Case study on Biomass use in CHP in Turku, Finland

Annex A.1 to Part 1 of the Study on the competitiveness of the renewable energy sector

ENER/C2/2016-501

28 June 2019

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Abstract

The European Commission aims to analyse the competitiveness of the European heating and cooling industry. Four case studies of successful and competitive deployment of heating and cooling solutions at a city level from selected organizations support this analysis. The case studies aim to illustrate how competitive renewable energy technologies such as solar-thermal, biomass, biogas and heat pump are in the context of different local factors across Europe, and what their impacts on local communities are.

The current case study is based on the desk search, field visit and interviews. It presents a multi-fuel combined heat and power (CHP) plant in the Turku region of Finland. The €240 million investment uses both biofuels as well as refinery gas, peat and coal to supply the heat to over 200,000 people in the Turku region.

1 Introduction

Finland is a country with temperatures varying from -30°C in winter and +30°C in the summer, thus having a considerable impact on the country's energy usage.[1] District heating is nowadays the most common type of heating in Finland and is available in almost all cities and urban centres. District heating accounted for 15.2 per cent of Finland's total greenhouse gas emissions in 2012 and in 2016 and 2017 both electricity and district heating production accounted for 43 per cent of all emissions in the energy sector.[2]

As regards the production of electricity, 47% was covered from renewable sources in 2017. Although nearly half of district heat production was based on fossil fuels in 2016, the use of renewable fuels (such as hydro power, wind power and wood-based fuels) increased by 7 per cent compared to the previous year. By contrast, in 2017 less than half of district heat production was based on fossil fuels and the use of renewable fuels increased by 6 per cent only from the previous year. Wood fuels accounted for 33 per cent of the production of district heat in 2017, followed by hard coal (23%) and peat (14%).[3]

Finland's forest resources provide good potential for increasing the use of biomass in energy production. As the emission factor of biomass in emission trading and greenhouse gas inventory is presently zero, increasing the energy use of biomass is an effective way of reaching the greenhouse gas goals.

The Government's national energy and climate strategy outlines that the use of coal in energy production will be prohibited by law in 2029.[4] At local level, the measures of the climate and environment program of the City of Turku aim at making it a carbon neutral city by 2029. The biggest reductions in GHG emissions is expected to be reached by increasing the share of renewable energy sources in district heating and electricity production, increasing energy efficiency in all operations and promoting sustainable modes of transport and mobility.

Naantali power plant was built by Fortum for pulverized coal fired condensing power production during the 1960s. At the beginning of the 1980s, units 2 and 3 were modified to combined heat and power (CHP) production. In 2011 a decision was made to merge energy production of Turku Energia and Fortum's local power plant into one company entitled Turun Seudun Energiantuotanto Oy (TSE) which produces heat and electricity for homes and process steam for the local industry (unit 4). The goal of TSE is to commit to the use of local and other sustainable sources of energy, while the longer-term strategic target is to pursue carbon-neutrality.

[1] Europe & Middle East Outlook (2015), TSE (TURUN SEUDUN ENERGIANTUOTANTO OY), https://www.emeoutlookmag.com/outlook-features/tse-turun-seudun-energiantuotanto-oy

[2] Statistics Finland (2018), National Inventory Report under the UNFCCC and the Kyoto Protocol, http://www.tilastokeskus.fi/static/media/uploads/tup/khkinv/fi_nir_un_2016_20180415.pdf and UNFCCC (2019), Finland 2019 National Inventory Report (NIR), https://unfccc.int/documents/194637

[3] UNFCCC (2019), Finland 2019 National Inventory Report (NIR), https://unfccc.int/documents/194637

[4] The International Atomic Energy Agency (2018), Country Nuclear Power Profiles Finland, https://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2018/countryprofiles/Finland/Finland.htm

