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Tehnical-economic Aspects of Construction of sSmall Hydro Power Plants in the Energy Market Environment

SUMMARY

As a result global trends in the energy market environment and of the political and regulatory decisions of the European Union, which put great emphasis on renewable energy sources and decentralized energy production, there is division of the traditional energy value chain into a increasing number of market segments. In these newly established market segments opportunities are created for new specialized players, which leads to competition in all phases of the value chain. Small hydropower plant also represent an essential renewable energy source. This article elaborate tehnical economics aspects of construction and operation of small hydropower plants in energy market environment. In this context, a concrete example is given of the mission and vision of the construction and operation of a small hydro power plants in energy market environment.

KEYWORDS

Renewable energy sources, decentralized energy production, small hydropower plant

INTRODUCTION

Energy companies from both sides of the Atlantic, as Susanne Fratzscher (2015) states in her paper, face a big question of their own survival in the environment of the new enwironment and energy policy. Therefore, faced with the dilemma of failure or sucess, the decommissioning or transition to new innovative business models. Utilities are experiencing an unprecedented change in their operating environment, which requires a broad reinvention of business models. Historicaly, a centralized and grid-connected power generation structure positioned utilities in the center of power system, with a culture focused on regulators and mandates rather than innovation and customer service expectations. This utility business model is now profoundly questioned by the accelerated deployment of distributed energy resources and smart grid technologies, as well as profound changes in market economics and regulatory frameworks. This is global trend, to which utilities and regulators around the world seek to find adequate solutions. Small hydropower plant also represent an essential renewable energy source. This article elaborate tehnical economics aspects of construction and operation of small hydropower plants in energy market environment

Figure 1 shows that in the structure of electricity generation in Germany renewable energy sources contribute significantly to 26.2%, coal and lignite coal and lignit power plants 43.2%, nuclear power 17.8%, and gas power plants 9,5%. It can also be seen that the energy produced from renewable sources consists of hydroelectric plants 3.3%, solar energy 5.7%, biomass 8%, offshore wind 0.2% and onshore wind 8.9%.

