Tehnoekonomska analiza mikrogeneracijskih postrojenja za biomasu u zgradama
8. Sabor hrvatskih graditelja

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Sažetak

Nedavni napori za ubrzanje energetske tranzicije Europe otvorili su nove poslovne mogućnosti za ulagače u obnovljivu energiju. Budući da je društveno prihvaćanje velikih energetskih infrastrukturnih projekata u opadanju, povećava se uloga potrošača u stambenim i industrijskim zgradama u proizvodnji energije. Dakle, s postrojenjima za proizvodnju energije, ove zgrade postaju proizvođači-potrošači. Mikrokogeneracijske jedinice biomase predstavljaju blagotvorno ulaganje u proizvodnju obnovljive energije u zgradama jer mogu opskrbljivati toplinskom i električnom energijom. Međutim, trebalo bi predložiti jasnu metodu za procjenu profitabilnosti takvih ulaganja. U radu je prikazana metoda investicijske evaluacije mikrokogeneracijskih jedinica biomase. Metoda uključuje mapiranje, analizu troškova i koristi te korake procjene. Studija slučaja provedena je na zgradi vlade u Hrvatskoj. Dobiveni rezultati pokazali su da je ulaganje u kogeneracijsko postrojenje biomase snage 30 kWe imalo unutarnju stopu povrata od 19,19% s neto sadašnjom vrijednošću od 185 005 € za promatranu zgradu. Rezultati uključuju da se zgrade mogu aktivno uključiti u proces energetske tranzicije ugradnjom mikrokogeneracije biomase. Štoviše, postojala je dodatna korist za investitora jer je osigurana sigurna opskrba toplinskom i električnom energijom te je ostvarena dodatna dobit od prodaje električne energije. Daljnje implikacije rezultata su da postoji potreba za ubrzavanjem integracije zgrada u proces energetske tranzicije.

Ključne riječi: Biomasa, Kotlovi na biomasu, Mikrokogeneracija, Energetska tranzicija, Zgradarstvo

Techno-economic analysis of biomass micro-cogeneration facilities in buildings
8th Congress of Croatian Builders

Abstract

The recent efforts to accelerate the energy transition of Europe have opened new business opportunities for investors in renewable energy. Since the social acceptance of large energy infrastructure projects is declining, the role of consumers in residential and industrial buildings in energy production is increasing. Thus, with the energy production facilities, these buildings become prosumers. Micro-cogeneration biomass units represent a beneficial renewable energy production investment in the buildings because they can supply thermal and electric energy. However, a clear method for the profitability assessment of such investments should be proposed. This paper presents a method for investment evaluation of biomass micro-cogeneration units. The method includes the mapping, cost-benefit analysis and evaluation step. The case study was conducted on a government building in Croatia. The obtained results showed that the investment in a 30 kWe biomass cogeneration plant had an internal rate of return of 19.19% with a net present value of 185 005 € for the observed building. The results implicate that buildings can be actively included in the energy transition process by installing biomass micro-cogeneration. Moreover, there was an additional benefit for the investor because the secure thermal and electric energy supply was assured and an additional profit was generated from the selling of the electric energy. Further implications of the results are that there is a need for accelerating the integration of buildings in the energy transition process.

Key words: Biomass, Biomass boilers, Microcogeneration, Energy transition, Buildings

1 Introduction

The European Union (EU) placed a strong emphasis on the energy transition. This includes the decarbonisation of different sectors such as electricity, heating, cooling and transport sector. Several documents on the EU level support these objectives. Clean energy for all Europeans Package [1] defined the key areas where action is needed, while The European Green deal [2] defined the measurable objectives to be achieved by 2050.
Large energy projects are exposed to many risks from environmental, technical complexity risks as well as social acceptance risks. On the other hand, buildings are significant energy consumers. New EU legislation aims to place consumers in buildings in the centre of the energy transition, thus making them prosumers. With this approach, the buildings become the leaders of the energy transition of the EU. Moreover, this approach is more likely to be accepted by the citizens as they are directly included in the process and can make a profit from the transition to renewable energy. This kind of citizen participation is also more energy-efficient than the conventional approaches as the energy is being spent at the place of production.
Many different studies emphasize the benefits of this approach. The benefits of stand-alone biomass CHP and PV were presented in [3]. A detailed experimental model of biomass-CHP was developed in [4] where authors emphasized the efficient operation of such facilities. Moreover, a 50 kW_t biomass CHP for domestic purposes was demonstrated in [5], further emphasizing the feasibility of biomass micro-CHP. Other extensive research on the development of small-scale and micro-scale biomass CHPs were summarized in [6].
Many studies examined the operation and feasibility of the micro-scale biomass CHPs. However, none of them proposed a method that allows buildings to make investment decisions regarding the installation of such facilities. This study proposed such method with contributions as below:

- The investment decision method for building facilities that include the key financial metrics was developed in this study
- The case study was conducted in the city of Rijeka, Croatia
- The sensitivity analysis was conducted so that the uncertainty of investment and operation cost was taken into account

The rest of this study is organised as follows: The second part describes the developed method and used materials and the third part describes the analysed case study. Results and discussion were presented in the fourth part, while the conclusion was given in the final part.

2 Materials and methods

2.1 General overview

This paper proposed a method for the investment evaluation for the micro-CHP facilities in buildings. The considered buildings are normally connected to the public electricity network. The new investment would be to install a micro-CHP facility that will cover the entire heating demand and part of electricity demand. It is considered that the building uses the electric energy from the CHP to cover its electricity demand and that it sells the rest on the electricity market. The configuration of such building installations is presented in Figure 1.

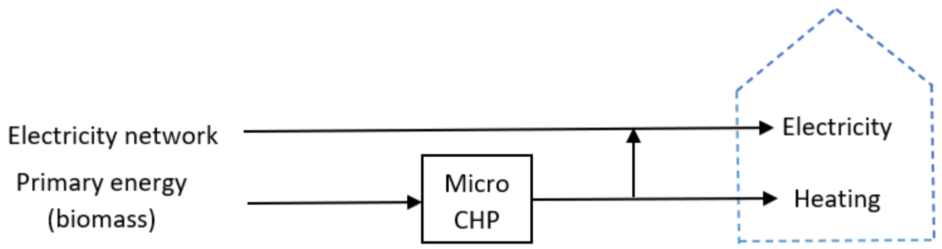

Figure 1. Combined heat and power generation and building connection to the electricity network

A general overview of the proposed method is given in Figure 2. There are two main kinds of input data required. It is necessary to know the energy consumption data of the observed building. Moreover, it is necessary to know cost specific data regarding the micro-CHP. With this data, the energy production values can be calculated as well as the income from the sold electricity. Two main parameters observed are the Net Present Value (NPV) and the Internal Rate of Return (IRR). These two parameters indicate if the investment should be made or not. Uncertainty of the input data should be considered in the sensitivity analysis. The uncertainty of the investment and operation cost is considered in the proposed method.

