APPLICATION FOR DISTRICT ENERGY AWARD

BIO-OIL PRODUCTION IN JOENSUU – A NEW TYPE OF TRIGENERATION CONNECTED TO EXISTING DH AND CHP

JOENSUU

Fortum

District heating, CHP and bio-oil production in city of Joensuu owned by Fortum.

1. MOTIVATION:

We are applying for award in category B, Expansion of district energy scheme to new sectors and areas.

The size of the system comprise existing district heating system, biomass fired CHP connected to district heating as well as new type of bio-oil production concept that is added to existing district energy system and CHP installation. The detailed description of district energy system and bio-oil production is presented in chapters 3 of this application. District energy system and bio-oil production in Joensuu are owned and operated by Fortum, the largest energy company in Finland. Fortum is fourth largest heat producer in the world. Fortum operates different types of district energy businesses in several countries in EU and also in Russia.

This application is made because we want to present a new type of concept to produce renewable bio-oil that increases utilization of existing DH and CHP system as well as expand district energy business to new markets and areas beyond traditional district energy businesses related to heating, cooling and electricity production. New bio-oil production is a great example about possibilities of district energy to utilize local biomass that otherwise would be unused. It makes visible how district energy systems can substitute traditional fossil fuels on the market by renewable fuels. It indicates that district energy have larger potential to reduce fossil supply and CO2 emissions in society.

One main target of this application is to reveal new business opportunities for existing district energy system and district energy companies. This new type of trigeneration increases profitability of the system as well as creates jobs, provides opportunities for other local businesses and generates welfare for whole county. We want to encourage every energy company to seek new opportunities for their existing district energy system and challenge them to think beyond their existing district heating or cooling businesses. This concept is a great example how district energy business can be enlarged to cover new market – in this case nationwide oil market.

This type of bio-oil production can be executed anywhere in the world. We presume that application creates awareness of opportunities to expand business to new sectors and areas. We believe that there are other similar sustainable business opportunities that could be added to traditional district energy businesses and those opportunities can be capitalized by new way of thinking and reshaped business definition. We hope that example presented in this application encourage DHC and CHP industry to seek new opportunities beyond their traditional businesses.

2. SUMMARY

Bio-oil production in city of Joensuu is new type of trigeneration concept that is added to existing district heating and CHP. It is a great example of expansion of district energy business to new markets and areas beyond traditional district energy scheme. Bio-oil production create another way to utilize and capitalize local biomass that otherwise would be unused. It provides profitable business opportunity for local district energy company as well as reduces fossil supply, cut CO2 emissions and decrease imported fuel dependency. It also increases utilization of existing district energy system and CHP plant.

PRF of district heating in Joensuu is equal to zero. District heat production is dominated by CHP (94 %) that is primarily fuelled by local biomass and also by local peat. Share of local fuels in Joensuu district energy system is 95 % and it will be 100 % next year. Current renewable share is 65 %. Current CO2 emission factor (2012) is 103 g/kWh and current yearly CO2 reduction by DH is about 120 000 tons. Bio-oil will lower CO2 emission factor close to zero by cutting yearly greenhouse gas emissions about 60 000 tons. Overall yearly CO2 reduction by trigeneration and entire district energy system in Joensuu will be 180 000 tons. SO2 emissions will be reduced more than 300 tons by bio-oil.

The productivity of DH and CHP is enhanced but bio-oil production has even larger positive impact on other local business like forestry and harvesting. Biomass chain for bio-oil production employs about 50 people. Alternative for bio-oil would be imported fuels when money would go out of the area and country. District energy system with new type of trigeneration provides the best heating option for DH customers, profitable business for Fortum and a lot of jobs around the area as well as enables to keep fuel expenditures in own county. Joensuu is a great example how district energy enables sustainable energy solution and generate welfare for entire area.

Joensuu plant is the first industrial scale bio-oil production that is integrated to CHP in the world. However, this type of bio-oil production can be executed anywhere in the world. New trigeneration concept enables expansion of district energy to new sectors, markets and areas.

