It is not important what year it will be as long as all cash flows refer to that year. Usually, a year, in which one project has been invested, is taken as a reference year. Net present value is the difference between the present value of future cash flows from an investment during the time of effectuating (from year 1 to year T) and costs of investment (in year 0). The profitability criterion is,

$$S > 0$$

In case that annual cash flows differ from each other every year ($C_1 \neq C_2 \neq C_3 \dots \neq C_T$), then the net profit value is

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \dots + \frac{C_T}{(1+r)^T}$$

It is usually assumed that the annual cash flows will be the same every year. In that case, the net profit value is expressed by following formula

$$NPV = -C_0 + C \frac{1-(1+r)^{-T}}{r}$$

Net present value is the fundamental criterion of financial decision making. Net present value of zero indicates that the project is able to return the invested capital. Projects with positive

net present value have higher profitability than those that are required in the market. The biggest difficulty in applying these methods is the choice of discount rate, which, depending on the rate of inflation, usually varies between 5% and 12%, what can significantly affect the net present value.⁴⁸ In recent times, there are certain studies which attempt to show that instead of using a constant discount rate for the entire planning period, it is more accurately to consider the falling discount rate during the planning time. In particular, this applies to long-term projects, whose time planning is longer than thirty years. Therefore, another fundamental method of financial decision making which is commonly used is internal rate of return.

4.3.5. Internal rate of return

Internal rate of return is certainly the most accurate indicator of profitability of one project. This indicator is also based on net profit value. The idea is to find the discount rate R which still makes the project profitable, as well as $C = 0$.⁴⁵

$$NPV = \sum_{n=0}^N \frac{C_n}{(1+r)^n} = 0$$

The internal rate of return is a rate of return often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero measures and compares the profitability of investments. Unlike criterion of net present value, where a predefined discount rate calculates the present value of future cash flows, in this method, the discount rate comes up as unknown. Internal rate of return is determined by an iterative procedure. Criteria for acceptance of the project will certainly be the highest internal rate of return. Each company will on the basis of its cost of capital determine the lower limit of acceptability. The greatest strength of this method is the possibility of comparison with other investment options.

4.3.6. Cash flow analysis

All previously mentioned indicators of project feasibility consider only the project itself. The annual economic impact of investing in a project depends on how the project is financed. Usually, an investor invests a portion of its funds and the rest will be financed through loans.

By taking into account the ways of financing the project, the cash flow analysis is being done. The cash flow analysis includes all cash revenues and expenditures associated with the project. In energy efficiency projects, cash income is cash savings based on reduced energy consumption and reduced maintenance costs while expenditures are investment in the form of equity, equity loans and accruing interest, operating costs, maintenance costs and, if applicable, taxes (such as income tax for companies). To put it simply, the basis of this analysis is the free cash flow which is equal to

$$\text{Free Cash Flow} = \text{Cash Flows from Operations} - \text{Capital Expenditure}^{45}$$

4.3.7. Life cycle cost analysis

When making decisions about investments in new equipment or systems, it is necessary to conduct an analysis of revenues and expenditures through the entire anticipated average life of the product (system). It means that besides the initial investment, it is necessary to take into account the costs of operation, maintenance, energy, environmental protection (emissions fees), decommissioning and waste disposal after the expiry of its working life. This economic method for project feasibility study that takes into account all the costs of the project throughout its lifetime is called the life cycle cost (LCC) analysis.⁴⁵ In fact, some simple methods such as simple payback period consider only how to return the initial investment quickly, not taking into account any other costs and benefits over the lifetime of the equipment (system) and neglecting the time value of money. The life cycle cost analysis is based on an analysis of cash flows and ranks the various options using indicators of profitability, primarily internal rate of return. It is necessary to apply the LCC analysis to energy efficiency projects because it assesses whether the increased initial investment costs can economically be justified by reduced energy costs through the considered lifetime of the system and other factors which affect the costs of the system (for example, reducing the emission fees, maintenance costs, etc.). Therefore, the LCC analysis is an economic technique for estimating the overall costs of ownership and use of a building or a system through the period of its use. The LCC analysis determines the present value of all future costs associated with an object or system.

These costs typically include:

- initial investment (plot, project, construction works, equipment),
- operating costs (energy and water costs),
- maintenance costs,
- equipment replacement costs (according to expected lifetime of equipment),
- decommissioning and waste disposal costs,
- other costs (various fees, taxes, etc.).

All costs should be brought to the present value of money (discounting), exactly as it was shown in the previous section. The LCC analysis should certainly be done in case that there are a few alternatives and it is needed to select economically most advantageous tender. The criterion will be, of course, the lowest LCC. It is particularly advisable to conduct the LCC analysis at the early stage of initial solution and project (for example, when projecting a new hydropower plant. Then, it is possible to select those options that will have minimum long-term costs because an option that has the least investment costs is not necessarily economically the most cost-effective option.

4.3.8. Benefit - Cost ratio

This method compares the present value of total benefits and costs based on their ratio.⁴⁹

$$R_{B/C} = \frac{\sum_0^n \frac{R_n}{(1+k)^n}}{\sum_0^n \frac{(I_n + M_n + O_n)}{(1+k)^n}}$$

where,

I_n – investments,

R_n – revenues,

⁴⁹ European Small Hydropower Association – ESHA: Guide on How to Develop a Small Hydropower Plant, 2004

On – operating costs,

Mn – maintenance costs,

k – discount rate,

n – number of periods for which the analysis is considered (year, quarter, etc.).

Previously displayed parameter is a degree of profitability. Projects with a ratio of less than 1 are unacceptable from an economic standpoint.

4.4. Economic analysis of the projects

4.4.1. Hydropower plant project

The following are entitled to be charged for electricity based on the tariff rates for tariff customers in the public service system:

- all customers in the residential category,
- other eligible customers⁵⁰

The price of electricity depends on types of customers and tariff models (low and high tariffs). In our case, we will take a standard low tariff for customers in the residential category. The guaranteed price is 0,69 HRK/kWh.

The total investment cost of the project is 36 400 000 HRK.⁵¹ We would like to calculate the net present value of an investment and break – even point in order to see when the profitability of an investment starts.

In the following table, we can see our investment cost as well as the current price of electricity, annual earnings and costs. Discount rate is supposed to be 10%.

