PRIVATE INVESTMENT FOR BUILDING A SMALL HYDROPOWER PLANT AT ZETEA DAM BASIS

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Zetea water management project comprise an earth gravity dam, made out of local materials, having as main purposes water supply, flood control and protection against flooding. The paper analyzes the possibility of building a small hydropower plant at the basis of the dam, using private investment resources, in order to put to good use the water flow evacuated from the storage lake.

Keywords: hydropower, small hydropower plant, economic analysis, investment.

1. Introduction

Zetea storage lake is built on the river Târnava Mare, approximately 22 km upstream from Odorheiul Secuiesc, and acts as a complex water management instrument in controlling floods, in protecting downstream settlements together with their communication lines and the agricultural lands around Târnava Mare against floods; it also provides drinking water supplies for Odorheiul Secuiesc, Cristurul Secuiesc, Sighişoara, Mediaş, Dumbrăveni, Copşa Mică.

The dam of Zetea reservoir is an earth gravity dam with a core made of clayed gravel-type material. The dam was inaugurated in 1993 and it characteristic volumes and levels (in meters above sea level – mASL) are presented in table 1.

Table 1

Characteristic levels and volumes of storage Zetea

Dead storage	mil. m^3	2.1
Active capacity	mil. m^3	14.4
Attenuation capacity under spillway crest	mil. m^3	18.4
Flood protection capacity above spillway crest	mil. m^3	9.2
Thalweg level	mASL	596
Minimum operating level for water uses	mASL	606
Normal retention level (NRL)	mASL	622
Spillway crest level	mASL	632.75
Verification maximum level	mASL	637

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The water management document stipulates that the minimum flow downstream from the dam must be 1.7 m^3/s. Currently, the water consumers downstream collect it straight from the river Târnava Mare, through water intakes placed in various locations that concentrate numerous consumers. The outflows from the storage lake are sent downstream by means of a water intake with outlet in the plunge basin of the bottom outlet.

The basic principles of Zetea reservoir operation are:

- during medium and low water supply intervals, reservoir operation is performed according to the chart designed by its beneficiary, without exceeding the normal retention level at 622 mASL. The attenuation storage is kept available, for partial or total retention of floods;

- after flood transit, the attenuation storage will be emptied in 6 to 7 days maximum, in case another flood needs to be avoided. As the 1970-1975 data confirm, floods with about 5% exceedance frequency may occur successively at intervals of about 7 days.

In a previous article, [1], the same authors presented a series of locations on which small hydropower plant (SHP) can be built, on the compensation water. The analysis demonstrated that part of those locations can become convenient under certain favorable economic circumstances.

The opportunity of building a SHP at the basis of Zetea dam has been studied by SC ISPH SA (Institute of Hydroelectric Studies and Design) and many documentations have been elaborated, [2], [3], [4].

2. Hydrologic data

For this analysis, the mean monthly discharges over a period of 27 years (1970-1996) were used. For the interval 1970-1989 inflows were calculated on basis of the values measured at Brădeşti hydrometric station and for 1990-1996 by direct measurement at Zetea hydrometric station. The mean discharge for the 27 years period is 3.91 m^3/s and it represents an annual stock of 123.7 mil. m^3. During the summer semester, 60% of the annual stock is achieved, which means 75.3 mil. m^3, and in the winter semester 40%, meaning 48.4 mil. m^3.

After analyzing the flows, the conclusion was that in summer there are no values lower than 0.7 m^3/s, and in winter none lower than 0.85 m^3/s. Only in 10% of the analyzed months there are flows lower than 1.45 m^3/s (in summer) and 1.12 m^3/s (in winter).

Hence, in a preliminary stage, when water consumption downstream is relatively little, a flow of 0.5 m^3/s should be discharged from the Zetea reservoir section, in order to face consumers' needs.

As downstream consumption increases, reaching values that exceed the minimum flows ensured by the natural conditions, people will resort to the reservoir in the intervals that require it. These principles were fundamental in designing the operation plan for the reservoir and the SHP.

3. Alternative approaches analyzed for Zetea SHP in 1998 and the results of the economic analysis

Many alternative approaches of SHP equipment were examined for the following values of the installed discharge: 3, 4, 5, 6, 7 and 8 m^3/s, numbered from I to VI. In the alternatives of 3 and 4 m^3/s installed discharge, the plant is equipped with one unit, whereas in the alternatives of 5, 6, 7 and 8 m^3/s installed discharge, the plant is equipped with two hydropower units.

