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An economic study of combined heat and power plants in district heat production

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A B S T R A C T

Combined heat and power plants are playing an essential role in Finland to reduce carbon dioxide emissions in district heat production. Some of the existing district heat producers need to adopt renewable energy sources to eliminate the use of fossil fuels. The northern countries face a challenge to tackle significant fluctuations of district heat consumption between summer and winter seasons concerning the production cost and the environmental impact of heat production. The municipality of Sodankylä is reorganising the district heat production to reduce emissions by constructing new wood-fuelled CHP plants. These plants will contribute to the existing district heating network. The profitability of CHP plants and the environmental impact in the region need evaluation. Results reveal that the profitable investment for the construction of CHP plants requires 16% subsidy with the predicted cost of heat production at 3.36 €/MWh. CO_2 emissions from fossil fuels can potentially eliminated by adapting renewable fuel in the existing plant. CH_4 and N_2O emissions from district heat production reduced by 78% and 53%.

1. Introduction

Energy policy in Finland dictates a clear objective for 2050, net-zero greenhouse gas (GHG) emission (Finnish Energy, 2019). Implementing net-zero goal requires setting interim objectives for 2030 and 2040, such as establishing a roadmap for carbon neutrality in the heating systems, targets for renewable energy production, energy management and energy storage. Building a cleaner future will need higher investments in renewable projects alongside nuclear and combined heat and power (CHP) solutions. These incentives will help Finland to achieve its pledge of carbon neutrality by 2035. Energy efficiency enhances by optimising the current state of the power plants by increasing more renewable energy sources and cutting down fossil fuel usage. These measures are incentivised by the government of Finland with massive subsidies either to balance the more expensive renewable technology integration to the current energy producers or to maximise the rate of investments on reducing carbon dioxide emission. Recent literature reveals how CHP plants in Finland can reduce carbon dioxide significantly by adding heat pumps (Clean district heating, 2018).

Sipila et al. (2005) studied three CHP plants elaborating the behaviour of 1–14 MW CHP plant. Simulations showed that biomass is more profitable than a gas power plant. Industrial-scale heat pumps also provide promising results with reasonable investment and high returns. A notable example of industrial-scale heat pumps in Finland is Esplanade heating and cooling plant (Helen Oy, 2018). Two heat pumps make up for 22 MW heat to the district heating system. The plant inaugurated in 2018 where heat pump used seawater as a heat source. Katri Vala heating and cooling plant said to be the most significant heat pump in the world (Friotherm AG, 2017 Oy, 2020). The plant combines five heat pumps with a capacity of 105 MW heating and 70 MW cooling.

The city of Helsinki is investigating the possibilities of using renewable energy from bedrock and caves in Esplanade and Pasila areas. Turku installed heat pump where wastewater used from Naantali power via a 14.5 km long tunnel (Friotherm AG, 2017). Several case studies of large-scale heat pumps are available from Sweden and Norway (Friotherm AG, 2020). European heat pump association produced a comprehensive report of a large-scale heat pump plant (European heat pump association, 2020). The report consisted of examples from German district heating system, Norway and Finland. When the heat source is readily available for a heat pump, it could be the most economically beneficial application for district heat production. Arpagaus et al. (2018) reviewed the availability of high-temperature heat pumps in the European market with a variety of potential ranging from 90 °C to 160 °C supply temperature. The study revealed that heat source temperature

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between 40 and 60 °C required to produce 80–100 °C of supply temperature. The deep borehole heat exploration proved expensive in the northern areas. Given the constraints on heat pump applications, CHP plants are promising for the district heat production in Finland. CHP plants produce the majority of the heat in Finland's district heating system where wood residue, forest chip, Coal, natural gas and Peat are the most prominent sources (Paiho and Reda, 2016). The next generation of district heating system will be able to supply 60–70 °C temperature to small districts with the majority of heat production from the renewable sources (von Rheina et al., 2019). These renewable sources include small-scale solar heating plant or seasonal heat storage (Bauer et al., 2010).