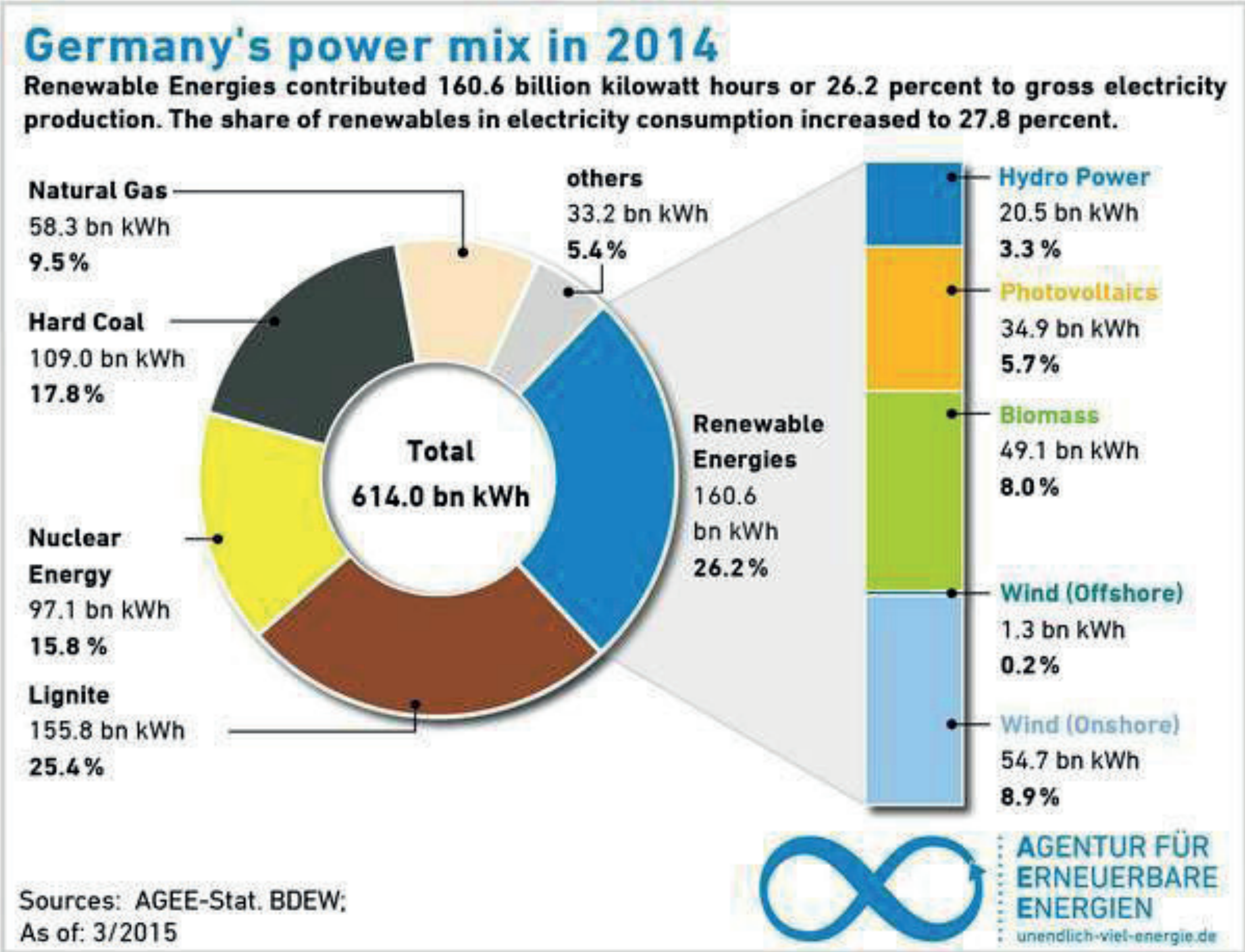

Figure 1. the share of electricity consumption in Germany [4]

SMALL HYDRO POWER PLANTS AS AN ESSENTIAL PART OF RENEWABLE ENERGY SOURCES

Energy supply will be increasingly decentralized. Humayun Tai (2013) states that this future state imply relocation of generation from high voltage to low voltage. Even if market share of renewable generation is still comparatively limited, as Fratzscher (2015) states and call on Bloomberg New Energy Finance (2015), small-scale distributed capacity represented about one third of new global investments in clean energy in 2014, approx. US$ 80bn. Overall, renewable energy (excluding large hydro) made 48% of the new power capacity added globally in 2014, the third succesive year in which this figure has been above 40% (Frankfurt School – Unep Centre/BNEF 2015). This investments are still strongly driven by government mandates and policy incentives, such as feed-in tariffs or quota systems (renewable Portfolio Standards). However, decreasing costs particulary for onshore wind and and solar photovoltaics (PV), continue to improve the economics of renewables even without incentives. The main reason for the construction of small hydro power plants is to enable the energy exploitation of the biological minimum water, which enables more precise flow regulation. By realizing such projects it is planned to increase the annual electricity production, optimize the use of water from accumulation, and thus provide additional GWh electricity from renewable sources. A small portion of the electricity produced by small hydro power plants is used to supply their own consumption, while the remaining electricity is delivered to the distribution grid via an accounting metering point that registers all the electricity delivered to the grid as well as the one used by the hydro power plant for its own consumption. Existing energy facilities are often used in the realization of such projects. Energy resources of river and water of the biological minimum are used, which, in accordance with water management conditions for hydroelectric plants, are constantly emitted from the reservoir lake into the natural river basin. These projects usually build a water catch on the existing bottom drainage on the right or left bank of the river. Furthermore, for small hydropower plants, it is planned to provide the status of eligible electricity producers, thus gaining the incentive price (premium), thus making the subject projects more economic and cost-effective, especially considering that energy policy and regulation environmental protection pushes towards the production of clean energy. Fratzscher (2015) states that 34% of carbon emissions in the USA and 33% in Germany are attributed to the power sector. As the evidence of climate change and the need for greater resiliency against its impacts become a publically supported reality, energy policy is seen as the key instrument to tackle climate change and to address geopolitical considerations.

