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BY-PRODUCT SYNERGIES IN ENERGY PRODUCTION AND BEYOND

Cases: industrial waste heat, biogas potential, and brewery by-product

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ABSTRACT

This report presents the research carried out during the EteVä Pilot project and its results. Three different thematic pilots were carried out during the project, and each has produced its own report. This is the first of these pilots, which went under the name "companies' synergies for energy production."

Companies' synergies for energy production - pilot purpose was to investigate the potential collaboration between companies to utilize waste streams and by-products streams with other companies in the region and in energy production. The pilot succeeded in investigating a potential energy waste stream and its potential use in several different ways, one being internal and two being external solutions. This report also outlines other relevant information in relation to biogas potential in the region, which illustrate the potential synergies between companies in energy production and while considering the topic of waste streams the project further investigated breweries and their potential to find a gap of how to effectively utilize and share by-product solutions. As such based on the needs of the area the final chapter deviates from the topic of energy to suggest a larger more holistic approach to by-product collaboration and circular economy.

The EteVä Pilot - Energy Efficient and Low Carbon Pilot Solutions project was implemented in the Central Ostrobothnia region from 1.6.2021 to 30.8.2023 and was funded by the European Regional Development Fund, the Regional Council of Central Ostrobothnia, the City of Kokkola, Kannus and Kaustinen. The companies involved in the project were Kokkolan Energia Oy, Boliden Kokkola Oy and Blaxar Oy.

CONCEPT DEFINITIONS

BSG
Brewers's spent grain

BSY
Brewer's spent yeast

CHP

Cogeneration or combined heat and power is the use of a heat engine or power station to generate electricity and useful heat at the same time.

COP

The efficiency of a heat pump is defined in a coefficient of performance.

CO2

Carbon dioxide

CSG
Coffee spent grain

CWH

Circular Wellness Hub

KIP

Kokkola Industrial Park

MW

Megawatt

MW

Megawatt

MWh

Megawatt-hour

ABSTRACT
CONCEPT DEFINITIONS
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1 INTRODUCTION

This report is one in a series of three produced during the project EteVä Pilot - energy efficient and low-carbon pilot solutions and outlines the research and results of the project. The aim of the project was to support local area of Central Ostrobothnia in the transition to renewable energy and low carbon solutions. The focus of the project was to investigate the different waste energy and by-product streams created by companies in the region and to improve their energy and material efficiency. To achieve this goal this project had three different thematic pilots carried out during the project, in which specified defined topics were investigated, data was collected from companies and existing solutions, and some new solutions were suggested. These results are presented in a Best Practices publication and a report series of which this is the first report. In figure 1 the thematic pilots of the project are presented.

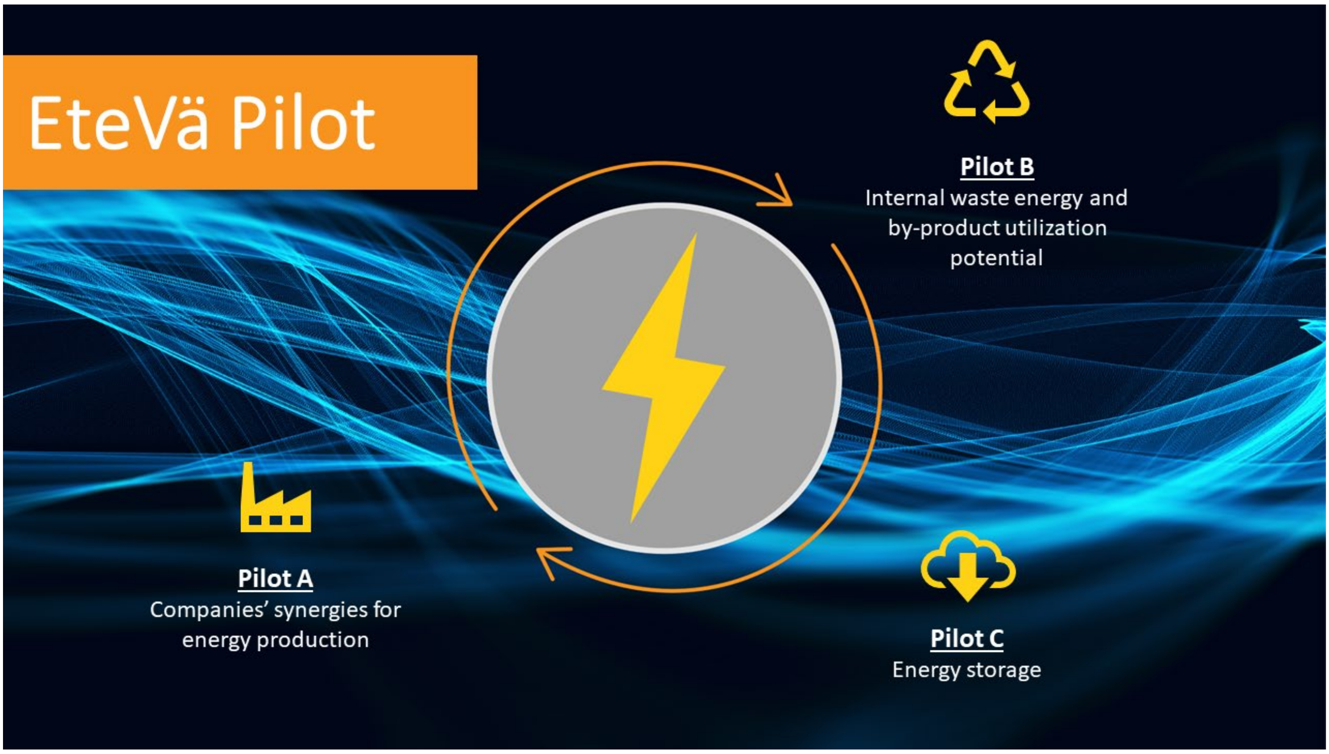


FIGURE 1. Thematic pilots of the EteVä Pilot -project.

This report is the first in the series and outlines the results of the first thematic pilot, Pilot A – companies' synergies for energy production. The other thematic pilots were Pilot B – Internal waste energy and by-product utilization potential and Pilot C – Energy storage.

The companies' synergies for energy production pilot focused on finding potential solutions for waste heat and by product utilization within the Central Ostrobothnia region between existing organisations that could be mutually beneficial. This report outlines potential solutions that aim to bridge companies throughout different fields, from industrial parks to biogas potential in the region to commercial hubs for sharing side streams and by-products. This report outlines larger scale solutions while the next report for Pilot B and Pilot C will outline more detailed specifications that this report is based on.

2 WASTE ENERGY TO UTILIZATION

2.1 Introduction

Waste heat is a common type of surplus energy in industrial applications. Often this waste heat is originating from thermal processes where cooling of an application is needed. The energy is therefore transferred from one process to another, and then released into the atmosphere, the sea, or a river. Often this waste heat is high in energy, but in such a low temperature range that commercial uses are difficult.

With the emergence of more efficient heat pumps, the low temperatures of these waste heat sources are no longer a showstopper. In some applications it is now possible to use heat pumps successfully in commercial applications, where waste heat is transferred into high value thermal heat. One option investigated in this report is the usage of this heat in district heating.

A large factory in the Kokkola industrial park has been a partner in this project, and the content of this report is focusing on the usage of waste heat from the factory.

2.2 The Process

The project partner's industrial manufacturing process involves several steps where cooling is needed. These cooling steps are all potential sources of waste heat thermal energy, that vary in power and temperature. All cooling processes release the excess energy to the surrounding air, via cooling towers. Below is a summary of the most promising sources of waste heat that are easy to be utilized, without risking disturbances of the actual manufacturing process.

2.2.1 Waste heat sources

The following sources of waste heat are suitable for potential use. In this study, we focused on the roaster, as this seemed the most promising source. All heat sources listed are available 24h a day, 7 days a week.

2.2.1.1 Heat source "A"

The heat is obtained from cooling of gas.

Waste heat power available: **5MW**

Temperature that is available: approximately 45°C

Return temperature to the process should be 20°C.

>90% of the year available.

This is the most promising source and selected as the focal point of this report and its calculations.

2.2.1.2 Heat source "B"

Waste heat power available: **1MW**

Temperature that is available: approximately 45°C

Return temperature to the process should be 20°C.

>90% of year available.

2.2.1.3 Heat source "C"

Waste heat power available: **0,8MW**

Temperature that is available: 25°C

The maximum return temperature must not exceed 18°C, the lower the temperature, the better.

2.3 Solution proposal

Two solution proposals were found to be possible. We focused on the first proposal in this report, which is the utilization of waste heat with a heat pump. The other solution proposal, which is the pre-heating of cold sludge in the biogas plant, is described in a separate report.

2.3.1 Utilizing a heat pump to boost the temperature for district heating network usage.

This solution consists of a heat pump system, that boosts the temperature of the waste heat to a range that is directly usable in the local district heating network. The following graph illustrates the process in a simple schematic overview.

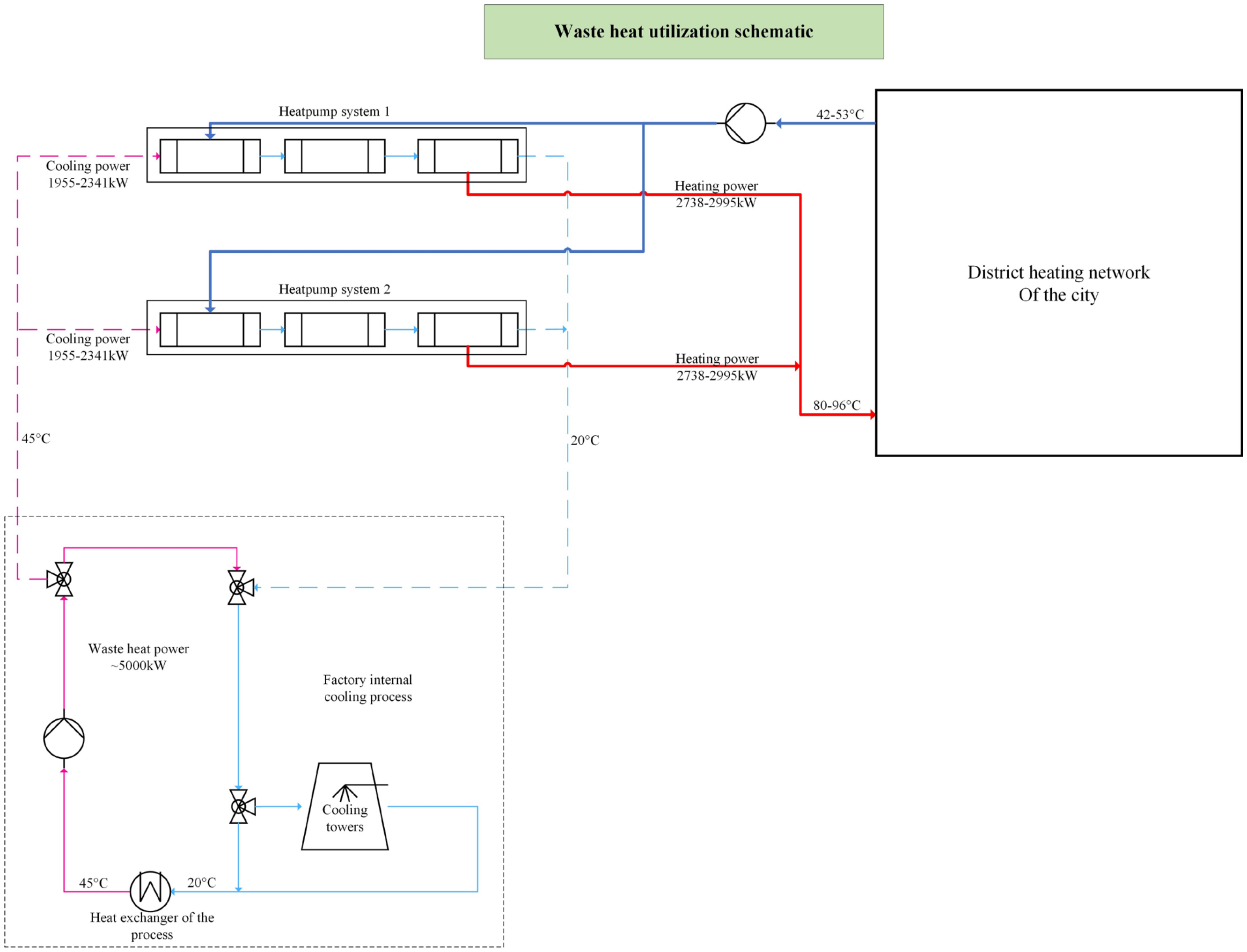


FIGURE 2. Schematic overview of the waste heat source, the heat pump system, and the connection to district heating network.

The heat pump system will receive the waste heat source of 45°C and increase the temperature to 80-96°C, depending on the outdoor temperature. This temperature is directly usable in the district heating network that is operated by the local energy company.

2.3.2 Using the heat in the biogas plant for pre-heating of cold sludge

This solution consists of a heat exchanger inside the biogas plant that is located on the wastewater treatment plant site in the Kokkola Industrial Park (KIP) area. The waste heat from the factory is transferred to the biogas plant via insulated pipes in the ground. The heat is used to pre-heat cold sludge that is pumped into the biogas reactors, thus reducing the amount of thermal heating of the biogas reactors.

The heating of the biogas reactors is achieved by heat generated from a biogas CHP unit, and an additional biogas burner unit. The reduced thermal heating need of the biogas reactors leads to a situation where more biogas is available for other usage such as:

a) more electricity generation in the CHP units.
b) to liquify some of the biogas for transportation fuel.

Details on this solution is **not included in this report**, it can be found in a separate report.

2.4 Heat pump

A heat pump is the ideal solution for a problem faced in the project. It extracts heat from the source, here the waste heat from the factory's process. Then it amplifies and transfers the heat to the district heating network, where it can be used for space heating of buildings.

2.4.1 Suggested models

The temperature range of the factory's waste heat sources vary between 45°C and 25°C. The temperature needed in the district heating network varies between 72°C and 115°C. In this project, we contacted the heat pump manufacturer Oilon and requested technical advice on the right type of heat pump for this case. The models suggested were taken into further consideration, and all calculation results are based on the following heat pump model:

2.4.1.1 Heat pump temperature range between 80-96°C

The following heat pump system has an upper temperature limit of 96°C (Oilon Oy technical brochure, 2023). This means that temperatures exceeding this, cannot be delivered by this model.

> 1x Oilon model S490 SU HC, with 1x a variable frequency drive, and R1234ze(E) as a refrigerant.
> connected in cascade with
> 1x ”Oilon” P450 SU HC, with 2x a variable frequency drive, and R450A as a refrigerant.
> connected in cascade with

1x ”Oilon” P450 SU HC with 2x a variable frequency drive, and R1234ze(E) as a refrigerant.

The following graph shows the 3 heat pump models connected in cascade, for a temperature output on the heating side of 80°C. This model can deliver an output temperature between 80°C and 96°C.

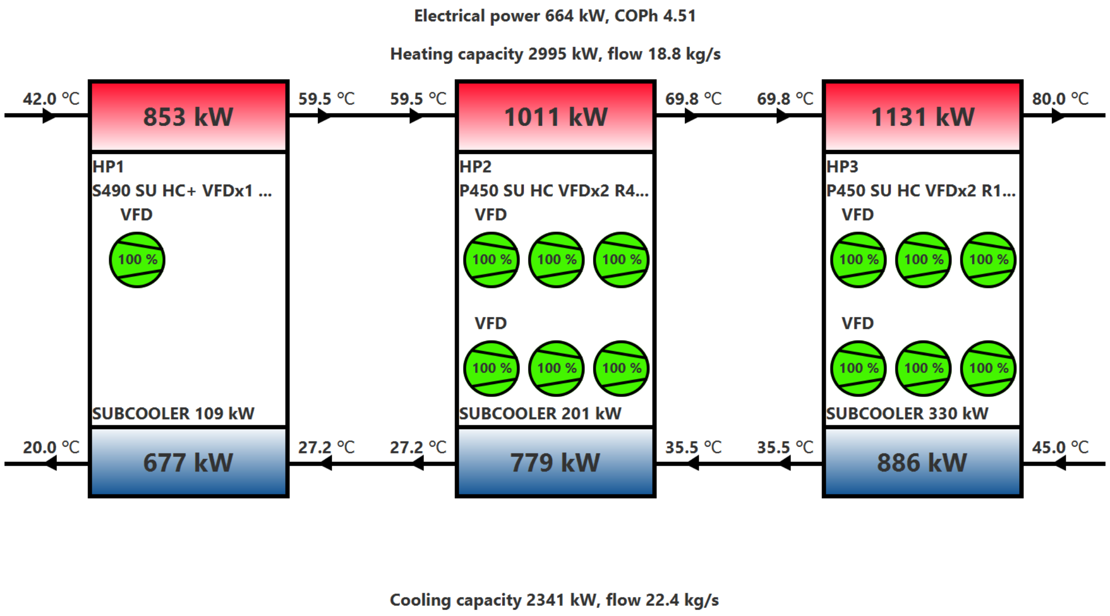


FIGURE 3. Oilon’s heat pump system schematic.

2.4.1.2 Heat pump temperature range between 101-111°C

The following heat pump system has a lower temperature limit of 101°C and an upper temperature limit of 111°C (Oilon Oy technical brochure, 2023).

It is therefore not suitable as an ideal solution for this case. If, however, temperatures above 101°C are needed, this model can fulfil this requirement.

1x ”Oilon” S490 AD SU HC with 1x a variable frequency drive and R1234ze(E) as a refrigerant.

connected in cascade with

1x ”Oilon” P450 SU HC with 2x a variable frequency drive, and R1233zd(E) as a refrigerant.

connected in cascade with

1x ”Oilon” P450 SU HC with 2x a variable frequency drive, and R1233zd(E) as a refrigerant.

The following graph shows the 3 heat pump models connected in cascade, for a temperature output on the heating side of 101°C. This model can deliver an output temperature between 101°C and 111°C.

