A follow up visit of Finnish experts to Croatia

Woodheat solutions – IEE/07/726/SI2.499568

Jyrki Raitila, VTT

Veli-Pekka Heiskanen, VTT

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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Keywords Woodheat, entrepreneurship, district heating

Abstract

Finnish woodheat experts of VTT visited Croatia in order to advice on three woodheat projects supported by the Woodheat Solutions project.

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. There were three options for using biomass for district heating under consideration. It is recommended to choose option that suggests one 400 kW biomass boiler with one new 700 kW oil boiler as a backup with a hot water accumulator tank because the hot water accumulator would enable better and easier operation of the whole system and would bring about running costs savings due to higher efficiency of combustion when the boiler is used.

Promming Ltd. was founded in 1990 as a small metal workshop. In about 20 years it has grown into a leading manufacturer of equipment in Croatia for shops, warehouses and stores. Currently the company is actively increasing the use of biomass for its own energy need. Also it wants to enlarge business into supplying wood fuels and woodheat for others, e.g. municipal buildings.

Installing the ORC power generator at the premises of Promming was discussed. Linking the ORC with the existing heating system seems feasible. About 800 kW of excess heat would be generated available for other purposes.

A pre-feasibility study of possibilities of installing biomass district heating and CHP systems in the town of Lepoglava was done by OKit consulting and engineering company (Zagreb) in 2007. This study was discussed and commented on during and after the visit.

Investments for a new 16 MW biomass CHP boiler plant were studied and compared with an option that no new boiler investment will be made but the heating energy will be produced with the existing gas boilers. This comparison showed that the investment in the biomass CHP boiler plant would be very profitable.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

General

Finnish woodheat experts from VTT visited Croatia in order to provide their expert support to woodheat projects chosen by local project partners. These projects were/are being delivered by participants of WP2 and 5 or others made known to the project partners.

Experts gave advice to these projects on the manner new technologies can be introduced and how the economics of new wood fuel supply chains can be optimized. Also contracts to sell heat, plans to store wood fuels and development of local woodheat markets were reviewed. In general, by visiting potential woodheat sites and investors and woodfuel suppliers the projects were to be advanced and barriers resolved.

The project partners in each country had chosen very promising projects that have potential to develop quickly if suitable investors can be found and required permissions can be obtained. Each partner had widely informed the possibility for an expert visit through their existing network and by different activities (e.g. engagement seminars) done in previous work packages. Eventually the hosting partners together with Finnish experts chose the projects from among those that expressed interest for such a visit and that could benefit most from it.

In general, it seems there is more need to give advice to and comment on technical issues than to advice woodfuel supply chains because of a lack of experience of wood boilers and wood fuel heating systems. Woodfuel supply is often done by suppliers of round wood, and therefore their methods are usually professionally developed. On the other hand, in most cases there was a local supplier of wood fuels already. Thus different supply issues were settled unless specifically addressed in the studies. Therefore the focus of the expert visits was on technical matters like choosing a right kind of boiler, sizing it, and planning of the storage. Yet costs and necessary investments were discussed too.

Finnish experts, Mr. Veli-Pekka Heiskanen and Mr. Jyrki Raitila, visited several potential woodheat sites and agreed to advice to and/or comment on these cases as stated in the project plan. The contents of each study are based on information provided by local stakeholders and project partners. These studies reflect on what was asked for in particular. The Finnish experts also provided support for the greatest needs at this stage of each project. The detailed case studies are included in separate document files and in the appendices.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Program in Croatia and Slovenia

Slovenia and Croatia were visited during the same trip in order to save time and travel costs. The program was as follows.

Monday 31 May 2010

18:40 Arrive in Ljubljana

Drive to Hotel Antunovic in Zagreb, Croatia.

Tuesday 1 June, 2010

(Host: Mr. Tomislav Starcic)

9:00 Pick up at hotel and meeting in Zagreb with the North West Croatia Energy Agency (Mr. Julije Domac and Mr. Velimir Segon, REGEA)

13:00 Visit Promming Ltd. and their woodheat project at Cakovec (Mr. Mihalj Novinscak, Mr. Tomislav Kralj, Promming Ltd.)

17:00 Visit Spa Sv. Martin (Mr. Tomislav Kralj, Promming Ltd., Mr. Sasa Gasparlin, Drvotrade Ltd.)