The investors should consider renewable energy to optimise the existing power plants. Huang et al. (2017) showed a performance analysis of a small-scale CHP energy production for a remote household where renewable heat incentive significantly improved the economic viability of such a plant. Modelling the dynamics of such complex systems performed with Modelica, IDA-ICE and Apros to study the distribution network for such power plants (Arce et al., 2018). Guelpa et al. (2018) presented an optimal approach to address the peak load of the individual users in a district heating network. Korpela et al. (2017) presented the flexibility of energy production capacity concerning the frequency reserve restoration (FRR) requirements. Dvorak and Havel (2012) proposed an optimisation strategy for CHP plant to maximise the profit and simultaneous planning for electricity trading. Introducing thermal energy storage is a popular choice for designing a district heating network. The weakness of current heat storage systems is the low efficiency of 40% at maximum. Thermal energy storage increases the cost of energy production and requires feasibility analysis (Nuytten et al., 2013). The ground source heat pump is an increasingly popular choice in Finland (Häkämies et al., 2015). Installations of heat pumps have rapidly increased in recent years, which helps reduce greenhouse gas emissions (Laitinen et al., 2014).

Finland reduced emissions by 12% from district heat production (Finnish energy, 2019). The use of Peat and coal reduced from 15.4% to 14% and 19.3%–18% during 2018. The forest fuelwood and the industrial wood residue increased from 18.8% to 10.2%–21% and 12% in the same year (Finnish energy, 2020). There has been incredible encouragement from the EU to use bioenergy sources in district heat production by refining carbon taxes (Finnish energy, 2020). The transition of energy sources has brought some criticism of energy prices fluctuations (Natural resource institute Finland, 2020).

Nonetheless, the government has provided instructions on how to approach this transition in existing CHP plant (Kurkela et al., 2019), and how to use the local biomass efficiently for district heat production (Paiho and Saastamoinen, 2018). The processes of biomass in CHP are fuel procurement, combustion and gasification (Alakangas and Flyktman, 2001). Different CHP plants have fuel-specific procurement processes. There are two types of combustion process: Grate combustion (fixed bed) and Fluidised combustion (fluidised bed) (Jarvinen and Alakangas, 2001).

Gasification allows the fuel to decompose into useable gas and carbon dioxide after filtration. Syngas burned directly to produce steam in case the plant has a steam turbine otherwise directly used in gas turbine (Sitrumorang et al., 2020). In a combined cycle power plant, the gas turbine combined with a steam turbine to produce electricity (Al Saedi et al., 2000). The produced steam fed into a steam turbine to produce more electricity (Kontor, 2013). Further details of CHP processes elaborated in (Madadian et al., 2014).

There is a clear gap in the literature to present profitability assessment of the construction of CHP plants in Finland. A significant reduction in the use of fossil fuels from district heat production requires highlighting the economic and environmental benefits of using renewable energy sources in CHP plants. The investments in utilizing renewable energy sources in CHP plants encouraged by presenting economic. The study projects emissions reduced from heat production in Sodankylä. The distribution network combines heat production from both existing and new CHP plants. The novelty of the study is to project emissions from district heat production for variety of input fuels option for existing plant. The next section elaborates the current state of the plant, highlighting input fuels and proposes a model for new CHP plants. The following section presents methodology of the study, section 4 reveals the results, and the study concludes in section 5.

2. System description

This section describes the current state of the system and restructuring plans—a conventional biomass CHP plant presented in (Fig. 1). There are three essential processes. 1- Fuel procurement, 2- Combustion and 3- Gasification.

2.1. Current system

Figure (2) shows a street view of the existing plant in Sodankylä, where stocks of Woodchip, Peat and boiler depicted. The peak demand for heating varies with the quality of input fuels. Fluidised bed combustion provides a nominal efficiency of 90%. The boiler maintains stable combustion with the help of extensive capacity inert bed material, low levels of NOx achieved with a low operating temperature. NOx level reduced by injecting ammonia or urea at the exhaust. Sulphur emissions controlled by injecting alkali sorbent compounds such as lime and variants. The fluidised bed operates between 800 and 950 °C.

Power consumption of the region projected in (Fig. 3). The plant shows woodchip stock on the left corner along with the processing chambers for Peat and Woodchip. Conveyer belt conjoins the fuels to the burning chamber and rest of the processes. In winter, air temperature in the region can be as low as −34 °C. Peak power consumption during the winter season estimated over 21 MW. The annual average production calculated at 9.92 MW, shown in (Fig. 4). The plant produces heat in the region with input fuels Peat, Woodchip and heavy oil calculated at 5.73 MW, 3.55 MW and 0.43 MW respectively. Most of the electricity supply in the region bought from external suppliers. The maximum capacity of the plant is 34 MW with network distributed over 30 km^2 in length.