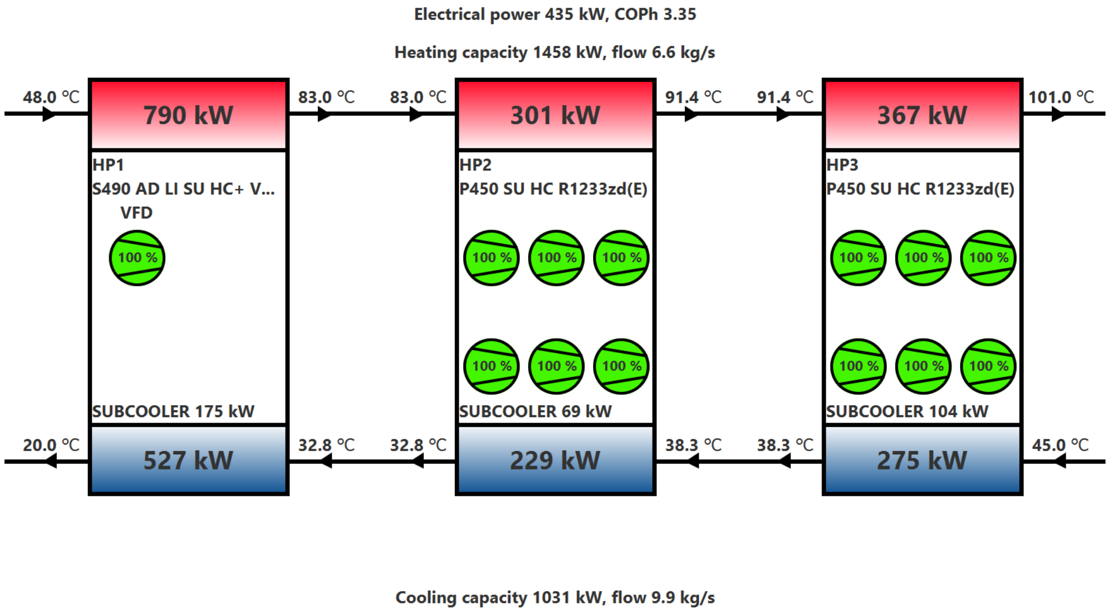


FIGURE 4. Oilon’s heat pump system schematic.

2.4.2 Output temperature limitations

Due to physical limitations in the use of refrigerants in the heat pumps, the required temperature range of the district heating network between 80°C and 115°C cannot be delivered by one single heat pump model.

- One model can deliver 80°C - 96°C.
  This is enough for most days of the year. Only days colder than -15°C will not be covered with this heat pump alone.

and

- the other model can deliver 101°C - 111°C.
  When the outdoor temperature is colder than -15°C, this model would be required to deliver the needed flow temperature in the district heating network.

It is possible to install both models, and use either the lower temperature range model, or the higher temperature range model. Installation costs are double in this case though.

- Another option is to use the heat pump for the temperature range between 80°C - 96°C, and use an **electric boiler** to prime the output temperature of the heat pump from 96°C to the required range on days colder than -15°C. This is used in large scale heat pump installations in the Helsinki region (Annastiina Airaksinen, 2023).

2.4.3 Efficiency of the heat pump: the COP

The efficiency of a heat pump is defined in a coefficient of performance (COP). The higher the COP number, the more efficient the heat pump operates.

- A COP of 4, for example, uses 1kW of electricity to generate 4kW of thermal heating power.
- A COP of 2, for example, uses 1kW of electricity to generate 2kW of thermal heating power.

With increasing output temperatures, the COP value decreases. The following graph shows the relation of the COP value of the heat pump in this specific case. A constant input temperature of 45°C from the waste heat source has been considered for this calculation.

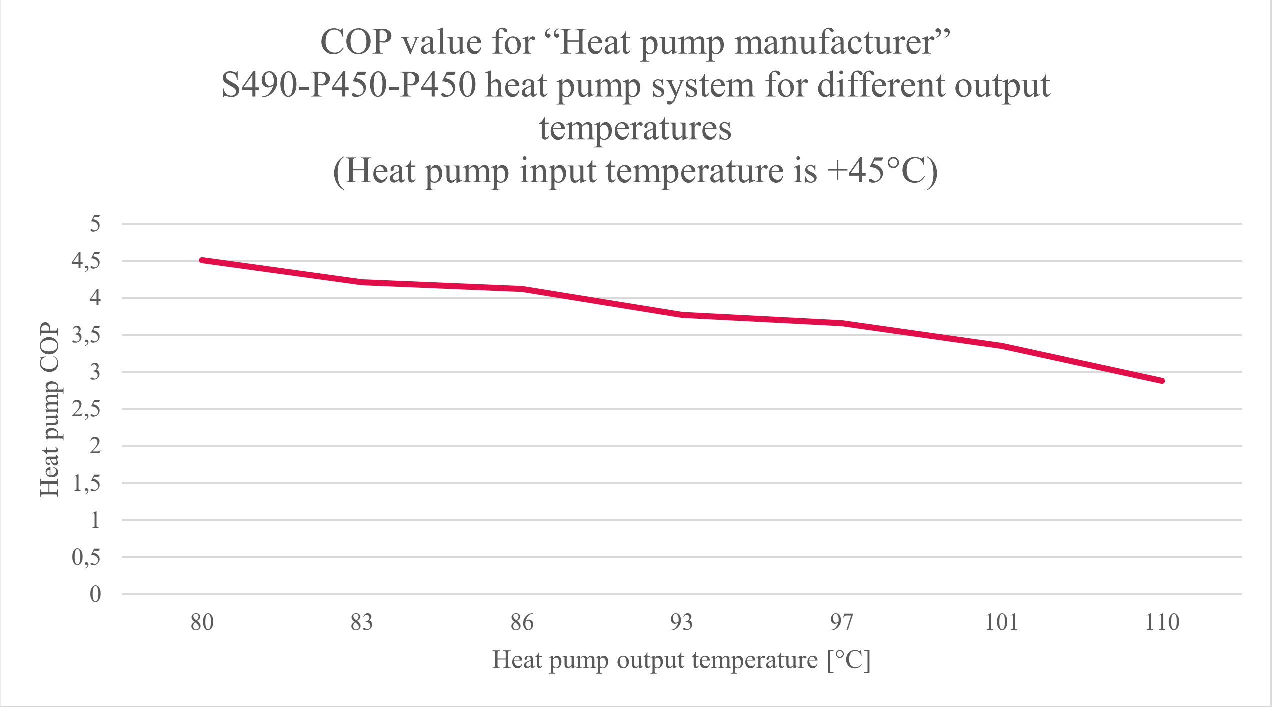


FIGURE 5. Heat pump efficiency COP in relation to output temperature.

2.4.4 Cooling and heating capacity of the heat pump

The suggested models have a specific capacity of cooling and heating. All numbers listed below are in Megawatt [MW] and are based on thermal power for water.

2.4.4.1 Cooling capacity of the heat pumps

The cooling capacity is the power that is taken from the factory's waste heat.

TABLE 1. Heat pump cooling capacity.

Heat pump model	**Min cooling capacity, one single system**	**Max cooling capacity, one single system**	**Min cooling capacity, two systems working together**	**Max cooling capacity, two systems working together**
80°C -96°C temperature range model	1,955MW	2,341MW	3,910MW	4,682MW
101°C -111°C temperature range model	0,827MW	1,031MW	1,654MW	2,062MW

Cooling capacity of model with 80°C - 96°C temperature range

Here, one single heat pump system consisting of Oilon's S490, P450 and P450 has a cooling capacity between 1,955-2,341MW.

With two of those systems installed in parallel connection, the capacity is doubled, to 3,910-4,682MW. This heat pump cooling power is slightly less than the waste heat source from the roaster, which is ~5MW.

Cooling capacity of model with 101°C - 111°C temperature range

Here, one single heat pump system consisting of Oilon's S490, P450 and P450 has a cooling capacity between 0,827-1,031MW.

With two of those systems installed in parallel connection, the capacity is doubled, to 1,654-2,062MW. This heat pump cooling power is significantly less than the waste heat source from the roaster, which is ~5MW.

2.4.4.2 Heating capacity of the heat pumps

The heating capacity is the power that is supplied to the district heating network by the heat pump.

TABLE 2. Heat pump heating capacity.

Heat pump model	**Min heating capacity, one single system**	**Max heating capacity, one single system**	**Min heating capacity, two systems working together**	**Max heating capacity, two systems working together**
80°C -96°C temperature range model	2,738MW	2,995MW	5,476MW	5,999MW
101°C -111°C temperature range model	1,367MW	1,458MW	2,734MW	2,916MW

Heating capacity of model with 80°C - 96°C temperature range

Here, the capacity of one single heat pump system consisting of Oilon’s S490, P450 and P450, with an output temperature between 80°C - 96°C, has a heating capacity between 2,738- 2,995MW. With two of those systems installed, the capacity is doubled to 5,476- 5,990MW.

Heating capacity of model with 101°C - 111°C temperature range

Here, the capacity of one single heat pump system consisting of Oilon’s S490, P450, P450 and P450, with an output temperature between 101°C - 111°C, has a heating capacity between 1,367 - 1,458MW. With two of those systems installed, the capacity is doubled to 2,734 - 2,916MW.

The following graph illustrates these numbers. The drop in cooling and heating capacity between 97°C and 101°C is due to a different type of heat pump model needed, which uses “R1233zd(E)” as a refrigerant. This refrigerant is optimized for higher temperatures but has a lower energy efficiency.

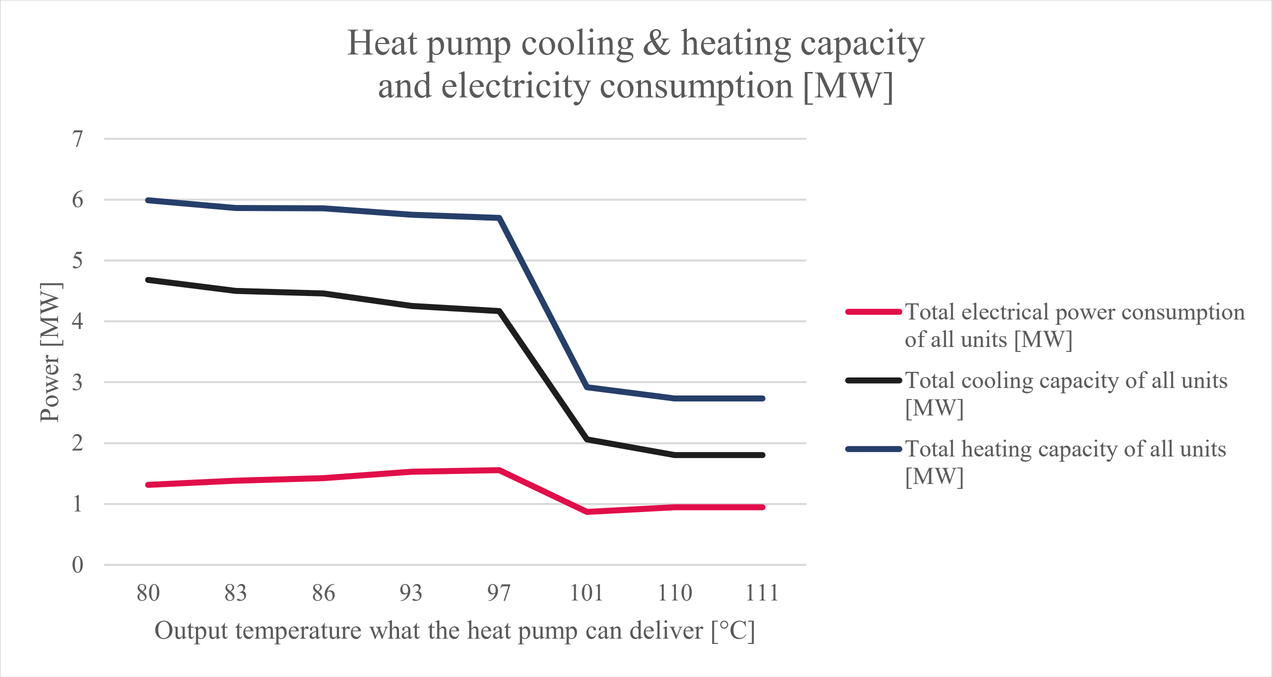


FIGURE 6. Heat pump cooling and heating capacity, with electricity consumption for different heat pump output temperatures.

2.5 District heating network

2.5.1 Overview to district heating

The district heating network in Kokkola is owned and operated by a local energy company. The main source of heat is located in the KIP area, from where it is supplied via insulated pipes to the city. The local energy company has expressed interest to accept an additional heat source for their network, which would be the heat pump described in this study, located at the factory.

2.5.2 Temperatures in 2021

For this study, the local energy company supplied a chart of the hourly measurements of outdoor air temperature in Kokkola, district heating network flow temperature and district heating network return temperature for the year 2021.

2021 was a good year for our calculations, because it had good winter conditions in February and March, and an exceptionally cold end of the year in November and December. The conditions of an average year will therefore be slightly milder, which will have a positive effect on the profitability of a heat pump system, because the output temperatures required will be lower in milder winters. This increases the COP value of the heat pump and leads to a reduced consumption of electricity.

The following graph illustrates the outdoor air temperature and the district heating network flow temperature for the year 2021.

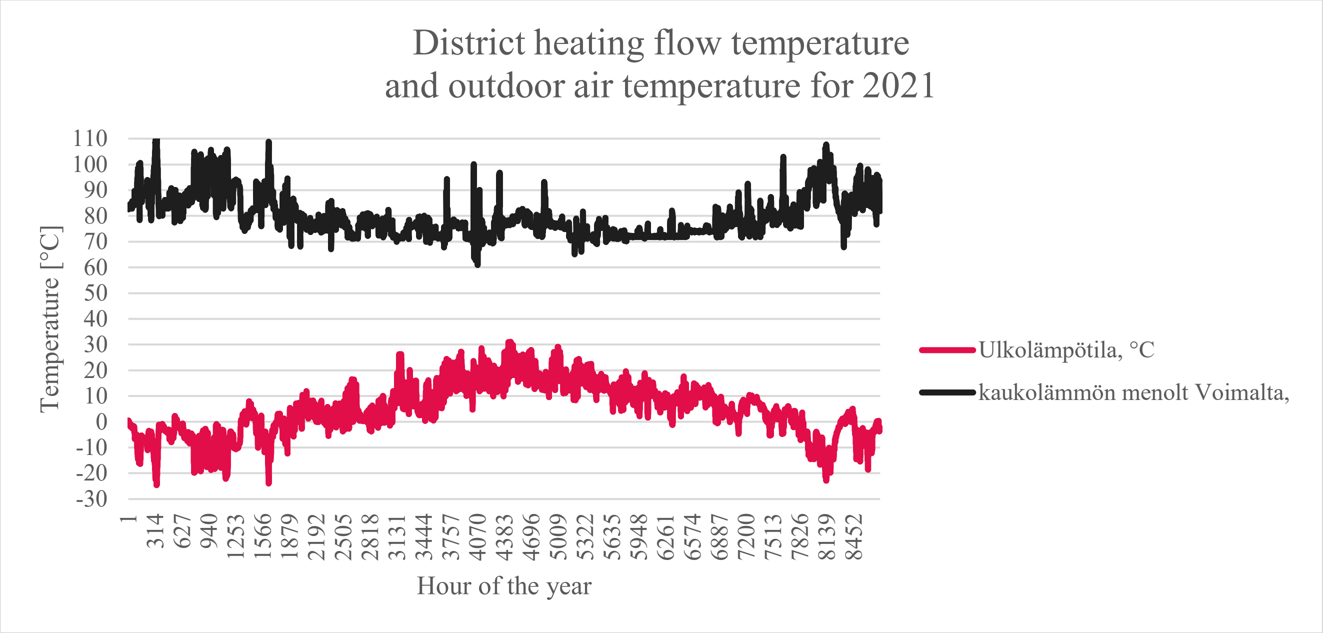


FIGURE 7. Outdoor air temperature in Kokkola and district heating network flow temperature for 2021

2.5.3 COP of the heat pump for the year 2021

The efficiency (COP) of the heat pump is depending on the output temperature delivered by the heat pump. The higher the temperature, the lower the efficiency. For the year 2021, the district heating network flow temperature is known, and from those numbers it was possible to calculate the heat pump COP value.

The following graph illustrates the value. During the winter months, where a higher flow temperature is needed, the COP value varied between 2,9 and 4,2. During spring and especially summer, when the required district heating network flow temperature is lower, the COP value of the heat pump is higher.

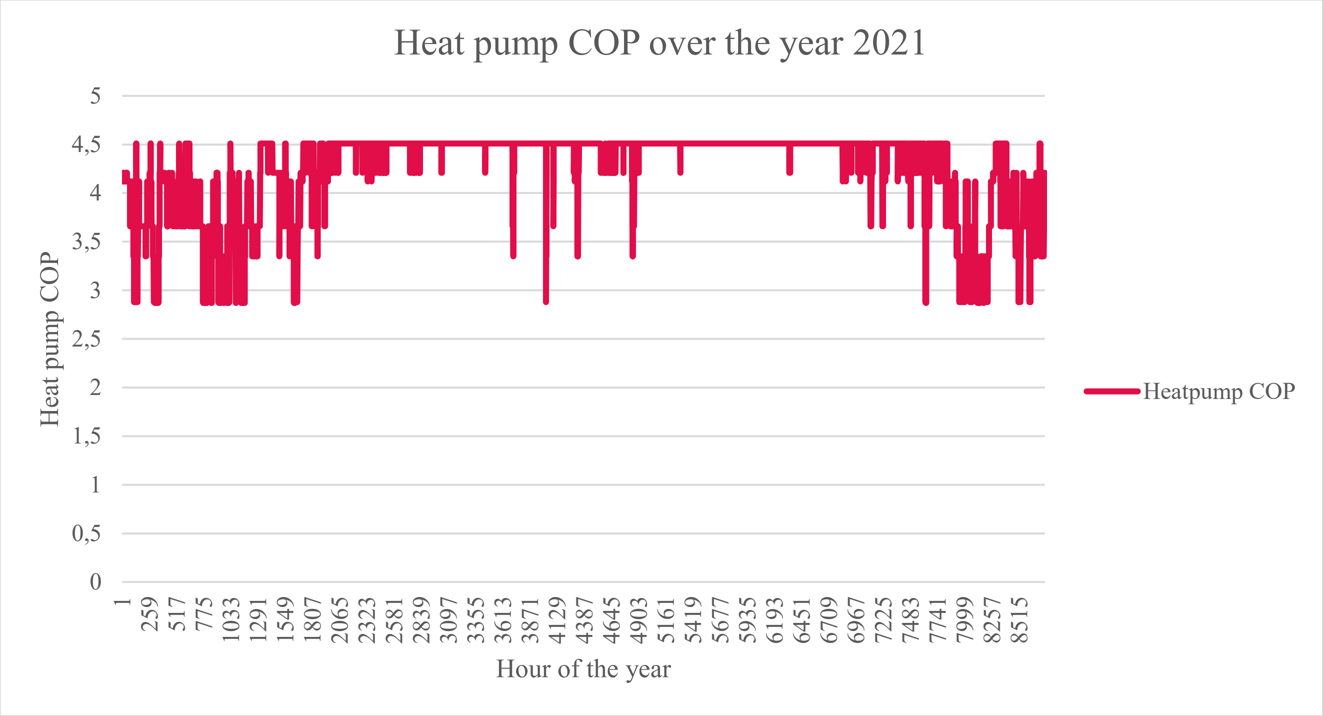


FIGURE 8. Heat pump efficiency, COP, for the year 2021.