The goals of building small hydro power plants

Small hydropower plants are considered to be sources of electricity that have a beneficial role to play in sustainable development, energy savings, increased energy security, and diversification of electricity sources. This future imply, as Humayun Tai (2013) states, that grid management complexity increases in the contest dana needs, physics, unpredictability and also that grid increasingly become a back up machine. In this context, the optimization of the power system will require significant investments and regulatory changes. System optimization takes two dimensions: market design to remunerate power flows and flexibilization services, and tehnical optimization of grid infrastructure and system operations to manage and balance the power system. Fratzscher (2015) states that these two dimensions of system optimization keep industry, regulators and policy makers busy on both sides of Atlantic. Firstly, revenue generation and long-term investment decisions will be profoundly influenced by the future market design if utilities are to be paid for just providing electrons in energy-only markets or if they are also to be remunerated in capacity and ancillary services markets for reserving generation capacity in case it is needed to balance demand and supply. Secondly, and as the other side of the same coin, tehnical optimization of system operations and infrastructure will continue to require significant regulatory adjustments and substantial regional planning for more flexible grid management and the integration of distributed energy resources. From the point of view of production planning and the necessary regulatory constraints for balancing the power system, small hydro power plants are highly desirable because of the predictability of electricity production and little influence on the scope of the regulatory reserve or balancing energy engagement. The fundamental energy input of small hydro power plants is the production of electricity with little impact on nature and the environment. Small hydropower plants are of great interest to the Republic of Croatia because their use has achieved developmental and energy objectives in the field of renewable energy sources. Also, for the assumed commitments of the Republic of Croatia to cover 20% of gross direct electricity consumption by renewable sources by 2020, the production of electricity from such sources is encouraged, thus making this project even more important. The basic aim of the construction of small hydro power plants is to solve the problem of discharge of the biological minimum and to use the basic drip regulator in accordance with the projected parameters. The construction of small hydro power plants enables more flexible operation of the main aggregates and enables the optimum use of water from accumulation according to the requirements of the hydro power system. Furthermore, the construction of small hydro power plants increases operational reliability and certainty and reduces the cost of regular annual maintenance. The construction of small hydropower plants achieves the following goals: solving the problem of discharge of the biological minimum, the energy utilization of the biological minimum water, increase of the total annual production of the hydro power plant, optimum use of water from the reservoir, more efficient operation of the main aggregates in the hydroelectric plant, additional water discharge by the basic tunnel, reducing the cost of regular annual maintenance of the existing equipment, an additional possibility of regulating the water discharge of the biological minimum, automation of aggregates and existing equipment with the introduction of process automatics, remote control, regulation and control of water discharge of the biological minimum, contribution to the realization of the investment plan of the power utility company and the overall investment cycle of production economical facilities and development of supporting industry, significant financial effects for the owner and the local community, the contribution of Republic of Croatia to the fulfillment of the commitments undertaken on the share of electricity generation from renewable sources, due to the more precise regulation of the water of the biological minimum, there will be a favorable influence on the plant and animal world in the downstream river. A small hydro power plant can, according to current legislation, acquire a status of a privileged electricity producer and retain the right to incentives in the future. Also, it is important to point out that these projects are highly competitive and without incentives, and electricity generation should not be a problem because of the growing demand for such sources. The reason lies in the fact that the electricity generation from this plant is relatively inexpensive, the life span is long and maintenance costs are minimal (an investment program for the construction of small hydropower plant Peruća).

3. Estimate the costs and revenues of small hydro power plants

At this point, an estimate of the costs of construction and estimation of the future revenues of a small hydro power plant is provided. The revenue estimate is made in accordance with the applicable legislative framework on the use of renewable energy sources. Furthermore, the status of eligible (privileged) electricity producers and the exercise of the right to a guaranteed preferential purchase price have been taken into account (Economic analysis of the construction of small hydro power plant Prančevići August 2014).