⁵⁰ <http://www.hep.hr/ods/kupci/tarifni.aspx>

⁵¹ Dasović: Konkurentnost obnovljivih izvora energije nuklearnoj energiji u Hrvatskoj, 2009

Power	2000 kW
Initial cost	36 400 000 HRK
Annual Operating Time	5000 h
Price of Electricity	0,69 HRK/kWh
Annual Earnings	5000h/year * 2000 kWh * 0,69 HRK/kWh = 6 900 000 HRK
Annual Costs	355 000 HRK
Discount Rate	10%
Duration (Time)	15 years

According to the formula which is shown below, we are firstly going to calculate the Net Present Value of the project. Calculations were done by using Microsoft Excel.

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \dots + \frac{C_T}{(1+r)^T}$$

$-C_0 = \text{Initial Investment}$

$C = \text{Cash Flow}$

$r = \text{Discount Rate}$

$T = \text{Time}$

Or,

$$NPV = -C_0 + \sum_{i=1}^T \frac{C_i}{(1+r)^i}$$

Period	Initial Cost	Annual Earning	Annual Costs	Cash Flow	Discounting	Present Value	Net Present Value
0	-36400000						-36400000
1		6900000	355000	6545000	0,909090909	5950000	-30450000
2		6900000	355000	6545000	0,826446281	5409090,909	-25040909,09
3		6900000	355000	6545000	0,751314801	4917355,372	-20123553,72
4		6900000	355000	6545000	0,683013455	4470323,065	-15653230,65
5		6900000	355000	6545000	0,620921323	4063930,059	-11589300,59
6		6900000	355000	6545000	0,56447393	3694481,872	-7894818,722
7		6900000	355000	6545000	0,513158118	3358619,884	-4536198,838
8		6900000	355000	6545000	0,46650738	3053290,803	-1482908,035
9		6900000	355000	6545000	0,424097618	2775718,912	1292810,878
10		6900000	355000	6545000	0,385543289	2523380,829	3816191,707
11		6900000	355000	6545000	0,350493899	2293982,572	6110174,279
12		6900000	355000	6545000	0,318630818	2085438,702	8195612,981
13		6900000	355000	6545000	0,28966438	1895853,365	10091466,35
14		6900000	355000	6545000	0,263331254	1723503,059	11814969,41
15		6900000	355000	6545000	0,239392049	1566820,963	13381790,37
						49781790,37	

Table 10: Economic evaluation of a small hydropower plant of 2 MW power

We got the following values for present and net present value respectively:

Present Value	49781790,37
Net Present Value	13381790,37

The investment is profitable at discount rate of 10%. Using the data from the table, we got the net present value of 13381790,37 HRK. If we chose a higher discount rate, we would get a negative net present value. In that case, it would mean that the investment is not profitable. It means that if we choose a wrong discount rate, we may bring a wrong investment decision about our project.

The Net Present Value criterion is: "An investment is worth if it brings at least as much as it costs".

Using Break - Even Analysis, we want to know at which point expenses and revenue are equal and there is no net loss or gain respectively.

The following formula shows us how to calculate it:

$$\text{Break-Even} = \text{Period of } C_1 - \frac{C_1}{C_2 - C_1}$$

where,

C_1 – last negative net present value (- 1 482 908,035)

C_2 – first positive net present value (1 292 810,878)

Break Even	8,534242869
-------------------	--------------------

The result of the Break – Even Analysis is 8 years and 6 months. This means that we would achieve a positive Net Present Value in 9th year and the Break - Even should be obtained in this year. This actually says that the project is paid off in this point.

The following figure shows us how it looks graphically:

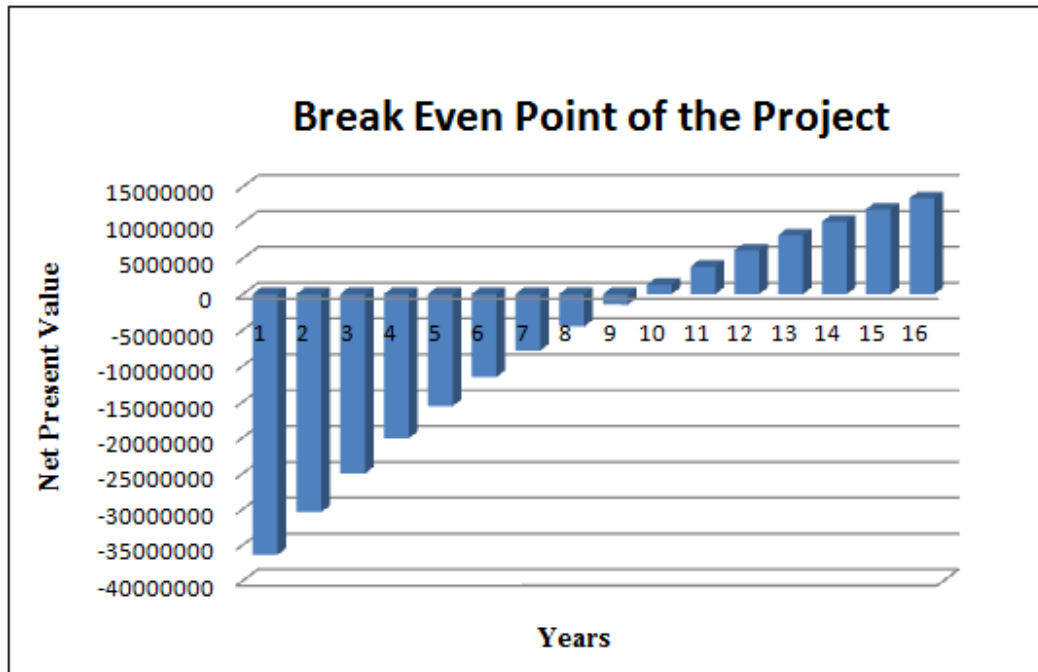


Figure 28: Break - Even Point of the Project

4.4.2. Wind power plant project

Software RETSCREEN is used for calculating the values of the model of 25 wind power plants, each with a 1 MW power. A model is based on the average values for different capacity factors and it is only a general indicator of the economic viability of 25 MW power.