2.5.4 District heating network flow temperature in relation to outdoor temperature

The water temperature inside the district heating network flow and return pipes are adjusted in relationship to the outdoor air temperature in Kokkola. The higher the outdoor temperature, the lower the temperature in the district heating network.

The following graph illustrates the relationship between these factors. Also shown is the maximum temperature that the heat pump model, presented in the previous chapter, can deliver.

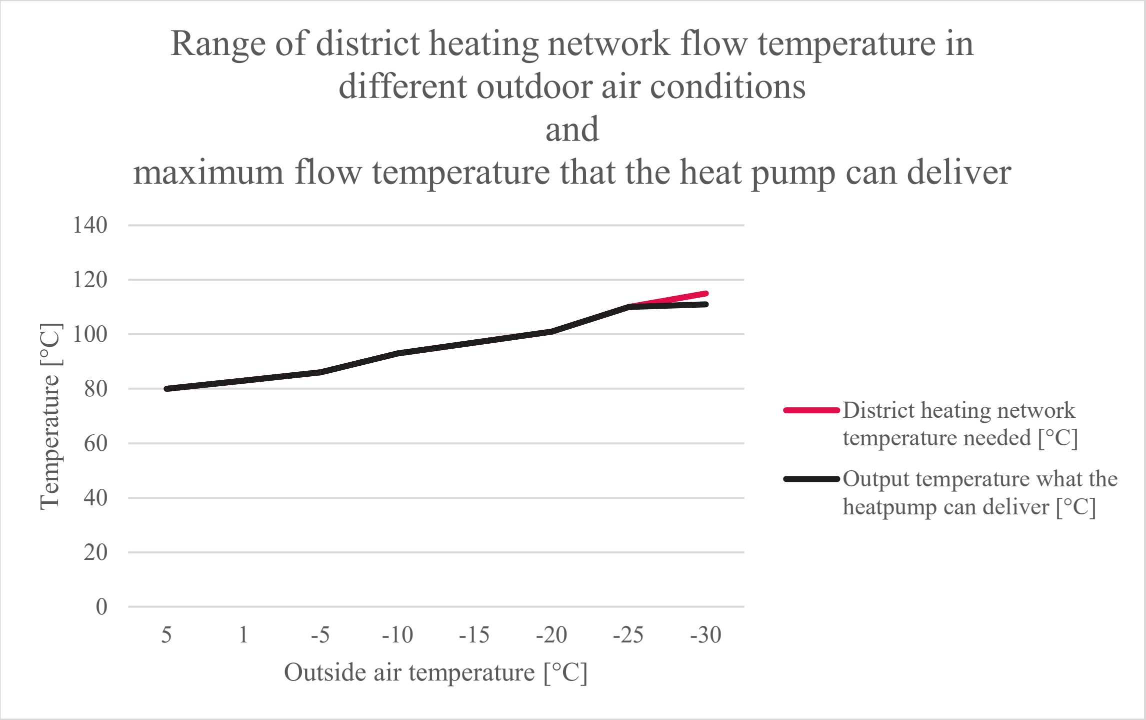


FIGURE 9. Outdoor air temperature and district heating network temperature.

2.5.5 Connection to the existing district heating network

The different sources of waste heat are located at different places inside the factory.
The following chapter lists the possible pipe connections between the heat pumps and the existing district heating network.

2.5.5.1 *"Production" building*

The location of both "waste heat source B" and "waste heat source C" are within the "production building". From this location, the distance to the existing district heating network, that supplies other buildings in the factory area, is ~250-300m.

Another district heating network pipe is directly supplying the "production building". The distance from the cooling towers to this pipe is <100m.

2.5.5.2 *"Pretreatment" building*

The location of the “waste heat source A” is within the gas handling building. From this location, the distance to the existing district heating network is ~112m.

2.6 Investment costs

The investment costs for the heat pump system have been estimated based on price information received from Oilon. The total investment costs consist of the heat pump system, electrical installation, mechanical installation, and the pipe connection to the district heating network.

2.6.1 Heat pump investment costs

The costs for one heat pump system, consisting of Oilon’s S490, P450 and P450 models connected in cascade, is approximately 460 000€. For technical details, see the chapter “heat pump”.

When two sets of these systems are installed, the costs are doubled.

2.6.2 Electrical connection

The installation costs of electrical connections and power supply to the heat pump has been estimated by Oilon sales representative. These costs vary a lot, depending on customer requirements and site-specific variables.

The rough price estimation for one heat pump system varies between 50 000 and 100 000€.
In the cost calculation in this report, we have used 75 000€ per heat pump system, due to the scaling effect of installing 2 or more heat pump systems at the same location.

2.6.3 Mechanical installation

Mechanical installation costs for installation of the heat pump system have been estimated by Oilon sales representative as well. These are usually between 200 000 – 300 000€ for one heat pump system. A large scaling effect for the installation of more than one heat pump system is beneficial for the customer, as certain costs occur only once, regardless of the number of heat pumps needed.

We have taken 250 000€ mechanical installation costs per heat pump system as the basis of our calculations.

2.6.4 Pipe connection costs

The pipe connection costs between the heat pump system and the district heating network are estimated to be approximately 250 000€. This assumes that the distance between the heat pump and district heating network is 250m. The costs are lower if a shorter distance is realized.

These costs are based on the following assumption:

- Required pipeline length: 500m in total. 1x 250m for the flow pipe, and 1x 250m for the return pipe.

- Pipe size: DN200.
  For a transfer of 5-6MW thermal power, at a temperature difference of 38°k and a flow of maximum 140m3/h.

Technical details of the pipe:

- Manufacturer: Brugg Pipes. Product name: PREMANT UNO district heating pipe.
- Steel pipe, pre-insulated.
- DN200: 219.1 x 4.5mm.
- Surface roughness e = 0.045 mm.
- Price per meter of pipe: 500€/m. This price is including:
    - The pre-insulated district heating pipe
    - All installation costs.
    - Pipe routing inside the building
    - Excavation of pipe trenches in a factory environment with many existing cables underground
    - Pipe elbows and bends
    - Welding work

2.6.5 Summary of investment costs

The following table summarizes the total investment costs.

TABLE 3. Investment cost overview.

Item	**Price per unit**	**Total price [€]**
Heat pump	460 000€	920 000
Electrical connection	75 000€	150 000
Mechanical connection	250 000€	500 000
Pipe connection	500€/m	250 000
Sum of all costs		**1 820 000**

2.7 Operating cost calculation

2.7.1 Electricity costs

The costs of electricity to operate the heat pumps is the main defining factor for the profitability of this study. The prediction of future electricity costs is no easy task, and therefore we requested aid from the projects partner to get more reliable data. Different options were calculated, based on different ways to source the electricity from the market. These are:

2.7.1.1 Average monthly electricity spot price

Here, the monthly average electricity spot price has been taken from a future prediction of upcoming prices in 2024 and 2025. The following graph shows the future price prediction for the remaining year 2023, for 2024 and 2025. Prices are in c/kWh in the graph, and in €/MWh in all other calculations in this report.

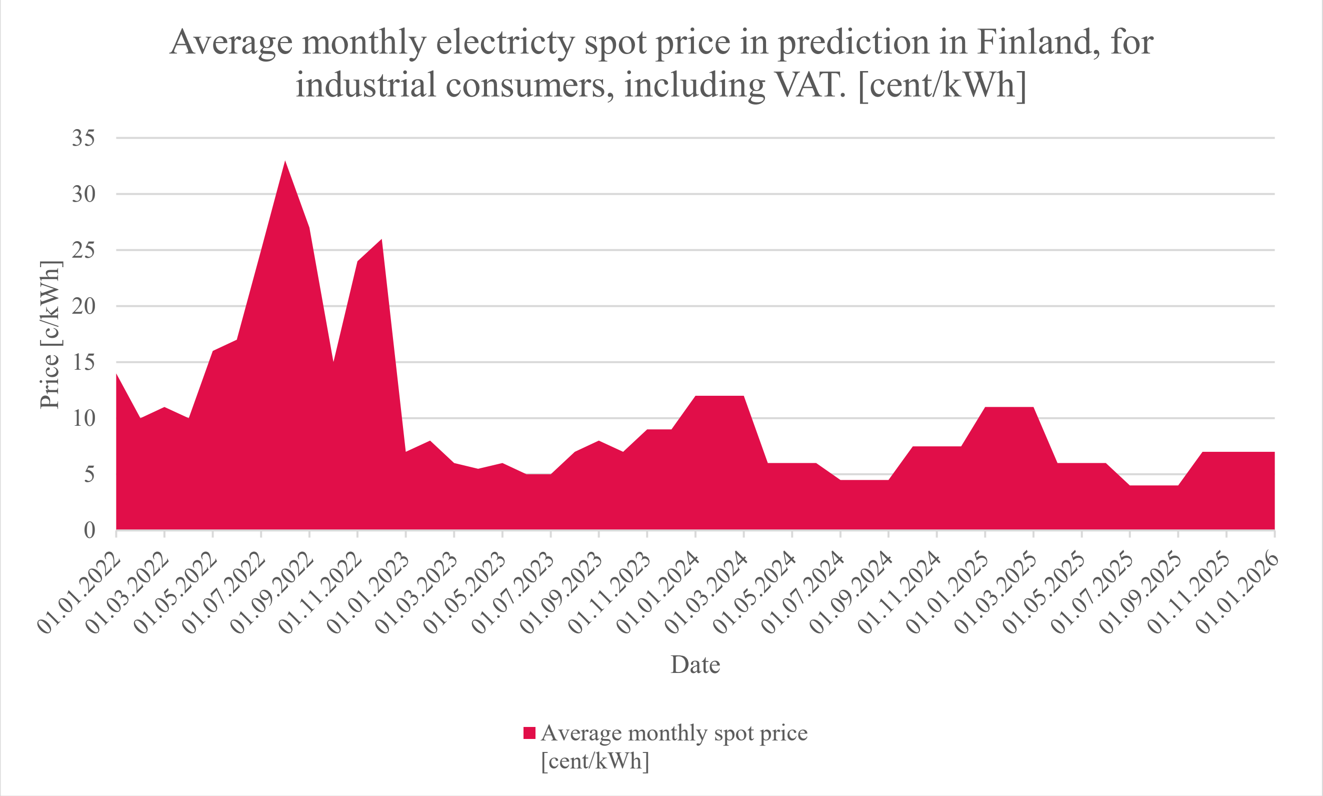


FIGURE 10. Predicted prices of electricity in the future.

Three different scenarios of monthly electricity prices, the “optimistic”, “realistic” and “pessimistic” option were taken into consideration from the spot price prediction.

- The “optimistic scenario” is assuming a slightly lower price of electricity than predicted in the chart above.
- The “realistic scenario” is following the price of electricity that is predicted in the chart above.
- The “pessimistic scenario” is assuming a slightly higher price of electricity than predicted in the chart above.

The following table shows the **average monthly** electricity price predictions for 2024.

TABLE 4. Monthly average electricity spot price prediction for 2024.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Price of average monthly electricity "**optimistic** scenario"	110	110	110	50	50	50	35	35	45	65	65	80

including VAT [€/MWh]												
Price of average monthly electricity "**realistic** scenario" including VAT [€/MWh]	120	120	120	60	60	60	40	40	55	75	75	90
Price of average monthly electricity "**pessimistic** scenario" including VAT [€/MWh]	130	130	130	70	70	70	50	50	65	85	85	100

An annual increase of 4% of these costs has been assumed.

2.7.1.2 Electricity fixed price

Here, instead of variable spot prices, a fixed annual price for electricity has been taken for the calculations. This price is only an assumption, and not based on actual price predictions.

2.7.2 Maintenance costs

For the service of heat pumps and replacement of parts that wear out, costs of 20 000€ per year were assumed. An annual increase of 4% of these costs has been assumed. After 10 years of operation, a service overhaul cost of 500 000€ has been considered as well.

2.8 Income from selling energy to district heating network

The thermal energy delivered by the heat pump system is supplied to the district heating network. The operator of the local district heating network has given price indications on how much they are willing to pay for this energy to the operator of the heat pump system.

We have made 3 different scenarios here, an “optimistic”, “realistic” and “pessimistic” version.

2.8.1 Pessimistic scenario

The “pessimistic scenario” is the price that the local energy company has offered.
It is **20€/MWh** of thermal energy supplied.

2.8.2 Realistic scenario

The “realistic scenario” is the price that the local energy company may be able to offer later. It is **22€/MWh** of thermal energy supplied.

2.8.3 Optimistic scenario

The “optimistic scenario” is the price that the local energy company may be able to offer if the profitability is still possible for them. It is **25€/MWh** of thermal energy supplied.

2.9 Cost calculations: Scenario 1

Cost calculations: Scenario 1 when heat pump runs constantly. Average monthly electricity spot price - if heat pump runs 24h a day

This scenario assumes the following general conditions:

- Heat pump **runs 24h/day, even if this would be unprofitable.**
- Summer break: The local district heating network does not need the heat in June, July, and August. Heat pump is switched off.
- Price of electricity is the average monthly spot price.

The optimistic scenario assumes:

- Income for energy sold to the district heating network: 25€/MWh.
- Costs of electricity taken from the optimistic scenario.

The realistic scenario assumes:

- Income for energy sold to the district heating network: 22€/MWh.
- Costs of electricity taken from the realistic scenario.

The pessimistic scenario assumes:

- Income for energy sold to the district heating network: 20€/MWh.
- Costs of electricity taken from the pessimistic scenario.

The following graph illustrates the income against the costs of the heat pump system for every month of the year. In some months, especially during the winter, the costs are higher than the income. This is due to the higher costs of electricity during the winter months. In June, July, and August the heat pump is switched off.

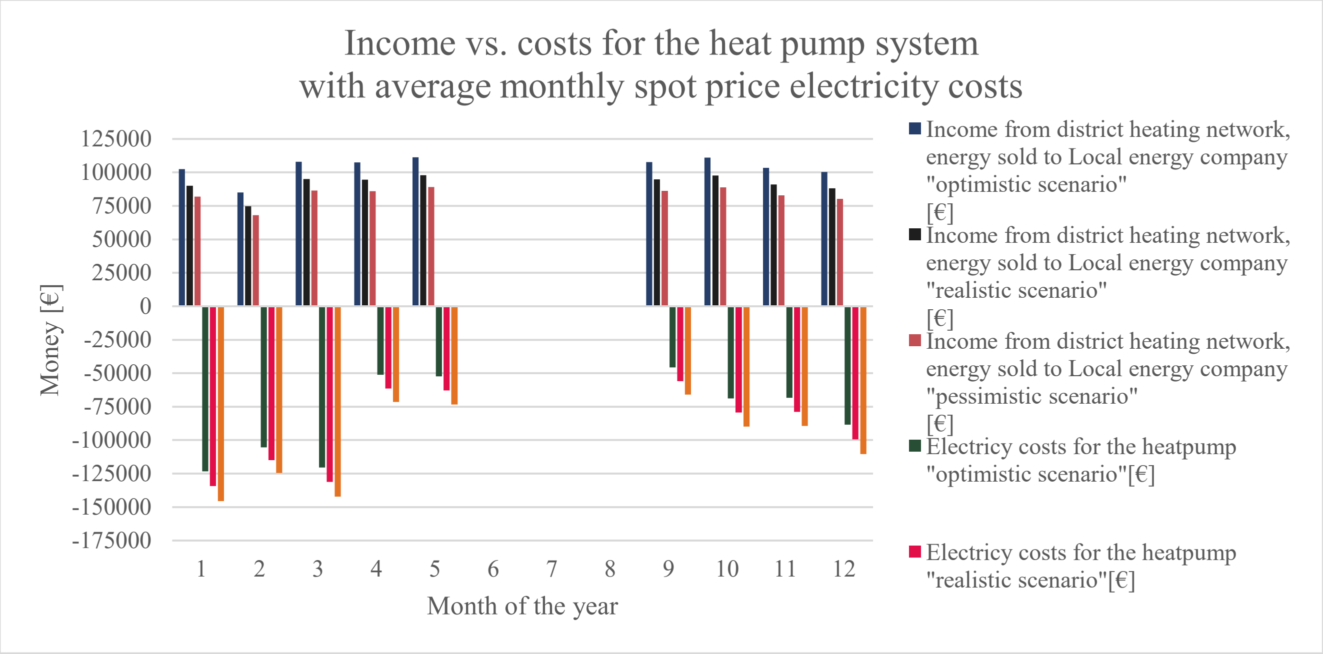


FIGURE 11. Income and costs comparison of the heat pump system in scenario 1.

The profitability of the heat pump system is illustrated in the following graph. It is based on the results from the previous graph. Also here, is it assuming that the heat pump runs 24h/day, even in loss making months.

It is visible that January, February, and March are not profitable at all, regardless of the scenario. April, May, September is profitable for every scenario. October, November, and December are profitable for the optimistic scenario, but partly unprofitable for the realistic and pessimistic scenarios. In June, July, and August the heat pump is switched off.

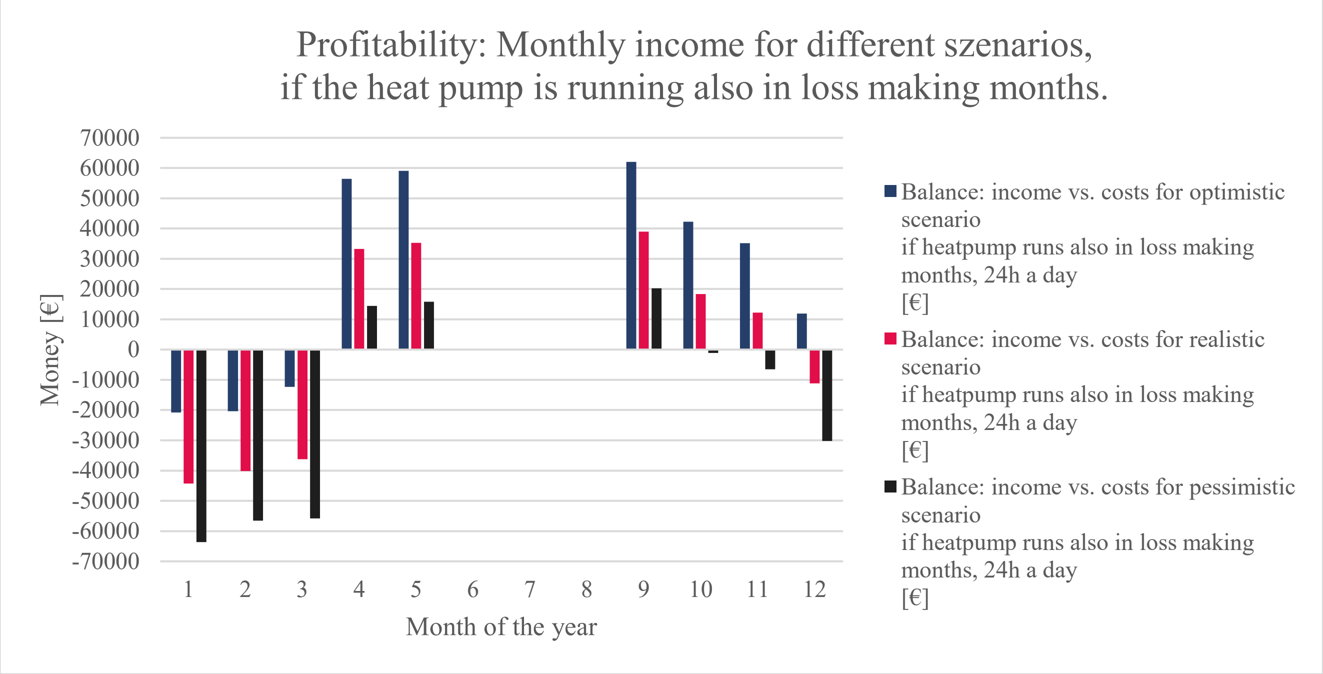


FIGURE 12. Profitability of the scenario 1

The next graph shows the heat pump's amount of monthly heating energy delivered, the amount of monthly cooling energy and the amount of monthly electricity consumption. This assumes that the heat pump runs 24h/day.

