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OPERATIONAL ENVIRONMENT FOR BIOMASS-BASED SMALL-SCALE CHP UNIT

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ABSTRACT

Lappeenranta University of Technology
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Operational Environment for Biomass-Based Small-Scale CHP Unit

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The main objectives of this thesis are to investigate and analyze the current operational environment for biomass-based small-scale CHP units in Finland. The study examines current policies and support measures, investment and production costs, and possible alternatives of small-scale CHP generation and provides a comparative analysis of operational environments in Finland, Germany, Austria, and Sweden. The majority of data was gained through the study of countries' legislations on the support schemes and policies for renewable energy. Moreover, the data about equipment related costs was obtained during direct communication with manufacturers. As a result of the work, proposals on support measures for small-scale renewable CHP installations are presented.

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Moscow, June 25, 2017
Anton Gissek

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS

A	yearly balance	[EUR/year]
I	investment costs	[EUR]
i	interest rate	[%]
N	payback time	[year]
O	annual operational costs	[EUR/year]
R	revenues for sold electricity	[EUR/year]
S	saved money for heat and electricity	[EUR/year]

ABBREVIATIONS

CHP	combined heat and power
EEG	the Renewable Energy Source Act
ETS	emissions trading system
EU	the European Union
GHG	greenhouse gasses
IEA	International Energy Agency
KWKG	the Law on Preservation, Modernisation, and Development of Combined Heat and Power Generation
ORC	Organic Rankine Cycle
R&D	research and development
SME	small and medium-sized enterprises
TPES	total primary energy supply

1 INTRODUCTION

Today, Europe, being extremely dependent on fossil fuels, is inevitably facing energy and climate challenges. Having a share of oil, gas, and coal accounting for 73% of the total primary energy supply (TPES), the European Union has to import approximately 53% of the energy it consumes (IEA 2014b, 27). On top of that, utilization of these fuels negatively affects the environment in multiple ways. Thus, in order to mitigate climate change, increase the security of energy supply and strengthen its competitiveness, in 2009, the EU adopted the climate and energy package, also known as “20-20-20” targets. Three main objectives of this strategy, which should be fully met by 2020, are the reduction of greenhouse gas (GHG) emissions by 20% comparing to 1990 levels; the increase of the share of renewable energy sources in final energy consumption up to 20%; and the improvement of energy efficiency by 20%. Latter, in March 2014, after substantial progress had been made towards the attainment of these targets, the European Council decided to review its strategy and agreed on the 2030 climate and energy policy framework for the EU. New objectives include a reduction of GHG emissions by at least 40% below 1990 levels; an increase of renewable energies’ share up to at least 27%; and an ambition to increase an energy efficiency by 27% (IEA 2014b, 18). Achieving of these targets should help Europe to decarbonize its economy, to hold the increase in global temperature below 2 °C above pre-industrial levels, and to reduce the dependence on energy imports.

Implementation of set goals requires co-operation of all EU member states. Each country has to develop its national energy policy, which will allow the EU and the country itself to continue moving towards the low-carbon economy development. Thus, in November 2016, the Finnish Government approved the National Energy and Climate Strategy for 2030 that outlines the concrete actions and objectives, enabling Finland to ensure its safe and secure energy supply, promote a sustainable energy future and support competitiveness.

In terms of Finland’s energy mix, a key pillar of the strategy is a sustained development in renewable energy production, which is intended to reduce the country’s dependence on energy imports from abroad. It is planned that the share of renewable energy in the final energy consumption will rise to more than 50% during the 2020s, and the self-sufficiency of Finland will be more than 55% by 2030. With an intention to stop using coal for energy production and halve the domestic use of imported oil, the strategy suggests that approximately 171 TWh of renewable energy will be needed to meet this target. The main role in this pursuit is assigned to biomass, which will account for 121 TWh in the final energy consumption. The increase of 31 TWh compared to the 2010 level will be required, and it is predicted that more than half of it will be covered by the growth in wood chips usage. (TEM 2017)

Finland’s transition towards being a carbon-neutral society will require the energy sector to undergo a powerful transformation. The main drivers of change are associated with technology development, decentralized and renewable energy generation, and the more important role of consumers. Thus, when the production of renewable energy increases, the power balance of the electricity system, including weather-dependent wind and solar power, will be more difficult to maintain. The arising need in flexible energy production and consumption will stimulate the development of intelligent electricity networks, which will serve as a base in the transition towards more decentralized and carbon-neutral electricity generation. They will change the role of the consumer, allowing him to perform at the same time as both the producer and the user of energy. In addition, the networks will improve the security of supply and create new business opportunities for Finland, especially in such fields as biofuels and biotechnologies as well as gas-fueled engines and plants. (Ibid)

One of the possible alternatives that would suit current Finland’s Strategy is the utilization of biomass-based small-scale CHP plants. Being decentralized and forest biomass-based technology, it will serve as a reliable energy source mostly for the rural areas of the country. Utilization of domestic wood chips will both increase the share of renewable energy in the country’s TPES and decrease the dependence on energy imports from abroad. In addition, switching towards forest biomass in decentralized production will help Finland to achieve its challenging target of a 39% emission reduction in the non-ETS sector by 2030. However, implementation of this objective will require the government to develop a number of support measures affecting the operational environment in a way, making the utilization of small-scale CHP technology a more common solution for the country.

1.1 Aims of the Thesis

One of the main objectives of this work is to provide an analysis of the current operational environment for biomass-based small-scale CHP units in Finland. This analysis should include an overview of present policies and support measures; possible alternatives for users, including self-production of heat and purchasing of electricity from the grid; and investment and production costs calculations intended to show the feasibility of the utilization of small-scale CHP technology within the country. Furthermore, in order to provide an adequate assessment of the current situation, it is necessary to conduct a comparative analysis of operational environments in other countries, such as Germany, Austria, and Sweden. In addition, ideas on how to improve the situation should be presented.

1.2 Research methodology

The majority of an information about operational environments in Finland, Germany, Austria, and Sweden was gained by means of the thorough study of countries' legislations on the support schemes and policies for renewable energy. Moreover, the data about equipment related costs was obtained through direct communication with manufacturers. On top of that, investment and production costs were calculated using a special tool, provided by the manufacturer, and taking into account features of the specific country and its policies.

1.3 Structure of the Thesis

The Thesis is divided into six chapters and supplemented with two appendices. The first chapter introduces the topic to the reader. It briefly describes the background of the work and presents the main objectives of the Thesis. On top of that, applied research methodology and the structure of the work are explained.

The second chapter tells about the basics of cogeneration. It shows the difference between centralized and decentralized energy production and presents their pros and cons. The chapter also explains the idea of small-scale CHP technology and factors limiting the utilization of such installations.

Chapter three presents an overview of the current operational environment in Finland. It discusses main obstacles for small-scale cogeneration technology as well as support measures from the government promoting development and deployment of renewable energy production units. In addition, the chapter provides investment and production costs calculations for plants of various types and capacities.

Chapter four investigates operational environments in Germany, Austria, and Sweden. The main objective of this part is to study how specific countries promote the utilization of small-scale CHP technology. Moreover, investment and production costs calculations for units installed in these countries are provided.

The fifth chapter presents author's ideas on how to promote the utilization of small-scale renewable installations in Finland by means of various support measures involving investment and operation stages.

Chapter six describes the work done and concludes the results of the analysis. In addition, it presents perspectives of the operational environment for small-scale CHP installations in Finland.

2 COMBINED HEAT AND POWER PRODUCTION

Today, the most efficient and flexible way of heat and power production is cogeneration, combined heat and power (CHP). CHP produces electricity whilst also utilizing excess amounts of heat for district heating purposes, which are usually simply wasted into the atmosphere in conventional gas and coal-fired power plants. This allows to reach the efficiency of up to 80% instead of 49-56% for gas power plants and 38% for coal ones (ADE 2017). The idea of a higher efficiency of CHP plants is introduced in figure 1.

Figure 1. Comparison of an efficiency of CHP and conventional plants. (ADE 2017)

The next advantage of CHP is its fuel neutrality. It means that a cogeneration process can be based on consumption of renewable and/or fossil fuel. Some technologies may be suitable for only one specific fuel, while others, for instance, fluidized bed boilers, are able to utilize several types of fuel (coal, wood, peat) during their lifetime without a need to be modified. Despite the fact, that employed technologies, available capacity, and efficiency vary from plant to plant, CHP is able to make a process of primary fuel use more efficient and effective. A variety of available CHP technologies and utilized fuels is presented in figure 2. (Ibid)

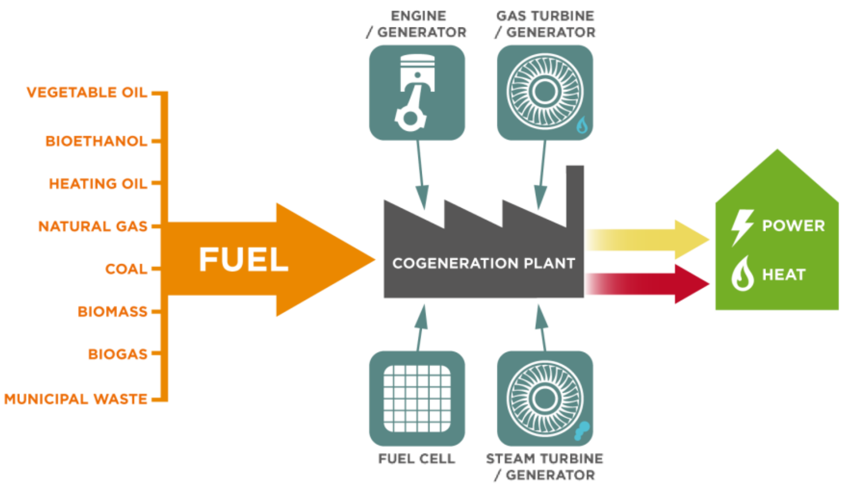


Figure 2. The principle of cogeneration. (ADE 2017)

Usually, CHP production is distinguished into two different groups: centralized and decentralized production. Depending on a user's location, fuel, power grid and heat network availability, and plenty of other factors, one of these types can be applied in a set area.

2.1 Centralised production

The most common type of energy production, especially in urban areas, is centralized production. The name comes from an idea that in the center of a system there is an energy production unit, a plant. This plant produces energy (in our case heat and power) and supplies consumers with it by means of electric grid and heat network (figure 3). Sometimes, for energy security purposes, there are several plants in one system, and a system itself can be presented as a closed loop.

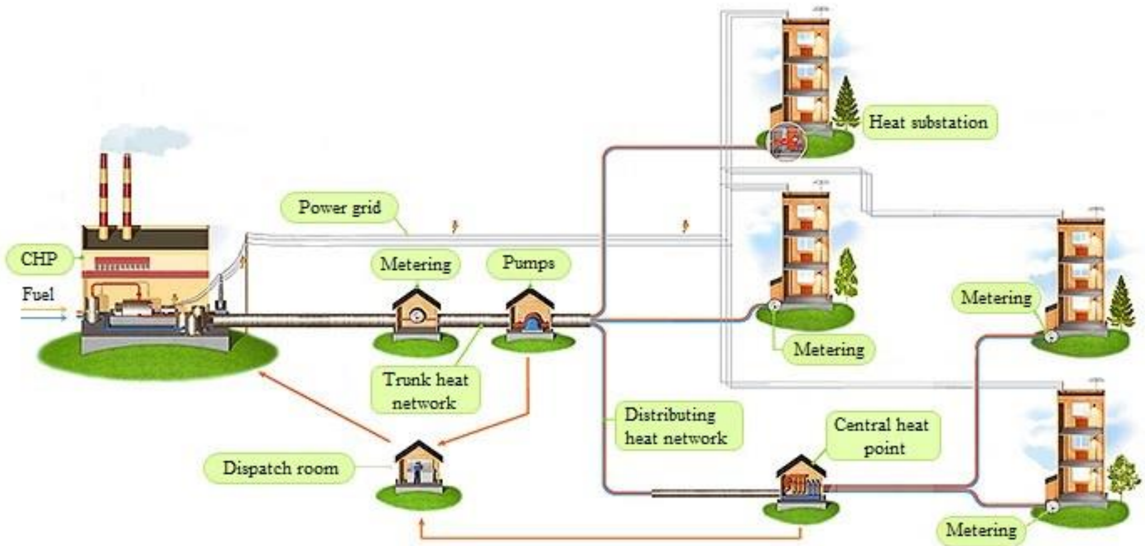


Figure 3. Centralized production. (Fortum 2014)

Since the average capacity of CHP plants for centralized production is above 10MWe (Kaikko & Vakkilainen 2016), next cycle types can be utilized: steam cycle, gas turbine cycle, gas turbine combined cycle (gas turbine with heat recovery boiler), large internal combustion engines, and nuclear cycle. Fuels combusted on these plants (except nuclear power plants) usually are natural gas, coal, oil, biogas, wood fuels, and peat. Latter two, as a rule, are co-fired with coal.