The average carbon dioxide emissions from the plant plotted in (Fig. 5). The Finnish statistics database estimated the emission factors on fossil fuels (Statistics Finland, 2018). Peat contributes the majority of the carbon dioxide emissions. By replacing Peat with a renewable energy source, the region can reduce a significant amount of carbon dioxide emission. According to OECD (2019), the carbon tax of using fossil fuel can be as high as 25 €/tCO_2. The emission factors of methane and nitrous oxide took from IPCC emission factor database (Intergovernmental panel on climate change, 2006).

2.2. Proposed system

The proposed Syncraft wood-gas plants will use the available energy resources in the region. The proposed size of the power plant known as CW700-200 (Syncraft, 2020). This plant is capable of producing 700 kW of high-temperature heat with 200 kW of electricity. The plant consists of three major processes, including drying of biomass followed with Pyrolysis and gasification depicted in (Fig. 6). The drying process

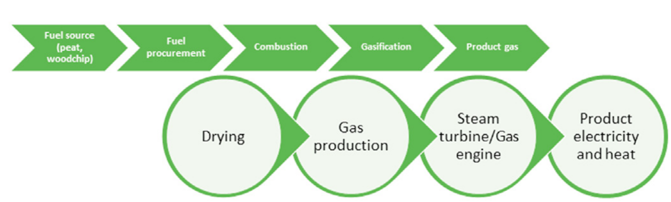

Fig. 1. Conceptual process representation of combined heat and power (CHP) plant.

Fig. 2. Current Combined Heat and Power (CHP) plant in Sodankylä, Finland (maps.google.com).

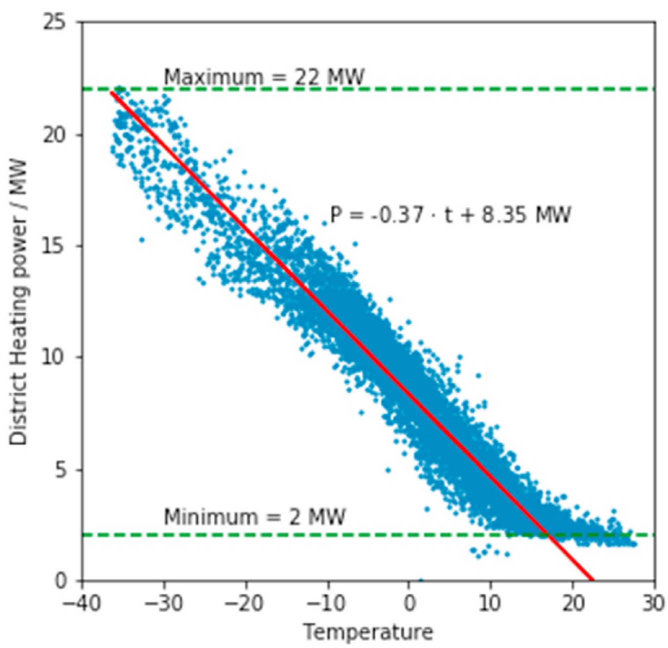

Fig. 3. District heat consumption for the year 2016.

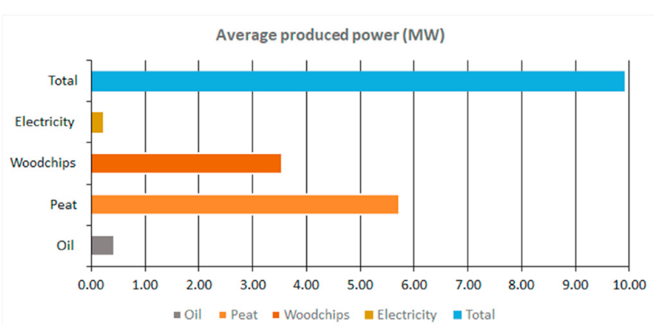

Fig. 4. Average power production of the current state of CHP.