Stay over night at Sv. Martin

Wednesday 2 June, 2010

(Host: Mr. Tomislav Starcic, Croatia; Ms. Nike Krajnc, Slovenia)

9:00 Visit Lepoglava (project site: a large prison + municipal buildings) (Mr. Damjan Zupanic, Council of Lepoglava, Mr. Miljenko Zupanic, Croatian Forest Institute)

12:00 Border crossing at Dobovec, Slovenia, meet with Slovenian host

14:00 Meet with potential investors in Kozje (Mr. Andrej Kocman, Mayor, Mr. Damjan Čokec, Municipality of Kozje, Spatial and Environment sector, Mr. Janez Veržun, investor)

19:00 Arrive in Ljubljana

Stay over night at hotel Pri-Mraku

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Thursday 3 June, 2010

(Host: Mr. Tine Premrl)

9:00 Depart from Ljubljana to Cerkno

11:00 Meeting with potential investors in Cerkno (district heating system) (Mr. Jurij Kavčič, Mayor)

16:00 Arrive in Ljubljana at hotel Pri-Mraku

Friday 4 June, 2010

12:05 Depart to Finland

Another visit to Slovenia (in connection to a project meeting in Croatia)

Tuesday 9 November, 2010

(Host: Tine Premrl)

11:00 Arrive in Ljubljana

13:00 Meeting in Sentrupert with mayor Mr. Rupert Gole and Mr. Iztok Kovacic from the municipality of Sentrupert

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Summary of the visit to Croatia

The expert visit to Croatia revealed that there are only a few good examples of installed modern woodheat systems in Croatia. Also some promising cases have been slowed down by lack of investors, complicated support systems, inadequate legislation and heavy bureaucracy. However, our Croatian partners had chosen good cases to be advised to because they were all developed enough to have concrete plans. Some of them had pre-feasibility studies conducted as well. Therefore it was possible to have very fruitful discussions with potential investors and users of woodheat on one hand and relevant background information from municipal and regional authorities on the other. Comments and preliminary techno-economic assessments of the biomass utilization options were based on these visits and materials provided by project partners and people involved in each woodheat case.

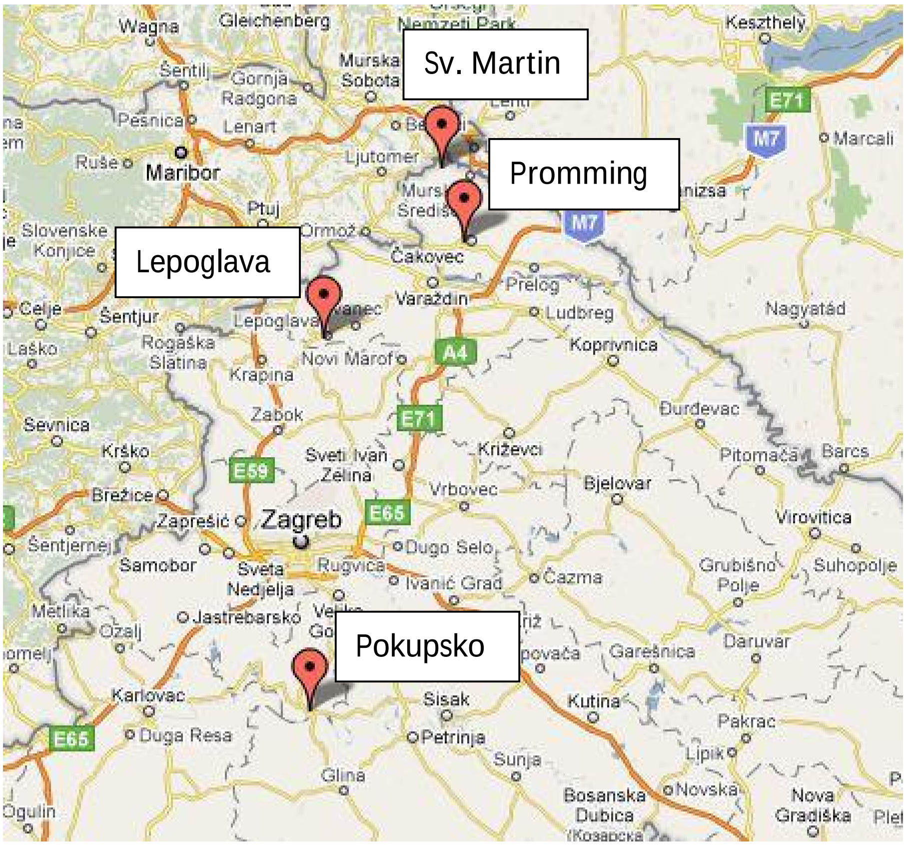

Figure 1: Location of woodheat projects adviced by Finnish experts.

Pokupsko

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.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

building permits). Finnish experts visited the office of REGEA and gained all needed materials for their study there.

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.

Three options for using biomass for district heating in the town center were considered: 1. One 400 kW biomass boiler with one new 700 kW oil boiler as a backup, 2. Like option one with a hot water accumulator, and 3. Two biomass boilers (500 and 200 kW) and one new 700 kW oil boiler as a backup. The most cost-effective alternative seemed option 1. In such a case the heat production costs without any subsidies would be 115 €/MWh and 47 €/MWh with available subsidies. However, it is recommended to choose option 2 because the hot water accumulator would enable better and easier operation of the whole system and would bring about running costs savings due to higher efficiency of combustion when the boiler is used.