This model can be taken as authoritative and can be used in the analysis of wind power plant projects, evaluating the energy production, life-cycle costs, and greenhouse gas emissions for different types of renewable energy technologies.

The aim of this model is to show how various factors influence the economic indicators of a wind power plant.⁵⁴

4.4.2.1. Technical parameters

The installed capacity of wind power plants which are currently being considered in Croatia varies. It depends on different factors such as size and configuration of the terrain, wind characteristics, type of the wind turbine, etc.

Most of the wind power plants projects in Croatia are supposed to have an installed power ranging from 20 to 200 MW. The present power that can be accepted by the Croatian electric power system is prescribed at 360 MW.⁵² Since the planned installed capacity is limited at 360 MW, this can cause a problem for potential investors.

The wind power plant considered in this model is supposed to have an installed power of 25 MW. It is an average value of registered projects on the list of the Transmission System Operator.⁵³

This model consists of several different capacity factors: 18%, 20%, 22%, 25%, 27% and 30%. It is important to mention that not only the production changes but also the maintenance costs.

The life time of the project is supposed to be 20 years. Although the incentive tariffs are paid for only first 12 years, experiences from other foreign countries say that a 20 year life-time assumption is realistic.⁵⁴

4.4.2.2. Economic parameters

The electric purchase price to be 0,64 HRK/kWh. The total investment in a wind power plant depends on the terrain, length and price of construction work, type of a wind turbine, etc. A rough estimate in Croatia and Europe says that 1 MW of installed power costs 10 000 000 HRK.

⁵² Hrvatska elektroprivreda: Kriterij za određivanje kandidata za dobivanje prethodne elektroenergetske suglasnosti za priključke vjetroelektrana na prijenosnu i distribucijsku mrežu, 2007

⁵³ Hrvatska elektroprivreda: Lista kandidata za dobivanje PEES za priključak vjetroelektrana na elektroenergetsku mrežu, 2007

⁵⁴ Ognjan / Stanić / Tomšić: Isplativost poticajne otkupne cijene za projekte vjetroelektrana u Republici Hrvatskoj, 2008

The price of a 2 MW wind turbine including transport and installation varies from 14 600 000 to 18 250 000 HRK. It means that the price of 1 MW of installed power vary from 7 to 9 million HRK. Since the wind turbine is the most expensive part of a wind power plant, the assumption that the total investment cost would be 10 000 000 HRK is realistic.⁵⁴

Maintenance costs on the terms and conditions of contract with the manufacturer and several other factors. Some manufacturers charge the maintenance of a wind power plant on an annual basis, some of them include it in the initial price or it can be also left to the investor.

Experiences from other European countries say that the maintenance costs are supposed to be 25% of total annual income.⁵⁵

In 2007, the Regulation on unit compensations, corrective coefficients and approximate criteria and measures for determining the amount of compensation for carbon dioxide emissions was adopted.⁵⁶

- in 2007, 11 HRK/t CO₂,
- in 2008, 14 HRK/t CO₂,
- in 2009, 18 HRK/t CO₂.

Since the model does not allow entering the amount of compensation for every year, the amount of 11 HRK/t CO₂ and the growth rate of 20 % are taken.⁵⁴

4.4.2.3. Financial parameters

The project will be financed by 20% of own capital and 80% loan from a commercial bank. The interest rate is 7% and a loan period is 12 years.

The profit tax is 20%. In case that the project is located in the Area of Special State Concern, there is a possibility of a lower profit tax.

⁵⁵ DEWI Seminar: Wind Energy Project Development, Cost structure of wind farm projects, 2007

⁵⁶ Narodne novine: Uredba o jediničnim naknadama, korektivnim koeficijentima i pobližim kriterijima i mjerilima za utvrđivanje naknade na emisiju u okoliš ugljikovog dioksida, 2007

Since the equipment of a wind power plant (wind turbine, transformers, etc) presents 90% of total cost, the total investment will be depreciated over a period of 15 years. A 3% inflation and a 7% discount rate are taken into account.⁵⁴

In order to have a better view of all parameters, we will create a tabular form.

<i>Technical parameters</i>	
Installed power	25 MW
Capacity factor	18%, 20%, 22%, 25%, 27%, 30%
Life time of the project	20 years
<i>Economic parameters</i>	
Purchase price of electricity	0,64 HRK/kWh
Annual growth of incentive price	3%
Compensation for reduced CO ₂	11 HRK/t CO ₂
Compensation period	20 years
Annual compensation growth rate	20 years
<i>Economic parameters – investment and maintenance</i>	
Total investment	10 000 000 HRK/MW
Maintenance	25% of total annual income
<i>Financial parameters</i>	
Debt share	80%
Loan period	12 years
Interest rate	7%
Inflation	3%
Profit rate	20%
Depreciation base	90% of total investment
Depreciation period	15 years
Discount rate	7%

Table 11: Summary of all parameters for calculation commercial feasibility of 25 MW wind farms

4.4.2.4. Results of modeling

Parameter / capacity factor	18%	20%	22%	25%	27%	30%
Total annual production (MWh)	39 420	43 800	48 180	54 750	59 130	65 700
Total investment	250 000 000	250 000 000	250 000 000	250 000 000	250 000 000	250 000 000
Annual costs – total	31 526 191	32 231 278	32 936 366	33 993 998	34 699 086	35 756 718
Operation and maintenance	6 345 793	7 050 880	7 755 968	8 813 600	9 518 688	10 576 320
Load repayment	25 180 398	25 180 398	25 180 398	25 180 398	25 180 398	25 180 398
Annual income – total	25 383 169	28 203 521	31 023 873	35 254 401	38 074 753	42 305 281
Earnings from the sale of electricity	25 228 800	28 032 000	30 835 200	35 040 000	37 843 200	42 048 000
Earnings from CO ₂ emission compensations	154 369	171 521	188 673	214 401	231 553	257 281
Financial viability						
After – tax IRR – capital	0,76%	3,82%	6,94%	11,72%	14,89%	19,65%
Simple return (year)	13,1	11,8	10,7	9,5	8,8	7,9
Net present value	-42 799 078	-21 361 502	-364 989	30 152 227	49 710 997	78 359 759
Benefit – cost ration	0,14	0,57	0,99	1,60	1,99	2,57
Debt coverage	0,78	0,87	0,95	1,08	1,17	1,30

Table 12: Economic evaluation of 25 wind power plants, each with 1 MW power⁵⁴

After a detailed review of technical, economic and financial parameters, we got the results of modeling that show the financial viability of the project at 6 capacity factors: 18%, 20%, 22%, 25%, 27% and 30%.