3.1. Estimation of the costs of operation and maintenance of small hydropower plants

The annual costs of operation and maintenance of small hydro power plants consist of the following components: regular and emergency maintenance (assumed in the amount of 1% of total investment, maintenance costs increased with a rate of 0.5% per annum), the reimbursement for the use of space (according to the »Decision on the amount of reimbursement for the use of premises using electricity production facilities«,(NN 84/2013 i 101/2013) for small hydro power plants with installed power greater than 1 MW is 0,01 kn/kWh and is paid for the delivered electricity). The water use fee (according to the »Regulation on the amount of the water use fee« is »5% of the price of one kWh, the realized average electricity price produced on the threshold of all hydroelectric power plants of an individual power company. In the past few years, the Croatian Electric Power Company paid for it on the basis of the average price of electricity produced at the hydro power plant treshold of about 15 lp/kWh. It is not expected that this will change significantly in the future, and the average cost of electricity produced in the budget is annually corrected only for the assumed inflation rate. Concession fee (in accordance with the »Decision on granting concession for the use of water power for the production of electricity to the Croatian Electric Power Company for HE Peruća" (NN 76/1998) is "1% of the realized average price of electricity produced at the hydro power plant threshold in each year of use.") As a small hydro power plant will only generate revenues through the sale of electricity, the concession fee is calculated in the amount of 1% of the realized income in each year. Administrative work and costs of guiding a small hydro power plant (it is assumed that a worker will be hired directly or indirectly) for performing technical and administrative tasks with a gross salary of 15000 kn. The cost of the electricity downloaded from the grid in the amount of 20.000 kn per year, based on estimates of the electricity consumption of the main project are also included in this item. This item is not expected to change significantly in the future and is revised annually in the budget for an assumed inflation rate of 2%. Based on the above, the operating costs of small hydro power plant Prančevići are given below.

Component	Operating costs	Annual Costs (kn/year)
Maintenance costs		338.269
Usage fee	10 kn/MWh	90.000
Water utility fee	7,5 kn/MWh	67.500
Concession fee	1% of gross income	87.937
Administration and management		150.000
Total (first year)		733.707

Table 1. Estimation of operating costs of small hydro power plant Prančevići [6]

The table above shows the estimate of the operating costs of small hydro power plant Prančevići in the first year of operation. The total operating costs amount to HRK 733,707 and consist of maintenance costs of HRK 338,269, usage fee of HRK 90,000, water utility fee of HRK 67,500, concession fee of HRK 87.937 administration and management of HRK 150.000.

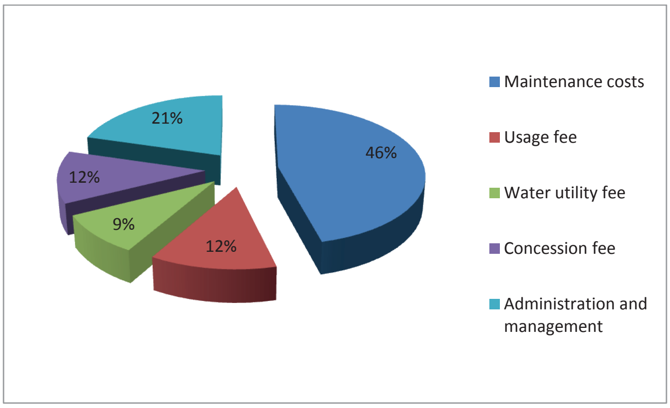

Figure 2. Shares of components in operating costs of small hydroelectric power plant Prančevići [6]

Figure 2 shows that most of the operating costs are maintenance (46%), administration and management participate with 21%, 12% usage fees, 12% concession fees and water utility charges 9% of the total operating costs of small hydro power plants.

Estimates of revenues from electricity sales

The annual revenue of a small hydro power plant is realized by selling electricity to the market. The estimate of annual revenues is made on the basis of the net annual electricity production budget and the expected electricity price trends during the analysis period. According to the current tariff model, small hydro power plants belong to a group of production plants, production facilities of installed power up to 5 MW, hydro power plants with installed power greater than 300 kW up to 2 MW. For this group, the incentive price was set at 0.93 kn / kWh. The purchase price in the financial analysis was calculated as follows: for the period of the Electricity Purchase Agreement (the first 14 years), the incentive price of electricity was HRK 0.93 / kWh and corrected at the annual inflation rate of 2.5%.The following figure shows the movement of electricity prices in the market.

