

CASE POKUPSKO IN CROATIA

Background

This study is part of an IEE (Intelligent Energy Europe) project called Woodheat Solutions (IEE/07/726/SI2.499568). Woodheat Solutions (WhS) aims to inspire investment in wood-based heat (and CHP) generation particularly from undermanaged forest. The project plans to transfer best practise from experinced EU Member States, namely Finland and Austria, through demonstration of case studies, training, engagement events and one to one support. The project will establish a network for long-term co-operation on biomass energy, offering tools and support that can be applied across the EU.

The municipality of Pokupsko (about 3,000 inhabitants) together with the North West Croatia Regional Energy Agency (REGEA) initiated a project of building a biomass district heating system in the town center. The project is currently in a planning stage with main permits obtained (e.g. building permits).

The project is planned to be financed by the IPARD program (5. Component of IPA instrument for Pre-accession Assistance) that has 958,000 €available as grants for municipalities and small towns having no more than 10,000 inhabitants.

Fuel availability and costs

The North-West Regional Energy Agency (REGEA) has estimated that there would be about **4,000 tonnes of wood chips** available annually from local forests within a reasonable trasport distance of 50 km. A government forest agency would sell wood chips at a set price of 35 €/tonne on the forest road side.

VAT is 23% of the fuel price, thus being 8.0 € Transportation cost has been calculated to be 10 €/tonne for 50 km distance. On the other hand, fuel will be available within 10 – 50 km radius from the plant. It is assumed in these calculations that an average transportation distance is 30 km, and its cost is linear in comparison with the given costs from 50 km distance. Therefore, the average transportation costs will be 6 €/tonne. Finally, the fuel price at the biomass plant is 35 + 8 + 6 = 49 €/tonne. Average fuel moisture content is 35%. Assuming that the heat value on a dry

basis is 19 MJ/kg, these figures result in 11.5 MJ/kg in heat value on a wet basis. This is equal to 3.2 MWh/tonne, and finally the fuel cost at the plant is **15.3 €/MWh**.

Annual energy consumption and fuel demand

According to REGEA there would be 10 groups of customers including municipal, public and commercial buildings and households. Their total annual heat consumption was estimated to be **2,100 MWh**. In addition it is assumed that the total efficiency in heat production will be 80% including boiler and network losses, 18 and 8%, respectively. This means that the annual fuel demand in terms of MWhs will be $2,100\text{MWh}/0.74 \sim 2,800 \text{ MWh}$.

Preliminary techno-economic assessment of three options for biomass boiler plant

Same assumptions for heat consumption and its periodic variation have been used in all described options. Figure 1 shows how many hours a year the heat consumption is higher than any selected value of the boiler output. For instance, the consumption is higher than 60% of its maximum during about 1,300 hours. Or correspondingly, the consumption is higher than 40% of the maximum about 3,800 hours. Figure 1 can be used to calculate annual total and average energy consumption, if the peak load is known. The surface area under any selected period of time represents energy consumption during that particular period of time. For instance, if the peak load is known to be 1 MW (100% boiler output), the heat consumption during the first 2,000 hours in the figure would be roughly $0.75 \text{ MW} * 2,000 \text{ h} = 1,500 \text{ MWh}$. Where 0.75 MW is the average consumption during the first 2,000 hours. Further on, the average annual energy consumption can be calculated by integrating the whole curve and dividing it with the number of hours in one year (8,760 h). This integration yields 0.38 MW as annual average consumption (38% of the maximum) and the annual total energy consumption $\sim 3,300 \text{ MWh}$.