From the presented results, we can see that the wind power plant becomes profitable at a capacity factor slightly above 22%. It is important to mention that this level actually just covers the cost. The real profitability starts at a capacity level of 25% (or 2190 operating hours per year). The easiest way to see it is to check the net present value at a capacity of 25% which becomes positive at that level. Another important parameter is internal rate of return that must be higher than the loan interest rate. We can also say that the tariff of 0,64 HRK/kWh for a wind power plant is favorable if we apply it to the project operating at a capacity level slightly above 22% (more than 1930 operating hours per year). The analysis has also shown that the price of 0,64 HRK/kWh is favorable for wind power farms which have investment cost of 10 000 000 HRK/MW and operate at capacity factor above 22%.

Another indicator of profitability is a debt coverage ratio. At a level of 25%, it shows a debt coverage ratio of more than 1 (1,08). It means that here is enough revenue to cover annual debt payments. In case of level of 22%, there is only enough net operating income to cover 95% of annual debt payments.

4.4.3. Discussion about the economic effects of hydropower, wind power and nuclear plants

4.4.3.1. Total cost of nuclear, small hydropower and wind power plants over its life time

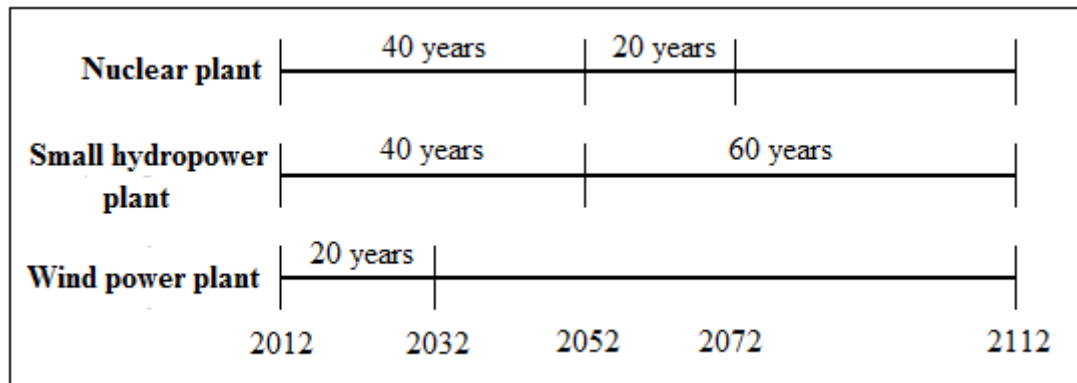


Figure 29: Comparison of the life time of nuclear, small hydropower and wind power plants

Figure 29 shows the comparison of the life time of a nuclear, small hydropower and wind power plant. The aim of this part of the work is to compare different energy sources of installed power of 1000 MW and to give possible solutions to energy problems in Croatia.

One solution is to build a nuclear power plant of a 1000 MW installed power and the other solution is to build hydropower and wind power plants of the same installed power.

In order to be able to compare these two solutions with respect to the given criteria, we will make a schema that optimistically estimates that one nuclear plant of a 1000 MW installed power or 39 wind power plants and 25 small hydropower plants of the same installed power can be built in a period of 15 years.⁵¹

The life time of a nuclear plant is approximately 40 years but most of them get the extension of life time for 20 years. So we take 60 years for the life time of a nuclear plant. The life time of a small hydropower plant is supposed to be 40 years but the real facts say that it is nearly 100 years, with periodic replacement of obsolete parts. As shown in the diagram above, the life time of a wind power plant is 20 years, although it does not necessarily have to be true

since most of the wind power plants will not be decommissioned after the end of their life time but failing parts will be replaced by the new ones.

In what follows, we calculate the total cost of a nuclear plant and compare them to the total cost of a small hydropower and wind power plant. Firstly, we calculate the total cost of a wind power plant of a 25 MW installed power for the life time of 20 years. From the Table 12, we can see that,

Total investment cost: $250 \cdot 10^6$ HRK

Annual operation and maintenance cost: $10,576 \cdot 10^6$ HRK/year

The life time of a wind power plant is 20 years. It means that the total operation and maintenance costs are:

Total operation and maintenance cost: $10,576 \cdot 10^6 \cdot 20 = 211,52 \cdot 10^6$ HRK

Since failing parts will be replaced by the new ones, we are not expecting decommissioning costs after 20 years. So, total costs during a 20 - year life time of a wind power plant is:

Total cost (period of 20 years): Total investment cost + Total operation and maintenance cost

Total cost (period of 20 years): $250 \cdot 10^6 + 211,52 \cdot 10^6 = 271,52 \cdot 10^6$ HRK

For the power of 975 MW, we need 39 wind farm locations of a 25 MW installed power. Comparing to a 60 - year life time of a nuclear plant, the life time of a wind power plant is 20 years. It means that the wind power plants should be built 3 times and have 3 times greater costs than their total cost over the life time of 20 years. That is of course not true, since only worn parts will be replaced after the end of its life time and not the whole project will be built 3 times. Due to lack of information about the replacement cost of worn parts, we will calculate it as follows:

Total cost (period of 60 years): Total cost (period of 20 years) · number of locations · 3

Total cost (period of 60 years): $271,52 \cdot 10^6 \cdot 39 \cdot 3 = \underline{\underline{31\,767,84 \cdot 10^6 \text{ HRK}}}$

Since the estimated life time of a small hydropower plan is 100 years and the total cost is multiplied only by the number of locations, here we have a much simpler way to calculate the total cost.