As any other system, centralized production has its pros and cons. There are several advantages of this kind of systems. First, plants can operate utilizing different fuels, for instance, fossil fuels, household wastes or renewables. Second, heat and power can be generated on industrial CHP plants, using waste heat from technological processes as a source of energy. Third, CHP plants for centralized energy production usually have better exhaust gasses treatment systems than their smaller competitors. And fourth, consumers do not have to maintain and work with explosive energy equipment. (Semenov 2008)

Despite the number of significant advantages, there are, however, few drawbacks of such systems. The main is that around 7% of useful energy, both heat and electricity, is lost when an extended network is used for an energy transmission from a plant to a final consumer (ADE 2017). Furthermore, customers can experience poor power quality, variations in voltage or electrical flow when are relied on one big and remote plant (VTCER 2007). Therefore, today, in order to improve economic and security aspects of energy supply, more cities opt for energy systems with several small-scale plants situated close to final consumers rather than for systems based on large energy generating facilities.

2.2 Decentralised production

There are plenty of definitions of decentralized production. According to (E.ON 2017), decentralized energy is produced close to its final consumer, rather than at large plants requiring a transition through public grids. Unlike centralized energy production, relatively small-scale units with a capacity of less than 1MWe are used. These units for CHP generation can be steam engines, internal combustion engines, microturbines, Stirling engines, ORC units, fuel cells. The primary fuels for such units are usually renewables (wood chips, pellets, biogas, et cetera) which are frequently available in a local area. However, in some cases, fossil fuels, like natural gas and oil, also can be utilized as an energy source.

Besides CHP production, decentralized production also intends an only electricity generation. In this case, photovoltaics, solar thermal, geothermal, wind, and ocean energy can be used.

Advantages of decentralized energy production are disadvantages of centralized generation. Thus, the local generation reduces energy transmission losses from a plant to a customer. Security of supply is increased since customers do not share a supply or rely on few, big and remote power plants. Moreover, relative CO_2 emissions (per kWh) of small-scale CHP units are usually smaller than those of large-scale units.

On top of that, already high heat and electricity prices are predicted to grow (Tipper 2013), therefore decentralized energy production can offer long-term benefits comparing to traditional energy. While investment costs can be higher, special feed-in tariffs for decentralized energy create the more stable pricing.

The main drawback of small-scale CHP units is, probably, a necessity of heat utilization during summer time. However, this problem can be solved by using the excess amounts of heat for fuel drying purposes or for greenhouses heating.

2.3 Small-scale CHP units

Since one of the main Finland's targets is to increase the share of renewables in the final energy consumption, forest biomass-based small-scale CHP units are a very good choice for decentralized heat and power generation. Currently, there are several European manufacturers producing energy installations for private use. Namely, they are Volter (Finland), Spanner (Germany), Urbas and Fröling (Austria). These units utilize wood chips as a primary fuel, and their electric capacity varies from 30 to 200 kW_e. Moreover, it is possible to combine several units into one multiple unit installation thereby increasing the total plant capacity.

2.3.1 The idea of technology

All above-mentioned manufacturers produce units, which are based on similar gasification technologies. Unlike combustion, gasification allows to produce not only such gasses as

CO_2 and H_2O but also a flammable gas, which is then converted into electricity and heat in a gas engine.

As an example, CHP installation Volter 40 Indoor (figure 4), converting wood chips into a wood gas, is described in this paragraph. Since the quality of fuel is a crucial factor for the proper work of the installation, it has to meet several requirements. First, wood chips could be originated only from stems of birch, spruce, pine or aspen. Logging residues are unsuitable for gasification purposes due to their component and size heterogeneity. Second, the majority of fuel particles has to have the length of between 16 and 50 mm. Longer chips may cause an instability of the gasification process. In addition, if a moisture content of chips is higher than 18%, the fuel should be dried up to the optimum condition. After chips have been treated properly, the cogeneration process itself may be started. At the beginning, wood chips are fed into a downdraft gasifier by external augers and chain conveyor, where they are heated to the high temperature with low oxygen level. During gasification process, chemical products, such as CO, CO_2, H_2, CH_4, H_2O, tar, and coke are created. After it, produced raw gas is cooled down in a heat exchanger and supplied to a filter unit. In this part of the process, all solid particles are filtered out of the gas. Collected ash is removed from the installation by a pneumatic system. Finally, cleaned gas is cooled down to 60 °C, mixed with air, and fed into a combustion engine, which runs a generator. The engine exhaust gasses flow to catalytic converter before they are cooled down and led out into the atmosphere. Waste heat from all heat recovery stages, including the radiant heat from the gasifier and the heat from engine cooling, can be utilized, for example, for domestic hot water production, hydronic underfloor heating, or preheating of air-conditioning. (Volter Oy 2013)

Volter 40 Indoor unit is designed for indoor installations. It is very compact and has dimensions (length/width/height) of 4.8/1.2/2.5 m and a mass of 4.5 ton. Fuel consumption rate is 4.5 loose m^3 per day (approximately 38 kg/h), what allows the unit to have an electric power of 40 kW and a heating power of 100 kW. Designed capacity is enough to supply a family of six with the necessary amount of heat and electricity. (Ibid)

Figure 4. Volter 40 Indoor unit. (Volter Oy 2013)

2.3.2 Use of small-scale CHP

Since the main issue of small-scale CHP usage is a continuous heat utilization, the most suitable consumers for this type of units are buildings that require long and uninterrupted heating, for instance, public and commercial buildings and larger houses. Moreover, pellet factories, sawmills, and farms can utilize small cogeneration units, since they need both heat and electricity for their production processes. Finally, it is possible to deploy local heat and power networks, covering a heat demand of a small village.

Besides the need of produced heat, several more factors determine a viability of small-scale CHP. For instance, climate plays a significant role. Northern regions are more likely to deploy such units than southern ones. However, latter can use trigeneration systems, where produced heat is converted into the cold for air conditioning.

Likewise, the government support of small CHP also has an impact on the economic viability of the systems. Several European countries, including Germany, the UK, and Belgium, provide an economic support on the electricity produced by individuals. (FREE 2010)

Thus, all above-mentioned pros and cons form today’s situation of small-scale CHP utilization. The majority of users is located in Europe, especially in Germany, the UK, and Italy. For example, only Spanner has more than 170 installation sites in Germany and more than 40 both in Italy and in the UK (Spanner 2017). Similarly, Finnish manufacturer Volter has approximately 70% of its units installed in the UK, while only eight cogeneration sites in Finland are equipped with company’s units (Volter Oy 2013).

3 CURRENT SITUATION IN FINLAND

Today, biomass-based small-scale CHP technology in Finland is in its early stage of development. According to available data (Volter Oy 2013; Spanner 2017), there are only nine operating plants utilizing this technology, while two of them are intended for research purposes. Almost all of installed units provide power and heat for residential buildings, and only two operators feed an excess amount of electricity into local grids. Such situation can be explained by a fact that it is usually unprofitable for small entrepreneurs or communities to switch from conventional energy sources towards CHP plants. There are several reasons for that. First, there is a variety of affordable heating methods in Finland. Thus, the majority of buildings in cities and municipalities are supplied with heat from heat networks. Users living outside towns prefer to utilize alternative energy sources, such as heat pumps, electricity or wood-based systems. Second, Finland has a well-developed power grid, covering almost the entire territory of the country. Low electricity prices make it convenient for customers to buy electricity from the grid. Third, there is no solid support for small-scale renewable installations from the government. The only two mechanisms, promoting the production of "green" energy, are an investment costs subsidy for plants located in rural areas and a flexible feed-in tariff system. Latter usually has a low value and could be allocated only to plants with a total capacity of more than 100 kVA. Dependence on such variable factors as emission allowance price, peat tax, and electricity price does not allow plant operators to rely on such support in the long term. Investment costs subsidy, in its turn, is intended only for plants in rural areas. In addition, due to several restrictions in the feed-in tariff system, grants may be obtained only by forest chip plants or by plants, which do not receive a remuneration for feeding electricity into the grid. As a result, these two mechanisms, even when applied together, do not allow users to pay their investments in earlier than six years. Moreover, this value of payback period may be reached only if a plant operator uses his installation almost continuously and consumes 100% of produced electricity, what is a rarity in real life. Thus, in order to improve the current operational environment for small-scale renewable energy installations in Finland, each of above-mentioned obstacles should be, at first, analyzed in more detail. Therefore, sections below present necessary analysis, which is also supplemented with investment and production costs calculations for plants with a capacity range of between 40 and 80 kW_e.

3.1 Available electricity and heat

3.1.1 Well-developed power grid

Finland is a part of the inter-Nordic power system, Nord Pool, which includes transmission grids of Norway, Sweden, and eastern Denmark. Moreover, Finland has DC (direct current) connections with Russia and Estonia. Being a part of such a well-functioning system allows Finland to perform both as an importer and as an exporter of electricity. Since hydro energy is the third largest source of power generation in Finland, the yearly amounts of imported electricity depend on the hydro situation along with electricity price in the Nord Pool. In average, about 19% of the country's supply is imported from abroad (IEA 2013b, 115).

Finland has a well-developed electricity transmission network, which covers the entire country (figure 5). The high-voltage trunk network, operated by Finnish public company Fingrid, has a total length of approximately 14 400 km and includes 400, 220, and 110 kV transmission lines and 116 substations. The network connects major power and industrial plants and regional distribution networks. At the moment, there are more than 100 retailers that provide customers with electricity. (Fingrid Oyj 2017; IEA 2013b, 123)

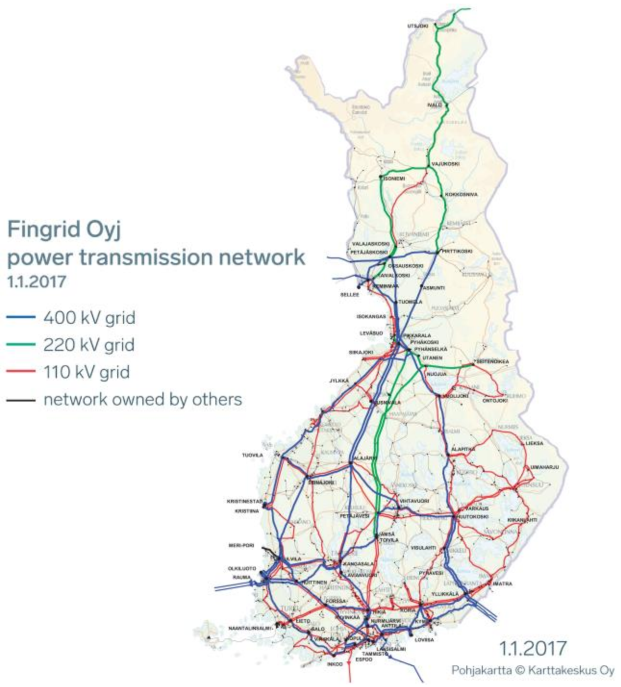


Figure 5. Fingrid power transmission network. (Fingrid Oyj, 2017)

The inter-Nordic power system is hydro-based, which means that electricity prices can vary significantly, even on a monthly basis. On top of that, every distribution company in Finland is able to set its own price level, which does not have to be approved by the Energy Market Authority, supervising the country's electricity market. This promotes the competition within electricity trade and consequently leads to lower prices. Thus, electricity prices in Finland, and in the Nord Pool, are lower than those in other IEA countries. (IEA 2013b) For instance, in 2016, the total electricity price for a detached house without electric space heating and with consumption rate of 5 MWh/a was 15.3 cent/kWh (Statistics Finland 2017); meanwhile the total price for industrial customers with consumption rate of between 500 MWh and 2 000 MWh was only 8.61 cent/kWh (Eurostat 2017). It worth mentioning that mentioned prices are the final prices users have to pay and consist of three main components: energy price, network charges, and taxes and levies. The share of each component varies according to the specific supplier and the type of the user. Thus, the composition of an average electricity price for household customers is presented in figure 6.