The variations between the months are due to the temperature requirements of the district heating network. The colder the outdoor temperature, the higher flow temperatures are needed. During February, for example, the efficiency of the heat pump is therefore lower, and consequently a lower amount of heating capacity is delivered by the heat pump in that month.

The summer months are also shown here, but, the heat pump would be switched off during June, July and August.

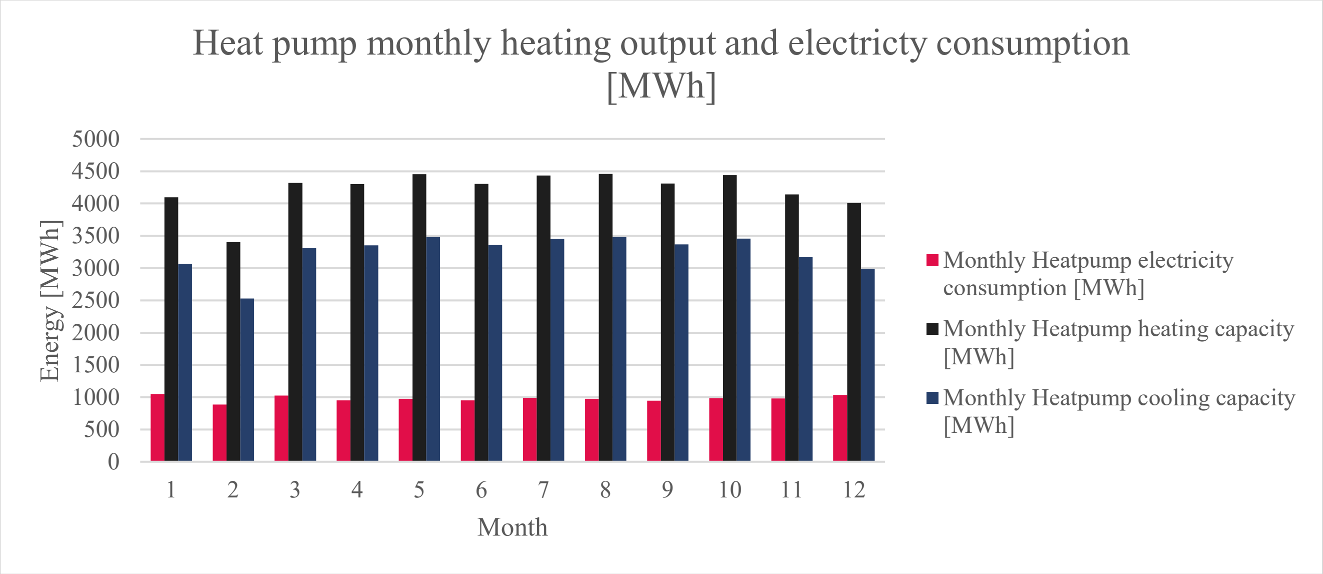


FIGURE 13. Monthly heat pump heating and cooling capacity in scenario 1.

Looking at the payback time:

- The optimistic scenario is the only profitable case that will generate profit after approximately 8 years.

After 20 years of operation, the optimistic scenario has generated a profit of 5 million euros.

- The realistic and pessimistic scenarios never generate profit at all.

The investment costs are deducted in the beginning, and maintenance costs are deducted every year, as well as the larger overhaul costs after 10 years.

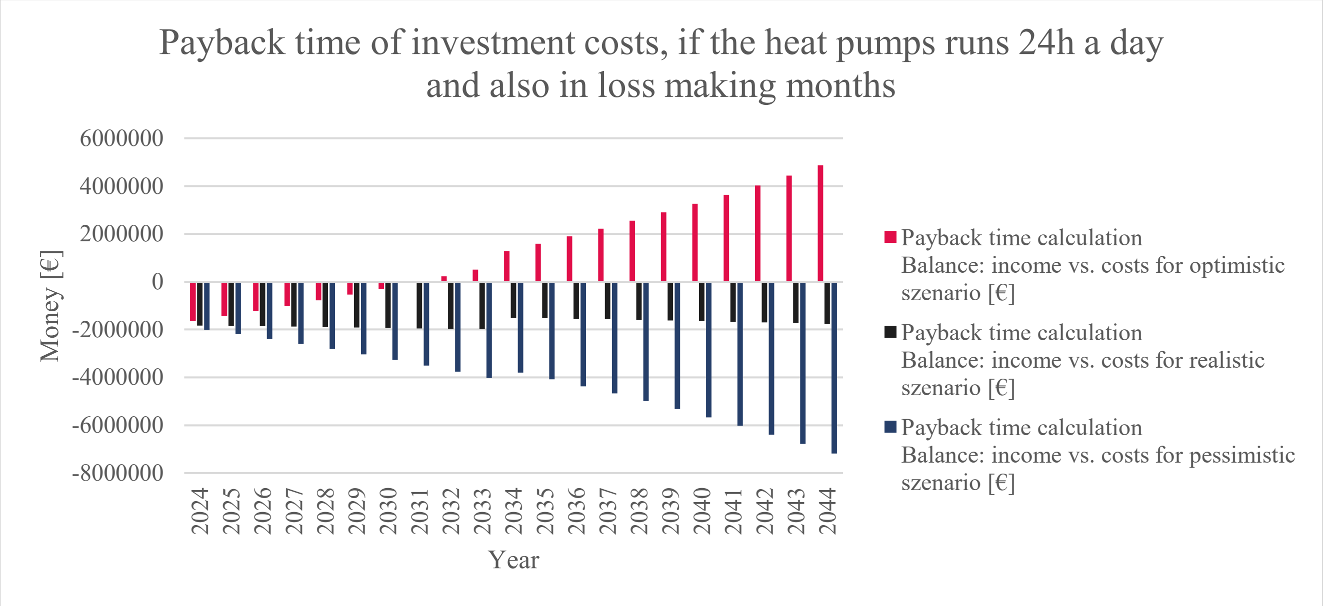


FIGURE 14. Payback time for scenario 1.

2.9.1 Conclusion of Scenario 1

The profitability of this case depends entirely on the variable electricity spot price, and how much the local energy company is willing to pay. During the colder winter months, the predicted average monthly costs of electricity are high, which results in losses.

Over the entire year though, **the optimistic scenario is profitable** with a payback time of 8 years. The realistic scenario is unprofitable, as well as the pessimistic scenario.

2.10 Cost calculations: Scenario 2

This scenario assumes the same conditions as the previous case ("Average monthly electricity spot price - if heat pump runs 24h a day"), **with only one difference:**

- If the heat pump would produce financial losses in one month, then it would be switched off.

All other conditions are the same, which are:

- Summer break: The local energy company does not need the heat in June, July and August. Heat pump is switched off.
- Price of electricity is the average monthly spot price.

The results of this case show that April, May, September, October, November, and December are profitable for the optimistic scenario. For the realistic scenario, April, May, September, October, and November are profitable. And for the pessimistic scenario, April, May, and September are profitable.

All other months would produce financial losses, and therefore the heat pump is switched off in this case.

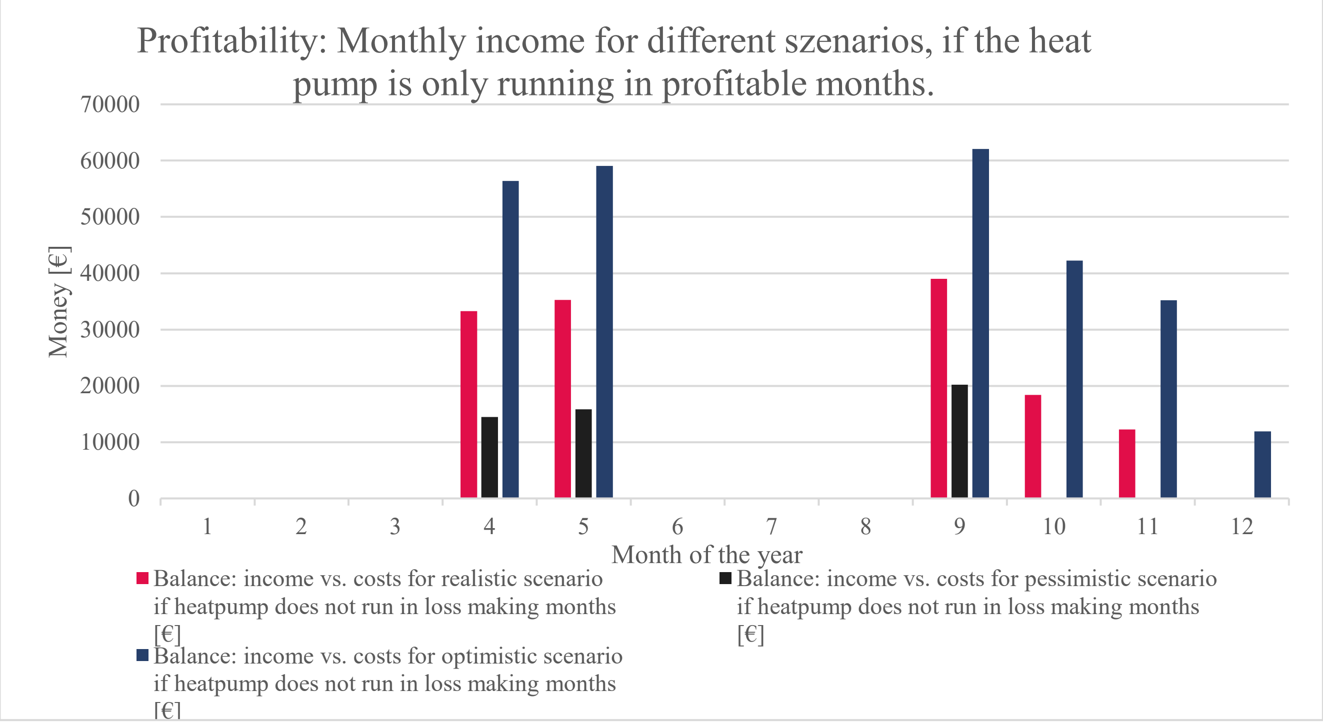


FIGURE 15. Heat pump in scenario 2. Profit of the three different scenarios.

Looking at the payback time for this case, the following results are visible:

- The optimistic scenario is profitable and will generate profit after approximately 7 years.

After 20 years of operation, the optimistic scenario has generated a profit of 3.1 million euros.

- The realistic scenario is also profitable, but the payback time is too long. It takes 16 years to reach the breakeven point.
- The pessimistic scenario will never reach profitability.

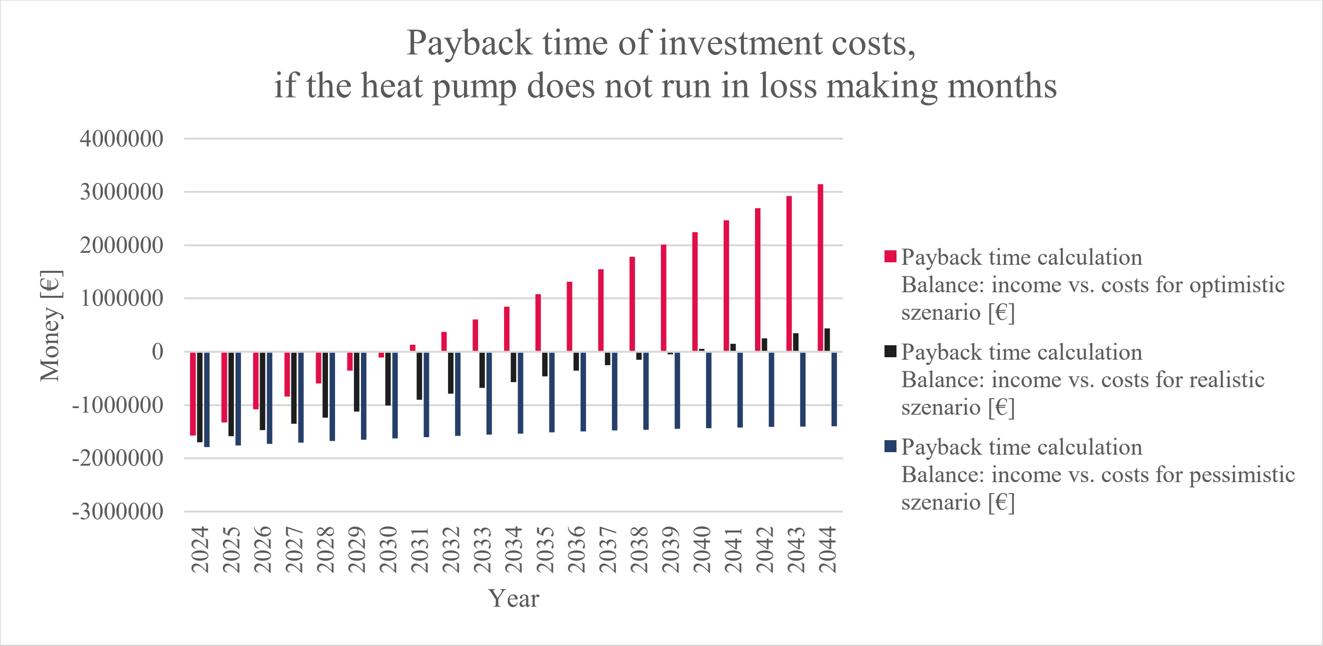


FIGURE 16. Payback time calculation for scenario 2.

2.10.1 Conclusion of Scenario 2

The idea to switch off the heat pump in loss making months is leading to a situation where losses are avoided. However, the short running time of the heat pump leads to a situation where the high investment costs take a long time to pay back. This is because the heat pump is switched off for several months during the winter, due to higher prices of electricity.

Can this case be a good solution? Probably not.

2.11 Cost calculations: Scenario 3

This scenario assumes the following general conditions:

- Heat pump **runs only during the cheapest 8h/day,** when the price of electricity is lowest. This is usually during the night.
- During the remaining 16h of the day, the heat pump is switched off, due to higher prices of electricity.
- Summer break: The local energy company does not need the heat in June, July, and August. Heat pump is switched off.
- Price of electricity is **half** of the average monthly spot price.

- For example: If the average monthly spot electricity price for February is 120€/MWh, then the price assumed for the cheapest 8h of the day is 120€/2 = 60€/MWh.

The optimistic scenario assumes:

- Income for energy sold to the local energy company: 25€/MWh.
- Costs of electricity is half of the price taken from the optimistic scenario.

The realistic scenario assumes:

- Income for energy sold to the local energy company: 22€/MWh.
- Costs of electricity is half of the price taken from the realistic scenario.

The pessimistic scenario assumes:

- Income for energy sold to the local energy company: 20€/MWh.
- Costs of electricity is half of the price taken from the pessimistic scenario.

The following graph illustrates the income against the costs of the heat pump system for every month of the year. Due to the lower costs of electricity during the cheapest 8h of the day, the income is higher than the costs for electricity. In June, July, and August the heat pump is switched off.

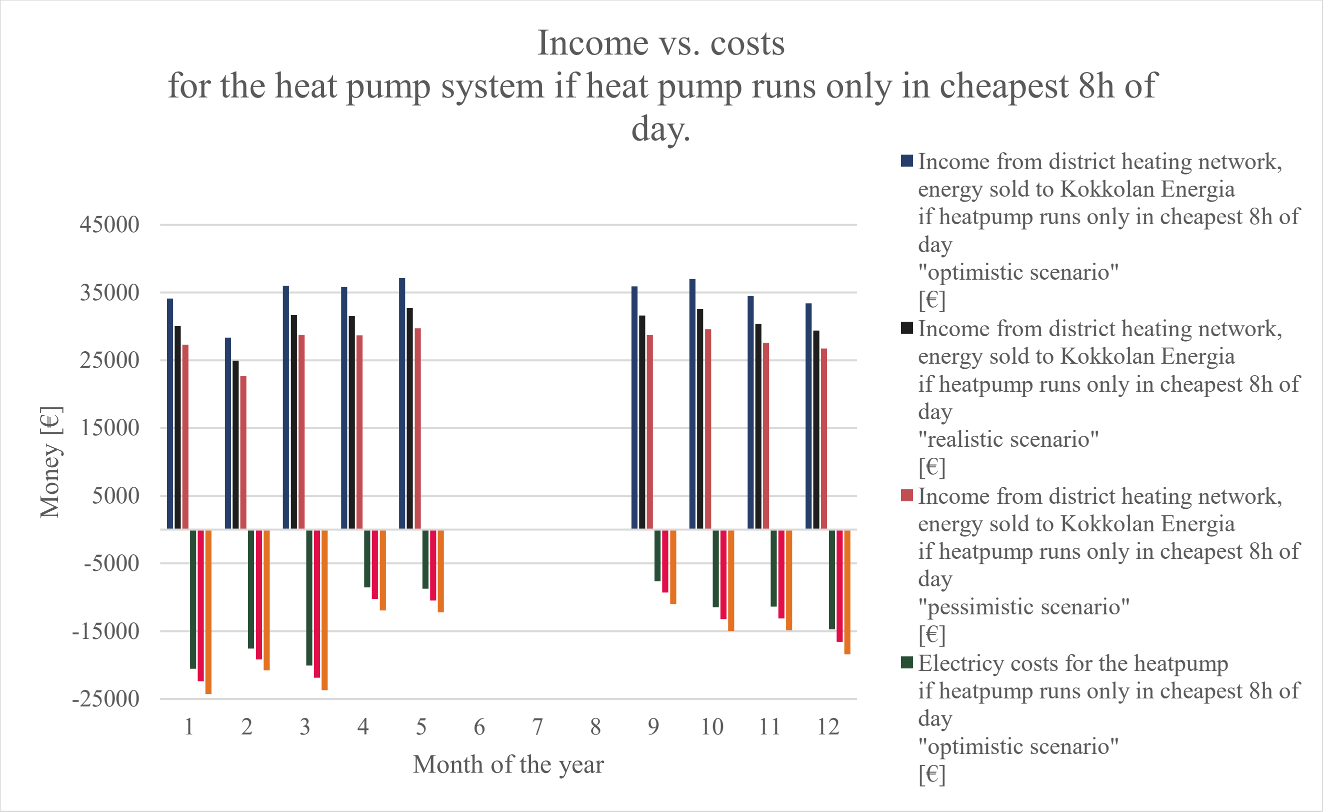


FIGURE 17. Profitability of scenario 3

The profitability of the heat pump system is illustrated in the following graph. It is based on the results from the previous graph. Also here, is it assuming that the heat pump runs only during the cheapest 8h/day. Now every month is profitable, even in the most pessimistic scenario. In June, July, and August the heat pump is switched off.