3. BACKGROUND INFORMATION AND SYSTEM DESCRIBTION:

3.1 City of Joensuu and existing system:

Joensuu is a town located in Eastern Finland about 400 km away from Helsinki. It is the most Eastern town in European Union on European continent. Number of inhabitants are 75 000 and population in whole area is about 125 000 people. Joensuu has its own university and there are versatile economic activities. The most well-known international companies are John Deere Forestry and Abloy but there are also a large amount small growing new businesses such as IT startups. The European Forest Institute is located in Joensuu.

http://www.jns.fi

http://en.wikipedia.org/wiki/Joensuu

Joensuu has had district heating system since 1965. It has been growing steadily during the decades based on customers own willingness to select district heating on free heating market. Current number of buildings connected to district heating is 2350 and contracted capacity is about 330 MW. More than 20 000 homes are heated by district heating but nearly 50 % of district heating is sold to commercial buildings, public buildings and to industries. Heated floor area is about 35 million square feet (3.5 million m2). Current market share of district heating is about 80 % of total heating energy demand of Joensuu. Yearly heat sales is about 550 000 MWh.

System is still growing and the growth will continue in the future as well. Every year about 50 buildings are connected to system that provides about 5 MW additional contracted capacity. The growth of the system is based on customers own willingness to select district heating on liberalized heating market. The key for growth has been relatively low price and reliable heat delivery. Current energy price is 44.8 €/MWh that is less than half compared to variable cost of own oil boiler. District heating is available more than 99.9 % of yearly hours. District heating is the most preferred heating alternative on heating market in Joensuu.

Production is dominated by CHP (94 %) and the rest is produced by heat only boilers fuelled by heavy fuel oil. CHP is designed to produce 100 MW heat and 50 MW electricity and it is fuelled by local biomass and peat. Biomass is forest residue and waste components from wood industry. Without district heating and CHP that type of local biomass would not be used. More than 95 % of current DH and CHP fuels are local biomass or peat from less than 100 km away from Joensuu. CHP plant is originally built in 1986 but there has been several modernization investments. Number of heat only boilers is 10 and their capacity altogether is 270 MW. The age of heat only boilers varies between 3 and 30 years. The length of network is 205 km and volume is 7300 m3. Average age of pipelines are about 25 years.

Picture 1. Typical biofuel of CHP plant in Joensuu.

Customers (buildings)	**2350**
Contracted load	**330 MW**
Market share	**80 %**
Heated floor area	**35 million sq ft**
Yearly heat sales	**550 000 MWh**
CHP production capacity (heat/el)	**100 MW / 50 MW**
CHP heat production	**560 000 MWh**
CHP electricity production	**240 000 MWh**
HOB heat production	**40 000 MWh**
Share of CHP heat	**95 %**
Share of renewable heat	**65 %**
Number of HOB plant	**10**
HOB capacity	**270 MW**
Length of network	**205 km**

Table 1. Key factors of current Joensuu district energy system.

3.2 New bio-oil business:

Bio-oil production is based on fast pyrolysis technology. Fast pyrolysis is the way of converting biomass into liquid fuel. In fast pyrolysis, biomass is heated quickly in the absence of oxygen to yield a liquid, gaseous and solid phase. The main advantage of pyrolysis oil (later bio-oil) is logistical advantages, which result from a higher energy density compared with wood chips. Bio-oil has, for example, 2.5–3.5 times higher energy density than Softwood.

Bio-oil production will be integrated to existing CHP plant. Concept is a new type of trigeneration where third product is added to existing CHP plant. Heat production of CHP plant is primarily delivered to district heating network but whenever district heat demand is low, surplus capacity can be used for bio-oil production. Plant is designed to use forest residues and other local wood based biomass. Trigeneration increases utilization of CHP plant as well as usage of local biomass that otherwise would be unused. Joensuu bio-oil plant will produce 50,000 tons bio-oil every year that is equal to 200 000 MWh. Trigeneration plant in Joensuu is shown in Picture 2.

Picture 2. Trigeneration plant in Joensuu.

Principle of pyrolysis process is relatively simple. First, logging residues are chipped and dried in a dryer using district heat, steam from the CHP plant and waste heat from pyrolysis process. Then the chips are crushed into small particles and fed into a reactor where they generate vapour, gases, aerosol and char. The heat needed in the pyrolysis process is transferred via hot sand from a fluidised bed boiler, and the sand is then returned to the boiler. Bio-oil is formed when vapour, gases and

aerosol condense in a scrubber. Fast pyrolysis also yields co-product gas because not all gases condense in the scrubber. Co-products coke and uncondensed gas can be fully utilized in CHP boiler. The principle of pyrolysis process is shown in Figure 1.