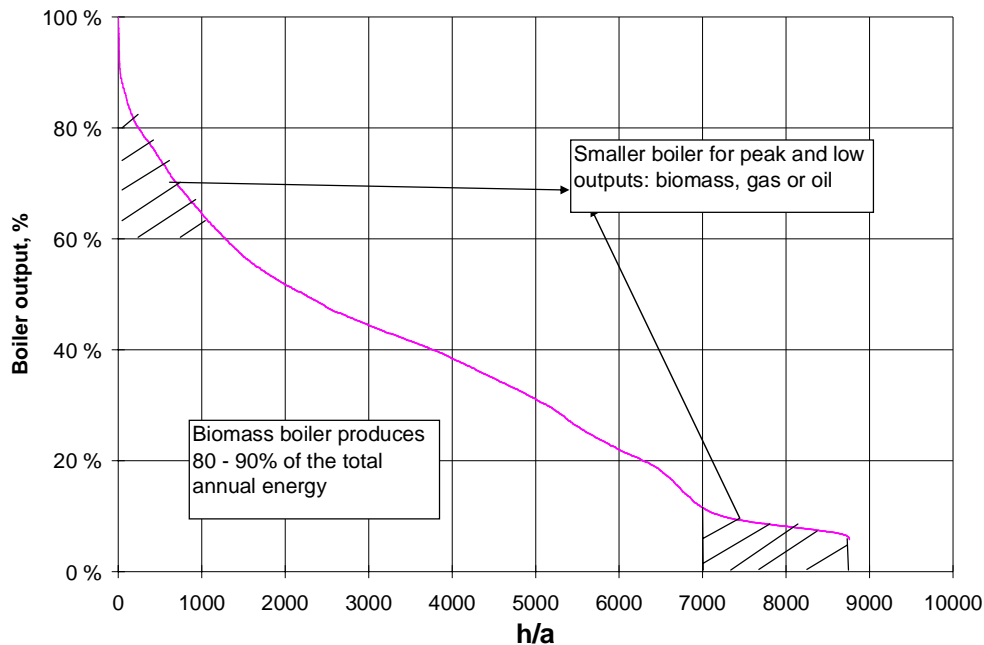


Figure 1. Heat consumption as a function of cumulative operating hours.

The size of the boiler is reasonable to choose to be clearly less than the peak load of the year. Firstly, the boilers normally do not work properly if the load is less than 20% of its maximum output, and consequently another boiler should be in use for such loads. Secondly, the investment cost will be significantly lower. Figure 1 shows an example when boiler's maximum output has been selected to match with 60% of the peak load of the energy consumption. In this case, if the maximum heat consumption load would be 1 MW as mentioned, the boiler's maximum output should correspond to 0.6 MW. Taking into account the 8% network losses, the boiler maximum output should be $0.6/0.92 = 0.65$ MW. The line-filled areas in Figure 1 represent the annual amount of energy that has to be produced using back-up boiler or other means. That amount is normally only 10 – 20 % of the total, as indicated in Figure 1. An oil boiler for instance can be used for that purpose. In this case, oil boiler's capacity should be at least $0.4/0.92 = 0.43$ MW (network losses taken into account). Investment for such an oil boiler is many times lower than if the biomass boiler's capacity would have been chosen to be $1/0.92 = 1.1$ MW. These savings in the investment costs can usually easily offset the increased fuel costs due to oil use. In addition, running the boiler plant will be technically much easier.

The before-mentioned concept is widely in use in Finland, and Figure 1 is valid for the heating and hot water production in the climate of southern Finland, where heating season is normally about 7 months. It can be employed with relatively good accuracy in the following calculations.

Option 1: One biomass boiler 400 kW and one new oil boiler 700 kW

Annual energy consumption was estimated above, being 2,100 MWh. Annual average consumption would be therefore $(380/3,300)*2,100 = 240$ kW (compare the example above where 1 MW maximum output and 3,300 MWh annual consumption resulted in 380 kW average output). Taking into account the network losses (8%), the average boiler load would be $240/0.92$ kW = **260 kW**. Given that this would be about 38% of the maximum load (see the example above), the peak boiler load would be therefore $260/0.38$ kW = **680 kW**. Selecting the biomass boiler's maximum output as 60% of the maximum load, the biomass boiler output should be $0.6 * 680$ kW ~ **400 kW**.

There are already at least three oil boilers available for the network: at municipal building, culture house and elementary school. Their total capacity is obviously some hundreds kW, and could perhaps supply enough heat to the network with the biomass boiler during the peak load. The need is $680 - 400$ kW = 280 kW. Since there is no certainty about their condition, and on the other hand, the whole heating system needs a back-up, it is necessary to buy also a new oil boiler that can back-up the whole network. Its capacity has to be therefore at least 680 kW. Investment costs for the new boilers including fuel storage, foundation, building, unloading and conveyors are according to discussions with boiler manufacturers:

- Biomass boiler plant 400 kW: 350,000 €
- New oil boiler 700 kW: 100,000 €
- 1.2 km district heating network: 500,000 €

Total investment costs would be therefore 950,000 € Following parameters has been used in annual costs calculations:

- Share of biomass and oil in annual energy use are 85 and 15%, respectively
- Interest rate is 8 %
- Investments will be paid in 10 years

- Annual labour costs have been calculated according to 1.0 man year for the biomass boiler and 0.2 man year for the oil boiler(s)
- Labour costs 800 €/person/month
- Maintenance costs correspond to 2 % of the boiler plant and network investment and 4 months labour per year
- Fuel prices: biomass 15.3 €/MWh, fuel oil 72 €/MWh,
- Losses: bioboiler 18%, oil boiler 10% and heating network 8%
- Total cost as supplied to the customers without taxes and profit

The annual costs are shown in Table 1. Third column shows a comparison, if only new 700 kW oil boiler and heating network would be invested and used with the existing boilers.