The investment and O&M cost over the life time of a small hydropower plant is:

Total cost: Installed power · costs (HRK/kWh)

Total cost: 1000 kWh · 18 200 HRK = $18,2 \cdot 10^6$ HRK

Since 25 small hydropower plants are planned to be build until 2025, the total cost over its life time is calculated as follows:

Total cost (of 25 small hydropower plants): Total cost · 25

Total cost (of 25 small hydropower plants): $18,2 \cdot 10^6 \cdot 25 = \underline{\underline{455 \cdot 10^6 \text{ HRK}}}$

So, total costs of wind power and small hydropower plants of a 1000 MW installed power over the life time of 60 years are:

Total cost (wind power and hydropower plants): $455 \cdot 10^6 + 31\,767,84 \cdot 10^6 = \underline{\underline{32\,222,84 \cdot 10^6 \text{ HRK}}}$

From the following table, we can see the total cost of a nuclear plant over the life time of 60 years:⁵¹

Construction costs	$36,14 \cdot 10^9$ HRK
Maintenance costs	$45,53 \cdot 10^9$ HRK
Recovering costs	$0,72 \cdot 10^9$ HRK
Fuel costs	$1,52 \cdot 10^9$ HRK
Waste disposal costs	$38,92 \cdot 10^9$ HRK
Decommissioning costs	$61,16 \cdot 10^9$ HRK
Total costs over the life time of 60 years	<u>$184 \cdot 10^9$ HRK</u>

Table 13: Total costs of a nuclear plant over the life time of 60 years

Following table shows the total cost of nuclear, small hydropower and wind power plants over the life time of 60 years:

Nuclear plant	$184 \cdot 10^9$ HRK
Small hydropower plant	$0,5 \cdot 10^9$ HRK
Wind power plant	$31,8 \cdot 10^9$ HRK
Small hydropower plant + Wind power plant	$32,3 \cdot 10^9$ HRK

Table 14: Total cost of nuclear, small hydropower and wind power plants over the life time of 60 years

The following figure shows it graphically:

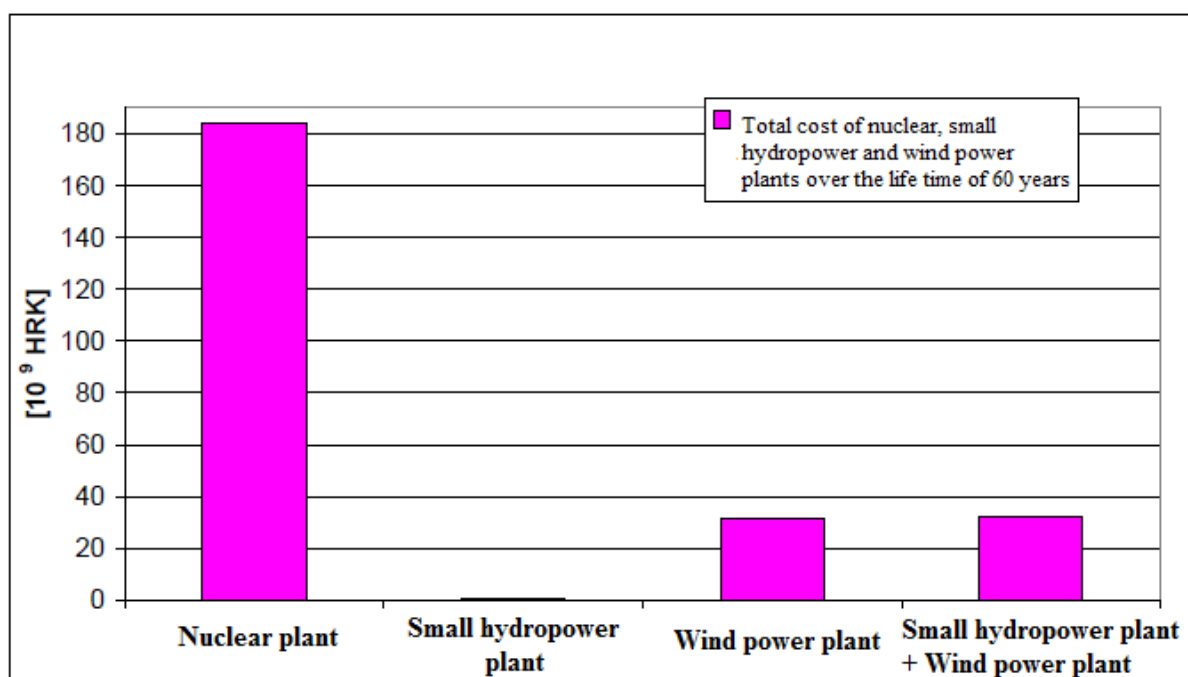


Figure 30: Total cost of nuclear, small hydropower and wind power plants over the life time of 60 years

Based on obtained results, we can conclude that the total cost of a nuclear plant over the period of 60 years is 6 times higher than the total cost of small hydropower and wind power plants as a result of high maintenance, waste disposal and decommissioning costs.

4.4.3.2. Total annual cost of nuclear, small hydropower and wind power plants

As we already discussed in the previous chapter, we need 39 wind farm locations of 25 MW and 25 hydropower plant locations of 1 MW in order to get an installed power of 1000 MW. We calculate the total annual cost as follows:

Total annual cost a small hydropower plant: $0,14 \cdot 10^6$ HRK/year⁵¹

In order to get the total annual cost of 25 small hydropower plants, we multiply it by 25.

Total annual cost (of 25 small hydropower plants): $25 \cdot 0,14 \cdot 10^6 = \underline{\underline{3,5 \cdot 10^6 \text{ HRK/year}}}$

We apply the same procedure to the wind power plants of 25 MW. We need 39 wind farm locations of 25 MW in order to get the total installed power of small hydropower and wind power plants of 1000 MW.

Total annual cost a wind power plant: $10,576 \cdot 10^6$ HRK/year⁵¹.

In order to get the total annual cost for 39 locations, we multiply it by 39.

