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Use of Absorption Heat Pumps to Raise District Cooling Waste Heat Temperature for District Heating Supply in Tallinn: Technical and Economic Analysis

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Abstract **– Decarbonisation of District Heating (DH) networks is essential to achieving the European Union's climate goals. In this context, there is growing interest among DH stakeholders in the recovery and reuse of underutilised heat sources. Waste heat recovery from district cooling (DC) networks offers a compelling option that can be used as input for various heat pump integrated DH solutions. In this regard, absorption heat pumps (AHP) showcase a promising solution to elevate a lower-temperature waste heat source with reduced electricity consumption. However, AHPs are not widely applied in DH context, primarily due to the lack of suitable waste heat sources or the necessary conditions for their effective operation. This article aims to explore various configurations of AHP and their potential integration with DC plant waste heat for DH application. The potential for adopting AHPs to boost efficiency and lower carbon emissions is evaluated through a techno-economic examination of three distinct technological configurations. For Tallinn case study, it was observed that AHPs can be more efficient, reduce energy consumption, and achieve a lower LCOH while being combined with HP condenser cooling. This study is expected to provide a theoretical support for the positive impact of using AHPs to reduce the usage of fossil fuels in the Tallinn DH network.**

Keywords **– 4GDH; absorption heat pump; coupling of district heating and cooling; district energy; sustainable heating; waste heat.**

Nomenclature	
DH	District heating
DC	District cooling
AHP	Absorption heat pump
4GDH	Fourth-generation district heating
HP	Electric heat pump
CCHP	Combined cooling, heating and power plants
COP	Coefficient of performance
LCOH	Levelized cost of heat
CHP	Combined heat and power

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1. INTRODUCTION

Nearly 50 % of global final energy consumption is attributed to heating for residential and industrial purposes. Energy-efficient heating technology must be quickly implemented in order to decarbonise the current heating supply. DH has proven itself to be an effective large-scale production method [1]. Over 70 million people in Europe are connected to the DH sector, which has a final energy consumption of more than 450 TWh [2]. DH networks have been transitioning towards lower operating temperatures for some time. The current 3rd generation district heating networks operate at temperatures exceeding 80 °C. These high temperatures cause heating network losses of over 20 % and limit the potential for using waste heat from thermal processes [3]. Transitioning to 4th generation district heating (4GDH) facilitates the use of various heat sources and improves the conditions for heat pumps. Several solutions with electrical heat pumps (HP) and AHP can be used [4].

Over the last twenty years, the demand for building space cooling has more than tripled, making it one of the most rapidly increasing energy end-use sectors. Moreover, it is expected that more than two-thirds of buildings will have space cooling systems installed. Cooling supply is expected to showcase significant growth in the near future [5]. By 2050, the cooling demand for residential and commercial buildings is estimated to increase by up to 750 % and 275 %, respectively. DC can also be integrated with waste heat from industrial processes or Combined Cooling, Heat, and Power plants (CCHP), enabling synergies with other energy systems [6]. DC is a sustainable and energy-efficient alternative to conventional, on-site air-conditioning units in individual buildings. DC plants may also reduce the amount of anthropogenic heat generated by units installed within specific buildings and help to lessen the effects of urban heat islands [7].

With a focus on smart energy systems, energy efficiency, and the utilisation of locally accessible renewable energy sources, DH is heading towards 4GDH. A reduced DH supply temperature is one of 4GDH's key features. This lower supply temperature reduces DH network losses and enables the economically feasible integration of a wider range of waste heat sources compared to the 3rd generation district heating [8]. Several studies looking into the use of waste heat for district heating applications have been conducted recently. A study conducted in the UK explored the use of mine water and industrial waste heat in DH networks [9]. Electric HPs were used to increase the mine water temperature to the required flow temperature. Due to the steady temperature of the mine workings, these systems are expected to have relatively constant coefficients of performance (COP) in the range of 3 to 6. By incorporating advanced network dynamics and conducting an in-depth techno-economic analysis, the research presented a model that is both adaptable and versatile, suitable for various regional characteristics. The integration of industrial waste heat resulted in a 7.5 % reduction in the carbon factor and 5.56 % reduction in the Levelised Cost of Heat (LCOH).