In all the analyzed alternatives, the plant can operate the necessary flows for meeting the water demands downstream.

The main parameters of SHP Zetea for the analyzed alternatives are presented in Table 2.

Table 2

Main hydropower parameters of SHP Zetea

Alternative	**I**	**II**	**III**	**IV**	**V**	**VI**
Installed discharge (m^3/s)	**3**	**4**	**5**	**6**	**7**	**8**
Number of units	1	1	2	2	2	2
Mean discharge (m^3/s)	3.92					
Turbine discharge (m^3/s)	2.23	2.61	3.17	3.40	3.56	3.67
Spilled discharge (m^3/s)	1.69	1.31	0.75	0.52	0.36	0.25
Mean storage for water use (mil.m^3)	13.8					
Mean upstream level (mASL)	621.2					
Mean gross head (m)	31.8					
Friction head at installed discharge (m)	0.60	0.80	1.20	1.70	2.30	3.00
Installed capacity (kW)	800	1,060	1,310	1,550	1,770	1,980
Average energy output (GWh/year)	5.2	6.0	7.2	7.6	8.0	8.1
Plant factor (h/day)	6,500	5,600	5,500	4,900	4,500	4,100

The investments required for accomplishing SHP Zetea in the analyzed installed discharge alternatives were evaluated on basis of the works volumes with the price indices valid for January 1998. Investment in mechanical and electrical equipment is given for providing the plant with asynchronous generators. In the case of equipping it with synchronous generators, the investment is 30% higher.

Annual expenses were calculated on categories consisting in amortizations and operation and maintenance expenses. Amortizations calculation was done on categories of works according to the scheduled functioning time of various hydropower structures. Operation and maintenance expenses consist in material expenses, salaries and contributions, general expenses and payments of the tax for using the water fall and water stock. For plant maintenance and operation, an employee per shift was considered necessary, which means a minimum number of

4 people. In order to calculate the salaries, an average monthly wage of 1, 2 mil. RON was taken into consideration, to which an increase by 32% was added, for social security and unemployment benefits. For dam generated hydropower potential payment, an amount of 31 RON/MWh was taken into account.

The annual income of Zetea SHP comes from selling the power it produces. Income assessment was done considering a price of 155 RON/MWh.

For evaluating the economic effectiveness of the analyzed alternatives, the specific energy investment, the B/C ratio, the updated unit cost, the updated net benefit, and the internal profit rate were calculated.

Table 3 shows the main energy/economy parameters of Zetea SHP in the analyzed alternatives.

Table 3

Main economical parameters for a discount rate of 10%

Alternative	**I**	**II**	**III**	**IV**	**V**	**VI**
Installed discharge (m^3/s)	**3**	**4**	**5**	**6**	**7**	**8**
Installed capacity (kW)	800	1,060	1,310	1,550	1,770	1,980
Average energy output (GWh/an)	5.2	6.0	7.2	7.6	8.0	8.1
Total investment (bil. RON)	7	8	11	12	13	14
Construction duration (years)	1					
Annual expenses (bil. RON/year)	0.7	0.8	1.0	1.1	1.2	1.2
Specific energy investment (RON/kWh)	1.4	1.4	1.5	1.6	1.6	1.7
Energy price (RON/kWh)	141	141	141	143	146	148
Discounted unit cost (RON/kWh)	236	245	257	263	272	277
B/C ratio	1,72	1,66	1,58	1,54	1,49	1,46
Discounted net income, DNI (bil. RON)	7,8	8,6	9,6	9,8	9,5	9,4
Internal rate of return, IRR (%)	23,4	21,9	20,0	19,2	18,2	17,7

The cost-benefit ratio is by definition the ratio of the discounted total incomes and discounted total costs and can be calculated with the relation:

$$B/C = \sum_{k=1}^{n} \frac{V_k}{(1+r)^k} \Bigg/ \sum_{k=1}^{n} \frac{C_k}{(1+r)^k}, \qquad (1)$$

where: V_k is the income in the current year k,

C_k – total cost in the current year k,

k – current year,

n – number of years within the study period,

r – discounted rate.

For Romania, the discounted rate varies between 8-12%.

The discounted net income, DNI, or the discounted benefit, is by definition the difference between the discounted total incomes and discounted total costs and can be calculated with the relation:

$$B/C=\sum_{k=1}^{n}\frac{V_k}{(1+r)^k}-\sum_{k=1}^{n}\frac{C_k}{(1+r)^k}=\sum_{k=1}^{n}\frac{V_k-C_k}{(1+r)^k}=\sum_{k=1}^{n}\frac{B_k}{(1+r)^k}, \quad (2)$$

where: B_k is the benefit in the current year k.