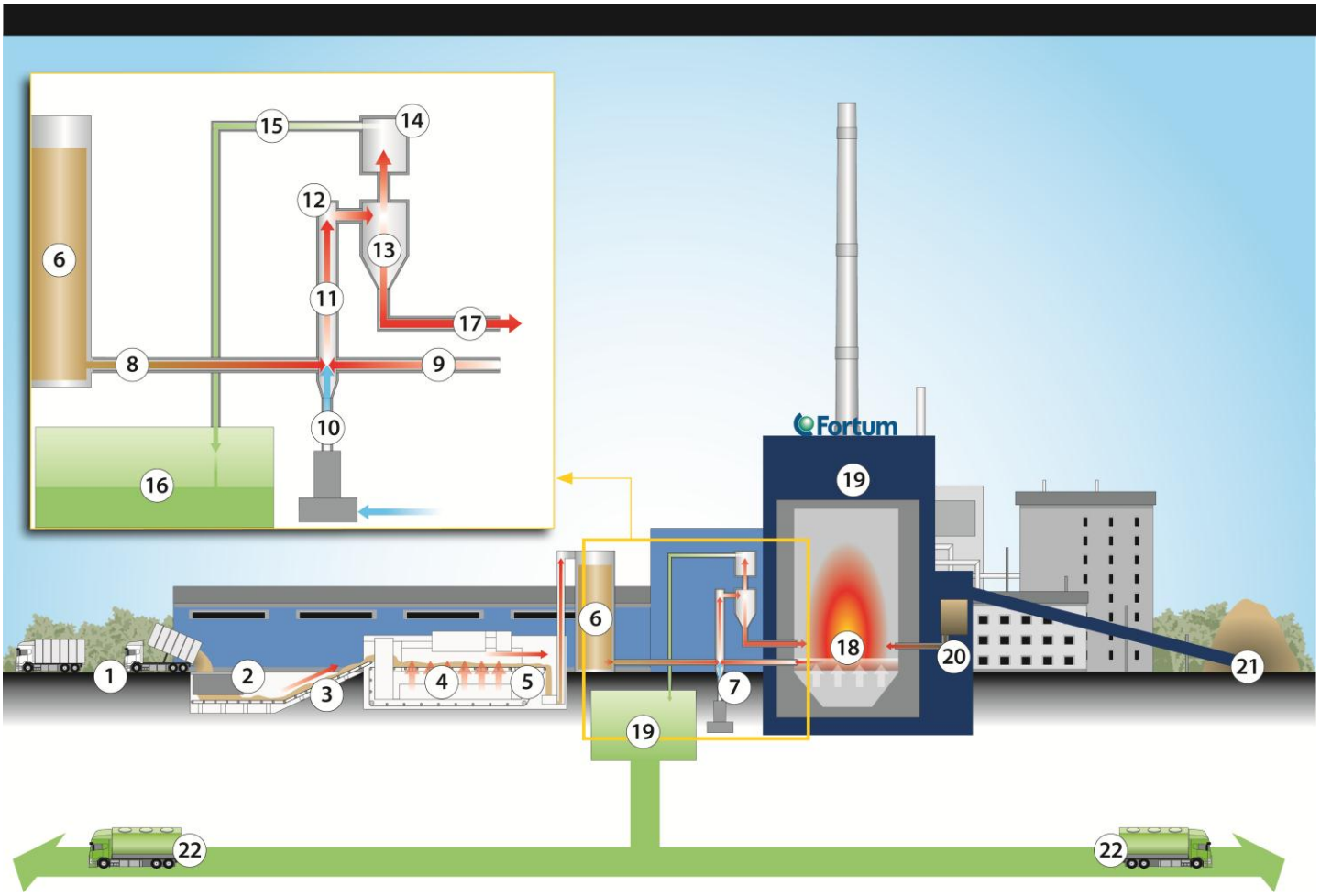

Figure 1. Principle of pyrolysis process connected to CHP. Key elements are following:

1-5) Feed in and drying of biomass
6-14) Pyrolysis reactor that consist of fuel silo (6&8) hot sand feeding (9), reactor (10-12), cyclone (13) and condenser (14)
15-16 & 19) Bio-oil storage tank
18-20) Existing CHP plant including fluidized bed boiler and other components
21) CHP fuel input
22) Transportation to bio-oil customers

Fortum has developed pyrolysis since 2001 when the first pilot was installed. The new technology is based on Technical Research Centre of Finland (VTT) IPR of integrated fast pyrolysis and has been developed in cooperation between Fortum, Metso, UPM and VTT as part of TEKES Biorefine research

program. Joensuu plant is the first of its kind in the world on an industrial scale. The construction work started in June 2012. The pyrolysis plant will be in commercial operation during the autumn 2013.

Picture 3. A turnkey contractor Metso's design about Joensuu trigeneration plant.

4. SYSTEM EFFICIENCY:

Current PRF, in other words fossil primary energy input divided by useful energy delivered to end use customers, is equal to zero for district heating in Joensuu. Calculation is made by Ecoheat4cities calculation tool by using Ecoheat4cities default values. Fuel consumption, production factors and energy delivered to customers are accurate measured factors from year 2012. The result calculation is negative because large amount of biomass in CHP plant and relatively large amount of CHP electricity that replace other electricity production on market. The result indicates that district heating in Joensuu does not generate any fossil fuel usage when whole energy chain and all the losses and benefits has been taken into account. Actually, overall impact for fossil supply is negative as shown in enclosed calculation sheets.

Pyrolysis will increase utilization of high efficiency CHP as well as replace fossil oil usage. Bio-oil production will improve PRF of system. However, it will remain zero because larger negative value is

still defined to zero. Yearly production information until 2011 including fuels, CHP electricity and other factors as well as energy delivery to customers can be found in district energy statistics of Finland. Statistics are provided by Finnish Energy Industry. PRF in Joensuu was equal to zero also in 2011.

PRF 2012	**0**
PRF 2014 (estimation)	0

Table 2. PRF of DH in Joensuu 2012 and estimation for 2014 with bio-oil operation

5. GREENHOUSE GAS EMISSION REDUCTION:

Current CO2 emissions for district heating in Joensuu is 103 g/kWh when calculation method is Ecoheat4cities and Ecoheat4cities default values are applied. Enclosed a copy of the calculation that is based on measured accurate factors from year 2012. However, result of Ecoheat4cities calculation tool is a slightly higher (143 g/kWh). There is no peat available in Ecoheat4cities calculation tool and therefore peat is replaced by lignite in calculation. The magnitude of CO2 emission factor is the same despite the calculation with lignite instead of peat. Both factors are relevant but tool "ClimateAward_Joensuu" reflects Joensuu system more accurately. When compared to heating based on light fuel oil, current yearly CO2 savings by DH and CHP are some 120 000 tons in Joensuu.

Bio-oil will lower yearly greenhouse gas emissions about 60 000 tons by replacing fossil oil. Emissions will be reduced either in Joensuu or in other towns when bio-oil is sold to other district heating companies. Bio-oil can be used in several industrial processes as well. Bio-oil production enables CO2 emission reduction beyond own DH system when bio-oil replace CO2 emission in other DH systems or industrial processes. Calculation "ClimateAward_Joensuu2014" reflects the CO2 emission when bio-oil production is in operation 2014. Biomass consumption has been increased as well as CHP electricity production. When taking into account CO2 reduction in other DH systems and industrial processes, total CO2 factor will be nearly zero. Overall CO2 reduction by trigeneration and entire district energy system in Joensuu will be about 180 000 tons every year compared to fossil oil usage.

CO2 2012 (accurate measured factor)	**103 g/kWh**
CO2 2014 (estimation)	65 g/kWh
CO2 2014 (fossil oil reduction elsewhere taken into account)	10 g/kWh
Current CO2 reduction (compared fossil oil)	**120 000 tons**
CO2 reduction 2014 (compared fossil oil, estimation)	180 000 tons
CO2 reduction by bio-oil (compared fossil oil)	**60 000 tons**

Table 3. CO2 emissions and yearly CO2 reduction for DH in Joensuu 2012 and estimation for 2014.