implemented to reduce the moisture content from the biomass varies between 30 and 60%. This process takes place at 200 °C, after which the moisture content in biomass reduces to 15% optimal for gasification (Sansaniwal et al., 2017). The second process is Pyrolysis, where the air added to burn the dried fuel at a temperature of 500 °C (Guan et al., 2016). During this process, hemicellulose, cellulose and lignin in the biomass decomposed to form volatile compound and solid residue (Dhyani and Bhaskar, 2018). The volatile compound consists of gases and liquid tar. This compound further burned by adding more air at a

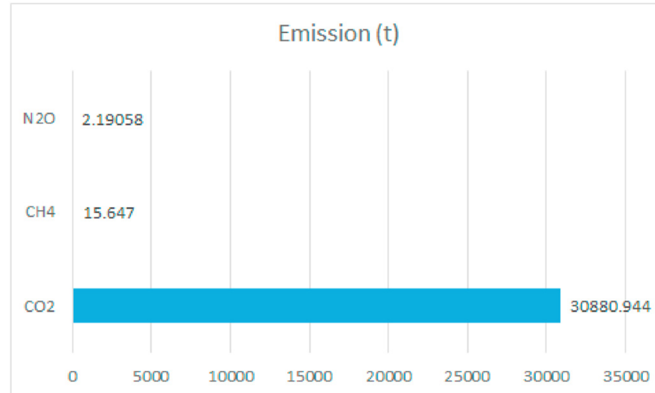

Fig. 5. Carbon dioxide and greenhouse gases emissions from the plant.

temperature of 850 °C in the floating bed reactor resulting in impurities collected at the bottom of the reactor (Kumar et al., 2009). Steam took out from the top of the reactor for filtration—added water to the compound left at the bottom producing Biochar. The gas then cooled at a temperature of 100 °C before entering the scrubber to remove pollutants (Kirubakaran et al., 2009). The gas injected into the gas engine at a temperature of 25 °C. The electrical efficiency of the engine estimated between 29 and 31% (Ruiz et al., 2013). The exhaust temperature from the engine used to provide heat for the district heating network. Biomass gasification further elaborated in (Ramos et al., 2018).

2.2.1. *Technical assessment of the proposed system*

The yearly average heat consumption of the region predicted over 8 MW. Six CHP plants proposed to meet the requirement of the region. The energy distribution of the plant illustrated in (Fig. 7). The plant consumes 4.838 MWh of energy including 5.171 MWh of electricity to operate. The quality of the fuel determines the amount of heat production. High-temperature heat makes up 55% of the energy production along with 29% of electricity production—the amount of electricity production directly related to the efficiency of the gas engine. Distributed high-temperature heat makes up 90% of the produced heat, 10% of the produced heat use for drying process in the plant, and 10% of the produced electricity contributes to plant power consumption. Biochar is a by-product of the plant. The production of Biochar estimated at 10% of the total production. The plant has minimal losses of 6%.

2.2.2. *Economic assessment of the proposed system*

An economic assessment of the proposed system conducted to facilitate the decision making of the project. A life cycle assessment of the project reveals the profitability of the project (Gaine and Duffy, 2010). Hennessy et al. (2018) concluded that the ORC is not feasible in the Nordic market conditions, but it can be feasible under different market conditions with low installation costs. System components such as heat pumps and thermal energy storage are only feasible if the investment costs are reasonable and operational costs are low (Dominkovic et al., 2015). Other economic parameters include depreciation cost, unaccounted in the current state of the study. More information on economic modelling detailed in (Short et al., 1995). A significant amount of costs reduced by predicting the best time to shut down some plants during summertime when heat demand is relatively lower than the wintertime (Dahl et al., 2017). Schweiger et al. (2017) showed the economic benefit of the utilizing the power to heat ratio in a district heating system where the negative residual load converted to the district heat load. The investment cost evaluated based on provided prices by Syncraft. The Natural Resource Institute Finland provided an initial estimate for operation and maintenance cost presented in Table 1. The cost of maintenance and operation of six CHP units is €0.2 million/year. The revenue estimated by adding the income from Biochar product, electricity, and heat (Table 2).