Table 1. Annual energy costs: biomass boiler 400 kW fuel oil boiler 700 kW.

| Costs, €/year | Biomass boiler plant: biomass 85%, oil 15% | Oil boiler plant: Fuel oil 100% |
|-------------------------|---|--|
| Investment | 142,000 | 89,500 |
| Labour | 11,500 | 1,900 |
| Fuel | 65,600 | 189,000 |
| Maintenance and service | 22,200 | 15,200 |
| Electricity | 2,400 | 1,100 |
| Total | 244,000 | 297,000 |
| Cost, €/MWh | 116 | 141 |

Table 1 indicates that biomass boiler plant could supply heat at a significantly lower cost than oil-based system. It does not include the investment grant. If the investment grant could cover

the whole investment 950,000 €, the annual total costs for the biomass boiler plant option would be only **101,700 € (48 €/MWh)**.

Option 2: Like option 1 with water heat buffer

This option is basically the same as option 1 but in addition, a heat buffer will be purchased. The heat buffer is sized to be able to supply heat 20 hours at peak load 0.7 MW. Its capacity is thus 14 MWh. It is assumed to operate within 30 °C temperature range, for instance from 90 to 60 °C. This means that its size should be:

$$V = 14 * 3,600 / (30 * 4.18) \text{ m}^3 = 400 \text{ m}^3$$

Its price is 90,000 € according to information from manufacturers. Thus the total investment costs would be 1,040,000 €. Table 2 shows the annual energy costs in this option. The total costs would increase about 6% because of the buffer investment. However, it has not been taken account that the heat buffer could enable better and easier operation of the whole system and would bring about some savings also. For instance, for weekends or low load periods the buffer could be loaded and the boiler could be stopped and consequently labour costs saved. In addition, it would enable to run boiler with more stable output and consequently with a higher boiler efficiency and savings due to that. Finally, oil use could be decreased since during peak and low load periods heat could be taken from the buffer instead of running oil boiler(s).

Table 2. Annual energy costs, biomass boiler 400 kW without and with heat buffer.

| Costs, €/year | Biomass boiler plant: biomass 85%, oil 15% | Biomass boiler plant with heat buffer |
|-------------------------|---|--|
| Investment | 142,000 | 155,000 |
| Labour | 11,500 | 11,000 |
| Fuel | 65,600 | 65,600 |
| Maintenance and service | 22,200 | 22,200 |
| Electricity | 2,400 | 2,400 |
| Total | 244,000 | 258,000 |
| Cost, €/MWh | 116 | 122 |

Again if the investment grant would be 950,000 €, the project owner should invest 90,000 €. In this case the annual total costs would be **115,000 € (54 €/MWh)**.

Option 3: Two biomass boilers (500 and 200 kW) and one new oil boiler 700 kW

In this option, investment costs are estimated:

- Biomass boiler plant 500 + 200 kW: 550,000 €
- Additional oil boiler 700 kW: 100,000 €
- 1.2 km district heating network: 500,000 €

Total investment costs would be 1,150,000 € in this option. Same parameters have been used in annual costs calculations as in the option 1 excluding that:

- Share of biomass in annual energy use is practically almost 100% (oil just for back-up)
- Annual labour costs have been calculated according to 1.4 man year for the biomass boilers and 0.2 man year for the oil boiler(s)
- Maintenance costs correspond to 2 % of the total investment and 6 months labour per year

The annual costs would be in this option about 17,000 € higher than in the option 1, see Table 3.

Table 3. Annual energy costs: biomass boilers 500 and 200 kW and fuel oil boiler 700 kW for back-up only.

| Costs, €/year | Biomass boiler plant: biomass 85%, oil 15% | Biomass boiler plant: biomass 100% |
|-------------------------|---|---------------------------------------|
| Investment | 142,000 | 171,000 |
| Labour | 11,500 | 15,400 |
| Fuel | 65,600 | 40,200 |
| Maintenance and service | 22,200 | 27,800 |
| Electricity | 2,400 | 3,000 |
| Total | 244,000 | 257,000 |
| Cost, €/MWh | 116 | 123 |

Now if the investment grant would be 950,000 € the project owner should invest 200,000 € In this case the annual total costs would be **116,000 € (55 €/MWh)**.

Conclusions

Different options for Pokupsko's new boiler plant and heating network investment were studied and compared. The most cost-effective option seems to be option 1: investment for 400 kW biomass boiler, 700 kW oil boiler and 1.2 km heating network. In such case the heat production costs would be 116 €/MWh without any investment support and 48 €/MWh with 950,000 € investment support. However, the authors would recommend option 2 instead of option 1 for Pokupsko because the heat buffer could enable better and easier operation of the whole system and would bring about some savings too. This option is identical with the option 1 but it includes also investment for a 14 MWh heat buffer. As a consequence of the somewhat higher investment costs, the heat production costs without and with the 950,000 € investment support would be 122 and 53 €/MWh. However, these calculations do not include the effects of several minor factors



that would decrease the costs comparable with the option 1 (see details in the text above). In addition, the heat buffer would make the use of the boiler plant significantly easier.

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