6. OTHER ENVIRONMENTAL BENEFITS:

Bio-oil will lower sulphur dioxide emissions more than 300 tons every year. It will have positive impact on local air quality. It also will have positive impact on air quality in areas where bio-oil will be used. Bio-oil also provides solution to HOB plants that would not otherwise fulfill the emission targets, especially SO2 emission target.

There are other possible bio-oil customers in the future. For example, shipping industry has been interested to switch heavy fuel oil to further refined bio-oil. Main driver for fuel switch is SO2 limits that are difficult to reach with traditional fuel oil. Another remarkable aspect is utilization of local fuels. When bio-oil production is in operation 2014, 100% of trigeneration fuels are local as well as fuels of entire district energy system in Joensuu.

RES share 2012	**64 %**
Yearly SO2 reduction	**320 tons**
Share of local fuels 2014	**100 %**

Table 4. SO2 reduction by bio-oil and some other key factors for Joensuu.

7. INNOVATION, including replicability:

CHP bio-oil production is new type of trigeneration where third production is combined to existing CHP plant. It expand district energy business to new market and also enlarge local district energy business to nationwide oil market. It is a new concept to utilize local biomass that otherwise would be unused and also a way to capitalize local biomass resources. It is a totally new way of defining district energy business to cover activities that traditionally has been out of district energy scope.

Heat production of CHP plant is primarily delivered to district heating network but whenever district heat demand is low, surplus CHP capacity can be utilized for bio-oil production. It fits to fundamental idea of district energy to utilize something that otherwise would be unused. Trigeneration increases utilization of CHP plant as well as usage of local biomass that otherwise would be unused. Heat is sold to DH customers, electricity is sold to Nordic market and bio-oil is sold to other heating companies or to process industry. Yearly bio-oil production will be 50 000 tons that will replace 200 000 MWh fossil oil. Naturally, oil can be used in Joensuu DH system as well for heat production. Bio-oil concept creates another component to district energy systems that can substitute traditional fossil fuels on the market by renewable fuels.

Trigeneration enhance economic performance of district energy system and provide new profitable business for energy company. The same idea and technology can be installed to any system where is local biomass available. Similar type of bio-oil may replace fossil oil in district energy systems and

industrial processes anywhere in the world. It is new market based way to cut emissions, increase share of renewable energy and decrease imported fuel dependency. Fortum is considering to install bio-oil production plants to other existing bio-CHP plants in Estonia, Finland and Latvia.

The new technology has been developed in co-operation between Fortum, Metso, UPM and VTT as part of TEKES Biorefine research program. Joensuu pyrolysis installation will be the first commercial bio-oil production plant in the world that is connected to CHP.

8. IMPACT ON COMMUNITY:

Bio-oil production provides healthy and sustainable business that increases productivity of existing district energy business. Turnover of bio-oil production is about 15 million euros yearly. However, impact of it is not limited to production. Largest influence is related to biomass fuel chain that cover all local forests maximum 100 km away from town. Biomass chain for bio-oil production employs about 50 people. Alternative for bio-oil would be imported fuels when money would go out of the area and country. District energy business enable to keep fuel expenditure in the area and it lower the usage of import fuels in other towns as well.

More than 95 % of current fuels in Joensuu DH and CHP are local. Next year when bio-oil plant is in operation, 100 % of fuels will be local. Actually, bio-oil production is 4 times larger than own oil usage in Joensuu. Therefore, most of bio-oil will be sold to other companies or used in other DH systems. The productivity of DH and CHP is enhanced but especially it has large positive impact on other local business like forestry and harvesting. It is a good example of healthy business for the area that is away from large cities. It provides the best heating option for DH customer, profitable business for Fortum and a lot of jobs around the area. Without district energy business and bio-oil production, local fuels would not be used, energy system would be less sustainable and local economic activities would be weaker.

This type of district energy business require co-operation between local forest owners, local harvesting industry, transportation companies, district energy company and local municipality. Everyone has their own interest to support local district energy business because it generates benefits to everyone. District energy and bio-oil are key elements for local welfare in Joensuu. It is also key for sustainable energy solution based on local renewable biomass.