Figure 1 TSE CHP Plant in Naantali

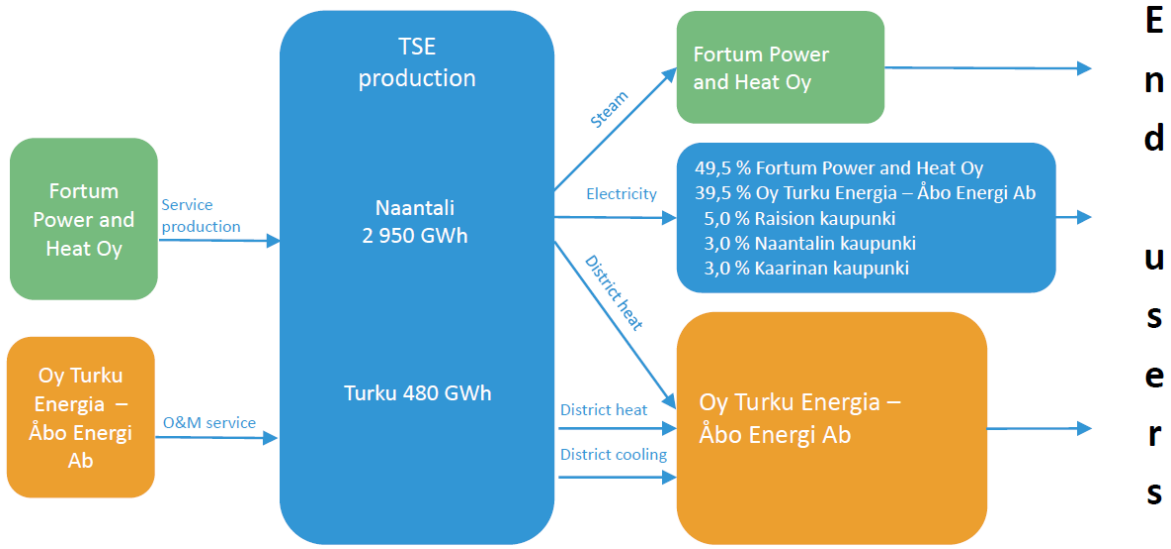
Source: COWI (2019)

The city of Turku and Fortum Power and Heat Oy entered into a long-term district heating contract for the Naantali power plant, which meant that all local district heating networks were connected, energy distribution and sales were centralized in one company (Turku Energia) and TSE became responsible for the energy production. The shareholding structure of TSE is the following: 49.5% is currently owned by Fortum (an energy company operating power plants), 39.5% by Turku Energia (energy company owned by the City of Turku), 5% by the city of Raisio, 3% by the city of Kaarina and 3% by the city of Naantali.

TSE energy production consists of:

- District heating and district cooling to Turku Energia (the company is responsible for district heat sales throughout the region)
- Industrial process steam to Fortum (the company is responsible for steam sales for the industry)
- Power to owners

Figure 2 TSE overview



Source: TSE

The capacity of the facilities at Naantali are 360 MW district heat, 60 MW steam power and 250 MW electricity. The heat is used primarily as district heat in Turku and surroundings. There is approximately 15 km of district heat transfer pipe running in a tunnel which carries district heat to users in Naantali, Raisio, Turku and Kaarina, thus covering about 85% of the residential areas in the region.[5] Over 200,000 people in the Turku region already live in homes receiving district heating produced by TSE. A small portion is used as process steam in industrial facilities.

Unit 4 in Naantali was commissioned in 2017 and uses both biofuels as well as refinery gas, peat and coal (multi-fuel power plant). A significant proportion of the fuel used is forest residues from nearby forests. About 600 GWh of biofuel is imported by sea (one shipment per week) from the Baltic Sea region (originating from Russia and Belarus).

2 Technology

The multi-fuel power plant in Naantali is one of the largest in Finland.[6] The engineering part of the project included architectural, structural, fire protection, as well as heating, ventilation, and air conditioning (HVAC), whereas the construction part included the construction of a steam turbine, boiler buildings, biofuel receiving station with automatic sampling system and A-frame storage facilities.

The steam turbine converts high pressure and temperature steam from the boiler into rotary motion. A generator coupled to the turbine shaft uses the rotary motion to generate electricity. Steam exiting the turbine is directed into district heat exchangers where it condenses and releases energy to produce district heat. High-pressure process steam is tapped from the steam turbine to be used internally in the power plant and to be delivered to customers.

[5] Europe & Middle East Outlook (2015), TSE (TURUN SEUDUN ENERGIANTUOTANTO OY), https://www.emeoutlookmag.com/outlook-features/tse-turun-seudun-energiantuotanto-oy
[6] Document sent by TSE to COWI

The plant is fully automatic and can be remotely controlled. On-site visits are only required to carry out maintenance. The expected technical life of the plant is several decades. The layout and structures of the plant allow for future development needs. The circulating fluidized bed technology (CFB) is used to gasify a range of low-quality forest residues which in return reduces operating costs.