According to Yuan *et al.* [10], space heating applications are the most effective way to exploit data center-driven waste heat. In cases where data centre waste heat was recovered with HP, central heat production and annual carbon emissions were reduced by up to 32 % and 50 %, respectively. Another study developed a method for evaluating the use of data centre waste heat in DH networks [11]. Thermodynamic and pinch models were made to calculate hourly waste heat amounts and temperatures, along with sizing the connecting pipes and calculating the cost dependency between DC waste heat and the DH network. Two integration methods were looked into: increasing waste heat temperature with a booster HP or transferring heat to DH via a heat exchanger. The booster HP COP equals the theoretical

Lorenz COP. According to the analysis, the heat exchanger can be used to preheat the DH return, while the booster HP should be used to increase the DH supply temperature. The results showed that the lower LCOH, the lower the DH supply temperature. The lowest LCOH, 12.4 €/MWh, would be in a neutral DH network, while in a low-temperature DH network, the LCOH would be 334 €/MWh. The study concluded that integrating waste heat into DH is more expensive when higher temperature regimes are required. The booster HP's operating costs have a major impact on the LCOH.

In a study conducted in Zagreb, multiple waste sources were analysed for potential use in a DH network [12]. Two sources were identified: a supermarket's CO_2 transcritical refrigeration system and power transformers. A technical solution using heat exchangers and booster HPs was proposed. The COP of the booster HP equals Lorenz COP. Cost analyses were conducted to find the optimal connection pipe for each source. The LCOH ranged from 30 €/MWh using only the heat exchanger to 70 €/MWh with the booster HP. In the case of power transformers, the LCOH ranged from 70 to 120 €/MWh, depending on the connection pipe length. The study concluded that both analysed waste heat sources can be utilised, with the LCOH depending on DH network temperatures. A study from Frankfurt, Germany [13], highlighted that the techno-economic feasibility of data centre waste heat utilisation in DH is influenced by supportive laws, data centre clusters, the share of HPs, associated energy costs, and linear heat density. According to the study, 144 GWh of heat can be recovered with an LCOH of 105 €/MWh, and CO_2 emissions can be reduced by 78 %.

In addition to electric HPs, AHPs can be used to raise the temperature of waste heat to a higher level. The benefits of using waste heat recovery and renewable energy sources are driving up the adoption of absorption chillers and AHPs. Because absorption systems can utilise low-grade heat, they have potential applications in waste heat cooling, geothermal cooling, and combined cooling and heating [14]. Sun *et al.* [15] concluded that AHPs integrated into solar-driven low-temperature DH and cooling systems offer higher technical performance, economic benefits, and emission reduction potential. The COP, energy cost (heating and cooling), and annual CO_2 emissions were observed to be 8.52, 39.26 ¥/GJ, and 23 kg per square metre of floor area, respectively.

Since waste heat is often a low-grade source, its utilisation often requires upgrading before being fed into DH networks. A study by Lagoeiro *et al.* [16] described a HP based waste heat recovery scheme for the London underground network. This system was estimated to provide an 82 % reduction in carbon emissions and 14 % reduction in costs. In the context of data centres, the quality of low-grade heat can be improved by adopting distributed cooling solutions and HPs. He *et al.* [17], investigated a similar waste heat recovery system and reported annual coal savings of about 18.000 tonnes for a data centre in Hohhot, China. Another innovative application involves using photovoltaic thermal waste heat in conjunction with an ejector HP system. Al-Sayyab *et al.* [18] reported an increase in COP for the proposed system across all investigated refrigerants.

A study on AHPs conducted in Spain [19] proposed a DH-driven AHP solution to provide space heating and cooling for a small office building in Berlin and Barcelona. The AHP in the study was a single-effect water/LiBr chiller with reversible heating and cooling modes. Because of the higher DH supply temperature in Barcelona, the study found that the AHP had a greater thermal COP when operating in heating mode. The annual thermal COP was 1.687 in Barcelona and 1.454 in Berlin. The annual thermal COP in cooling mode was found to be between 0.79 and 0.81. The primary energy ratios of the proposed systems were compared to a reference solution, with primary energy savings in heating mode estimated at 27.4 % in Barcelona and 30.3 % in Berlin. In cooling mode, the AHP has lower energy efficiency than the refence system, but fewer annual cooling hours did not make the reference system more advantageous.