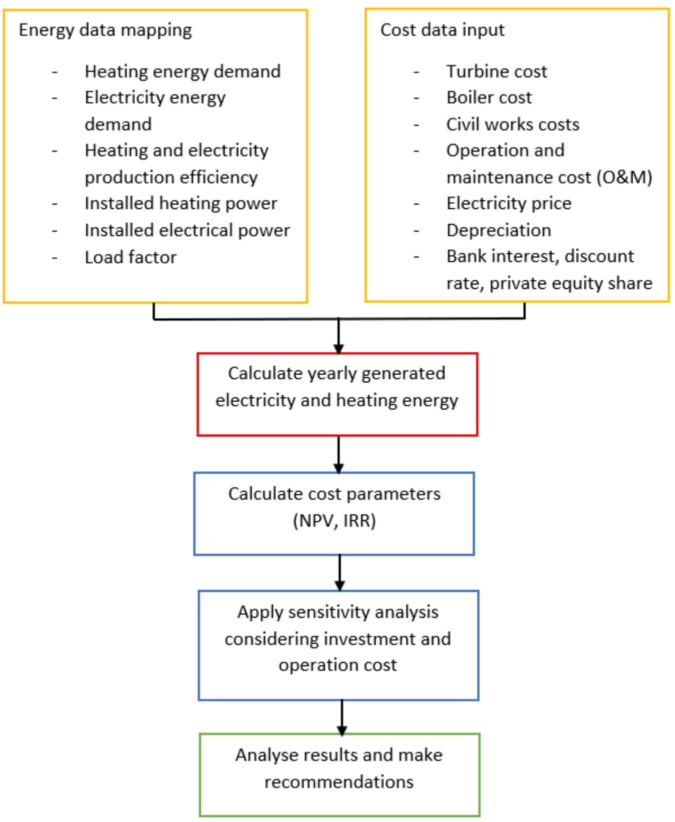

Figure 2. Flow chart of the proposed method – input data is marked in yellow, calculated energy data in red, cost analysis in blue and investment evaluation in green

2.2 Energy production

Energy production values represent estimated heating and electric energy production. These values depend on the installed electricity and heating power as well as the load factor obtained from the historic consumption data. These values are calculated for one year. The heating production value is calculated as (1):

$$E_{heating} = m \cdot P_{heating} \cdot 8760\ [kWh] \tag{1}$$

While the produced electric energy is calculated as (2):

$$E_{electricity} = m \cdot P_{electricity} \cdot 8760\ [kWh] \tag{2}$$

Where:

$E_{electricity}$– produced electric energy [kWh]

$E_{heating}$ – produced heating energy [kWh]

m – load factor

$P_{electricity}$ – installed electric power [kW]

$P_{heating}$ – installed heating power [kW]

2.3 Net Present Value (NPV)

Because the monetary means don't have the same value over time, it is necessary to consider this effect to evaluate the investments in the energy sector. In order to sum all discount values of yearly savings (profits), it is necessary to define the referent year. It is not significant what year that is and, in most cases, the year of investment is taken as a referent year. Net Present Value (NPV) is today's value of all future savings made during the project time decreased for the investment cost. The criterium of profitability is NPV>0, while the value of NPV is calculated as in (3):

$$NPV = \sum_{t}^{T} \frac{V_t}{(1+k)^t} - I_0 \tag{3}$$

Where:

T – project lifetime

t – current year

V_t – yearly savings

k – discount rate

I_0 – initial investment

2.4 Internal Rate of Return (IRR)

Internal rate of return (IRR) is one of the most reliable indicators when evaluating an investment. However, this indicator is also based on the NPV. The main objective is to find a discount rate *R* such that the project is still positively evaluated, thus for which *NPV* = 0. This is denoted with the equation (4):

$$NPV = \sum_{t}^{T} \frac{V_t}{(1+R)^t} - I_0 = 0 \tag{4}$$

The IRR is the discount rate that reduces the project cash flows on the value of its investment costs. Thus, in comparison to the NPV method where cash flows are reduced to the present value by using the known discount rate, in the IRR method, the discount rate is unknown. The criterium for positive project evaluation is the higher value of the IRR. The project is negatively evaluated if the IRR is lower than the known discount rate.

3 Case study

The installation of the biomass micro-cogeneration is a secure investment for government buildings, schools, larger industrial facilities, residential buildings etc. If these buildings are located in areas with cold climate, the investment has even greater profitability potential. In this paper, the case study was conducted on a government building in Rijeka, Croatia. The data was obtained based on the study [7]. The city government has two buildings with a total area of 8 867 m^2 and another 33 objects of local government with a total area of 5 406 m^2. Total electric energy consumption for these objects was 1.073 GWh, out of which 0.292 GWh was spent for heating which gives a specific heating consumption of 54.66 kWh/m^2. From these values, it is possible to derive the energy consumption values for one building. Additionally, it is possible to propose the necessary values of the installed facility. For this case study, a micro-CHP with 60 kWh$_t$ and 30 kWh$_e$ was chosen for the analysed investment. The energy data is summarized in Table 1.

Table 1. Energy data for the anaylsed case study

Energy data	**Value**
Heating energy demand	285 MWh
Electric energy demand	230 MWh
Heating energy production efficiency	80%
Electric energy production efficiency	30%
Installed heating power	60 kW
Installed electrical power	30 kW
Load factor	0.75

Cost specific data varies from different micro-CHP technologies. Because of this, it is necessary to conduct the sensitivity analysis for the observed system with respect to the investment and operation cost. However, the deterministic values should still be provided for the analysed case. Detailed monetary data for the micro-CHP was provided in [8] and this data was used in this study as well. The monetary costs for the analysed system are provided in Table 2.