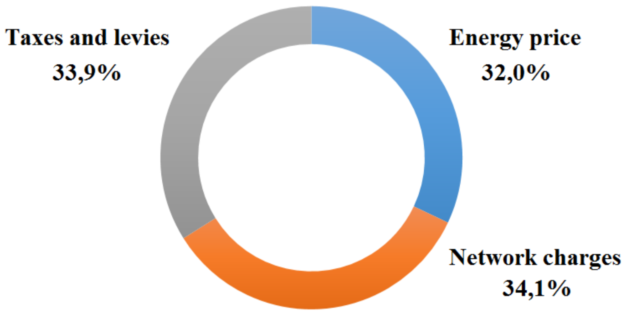
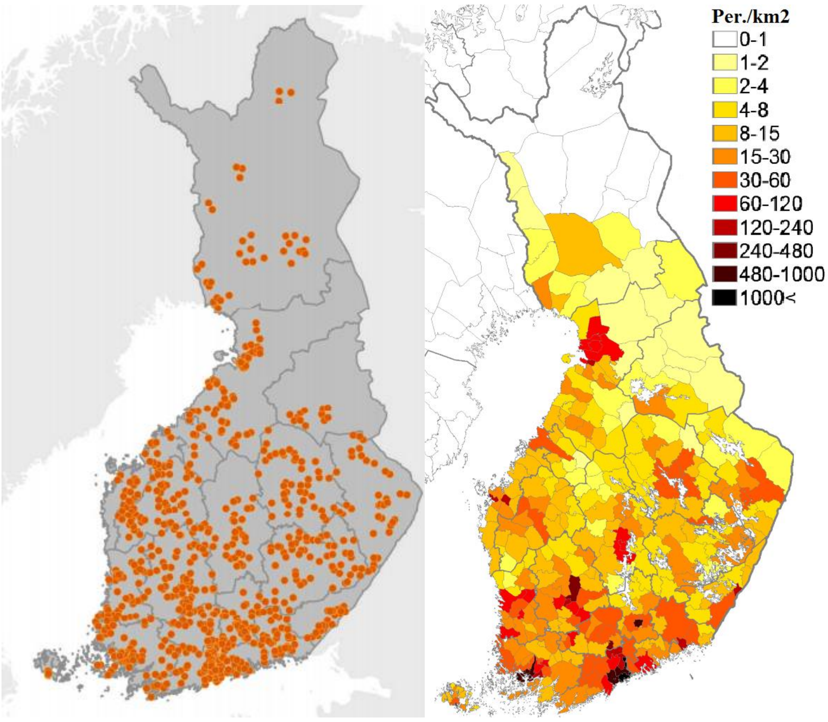


Figure 6. Electricity price composition for a household customer with a consumption rate of between 2 500 and 5 000 kWh/a. (Eurostat 2017)

3.1.2 Availability of various heat sources

Nowadays, district heating is the most popular heating method within households in Finland, supplying heat to about 2.7 million people in 166 towns and covering one-third of country's heating demand. Approximately 26% of heating is based on wood, and 22% of heat comes from electricity-based systems. The smallest shares on the market are of heat pumps and light fuel oil boilers, 11% and 7%, respectively. It worth mentioning that district heating is situated mainly in dense areas (figure 7) and supplies heat to the majority of apartment and terraced buildings, while detached houses, as a rule, use wood (42%) and electricity (28%) to cover their heat demand. Latter type of users is the biggest in Finland and demands 60% of total heat intended for household consumption. Apartment and terraced buildings account for approximately 25% and 9% of total heat demand, respectively. (Energia Oy 2016; Statistics Finland 2017)



a) b)

Figure 7. District heating production units (a); population density map (b). (Energia Oy 2016; PDM 2017)

Therefore, the selection of a heating method in Finland strongly depends on the location and the type of a final user. Figure 8 shows what heating systems are preferred by different groups of customers.

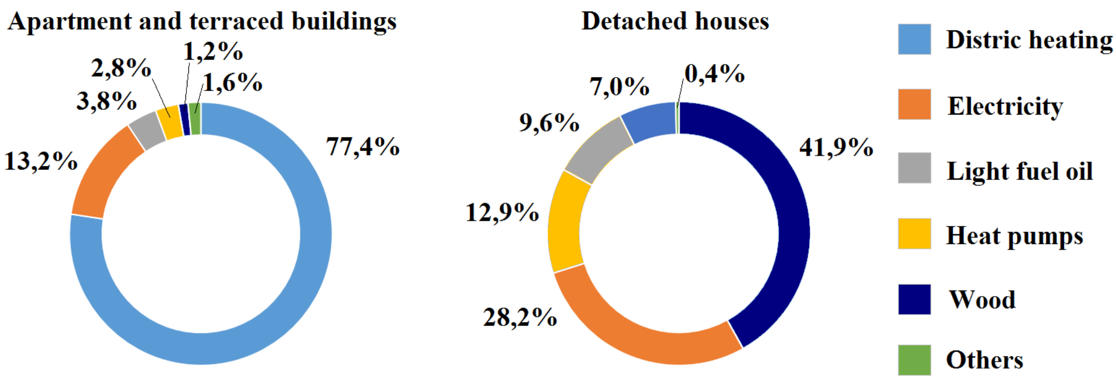


Figure 8. Heating methods in Finnish households. Others include natural gas, heavy fuel oil, peat, and coal systems. Data source (Statistics Finland 2017).

In order to understand how much customers in Finland pay for hot water and heating, it is necessary to consider three main heating methods: district heating, electricity, and wood-based systems. The most expensive among mentioned is electricity heating. Thus, in 2016, an average user in a detached house with an annual consumption rate of 18 MWh should pay 12.6 cents per kWh of consumed electricity (Statistics Finland 2017). The second place is taken by district heating. It worth mentioning that there are significant variations of district heating price in Finland, up to 200%. It is mostly due to such factors as ownership structures in the district heating companies, profitability requirements, type of fuel used, and geographical location. Thus, the price in Haapajärvi can be 4 cent/kWh while the price in Kristiinakaupinki is 11.9 cent/kWh (IEA 2013b, 142). In 2016, the mean price of district heat was 7.5 cent/kWh (Energia Oy 2017), and an average user in a detached house with an annual heat consumption rate of 18 MWh was charged a price of 8.4 cent/kWh (Statistics Finland, 2017). Finally, using wood-based systems is the cheapest option in Finland. Thus, if pellet boiler is utilized, an average price that users have to pay for 1 kWh of produced heat amounts to 7.24 cent (Versowood 2017; Fröling 2017). However, it worth mentioning that presented analysis is for current users and does not include investment and maintenance costs.

3.2 Policies and support measures

In Finland, renewable energy is mainly promoted through a feed-in tariff system, allocated to electricity produced from wind, biogas, and biomass. In addition, a special heat bonus for heat generation may be obtained by biogas and wood fuel CHP plants. On top of that, the Finnish government provides several support schemes for investment and research projects promoting the use and production of renewable energy.

At the beginning of 2012, the fixed production support for electricity from renewable energy sources, namely hydropower, wind power, and power from biogas and wood chips, was abolished (IEA 2013b, 103). Today, electricity produced from wind, biogas, forest chips[1], and wood fuel[2] is eligible for receiving a flexible subsidy (feed-in tariff) based on the market price for electricity or on the emission allowance price and the peat tax. The feed-in tariff is allocated for a period from at least three months (one tariff period) and up to twelve years and financed by the government's budget. All plants/systems with above-mentioned technologies can receive the support if they are located in Finland or in Finnish territorial waters and are connected to the electricity network. On top of that, plants should meet additional economic and technical requirements for electricity production. (Act 1396/2010) For a better understanding of the support scheme, feed-in tariffs and specific requirements for plants based on forest chips and wood fuel are presented in two separate subsections and then in table 1.

3.2.1 Forest chip power plants

In order to get a support, forest chip power plant should meet two additional requirements. First, the nominal capacity of installed generators should be not less than 100 kVA (kilovolt amperes). And second, the plant has not been included in the feed-in tariff scheme before. (Ibid) If the plant meets these requirements, the amount of the feed-in tariff paid for 1 MWh of renewable electricity is calculated using the following equations:

$$35.65 - 1.827 * \textit{peat tax} - 1.359 * \textit{three-month average emission allowance price}; \quad (1)$$

$$22.06 - 1.827 * \textit{peat tax}. \quad (2)$$

Equation (1) is used when the average emission allowance price for three months is at least 10 EUR/tCO_2, and equation (2) – when the price is less than 10 EUR/tCO_2. However, electricity producer is eligible to obtain a support only if the calculated feed-in tariff is at least 1 EUR/MWh. (Decree 1397/2010)

3.2.2 Wood fuel power plants

The wood fuel power plant is eligible for feed-in tariff only if:

1. it has not received the State support;
2. it is built entirely from new parts;
3. the total capacity of installed generators is between 100 kVA and 8 MVA (megavolt amperes);

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[1] Forest chips – chips produced from the stem wood obtained directly from the forest and which is not suitable for the forest industry.
[2] Wood fuel – wood chips and by-products arising from production processes of the forest industry.

4. it simultaneously produces both electricity and heat (cogeneration);
5. it has an overall efficiency of 50% or 70% if the total capacity of generators is 1 MVA or more. (Act 1396/2010)

In addition, produced heat should be fully consumed by the plant operator and its amount cannot exceed the heating need of the operator (Decree 1397/2010). Thus, if all conditions are met, the plant is eligible for the production subsidy, which is calculated as the difference between the fixed target price and the average market electricity price of the previous three months at the place, where this plant is located. For wood fuel power plants, the target price is 83.5 EUR/MWh. If the average market price of the previous three months is less than 30 EUR/MWh, the feed-in tariff to be paid amounts to the target price minus 30 EUR/MWh. On top of that, a special heat premium of 20 EUR/MWh for heat generation is added to the target price if the average total efficiency of the plant during the past tariff period and the three preceding periods has been at least as that, specified earlier. (Act 1396/2010)

However, there are a couple of limits for large wood fuel plants receiving support under the feed-in tariff scheme. First, no support is allocated if the number of installed generators exceeds 50 units and their combined capacity is more than 150 MVA. Second, the maximum amount of support that the plant operator can be granted during four consecutive tariff periods is EUR 750 000. Furthermore, all wood fuel plants receive no subsidy per hour when the electricity price is negative. (Ibid)

Table 1. Feed-in tariff system conditions for plants based on forest chips and wood fuel.

	Forest chip plants	**Wood fuel plants**
Requirements	100 kVA* (old and new plants); have not been included in the feed-in tariff scheme before	100 kVA – 8 MVA (only new CHP plants); total efficiency of 50% or 70%; produced heat is consumed entirely; have not received the State subsidy
Target price	n/a	EUR 83.5/MWh + heat bonus of 20/MWh
Feed-in tariff	According to equations (1) and (2)	Target price minus spot electricity price; max EUR 0.75 million per year per plant

* 1 kVA ≈ 0.8 kW.

Along with the feed-in tariff system, there are several investment support programs provided for both RES production facilities and research projects related to it. First of them is an investment support for farmers, which is described in (Decree 241/2015). This aid is presented in a form of a non-repayable grant and allocated for the construction, expansion, or renovation of heating facilities used for agricultural purposes. Besides heating installations, the support may be granted for biomass-based CHP plants if at least 10% of generated heat is used for agricultural needs. The grant can cover up to 40% of total investment costs, however, its amount should not exceed EUR 1.5 million. If a project is carried out in cooperation with the European Innovation Partnership, the amount of support may be increased by 5 – 20%.

Besides the investment support for farmers, there are two more investment aid schemes (Decree 145/2016; Regulation 1063/2012) allocated to projects promoting the use or production of renewable energy. The support is granted for investment projects where costs exceed EUR 5 million and for research projects with costs beyond EUR 250 000. The maximum share of costs that can be covered with the subsidies is 40%, and only companies, municipalities, and communities are eligible for these programs. The support cannot be allocated to farms, housing companies, and residential properties. (Siniloo 2017)

In addition, under the Rural Development Programme, Finland provides the support to micro- and small-scale enterprises as well as to multisectoral agricultural enterprises operating in rural areas. The support is presented in a form of non-repayable grants and intended to partially cover investment costs concerning the production of renewable energy. The amount of the aid varies according to such factors as type, scale, and location of an enterprise. Thus, the grant for agricultural entrepreneurs may reach 35% of energy generation unit cost, while non-agricultural companies are able to cover only 30% of their investments in renewable installations. (RDP 2014)

3.3 Investment and production costs

In order to evaluate the operational environment in Finland (and later in Germany, Austria, and Sweden), it is necessary to conduct calculations of costs that CHP plants' users have to bear during investment and operation stages. To provide a fair comparison among all four countries, it was decided to choose a hotel to be a user of such installations. It can be explained by the fact that hotels and catering businesses can be placed in every country and they require large amounts of electricity and heat for their services. Furthermore, unlike other users (sawmills, farms), hotels have to buy fuel from the market, inasmuch as they cannot produce it by themselves, what makes expenditures for wood chips depend only on the current market price. In addition, used CHP units are from the closest producers, Volter's installations are for Finland and Sweden, whilst Spanner's – for Germany and Austria.

Calculations for every country have their own boundary conditions, however, there are several of them, which are common for all cases. First, before the commissioning of CHP plants, hotels were buying electricity from the grid and producing heat with oil, gas, or wood-fueled boilers. Electricity prices, users had to pay, depended on contracts concluded with local supply companies. Second, after deployment of new small-scale CHP installations, 80% of produced heat is used for heating and hot water production, while the rest 20% is intended for fuel drying. Third, in order to show the changes of payback time, the number of running hours and the share of produced electricity consumed by hotels vary from case to case. Finally, the excess amount of electricity is fed into the grid and, if legislations allow, remunerated with a feed-in tariff.

According to data (Statistics Finland 2017), approximately 60% of free-time residential buildings (recreational buildings or holiday dwellings) in Finland prefer to use wood-based systems for heating and hot water production. Therefore, it was assumed that before the commissioning of CHP plant, the hotel was using pellet boiler to cover its heat demand. Moreover, the electricity price for enterprise and corporate clients in Finland depends on their consumption rate (table 2). Thus, the final price that the user paid and that is used for calculation of feed-in tariff varies accordingly.

Table 2. Total electricity prices for enterprise and corporate clients in 2016. (Ibid)

Consumption rate, MWh/a	**< 20**	**20 – 500**	**500 – 2 000**
Price, cent/kWh	10.90	10.37	8.54

Furthermore, a CHP unit Volter 40 Indoor was chosen to be installed in the hotel. A unit has an electric and thermal capacity of 40 kW_e and 100 kW_{th}, respectively, and can work maximum 7 800 hours per year, utilizing wood chips as its primary fuel (Volter Oy 2013). The price of a unit is EUR 179 650 and a fuel conveyor, which costs additional EUR 15 000, is required (Haapakoski 2017). Moreover, Lauber's dryer with drying container were installed on the plant. The price of the system suitable for one Volter 40 Indoor unit is approximately EUR 35 000 and for two units – EUR 45 000 (Ibid). Installation costs are assumed being EUR 15 000 for plumbing and EUR 10 000 for electrical installation (Westermaier 2017). The price of wood chips in Finland is approximately 100 EUR per wet ton or 25 EUR/MWh. The summary of equipment related costs is presented in table 3.