Promming

Promming Ltd. was founded in 1990 as a small metal workshop. In about 20 years it has grown into a leading manufacturer of equipment in Croatia for shops, warehouses and stores. Currently the company employs 120 workers of which more than 100 directly in manufacturing processes.

Manufacturing of the products demands a lot of heat and power, e.g. for painting and drying of metal products. Due to rapid increase of fossil fuel prices Promming Ltd. invested in a thermal oil boiler mainly using wood chips and grinding dust as fuels. Wood chips are made of wood residues from own furniture manufacturing and roundwood available in the area.

The company has acquired 1.6 MW thermal oil boiler (KARA KTO 1350, made in the Netherlands) for heat production. The inlet and outlet temperatures of the thermal oil are 235 and 250 ^{0}C, respectively. Its maximum temperature is about 300 ^{0}C. The boiler output is clearly higher than what is normally needed for their production process. The boiler output is typically 0.6 – 0.7 MW for such a demand. Therefore the Promming company is considering to buy an ORC system for generating electricity in addition to heat production. They also want to sell excess heat to neigboring companies or to municipal buildings. They also consider a possibility to dry saw dust for pellet manufacturing with excess heat, and possibly start manufacturing wood pellets. In a long run they want to become a supplier of woodheat to other intallations, e.g. Sveti Martin spa, and a supplier of wood fuels for their own businesses.

All these aspects were considered and commented on while visiting the company. Because of limited cases (3) in Croatia experts chose to advice the plan to acquire a ORC unit for the Promming factory. Woodfuel supply chains were also addresses in discussions but no specific study was done, mainly because the company had already made a decision to set up a professional

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

woodfuel supply chain. They only needed confirmation for some details, e.g. type or make of machines to be bought.

If Promming Ltd. decides to install an ORC power generation to its existing thermal oil boiler, the ORC system can generate 150 – 180 kW of electricity. In addition, about 0.80 MW of excess heat will be produced. This heat can be used for drying saw dust in order to manufacture pellets after drying it. The excess heat enables 0.9 – 2.3 t/h pellet production depending on the moisture content of the wet wood entering the drier system. In addition, pellet production would consume 120 – 300 kW of electricity depending again on the moisture content of the wet wood and consequent production rate of pellets.

Lepoglava

A pre-feasibility study of possibilities of installing biomass district heating and CHP systems in the town of Lepoglava was done by OKit consulting and engineering company (Zagreb) in 2007. Finnish experts visited the town and discussed different possibilities of generating heat and power from biomass. Based on the visit and the pre-feasibility study of OKit they draw conclusions of the study and suggest some viable options for further development of the project.

Lepoglava is in the county of Varazdin in northern Croatia which has large woodland areas. According to the Agency for the Development of the Varazdin County (AZRA), there is about 50,000 m^3 of fuelwood (including firewood) directly from forests and about 8,000 m^3 of wood residues from local wood industry annually available in the vicinity of Lepoglava (<30 km). If neighboring counties are included (Krapina-Zagorje and Zagreb), the total estimated woodfuel potential is as high as 200,000 m^3. Because the possible district heating plant would need about 60,000 m3 (47,000 tonnes) of wood chips, it can be concluded that there is enough wood fuel resources available in the region.

In the study by OKit consulting and engineering company it was estimated that the total highest energy demand would be about 86,000 MWh (44,000 MW_{th} and 42,000 MWh_{el}). It is assumed that the new boiler would be running at full capacity (16 MW) 8,000 h/year. This study discusses four different biomass boiler plant options:

- Biomass boiler and steam turbine
- Biomass boiler with ORC system
- Biomass gasification and gas/steam turbine (Integrated Gasification Combined Cycles)
- CHP systems with gas turbines (ENITEH)

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

The third and fourth options are not proven, commercial-level technologies for biomass, and were therefore omitted. There are manufacturers of ORC systems for biomass boilers, but the biggest plants delivered so far are < 2 MW by power output. Therefore here only the first option was considered.

Investments for a new 16 MW biomass CHP boiler plant were studied and compared with an option that no new boiler investment will be made but the heating energy will be produced with the existing gas boilers. The use of the plant was fixed so that 4,600 h/year the boiler plant will be working in the CHP mode, and 3,400 h/year in the condensing mode. This was based on the heat consumption curve that shows that the consumption load is between 5 and 16 MW during the mentioned 4,600 h and only about 2 MW during the rest of the year (4,160 h). This comparison showed that the investment in the biomass CHP boiler plant would be very profitable. However, a more extensive study should be made in order to find most profitable combination of the boiler capacity, annual hours of the CHP mode use and annual hours of condensing mode use. In this study these were fixed, and therefore it is possible that there could be even a more profitable concept to use. This would need optimization for these parameters. In addition, hot water production and use could be still optimized also during the period when the biomass boiler is in the condensing mode.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Appendices (Woodheat projects)