Total annual cost (for 39 locations): $39 \cdot 10,576 \cdot 10^6 = \underline{\underline{412,464 \cdot 10^6 \text{ HRK/year}}}$

The following table shows the total annual cost of a nuclear plant:⁵¹

Construction costs	$602 \cdot 10^6$ HRK/year
Maintenance costs	$758,9 \cdot 10^6$ HRK/year
Fuel costs	$25,4 \cdot 10^6$ HRK/year
<i>Total annual costs of a nuclear plant</i>	<u>$1387 \cdot 10^6$ HRK/year</u>

Table 15: Total annual cost of a nuclear plant

The following table shows the total annual cost of nuclear, small hydropower and wind power plants:

Nuclear plant	$1,387 \cdot 10^9$ HRK/year
Small hydropower plant	$0,0035 \cdot 10^9$ HRK/year
Wind power plant	$0,412 \cdot 10^9$ HRK/year
Small hydropower plant + Wind power plant	$0,4155 \cdot 10^9$ HRK/year

Table 16: Total annual cost of nuclear, small hydropower and wind power plants

The following figure shows it graphically:

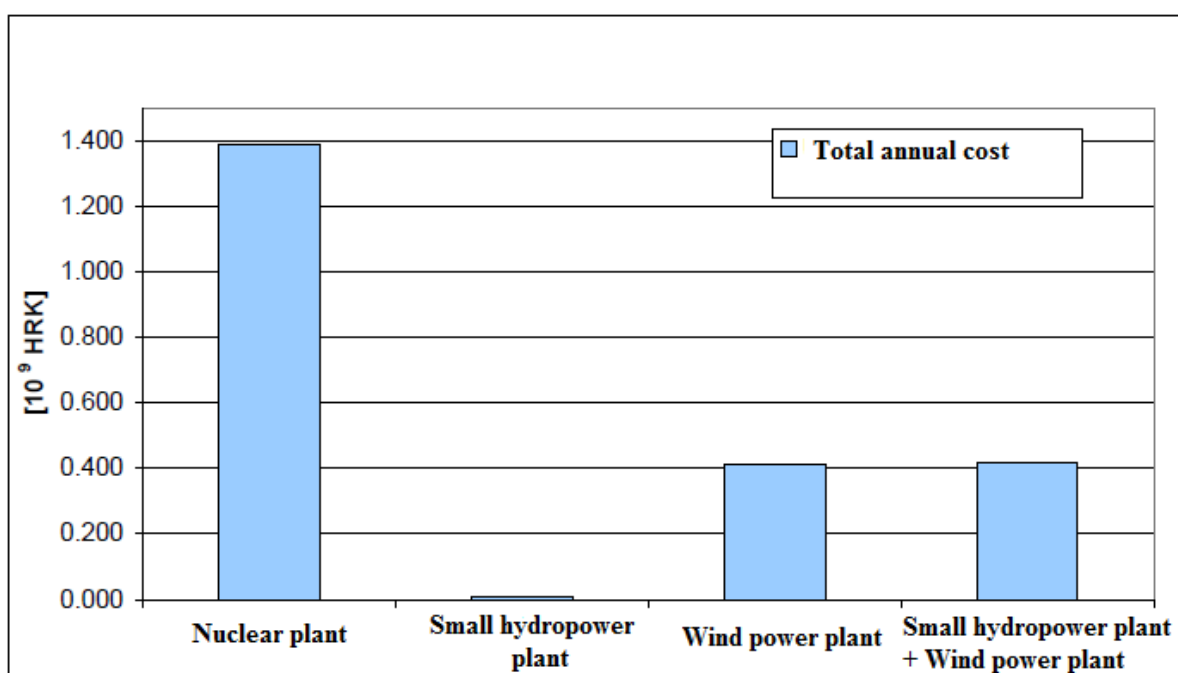


Figure 31: Total annual cost of nuclear, small hydropower and wind power plants

According to criteria of total annual cost, we see that the total cost of a nuclear plant is 3,5 times higher than the total cost of small hydropower and wind power plants.

4.4.3.3. Production cost

The following table shows the production cost of 1 kWh of electricity:

Nuclear plant	0,23 HRK/kWh	1
Nuclear plant	0,34 HRK/kWh	2
Small hydropower plant	0,036 HRK/kWh	
Wind power plant	0,161 HRK/kWh	

Table 17: Production cost of 1 kWh of electricity⁵¹

Numbers 1 and 2 represent two different ways of getting production cost of 1 kWh of electricity.

- 1 – an average production cost that does not include decommissioning costs, annual waste disposal costs and loan interest.
- 2 - an average production cost that includes annual waste disposal costs but not loan interest.

In the table above, we can see that the production cost of electricity obtained from a small hydropower plant is 6 times lower and the production cost of electricity obtained from a wind power plant is 2 times lower than both production costs of electricity obtained from a nuclear plant. According to this criterion, renewable water and wind resources are very competitive with nuclear energy.

4.4.3.4. Net profit

The following table shows the energy net profit:

Nuclear plant	$2222 \cdot 10^6$ HRK	1
Nuclear plant	$1564 \cdot 10^6$ HRK	2
Small hydropower plant	$64,75 \cdot 10^6$ HRK	
Wind power plant	$1227,4 \cdot 10^6$ HRK	
Small hydropower plant + Wind power plant	$1292,15 \cdot 10^6$ HRK	

Table 18: Energy net profit⁵¹

We calculate the energy net profit of nuclear, small hydropower and wind power plants as follows:

Nuclear plant:

Gross profit: relevant market price \cdot total annual production

Gross profit: $0,6 \cdot 6000 \cdot 10^6 = 3600 \cdot 10^6$ HRK/kWh

Net profit: Gross profit – annual cost

Net profit (1): $3600 \cdot 10^6 - 1378 \cdot 10^6 = \underline{\underline{2222 \cdot 10^6 \text{ HRK/kWh}}}$

Net profit (2): $3600 \cdot 10^6 - 2035,7 \cdot 10^6 = \underline{\underline{1564,3 \cdot 10^6 \text{ HRK/kWh}}}$

Small hydropower plants:

Gross profit: relevant market price \cdot total annual production

Gross profit (of 1 MW): $0,69 \cdot 3956,5 \cdot 10^3 = 2730 \cdot 10^3$ HRK/kWh

Net profit: Gross profit – annual cost

Net profit (of 1 MW): $2730 \cdot 10^3 - 140 \cdot 10^3 = 2590 \cdot 10^3$ HRK/kWh

Net profit (of 25 small hydropower plants): $2590 \cdot 10^3 \cdot 25 = \underline{\underline{64750 \cdot 10^3 \text{ HRK/kWh}}}$

Wind power plants:

Net profit: Gross profit – annual cost

Net profit (of 25 MW): $42,048 \cdot 10^6 - 10,576 \cdot 10^6 = 31,472 \cdot 10^6 \text{ HRK/kWh}$

Net profit (for 39 locations): $31,472 \cdot 10^6 \cdot 39 = \underline{\underline{1227,48 \cdot 10^6}}$

4.4.3.5. Discussion

From the table above, we see that, despite much lower production and annual costs, net profit obtained from small hydropower and wind power plants of total capacity of 1000 MW is lower than the net profit obtained from a nuclear plant of the same installed power. The only reason for it is that the nuclear plant has a larger number of working hours what results in a greater electricity production.