Table 3. Summary of equipment related costs.

	Unit	**Value**
CHP unit	-	Volter 40 Indoor
Electrical / thermal capacity	kW	40 / 100
Maximum number of working hours	hour/year	7 800
Unit price	EUR	179 650
Dryer price	EUR	35 000 or 45 000
Fuel conveyer price	EUR	15 000
Plumbing price	EUR	15 000
Electrical installation price	EUR	10 000
Price of wood chips	EUR/wet ton (EUR/MWh)	100 (25)
Total investments for 1 unit **for 2 units**	EUR	254 650 459 300
Investment grant for 1 unit **for 2 units**	EUR	53 895 107 790

Since there are two types of the feed-in tariff in Finland and both of them are for plants with generators' total capacity of more than 100 kVA (about 80 kW), it was decided to consider three different cases. The basic case is for the plant with one Volter 40 Indoor unit, which is ineligible for the feed-in tariff scheme. Two other cases are for the forest chip and for the wood fuel plants with two installed units, respectively. In addition, all plants are located in a rural area, therefore, they are able to receive an investment support under the Rural Development Programme.

3.3.1 Plant ineligible for the feed-in tariff

The number of installed units mainly depends on the demand of a user. The case when a hotel or a user of other type needs only one installation is the most common in Finland. For instance, all plants in the country that utilize Volter units are equipped with only one Volter 30 Indoor or Volter 40 Indoor unit each. Hence, it is relevant to consider a plant that has a total capacity of less than 100 kVA and is not eligible for the feed-in tariff scheme. In such case, the only support, the plant may demand, is an investment grant covering 30% of the CHP unit price, and the payback time is calculated using equation (3):

$$N = \frac{I}{A}, \tag{3}$$

where	N is payback time	[year]
	I is investment costs	[EUR]
	A is yearly balance	[EUR/year]

The yearly balance, in its turn, is described by the equation (4):

$$A = R + S - O, \tag{4}$$

where	R is revenues for sold electricity	[EUR/year]
	S is saved money for heat and electricity	[EUR/year]
	O is annual operational costs	[EUR/year]

For the comparison of payback time, depending on a number of running hours and the share of consumed electricity, table 4, which is presented in section 3.4, may be used. Detailed information on the investment and production costs for the case with 7 800 running hours per year and 80% of produced electricity consumed by the hotel is presented in Appendix 1.

3.3.2 Forest chip and wood fuel plants

For the plant, fueled with forest chips, the amount of the feed-in tariff depends on two factors and is calculated using either equation (1) or (2). These two factors, determining how much the user will be paid for selling electricity, are the peat tax and the three-month average emission allowance price. Thus, during the period between mid-January and mid-April 2017, the average emission allowance price was approximately 5 EUR/tCO_2 (EEE AG 2017). Since this value is lower than 10 EUR/tCO_2, equation (2) should be used. In this case, the amount of support depends only on the peat tax, which is 1.9 EUR/MWh (TEM 2016), and equals to:

$$22.06 - 1.827*1.9 = 18.589 \text{ EUR/MWh } (1.86 \text{ cent/kWh}). \quad (5)$$

On top of that, besides the feed-in tariff, the plant may be granted an investment support covering 30% of the CHP unit price. Thus, using these values, it is possible to estimate the payback time of the plant and how the user will be able to benefit from feeding electricity into the grid.

If wood fuel CHP plant is used, the only support, the plant may demand, is the allocation of the feed-in tariff. The value of the tariff solely depends on the average market electricity price of the previous three months. According to data (Nord Pool 2017), the average electricity price on the Nord Pool Spot for Finland for a period February - April 2017 was 32.38 EUR/MWh. Therefore, the feed-in tariff for wood fuel CHP plant amounts to:

$$83.5 + 20 - 32.38 = 71.12 \text{ EUR/MWh } (7.11 \text{ cent/kWh}). \quad (6)$$

However, the maximum amount of yearly support should not exceed EUR 750 million.

It worth mentioning that for the calculation of operational costs of forest chip and wood fuel plants, it was assumed that all factors (peat tax, emission allowance price, and market electricity price) remain constant through the whole support period. Similarly to the case with one CHP unit, the payback time was calculated using equation (3), and obtained results are presented in Appendix 1 and table 5.

3.4 Payback time in Finland

3.4.1 Plant ineligible for the feed-in tariff

Thus, if only one unit is utilized, and no feed-in tariff is allocated, it is more profitable to run the plant as long as possible and consume as much electricity as possible. The reason is low electricity prices in Finland, which make yearly savings for heat and electricity, when a hotel uses small amounts of produced energy, almost the same as annual operational costs. However, the case when a plant operator needs all energy, a unit can produce, is ideal. Hence, the payback time is usually longer than 6 years, and almost nobody opts for his own CHP plant rather than for such more common energy sources as wood-based boilers and electricity from the grid.

Table 4. Payback time (in years) depending on the number of running hours and the share of consumed electricity.

Running hours per year	**Share of consumed electricity**				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	-*	-	49.4	27.2	18.8
6 000 h/year	76.0	26.4	15.9	11.4	8.9
7 800 h/year	27.4	14.5	9.9	7.5	6.0

* plant cannot be paid off.

3.4.2 Forest chip and wood fuel plants

Table 5. Payback time (in years) depending on the number of running hours, the share of consumed electricity, and the type of a plant.

Running hours per year	**Share of consumed electricity**				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	-* (35.2)**	69.5 (30.3)	33.5 (26.7)	22.0 (23.8)	16.4 (21.5)
6 000 h/year	28.0 (14.0)	17.0 (12.8)	12.2 (11.8)	9.5 (10.9)	7.8 (10.2)
7 800 h/year	14.6 (9.1)	10.1 (8.4)	7.8 (7.9)	6.3 (7.3)	6.4 (8.3)

* plant cannot be paid off;
** values in brackets are for the wood fuel plant.

When planning to invest in a forest chip power plant, it is possible to expect the similar payback time tendency as for a plant with one CHP unit. Nevertheless, the possibility to sell electricity allows to reduce the length of payback period, especially in those cases, when a plant operator produces and consumes less energy. Increased payback period for the case with 7 800 running hours and entirely consumed electricity is due to a lower electricity price used for yearly savings calculations.

The better situation for the cases with low shares of consumed electricity occurs when a wood fuel plant is utilized. Allocation of the support in a form of the feed-in tariff of a high value leads to an increase of a yearly balance. Latter, consequently, significantly decreases the payback time and makes it possible for a plant operator to pay his investments off even in those cases, when it was impossible for other plants. However, if a user tends to sell less electricity than he consumes, the benefit from the feed-in tariff loses its value compared to the investment grant. Therefore, the payback time is longer than for a forest chip plant.

Considered cases show that the current support system for the small-scale renewable energy production in Finland does not always work as it should. Allocation of investment grants for plants with a total capacity of less than 100 kVA and for forest chip plants does not allow to reduce the payback time to reasonable levels. Granted to forest chip plants right to sell electricity makes an insignificant difference but does increase yearly balance. Finally, even wood fuel plants with a possibility to receive a remuneration of a high value do not show short payback periods; however, if small amounts of electricity are used, the support for wood fuel plants has the best efficiency among others. Thus, it is necessary to adjust the current system to make it more adapted to cases with lower rates of energy production and consumption as well as make it equally useful for all types of plants, and the next chapter may give some hints on what exactly can be changed in the system.

4 OPERATIONAL ENVIRONMENTS IN GERMANY, AUSTRIA, AND SWEDEN

The current situation in Finland clearly shows that if the country wants to increase the utilization rate of biomass-based small-scale CHP technology, it should change its government’s incentive system, either completely or adjust some points. For this purpose, it could be useful to seek an advice from more experienced countries, for instance, from Germany and Austria, which promote the utilization of renewable installations with a help of solid support systems, including a variety of such measures as investment grants and feed-in tariffs. In addition, Sweden with the only working plant (Volter Oy 2013) may also be an example for Finland and help to avoid possible mistakes in the legislation development process in the future.

4.1 Germany

Nowadays, Germany is one of the flagships in the utilization of small-scale CHP technology. Only Spanner has more than 170 installation sites located within the country and equipped with biomass-based CHP units, allowing farmers, entrepreneurs, and dwellers to produce heat and electricity for self-consumption and feeding into the grid. This success is mainly due to the federal government plans to increase the share of renewable energy in the country’s final energy consumption up to 60% by 2050 (IEA 2013a, 111). Thorough work of German’s authorities and research institutions makes small-scale CHP an available and feasible technology solution for private use.

4.1.1 Policies and support measures

Two key support instruments promoting production and utilization of renewable energy, particularly small-scale CHP, in Germany are the Renewable Energy Source Act (Erneuerbare-Energien-Gesetz, EEG) and the Law on Preservation, Modernisation, and Development of Combined Heat and Power Generation (KWKG). The purpose of EEG is to develop the energy supply in a sustainable manner, to reduce its costs to the national economy, to conserve fossil fuels, and to promote the development of renewable electricity generation technologies (EEG 2016). KWKG, in its turn, is intended to increase the electricity generation from CHP plants in order to promote energy savings, environment and climate protection (KWKG 2016). However, either EEG or KWKG can be applied to the distinct installation at the same time.

Under EEG and KWKG, Germany provides a solid, versatile support to small-scale CHP plants, utilizing renewable energy sources. First, electricity producers are able to demand a feed-in tariff from the grid system operators for the electricity, fed into the grid. Feed-in tariff of 13.32 and 11.49 cent/kWh minus 0.2 cent/kWh is allocated to biomass-based installations with a total capacity of up to 150 kW and 500 kW, respectively. The remuneration remains constant for a period of 20 years from the day of commissioning. On top of that, for plants receiving the feed-in tariff, this period may be prolonged until 31 December of the 20th year. However, it worth mentioning that there is a gradual digression of this support, which reflects technical progress and cost reductions. Starting from April 2017, the feed-in tariff values are reduced every half a year by 0.5% compared with the values of the six preceding calendar months. In other words, the amount of support depends on when the installation goes into operation. Later the installation is commissioned, lower the applicable feed-in tariff is. (EEG 2016)

On top of that, in order to achieve German's renewable goals, starting from 2014, EEG specifies distinct growth targets, expansion corridors, for different technologies. Thus, biomass capacity should grow by 150 MW annually. To ensure the implementation of set goals, so-called breathing gaps for biomass, solar and onshore wind power have been introduced by EEG. The purpose of breathing gaps is to adjust the feed-in tariff value in order to comply the corridor targets. It means that exceeding of the target growth value will lead to the drop of the financial support from the feed-in tariff, and vice versa. (Ibid)

Second, all plants, producing renewable power, have the priority of grid connection over conventional plants, despite the fact that all costs for the grid connection should be paid by the plant operator. The network operator, in his turn, has to optimize, reinforce, and expand his network in order to accommodate all electricity, fed into the grid from renewable sources. However, expenditures, associated with grid expansion, are not paid directly by network operators; rather, they are funded through an additional tariff, so-called EEG surcharge, which is paid by all electricity consumers. In 2017, the EEG surcharge is set 6.88 cents per kWh (Eckert 2016). Furthermore, after 1 January 2017, even consumed power, which was generated by the producer itself, shout be levied on 40% surcharge. (IEA 2013a, 122; Lang and Lang 2014)

However, if the power generation unit is not connected to the public grid or if the power producer fully supplies himself with generated electricity and does not claim any financial support in the form of feed-in tariff, no EEG surcharge should be applied to such installation. (EEG 2016)

Finally, third, there is an investment support scheme provided by the Bank for Reconstruction (KfW Bankengruppe), which is owned by the federal government and the Länder (federal states), 80% and 20% (IEA 2013a, 114). The Bank offers long-term, low-interest loans with a fixed interest period of 5 or 10 years for small- and large-scale renewable installations, including CHP plants based on solid biomass. Annual interest rate is from 1.05%, and a fixed interest period of up to 20 years is provided if the duration of co-financed investment is longer than 10 years. Loans can cover up to 100% of project investment costs and can reach 50 million euros. A commitment fee of 0.25% is charged monthly. (KfW 2016; Nicola 2017)

On top of that, the increase of heat generated from the renewables is promoted by the Renewable Energies Heat Act. This document states, that new buildings must cover a portion of their heating and cooling requirements with the use of energy from renewable sources, particularly biomass. This applies to both residential and non-residential buildings for which a building notice or building application was submitted after 1 January 2009. On top of that, all existing buildings of the public authorities are also obliged to use the renewables as an energy source for their heating and cooling demand. (IEA 2013a, 119)

The summary of the main support measures for small-scale renewable energy generation in Germany is presented in table 6.

Table 6. Summary of support measures in Germany.