CASE POKUPSKO IN CROATIA

Backgound

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**.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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 2,100MWh/0.74 ~ 2,800 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 MW * 2,000 h = 1,500 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 ~ 3,300 MWh.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

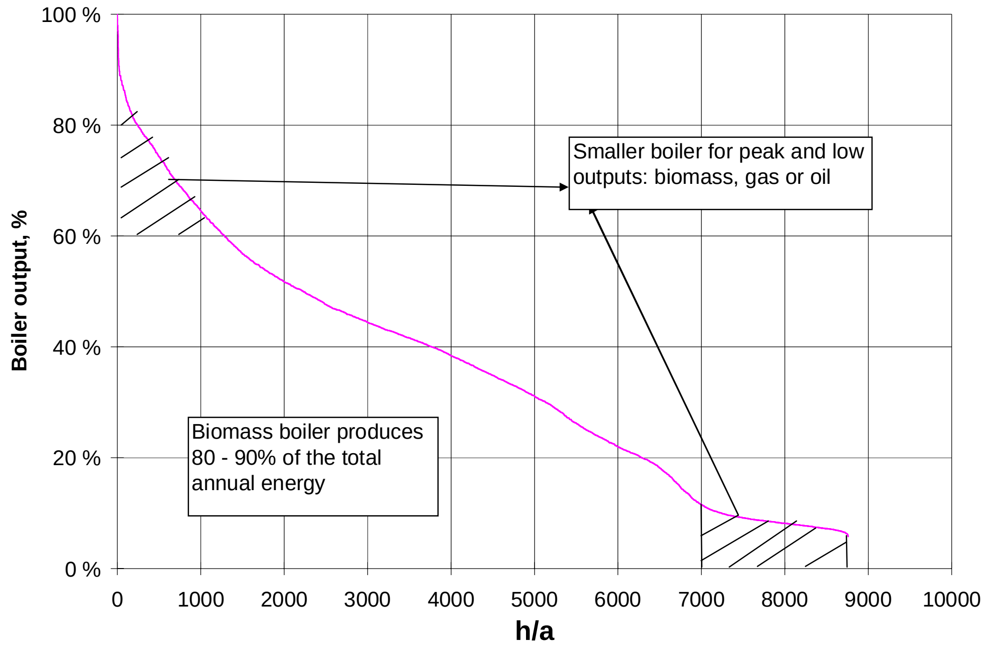

Figure 1. Heat consumption as a function of cumulative operating hours.

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.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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 utput). 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 kWs, 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: bio boiler 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)**.

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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 ^{0}C temperature range, for instance from 90 to 60 ^{0}C. This means that its size should be:

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

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).

VTT
P.O. Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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**	**257,000**
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	**240,600**	**257,400**
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 54 €/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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Jyrki Raitila
Research Scientist, M.Sc. (For.), MA
Technical Research Centre of Finland
Team Leader
Biomass Fuel Production
Tel. +358-40-7195117
Email: jyrki.raitila@vtt.fi

Veli-Pekka Heiskanen
Senior Research Scientist, Lic.Sc. (Tech.)
Technical Research Centre of Finland
Multifuel Operations
Tel. +358-40-547 8960
Email: veli-pekka.heiskanen@vtt.fi

CASE PROMMING IN CROATIA

Backgound

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.

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Picture 1: Experts visiting Promming Ltd. Photo: Jyrki Raitila, VTT.

Existing boiler and its connection to ORC cycle for power generation

The company has acquired 1.6 MW thermal oil boiler (KARA KTO 1350, made in the Netherlands) for heat production. The inlet and outlet temperatures of the thermal oil are 235 and 250 ^{0}C, respectively. Its maximum temperature is about 300 ^{0}C. The boiler output is clearly higher than what is normally needed for the production process. The boiler output is typically 0.6 – 0.7 MW. Therefore the Promming company is considering to buy an ORC system for generating electricity in addition to heat production.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

In order to calculate first how much energy can be transferred in thermal oil if the boiler is working within 235 – 250 ^{0}C range, the oil flow rate has to be known. According to the information from an oil pump manufacturer, pump capacity is 71 m^3/h. On the other hand, a typical density and heat capacity of thermal oil are ~ 750 kg/m^3 and 2.7 kJ/kg ^{0}C in the temperatures in question. On this basis it is possible to calculate that the thermal oil boiler could produce heat:

Picture 2: The heating system of Promming. Photo: Jyrki Raitila, VTT.