By definition the internal rate of return, IRR is the discount rate corresponding to B/C=1 or DNI=0, so it can be calculated from the equation:

$$\sum_{k=1}^{n}\frac{V_k}{(1+r)^k}=\sum_{k=1}^{n}\frac{C_k}{(1+r)^k}, \quad (3)$$

and it results: $r = IRR$.

The values of these indicators, give to the investor the answer as if the investment is efficient from the economical point of view:

- if B/C > 1, VNA > 0, the investment is efficient;
- if B/C < 1, VNA < 0, the investment is not efficient.

Results analysis leads us to believe that all the alternatives we took into account have the B/C ratio greater than the unit at an updating rate of 10% and the internal rate of return (IRR) well over 10% (considered as low limit of economic efficiency), therefore they are effective from the economic point of view. As the installed discharge increases, a worse situation in all parameters becomes visible (the specific energy investment, the cost, the discounted unit cost, the B/C ratio, the internal rate of return), fig. 1.

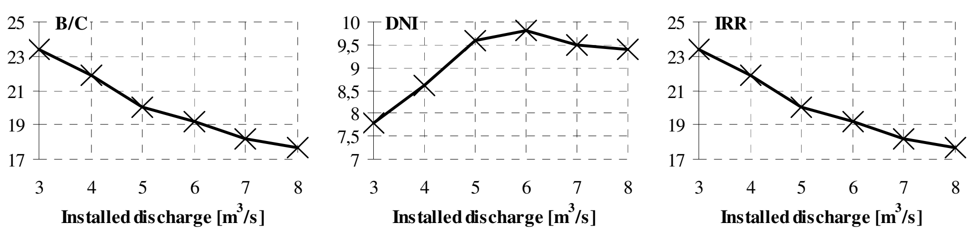

Fig.1. B/C, DNI and IRR variations for the alternative approaches.

As a consequence, it is advisable that the plant should be equipped with two units with asynchronous generators, having an installed discharge of 6 m^3/s.

For the two-unit alternative and the installed discharge of 6 m^3/s a minimum price for energy valuation was calculated, so that the investment should be recuperated in 10 years, at an discounted rate of 10%, resulting 140 RON/MWh.

The investment can be achieved using ANAR (The Romanian Waters National Administration)'s own funds, or by means of a joint venture between ANAR and a partner, the participation terms being specified by a subsequent agreement. This agreement should include elements such as: each partner's amount of capital and the source (private capital or bank loans); the interest rate for the bank loans, time interval for paying back the loan, the period of grace and the modality of paying back the loan; electric energy buyers and its acquisition price; partnership period; modalities of sharing the profit between the partners etc.

4. Updating and structure of the investment

In 2006, at ANAR demanding, the investment and his efficiency were updated from the perspective of a private investor.

The total value of the new investment is 8,102,272 RON and 2,203,441 €, respectively. We mention that the prices are the ones of the 31st of December 2005 when the exchange rate was 3.6771 RON/€ and 3.1078 RON/$, respectively.

The time interval for completing the works is of 2 years, and the whole investment is scheduled to take place in two equal shares.

Finally, the results of economic analysis are presented as economic indicators, like:

- cost-benefit ratio, B/C;
- discounted net income, DNI;
- internal rate of return, IRR.

As stipulated by government decision, according to European Union decisions, a hydropower plant wit the installed capacity above 10 MW is a small hydropower (SHP) and produce green electricity. If it is the case, for each MWh produced the owner receive a green certificate (GC). The regulated price for green electricity is the equivalent in RON of 36.6 €/MWh and one GC can be sold on the centralized market for green certificates with a price between a minimum of 24 €/MWh and a maximum of 42 €/MWh. It results a price that can be obtained for 1 MWh within the range 60 and 78 €/MWh.

The calculations were made for a mean price for GC, 33 €/MWh, corresponding to the arithmetic mean between the two values, minimal and maximal, for GC.

In table 5 are presented the main technical and economy parameters of SHP Zetea.