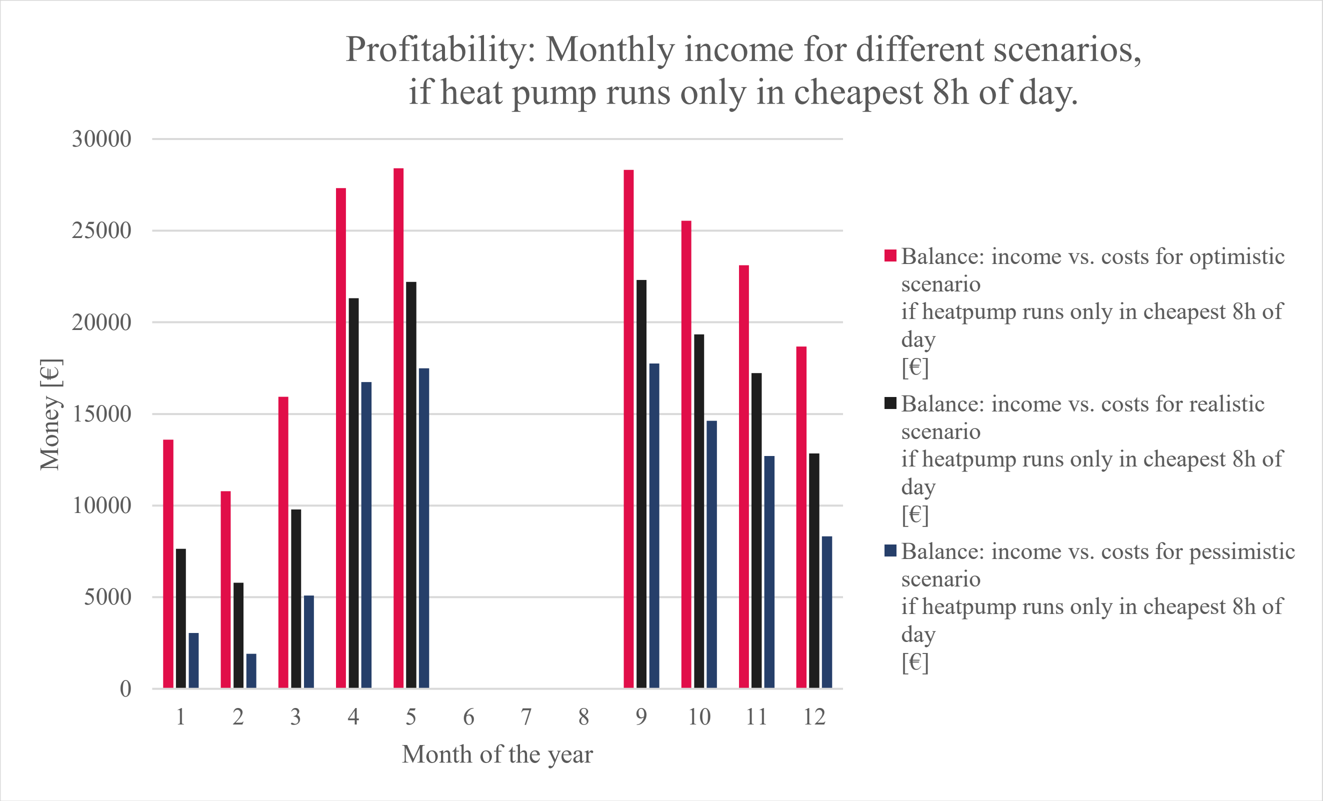


FIGURE 18. Profitability calculation scenario 3.

The next graph shows the heat pump’s amount of monthly heating energy delivered, the amount of monthly cooling energy and the amount of monthly electricity consumption. This assumes that the heat pump runs only in the cheapest 8h/day. Thus, it only generates 1/3 of the potential capacity, because it is switched off the other 2/3 of the day. During the summer months, the heat pump is switched off.

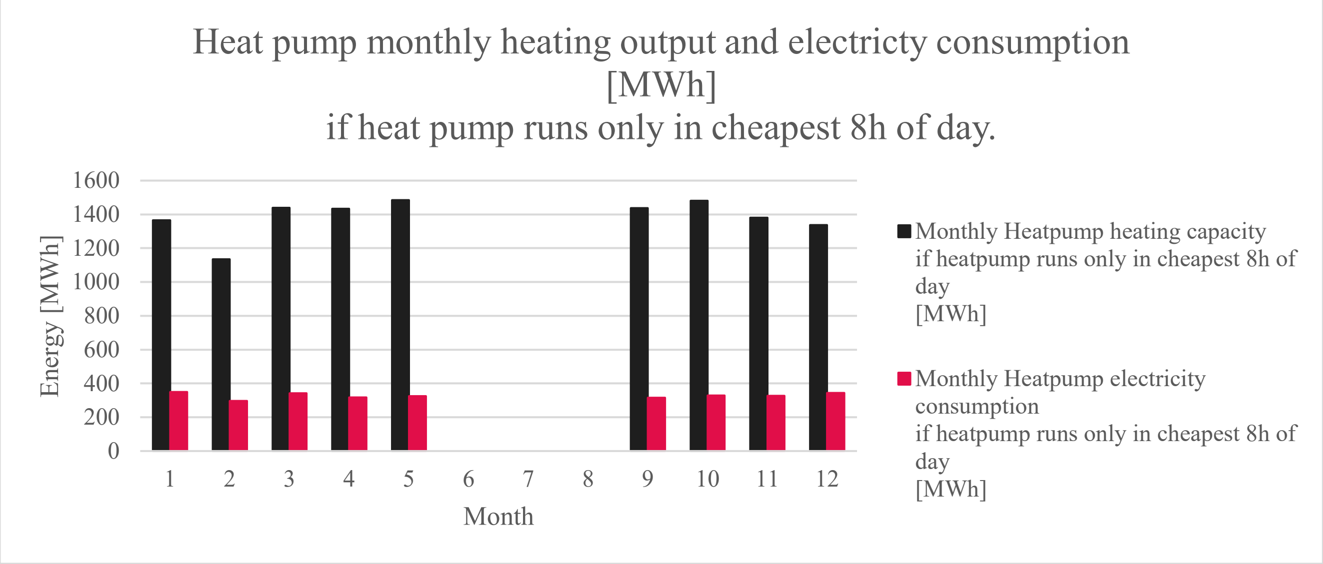


FIGURE 19. Monthly heat pump heating & cooling capacity and electricity consumption.

Looking at the payback time:

- The **optimistic scenario** is profitable, and the payback time of the investment is approximately 10 years.
  - After 20 years of operation, a profit of 1.5 million euros has been generated in the optimistic scenario.
- The **realistic scenario** is also profitable, but the payback time is very long. It takes 16 years to reach the breakeven point of the investment.
  - After 20 years of operation, a profit of 450 000 euros has been generated.
- The **pessimistic scenario** never reaches the breakeven point, thus is it unprofitable.

The investment costs in every scenario are deducted in the beginning, and maintenance costs are deducted every year, as well as the larger overhaul costs after 10 years.

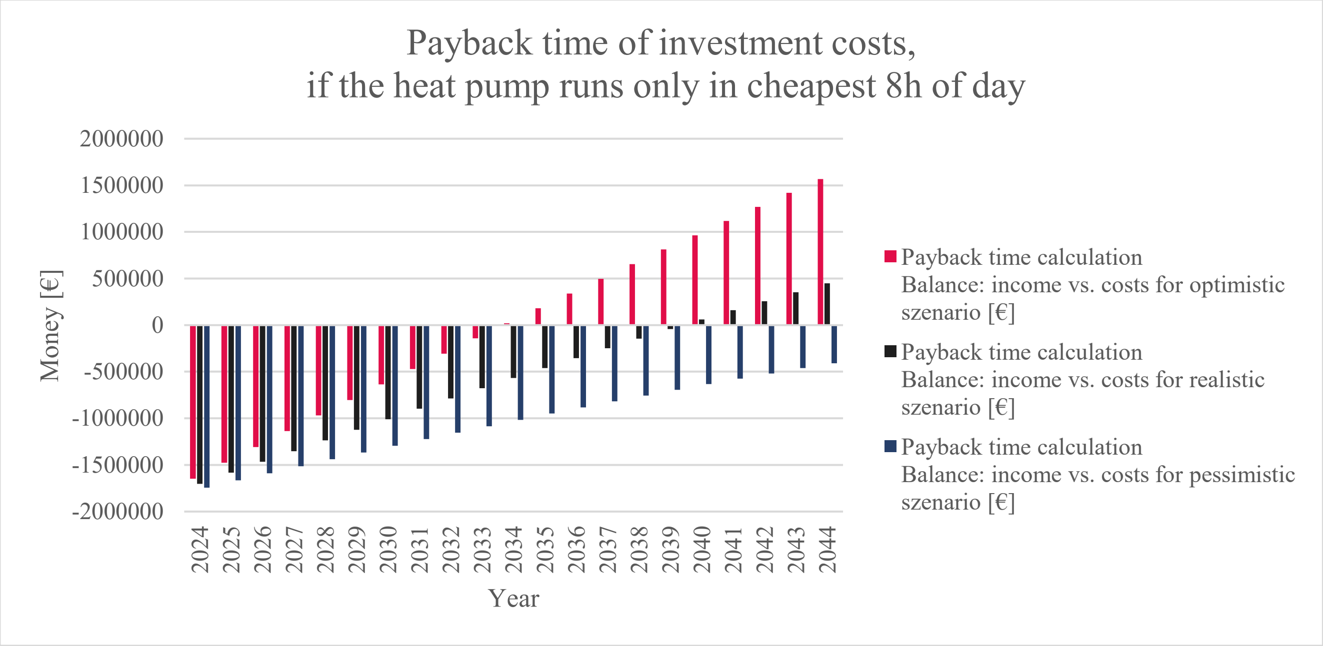


FIGURE 20. Payback time calculation for scenario 3.

2.11.1 Conclusion of the case: Scenario 3

In comparison to the case where the heat pumps run 24/7, this case where the heat pump runs only in the cheapest 8h of the day, all scenarios are profitable. However, the generated profit is small, since the heat pump runs only 1/3 of the day, and thus is switched off 2/3 of the day. This leads to a situation where the payback time is very long.

- The optimistic scenario is profitable, and the payback time is 10 years.
- The realistic scenario is also profitable, but the payback time of 16 years is too long.
- The pessimistic scenario is not profitable, as the payback time would be longer than 30 years.

Can this case be a good solution? Probably not either.

2.12 Cost calculation: Scenario 4

Cost calculation: breakeven point of electricity price. This scenario calculates the price of electricity that needs to be reached to enable a profitable business case.

This scenario assumes the following general conditions:

- Summer break: The local energy company does not need the heat in June, July, and August. Heat pump is switched off.

The optimistic scenario assumes:

- Income for energy sold to the local energy company: 25€/MWh.

The realistic scenario assumes:

- Income for energy sold to the local energy company: 22€/MWh.

The pessimistic scenario assumes:

- Income for energy sold to the local energy company: 20€/MWh.

The following graph shows the price limit of electricity. **If the price is below the value, the business will be profitable.** For example, in January, the price limit for the realistic case is 85€/MWh. If the price is lower than 85€, the case is profitable.

During the summer months, the price limit is higher, this is because the heat pump operates more efficient during this time, due to lower temperature requirements in the district heating network.

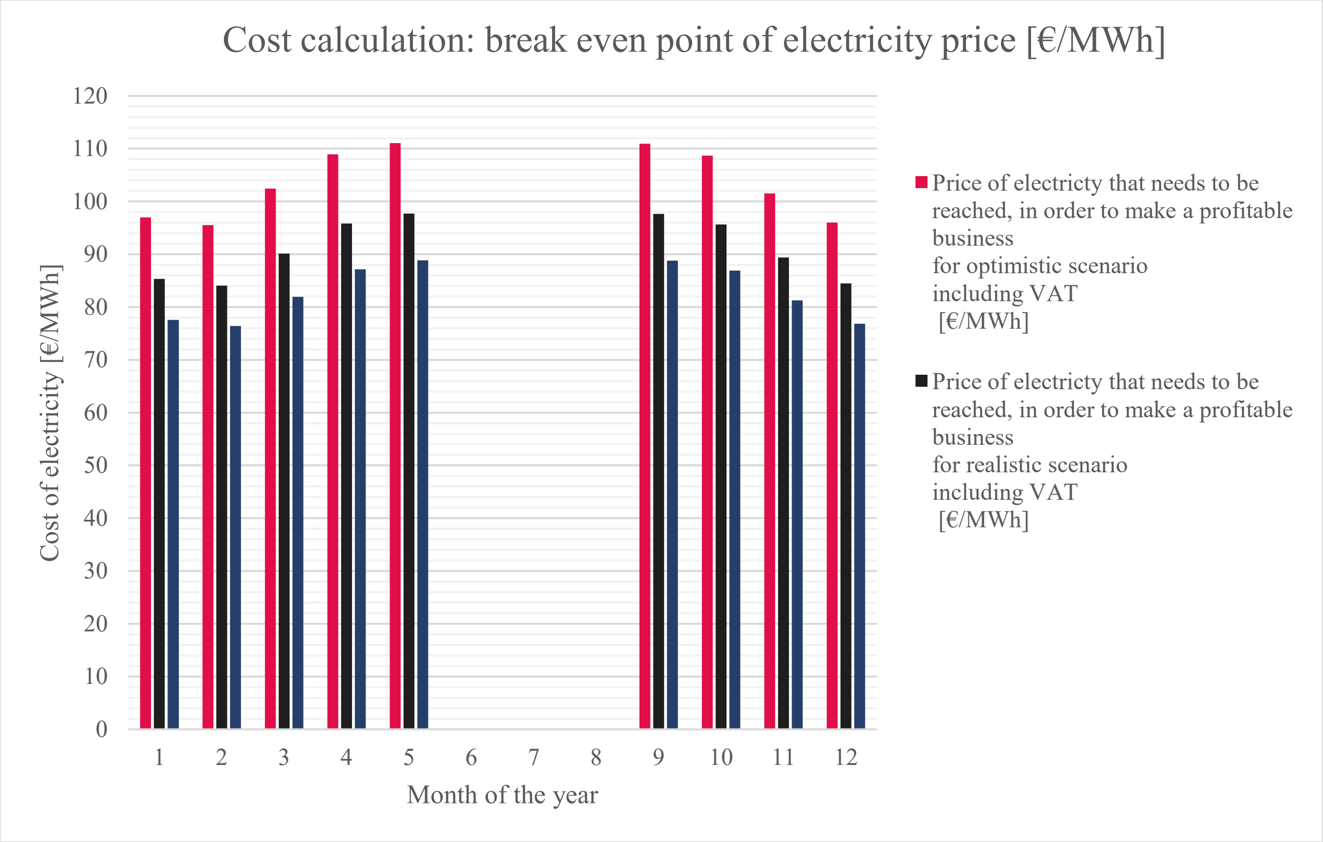


FIGURE 21. Electricity price limit in different months.

If the price is below the value, the business will be profitable.

2.12.1 Conclusion of the case: Scenario 4

The electricity price limit is a good indicator for a long-term purchasing agreement. If a price below the limit can be procured, the business case looks very positive.

2.13 Cost calculation: Scenario 5

This scenario assumes the following general conditions:

- Heat pump **runs 24h/day**, even if this would be unprofitable.
- Summer break: The local energy company does not need the heat in June, July, and August. Heat pump is switched off.
- **Price of electricity is a fixed.**

The optimistic scenario assumes:

- Income for energy sold to the local energy company: 25€/MWh.

The realistic scenario assumes:

- Income for energy sold to the local energy company: 22€/MWh.

The pessimistic scenario assumes:

- Income for energy sold to the local energy company: 20€/MWh.

The following graph illustrates the income against the costs of the heat pump system for every month of the year. In June, July, and August the heat pump is switched off.

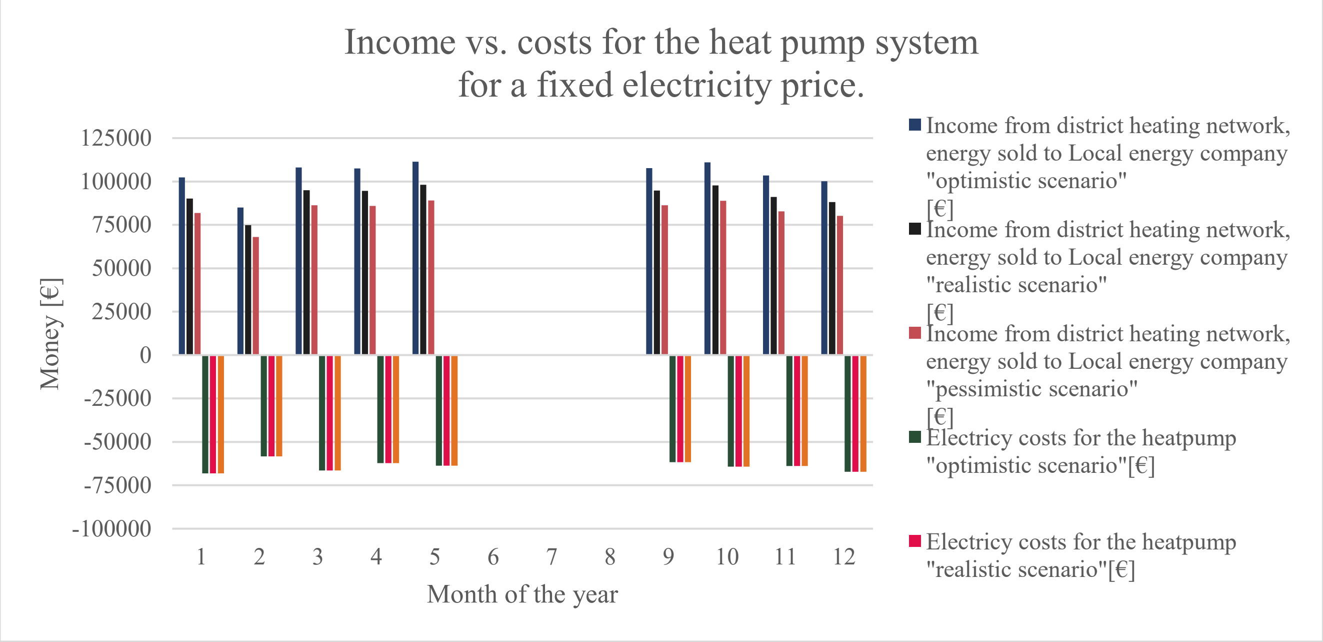


FIGURE 22. Income against costs of the heat pump system, scenario 5.