P = 71 * 750 * 2.7 (250 – 235)/3 600 = 600 kW = **0.6 MW**

This is practically the same output at which the boiler is normally working. If the boiler is working at its maximum output 1.6 MW using 71 m^3/h oil flow rate, the temperature rise in the boiler for transferring 1.6 MW heat would be:

ΔT = (1.6/0.6) * (250 – 235) = **40 ^{0}C**

Since the maximum temperature of the thermal oil should not exceed 300 ^{0}C, the process with ORC could work within the temperature range 250 – 290 ^{0}C, for instance.

Figure 1 shows an example where a thermal oil boiler runs ORC cycle using silicon oil as work fluid. Thermal oil temperature drops from 300 to 250 ^{0}C in the evaporator and silicon oil evaporates and heats up to almost 300^{0}C. Silicon oil temperature after the condenser is about 100 ^{0}C.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

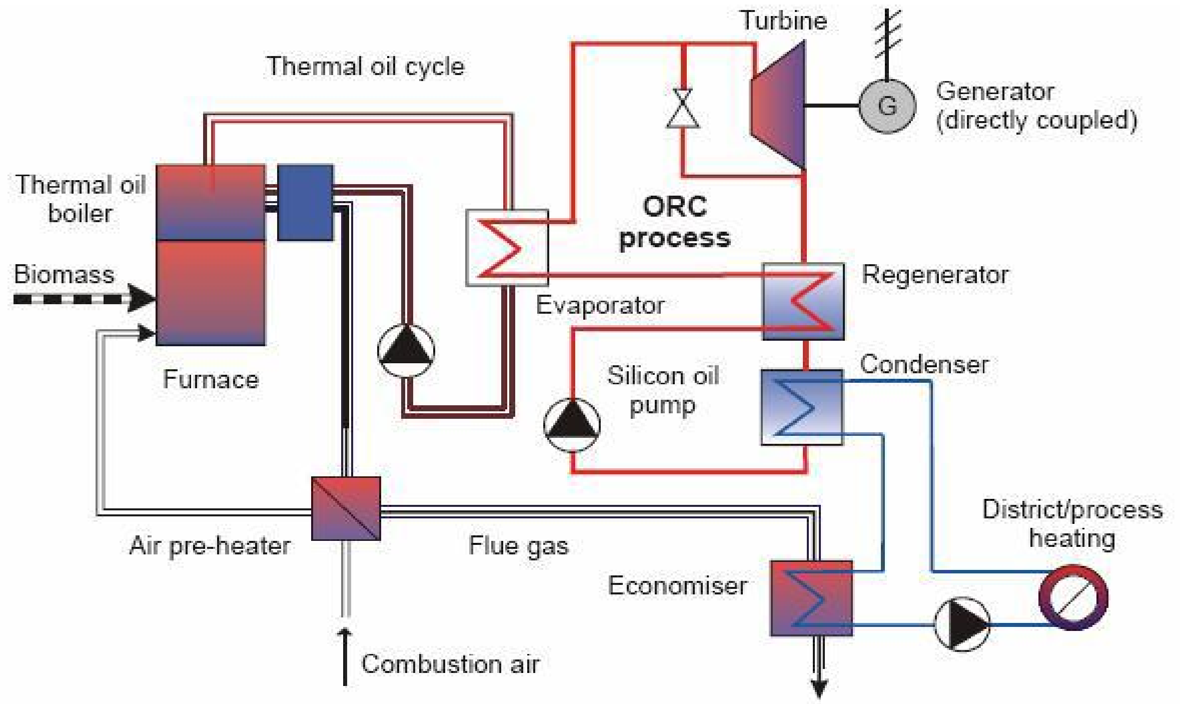

Figure 1. A schematic picture of an ORC system..

The process in Figure 1 could be applied with some modifications to the Promming case. The evaporator of the ORC system would be placed in the thermal oil cycle before the present boiler load 0.6 MW. In such a case the thermal oil would enter the evaporator in its maximum temperature 290 ^{0}C. The temperature drop in that stage would be 25 ^{0}C from 290 to 265 ^{0}C. The temperature drop to enable the present load should be 15 ^{0}C from 265 to 250 ^{0}C. The temperature drop in the evaporator would correspond to about 1.0 MW in terms of energy and the temperature drop for the present load would correspond to 0.6 MW. Taking into account that the power generation efficiency of ORC systems is typically 15 – 18%, it implies that about 0.15 – 0.18 MW of electricity could be generated and in addition to that, about 0.80 MW of heat in the condenser taking into account the losses in the cycle. This heat could be used for example for drying wood before pelletising it.

Wood drying capacity after ORC installation

If the excess heat 0.80 MW will be used for drying wood in order to produce pellets for instance, following amount of energy is required for every tonne of wood:

$$E = (1000 - (1000 - f_i * 1000/100)/((100 - f_d)/100)) * 2.44 \text{ MJ}$$

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Where f_i and f_d are moisture contents of wood before and after drying.