Table 2. Monetary data regarding observed biomass micro-CHP system

Cost data	**Value**
Turbine cost	70 000 €
Boiler cost	70 000 €
Civil works cost	45 000 €
O&M costs	3 300 €
Generated electricity price	55 €
Bought electricity price	120 €
Equipment depreciation	15 years
Civil works depreciation	15 years
Average discount rate	6%
Corporate tax	25%
Private equity	50%
Bank interest rate	5.7%
Loan period	15 years
Price of pellets	25 €/MWh

4 Results and discussion

4.1 Energy production results and return of investment

The energy production results per year are given in Table 3. The results for the generated energy and income from selling the electric energy of the market was calculated from the input case study data. There is no revenue from the heating energy selling as it was assumed that the heating energy is only used for the building. In order to sell heating energy as well, the building should have access to the district heating network as well.

Table 3. Generated energy and estimated income

Energy production results	**Value**
Generated heating energy	394.2 MWh
Generated electric energy	197.1 MWh
Yearly income from sold electric energy	10 840.5 €

The results of the study showed that the number of years for the investment return was similar for the case when the discount rate was considered and when it was not. For the case without the discount rate, it took 5 years to return the investment, while for the case with the discount rate of 6%, it took 6 years to return the investment. Detailed results are presented in Figure 3 that presents the cumulative net profit and discounted profit. The difference of 1-year payback can be visible in Figure 3.

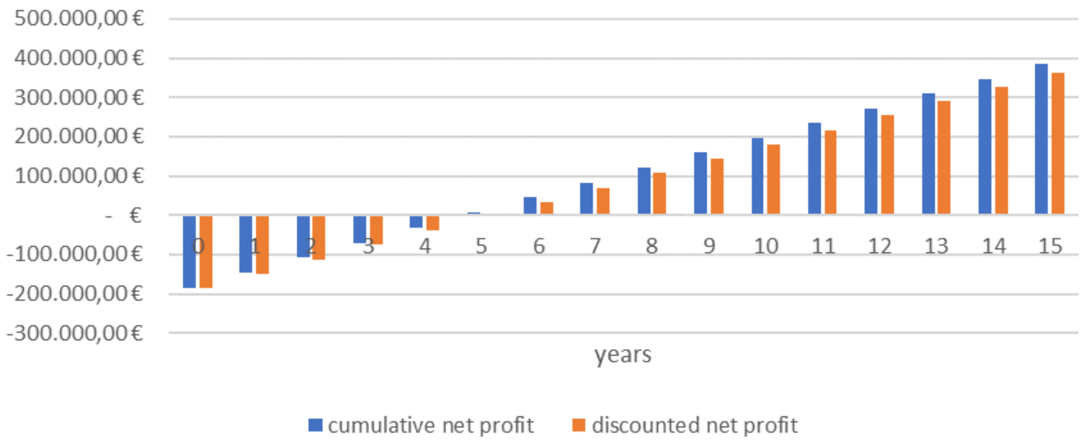

Figure 3. Cumulative net profit and discounted net profit

Such a small difference can be explained by the relatively small investment in such a micro CHP facility. The results indicate that the monetary risk is minimal for the potential investors. This is an important result as it further supports the usage of renewable energy and decarbonization of heating and electricity sectors in residential buildings.

Other key results include the NPV and the IRR. The NPV for the analysed project was equal to 185 005 €, while the IRR was equal to 19.19%. Since the NPV is significantly higher than zero and the IRR is significantly higher than the discount rate of 6%, this investment can be positively evaluated.

4.2 Sensitivity analysis

In order to assess the dependency of the result with regard to the initial investment cost and operation cost of the facility, a sensitivity analysis was conducted. The value of IRR was assessed with respect to the two mentioned cost parameters. The value of both costs was assumed to vary between -50% and 50% of the initially considered value. The results of the analysis are presented in Figure 4.