A three-stage cascade method was put forward in an article [20] on AHPs combined with vapour compression HPs to build an improved hybrid absorption-compression HP. In this system, the intermediate heat exchanger in the vapour compression HP sub-cycle's medium-temperature stage recovers heat from the AHP condenser. Starting from an ambient temperature of 20 °C, two HPs in cascade connection produce driving heat for the AHP, which outputs heat at 130 °C. The study shows, that in comparison to the reference solution, the proposed solution has a higher COP, maximum temperature output, and maximum temperature increase under various conditions. It was determined that the suggested approach provides a higher temperature output and a broader working range, which are scenarios in which conventional HPs would not function well. According to Bruno and Usman [21], improvements in system components and thermal cooling cycles are the new features of high-efficiency AHPs and chillers. Depending on the driving heat temperature, there are two types of heat pumps: Type I and Type II (also called as heat transformers). A brief description about these categories is provided along with Fig. 1.

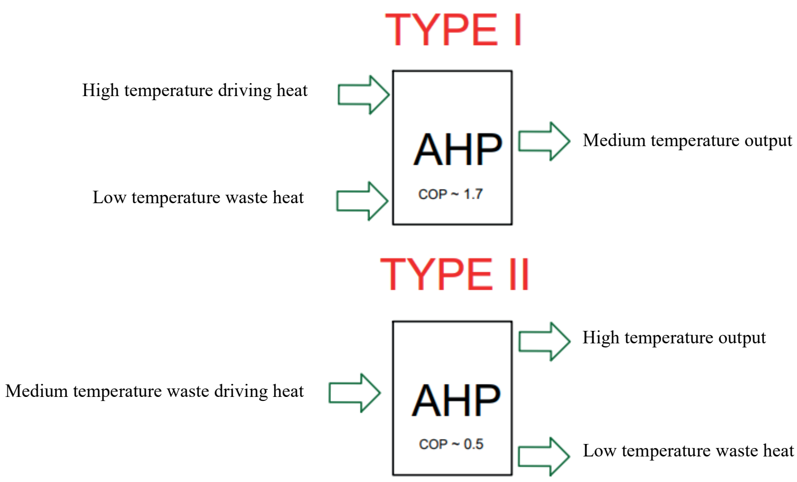


Fig. 1. Thermodynamic working principle of AHP Types [23].

Type I AHP: It is capable of taking high-temperature driving heat and low-temperature waste heat and combine them into a medium-temperature output. The generator heats the LiBr solution to a high temperature and high-pressure vapour. When this vapour reaches the condenser, it condenses and releases heat from condensation. After expanding in the expansion valve, the condensed vapour enters the evaporator, where it absorbs waste heat and evaporates. The absorbent (LiBr solution) follows the following process: the strong solution from the generator enters the absorber, where it absorbs vapour and releases heat. The diluted solution is then pumped into the solution heat exchanger, transferring heat to the strong solution from the generator. The heated, diluted solution enters the generator, where the vapour is boiled off and subsequently condensed in the condenser. Throughout this process, heat is sequentially released by both the absorber and the condenser.

Type II AHP: This type can use medium-temperature driving heat and divide it into high-temperature useful output and low-temperature waste heat for condenser cooling. In this cycle, heat is supplied at a medium temperature, with part of it being upgraded to a high temperature and the rest discharged at a low temperature, differing from the Type I AHP cycle. In the Type II absorption cycle, the absorber heats hot water, which is then delivered to the user. The COP of a Type II AHP is around 0.5, indicating that half of the heat at the medium temperature is upgraded to a high temperature [22].