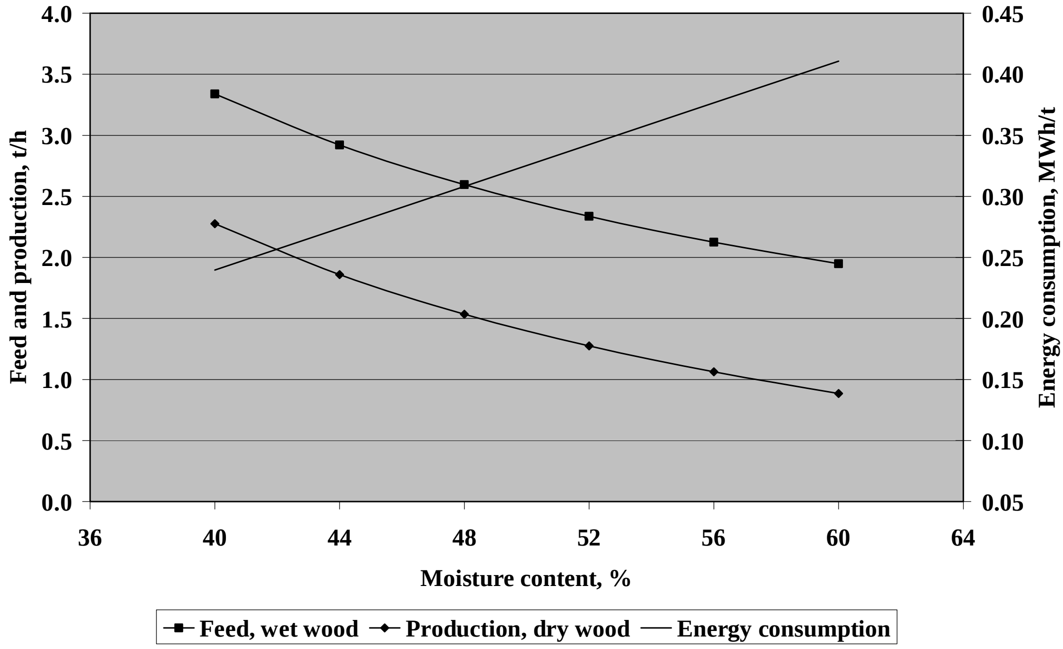

Figure 2. Feed, production and energy consumption in wood drying.

Figure 2 shows how much wet wood could be dried in an hour with 0.80 MW heat input and how much dry wood (moisture 12%) would be obtained. In addition, Figure 2 shows heat consumption per every wet tonne of wood. The overall efficiency in drying has been assumed to be 90%. If the fuel moisture would be 50% for instance, Figure 2 indicates that about 2.4 t/h of wet wood could be dried, yielding about 1.3 t/h of dried wood. Energy consumption would be correspondingly almost 0.33 MWh per every wet tonne. Figure 2 indicates also how strong effect the fuel moisture has on the yield. If the moisture is 60% instead of 40%, the yields are about 0.9 and 2.3 tonnes/h, respectively. Therefore it is extremely important to let the wood dry as much as possible in the forest or whatever place where it is stored.

If the dried wood will be pelletised, it would use electricity approximately 130 kWh/tonne, which accounts for 2.8% of the product's energy content. Further on, if the moisture content of the wet wood would be 50% for instance, its production rate would be 1.3 t/h (see Figure 2) and the corresponding power consumption 1.3 * 130 kW ~ 170 kW. In such case, the pellet production would consume practically all the electricity that ORC system generates.

Conclusions

If Promming Ltd. decides to install an ORC power generation to its existing thermal oil boiler, the ORC system can generate 150 – 180 kW of electricity. In addition, about 0.80 MW of excess heat will be produced. This heat can be used for drying saw dust in order to manufacture pellets after drying it. The excess heat enables 0.9 – 2.3 t/h pellet production depending on the moisture content of the wet wood entering the drier system. In addition, pellet production would consume 120 – 300 kW of electricity depending again on the moisture content of the wet wood and consequent production rate of pellets.

2.7. 2010 Jyväskylä

Jyrki Raitila
Research Scientist, M.Sc. (For.), MA
Technical Research Centre of Finland
Team Leader
Biomass Fuel Production
Tel. +358-40-7195117
Email: jyrki.raitila@vtt.fi

Veli-Pekka Heiskanen
Senior Research Scientist, Lic.Sc. (Tech.)
Technical Research Centre of Finland
Multifuel Operations
Tel. +358-40-547 8960
Email: veli-pekka.heiskanen@vtt.fi

CASE LEPOGLAVA IN CROATIA

Backgound

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 practice from experienced 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.

A pre-feasibility study of possibilities of installing biomass district heating and CHP systems in the town of Lepoglava was done by OKit consulting and engineering company (Zagreb) in 2007. Finnish experts visited the town and discussed different possibilities of generating heat and power from biomass. Based on the visit and the pre-feasibility study of OKit they draw conclusions of the study and suggest some viable options for further development of the project.