The profitability of the heat pump system is illustrated in the following graph. Every single month of the year is profitable.

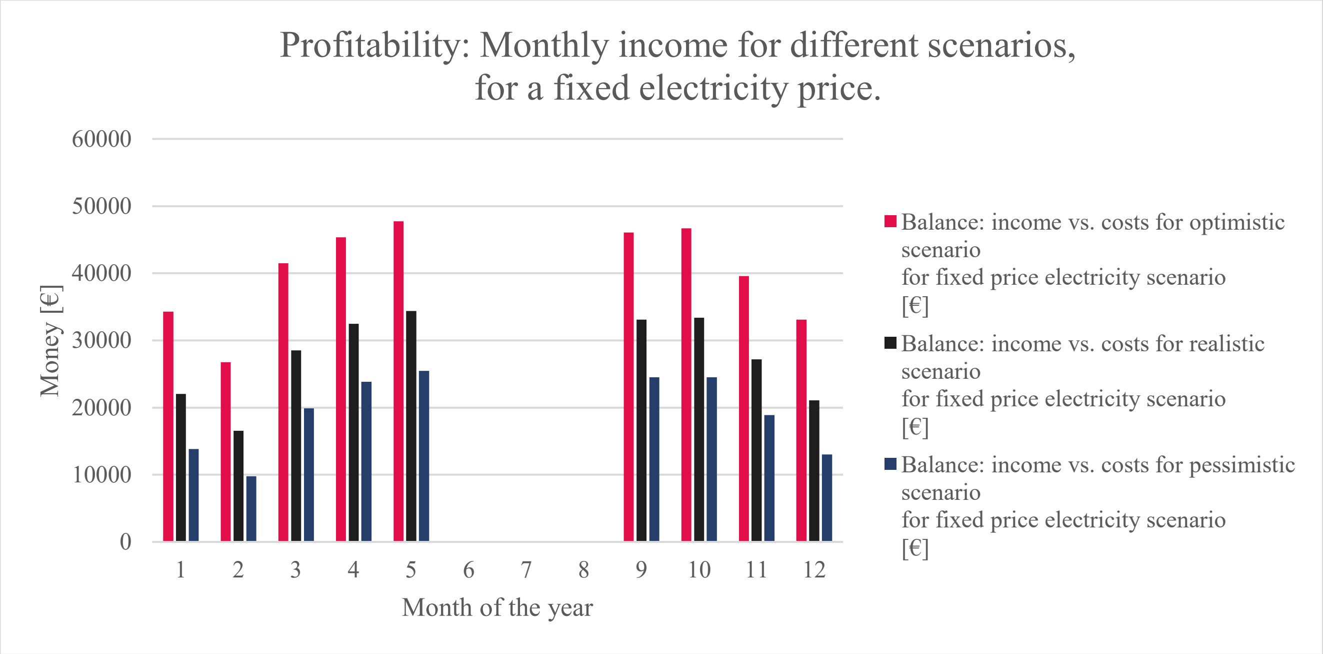


FIGURE 23. Profitability of the case, scenario 5.

Looking at the payback time:

- The **optimistic scenario** is profitable, and the payback time of the investment is approximately 4 years.
    - After 20 years of operation, a profit of 9.5 million euros has been generated in the optimistic scenario.
- The **realistic scenario** is also profitable, with a payback time of 7 years.
    - After 20 years of operation, a profit of 6 million euros has been generated.
- The **pessimistic scenario** is also profitable, with a payback time of 9 years.
    - After 20 years of operation, a profit of 3.5 million euros has been generated.

The investment costs in every scenario are deducted in the beginning, and maintenance costs are deducted every year, as well as the larger overhaul costs after 10 years.

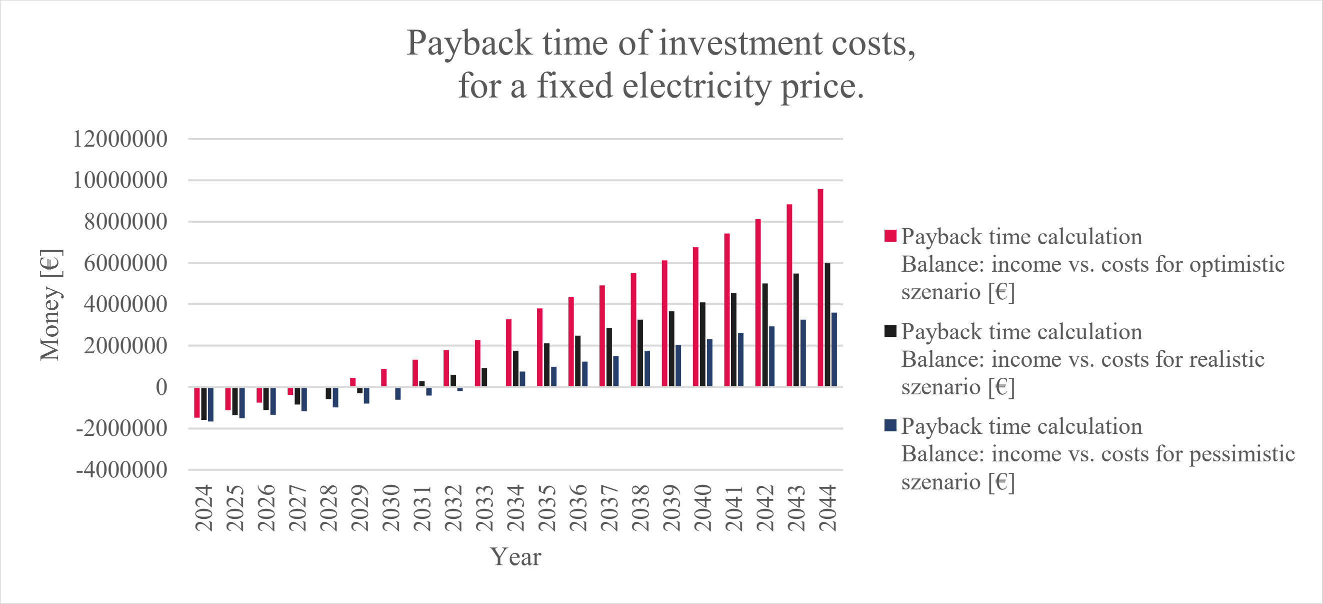


FIGURE 24. Payback time calculation for scenario 5.

2.13.1 Conclusion of the case: Scenario 5

If the procurement of electricity can achieve a fixed price, all scenarios are profitable. Also, the entire investment is profitable, with a payback time of 4 years for the optimistic scenario, 7 years for the realistic scenario, and 9 years for the pessimistic scenario.

Can this case be a good solution? Yes, it would be. It is worth to investigate this case in more detail.

2.14 Conclusion

The utilization of industrial waste heat for district heating is one key solution for CO2 emission free heating in the future. The waste heat sources from the factory have a high potential for successful implementation for the following reasons:

- They are available 24/7, at a constant temperature.
- They are water based.
- They look promising also in terms of business profitability.
- They will be easy to control, with little maintenance required.
- They will reduce the CO2 footprint of the district heating network.
- They will be good for marketing, to show that the reduction of CO2 emissions is taken seriously.

3 KOKKOLA AREA POTENTIAL FOR BIOGAS

The theoretical potential for biogas production from farm inputs in the Kokkola area has been estimated in this report by compiling the available input quantities from the data found in the biomass atlas. The data from the Biomass Atlas are for 2020. The biomass types and their quantities are presented in Table 1. Only feedstocks available from farm by-products or feedstocks that do not reduce the area available for food production have been selected as feedstocks.

The theoretical methane yield potential of biomass has been calculated by multiplying the input quantity by the dry matter content, the organic dry matter content, and the methane yield, or by multiplying the dry matter mass of the input quantity by the organic dry matter content and the methane yield. The methane content of the biogas is estimated to be 60%, the carbon dioxide content 39% and the rest of the raw gas is other substances such as sulphur and water. The energy content of methane in biogas is used in this report as 0.00997 MWh/Nm^3.

In the report, the characteristics of the different feedstocks that affect their ability to produce methane and are used to calculate the methane yield potential are based on a table compiled in Luke's biogas calculator manual. The output values of this table, on the other hand, are based on data compiled from several different sources and are presented as extreme values. In this report, the extreme values have been averaged and the theoretical methane production potential has been estimated based on their values. The figures used in the calculation are summarised in Table 2 on the following page. For dry matter, no figures are given in the biogas calculator instructions and the values obtained for these biomasses are based on the normative system.

TABLE 5. Theoretical biogas production potential in the Kokkola area.

	Mass volume	**Biogas**	**Methane**	**Energy content of methane**
Turf	t/(k-a)/a	nm^3/a	nm^3	MWh/a
Possible initial harvest of green manure roots	108	46413	27847,8	278
Summer turf	977	419865,75	251919,45	2512
Protection zone turf	1204	517419	310451,4	3095
Total	**2289**	**983697,75**	**590218,65**	**5884**
Manure	t/a			

Dairy cattle slurry from storage	101497	2699820,2	1619892,12	16150
Dairy cattle dry manure from stock	45418	170944,27	102566,561	1023
Meat cattle slurry from storage	19930	530138	318082,8	3171
Meat cattle dry manure from stock	22191	121089,63	72653,7778	724
Fur animal dry manure from storage	2170	220038	132022,8	1316
Total	**191206**	**3742030,1**	**2245218,06**	**22385**
Other plant masses	t/(k-a)/a			
Straw 1/3 of the mass	4056	1399320	839592	8371
Total	**4056**	**1399320**	**839592**	**8371**
	t	nm^3/a		
Total	**197551**	**6125047,8**	**3675028,71**	**36640**

TABLE 6. Output values used in the calculation.

	Mass volume	**TS**	**VS/TS**	**CH4-pot.**
Turf	t/(k-a)/a	%	%	m^3/tVS
Possible initial harvest of green manure roots	108	30,0 %	90,0 %	286,5
Summer turf	977	30,0 %	90,0 %	286,5
Protection zone turf	1204	30,0 %	90,0 %	286,5
Manure	t/a			
Dairy cattle slurry from storage	101497	9,5 %	80,0 %	210
Dairy cattle dry manure from stock	45418	12,3 %	10,2 %	180
Meat cattle slurry from storage	19930	9,5 %	80,0 %	210
Meat cattle dry manure from stock	22191	14,1 %	12,9 %	180
Fur animal dry manure from storage	2170	39,0 %	78,0 %	200
Other plant masses	t/(k-a)/a			
Straw 1/3 of the mass	4056	85,0 %	90,0 %	230

4 CIRCULAR WELLNESS HUB

In an era marked by a growing awareness of environmental sustainability and the pressing need to reduce waste and resource consumption, the concept of circular economy has gained immense traction. The circular economy model aims to create a closed-loop system where waste is minimized, and by-products are repurposed, thus contributing to both ecological and economic sustainability. During this project many streams of waste were identified, not only energy streams but other materials as well, while many of these streams of waste may be turned into products and sold, the bigger question arises of where to sell the products created and tested. This section of the report first outlines the investigated field of breweries and their waste streams, the possible solutions for utilization (some of which were tested during the project, more details of this in the second report in the series) and a solution to share the resources and collaborate effectively to achieve a circular economy. Thus, solving and reaching the aims of the project to support the regions green transition and low carbon energy targets.

4.1 Background into circular beer industry

The food industry has adapted circular principles already before circular economy became popular. The industry has faced issues of resource deficiency and thus was forced to adapt to sustainable principles to reduce waste. Often the biowaste produced by the food sector has been utilized locally in the production of food, e.g., as feed for cattle or as fertilizer for agriculture. Yet given development and industrialisation processes of most industries have caused even the food industry to be riddled with overproduction, large streams of waste and overconsumption.

While taking a beer industry when can see the currently circular economy is seen in the effective use of raw materials, energy, and water. Especially larger companies must find efficient ways to reduce costs related to waste handling, smaller companies are often left behind in development and research.

Figure 1 illustrated the annual production of been in Finland during the years of 2015 to 2020. As figure 1 illustrates production of beer has been on a slight downturn but mostly having a stable output, yet at the same time the number of breweries has grown substantially since 2015. The three largest producers being Olvi, Harwall and Sinebrychoff. Yet as we can see from the figure the number of breweries is increasing but the production of the larger companies is going down, which could indicate that consumers appreciate more specialized craft beers than before.

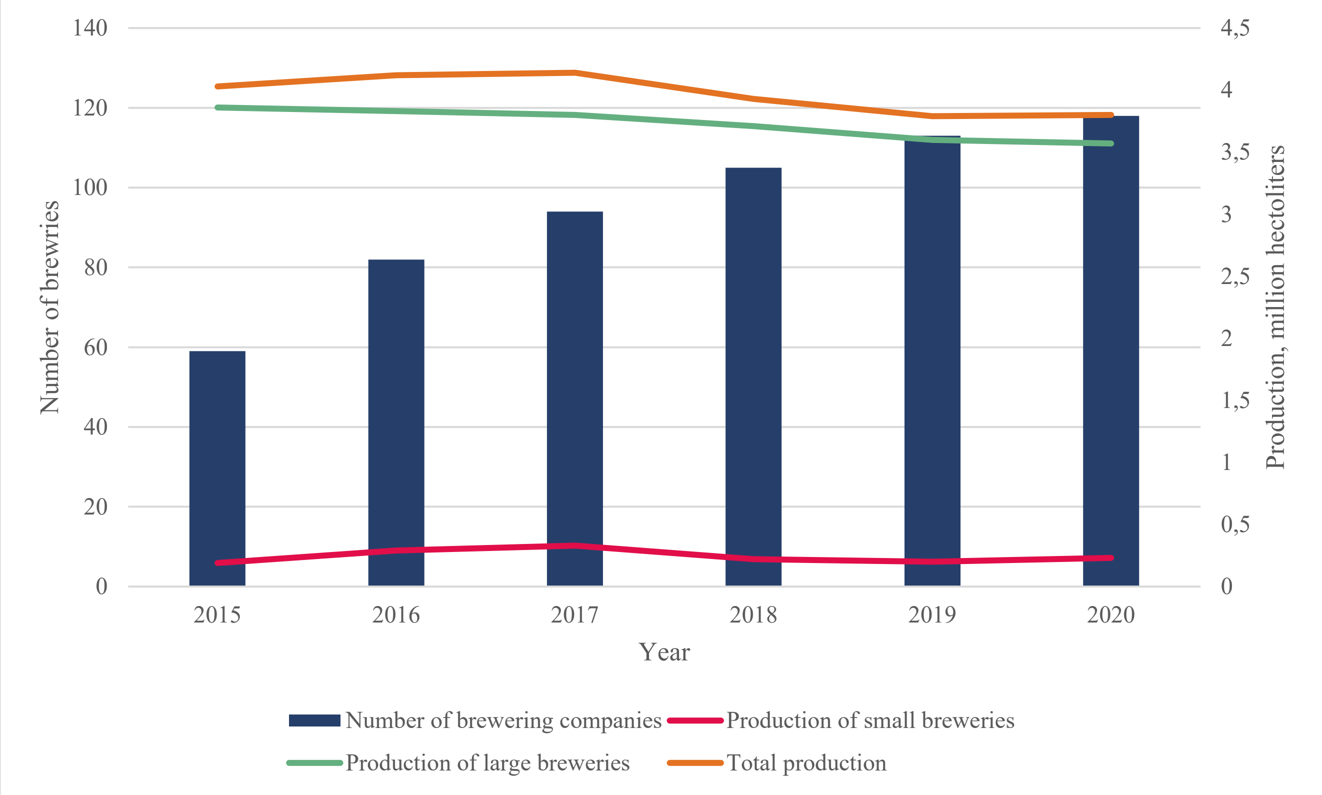


FIGURE 25. Breweries and their production capacity in Finland

The data collected in figure 25 is collected from The Brewers of Europe (2022), Panimo- ja virvoitusjuomateollisuusliitto (2022), and Statistics of Finland (2022). Number of breweries is from The Brewers of Europe (2022); production of large breweries from Panimo- ja virvoitusjuomateollisuusliitto (2022); total production is from Statistics Finland (2022) databases; production by small breweries calculated as difference between total and large breweries production.

As figure 26 (Pienpanimoliitto 2020) shows geographically most of breweries are established in South and Southwest of Finland. The largest breweries are in Kerava, Iisalmi and Helsinki, others are small breweries and are scattered through the country. Small breweries are defined as those that produce less than 150 00 hectolitres (15 million litres) of beers annually (Finlex 1994). Analysis of production volumes of breweries show that most Finnish small breweries produce 100-2000 hL of beer (Pienpanimoliitto 2020).

FIGURE 26. Distribution of breweries in Finland. (Pienpanimoliitto 2020)

4.1.1 Side and waste streams and current handling routes

Figure 27 shows main stages of beer production. The input into the brewing process consists of water and raw materials such as malt and/or grain, with barley being the most common. Additionally, hops (fresh or dried and pelletized), yeast, and Kieselguhr are typically included. During packaging, such as bottling or canning, CO2 is also sometimes added in certain types of beers.

The brewing process begins with the addition of ground malt to hot water, which is then slowly stirred at approximately 63-65°C for one hour before being lautered, separating spent grain from wort. The wort is subsequently pumped into a brewing tank where hops are added, and the mixture is boiled for approximately 1-2 hours. Following this, solids are separated from the liquid in a whirlpool, and the liquid is cooled before being transferred to a fermenter, where yeast is introduced. After fermentation, the yeast is removed, and the beer undergoes aging, clarification, if necessary, filtration, and finally, bottling or canning.

Besides beer, process generates significant amount of other solid, liquid and gaseous streams. As figure 27 presents solid streams are generated mainly in four steps of the process. The biggest amount of solid by-product is spent grain, it is also often called brewers spent grain (BSG) or mash. Its volume constitutes approximately 40% of the mashing tank volume. It is estimated that the production of 100 hectolitres of beer would generate 2 tons of wet spent grain. After the separation of spent grain from solids, it typically contains 80-85% water. (Mathias, Mello & Sérvulo 2014).