3 Value chain

On average, 60 truckloads of biomass are transported to the Naantali power plant each day from maximum 150 km[7], and about 600 GWh of biomass is imported by sea (one shipment per week) from the Baltic Sea region. The biofuel reception conveyors carry materials such as chips, bark and peat onto screening belts at a maximum rate of 600 cubic metres an hour to a 15,000-cubic-metre storage. The storage holds about two days' worth of materials.[8]

The biomass fuel receiving end comprises three reception lines which convey biomass, such as wood chips, bark and peat, into two screening lines at a rate of 600 cubic metres per hour. The biomass, prepared into a suitable mixture on the reception lines, is reclaimed from the storage using two screw reclaimers.

Table 1 Value chain of the Biomass CHP plant

Inbound logistics	Operations	Outbound logistics	Sales	Service
Delivery of technology components (CFB boiler with steam reheat system, steam turbine, fuel receiving and handling and automation system).	Energy production consists of district heat and district cooling, industrial process steam and electricity (power). The multi-fuel power plant uses both biofuels as well as refinery gas, peat and coal.	Distribution to the network (15-km district heat tunnel). The DH network is owned by a company other than TSE.	85% of the population in the region uses the DH produced by TSE. Turku Energia Oy is responsible for district heat sales throughout the Turku region.	The final services are district heat and district cooling, industrial process steam and power.

Source: Authors' own elaboration

4 Local factors

Finland's goal is 38% renewable energy of end consumption by 2020, with forest chips covering a share of 25 TWh of electricity and heat production in 2020 (the largest growth objective amongst biomass and forest biomass).[9] While nearly 80 per cent of the electricity production is already emission-free in Finland, only 36 per cent of

[7] Interviews conducted by COWI with TSE representatives
[8] Document sent by TSE to COWI
[9] Ministry of Employment and the Economy (2014), Energy and Climate Roadmap 2050, https://tem.fi/documents/1410877/2769658/Energy+and+Climate+Roadmap+2050/9fd1b4ca-346d-4d05-914a-2e20e5d33074/Energy+and+Climate+Roadmap+2050.pdf

district heating uses renewable energy sources.[10] Taking into consideration the 2029 ban on coal, it is expected that the coal-fired district heat capacity will decrease from 2,055 MW to 1,100 MW by 2025, and to 480 MW by 2030.[11]

Combined heat and power production is an efficient way of generating energy. However, the low price of electricity and the reduced need for heating in new buildings have undermined the profitability of CHP production. As a result, less new investments in heating have been made in the past years.[12]

In order to increase the share of renewable and low-emission district heating production, the Government has made amendments to energy taxation and operating aid for forest chip electricity. Energy taxation is expected to provide an incentive for the primary use of forest chips and by-products.[13]

The Governmental support paid to forest chip electricity in 2015 amounted to EUR 33 million. 300,000 solid cubic metres of forest chips were imported by Finland in 2015, 80% of which being used for CHP production. The volume and share of imported chips is monitored regularly. However, the decisions to use either domestic or imported chips rest with the power companies. The report on the National Energy and Climate Strategy for 2030 mentions that new technology investments that produce district heating from renewable energy sources, such as large heat pumps, low-grade and industrial residual heat and solar heat, could be supported if the risks and costs associated with the technology are high and they cannot compete on a commercial basis.

Forest biomass will be crucial for Finland as a raw material for renewable energy, and the objective of the Finnish Government is for most of the forest-based energy to continue to be produced on market terms. Although the use of wood-based fuels will not be promoted by means of an aid scheme, such scheme will be needed for the use of forest chips in CHP production, the production of which depends on the wood market.