Fuel availability and costs

Lepoglava is in the county of Varazdin in northern Croatia which has large woodland areas. According to the Agency for the Development of the Varazdin County (AZRA), there is about 50,000 m^3 of fuelwood (including firewood) directly from forests and about 8,000 m^3 of wood residues from local wood industry annually available in the vicinity of Lepoglava (<30 km). If neighboring counties are included (Krapina-Zagorje and Zagreb), the total estimated woodfuel potential is as high as 200,000 m^3. Extensive management plans have been made and wood fuel exploitation assessment has been done for the region, as for the whole of Croatia. This assessment shows good balance with annual increment in the growing stock of forests. Wood fuel utilization plans and strategies have been made in a sound and sustainable way.

In this study it is estimated that the total maximum wood fuel demand of the plant would be 145,000 MWh equaling 46,800 tonnes (60,000 solid-m^3, 30-35 %-w) of wood chips. Thus it can be concluded that there is enough woodfuel resources available in the region. The price of wood chips in the study of OKit was only 13 €/MWh. However, in this study the price of 17 MWh was used based on other studies and interviews of local experts.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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

In the OKit study it was estimated that the total highest energy demand would be about 86,000 MWh (44,000 MW_{th} and 42,000 MWh_{el}). It is assumed that the new boiler would be running at full capacity (16 MW) 8,000 h/year. It is also assumed that the boiler would work in a CHP mode for 4,600 h, and in a condensing mode for another 3,400 h, and its maximum output would be 16 MW. In the CHP use the boiler would produce 11.8 MW of heat and 4.2 MW of electricity. In the condensing mode, the boiler would generate 6 MW of electricity. The annual heat and power productions are therefore (taking into account the network losses 8%):

- Heat 4,600 * 11.8 * 0.92 = 49,900 MWh
- Electricity 4,600 * 4.2 + 3,400 * 6.0 = 39,700 MWh

On the other hand, the annual heat demand is 44,000 MWh. The variation of the heat load within a year is presented in Figure 1.

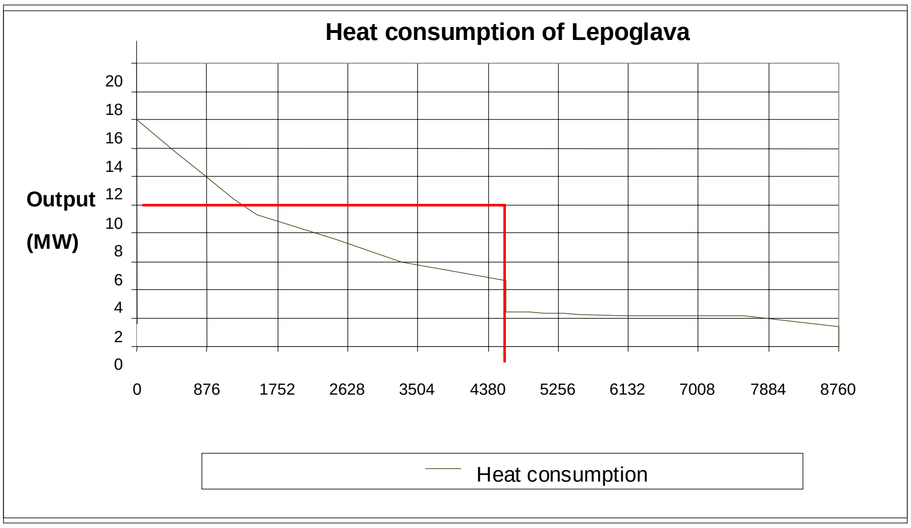

Figure 1. Heat load variation during one year.

Figure 1 indicates that if the boiler is producing heat 4,600 h/year at 11.8 MW output delivering 0.92 * 11.8 MW = 10.9 to the customers (network losses 8%), the heat load is higher than 10.9 MW about 1,100 h/year, and additional heat should be produced with the existing gas boilers. In addition, during the 4,160 h when the heat load (obviously only hot water and/or steam use) is about 2 MW, additional heat should also be produced with the existing gas boilers, since during that period the biomass boiler is running in the condensing mode (3,400 h) or is

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

maintained/serviced (760 h). The required additional heat production using existing boilers can be estimated from Figure 1. When the heat load is higher than 10.9 MW, about 2,800 MWh additional heat is required. When the heat load is about 2 MW, about 8,300 MWh additional heat will be needed. All in all, about 11,100 MWh of heat has to be delivered annually using the existing boilers.