But despite lower production, net profit of renewable energy sources (in this case, hydropower and wind power plants) is not much lower than the net profit of a nuclear plant, especially if we consider the net profit marked with the number 2, which includes annual waste disposal costs.

In this paper, disposal costs are based on estimates from the literature because the actual annual waste disposal costs are not available.

On the other hand, if we consider and compare other aspects such as CO₂ emissions, waste, impact on the environment and people, we can see that a nuclear plant is a significantly greater causer of potential adverse effects on human health and environment.

According to all obtained results and data, we can conclude that solution to the energy problem in Croatia is primarily renewable energy sources from water and wind.

5. Conclusion

In this paper, two different projects of renewable energy sources were presented: on the one side, we had a wind power plant project, which is a very complex and expensive project that requires many years for its implementation, and on the other side, a hydropower plant project which is a quite reliable project.

After fossil fuel energy, hydroelectric energy still represents the second most significant source for generating electricity in Croatia. Anyway, the need for wind energy in comparison with a hydroelectric energy is more than doubled in last few years.

The construction of a wind power plant project requires many years, from the seeking of location to production. The main difference between Croatia and countries of European Union is evident in the administrative risks. Since Croatia should join the European Union in 2012, these risks should be reduced. There are lots of benefits for using wind energy in Croatia. Wind energy is a renewable power source. It is infinite and can not be used up, unlike fossil fuels, which have finite supplies. It is environmentally friendly and emits no greenhouse gas emissions or polluting particles.

On the basis of conducted risk analysis and economic evaluation of both projects, we can conclude that not only hydropower plants projects, but also wind power plant projects in Croatia are cost effective. Taking into account that the wind measurements have been calculated correctly, we can say that it is a relatively safe investment that is returned after 12 to 15 years. In Croatia, wind energy represents an energy source, which offers great potential for diversification of production, security of supply and domestic production. It also plays an important role in economic growth and development of domestic industry.

6. Literature

6.1. Books

- **Bernasconi, J.** (2004): Risk Tutorial, ABB Review (ABB Switzerland Ltd., Corporate Research)
- **Blanco, Maria Isabel** (2009): Renewable and Sustainable Energy Reviews, No. 13, Department of Economics, University of Alcala, Madrid, Spain, pp. 1372 – 1382.
- **Car, S.** (2009): Obnovljivi izvori energije, Tehnologije i razvoj gospodarstva, Hrvatski IEEE Odjel za Elektrotehniku, FER Zagreb
- **Cooper, D. F. / Grey, S. / Raymond, G. / Walker, P.** (2005): Project Risk Management Guidelines Managing Risk in Large Projects and Complex Procurements, John Wiley & Sons Ltd.
- **Dasović Jelena** (2009): Konkurentnost obnovljivih izvora energije nuklearnoj energiji u Hrvatskoj, Građevinski fakultet, Sveučilište u Zagrebu
- **DEWI Seminar** (2007): Wind Energy Project Development, Cost structure of wind farm projects, Mostar, Bosnia and Herzegovina
- **Elektrotehnički fakultet Osijek:** Male hidroelektrane, (http://www.etfos.hr/upload/OBAVIJESTI/obavijesti_dodiplomski/2243.DIE_MHE.pdf), 18. 04. 2012
- **Energetski Institut Hrvoje Požar** (2002): Strategija energetskeg razvitka, u okviru projekta Strategija razvitka Republike Hrvatske – Hrvatska u 21 stoljeću
- **Energetski Institut Hrvoje Požar:** Male hidroelektrane, (http://www.eihp.hr/hrvatski/projekti/see_ener-supply/pdf/5_Mahe.pdf), 03.05.2012
- **Exergia – IHGF** (2009): Prethodna procjena uticaja na okoliš za projekat izgradnje vjetroelektrane Msihovina
- **European Small Hydropower Association – ESHA** (2004): Guide on How to Develop a Small Hydropower Plant
- **FER** (2008/2009): Ekonomija u energetici - Ocjena isplativosti investiranja u energetici
- **Franjić, K.** (1997): Analiza isplativosti izgradnje malih hidroelektrana u Hrvatskoj
- **Frequently Asked Questions on Small Hydropower** (2007): (<http://www.esha.be>), 04.05.2012

- **Hosseini S. M. H. / Forouzbakhsh, F. / Rahimpour, M** (2004): Determination of the optimal installation capacity of small hydro-power plants through the use of technical, economic and reliability indices
- **Howatson, A. / Churchill, J. L.** (2006) : International Experience With Implementing Wind Energy, The Conference Board of Canada
- **Hrvatska elektroprivreda** (2007): Kriterij za određivanje kandidata za dobivanje prethodne elektroenergetske suglasnosti za priključke vjetroelektrana na prijenosnu i distribucijsku mrežu, (<http://www.hep.hr/ops>), 22.09.2012
- **Hrvatska elektroprivreda** (2007): Lista kandidata za dobivanje PEES za priključak vjetroelektrana na elektroenergetsku mrežu, 2007 (<http://www.hep.hr/ops>), 22.09.2012
- **Hrvatske vode:** Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (<http://www.voda.hr/Default.aspx?sec=194>), 07.05.2012
- **Lipovača, N.** (1995): Analiza mogućnosti priključaka hidroelektrane na srednjenaponsku mrežu
- **Marrison, C.** (2002): The Fundamentals of Risk Management, New York, McGraw Hill
- **Marsh / McLennan Companies** (2004): Scoping Study Financial Risk Management Instruments for Renewable Energy Projects; Sustainable Energy Finance Initiative (SEFI) United Nations Environment Programme
- **Micro - Hydropower Systems** (2004): A Buyer's Guide
- **Mužinić, Filip / Škrlec, Davor** (2007): Modeliranje projektnih rizika u razvoju projekta vjetroelektrane (Modeling project risks in the development of a wind power plant project), Vol. 56, No. 4, pp. 490 – 517.
- **Narodne novine** (73/2007): Uredba o jediničnim naknadama, korektivnim koeficijentima i pobližim kriterijima i mjerilima za utvrđivanje naknade na emisiju u okoliš ugljikovog dioksida, (<http://www.nn.hr>), 23.09.2012
- **Ognjan / Stanić / Tomšić** (2008): Isplativost poticajne otkupne cijene za projekte vjetroelektrana u Republici Hrvatskoj (Profitability of incentive purchase prices for wind farm projects in Croatia), Energija, Vol. 57, No. 2, pp. 178 – 199.
- **Skytte, K. / Meiborn, P. / Uytterlinde, M. A. / Lescot, D. Hoffmann, T. / Del Rio, P.** (2003): Challenges for Investment in Renewable Electricity in the European Union, Background report in the ADMIRE REBUS project