The use of waste heat from DC with various HP types – such as electrical and AHP – is compared in the current study. The compatibility of the AHP type with low temperature driving heat makes it more appropriate for the current study. Previous research used electrical HPs to increase waste heat temperatures for DH. In most papers on AHPs, high temperatures are produced for localised application by using DH as the driving heat source rather than as a heat sink. This study examined the use of low-temperature waste heat as a possible driving heat source for AHPs to produce heat for DH networks. An energy simulation was performed to determine whether AHPs can be more efficient than HPs using waste heat to produce DH. Different scenarios were evaluated using performance indicators, including technical and economic factors. AHPs can be divided into two categories: Type I and Type II. Type I takes high-temperature driving heat and low-temperature evaporator input to produce medium-temperature heat with a capacity equal to the sum of the inputs. Type II takes medium-temperature driving heat and divides it into high-temperature heating output and lower-temperature waste heat [24]. This paper investigated the possibility of using lower driving heat temperatures for waste heat, meaning that Type I AHPs are not suitable.

According to the literature review, previous research has mostly concentrated on data centres and the industrial sector's waste heat recovery. In previous research, the integration of district heating and cooling systems has been studied, with a particular focus on utilizing waste heat from district heating combined heat and power as source for district cooling [25]. As far as we are aware, very few studies have investigated the utilisation of waste heat from DC networks or DC plants. In terms of technology, waste heat is most frequently reused in DH networks by HPs. This paper aims to explore the techno-economic performance of DC plant waste heat integration for DH applications. In this context, the potential for adopting Type II AHPs to boost efficiency and lower carbon emissions is evaluated through a comparative examination of three distinct technological configurations. This study has two primary contributions: Firstly, it evaluates whether DC waste heat is a suitable heat source for DH networks during the heating season; Secondly, it incorporates Type II AHPs into the heat recovery process in DH networks to improve efficiency and lower carbon emissions.

2. METHODS

As shown in Fig. 2, the process entails creating a simulation model of the energy system. The input parameters for these models include calculations such as the potential waste heat based on DC consumption and the operating data of AHPs and HPs under various conditions. The current DC network data is used to calculate the DC base load. The waste heat is then estimated by applying this calculation to DC development plans. The methodology includes the calculation of certain parameters. This model will be used to compare various waste heat recovering options, such as those that employ electric HPs and AHPs. The model was validated using a case study of Tallinn.

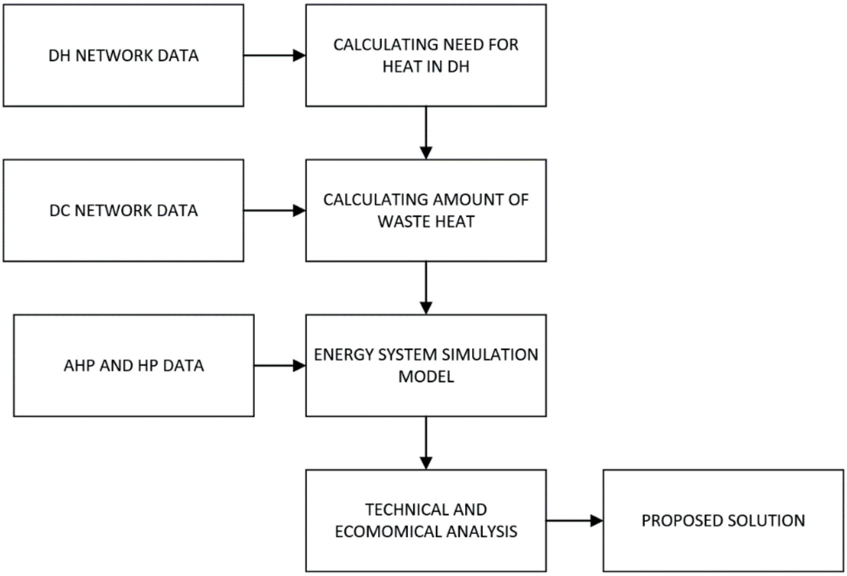


Fig. 2. Flowchart of the Proposed Methodology.