Now the annual fuel demand and costs can be calculated:

- Biomass: 16 * 8,000/0.88 = 145,000 MWh that costs 145,000 * 17 €/MWh= 2,470,000 €
- Natural gas: 11,100/0.80 = 13,900 MWh that costs 1,390,000 m^3 * 0.3 €/m^3 = 420,000 €

It has been assumed in these calculations that the boiler losses are 12% for all boilers, and the network losses are 8% of the fuel input. Total fuel costs would therefore be 2,890,000 €.

The OKit study discusses four different biomass boiler plant options:

- Biomass boiler and steam turbine
- Biomass boiler with ORC system
- Biomass gasification and gas/steam turbine (Integrated Gasification Combined Cycles)
- CHP systems with gas turbines (ENITEH)

The third and fourth options are not proven, commercial-level technologies for biomass, and will therefore be omitted. There are manufacturers of ORC systems for biomass boilers, but the biggest plants delivered so far are < 2 MW by power output. Therefore here only the first option is discussed. The biomass boiler plants total output is as mentioned 16 MW. Such boiler plants investment cost is in a range of 15 – 25 million € according to the manufacturers. Therefore 20 million € is used here as an estimate for the investment costs. Table 1 shows the total energy production costs in two options. The production costs if the new biomass boiler plant will be invested and used are compared with the existing situation (existing gas boilers used to produce heat only). Following assumptions have been used:

- Share of biomass and gas in annual fuel use of the first option are 91% (145,000 MWh) and 9% (13,900 MWh)
- 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 plant and 0.2 man year for the gas boiler(s)

- Labour costs 800 €/person/month
- Maintenance costs correspond to 2 % of the boiler plant investment and 4 months labour per year
- Fuel prices: biomass 17 €/MWh, gas 30 €/MWh (0.3 €/m^3)
- Losses: boilers 12% and network 8% of the fuel input
- Total cost as supplied to the customers without taxes and profit

Table 1. Annual energy production costs.

Costs, €/year	Biomass boiler plant and existing boilers: biomass 91%, gas 9%	Existing boilers: gas 100% (heat/steam production only as presently)
Investment	**2,590,000**	**0**
Labour	**13,800**	**1,800**
Fuel	**2,900,000**	**1,650,000**
Maintenance and service	**407,000**	**3,100**
Electricity	**176,000**	**42,000**
Total	**5,090,000**	**1,700,000**
Cost, €/MWh	**73**	**39**

When comparing the figures in Table 1, it should be noted that in the first option the total energy production (44,000 MWh of heat and 39,700 MWh of electricity) is higher than in the second option (44,000 MWh of heat only).

Finally, Table 2 compares the profits in the two options. It has been assumed that:

- Electricity generated from biomass gets an incentive of 90 €/MWh

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

- Heat sales price is assumed to be 60 €/MWh
- Electricity sales price without an incentive is 158 €/MWh

Table 2. Profits from energy production (new biomass plant vs. existing system).

Revenue, €/year	**Biomass boiler plant and existing gas boilers: biomass 91%, gas 9%**	**Existing gas boilers: gas 100%**
Heat sales	**2,640,000**	**2,640,000**
Electricity sales	**6,270,000**	**0**
Support/electricity	**3,570,000**	**0**
Total	**12,480,000**	**2,640,000**
Annual costs	**5,090,000**	**1,700,000**
Annual profit	**7,390,000**	**940,000**

The comparison indicates that the investment in the biomass plant is clearly more profitable than just continuing to use the existing boilers because of the high incentive for electricity generated from biomass.

Conclusions

Investments for a new 16 MW biomass CHP boiler plant were studied and compared with an option that no new boiler investment will be made but the heating energy will be produced with the existing gas boilers.

This study discussed only the new biomass power plant option to produce energy and compared it with the existing system and energy production. The capacity of the new boiler plant was selected to be 16 MW. The use of the plant was fixed so that 4,600 h/year the boiler plant will be

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

working in the CHP mode, and 3,400 h/year in the condensing mode. This was based on the heat consumption curve that shows that the consumption load is between 5 and 16 MW during the mentioned 4,600 h and only about 2 MW during the rest of the year (4,160 h). This comparison showed that the investment in the biomass CHP boiler plant would be very profitable. However, a more extensive study should be made in order to find most profitable combination of the boiler capacity, annual hours of the CHP mode use and annual hours of condensing mode use. In this study these were fixed, and therefore it is possible that there could be even a more profitable concept to use. This would need optimization for these parameters. In addition, hot water production and use could be still optimized also during the period when the biomass boiler is in the condensing mode.

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Jyrki Raitila
Research Scientist, M.Sc. (For.), MA
Technical Research Centre of Finland
Team Leader
Biomass Fuel Production
Tel. +358-40-7195117
Email: jyrki.raitila@vtt.fi

Veli-Pekka Heiskanen
Senior Research Scientist, Lic.Sc. (Tech.)
Technical Research Centre of Finland
Multifuel Operations
Tel. +358-40-547 8960
Email: veli-pekka.heiskanen@vtt.fi

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111