- **Škrlec, Davor / Mužinić, Filip / Maderčić, Miroslav** (2007): Modeliranje rizika u projektima vjetroelektrana, pp. 1 – 10.
- **Tomišić, I.** (2009): Značaj i uloga malih hidroelektrana u elektroenergetskom sustavu
- **Uran, V.** (2005): Isplativost ulaganja vlastitog kapitala u projekt za zajedničku proizvodnju toplinske i električne energije, *Energija*, Vol. 54, No. 3.
- **Vlada Republike Hrvatske** (2004): Uredba o uređenju i zaštiti zaštićenog obalnog područja mora
- **Žiković, S.** (2005): Formiranje optimalnog portfelja hrvatskih dionica i mjerenje tržišnog rizika primjenom VaR metode

6.2. Internet Sources

- <http://chrisnbecky.com/pictures/ainsworthimages/FishLadder.jpg>, 11.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/125901.html>, 17.03.2012
- http://narodne-novine.nn.hr/clanci/sluzbeni/2009_03_30_658.html, 17.03.2012
- http://narodne-novine.nn.hr/clanci/sluzbeni/2009_09_118_2915.html, 17.03.2012
- http://narodne-novine.nn.hr/clanci/sluzbeni/2009_10_130_3192.html, 17.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/288893.html>, 18.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/298715.html>, 18.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/308683.html>, 21.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/329431.html>, 23.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/329475.html>, 31.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/339664.html>, 31.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/339665.html>, 31.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/340787.html>, 31.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/378092.html>, 31.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/358123.htm>, 31.03.2012
- <http://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/358127.htm>, 31.03.2012
- <http://www.businessdictionary.com/definition/discounting.html#ixzz1jZm4khg6>, 18.05.2012
- <http://www.dnr.sc.gov/news/Yr2006/feb20/fishlift.jpg>, 06.05.2012
- http://www.dzrp.hr/dokumenti_upload/20100311/dzrp201003111026000.pdf, 02.06.2012
- http://www.esha.be/fileadmin/esha_files/documents/SHERPA/Environmental_Barometer_SHP.pdf, 20.03.2012
- <http://www.investopedia.com/terms/c/compounding.asp#ixzz1jZjPHgCC>, 18.05.2012
- <http://www.nj.gov/dep/fgw/images/fishpump.jpg>, 06.05.2012
- <http://www.sswm.info/sites/default/files/toolbox/FAO%202010%20Overview.png>, 06.05.2012
- <http://www.zakon.hr/z/124/Zakon-o-vodama>, 29.03.2012
- <http://www.hep.hr/ods/kupci/tarifni.aspx>, 15.09.2012

Abstract (English)

Since currently there are practically no or very few renewable energy sources in Croatia, great interest in constructing wind power plants has been seen in last few years. Croatia has very significant natural potentials for the development of wind power plant projects.

This study compares two different projects of renewable energy: The wind power plant project and the 3E (energy, economy, ecology) project of a small hydropower plant in Croatia. The wind power plant project is a complex issue that requires many years. During this project, all the interested parties, such as project developer, investor, etc. are exposed to numerous risks, including some with potential devastating consequences.

Therefore, it is very important to conduct a risk analysis in order for the investor and project developer to be able to avoid future problems. Model for qualitative and quantitative risk assessment will help us to anticipate these problems.

The key element of this study is the risk analysis and economic evaluation of above mentioned projects. This involves identification, measurement, valuation and then comparison of the inputs and outcomes of these two alternatives.

Abstract (German)

Bis vor kurzem gab es praktisch kaum oder nur wenige erneuerbare Energieressourcen in Kroatien. Das Interesse Windkraftanlagen zu bauen hat in den vergangenen Jahren stark zugenommen. Kroatien hat ein sehr bedeutendes Potential für die Entwicklung von Windkraftanlagen.

Diese Studie vergleicht zwei verschiedene erneuerbare Energie Projekte. Ein Windkraftwerkprojekt wird dabei mit dem 3E (Energie, Wirtschaft, Ökologie) Projekt verglichen. Das 3E ist ein Modell eines kleinen Wasserkraftwerkes in Kroatien. Das Windkraftwerkprojekt ist ein sehr komplexes Thema und benötigt mehrere Jahre bis zur Fertigstellung. Während dieses Projektes sind alle beteiligten Parteien wie z.B. die Projektentwickler und die Investoren mehreren Risiken mit zum Teil zerstörerischen Konsequenzen ausgesetzt.

Deshalb ist es sehr wichtig eine Risikoanalyse für die Investoren und Entwickler des Projektes durchzuführen um mögliche zukünftige Probleme zu vermeiden. Qualitative und Quantitative Modelle für die Risikoeinschätzung sollen dabei helfen diese Probleme zu antizipieren.

Das Schlüsselement dieser Studie ist die Risikoanalyse und die wirtschaftliche Bewertung der oben genannten Projekte. Dies beinhaltet die Identifikation, Gewichtung, Bewertung und Vergleichung der Inputs und der Ergebnisse dieser zwei Alternativen.

Resume

PERSONAL DETAILS

Name: Sadko Tajić

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EDUCATION

- (Oct. 2009 – Nov. 2012) **Master of Science in Economics**, University of Vienna

Administration specialization:

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