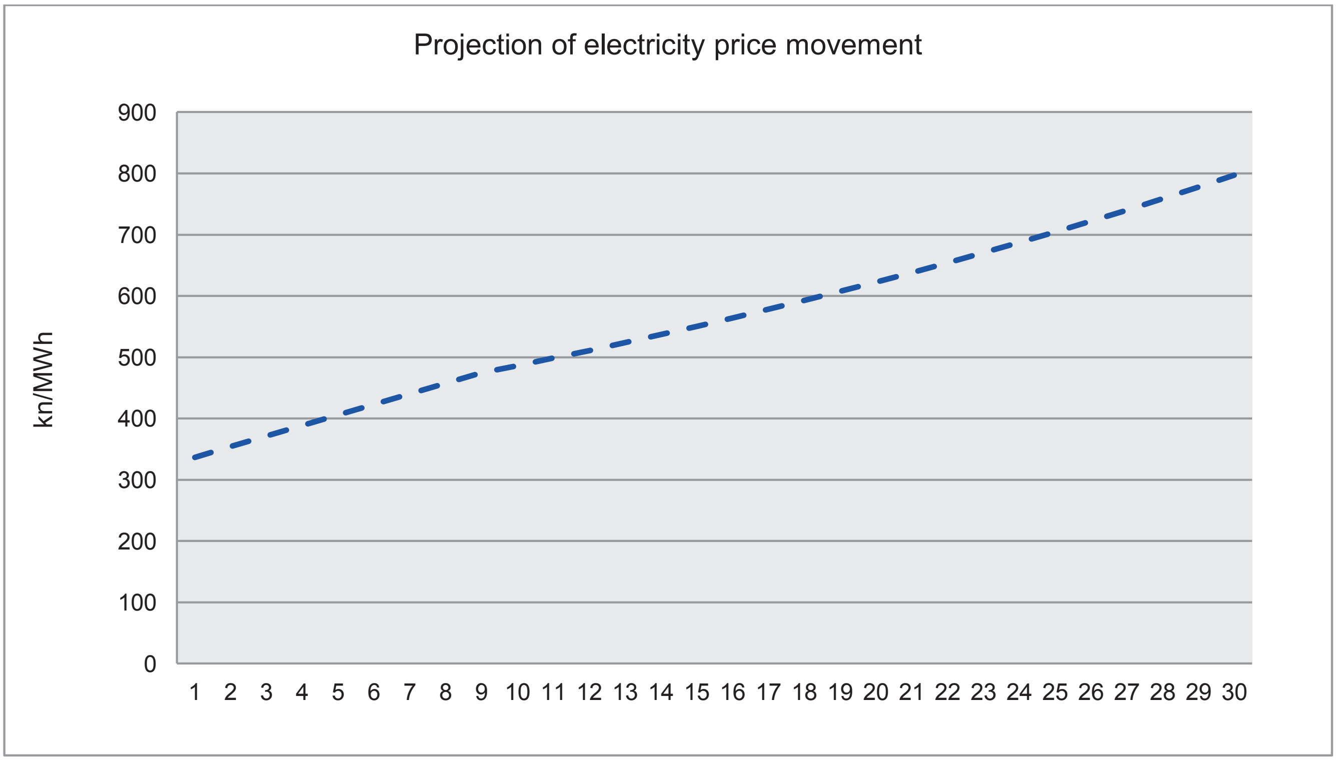

Figure 3. Projection of electricity price movement on the market kn/MWh (2022-2051) [9]

In the period after the expiration of the Electricity Purchase Agreement (from the fifteenth year onwards), according to the Electricity Market Act, the obligation of the Transmission System Operator or the Distribution System Operator has been established for the collection of the total produced electricity from eligible electricity producers. Thus, one can count on free access to the electricity grid and the sale of total electricity produced in the energy market.

Table 2. An estimate of the revenue from the sale of small hydro power plant Prančevići [6]

Year	Net electricity production (MWh)	Purchase price of electricity (kn/MWh)	Gross annual income (kn)
2016	9.000	977,1	8.793.731
2018	9.000	1.026,5	9.238.914
2020	9.000	1.078,5	9.706.634
2023	9.000	1.161,4	10.452.983
2026	9.000	1.250,7	11.256.719
2029	9.000	1.346,9	12.122.256
2030	9.000	574,8	5.173.057
2033	9.000	628,1	5.652.739
2037	9.000	706,9	6.362.207
2040	9.000	772,5	6.952.156

Estimated market price of electricity for each year is determined on the basis of the reference market price increased by the estimated increase in electricity prices. For the reference market price of electricity, an estimate of the average market price of electricity on the stock exchange in the past 3 years is taken and increased by 10%, which is 50 EUR / MWh. It is also accounted for by an average annual growth rate of electricity price of 3% per year, which is slightly above the estimated inflation rate. In the table above is an estimate of the revenues of electricity sales. The table above shows revenues for years where the “green” part represents an incentive purchase price of electricity while the “red” part represents the market price of electricity. The incentive price of electricity is corrected yearly for the annual inflation rate, while the market price of electricity increases for the estimated electricity price.