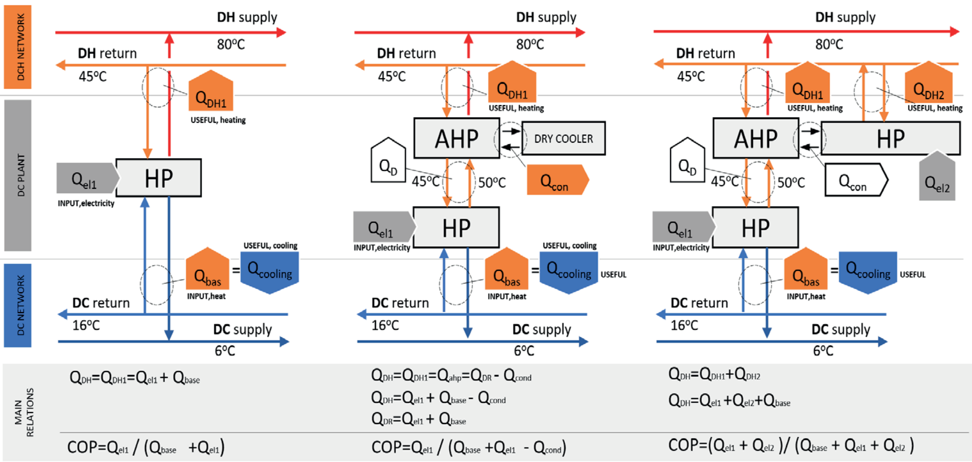
The proposed methodology is applied as a case study in Tallinn, Estonia. This city's DH system has 68 % renewable heat in its portfolio. In 2021, a DH plan was developed with a goal to achieve carbon neutrality by 2027. HP technology is essential for generating renewable heating and cooling from ambient energy and enabling the utilisation of waste heat and cold, according to the strategy "From Low to Zero Carbon". The network reconstruction has started to incorporate low-grade waste heat sources and proceed towards decreasing DH temperatures to facilitate the use of HPs [27], [14], [16]. One potential source of waste heat for HPs is the waste heat from the DC network. Tallinn DH has eight production plants, of which four are renewable and four fossil fuel-based (gas boilers). Waste incineration and woodchip CHPs are used to cover base loads in DH. Renewable plants are prioritised, while fossil fuel plants are used to meet peak demand during the winter. Data from the network in 2023 showed that the gas boiler with longest operating time worked for 4.209 hours. This figure was used as the potential running time for the AHP. The AHP is considered the last renewable DH plant before the first fossil fuel plant, according to the latest DH network data.

An energy system simulation model has been developed to compare different technical configurations for waste heat recovery. All technical solutions involve using waste heat from the DC system in the DH system. The scenarios for technical configurations are presented in Fig. 3. In all scenarios, the heat load demand and DC demand are the same. The DC network in the model operates at 6/16 °C, while the DH network operates at 45/80 °C.

- **Scenario 1-SC1 (Fig. 3a):** In this case, the DC and DH systems are both directly connected to an electric HP in terms of configuration. This particular arrangement was chosen due to the demonstrated efficiency of waste heat recovery using vapour compression HPs and the DC system's suitability as a heat source [28].
- **Scenario 2-SC2 (Fig. 3b):** The application of AHP Type II is examined for the first time in this scenario. The AHP uses medium-temperature driving heat from the water chiller in

DC plant, and dry coolers are employed to cool the condenser. Condenser cooling is seen as waste, and recovery efforts are not undertaken. This design makes it possible to use the dry coolers that were previously installed more effectively by integrating the AHP into the DH and DC production.

- **Scenario 3-SC3 (Fig. 3c):** This is the second solution that examines how AHP Type II is used. The recovery of waste heat from the cooling of the AHP condenser distinguishes SC3 from SC2. The AHP employs an HP that was previously installed in the same plant to achieve this. The goal of this setup is to reduce the amount of energy lost during condenser cooling. If effective, it would generate more heat that is useful than SC2.



(a) (b) (c)

Fig. 3. Energy System Simulation Scenarios: a) Scenario 1, (SC1), b) Scenario 2 (SC2), c) Scenario 3 (SC3).

2.1. Input Parameters and Assumptions

2.1.1. Calculation of Waste Heat Potential

The amount of available waste heat from DC serves as the primary input parameter for the energy system simulation model. The DC system has a base load that is not dependent on outdoor temperature and is available during the heating season. This is considered waste heat that can be utilised by the AHP. The waste heat amount is calculated from the measured DC network data as an average during the AHP's potential working hours.