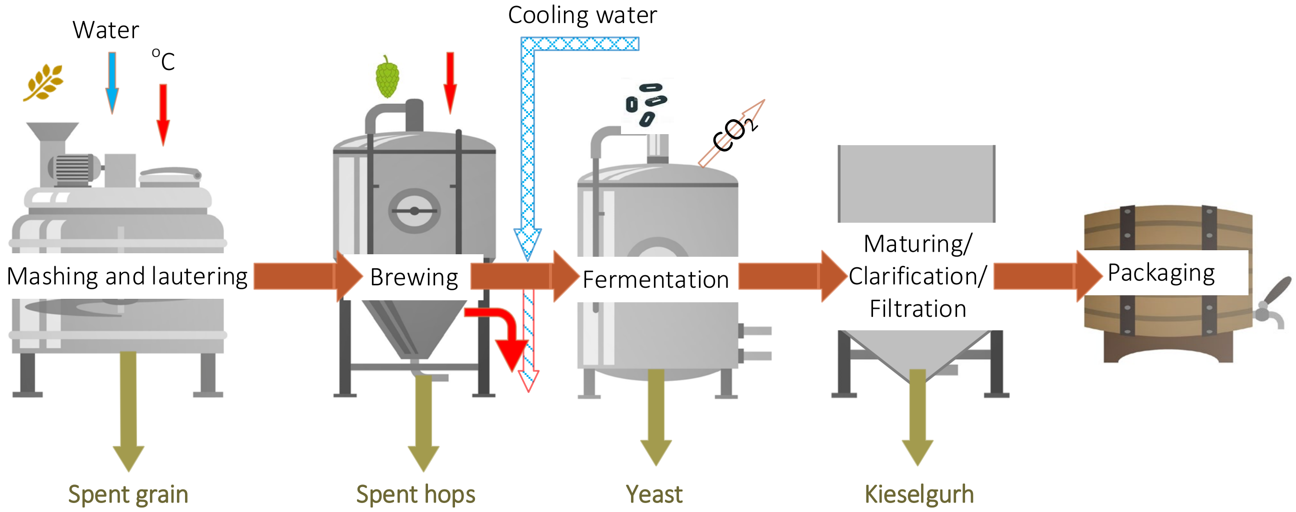


FIGURE 27. Beer production main stages, including inputs and outputs (side or waste streams).

Significantly less spent hops and yeast are generated. Amounts are presented in table 17.

TABLE 7. Indicative amount of main waste and side streams for 1 hL of beer, kg

Type	Amount of side streams	Comments (reference)
Brewers spent grain, wet	14-20	Content of solid matter after drying 15-20 %, (Mathias, de Mello & Sérvulo 2014)
Spent hops (also called trub)	0,2-0,4	Content of solid matter after drying 10-20%, (Mathias, de Mello & Sérvulo 2014)
Spent yeast	1,5-3	Content of solid matter after drying 10-15%, (Zerowaste)
Kieselguhr	0,17	(Zerowaste)
CO_2	3,2	(Zerowaste)

Another critical resource is water. The input of water into the product itself, due to significant losses with spent grain, hops, and yeast, is almost double compared to the amount of obtained product. Additionally, a significant amount of water is used for cooling purposes. Estimates suggest that up to 10 litres of water may be required to produce 1 litre of beer. This is particularly pronounced in small companies where water recirculation and reuse are absent, resulting in water discharge to sewage. In contrast, large companies typically employ recirculation systems, resulting in a consumption of less than 3 litres of water for every 1 litre of beer produced. (e.g. Olvi Group 2021, 29; Hartwall 2021,8).

Gaseous emissions from the process primarily consist of CO2. In large companies, CO2 is captured and repurposed as a carbonation agent in the production of sparkling beverages, e.g., Olvi Group (2021, 27). However, for smaller companies this investment may be too great.

The brewing industry is energy-intensive, requiring a substantial amount of thermal energy for generating hot water and steam essential for the mashing and brewing processes. Thermal energy is also consumed in other operations and for heating the premises. Electrical energy is predominantly used by the process equipment and refrigeration systems. Given the high costs associated with energy, reducing energy consumption through methods such as recirculation and heat recovery improve the cost structures of the business while simultaneously reducing emissions. E.g., at Hartwall (2023) heat and steam are used as many times as possible, residue heat from production is used to heat the premises.

4.1.2 Potential utilisation of by-products from brewing industry

Desk research revealed several potential solutions to utilise these identified streams of waste within the small breweries. Some solutions are easy to implement and do not have intense technological requirements, while others do require substantial investments. Spent grain of the same consistence is obtained also in whisky distilleries. Therefore, literature for the use of spent grains is distilleries is also reviewed.

4.1.2.1 Brewer’s spent grain utilisation

Feedstock of animals

The predominant method of disposing of spent grain is by donating it to local livestock farmers. Spent grain, abundant in proteins and fibres, serves as valuable feed for cattle, making it the most widely utilized form of Brewer's Spent Grain (BSG). This arrangement is mutually beneficial for both parties involved: the brewery gains a free of charge solution for disposing of biowaste, while the farmer reduces expenses associated with purchasing livestock feed. Additionally, there is the option to deliver spent grain to feed producers, who can incorporate it into a mixture with silage. The concept is commercialised by pet feed producers, e.g., Brew’ed Biscuits (Brew'ed Biscuits 2023).

Baked goods and food

Another possible solution to utilize BSG is within the food industry and in the production of food. Commonly BSG can be utilized to replace flour and as such it could be utilized to make bakery goods or past, among other products. Breweries that are attached or operate their own restaurant often offer such products. While this solution is one of low investment costs and can be utilized soon after the brewing process, it does have some challenges especially related to scale. In addition, the most cost-effective way to utilize this stream is to use it directly after the brewing process as otherwise costs related to preservation will be included. Thus, we come to the issue of supply and demand, the brewing process and local bakeries may not operate in a similar time schedule. As such if the demand is further away, the longer the value chain is the more complicated the process becomes as the BSG must then be dried and transported. If the costs of the by-product material or BSG increase, then the benefits of replacing flour with it decrease. This solution is adapted by only a few companies in the market selling cookies, which they claim are produced using BSG, Brewers foods (2023) and Brew'ed biscuits (2023).

Growing media for mushrooms

A quite traditional approach to handling the waste stream is of course composting which will later produce soil or in other words a growing media. While considering growing medias, a novel approach to this is to utilize the waste as it is to grow mushrooms. A company in Belgium, Eclo (2023) and Canadian Ceres Solutions (Ceres 2023) cultivates mushrooms on spent grains from breweries. Ceres claims also that Canadian Food Inspection Agency has approved the use of residue grains with mycelium as a feed to livestock feed, this waste is even 20% richer in proteins as pure spent grains. Mycelium can be used also for other novel products such as packaging, composites for construction industry, (Ecovative 2023) food and leather like materials (Ecovative 2023, Bolt threads 2023, VTT 2021).

Cosmetics

Another possible application for the brewery by-product is to utilize the materials in cosmetics. The rise in natural cosmetics and its popularity, especially with the ban on plastics within cosmetics make this a suitable application. Already existing exfoliants such as rice bran, oat, nutshell, coffee grounds and sugars are already used in cosmetics (Cosmetics 2023). BSG has similar characteristics to oat, and it can be grinded and used as natural exfoliate in body scrubs or added to facial cleansers.

BSG contains proteins (15-31%), cellulose (12-25%), hemicellulose (20-25%), lignin (12-28%) and a small number of phenolic compounds (Lynch, Steffen & Arendt 2016). Currently on the market there are some products that utilize grain proteins, especially oats in the formulation of dry shampoos (Flow Cosmetics 2023) and other products (Oat Cosmetics 2023). During the SYMBIOMA project (Demmel & Junttila) it was found that with careful formulations BSG could also be a suitable ingredient for cosmetics. Yet to do so it would require the extraction of fractions and purification of the BSG, while this may increase the costs of the process, it also improves the material and benefits.

Other applications

Other products from BSG are absorbents, chemicals, nanocellulose, biodiesel, etc. (Demmel & Junttila). Yet these solutions require investments and larger scale operations and larger waste streams of the BSG.

4.1.2.2 Brewer's Spent Yeast

Spent yeast presents a valuable component within the food ecosystem. It is routinely utilized by brewers in their brewing processes and is occasionally supplied to bakeries to produce bread. Rich in proteins, B group vitamins, and minerals, spent yeast is repurposed as a protein supplement for human consumption, contributing to the sustainable utilization of food by-products. Such supplement products can be found on Alibaba (2023) and some other online retailers.

Additionally, apart from human consumption, spent yeast is also suitable for cattle feed. For instance, a notable product is Progut (2023), where spent yeast is hydrolysed to enhance its bioactivity. This process not only increases its nutritional value but also facilitates its utilization in animal feed, thereby offering a sustainable solution for repurposing spent yeast within the agricultural sector.

As proteins from oats have found utility in various cosmetic products, such as hair care items, proteins extracted from yeast have also emerged as viable alternatives. For instance, Hairlust (2023) incorporates yeast-derived proteins into its hair products, showcasing the versatility of yeast-derived proteins in the cosmetic industry.

Brewery wastewater has also been investigated for its properties. Several research articles found that irrigation with the wastewater, which contains spent yeast, improved crop yield of plants such as maize, sunflower and sesame (Senthilraja, Jothimani & Rajannan 2013). Also hydroponic, i.e., soilless, indoor growing of maize benefitted from the addition of yeast (Bedolla-Torres et al 2015). Considering the perspective of wastewater treatment from breweries, the cultivation of biomass helps to decrease the nutrient content in the wastewater (Wolcott, Endreny & Newman 2022).

4.1.2.3 Spent Hops

Hops contribute to the flavour and character profile of beer. Hops are incorporated into the brewing process in various forms, including fresh, dried, pelletized, or as hop extracts. When hop extracts are utilized, no solid waste is produced. However, when fresh or dried hops are employed, they are added to the wort, which is subsequently boiled for 1-2 hours. It is anticipated that during this boiling period, water-soluble components from the hops are extracted into the wort.

Like the other streams of waste, spent hops can be composted or used in biogas production. The difference between the two earlier mentioned by-products is that spent hops has a bitter taste and as such only small amounts can be added to cattle feed or other food products.

In similar way as other biomass, it can be composted and used in biogas production. Spent hops has bitter taste and therefore only small amount can be added to feed of cattle. Tests have demonstrated that essential oils, which remain present in spent hops, serve as effective repellents for pests, thus confirming their suitability for this purpose (Bedini et al 2015). While the extraction of components from spent hops is feasible, it requires methods more precise than mere water solvents and may necessitate the use of more stringent technological conditions. Despite the potential for extraction, the commercial utilization of spent hops appears to be limited, as evidenced by the lack of relevant findings through the desk research.

4.1.2.4 Carbon Dioxide

The fermentation process in brewing yields a significant amount of CO2 emissions. While large breweries and industrial sites have the capacity to capture and purify CO2, utilizing it for various purposes, such technology remains financially out of reach for smaller breweries. However, research indicates promising avenues for CO2 utilization. Studies have shown that enriching greenhouses with CO2 can enhance plant growth rates and increase yield (Hao et al., 2020). Another intriguing solution involves utilizing CO2 in photobioreactors for cultivating algae (Nad et al., 2023). Algae exhibits diverse applications currently under research, including biofuel production, food and feed supplements, cosmetics, among others.

4.1.2.5 Summary of potential utilisation and comments

According to the number of research articles, piloted applications, and commercially available solutions the most utilised by-products is spent grain, followed by spent yeast. Other by-products are in some extent tested at a laboratory scale, but not further commercialised. Table 3 summarises the most common cases and analysis their commercial potential for small breweries in rural and remote locations.

TABLE 8. Potential utilisation of brewery by-products

Stream	Type of product	Suitability for small breweries in remote locations and gained shared value
Brewers spent grain	Compost	Suitable for small breweries and in rural areas. Gate fees and transport fees are required to pay if delivered to common composting facilities. Circular loop is comparatively short, economic value possible only if biowaste handling is done at own lot and user of compost is identified.
	Livestock feed	Suitable for small breweries in rural areas where are livestock growing facilities in nearby locations. Brewery saves biowaste handling fees, farmer saves some feeding costs. Circular loop is longer than compost.
	Bakery products	As single solution it requires large scale bakery product producer. Circular loops are as long as in animal feed, but it could have greater economic value
	Growing media for mushrooms	Suitable for small breweries in rural areas, circular loops are extended through providing food (mushrooms) and protein rich feed (mycelium). Growing technology reduces need for land, land can be used for other purposes, e.g. growing carbon dioxide sequesters.
	Biogas	Suitable for small breweries in rural areas only if there are other biomass streams available and technology is co-owned. Social value is also questionable as food grade biomass is used for bulk product,

		which can be produced from lower quality and otherwise not utilisable biomass.
	Extracts for natural cosmetics	As single solution it requires presence of large cosmetic industry or extraction infrastructure. Small amount can be consumer locally by small beauty businesses
	Chemicals and other spec. products	Requires large investments and therefore need large raw material volumes, not suitable for small breweries in rural areas.
Brewers spent yeast	Food supplement	Amount of by-product is low and therefore processing might lack costs effectiveness unless cooperation with other food producer can be established and common product, e.g. protein bars produced.
	Livestock feed	Suitable for small breweries in rural areas, can be combined with spent grain. However, it needs to be consumed fast. Production into commercial products would need large scale.
	Yeast for bioindustry	Need investments into cleaning and assuring storage of product and needs scale to be profitable.
	Nutrients for agriculture	Suitable for small breweries in rural areas, can be used directly or used in hydroponic farming.
	Cosmetics	As single solution it requires presence of large cosmetic industry or extraction infrastructure. Small amount can be consumer locally by small beauty businesses
Spent hops	Pest repellents	As single solution it requires large amount. Synergies with other raw material needed to reach economic feasibility
CO_2	Greenhouse and bioreactors	Suitable for small breweries in rural areas if there is possibility to build greenhouse close to the brewery and guide CO_2 directly to green house without need for special capture technology.

4.2 Case: Kahakka brewery

Kahakka brewery (Oy NBC Brewery Ab) was established in 2017 and first beers were produced in 2018. Brewery currently employs 3 people. Initial production capacity was 40 000 l/year, in 2022 capacity extended to 150 000 l/year.

> *We started with the high passion in developing new recipes and together with research organisation special taste yeasts. Production of social beers where customers in digital platform can create own beers and we would manufacture them was one of our dreams. However, the competition and lock down of restaurants during COVID-19 forced company to reduce development work and focus on fewer recipes. (Nicke Kavilo)*

The brewery donates approximately 500 kg of spent grain per week to a local farmer, who collects the waste on a weekly basis. This practice of donating spent grain to farmers yields significant cost savings for the brewery. Calculating based on a gate fee of €140 per ton for biobased waste, this results in an approximate weekly saving of €70 (for 500 kg/week), equating to €3,500 annually, considering the typical 50 productive weeks in a year.

While considering the utilization of BSG and other waste streams the brewery finds themselves too small, lacking finances and that the solutions may not yield enough benefits to be viable. The closest brewery for potential collaboration in BSG utilization is 40 km away from the brewery with others being even further away at 100-120 km. Transporting small batches is not cost-effective, and aggregating a large quantity of waste for transportation would necessitate the establishment of preservation and storage facilities, thereby further increasing costs.

Regarding wastewater the company does not face issues with its utilization as the amount is quite small and does not require pre-treatment before being discharged to municipal sewage. This wastewater includes spent yeast, yet a small amount is captured to utilize in the fermentation of new batches of beer. Water is also utilized in the company's brewing process for cooling purposes and recovered at the end. The recovered water is directed to the mast thank and warmed to the required mashing temperature. Utilizing this already slightly warm cooling water in the mashing process saves water and reduces energy costs.

The company has emphasized the necessity for increased revenues and has explored various potential avenues. Presently, the beer production operations utilize only a fraction of the available capacity, suggesting that renting out excess capacity could generate additional revenue streams. Furthermore, monetizing yeast through productization offers another avenue for revenue generation. Alternatively, the feasibility of procuring services on demand rather than investing in equipment has been discussed. Drawing from experience, the company has successfully adopted this model in the canning process, where service providers are engaged as needed to execute operations.

The company believes that pursuing technological solutions is not suitable due to their lack of expertise and financial resources required for the development and commercialization of new products. They view such endeavours as beyond their capabilities, as they would entail significant investments in knowledge, capital, and marketing strategies, with uncertain economic returns. Instead, the company favours simpler solutions that can be easily implemented with the collaboration of suitable partners. They are particularly interested in participating in the circular economy by providing raw materials to other companies. Additionally, they recognize the potential for increased brand value through involvement in environmental and social initiatives. However, they acknowledge regulatory barriers, such as the need for premises rearrangement and increased surveillance, if by-products were to be further utilized in the food industry, which could raise operational costs.

As one of the challenges Kahakka sees location of the brewery.

> *Brewery is situated outside the city centre in the quite industrial area. Area is not attractive to anyone to come for spending time more than necessary. We are looking for the location closer to the main streams of people, for example city centre, some shopping area, place where more services are concentrated. Important is that people are coming to that area for some reason and can stay longer. Then of course reachability by foot or by bicycle, public transport and parking needs to be considered. We still did not find that place, we had in mind one, but it is privately own and when we were placing the brewery in the current place, we did not come to the agreement. (Nicke Kavilo)*

The insights gleaned from the interview underscore the brewery's keen interest in participating in the circular economy by sharing its by-products. However, it becomes evident that the company lacks the capacity and inclination to independently orchestrate the establishment of a value network. This overarching challenge resonates with findings observed by other researchers (referenced in Section 2.1.6.), emphasizing the necessity for an external facilitator or orchestrator to initiate and sustain circular value chains, particularly when multiple by-products from one company necessitate diverse utilization routes. Moreover, the geographical location of the brewery emerges as a critical factor in attracting customers.

4.3 Circular Wellness Hub Concept

Based on the reviewed literature and case study of the Kahakka brewery, this final chapter will outline the framework of an ecosystem of players to utilize and distribute the by-products of the brewery and eventually others with similar by-product streams. The concept is named Kokkola Circular Wellness Hub (CWH).

In addition to provision of solution for brewery to better utilise by-products the mission of CWH is to provide meaningful space for Kokkola inhabitants to be engaged into economic, social, and environmental wellbeing of the community.

At the heart of the CWH lie social engagement and wellbeing. The hub's activities foster social interactions and are customized to address individual needs, including caregiving, social engagement, connecting with peers, spending quality time with family and friends, and forging new relationships. Through utilizing the services offered by the CWH, individuals actively contribute to the enhancement of environmental wellbeing in Kokkola, as the hub predominantly utilizes local by-products and resources as raw materials and circulating products. Additionally, by patronizing services and products from the CWH, people play a role in sustaining or bolstering the economic wellbeing of small businesses in Kokkola.