Feed-in tariff	
Value for plants < 150 kW	13.12 cent/kWh
Value is constant	Yes
Duration of support	20 years
Investment support	
Type of support	Loan
Amount of support	Up to 100% of total investment costs
Annual interest rate	From 1.05%
Duration of loan	Up to 10 years
Other	
EEG surcharge	2.75 cent/kWh

4.1.2 Electricity and heat prices

Germany has the second highest electricity price for household consumers among other European countries, outrun only by Denmark. In 2016, the average price for household customers with an annual consumption rate of between 2 500 kWh and 5 000 kWh was 29.7 cent/kWh. This is 93%, 57%, and 46% higher than in Finland, Sweden, and Austria, respectively. Such high price is due to a huge share of surcharges and taxes (figure 9). Only the EEG surcharge accounts for more than 21% of the final price. Moreover, there is a constant increase in the state-determined price components of the offshore liability surcharge and the surcharges paid under EEG, KWKG and section 19 of the StromNEV (The Electricity Network Charges Ordinance). Thus, in 2016, the price components, which are not controlled by the supplier (surcharges, levies, taxes, and network charges), amounted in total to approximately 75%, meanwhile the competitive part of the price (energy procurement, supply, and margin) was only 25%. (Eurostat 2017; Bundesnetzagentur 2016a)

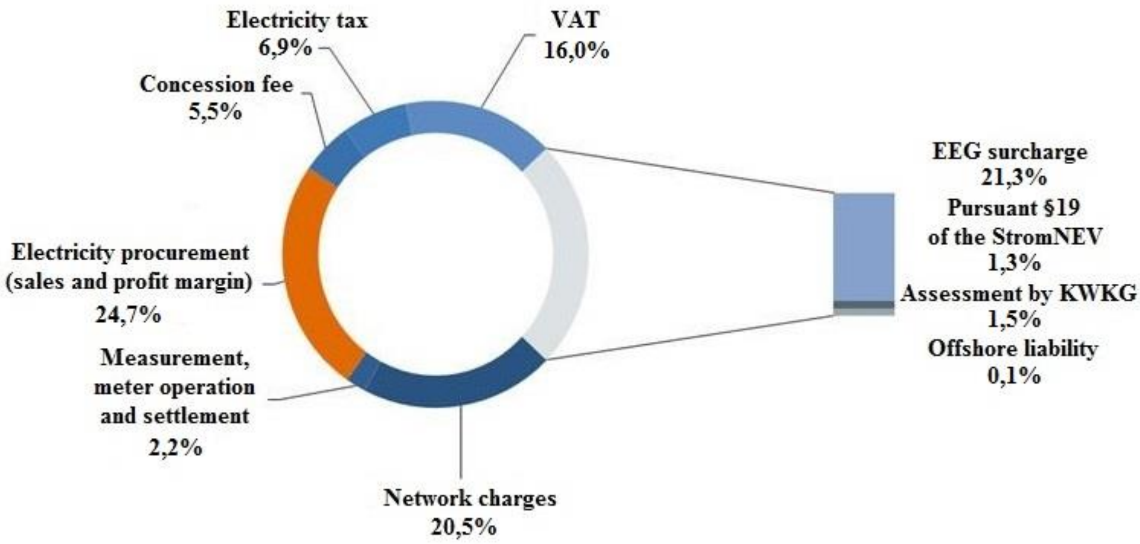

Figure 9. Household customer price breakdown as of 1 April 2016. (Bundesnetzagentur 2016b)

The same tendency can be seen for electricity prices for industrial consumers. Germany shows the second highest price within Europe for customers with an annual consumption rate of between 500 MWh and 2 000 MWh, outrun again only by Denmark. In the second semester of 2016, the average price was 19.58 cent/kWh, what is twice higher than the price in Finland and Sweden. Alike price for household consumers, the better part of electricity price for industrial customers is taxes and levies. The average national price without tax part in 2016 amounted to 7.93 cent/kWh, what shows that taxes and levies took approximately 60% of the final price. (Eurostat 2017)

Despite the fact that Germany with 3 372 heating plants has the biggest district heating market in the European Union, only 13.5% of all existing houses are connected to the DH network. In 2014, the percentage of new houses purchasing heat from the network was 21.5%. Nevertheless, the majority of new buildings (49.8%) were equipped with natural gas boilers; heat pumps and wood/wood pellet boilers were installed in 19.9% and 7% of recently built houses, respectively. (E&P 2015; FMEAE 2015) On top of that, there is still a big amount of houses, which use oil and coal to satisfy their heat demand; however, this amount is continuously decreasing due to the government’s program for phasing-out of such installations. Thus, to compare the costs of heat from conventional sources, it is necessary to mention not only the district heating price but also the price of natural gas. According to data (Eurostat 2017), in 2016, the average natural gas price for household customers with an annual consumption rate of between 20 GJ and 200 GJ (5.6 MWh and 55.6 MWh) was 17.83 euro/GJ (6.42 cent/kWh). The price for customers with a consumption rate of between 10 000 GJ and 100 000 GJ (2 777.8 MWh and 27 777.8 MWh) was 10.96 euro/GJ (3.95 cent/kWh). Assuming the efficiency of gas boilers with a heat capacity of 14 kW and 101-545 kW being 95.6% and 97% (Rinnai 2017; Viessmann 2016), respectively, it is possible to roughly estimate the price, gas boilers' users had to pay for the heating of their homes. Therefore, the heat price (not including operational costs) for users with own boilers was 6.72 cent/kWh and for those with the central heating system (one common boiler for several dwellings) was 4.07 cent/kWh, while the district heating price was 7.6 cent/kWh (Energiforsk 2016).

4.1.3 Investment and production costs

For the rough estimation of investment and production costs in Germany, a CHP unit Spanner HK 45 with a capacity of 45 kW_e and 108 kW_{th} was chosen. Since there are no capacity restrictions for plants to be eligible for the government support, only one unit is installed in the hotel. The price of a unit is EUR 176 000 and installation costs are EUR 15 000 for plumbing and EUR 10 000 for electrical installation. The price of a drying system is EUR 35 000. The average price of wood chips in Germany is between 15 and 20 EUR/m^3, which means 75-100 EUR/t of wet chips. (Spanner 2017; Westermaier 2017) The number of running hours per year and the share of electricity consumed on site are varied from case to case. All produced heat is utilized for heating and hot water production (80%) and fuel drying (20%). Excess of electricity is fed into the grid and remunerated with a feed-in tariff. On top of that, it was assumed that a loan, fully covering investment costs, for a period of 10 years was granted by KfW. Furthermore, in order to estimate yearly savings from the utilization of CHP installation, it was assumed that before the commissioning of a CHP unit, the hotel was buying electricity from the grid and was producing heat with a natural gas boiler. According to data from the Association of Energy Consumers (BEV 2017), in all considered cases, the hotel with its consumption rate is treated as a household consumer; therefore, prices of gas and electricity are 6.42 cent/kWh and 29.7 cent/kWh, respectively. Finally, for payback time calculation, equation (7) (Calculator 2017), considering the loan interest rate, was used:

$$N = \frac{\ln\left(1 - \frac{I}{A} i\right)}{\ln\left(\frac{1}{1+i}\right)}, \tag{7}$$

where N is payback time [year]

I is investment costs [EUR]

A is yearly balance [EUR/year]

i is interest rate [%]

The summary of equipment related costs is presented in table 7.

Table 7. Summary of equipment related costs.

	Unit	**Value**
CHP unit	-	Spanner HK 45
Electrical / thermal capacity	kW	45 / 108
Maximum number of working hours	hour/year	8 000
Unit price	EUR	176 000
Dryer price	EUR	35 000
Plumbing price	EUR	15 000
Electrical installation price	EUR	10 000
Price of wood chips	EUR/wet ton (EUR/MWh)	100 (20)
Total investments	EUR	236 000
Amount of a loan	EUR	236 000

As a result of calculations, data, such as yearly savings and expenditures, payback time, was obtained. Detailed information for the case with 8 000 running hours per year and 80% of produced electricity consumed by the user can be found in Appendix 2. For the fast comparison of payback time, depending on the number of running hours and consumed electricity, table 8 can be used.

4.1.4 Payback time in Germany

Table 8. Payback time (in years) depending on the number of running hours and the share of consumed electricity.

Running hours per year	Share of consumed electricity				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	10.5	8.6	7.3	6.3	5.0
6 000 h/year	6.8	5.6	4.8	4.1	3.3
8 000 h/year	5.0	4.1	3.5	3.1	2.4

Therefore, as it can be seen from the table above, the more time during the year the unit works, and the more electricity is consumed by the user, the less payback time is. The reason for that is consuming self-produced electricity during the payback period is more profitable than selling it, inasmuch as the electricity price is more than twice higher than the value of feed-in tariff. In addition, no EEG surcharge is levied on the plant operator when he entirely consumes self-produced electricity. However, the case, when the user needs the exact amount of heat and electricity that the unit can produce, is ideal. Usually, the share of consumed electricity is lower than 100%, thus, the excess amount is typically fed into the grid. However, when the loan is paid back, an opposite situation occurs. The more electricity the user feeds into the grid, the less his yearly expenditures are.

4.2 Austria

One of the three pillars of the Austria’s energy policy is the renewable energy. The country is in among the leaders for biomass usage and has the fourth highest target share (34%) of renewable energy in gross final energy consumption in 2020 among other European Union countries (IEA 2014a, 103). Abundant forest stocks (47% of the total land area) and a strong government support give Austria a favorable environment for the deployment of biomass-based energy installations (CIA 2017).

4.2.1 Policies and support measures

Similarly to Germany, Austria provides a solid support for electricity and heat production from renewable sources. The support is presented in a form of feed-in tariffs and investment cost subsidies, which can be changed depending on different provisions. The major legal instruments for the promotion of renewable energy in Austria are the Green Electricity Act (Ökostromgesetz – ÖSG), the Regulation 459 (ÖSET-VO), the CHP-Act (KWK-Gesetz), and the Environment Aid Act (UFG).

The main support for electricity from renewable energy sources is a feed-in tariff. In order to get this support, the plant operator has to conclude a contract with the Clearing and Settlement Agency. This organization is a private enterprise, granted a state license, which is obliged to buy the renewable electricity and sell it within the Austrian territory. In 2017, the feed-in tariff for biomass-based installations with a total electric capacity of up to 500 kW and total efficiency of more than 70% is the largest among other feed-in tariffs for all renewable sources and amounts to 22 cent/kWh (ÖSET-VO 2016). If a power plant has a total efficiency lower than 70%, the feed-in tariff decreases to 18.61 cent/kWh (Ibid). This feed-in tariff is usually granted for a period of 15 years and, unlike Germany, does not remain constant. This is due to an annual tariff reduction, which is determined by the Minister of Science, Research, and Economy, and which reflects the technology costs development. On top of that, the Clearing and Settlement Agency is able to conclude new contracts for the purchasing of electricity only if the additional annual support funds for renewable electricity are available. It means that if there are no funds left, the Agency has a right to refuse electricity purchasing from a renewable source. Thus, in 2017, the support funds for solid biomass plants with a total capacity of up to 500 kW account for EUR 3 million. (ÖSG 2012)

In Austria, renewable energy plants have no priority for the connection to the power grid over conventional plants. Furthermore, all connection costs, so-called grid-access fee, should be fully paid by the plant operator. Apart from that, grid operators are not obliged to reinforce their grids in order to connect new plants. Therefore, if the reinforcement is needed, a plant operator has to conclude a contract for such works with a grid operator. However, electricity from renewable energy sources does have the priority for the transmission via public grids. It is so only when the grid capacity is insufficient to meet the demand for the use of the grid. On top of that, a grid operator may refuse to provide an access to the grid for the electricity from non-renewable sources in order to prevent the renewable electricity from being crowded out from the market. (ElWOG 2013)

Under the Environmental Aid Act (UFG), Austria provides an investment support for technologies protecting the environment. The annual budget for a period until 2020 is EUR 90.238 million and financed by the Austrian Federal Ministry of Agriculture, Forestry, Environment, and Water Management. (Borek 2017) Thus, a support of 20% of total investment costs may be granted for biomass-based CHP installations. The support is presented in a form of a one-off, non-repayable investment cost subsidy. Moreover, a special sustainability surcharge (5% of investment costs) may be paid to the plant operator if he utilizes at least 80% of fuel collected in a local area within a range of up to 50 km. However, if the operator is unable to fully utilize produced heat, a proportional reduction of a base subsidy amount occurs. (KPC 2017)

In addition, the government of Austria released the Act on Energy Efficiency (EEffG), intended to increase the energy efficiency of energy use by households and companies, which clearly sets an exemplary role of public authorities. It obliges recently erected federal government buildings to fulfill the criteria of low-energy buildings. Moreover, the energy demand of such buildings, that is close to zero or very low, should be covered with renewable sources. (Borek 2017; EEffG 2014)

The summary of the main support measures for small-scale renewable energy generation in Austria is presented in table 9.

Table 9. Summary of support measures in Austria.