The DC base load is calculated according to Eq. (1):

$$Q_{\text{base}} = \frac{Q_{\text{cool}}}{A_{\text{T}}} \times A_{\text{F}} \,, \tag{1}$$

where

Q_{base} is the DC base load in the fully developed network, MW;
Q_{cool} is the average DC consumption during the heating season, MW;
A_{T} is the DC cooling surface area today in m^2;
A_{F} is the DC cooling surface area in the fully developed network, m^2.

According to data collected from the DHC operator in Tallinn regarding the DC network and development plans, approximately 60 000 m^2 has been added to the DC network today, with a goal of 1 200 000 m^2. The main goal of this study is not to determine the most suitable method for estimating DC potential in Tallinn, but rather to explore the use of its waste heat. Therefore, 1 200 000 m^2 is used as the input A_F for Formula (1).

2.1.2. Calculations for Absorption Heat Pump Parameters

To obtain accurate data on AHP performance under different operating conditions, meetings with AHP producers were conducted, and information was gathered, as shown in Table 1. For the operating conditions, the DH supply temperature from the AHP was set at 80 °C. Different waste heat and condenser cooling operating points were calculated. The minimum driving heat temperature was set at 50 °C and the maximum at 60 °C. Two types of AHP Type II were analysed: a standard product and a custom-made solution tailored to the client's conditions. As shown in Table 1, column 1 represents the custom-made AHP, which meets the required conditions – driving heat as low as possible and a DH supply of 80 °C. Standard products have certain limitations regarding temperature. The custom-made AHP can achieve an 80 °C output with 50 °C driving heat, while the standard product requires more than 55 °C. Since low temperature driving heat is crucial for the AHP, the custom-made AHP parameters from column 1 in Table 1 are used in the simulation model.

TABLE 1. AHP OPERATING POINTS

		1	**2**	**3**	**4**
Cooling Capacity	MW	5	1	1	1
Heating Capacity	MW	2.4	0.45	0.45	0.45
Driving Heat Inlet	°C	50	50	55	60
Driving Heat Outlet	°C	40	45	50	55
Cooling Inlet	°C	5	15	15	15
Cooling Outlet	°C	10	20	20	20
Heating Inlet	°C	45	50	50	50
Heating Outlet	°C	80	67.5	78.3	89

2.1.3. Calculations of Electric Heat Pump Parameters

Electric HPs need to be incorporated into production for various scenarios. Off-design point efficiency is determined under various conditions using Eq. (2), which was adopted in the study [29]. It was compared with HP operating data collected from the Tallinn DH network.

$$COP_{\text{off}} = COP_{\text{d}} + a(T_{\text{source, i}} - T_{\text{source, i, d}}) + b(T_{\text{DH, s}} - T_{\text{DH, s, d}}) + c(T_{\text{DH, r}} - T_{\text{DH, r, d}}), \tag{2}$$

where
COP_{off} is the COP for off-design operation;
COP_{d} is the COP for design conditions;
$T_{\text{source, i}}$ is the heat source inlet temperature for off-design operation of heat source i, K;
$T_{\text{source, i}}$ is the heat source inlet temperature for off-design operation of heat source i, K;
$T_{\text{DH, s}}$ is the DH supply temperature for off-design operation, K;

$T_{DH,\,s,\,d}$ is the DH supply temperature for design conditions, K;
$T_{DH,\,r}$ is the DH return temperature for off-design operation, K;
$T_{DH,\,r,\,d}$ is the DH return temperature for design conditions, K;
a, b and c are coefficients based on linear regression.

2.2. Performance Indicators

Three scenarios (Fig. 1) were evaluated using technical and economic performance indicators. Technical parameters include the heat recovered from DC for DH, system electricity demand, and electrical COP. The LCOH is used as an economic indicator for scenario comparison.

For the calculation of waste heat from DC that can be recovered for use in DH, both heat produced by HPs and AHPs should be taken into account Eq. (3):

$$Q_{DH} = Q_{HP} + Q_{AHP}, \tag{3}$$

where
Q_{DH} is the total useful heat produced for the DH network, MW;
Q_{HP} is heat produced in DH production by HP, MW;
Q_{AHP} is heat produced in DH production by AHP, MW.