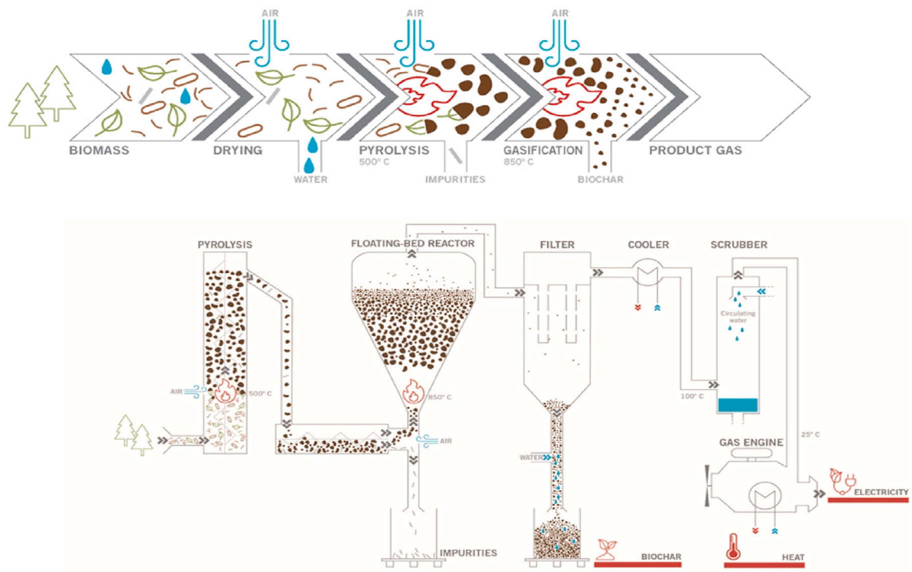

Fig. 6. Process flow representation of the proposed combined heat and power (CHP) plant.

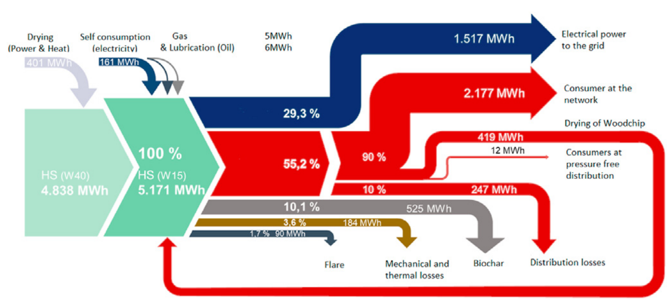

Fig. 7. Proposed model of the combined heat and power (CHP) plant (Syncraft CW700-200).

Table 1
Parameters used in the calculation.

Items	Symbol	Value
Investment cost	I_a	€16.5 (million)
Maintenance cost	M_a	€0.2 (million/year)
Operational cost	O_a	€0.1 (million/year)
Revenue	R_a	€1.58 (million/year)
Interest rate	r	4%
Investment cost of Heat pump	I_a	€7.6 (million)
Interest rate for Heat pump	r	6%
Revenue from the Heat pump	R_a	€5.16 (million/year)

2.3. An alternate option to the proposed system

A viable option compared to the proposed system is to install an industrial heat pump. The industrial heat pump has a relatively low investment cost and high efficiency of heat production and reduces the investment cost by more than half of the cost of the proposed plants. An industrial heat pump covers the heating requirements as well as the cooling requirements of the region and capable of providing 10 MW of heat to the district heating system with around €7 million of investment cost according to the research data collected by the contractors. The installation of heat pump rejected due to unavailable heat source required. The unavailability of heat sources such as seawater or deep borehole makes the consideration of heat pump impossible in this study because of the geographical location of the region. The seawater heat source is unavailable in Sodankylä and drilling deep boreholes in northern Finland is expensive. Therefore, an industrial heat pump altogether excluded from the proposed system. Nonetheless, the economic assessment of the alternate option conducted. The Levelized cost of heat production from heat pump estimated at 3.77 €/MWh. The interest rate for installing the heat pump assumed at 6%. The revenues collected from the heat production from an industrial heat pump are three times higher than the revenues collected from the proposed CHP plants. The industrial heat pumps are a very interesting area to replace conventional fossil fuel energy sources. If the energy source for the heat pump were readily available, the installation would provide a very feasible investment opportunity to maximise the revenues.

2.4. Analysis of the restructuring

The heat production in Sodankylä prone to enormous carbon dioxide emission, which results in a high tax rate on the product. The amount could very well exceed over a hundred thousand euros in carbon taxes with the use of Peat and heavy oil. According to the OECD (2018), emission from woodchip burning considered carbon-free. A significant reduction in carbon dioxide emission achieved by constructing the new plants. The proposed system will use the local Woodchip helping the regional economy and reduce significant taxes from heat production—Biochar sold to the local farms in the region.