WEIGHTED AVERAGE COST OF CAPITAL (WACC) IN THE CONSTRUCTION OF SMALL HYDRO POWER PLANTS

In methods for calculating the cost of capital investment projects (Vidučić 2002), certain cash flows are assumed, ie risk-free projects. Cash flows of risk-free projects using the net present value method can be discounted at a zero interest rate. However, for risky cash flows it is necessary to determine the appropriate discount rate (required rate of return). The approach to using it depends on whether the company is funded solely by its own capital or its use and borrowing (leverage), as well as on the project’s risk as compared to the company’s risk. For companies funded solely by their own capital, the appropriate discount rate is the cost of permanent capital. For companies that use and borrowing the appropriate discount rate is the total cost of capital ie Weighted Average Cost of Capital (WACC). According to the WACC approach, the sum of expected cash flows from the project is discounted at cost of capital, which is determined as the weighted average of the combination of sources from which the company plans to finance.

WACC of small hydropower plants vs WACC renewable energy sources E.ON

At this point, a comparison of the Weighted Average Cost of Capital in the operation of small hydro power plants and Weighted Average Cost of Capital of E.ON energy company operating across Europe. Therefore, instead of using the WACC approach, the German regulator publishes a permitted return on equity (common equity). For existing investments, the return on equity (before corporation tax and after the commercial tax) is 7.14%, while in the case of new investments the return on equity 9.05%, assuming 4% of the debt price and the ratio 60/40 debt / own capital. According to the mentioned operating pro forma WACC in Germany in the amount of 5.9% was derived by weighting the share of existing assets (WACC 5,7%) and new assets (WACC 6,5%). WACC for business operations in Sweden amounted to 4.5%, and is the real WACC before tax. Current WACC of 4.5% in Sweden are disputed at the Court for Network Operations. The average expected rate of inflation in Sweden is 1.6%. Furthermore, based on the model of financing and business risk, the cost of capital (WACC) for the construction of small hydro power plants is also estimated and it is 5%.The next figure shows the equivalent of Weighted Average Costs of Capital (WACC) by countries in Europe where E.ON Group operates and equivalent of Weighted Average Cost of Capital (WACC) for a small hydro power plant Prančevići.

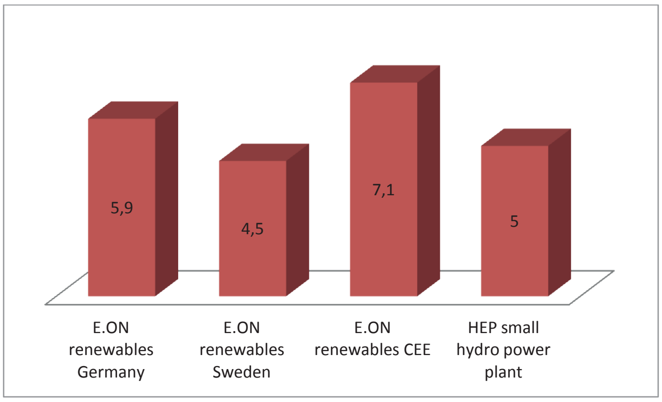

Figure 4. Weighted Average Cost of Capital WACC E.ON vs WACC small hydro power plant Prančevići [7] [6]

Essential parameters for a technical economic analysis

The input parameters required for financial analysis are revenue and expense, together with other technical and financial parameters required for the calculation and analysis of discounted cash flows. Operating costs are shown in Table 1, the estimated revenue for the entire planned period is shown in Table 2. An overview of the estimated values of the other input parameters is shown in the following table.

Common input parameters	Unit	Amount
Number of aggregates		1
The power of the aggregate	MW	1,15
Total installed power	MW	1,15
Inflation rate	%	2,5
Annual rate of increase in electricity prices	%	3
Profit tax rate	%	20
Amortization rate	%	5
Depreciation charge (% of investment costs)	%	100
Weighted Average Cost of Capital (WACC)	%	5
Incentive purchase price of electricity (first year)	kn/MWh	977
The duration of the incentive purchase price	god	14
Market price of electricity (first year)	kn/MWh	380
Annual growth in maintenance costs	%	0,5
Interest rate	%	
Loan repayment time	god	
Cost of borrowing	%	
The period observed in the analysis	year	25

Table 3. Other input parameters [6]