Electricity is used by both electric HPs and AHPs to increase the temperature of waste heat. System electricity demand includes electricity for HPs and electricity needed for pumping, as shown in Eq. (4):

$$P_{EL} = P_{HP} + P_{AHP} + P_{PUMP}, \tag{4}$$

where
$P_{EL}$is total electricity demand, MW;
P_{HP} is the electricity input for HP in DH production, MW;
P_{AHP} is the electricity input for AHP in DH production, MW;
P_{PUMP} is electricity used for pumping, MW.

In this case P_{PUMP} is calculated using Eq. (5):

$$P_{PUMP} = P_{PUMPHP} + P_{PUMPAHP}, \tag{5}$$

where
P_{PUMPHP} is electricity for HPs;
$P_{PUMPAHP}$ is electricity for AHPs.

The pressure losses in the heat exchangers for AHPs and HPs were calculated using the datasheets provided by the manufacturers. Because the system layout and pipe size in the simulation were not the same for each of the three scenarios that were examined, pressure loss from flow in the pipes was not taken into account. The online selection tool from Grundfos was used to identify the electrical inputs of the pumps. COP (electrical) of heat production, using Eq. (6) [20].

$$COP = Q_{DH}/P_{EL}, \tag{6}$$

where
Q_{DH} is total electricity demand, MW;
P_{EL} is electricity input for HP in DH production, MW.

Levelized cost of heat LCOH using Eq. (7) [30]:

$$\text{LCOH} = \frac{\text{CAPEX} + \text{Price}_{\text{el}} \cdot \sum_{n=0}^{n} \left(\frac{W_{sys}}{(1+DR)^n} \right) + \sum_{n=0}^{n} \left(\frac{\text{OPEX}}{(1+DR)^n} \right)}{\sum_{n=0}^{n} \left(\frac{Q_y}{(1+DR)^n} \right)}, \quad (7)$$

where
CAPEX capital cost of complete system including installation and commissioning, EUR;
OPEX operation cost of complete system including fixed and variable O&M, EUR;
Price_{el} unit price of electricity, €/MWh;
W_{sys} annual power consumption of heat pumps and fluid pumps, MWh;
DR discount rate, %;
N project lifetime, years;
Q_{y} thermal demand met by DH network, MWh.

CAPEX and OPEX in LCOH calculations are based on analysis of similar projects and information gathered from manufacturers. Total investments in SC1 are 4.2 million euros, SC2 4.2 million euros and SC3 5.4 million euros. Electricity price is considered 130 €/MWh. Discount rate 8 % and project lifetime 20 years.

2.3. Limitations

The DC and DH networks' static temperatures are one of the model's limitations. There is no use of hourly-based temperature control; the temperatures of the heat sink and heat source remain constant throughout the year. This approach does not allow for the lowest possible temperature increase, as the temperature increase remains at 6 °C to 80 °C throughout the year.

3. RESULTS

According to the energy system simulation, a potential waste heat capacity of 3.6 MW was calculated using Formula1 for all three scenarios. The amount of useful heat produced for DH is shown in Fig. 4.

Compared to the base scenario, SC2 has a much lower heating capacity because half of the heat wasted in the AHP's condenser. SC2 produces 2.1 MW of useful heat out from 3.6 MW of DC waste. SC3 performs better, as it utilises the AHP's condenser cooling with a smaller HP. As a result, the useful heating output in SC3 is 5.1 MW from 3.6 MW of waste heat. Although this is slightly less than in SC1, it is more efficient.