During November and March, the heat capacity of the region rapidly increased. The maximum and minimum capacity during the winter season estimated at 14.72 MW and 10.45 MW with an average 12 MW. Under these circumstances, the proposed Syncraft plants expected to operate at full capacity of 4.6 MW. The energy deficit recovered from the

Table 2
Preliminary costs of proposed plants.

	Energy	Price	Total price
Number of stations	6		€16.5 (million)
Number of yearly hours/station	6000		
Consumed fuel cost			€1.7 (million)
High temp heat produced (Mwh)	24,120	€49-59	
Electricity produced (Mwh)	16,560	€40-46	
Biochar (ton)		€225	€1.1 (million)

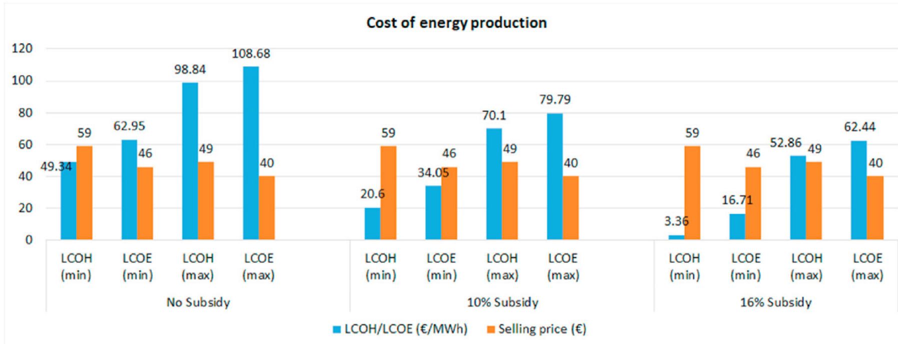

Fig. 8. The cost of energy production in combined heat and power (CHP) plants.

existing plant where wood pellets co-fired with the Woodchip. The wood pellets will contribute 50% of the solid input fuel in the existing plant. During the winter season, the energy production from the existing plant recommended at 7 MW with an average of 5 MW. The heat capacity of the region systematically reduced during April and May at 7.87 MW and 6.12 MW with a proportional increase during September and October at 5.71 MW and 7.92 MW.

3. Methodology

The district heat production consists of the existing plant and the proposed CHP plants. Levelized cost of energy production includes all the costs parameters to provide the production cost over a life cycle of power plants. It formulated as (Welsch et al., 2018):

$$LCOH \Big/ LCOE = \frac{\sum_{a=0}^{a_{end}} (I_a + M_a + O_a - R_a)(1+r)^{-a}}{\sum_{a}^{a_{end}} Q_a (1+r)^{-a}} \tag{1}$$

where, a is the number of years, I_a is the investment cost, M_a is the yearly maintenance cost, O_a is the yearly operational cost, R_a is the yearly revenue, r is the discount rate, and Q_a is the produced power. These costs summed up for the entire life of the power plant. Parameters used to calculate the cost of production presented in Table 1. Levelized cost of heat and electricity is an estimate of the cost per unit power concerning the total investments in a lifetime of the plant. It highlights the difference between the cost of production and selling price of the energy. The net present value formulated as:

$$NPV = \sum_{a}^{a_{end}} CF_a (1+r)^{-a} \tag{2}$$

where NPV is the net present value, CF_a is the cash flow and r is the discount rate. A depreciation cost avoided in this study, which may result in underestimation of the net present value of the project. Net present value illustrates the profitability of the investment in CHP plants. The NPV facilitates the decision-making on the construction of CHP plants. The study also uses the illustrated economic model to present an optimal investment scenario for the construction of CHP plants. The environmental impact of the district heat production calculated by standard IPCC guidelines. Emissions from energy production formulated as (Intergovernmental panel on climate change, 2006):

$$Emissions = Fuel * EF \tag{3}$$

The environmental impact includes carbon dioxide and greenhouse gas emissions. *Emissions* calculated in ton of carbon dioxide, methane and nitrous oxide. *Fuel* is the amount of fuel consumed in (TJ) for both CHP and main power plant. *EF* is the emission factor (t/TJ) for fuels used in plants.