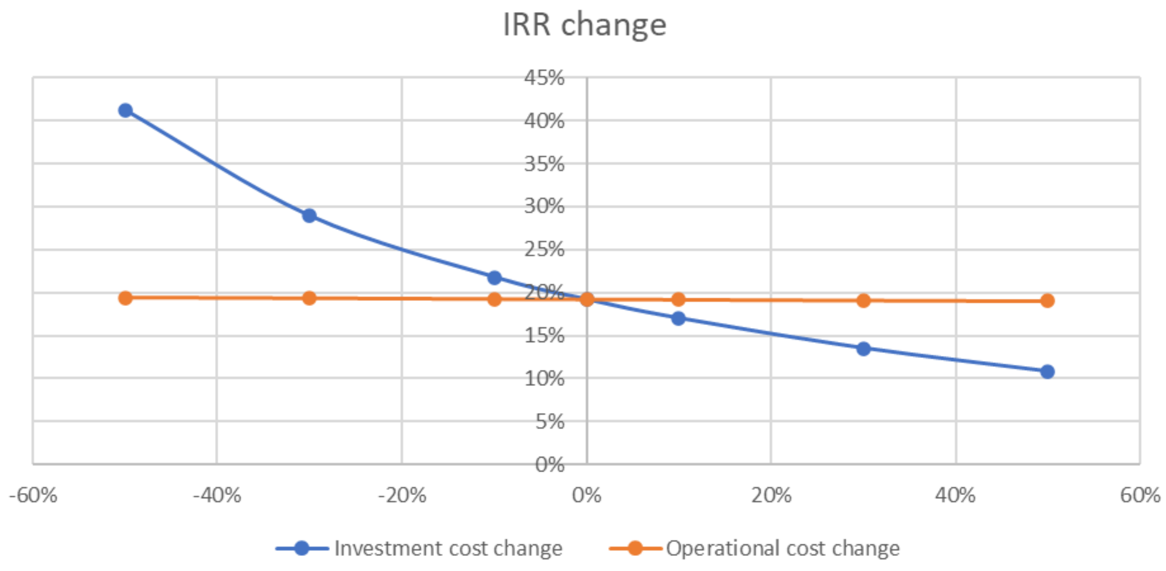

Figure 4. IRR values for different investment and operation cost

The results indicate that the value of IRR is significantly more dependable on the investment cost change than on the operational cost change. This is the expected result as the investment cost for this kind of facility represents the most significant expenditure. For the most optimistic case of investment cost value, the IRR was equal to 41.26%, while for the most pessimistic case, it was equal to 10.8%. It is clear that, even for the most pessimistic case, the investment in the micro-CHP for heating and electricity production would be feasible. This is a significant result as it further underlines the benefits of investing in the energy transition of buildings.

Moreover, for the most optimistic case of operational cost, the IRR was equal to 19.37%, while for the most pessimistic case, the IRR was equal to 19.01%. The results indicate that there is a difference of 0.36% in IRR value for different operational cost values. Although the difference is not significant, an important point can be derived from this result. Since the operational costs are primarily related to the fuel (biomass), this result indicates that the investor is not exposed to a significant risk of a biomass price increase. This is another confirmation that investments in renewable generation in buildings is a secure investment.

5 Conclusion

This paper presented a method for investment evaluation of micro-CHP facilities in the buildings. The case study was conducted in a public authority building in the city of Rijeka, Croatia. Several conclusions can be derived from the obtained results:

- The investment in micro-CHP for this case study paid off after 6 years of operation which indicates that the investment in biomass micro-CHPs represent a valuable solution for the energy transitions for such buildings
- The NPV and IRR values were equal to 185 005 € and 19.19% respectively. Since the NPV is higher than zero and IRR is higher than the considered discount rate of 6%, the investment is positively evaluated
- The sensitivity analysis with respect to the investment and operation cost showed that the investment is still positively evaluated even when these costs are assumed to be 50% higher which indicates that potential investors are exposed to low risk when making this kind of investment

The overall results of the study indicated that the biomass micro-CHP solutions represent a viable solution for the energy transition of buildings. Furthermore, the investment in biomass micro-CHP represents a low-risk investment making it more attractive for potential investors. Further research will concentrate on a more detailed financial analysis of the proposed technology, as well as similar technologies such as Waste to Energy that has also proven as a viable solution for the energy transition of buildings.

Acknowledgement

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