Feed-in tariff	
Value for plants with total efficiency of < 70%	18.61 cent/kWh
Value for plants with total efficiency of > 70%	22.00 cent/kWh
Value is constant	No
Duration of support	15 years
Investment support	
Type of support	Non-repayable grant
Amount of support	Up to 20% of total investments

4.2.2 Electricity and heat prices

Despite the fact that Austrian and German electricity markets form a common German-Austrian price zone (IEA 2014a, 92), electricity prices in Austria are much lower than those in Germany. Thus, for instance, in 2016, the average price for household customers with an annual consumption rate of between 2 500 kWh and 5 000 kWh was 20.3 cent/kWh, what is approximately 30% lower than the price German customers had to pay. Comparing to other European countries, Austria has the eighth highest electricity price for household consumers, staying close to Sweden. (Eurostat 2017) The price of electricity in Austria consists of three main components: the energy price, the network charges, and the taxes and surcharges (figure 10). The liberalized Austrian electricity market allows energy suppliers to fairly compete with each other, and therefore set the price, they charge for supplied energy, by themselves. The network charges are a grid utilization charge, a charge for grid losses, and a metering charge. All these charges are regulated by the E-Control Commission, the independent body responsible for the overseeing of the country's electricity market. Finally, the taxes and surcharges include an energy charge (1.5 cent/kWh), VAT (20%), a community levy, which is collected by some communities for the use of public property, and green electricity costs, which are paid by every customer for the promotion of renewable energy. (E-Control 2017)

Figure 10. Electricity price composition for a household customer with a consumption rate of 3 500 kWh/a in Vienna. (E-Control 2017)

In 2016, the average electricity price for industrial customers with an annual consumption rate of between 500 MWh and 2 000 MWh in Austria was approximately 15% lower than the average price in 28 European countries and amounted for 12.29 cent/kWh. Similarly to household consumers, the large share of the price is taxes and levies. Thus, the additional part was 5.44 cent/kWh or 44% of the final electricity price. (Eurostat 2017)

Nowadays, the major part of space heating demand (about 60%) in Austria is covered by central heating, fueled mainly by natural gas. Approximately 24% of households are connected to rapidly growing heat network, and the rest part utilizes individual heating, for example, wood or oil boilers. District heating is typically used in urban areas to provide a heat for large residential buildings. For instance, more than 40% of households in Vienna are connected to heat network, and this value is predicted to increase up to 50% by 2020 due to the government’s energy efficiency program. (FGW 2016; IEA 2014a, 108-109) On top of that, local heat networks, purchasing heat from small-scale wood boilers, are gaining popularity in less-dense areas of the country. Therefore, in order to cover all groups of users, it was decided to compare prices of heat not only from heat network and gas boilers, as it was for Germany, but also from oil boilers. Thus, in 2016, the average natural gas price for household customers with an annual consumption rate of between 20 GJ and 200 GJ (5.6 MWh and 55.6 MWh) was 18.71 euro/GJ (6.74 cent/kWh), what results in the heat price of 7.05 cent/kWh (Eurostat 2017). The price for customers with a consumption rate of between 10 000 GJ and 100 000 GJ (2 777.8 MWh and 27 777.8 MWh) was 11.95

euro/GJ (4.30 cent/kWh), what, in its turn, gives the heat price of 4.43 cent/kWh (Ibid). Furthermore, the average price of heating oil in Austria in 2016 was 0.53 euro/liter (4.90 cent/kWh) (Statista 2017). Therefore, the price of heat from oil boiler with a total efficiency of 97% (Viessmann 2016) was approximately 5.05 cent/kWh. At the same time, the district heating price was 6.8 cent/kWh (Energiforsk 2016).

4.2.3 Investment and production costs

Since Austria and Germany are neighboring countries, and Spanner operates also on Austrian market, it was decided to choose Spanner HK 45 as a CHP unit for the estimation of investment and production costs in Austria. All conditions for calculations, except few of them, remained the same as for Germany. First, the price of wood chips with a moisture content of between 20% and 30% is approximately EUR 132 per ton (Prislan et al. 2014) or 33 EUR/MWh. Second, since the efficiency of a plant may vary within a year, depending on the amount of produced electricity and heat, and drop below 70%, it was decided to consider two cases, when a feed-in tariff amounts to 22 cent/kWh and 18.61 cent/kWh. These values remain constant through the whole support period. Third, a non-repayable investment costs subsidy, covering 20% of total investment costs, was granted under the Environmental Aid Act. Similar to those for Germany results were obtained. The summary of equipment related costs is presented in table 10.

For the easier comparison of costs in Austria and Germany, results for one of the cases with 8 000 running hours per year and 80% of produced electricity, which was consumed on site, was placed also in Appendix 2. Finally, changes of payback time, calculated using equation (3), may be found in table 11.

Table 10. Summary of equipment related costs.

	Unit	Value
CHP unit	-	Spanner HK 45
Electrical / thermal capacity	kW	45 / 108
Maximum number of working hours	hour/year	8 000
Unit price	EUR	176 000
Dryer price	EUR	35 000
Plumbing price	EUR	15 000
Electrical installation price	EUR	10 000
Price of wood chips	EUR/wet ton (EUR/MWh)	132 (33)
Total investments	EUR	236 000
Investment grant	EUR	47 200

4.2.4 Payback time in Austria

Table 11. Payback time (in years) depending on the number of running hours, the share of consumed electricity, and the value of the feed-in tariff.

Running hours per year	**Share of consumed electricity**				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	5.8 (6.8)*	5.9 (6.7)	6.0 (6.5)	6.1 (6.4)	6.3 (6.3)
6 000 h/year	3.9 (4.5)	3.9 (4.4)	4.0 (4.3)	4.1 (4.3)	4.2 (4.2)
8 000 h/year	2.9 (3.4)	2.9 (3.3)	3.0 (3.3)	3.1 (3.2)	3.1 (3.1)

* values in brackets are for the feed-in tariff of 18.61 cent/kWh.

In Austria, a relative equality of the electricity price and the values of the feed-in tariff along with a possibility to get an investment grant from the government make payback time shorter than in Germany. Both values of feed-in tariff stand on the same distance (1.7 cent/kWh) from the electricity price, therefore, the difference between the duration of payback period in two cases is small, especially when the share of consumed electricity approaches the point of 100%. Obviously, in order to decrease that period when the feed-in tariff is 22 cent/kWh, it is better to sell electricity than to consume it, and vice versa. However, when the investment costs are paid off, the higher value of the remuneration allows the user to decrease his yearly expenditures or, for the case with a consumption rate of 20%, even to profit from the utilization of his plant.

4.3 Sweden

Starting from the 1960s, Sweden has always been considered as an environmental pioneer. Thus, the country was the first to create an environmental protection agency, in 1967, and also one of the first to sign and ratify Kyoto Protocol. Today, Sweden with an intention to become one of the world’s first fossil-free welfare nations sets ambitious targets in areas of energy efficiency, sustainability, and environment. (Sweden 2016) The country is already ahead of its 2020 target for renewable energy, reaching the point of 53.9% of renewables in its TPES (Eurostat 2017). Nevertheless, even being ranked as one of the most sustainable communities, Sweden cannot boast about the abundance of installed small-scale CHP units, what can be a consequence of an insufficient support for such installations from the government.

4.3.1 Policies and support measures

In Sweden, renewable energy gets a support mainly from the electricity certificate system and tax regulation mechanism. Both measures are intended to stimulate production and utilization of electricity from renewable energy sources, while the latter also promotes the production of renewable heat.

The electricity certificate scheme was first introduced in Sweden in May 2003. The aim of this mechanism was to increase, by 2020, the production of electricity from renewable sources by 25 TWh comparing to 2002 level. Later, in January 2012, Norway joined this system, forming a common Swedish/Norwegian electricity certificate market and increasing the annual production rate by a further 13.2 TWh relative to the 2012 level. The certificate program is intended to run until the end of 2035 and it allows electricity producers with next energy sources to participate in the electricity certificate trade: wind and hydropower; solar, wave, and geothermal energy; peat, when burnt in CHP plants; and biofuels, including forest biomass. (SEA 2012)

The idea of the electricity certificate system is a bit more complicated than that of the feed-in tariff. Therefore, it could be necessary to explain the principle, how plant operators are able to profit from the production of green electricity. The process of certificate trade can be divided into 6 steps (figure 11). At the very beginning, (1), producers of electricity receive one electronic electricity certificate from the Swedish or Norwegian State for every MWh of electricity they have produced from renewable energy sources or from peat. Later, (2), electricity producers can sell their certificates along with produced electricity in order to obtain additional revenues. Certificates from both Sweden and Norway are traded on the same open market, (3). The setting of prices is affected by several factors, such as the expected demand for electricity and the expected introduction of new production capacities. Changes in the certificate system, caused by recent political decisions, may also affect the final price of certificates. Thus, in 2016, the average certificate price in Sweden was SEK 155.96 or approximately EUR 16.48 (Poblocka-Dirakis 2017). After prices are set, (4), certificates are purchased by electricity suppliers and by certain electricity end users, which are required to buy certificates corresponding to the certain proportion (quota) of their electricity sales or use. The quota is set by the States and helps to maintain a demand for certificates. If the purchaser of certificates is an electricity supplier, the costs of certificates are passed on to final consumers, (5), via their electricity bills. Thus, electricity customers indirectly support the promotion of renewable energy in both countries. Finally, (6), on 1 April of each year, parties having quota obligations have to possess the defined amount of electricity certificates, which will be then canceled by the account management authority. After certificates are invalidated, the parties are obliged to obtain new certificates in order to meet next year’s quota obligation. In this way, a constant demand for electricity certificates is created. (SEA 2012)

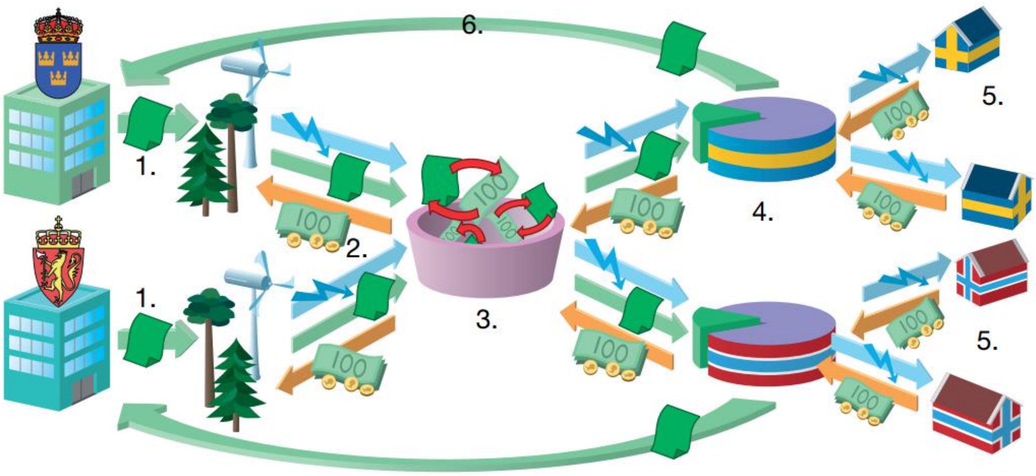

Figure 11. The electricity certificate system. (SEA 2012)

The electricity certificate system is intended to support an electricity production by new power or CHP plants. Therefore, in order to limit the costs to consumers of electricity from old but still commercially viable plants, there is a time limit to the right of electricity producers to obtain certificates from the States. Thus, all plants commissioned after May 2003 are eligible to receive electricity certificates either for a period of 15 years or until 2035, whichever is the earlier. Those plants that had been commissioned before the mentioned date stopped to receive the support in 2012 or 2014. Moreover, electricity producers, who utilize installations with a total capacity of more than 50 kW and whose consumption rate of own electricity exceeds 60 MWh per year, are also obliged to fulfill quota obligations. On top of that, since the system is also aimed to increase the production rate of renewable electricity up to the certain point, the value of quota obligation has to reflect the current situation of the target fulfillment. Thereby, the government sets the distinct quota obligations for each year until 2035 (table 12) and is able to adjust them whenever it is necessary. The quota, which supplier or consumer has to obtain, is calculated by the multiplying the number of MWh of electricity sold or used by the quota obligation of a certain year. (Ibid; Poblocka-Dirakis 2017)

Table 12. Quota obligation per MWh of electricity sold or consumed in Sweden. (Sveriges Riksdag 2015)

Year	**2003**	…	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	…	**2035**
Obligation	0.074		0.247	0.270	0.291	0.288	0.272	0.257	0.244		0.013

Besides electricity certificate mechanism, Sweden has a complex system of taxation in the energy sector. It comprises four main elements: an energy tax, a CO_2 tax, an NO_x tax, and a sulfur tax. An energy tax is levied on electricity production, supply, and consumption. The basic value of the tax is 29.5 öre/kWh (3.08 cent/kWh), however, in some municipalities in northern Sweden, there is a deduction of 9.6 öre/kWh (1.00 cent/kWh) for household consumers and customers in the service sector. On top of that, electricity produced on plants with a capacity of less than 50 kW or fueled with most of biofuels (including biomass) is exempt from taxation. A carbon dioxide tax, in its turn, is levied on production, supply, and import of fossil fuels for heating purposes, which means that producers of heat from renewable energy sources do not have to pay a CO_2 tax. Furthermore, an NO_x tax is applied for heat production, while a sulfur tax – to emissions where sulfur is measured. If sulfur is removed from exhaust gasses, the tax is refunded to the plant operator. Similarly to first two taxes, biofuels are exempt from these obligations. In addition, micro-producers of renewable electricity may seek for the tax reduction of 60 öre/kWh (6.25 cent/kWh) for an excess amount of electricity fed into the grid. However, this amount should not exceed 30 000 kWh per year. (Poblocka-Dirakis 2017; Skatteverket 2017)

The summary of the main support measures for small-scale renewable energy generation in Sweden is presented in table 13.