Table 3
The profitability of the possible scenarios.

	Investment option	NPV (million €)	Payback time (years)
Scenario 1	No subsidy	5	15
Scenario 2	10% subsidy	6.6	12
Scenario 3	16% subsidy	7.6	10

4. Results and discussion

This section presents economic assessment and profitability of the proposed CHP plants. The emissions generate from the combined district heat production estimated. The projected emissions illustrate three options of input fuel for existing CHP plant.

4.1. Profitability of the proposed CHP plants

The costs of the proposed model of power plants presented in Table (2)—maximum capacity of given power stations delivered with 6000 h in a year—the Levelized cost of energy production presented in (Fig. 8). There are three scenarios depicted with subsidy investigation. The first scenario does not assume any subsidy in the calculation. The maximum cost of heat production estimated at 98 €/MWh with a selling price of 49 €/MWh, while the maximum cost of electricity calculated at 108 €/MWh when the selling price is 40 €/MWh.

Similarly, the minimum cost of heat and electricity production presented. LCOH calculated at 49 €/MWh with a selling price of 59 €/MWh while LCOE estimated at 62 €/MWh with a selling price of 46 €/MWh. The second scenario considered a subsidy of 10% on investment cost. The minimum cost of heat production predicted at 20 €/MWh with a selling price of 59 €/MWh while the maximum cost predicted at 70 €/MWh with a selling price of 49 €/MWh. Besides, the minimum cost of electricity production predicted at 34 €/MWh with a selling price of 46 €/MWh while the maximum cost predicted at 79 €/MWh with a selling price of 40 €/MWh. The third scenario assumed a 16% subsidy on investment cost. The minimum and maximum cost of heat production projected at 3.36 and 52.86 €/MWh while the minimum and the maximum cost of electricity production projected at 16.71 and 62.44 €/MWh.

The profitability of CHP plants showed in Table 3. Scenario 1 revealed a valuation of €5 million with a payback time of 15 years, making it an unattractive project for the investors. The payback time is too long, and the profitability is minimal. Scenario 2 estimated value of €6.6 million with a payback time of 12 years, an improvement from the previous scenario but still unappealing to the investors. The payback time, preferably under 10 years, considered a reasonable investment opportunity. Therefore, Scenario 3 resulted in an optimal valuation of €7.6 million with a payback time of 10 years. Scenario 3 provides an optimal payback time under 10 years. The profitability of scenario 3 is relatively better than the rest of the scenarios with a 16% subsidy.

4.2. District heat production in sodankylä

District heat production combines energy production from both new and existing CHP plants. The proposed CHP will contribute to the existing district heat network. The average contribution from both plants in district heat production illustrated in (Fig. 9). The CHP plants run at full load during the entire year except for summer season (June–August). Two of the six CHP plants close during summer for service and maintenance. The average production from the existing plant fluctuates significantly during the year. The plant shuts down in July. The average required heat production from existing plant estimated at 6.5 MW.

District heat in Sodankylä can produce with three input fuel options. The existing CHP plant can adopt renewable fuel (Woodchip), eliminating the fossil fuel emissions. The CH_4 and N_2O emissions reduce by 78% and 53% using renewable fuel. Peat is also a viable option to use in the existing plant. Peat is cheaper than Woodchip with higher energy coefficient. The amount of carbon dioxide reduced to 37% compared to the current production. The CH_4 and N_2O emissions reduce by 78% and 53% using Peat. The plant can also keep the current combination of input fuels (Peat + Woodchip + Heavy oil) for district heat production. The carbon dioxide emissions reduced by 34% compared to the current model of district heat production. The CH_4 and N_2O emissions reduce by 25% and 16% using input fuels (Peat + Woodchip + Heavy oil). One reason to prefer this system is to fulfil the peak consumption during January, November and December. The peak consumption during winter season exceeds 22 MW that requires the use of heavy oil fuel in district heat production. The district emissions illustrated in (Fig. 10). CHP referred to the proposed CHP plant. MPP is the existing power plant.