Table 5

Technical and economical indicators of SHP Zetea

Installed discharge (m^3/s)	6
Installed capacity (kW)	1,516
Average energy output (MWh/year)	6,857
Total investment, (RON), without value added tax (VAT)	8,102,272
Time of execution (years)	2
Exploitation expenses, (RON/ year)	97,226
Specific investment of energy, (RON/kWh/ year)	1.18
B/C ratio at the discount rate: 10% / 12%	1.69 / 1.47
Discounted net income, DNI (RON) at the discount rate:10% / 12%	5,385,673 / 3,476,211
Internal rate of return, IRR (%)	18.3

For determine the influence of GC price upon economic efficiency, two supplementary analyses were achieved: the pessimistic option – 24 €/GC and the optimistic one – 42 €/GC. B/C, DNI and IRR variations are represented on fig. 2.

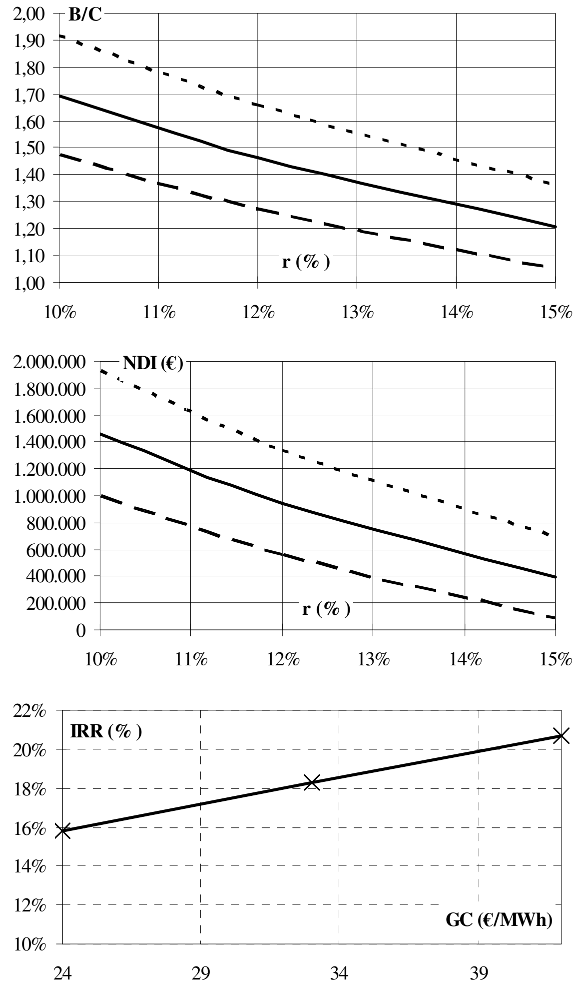

Fig. 2. B/C, DNI and IRR variations with respect to GC price.
Legend: Interrupted line – 24 €/MWh, continuous line – 33 €/MWh and dotted line – 24 €/MWh.

The following hypotheses lay at the foundation of the financial analysis:

- SHP Zetea financing comes from mixed sources: 25% of the investment is covered from private sources to be recovered in 7 years after start-up, by means of annuities with 8% interest and 75% of the investment comes from bank loans to be paid back in 10 years each, with a two-year period of grace, with 8% interest.
- pledge commission is of 0.1% of the investment;

- initial commission is of 0.45% of the investment;
- annual risk commission is of 0.9% of the investment;
- annual maintenance and operation expenses (including water costs) are of 100,000 RON;
- income obtained through valuation of the electric energy production at a price of 132 RON/ MWh (36 €/MWh);
- valuation price of Green Certificates (GC) is of 121.34 RON, corresponding to the arithmetic mean between the minimum and maximum values established by law, 24 and 42 €/GC, respectively.

As a result of applying the financial analysis to the studied period of 13 years, including, among other things, financial payments (interest rates and commissions), credit rate and total costs, income, as well as yearly brut profit, the value of 3,509,484 € is obtained for the costs required by achieving and maintaining this investment, of which:

- total amount to pay back for pledged credits: 2.477.995 € (as compared to the initial pledge credit of 1,652,581 €);
- recovery of private sources: 740,635 € (as compared to the sum initially invested from private sources, of 550,860 €);
- operation expenses: 290,854 €.

It is obvious that any alteration in the entry data of the financial analysis generates alteration of the results.

7. Conclusions

Obviously, the closer the GC price gets to the maximum value, the more profitable the values of the effectiveness parameters become. The same observation is valid for the case of energy valuation price, too.

Taking into account the results of the sensitivity analysis, with value GC as parameter, we come to the conclusion that for any value ranging within the range 24 – 42 €/MWh, the investment in Zetea SHP is efficient from the energy / economy perspective, so a private investor may be interested it as a good opportunity for him.

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