Table 13. Summary of support measures in Sweden.

Electricity certificates	
Value of certificates	1.65 cent/kWh
Value is constant	No
Duration of support	15 years or until 2035
Tax regulation	
Exemption from taxes	CO_2, NO_x, Sulfur; Energy tax for plants < 50 kW
Tax reduction for micro-producers	6.25 cent/kWh; maximum 30 MWh per year

4.3.2 Electricity and heat prices

Sweden has relatively modest electricity prices if compared to other European Union countries. Thus, in 2016, the price for household consumers was a bit lower than the average price in EU, while the price for industrial customers was twice lower than the average one. One of the reasons is that the final price is not overburdened with a large amount of taxes and levies as it is, for instance, in Germany. (Eurostat 2017) Besides it, the price of electricity in Sweden depends on several factors. First, since the country is a member of the Nord Pool, where electricity is mainly produced from sources other than fossil fuels, the price of electricity may vary significantly, reflecting the wholesale price on the Pool Spot. Second, since the end of 2011, by the order of the European Commission, Sweden has been divided into four different price zones. The aim of the portioning is to determine where in the country there is a need for the reinforcement and the expansion of the public grid. It also helps to indicate if there is a need in any regions to increase an electricity production. Third, electricity prices in Sweden are not regulated by the authorities; rather, the final price, consumers have to pay, is set by the electricity supplier. Latter offer variety of different contract types, allowing customers to choose the duration of the contract and whether electricity price will be constant or not. (IEA 2013c, 124; SEA 2015) Therefore, there is no single electricity price in Sweden; and in order to estimate how much different users have to pay for electricity usage, an averaged data from (Statistics Sweden 2017) can be used (table 14).

Table 14. Average total electricity price in Sweden in 2016. (Statistics Sweden 2017)

Consumption rate, MWh/a	**2.5 - 5**	**5 – 15**	**20 - 500**	**500 - 2 000**
Price in CSEK/kWh	183	149	71	60
Price in cent/kWh*	19.28	15.74	7.50	6.34

* SEK 1 = EUR 0.10565 in 2016 (X-Rates 2017).

Today, district heating covers more than half of total heating demand in Sweden, whilst a third of heating is based on electricity (electric boilers, direct-acting electric heating, and heat pumps). Approximately 15% of heating comes from individual biomass boilers, and the rest part is represented with oil and gas systems. It worth mentioning that each of three main groups has its own sub-market. Thus, district heating is the main heat supplier for multi-family houses and premises, while electricity and biomass-based heating have the largest share in single-family houses. Latter type of users covers approximately 40% of the country's heating demand, and multi-family houses and premises account for 30% and 25% of the demand, respectively. (Sköldberg & Rydén 2014) Therefore, four main options that can be considered when talking about heating in Sweden are district heating, heat pumps, electric heating (boilers and direct heating), and biomass-based heating. The most expensive among mentioned is electric heating, since it directly converts electricity into heat with an efficiency close to 100% (TheGreenAge 2017), and the final price of heat is that of electricity. The second place is taken by district heating. According to (Energi Företagen 2017), in 2016, tenants of large apartment buildings had to pay 81.6 öre/kWh (8.62 cent/kWh) for taking the heat from the grid, while owners of single-family houses were charged 89.5 öre/kWh (9.46 cent/kWh). However, if heat is needed in large amounts (more than 20 MWh per year), electric heating can be competitive with district heating. Next cheaper option is biomass-based heating. Thus, for instance, if pellet boiler is used, the price of heat equals to 63.39 öre/kWh or 6.70 cent/kWh (Varmavillan 2017; Fröling 2017). Finally, the cheapest heating method among all four is the utilization of heat pumps. Heat pumps allow converting electric energy into heat energy with a coefficient of about 4.2 (Mitsubishi Electric 2017), making yearly expenses for heating quite small. In this case, the heat price is that of electricity divided by 4.2. However, heat pumps have several drawbacks, for instance, higher investment costs and limited temperature range of heat sources, making the decision of their utilization not as clear as it could be.

4.3.3 Investment and production costs

For the calculation of investment and production costs in Sweden, the same basic boundary conditions as for previous countries were chosen. Nevertheless, there are several distinctions. First, one Volter 40 Indoor unit is used. Second, the price of chips, it consumes, is approximately 20 EUR/MWh (Statistics Sweden 2017) or 80 EUR per wet ton. Third, an excess amount of produced electricity is fed into the grid and remunerated with electricity certificates. The price of certificates is 16.48 EUR/MWh. In addition, the hotel may seek for an energy tax reduction, what means that 6.25 cents will be allocated per each kWh of produced electricity it sells. However, this system can be applied maximum for 30 MWh of fed electricity per year. Fourth, before the commissioning of the plant, the hotel was buying electricity from the grid and producing heat with a pellet boiler.

The price of electricity varied according to hotel's consumption rate and table 14. The summary of equipment related costs may be found in table 15.

Table 15. Summary of equipment related costs.

	Unit	Value
CHP unit	-	Volter 40 Indoor
Electrical / thermal capacity	kW	40 / 100
Maximum number of working hours	hour/year	7 800
Unit price	EUR	179 650
Dryer price	EUR	35 000
Fuel conveyer price	EUR	15 000
Plumbing price	EUR	15 000
Electrical installation price	EUR	10 000
Price of wood chips	EUR/wet ton (EUR/MWh)	80 (20)
Total investments	EUR	254 650

Similarly to previous calculations, results for one of the cases with 7 800 running hours per year and 80% of produced electricity, which was consumed on site, was placed in Appendix 2. On top of that, changes of payback time, which was calculated with a help of equation (3), are presented in table 16.

4.3.4 Payback time in Sweden

Table 16. Payback time (in years) depending on the number of running hours and the share of consumed electricity.

Running hours per year	**Share of consumed electricity**				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	-*	-	72.6	47.3	35.1
6 000 h/year	46.7	30.8	23.0	18.3	15.3
7 800 h/year	24.1	17.9	14.2	11.8	10.1

* plant cannot be paid off.

The obtained tendency of the payback time change is similar to that for Finland. The low price of electricity certificates and the possibility to cover only 30 MWh of sold electricity with an energy tax reduction mechanism do not bring tangible profit for plant operators. Moreover, low electricity prices for enterprise customers make yearly savings for electricity relatively small, therefore, in cases, when the user consumes little electricity, annual operational costs are even bigger than savings. Hence, utilization of small-scale plants in Sweden is reasonable only when installations are used during high numbers of running hours and with big shares of consumed electricity.

4.4 Summary

Overview of operational environments in different countries allows to see what obstacles small-scale CHP installations have to face with, and how local governments help to overcome these barriers. According to conducted analysis, the main support is presented in a form of feed-in tariff, which allows plant operators to feed excess amounts of produced electricity into the grid and receive a remuneration for it. Moreover, Germany and Austria also provides investment cost subsidies, intended to make initial expenses more bearable for users. Sweden, in its turn, exempts plants, producing electricity and heat from renewable energy sources, from emission and energy taxes. Nevertheless, the amount of support differs in each country and, consequently, affects operation process differently. Table 17 sums up main elements of operational environments in each country and shows how they influence the duration of the payback period.

Thus, the most favorable environment for the utilization of small-scale renewable installation is in Austria and Germany. Possibility to receive a feed-in tariff of a high value as well as a non-repayable grant or a low-interest loan, covering 20% or 100% of total investment costs, respectively, allows plant operators to pay off their initial costs within approximately three years. Opposite situation occurs in Sweden, where electricity certificate system, unsuitable for small plants, and tax reduction mechanism do not bring a tangible profit for users, what leads to a significantly longer payback period.

Table 17. Summary of operational environments in different countries.

	Germany	Austria	Sweden	Finland*
Electricity price for household consumers (2500 - 5000 kWh/a), cent/kWh	29.70	20.30	19.28	15.30
Electricity price for enterprise consumers (500 - 2000 MWh/a), cent/kWh	19.58	12.29	7.50	8.61
Alternative heat price, cent/kWh	6.62	6.74	5.20	7.24
Investment costs, EUR	236 000	236 000	254 650	459 300
Wood chips price, EUR/wt; EUR/MWh	100; 25	132; 33	80; 20	100; 25
Feed-in tariff, cent/kWh	13.12	22.00 (18.61)	1.65	1.86 (7.11)
Payback time, years**	3.1	3.1 (3.2)	11.8	6.3 (7.3)

* plant with two CHP units;
** payback period was calculated using 8 000 running hours per year for Germany and Austria, and 7 800 hours – for Sweden and Finland; and 80% of produced electricity consumed by the user.

5 IMPROVEMENTS IN FINLAND

Overview of support measures in considered countries allowed to formulate several ideas on what can be changed in Finnish legislation in order to promote the utilization of small-scale CHP installations within the country. Based on the experience of Germany and Austria, it is reasonable to say that the main mechanism, fostering this technology, is a feed-in tariff system. In addition, investment costs subsidies play an important role when considering a construction of a new plant. Thereby, these two measures should be used as a baseline for developing of a new support system in Finland.

5.1 Feed-in tariff system

The present feed-in tariff system in Finland is designed mostly for large-scale plants, whose aim is to produce electricity for selling. For instance, the system for forest chip plants is intended to make the utilization of chips more competitive to that of peat and fossil fuels, since it takes into account a value of a peat tax and emission allowance price for the calculation of the tariff. The feed-in tariff for wood fuel plants, in its turn, is determined using the market electricity price instead of the total price, what, actually, increases the value of the remuneration. However, if wood fuel plants receive any additional support, they instantly become ineligible for the feed-in tariff system. Therefore, it is important to develop a system that would suit small-scale installations used mainly to satisfy the owner’s demand, while excess electricity may be freely fed into the grid. Moreover, developed system has to avoid any provisions restricting simultaneous allocation of the tariff and an investment support. In addition, since users of such installations are usually referred to the non-ETS sector (households, agriculture) and do not utilize peat for energy generation, the support system should not depend on such variables as a peat tax or emission allowance price. Thus, the value of the feed-in tariff could either be stable or reflect the current total electricity price for a specific group of consumers.

5.1.1 Stable value of feed-in tariff

In order to maintain the support for plant operators on an appropriate level, it could be possible to make the feed-in tariff dependent only on the capacity of a plant. For instance, there could be three tariff groups for the capacity range of up to 100 kW; between 100 kW and 500 kW; and between 500 kW and 1 MW. Thus, it would be possible to properly reflect the difference in electricity prices between various groups of consumers (with a consumption rate of less than 20 MWh/year, between 20 MWh/year and 500 MWh/year, and so on) and the difference of operational costs that plant users have to bear. Moreover, in order to make the length of payback period reasonable enough, the value of the tariff should be relatively high. Thus, if a plant is able to receive the feed-in tariff of 9 cent/kWh and an investment grant covering 30% of a unit price, the payback time will amount to:

Table 18. Payback time (in years) depending on the number of running hours, the share of consumed electricity, and the number of installed CHP units.

Running hours per year	**Share of consumed electricity**				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	22.4 (19.6)*	21.4 (18.7)	20.4 (17.9)	19.6 (17.1)	18.8 (16.4)
6 000 h/year	10.1 (8.8)	9.8 (8.5)	9.5 (8.3)	9.2 (8.0)	8.9 (7.8)
7 800 h/year	6.7 (5.9)	6.5 (5.7)	6.4 (5.6)	6.2 (5.4)	6.0 (6.4)

* values in brackets are for a plant with two CHP units.

Thus, allocation of an increased feed-in tariff along with an investment grant may significantly reduce the length of payback period, especially in cases when a user is unable to consume all produced electricity. On top of that, provided support makes it possible for a plant operator to pay his investment costs off even in those cases, where it was impossible without receiving a remuneration for fed electricity or when utilizing a forest chip plant. Since the value of the tariff is lower than the electricity price, the payback period gradually reduces as the number of running hours and the rate of an electricity consumption grow. The only exception is an increased payback time for the case with 7 800 running hours and entirely consumed electricity, what is due to a lower electricity price used for yearly savings calculations.

5.1.2 Variable value of feed-in tariff

Another option is to make a feed-in tariff dependent on the current value of electricity price. For instance, the support may equal to 85% of the price, or the percentage may vary depending on the consumer group: 90% for the consumption rate of less than 20

MWh/year; 85% for the rate of 20 – 500 MWh/year; and 80% for the rate of 500 – 2 000 MWh/year. In this case, allocated support will always reflect changes in electricity prices and not be too low or too high.

Moreover, since the constitutional law of Finland does not allow the costs of the feed-in tariff system to be paid by end-users, and the program is subsided by the government's budget (IEA 2013b, 105), it could be necessary to introduce several restrictions into this system that will allow country to properly manage its budget. First, the support should be allocated only to small-scale CHP plants. Second, the main purpose of plants should be the production of electricity and heat to satisfy the owner's demand. It means that the user could be a farmer, stockbreeder, an owner of a forestry, a hotel or catering business. In addition, local heat and electricity networks for communities consisting of several buildings may also be eligible for the support. On top of that, a plant operator should justify the installation of a CHP plant instead of a conventional wood-based boiler. The authority, responsible for the allocation of the support, has to get monthly or annual reports that, for instance, more than 30% of produced electricity is consumed on site. Third, if the Finnish government aims to make a transition towards more decentralized energy production but is not going to support plants during a long period, the support may be granted only until investment costs are paid off. This scheme will motivate new users to opt for CHP plants rather than for boilers and current operators to replace their old equipment with new and more efficient one. During the payback period, users will get a support that will make yearly expenditures lower comparing to that with conventional sources. After investments are paid off, operational costs will be same or lower depending on the share of consumed electricity and heat and an equipment used before.