The district heating market is liberalised, and price level is set to be competitive with best-alternatives for end-customers. Since CHP returns are non-regulated, there is a strong economic incentive for cost efficiency.[14] Heat production price is set based on own production costs or based on voluntarily negotiated long-term heat supply agreements with 3rd parties. TSE has developed its own program to optimise their systems on an hourly basis, taking into consideration estimated heat load, estimated fuel prices, estimated power price and energy taxation.[15]

[10] Ministry of Economic Affairs and Employment (2018), Finland to ban coal in 2029 – incentives package for faster phase-out, https://tem.fi/en/article/-/asset_publisher/ministeri-tiilikainen-kivihiilen-kielto-2029-kannustepaketti-nopeille-luopujille

[11] Ministry of Economic Affairs and Employment (2018), Report: Banning coal in 2030 would affect only a few energy companies, while a ban in 2025 would cause significant costs for many, https://tem.fi/en/article/-/asset_publisher/selvitys-kivihiilikiellosta-vuonna-2030-vaikutuksia-vain-muutamalle-energiayhtiolle-kielto-vuonna-2025-toisi-merkittavia-kustannuksia-usealle

[12] Ministry of Economic Affairs and Employment (2017), Government report on the National Energy and Climate Strategy for 2030, http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu.pdf

[13] Ministry of Economic Affairs and Employment (2017), Government report on the National Energy and Climate Strategy for 2030 http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu.pdf

[14] Document sent by TSE to COWI

[15] Europe & Middle East Outlook (2015), TSE (TURUN SEUDUN ENERGIANTUOTANTO OY), https://www.emeoutlookmag.com/outlook-features/tse-turun-seudun-energiantuotanto-oy

Despite biomass being cheaper than coal in Finland nowadays, taxation and CO_2 emission fees have been on the rise for the past five years. As the main fuel used for heating in the Helsinki area is coal, which is expected to be phased out by 2029, the expected knock-on effect of this is increased competition for biomass purchase in Finland, thereby driving up prices. As TSE expects to increase its share of biomass to 70%, imports of biomass from the Baltic Sea region are projected to rise.

At the current price levels of emission allowances, peat is competitive compared to coal. A significant increase in the tax rate on peat could undermine its competitiveness compared to coal, especially in coastal CHP plants.[16] On the other hand, the competitiveness of forest chips compared to peat in CHP production is being ensured by an aid scheme for forest chip electricity production. Also, whilst CHP electricity is exempt from taxes, the same does not hold true for CHP heating.

In addition to the EU emissions trading system, coal use is being regulated by Government by means of tax and aid schemes to ensure that domestic fuels maintain their competitiveness in the combined production of electricity and district heat compared to coal. The largest harvest potential for forest chips is in eastern Finland, but the use is expected to grow strongest in south-western and southern Finland. Given that subsidies are linked to CO2 emissions price, which is currently high (according to interviews with TSE), biomass fuels receive a low Government subsidy.

Electricity generated by a forest chipping power plant approved for the Finnish feed-in tariff scheme will receive variable production support so that the use of forest chips as fuel in combined electricity and heat production remains competitive compared to peat. The variable rate production subsidy for the production of electricity eligible for production aid at a forest chips plant is determined by the following criteria:

- the difference between the taxpayers' ability to pay and the tax-free price of peat for electricity production and taking into account the efficiency of the type plant
- peat tax
- the cost of emission rights for peat and the average market price of the three-month allowance

Those real estates that are not connected to the district heating network are mainly heated by electricity or electricity-based technologies like heat pumps. There are also some oil-based heating systems still left. Those real estates that are not connected to the district heating network, are mainly small single home houses and far from the district heating network. When a real estate is located within a reasonable distance from district heating network, district heating is almost without exception the most economical form of heating.[17]

5 Impacts

One of the main objectives of unit 4 is to increase the use of renewable energy, given that the proportion of biofuels can be brought up to 100% with using the existing boiler technology (thus no large capital investment is needed). For 2019, the target of TSE is to run 70% on biomass and invest in a flue gas condenser that will increase the production of district heat by 60 MW.

[16] Ministry of Economic Affairs and Employment (2017), Government report on the National Energy and Climate Strategy for 2030 http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu.pdf

[17] Interviews conducted by COWI with TSE representatives

The €240 million investment has created employment opportunities. For instance, at its busiest, the construction site has employed around 500 people. Additional jobs have been created afterwards along the supply chain.[18] The biofuel used by TSE consists of industry by-products, meaning sawdust and bark or forest and stem chips. The domestic procurement of these materials has indirectly created about 250 jobs.[19] Over half of the fuel at the new power plant consists of biofuels. In the coming years, the share of biomass is expected to continue to increase as TSE studies ways to stop using coal.