According to Article 12 of the "Income Tax Act" (NN 177/04, 90/05, 57/06, 146/08, 80/10, 22/12, 148/13), amortization of tangible fixed assets is recognized as tax expense. It is calculated on the basis of the cost of procurement (depreciation base) using a linear method using annual depreciation rates. A small hydro power plant belongs to a group of long-term assets"1- construction objects and ships of more than 1000 gross tonnage (BRT)", for which the annual depreciation rate of 5%. Under the cost of procurement is considered to be all the costs of placing the assets in use. Therefore, in the case of small hydro power plant Prančevići, this is the total investment cost. Accordingly, depreciation for a small hydro power plant has been calculated linearly for 20 years in the amount of 5% of the total investment value.

COST-EFFECTIVENESS ANALYSIS OF SMALL HYDROPOWER PLANTS PRANČEVIĆI

Funding is assumed using only own resources and in that case lose the elements of credit (project financing). The analysis uses the cash flow projections (economic flows) for the observed period and the projections of the profit and loss account. The calculated net profit is increased for amortization and thus the cash flow is obtained. The free cash flow is discounted at a discount rate that for those companies that are funded exclusively with their own equity, is equal to the cost of permanent capital, while for the companies that use the debt, the appropriate discount rate is Weighted Average Cost of Capital (WACC). In the case of a small hydro power plant with a basic variant without discounting (DR = 0), two variants of discount rates were used, namely DR = 5% and DR = 10%. Based on the financing model and business risk, the Weighted Average Cost of Capital (WACC) is estimated, and it is 5%. Thus, in the case of small hydro power plants, the relevant discount rate is 5%. Below are shown calculations of the financial indicators of building a small hydroelectric power plant Prančevići. The following table (Table 4) represents the economic flow of small hydro power plant Prančevići. Two years have elapsed from the total 26-year analysis period: the first year of work for which the electricity price incentive for the eligible producer and fifteen years of work are worth the electricity market price.

Table 4. Economic flow of small hydropower plants Prančevići [6]

Indicators of financial analysis	2016 Incentive price	2030 Market price
Purchase price kn/MWh	977	575
Annual electricity production (MWh)	9.000	9.000
Gross annual income (kn)	8.793.731	5.173.057
Operating Annual Costs – OPEX (kn)	733.707	960.715
Gross profits – EBITDA (kn)	8.060.025	4.212.342
Amortization (kn)	1.691.346	1.691.346
Operating profit – EBIT (kn)	6.368.678	2.520.996
Profit tax (kn)	1.273.736	504.199
Net profit	5.094.943	2.016.796
Net profit + Amortization	6.786.289	3.708.143
Free cash flow	6.786.289	3.708.143

The table above presents the projection of the cash flow, ie the economic flow of the small hydroelectric power plant Prančevići. In this respect, the processing was initiated from the beginning of the 14-year incentive price period for the eligible electricity producer, and for the fifteen years of operation, ie the first year for which the market price of electricity was increased by the average rate of increase of electricity price in the observed period. The period from 2016 to 2040 was observed. Using the economic outlook and projection of the profit and loss account, discounted cash flows and cumulative flows are produced. With variant without discount (zero discount rate), two variants of the discount rate of 5 and 10 percent were used. The following figure shows the cumulative cash flows for all three variants.

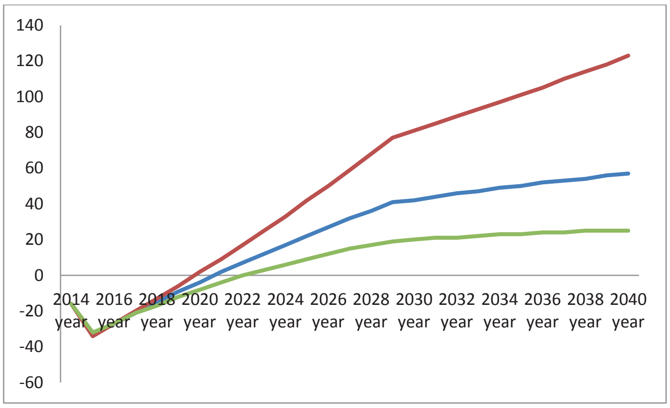

Figure 7. Cumulative discounted cash flows DR = 0, DR = 5%, DR = 10% small hydro power plant Prančevići [6]

The above figure shows the cumulative cash flow for the zero discount rate, a discount rate of 5% and a discount rate of 10%. In the case of non-discounting, the cumulative cash flow is positive in the fifth year of the business, with a discount rate of 5% in the sixth year of operation, with a discount rate of 10% in the eighth year of the business. The assessment of the viability of the investment of the construction of a small hydro power plant is obtained through the calculation of the discounted free cash flow. The result of the underlying analyzes and calculations are the basic financial indicators: Internal Rate of Profitability, Net Present Value and Time of Return on Investment. These financial indicators are shown in the following table.