5.2 Investment and operation support

Besides indirect support in a form of a feed-in tariff, it could be necessary to provide additional funding during investment and/or operation stages. Today in Finland, the only plants that may receive an investment costs subsidy are plants located on farms or in rural areas. Therefore, in order to make small-scale CHP technology widely used in Finland, it is important to promote its utilization also among other users. Investment grants should be allocated according to non-discriminatory principles, whether it is a micro-scale entrepreneur, SME, or a small community and whether it is a rural area or not. The support may be presented in a form of non-repayable grants or low-interest loans. Nevertheless, the decision on a type and an amount of the support to be allocated could depend on such factors as a type of a business, total investment costs, a presence of other loans, an estimated consumption rate, and so on. This scheme should be used especially along with a feed-in tariff aid granted only for a payback period. Thus, it will create additional incentives for current users to renovate their outdated plants.

Moreover, aid fully or partially covering maintenance costs may be granted to plant operators. The support could be presented in a form of special contracts with maintenance companies or in a form of annual repayments from the government. Thus, if users do not have to bear these costs, the value of yearly expenditures and, consequently, the payback time will be decreased significantly.

In addition, the government could support plants producing renewable energy via special discounts for domestic wood chips. Reduced price for chips would allow both Finland and local plant operators to benefit from it. First, the lower price could stimulate users to avoid purchasing of imported fuel, what, in its turn, would decrease country's dependence on imports from abroad and, hence, improve the energy security of Finland. Second, this measure would lead to a significant reduction of users' operational costs, since the main share of it (up to 70%) is expenditures for fuel. Thus, if a plant operator is able to receive only an investment grant for 30% of a unit price and a fuel price reduction of 25%, the payback time will be as that presented in table 19.

All proposed support measures may be combined with each other and applied at the same time. Nevertheless, depending on what aid is allocated to a plant operator, its amount and duration should reflect the current situation in the country. The idea is to promote small-scale renewable installations but not to make their operation free for users.

Table 19. Payback time (in years) depending on the number of running hours, the share of consumed electricity, and the number of installed CHP units.

Running hours per year	**Share of consumed electricity**				
	20%	**40%**	**60%**	**80%**	**100%**
4 000 h/year	-* (-)**	44.2 (38.7)	25.5 (22.4)	18.0 (15.7)	13.8 (12.1)
6 000 h/year	24.1 (20.9)	15.1 (13.1)	11.0 (9.6)	8.6 (7.5)	7.1 (6.2)
7 800 h/year	13.6 (11.9)	9.5 (8.3)	7.3 (6.3)	5.9 (5.1)	4.9 (5.0)

* plant cannot be paid off;
** values in brackets are for a plant with two CHP units.

6 CONCLUSION

The main objective of this work was to analyze the current operational environment for biomass-based small-scale CHP plants in Finland. The key points for the analysis included such preconditions for switching towards utilization of these plants as price levels of heat and electricity; investment and production costs; and availability of support from the government. The study showed that despite the National Strategy, aiming to increase the development rate of decentralized and renewable energy production, it is usually unprofitable for small entrepreneurs or communities to switch from conventional energy sources towards small-scale CHP plants. Main factors constraining the distribution of this technology appeared to be the satisfaction of current users with traditional energy sources and the absence of the necessary support from the government reducing the payback period to reasonable levels. Thus, low electricity prices and easy access to power grids in almost every part of the country, as well as the availability of various cheap heating methods, do not motivate people to invest into the installation of renewable plants. In addition, the only two mechanisms promoting the production of “green” energy are an investment costs subsidy for farmers and plants located in rural areas and a flexible feed-in tariff system. Latter usually has a low value and could be allocated only to plants with a total capacity of more than 100 kVA (≈ 80 kW). Dependence on such variable factors as emission allowance price, peat tax, and market electricity price does not allow plant operators to rely on such support in the long term. Investment costs subsidy, in its turn, is intended only for farmers and plants in rural areas. In addition, due to several restrictions in the feed-in tariff system, grants may be obtained only by forest chip plants or by plants, which do not receive a remuneration for feeding electricity into the grid. Thereby, some users have to choose whether they are going to receive a one-off subsidy or an unstable support in a form of the feed-in tariff. As a result, these two mechanisms, even when are applied together, do not allow users to pay their investments in earlier than six years. Thus, the analysis showed an urgency of the introduction of new support measures in order to make the operational environment more suitable for renewable installations of different types and capacities.

For this reason, it was decided to study operational environments in other countries, such as Germany, Austria, and Sweden. Conducted investigation revealed what obstacles operators of small-scale CHP installations have to face with, and how local governments help to overcome these barriers. Thus, the main support is presented in a form of a feed-in tariff, which allows plant operators to feed excess amounts of produced electricity into the grid and receive a remuneration for it. Furthermore, Germany and Austria provide investment cost subsidies, intended to make initial expenses more bearable for users. Sweden, in its turn, exempts plants producing energy from renewable energy sources from emission and energy taxes. Nevertheless, the amount of the support differs in each country and, consequently, affects operation process differently. Thus, the most favorable environment for the utilization of small-scale renewable installations is in Austria and Germany. Possibility to receive a feed-in tariff of a high value as well as a non-repayable grant or a low-interest loan, covering 20% or 100% of total investment costs, respectively, allows plant operators to pay off their initial costs within approximately three years. Opposite situation occurs in Sweden where electricity certificate system, unsuitable for small plants, and the tax reduction mechanism do not bring a tangible profit for users, what leads to a significantly longer payback period.

Thus, the analysis of operational environments in above-mentioned countries allowed to formulate several ideas on what support measures could be introduced in Finland in order to increase the utilization rate of small-scale renewable CHP installations within the country. Presented ideas included measures that may affect both investment and operation stages in direct and indirect ways. First, there should be a feed-in tariff system, which does not depend on such variables as a peat tax or emission allowance price. The value of a tariff has to be calculated only taking into account either a plant's capacity or the current total electricity price. As an option, the right for receiving a remuneration for fed electricity may be granted only until investment costs are paid off. Second, it could be necessary to provide additional funding during investment and/or operation stages. The support may be presented in a form of non-repayable grants or low-interest loans and should be allocated according to non-discriminatory principles, whether it is a micro-scale entrepreneur, SME, or a small community and whether it is a rural area or not. This scheme should be used especially along with a feed-in tariff aid granted only for a payback period. Thus, it will create additional incentives for current users to renovate their outdated plants. Moreover, aid fully or partially covering maintenance costs may be granted to plant operators. The support could be presented in a form of special contracts with maintenance companies or in a form of annual repayments from the government. In addition, the government could support plants producing renewable energy via special discounts for domestic wood chips. This measure would not only reduce operational costs born by users but also decrease the country's dependence on wood fuel imports from abroad. All introduced support measures may be combined with each other and applied at the same time. Nevertheless, depending on what aid is allocated to a plant operator, its amount and duration should reflect the current situation in the country.

In conclusion, it worth mentioning that the operational environment is a complex system affected by plenty of factors, therefore, it is difficult to predict what situation will occur in Finland in the future. For instance, the transition towards more renewable energy production could dramatically lower prices for electricity and heat. The price of wood chips, in its turn, may change significantly depending on forest management programs conducted by the government. Nevertheless, growing public awareness of the importance of the renewable energy utilization may neglect possible reduction of small-scale CHP plants' competitiveness and stimulate people to switch towards renewable electricity and heat production even if it is more expensive when compared to fossil fuels. On top of that, if the utilization rate of such technology increases, it will lead to favorable changes in the country. First, higher consumption rates of renewables will improve the ecological situation. Second, utilization of domestic wood chips will allow users in rural areas and in Finland in general to improve their energy security. In addition, the developed market of small-scale CHP installations will provide new business opportunities in such sectors as forestry, maintenance service, and R&D, thereby creating new workplaces especially in rural areas of the country.

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Investment and production costs for CHP units installed in Finland

Special conditions			
Feed-in tariff for plant	Forest chip	Wood fuel	-
Technical data			
Power plant	Volter 40 Indoor		
Number of plants	2	2	1
Total electric capacity, kW	80	80	40
Total thermal capacity, kW	200	200	100
Running hours per year, hour	7 800	7 800	7 800
Costs			
Investment costs			
Unit and conveyor price, EUR	2 * 194 650	2 * 194 650	194 650
Dryer price, EUR	45 000	45 000	35 000
Installation costs (plumbing and electrical), EUR	25 000	25 000	25 000
Total costs, EUR	459 300	459 300	254 650
Other costs			
Value of wet wood chips, EUR/wet ton	100	100	100
Expenses for wood chips per year, EUR	59 280	59 280	29 640
Maintenance costs per year, EUR	20 000	20 000	10 000
Expenses for work per year, EUR	6 000	6 000	3 000
Electricity price, cent/kWh	10.37	10.37	10.90
Electricity consumed by unit per year, EUR	3 235	3 235	1 700
Total operational costs per year, EUR	88 515	88 515	44 340
Generated energy per year			
Generated electricity, kWh	624 000	624 000	312 000
Generated heat, kWh	1 560 000	1 560 000	780 000
Revenues from sold electricity per year			
Share of consumed electricity, %	80	80	80
Sold electricity, kWh	124 800	124 800	0

Feed-in tariff, cent/kWh	1.86	7.11	-
Total revenues from feed-in tariff, EUR	2 320	8 876	-
Budget			
Financing			
Investment grant, %	30	-	30
Amount of support, EUR	107 790	-	53 895
Yearly budget			
Electricity price, cent/kWh	10.37	10.37	10.37
Consumed electricity, kWh	499 200	499 200	249 600
Saved money for consumed electricity, EUR	51 767	51 767	25 884
Pellets price, cent/kWh	5.94	5.94	5.94
Consumed heat for heating and hot water production, kWh	1 248 000	1 248 000	624 000
Saved money for heat, EUR	90 404	90 404	45 202
Total saved money for electricity and heat, EUR	142 171	142 171	71 085
Balance (savings and revenues minus operational costs), EUR	55 975	62 531	26 745
Payback time, year	6.3	7.3	7.5
Expenditure per year after plant is paid off, EUR	86 196	79 640	44 340

Investment and production costs for CHP units installed in Germany, Austria, and Sweden

Location			
Country	Germany	Austria	Sweden
Technical data			
Power plant	Spanner HK 45	Spanner HK 45	Volter 40 Indoor
Electric capacity, kW	45	45	40
Thermal capacity, kW	108	108	100
Electrical efficiency, %	24	24	-
Running hours per year, hour	8000	8000	7 800
Costs			
Investment costs			
Unit price, EUR	176 000	176 000	194 650
Dryer price, EUR	35 000	35 000	35 000
Installations costs (plumbing and electrical), EUR	25 000	25 000	25 000
Total costs, EUR	236 000	236 000	254 650
Other costs			
Value of wet wood chips, EUR/wet ton	100	132	80
Expenses for wood chips per year, EUR	30 000	39 600	23 712
Maintenance costs per year, EUR	7 920	7 920	10 000
Expenses for work per year, EUR	9 600	9 600	3 000
Electricity price, cent/kWh	29.7	20.3	15.74
Electricity consumed by unit per year, EUR	5 346	3 654	2 455
Total operational costs per year, EUR	52 866	60 774	39 167
Generated energy per year			
Generated electricity, kWh	360 000	360 000	312 000
Generated heat, kWh	864 000	864 000	780 000
Revenues from sold electricity per year			
Share of consumed electricity, %	80	80	80

Sold electricity, kWh	72 000	72 000	62 400
Feed-in tariff, cent/kWh	13.12	22.00 (18.61)*	6.25
Electricity certificate, cent/kWh	-	-	1.65
Total revenues from feed-in tariff, EUR	9 446	15 840 (13 399)	2 409
Budget			
Financing			
Interest rate per year, %	2.0	-	-
Financing period, month	120	-	-
Amount of the credit (or grant), EUR	236 000	47 200	-
Monthly payment, EUR/month	2 172	-	-
Yearly budget			
Electricity price, cent/kWh	29.7	20.3	7.5
Consumed electricity, kWh	288 000	288 000	249 600
Saved money for electricity, EUR	85 536	58 464	18 720
Natural gas/pellet price, cent/kWh	6.42	6.74	5.20
Consumed heat for heating and hot water production, kWh	691 200	691 200	624 000
Saved money for heat, EUR	45 747	48 028	39 571
Total saved money for electricity and heat, EUR	131 283	106 492	58 291
EEG surcharge, cent/kWh	2.8	-	-
Total surcharge payments, EUR	7 926	-	-
Balance (savings and revenues minus operational costs, EEG surcharge, and loan payments), EUR	53 880	61 558 (59 117)	21 532
Payback time, year	3.1	3.1 (3.2)	11.8
Expenditures per year after plant is paid off, EUR	51 345	44 934 (47 375)	36 758

* values in brackets are for the feed-in tariff of 18.61 cent/kWh.