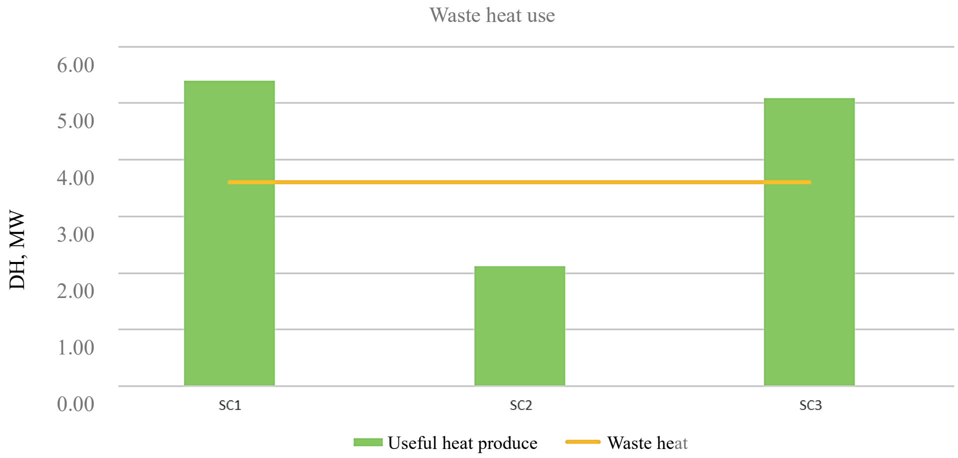


Fig. 4. Useful Heat produced from Waste Heat.

As shown in Table 3, the electricity demand and COP vary significantly between SC1, SC2, and SC3. SC1 requires an electrical input of 1.851 MW for HPs to raise the temperature from 6 °C to 80 °C. In SC2, the AHP uses less electricity, resulting in a 41 % reduction in electrical input (1.091 MW), but there is also significant loss, 61 %, in heat production. However, since the AHP's condenser cooling temperature is 5/10 °C, SC2 can only operate in full capacity when the outside temperature is below minus 2 °C. SC3 has a 14 % lower electrical input and because it uses a smaller HP for the AHP's condenser cooling, and its operation is not dependent on outside temperature. Since COP in SC3 is 7 % higher than SC1, heating production will be lower 6 %.

TABLE 3. SCENARIO COMPARISON

Energy Parameters	**Unit**	**SC 1**	**SC 2**	**SC 3**
Electrical Input	MW	1.851	1.091	1.596
COP	Unitless	2.92	1.94	3.13
Annual Heat Production	MWh	22 728.60	8916.07	21 446.61
Annual Electricity Consumption	MWh	7783.74	4595.91	6851.95
LCOH	€/MWh	80.65	138.37	79.02

The LCOH for SC1 is estimated as 80.65 €/MWh. In SC2, it is 72 % higher at 138.37 €/MWh because the AHP's heating production from the same amount of waste heat is lower than in SC1. In SC3, the LCOH is 2 % lower than in SC1, at 79.02 €/MWh, due to the AHP and the use of its condenser cooling in the DH return and DH water preheating system. SC 1 has the highest heat production during expected lifetime of 20 years, 22 728.6 MWh. SC2 and SC3 produce 61 % and 6 % less in their lifetime respectively. Therefore, the biggest reduction on fossil fuel is expected in case of base SC1.

4. Conclusion

The use of waste heat as a source for DH has been widely studied, like the topic of power-to-heat. These technological upgradations present a viable replacement for fossil fuels in DH. This paper proposes an AHP solution instead of an electric HP under more efficient conditions. As Tallinn progresses towards 4GDH, AHPs present a potential solution for more efficient waste heat use in the DH network.

This paper investigated the potential of using AHPs to raise DC waste heat temperatures for DH application. The use of AHPs was compared to electric HPs as a base scenario. In this study, DC, which has a steady load even during the heating season, provided the waste heat needed to power the AHP. To prevent wasting AHP condenser cooling, new technical solutions and investigation into the possibility of using alternative sources to power are explored.

Data on different HPs was gathered from manufacturers, and an analysis was conducted where various solutions were evaluated using performance indicators. Two different AHP scenarios were compared to base scenario: one that utilises AHP condenser cooling as useful heat and another that does not. The analysis shows that AHPs can be more efficient, reduce energy consumption, and achieve a lower LCOH while being combined with HP condenser cooling. Making heat production with heat pumps more efficient reduces the amount of heat produced from the same source. As the energy simulation showed, using AHP can make the process more efficient, but will also reduce the heat produced. If more efficient technology is much more expensive, it will raise the price of heat produced.

Greater efficiency means lower electrical input, which is crucial for achieving renewable energy goals. Because of its great efficiency, it can be concluded that AHP technology can be used to utilise waste heat in DH networks on a much wider scale. Future scope can be suitability analysis of additional waste heat sources as the driving heat for Type II AHPs. Those configurations with a higher COP, lower LCOH, and reduced electricity demand can have a positive impact on the transition to green and affordable DH supply.

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