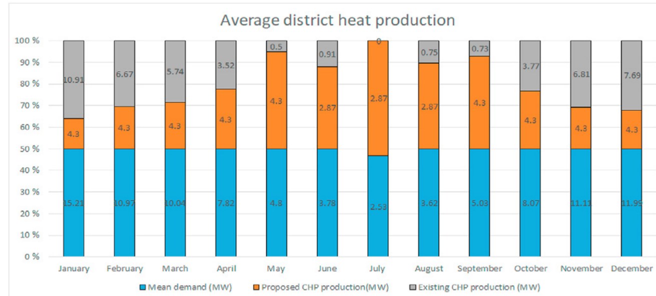

Fig. 9. Average heat production and consumption in Sodankylä.

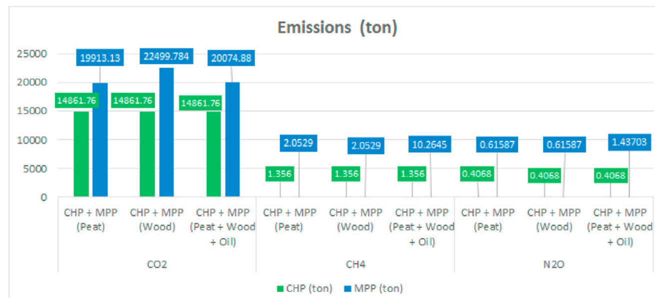

Fig. 10. Emissions from district heat production in Sodankylä.

4.3. Discussion and future consideration

The study conducts economic assessment of the proposed CHP plants in Sodankylä. The cost of production from new plants determined and the profitability calculated. The distribution of heat in the region combines the production from both new and existing CHP plants to the network. Three input fuel options (fossil fuel and renewable fuel) presented for the existing plant. The plant can adapt renewable fuel for entire year, eliminating the use of fossil fuels. Current production from renewable fuel generates 3.55 MW of heat. The average monthly consumption of the district heating network between April–October met with renewable fuels without adding additional fuel to the plant.

On the other hand, heat consumption rose significantly between January–March and November–December, which will require the main power plant to produce 10.91 MW of heat energy. During the winter season, the main power plant can either maximise renewable input fuel or combine fossil fuel. The decision solely depend on compromising either economical or environmental aspect. The combined input fuel increase the emissions significantly in the region. The plant may avoid heavy oil fuel and use combined Woodchip and Peat. An economic point of consideration is the standard IPCC emission factors on the capacity of heat production. The emission factor of 5 MW plant is significantly higher than 50 MW plant. An economical way of district heat production is to use peat fuel when the demand is higher than 5 MW reducing significant amount of taxes.

5. Conclusion

The study evaluates the possibility of constructing a new combined heat and power plant with a renewable energy source. The existing structure of the heat production discussed in detail, the demand for new plants highlighted, and the construction of new plants illustrated with technical information and economic assessment. The plants expected to deliver 4.3 MW of heat to the district heating network with only 6% losses. Biochar estimated 10% of the total production from the plant sold to the local and external markets. There are three economic scenarios drawn presented in the study and an optimal economic scenario reported with a reasonable payback time. The optimal energy production of the plant estimated with 16% subsidy. The cost of heat and electricity production resulted at 3.36 and 16.71 euros per MWh.

The goal of the municipality is to reduce the overall emissions from the region. The emissions from district heat production significantly reduced with the construction of CHP plants. The study also articulates three possible scenarios to operate the existing plant. The plant can entirely run with available fuel, either Woodchip (renewable fuel) or Peat (fossil fuel). Although Woodchip fuel costs slightly higher than Peat, district heat production from renewable fuel is highly recommended considering the amount of greenhouse gas reduction and carbon tax savings. Peat input fuel is economically attractive, but there is an uncertainty of Peat tax rate in Finland. Increase in Peat tax is under the government's consideration. The cost of production from Peat fuel may become more expensive after a few years. The district heat consumption during winter is significantly higher in Sodankylä compared to the rest of the year. During the peak season, the main power plant uses heavy oil fuel to meet the demand. In the future, the municipality should consider peak shaving for the environmental impact of district heat production.

Declarations

Ethics approval and consent to participate.
Not applicable.

Availability of data and materials

All relevant data presented in the manuscript.

Conflicts of interest

The author does not intend to compete and declare no competing interests.

Consent for publication

The author declares full contribution towards the manuscript. The author edited the manuscript and approved the final manuscript.

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