Indicators of financial viability	
Internal rate of return (IRR)	19,26%
Net present value (NPV) - discount rate 0%	122.851.370 kn
Net present value (NPV) - discount rate 5%	56.897.681 kn
Net present value (NPV) - discount rate 10%	25.424.047 kn
Time of Return on Investment - discount rate 0%	5 year
Time of Return on Investment - discount rate 5%	6 year
Time of Return on Investment - discount rate 10%	8 year

Table 5. Indicators of financial viability of small hydropower plant Prančevići [6]

The above table shows that the financial ratios are exceptionally good as reflected in the high internal rate of profitability, the high net present value, the short investment return time, taking into account the most unfavorable discount rate of 10% which is really too high for this type of low risk project. The relevant discount rate for a small hydro power plant is 5%.

CONCLUSION

The project is competitive and market-oriented as the demand for electricity is growing. The project has good economic indicators that guarantee good profitability and return on investment. Realization of the project uses existing energy facilities, exploits the natural potential of the Cetina River, while the installation of new equipment extends the lifetime of the existing equipment which has not been used optimally so far. Financial analysis has resulted in positive indicators of profitability: the internal rate of return of the project is 19% and meets the condition of profitability, ie significantly higher than Weighted Average Cost of Capital (WACC). Net present value (NPV) of the project with a discount rate of 5% is HRK 56,897,681. Time of Return on Investment is five years, and the discounted period of return is 8 years, which is acceptable. It can be concluded that such projects are economically and financially justified, acceptable and desirable for investors. The project is market-oriented and competitive, given that the electricity price in the European electricity market is growing, and there is growing demand for renewable energy sources. With its production, hydro-electric and power parameters, small hydro power plants with expected annual electricity generation of 9,000 MWh, it is imposed as a durable and reliable and above all an environmentally friendly renewable source of electricity. Such energy sources are of great interest to the Republic of Croatia because their use increases the utilization of existing hydro power plants and the use of their own natural energy resources, reducing the dependence on energy imports and the impact of fossil fuels on the environment in the long term. With the increase in electricity prices, cumulative economic effects and other significant uses of investment in the construction of small hydro power plants are growing, and they are energy economically viable. It should also be emphasized that the character of such renewable energy sources contributes to overall social acceptance. However, this kind of intervention in the area carries certain environmental and financial risks. Ecological risk is the possibility of contaminating river water streams when constructing and using small hydropower plants. The stated risk is planned to be minimized through the organization of work and the application of strictly prescribed environmental standards. Another ecological risk is a possible failure on the equipment of a future energy facility, which would limit the discharge of the biological minimum water stream into the river. Its possible negative impact is planned to be prevented by by-pass pipeline. Together, both ecological and economic risk pose a demand for managing water accumulation. The connection of the pressure pipeline to the basin tunnel requires good preparation and a few days empty of the water tunnel, which limits the release of the biological minimum only through the operation of the aggregate and depends solely on their availability. In order to reduce the risk of such an event, it is necessary to manage the accumulation of water in such a way that a moment of fitting small hydroelectric power plants to the supply system is in such holes of lakes when it is possible to discharge the biological minimum water through the overflowing klapa. The financial risk is certainly a consequence of the mentioned environmental risks, and especially the last mentioned, because the matching of the term plan with conditions in the reservoir lake does not have to coincide, and fostering their coincidence may have demands for a completely different accumulation management. This may have negative financial effects for water accumulation users or Investors. The financial risks of the project for the construction of small hydro power plants are as follows: electricity prices at the international and domestic electricity market, possible change of water supply conditions, capital cost, investor business, company environment and unplanned cost of project participants. given the low probability of occurrence of any of the risky events, taking into account the previously conducted analysis, it can be concluded that such projects are economically and financially justified, acceptable and desirable for investors.

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