The plant reduces CO_2 emissions by more than 400,000 tonnes a year, an amount which is equal to emissions from over 60,000 single-family houses every year.

Table 2 Impacts

Energy from renewables generated	1 500 000 MWh/year
Increase in energy efficiency	3 % of fuel savings
CO_2 reductions	400 000 Ton/year
Employment	1000 person-year during the project and 250 employees per year for the operation (incl. fuel chain)

Source: Authors' own elaboration

6 Summary

The district heating sector in Finland can reduce CO_2 emissions and increase the share of renewable energy mainly by increasing the share of wood-based fuels. New energy sources for district heating may also be introduced, including large heat pumps, low-grade residual heat, solar heat and industrial residual heat. Production modes that are completely new in Finland such as geothermal energy may bring new possibilities for increasing the share of renewable energy in district heating production.

Biomass is a competitive energy source in Finland compared to other technologies, which explains the low Government subsidy it receives. Use of biomass will increase in the future, and all other non-fossil alternatives (fuels for example solid recovered fuels - SRF and technologies) should also be taken into account. Biomass is competitive compared to coal also without subsidy. Biomass is so much cheaper than coal in CHP production that the subsidy doesn't change the fuel ratio between biomass and coal. Instead, the fuel ratio between biomass and peat will be changing because of the feed-in tariff.[20]

Competition in the heating market is tougher and especially geothermal heat and various hybrid systems have become more common. Wood heating is mostly used in rural municipalities and urban centres. Forest biomass will be crucial for Finland as a raw material for renewable energy, and the objective of the Finnish Government is for most of the forest-based energy to continue to be produced on market terms.

The district heating market is liberalised and CHP returns are non-regulated, which translates into a strong economic incentive for cost efficiency. Despite biomass being

[18] Document sent by TSE to COWI
[19] Document sent by TSE to COWI
[20] Interviews conducted by COWI with TSE representatives

cheaper than coal in Finland nowadays, the knock-on effect of the coal phase out will be increased competition for purchasing biomass in a context of already low Government subsidy for biomass fuels.

At the current price levels of emission allowances, peat is competitive compared to coal. A significant increase in the tax rate on peat could undermine its competitiveness compared to coal, especially in coastal CHP plants. On the other hand, the competitiveness of forest chips compared to peat in CHP production is being ensured by an aid scheme for forest chip electricity production. Also, whilst CHP electricity is exempt from taxes, the same does not hold true for CHP heating.

CASE STUDY

Biomass in Naantali, Finland (A1)

Source: COWI (2019)

Biomass in Naantali, Finland

Overview and value chain analysis

Key information

- Naantali Unit 4 Combined Heat and Power (CHP)
- Multi-fuel power plant - circulating fluidized bed technology (CFB)
- Commissioned: 2017
- Investment costs: EUR 240 million
- Capacity: DH 360 MW, electricity250 MW and steam 60 MW
- Yearly energy output (GWh/a): DH 1500, electricity 1100, steam 350

Value chain

Inbound logistics	Operations	Outbound logistics	Sales activities	Service provided
Delivery of technology components (e.g. CFB boiler, steam turbine).	Energy production consists of district heat and district cooling, industrial process steam and electricity.	Distribution to the network (15-km district heat tunnel).	85% of the population in the region uses the DH produced by TSE.	The final services are district heat and district cooling, industrial process steam and power.

Biomass in Naantali, Finland

Factors and impacts

Enablers

- Government prohibits the use of coal in energy production by 2029
- Subsidies are flexible and set in relation to CO_2 prices thus maintaining the competitiveness of biomass compared to coal: high CO_2 prices leads to low biomass subsidy and vice versa

Other factors

- The energy tax system provides an incentive for using forest chips and by-products in heat and CH production and ensures that today peat is competitive to coal
- The district heating market is liberalised with price levels set to be competitive with best alternatives for end-users - thus providing a strong incentive for products to be cost-effective
- Heat production price is set based on own production costs or on voluntarily negotiated long-term heat supply agreements with 3rd parties

Impacts

- CO_2 emissions saving of no less than 400 000 Kg per year
- The amount of CO_2 savings equals the emissions from over 60,000 single-family houses every year
- Contribution to the commitment to phase out coal by 2029 in Finland