Currently, Kokkola boasts a robust brand as a city renowned for its chemical industry, with a particular emphasis on battery chemicals and hydrogen production. The CWH holds the potential to reshape Kokkola's image from that of a heavy industrial centre to an inviting locale for new residents and small businesses. By cultivating a reputation as a city that prioritizes inclusivity and environmental stewardship, Kokkola stands to attract a broader demographic and increase tourism influx.

4.3.1 Customers

To effectively tailor offerings and services provided by businesses within the CWH, it is imperative to analyse the interests and needs of target customer groups. Accurately defining potential customer groups will not only influence the success of businesses within the CWH but also significantly impact the environmental and social performance of the concept. Table 19 provides an analysis of potential customers, their habits, and the services that the CWH could potentially offer. It is imperative to acknowledge that Table 19 is predicated upon subjective perceptions. Each business operating within the CWH requires a more comprehensive analysis of its specific customer segments to shape the services they offer accordingly.

TABLE 9. Potential customer segments for CWH

Customer segment	Shopping and service use habits	What features in products and services could be attractive
Eco-conscious customers	• Buy products and services which are known for their sustainability • Prefer multiple use products over single use	• Market and/or shop of fresh, local and sustainable products • Natural cosmetics • Reusable packaging or refilling of e.g. cosmetics

	• Willing to put effort to improve environmental sustainability • Support local eco-businesses and eco-initiatives • Eager to learn more about sustainability issues	• Second hand shop • Eco-training
Families with children	• Time saving shopping • Healthy food for children • Effortless time with children • Services for children parties • Parents own time along with children activities	• Location of CWH near the food shop • Family friendly restaurant • Children playground, indoor and outdoor • Guided activities for children • Family friendly fitness • Short time children care • Theme based birthday parties for children
Schools/kinder gardens	• Activities to enrich education • Places to visit and learn about circular economy	• Workshops for school classes • Training modules • Visits and lectures
Elderly people	• Healthy and nutritious food • Come to places where alike people are gathering • Like taking care and feeling being part of society • Have time and resources to indulge themselves	• Market and/or shop of fresh, local and sustainable products • Elderly "day care", place to gather and spend time • Various courses to learn new • Gardening • Restaurant, pub, cafeteria • Beauty businesses • Gym • Hotel • SPA
Working people	• Time saving shopping • Purchase convenient and accessible ways to take care of their health • Place to spend free time • Nice place for hobbies	• Multiservice packages which include on-site wellness programs and healthy food options. • Market and/or shop of fresh products • Lunch restaurant • Gym
Health enthusiasts	• Passionate about health and wellness and are always on the lookout for new and innovative ways to take care of their health.	• Healthy food restaurant • Culinary courses • Healthy products for purchase • Lectures
Local industry	• Participate in social programmes to improve handprint • Interesting places to show/spend time with visitors	• Restaurant/pub • Event organisation service

Based on table 19 the activities of the CWH can be grouped into beauty, food, cultivation, events, and training.

4.3.2 Analysis of activities in the CWH value network

The operation of the CWH necessitates the involvement of multiple business actors. The quantity of these actors is dependent upon the capacity of each operator and the range of activities they undertake. As a result, the analysis of the value network is conducted based on the various activities rather than individual businesses. It's important to note that a single business operator may be involved in one or multiple activities within the CWH. An overview of the businesses and activities within the CWH is provided in Figure 28.

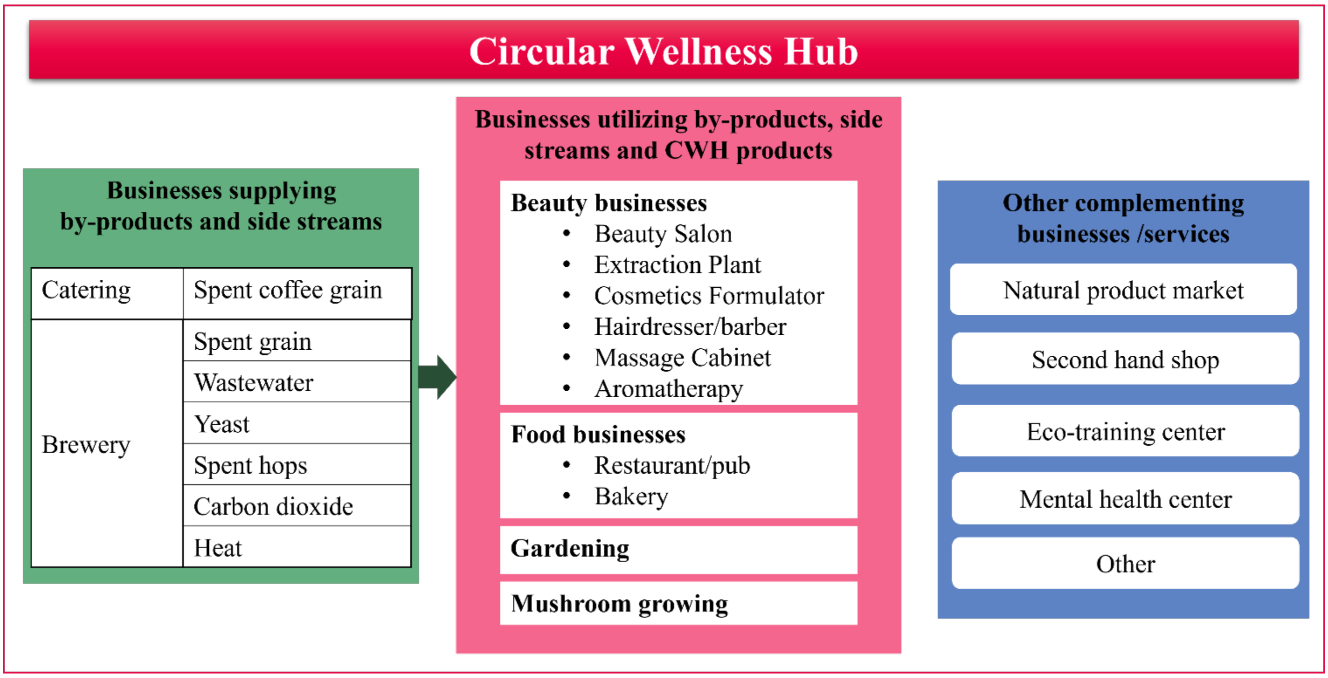


FIGURE 28. Circular Wellness Hub concept - main businesses in the area.

4.3.3 Beauty businesses

The beauty industry encompasses a variety of services that vary in their scale of operations. Beauty salons, hairdressers/barbers, massages, and aromatherapy businesses typically operate on a smaller scale. Conversely, extraction plants and cosmetic formulation businesses have the potential to begin at a small scale and expand over time.

The overarching business philosophy within this sector emphasizes the utilization of resources available from CWH operators as a primary priority. Secondly, businesses prioritize the use of natural local resources and products, followed by natural Finnish products.

4.3.3.1 Beauty salon

The beauty salon within the CWH offers clients freshly made skincare products, emphasizing natural ingredients. The beauty shop sources ingredients from the brewery (BSG) and the coffee shop (such as spent coffee grains) for its scrubbing products. Additionally, the extraction plant and cosmetic formulator supply natural extracts, other ingredients, or finished products.

The primary value and competitive advantage provided by the CWH beauty salon include formulations that are free from preservatives, transparent disclosure of ingredients and their origins to customers, and the ability to tailor products to individual skin types and preferences. Clients are informed about their involvement in the development process by the cosmetics formulator.

The cosmetics formulator specializes in developing and commercializing natural cosmetics products, including the establishment of an in-house cosmetics brand for the CWH. They provide the beauty salon and hairdresser within the CWH with both individual ingredients and formulations. Moreover, they retail ready-made products through the CWH shop and operate an online store.

Furthermore, the cosmetics formulator offers in-person and online courses for individuals interested in crafting their own cosmetic products at home.

4.3.3.2 Extraction plant

The extraction plant within the CWH is dedicated to upcycling BSG, BSY from the brewery, and Cafeteria/Restaurant CSG into higher-value ingredients. Initially, extraction activities can commence on a small scale and gradually expand in the future. In addition to the sources, the extraction plant holds the potential to extract valuable components from a diverse range of natural sources, including herbs, berries, and other suitable biomass. This operation within the CWH exhibits significant potential for scalability, with the capacity to transition to an industrial scale operation. Moreover, it has the capability to expand its customer base to a global level, capitalizing on the growing demand for sustainable and natural ingredients in various industries.

4.3.4 Food businesses

CWH bakery products, which include BSG, consist of bread and biscuits. Up to 10-15% of the wheat and/or rye content in bakery items can be substituted with BSG. By incorporating BSG, bread and biscuits can be promoted as protein and fibre-enriched whole grain products. This is because during the mashing process, sugars from the grains are extracted into the water, leaving BSG with significantly lower sugar content compared to virgin grains or malt. As a result, the protein and fibre content in BSG is higher. Additionally, malt is a product of germinated and processed whole grains.

Freshly baked bread from CWH is supplied not only to CWH operators, restaurants, cafeterias, and natural product shops, but also to supermarkets in Kokkola. These outlets ensure that customers across various settings have access to high-quality baked goods. For longer shelf-life products like biscuits, they are primarily distributed by CWH operators, available for purchase through the online shops, and sold at markets in Kokkola. This diverse distribution network ensures that both perishable and non-perishable bakery items reach consumers through multiple convenient channels.

In the area, aside from the CWH, there are other food businesses including a cafeteria and a restaurant/pub. The cafeteria is known for being family-friendly and focuses on promoting healthy eating habits through its product offerings. Additionally, the cafeteria provides catering services and can organize themed parties for both children and adults upon request. The restaurant/pub primarily serves lunch during the daytime. Both the cafeteria and the restaurant/pub extensively utilize raw materials sourced from CWH operators and producers within the Kokkola region, ensuring a local and fresh supply chain.

On average a Finnish person annually consumes 41 kg of bread, 7,4 kg of pastries and confectionery goods and 10 kg of savoury bakery goods. (Toimialaraportti 2021, 40). Kokkola consumption is estimated to be 2.7 million kg and with 10% of bread weight being replaced with BSG and 10% market share 27 t of BSG could be consumed. The total amount of BSG produced by Kahakka is some 30 t, what would mean that bakery could consumes almost all the available by-product. Current challenges are that there are only several small bakeries in the region, most of the bread is produced outside the Central Ostrobothnia. On the other hand, availability of material locally could inspire new business.

4.3.5 Cultivation businesses

The scale of cultivation businesses is contingent upon the proximity to CWH facilities. Priority is given to year-round cultivation practices, particularly those utilizing vertical hydroponic systems and mushroom growing techniques. These methods require minimal space, can be integrated into existing structures, and benefit from a consistent supply of by-products from CWH operators. In addition, the benefits of hydroponic systems include:

1. **Space efficiency** as hydroponic systems require substantially less space than traditional farming.
2. **Year-round cultivation** as hydroponic systems are not dependant on natural weather patterns but operate in a closed system that has constantly optimal conditions for cultivation.
3. **Integration potential** as these systems can be easily integrated into existing structures and buildings, making such investments in terms of location more cost effective.
4. **Resource utilization** as hydroponic systems and efficiently utilize by-products from CWH operators, such as wastewater and other organic matter that has high nutrient contents.
5. **Consistent output** as a controlled ecosystem which enables year-round cultivation also enables cultivated crops to yield consistent quality and amounts of crops.

Additionally, seasonal soil gardening in open-air settings is feasible, provided that the location of CWH permits such activities. These new types of farming practices help forward sustainability and circular economy as they are easily fitted into existing infrastructure but also can utilize by-products of other processes that otherwise would be just waste.

4.3.5.1 Green house operations

The greenhouse plays a pivotal role within CWH, serving not only as a means of efficiently utilizing by-products from the brewery but also as a platform for advancing the social mission of the organization. To effectively function, the greenhouse requires a range of resources including water, electricity, heat, light, CO2, and nutrients. As such, hydroponic vertical gardening facilities have been strategically integrated into CWH operations. These facilities are seamlessly incorporated into the brewery's infrastructure, utilizing excess heat and water to maintain optimal greenhouse temperatures, while brewery by-products serve as a nutrient source for plant growth. Furthermore, CO2 emitted from exhaust pipes is redirected into the greenhouse environment, enhancing plant growth and overall greenhouse productivity. This holistic approach underscores CWH's commitment to sustainability and innovation in agricultural practices.

The greenhouses can either be commercially utilized but to further the social mission of the CWH and promote wellness it is recommended that at least a portion of the greenhouses could be in community use. This could either be done with a sharing economy logic or by renting lots to interested individuals. Technically equipped greenhouse lots could be rented to individuals, schools, elderly houses, and food businesses in the CWH. This way the renters of the lots are utilizing the lots in accordance with their interest and skills, ensuring that crops are planted, maintain, and finally harvested. Harvested goods can be consumed to their own purposes or sold to other operators in the CWH or in the QWH market. This also opens other potential service provides for the greenhouses and renters may require different types of tools depending on the plants grown in the greenhouses. It is also recommended to have flexible and digital solutions to optimize renting and shifting interests of individuals so that the greenhouses still operate year-round. Other services that can be provided for the greenhouses can be in terms of training individuals renting the lots to be better at agriculture and for those that which to have the produce with limited time spent in the greenhouse can purchase maintenance services from operators within the greenhouses.

4.3.5.2 Mushroom growing

Mushroom growing in CWH thrives as a sustainable business venture, deeply rooted in the cultivation of nourishment. Utilizing coffee grains and excess BSG as growing mediums underscores the region's commitment to resourcefulness and environmental stewardship. The harvested mushrooms find their way into local eateries, enriching the culinary landscape of CWH, while also gracing the shelves of markets in Kokkola and beyond. Beyond its culinary appeal, the mycelium produced in the process serves as a potent source of protein-rich feed supplement, further demonstrating the holistic approach to agricultural innovation. Moreover, the mushroom growing operators play a pivotal role in community development by offering training programs, empowering individuals with the knowledge and skills needed to partake in this thriving industry, fostering a sustainable cycle of growth and prosperity.

4.3.6 Social engagement activities: classroom training and workshops

In CWH, social activities are meticulously crafted to catalyse a circular transformation and foster sustainable development within the community. With a keen focus on inclusivity, the diverse needs and interests of various societal groups are meticulously considered. Services and initiatives are intricately tailored to not only encourage social engagement but also to deliver tangible social value to the residents of CWH. These activities span a spectrum of endeavours, ranging from educational workshops and skill-building programs to cultural events and environmental initiatives. By providing avenues for learning, creativity, and collaboration, CWH cultivates a vibrant social fabric wherein every individual feels empowered to contribute positively to the community's collective growth. Moreover, these social activities serve as a platform for fostering a sense of belonging and interconnectedness among residents, transcending barriers and forging strong bonds that underpin the community's resilience and cohesion. By embracing principles of sustainability and circularity in its social endeavours, CWH not only enriches the lives of its inhabitants but also paves the way for a more harmonious and prosperous future for generations to come.

The realization of the CWH concept hinges upon a synergistic collaboration not only among businesses within the community but also with neighbouring enterprises and the active involvement of diverse social groups. Consequently, in addition to the focus of businesses utilizing locally available by-products, those situated in CWH are also encouraged to engage in various social initiatives, such as classroom training and workshops. These social engagement actions are integral components of each operator's business plan. As previously mentioned, operators in beauty, cultivation, and food industries are actively involved in delivering training sessions, thereby fostering a culture of shared learning and community enrichment.

CWH businesses serve as demonstration sites to learn and observe in practise phenomena of chemistry, physics, botanic, environmental sciences, and entrepreneurship. It is a space that schools can utilize as a hand on means of demonstrating how circular economy can as an ecosystem support sustainable development but also inspire and introduce the concepts of eco- and social entrepreneurship. The CWH can be a part of the offered services schools in Kokkola utilize, table 20 gathers services used by schools in Kokkola.

Courses to adults in Kokkola are provided by Kokkolan seudun opisto (Kokkola adult education centre). Themes of courses are related to information technology, music, dance, arts, handicrafts, culi-nary, etc. Furthermore, educational organisations, Centria, KYC, KPEDU are delivering non-degree courses for adults and numerous one-time based knowledge exchange events designed often for businesses, but open for all. Synergies between existing training and knowledge delivery events providing organizations and CWH infrastructure are evident and need further to be explored when designing CWH social engagement actions.

TABLE 10. Training and educational services provided to and used by Kokkola schools.

Benchmarked service providers	**Target group**	**Service description**
Yrityskylä Pohjanmaa, Vaasa (Business village)	6th grade and 9th grade school children	Inspiring way to learn about working life, the economy and society, children spend a day in a village, “run business, go to work, purchase products and services, etc.
LUMA Center, Kokkola University Consortium Chydenius	Teachers and school children	Promotes learning and teaching of natural sciences, mathematics, information technology and technology at all levels. Laboratory work, small projects are part of the education provided through LUMA in Kokkola.
Kokkola Nature School at Villa Elba	Teachers and school children	Long-term environmental education for 3-5 grade school classes.

4.3.7 Other potential activities at CWH site

Existing services in Kokkola, while currently dispersed across various locations, include initiatives like REKO, a platform where local farmers and self-employed individuals gather to sell their products, as well as establishments like the Chaga natural product shop and second-hand stores.

Depending on the allocated space and available resources within CWH, the site has the potential to serve as a hub for a diverse range of activities. This could encompass facilities for hobbies, a variety of fitness options, relaxation, and rehabilitation services, as well as hosting events such as concerts, performances, and exhibitions.

It is anticipated that the infrastructure of CWH itself will act as a magnet for entrepreneurs, offering an environment conducive to collaboration and synergy between different activities. This integrated approach is poised to attract a steady stream of customers, drawn by the convenience and interconnectedness of the offerings within the community hub.

4.3.8 Orchestration of CWH development and implementation.

Development and implementation of CWH infrastructure, products and services and its operational model undergoes multiple stages and considers the entire lifecycle from planning and design to implementation, maintenance, monitoring and evaluation. Furthermore, CWH is constantly evolving concept with possible new stakeholders being involved in circular loops, new products and services developed and therefore it is being constantly developed and renewed if needed also after the implementation stage. Figure 29 presents simplified sequence of CWH development and implementation stages.

FIGURE 29. Stages of CWH development and implementation

Orchestration of the CE loops and delivering shared value is an important part in circular economy cases as described by Palmié et al (2021). Orchestrator can be treated as service provider to any CE case and assist in organising supply chain within and between circular loops, providing with knowledge and managerial skills, and assisting in delivering environmental and social value when loops are in operation.

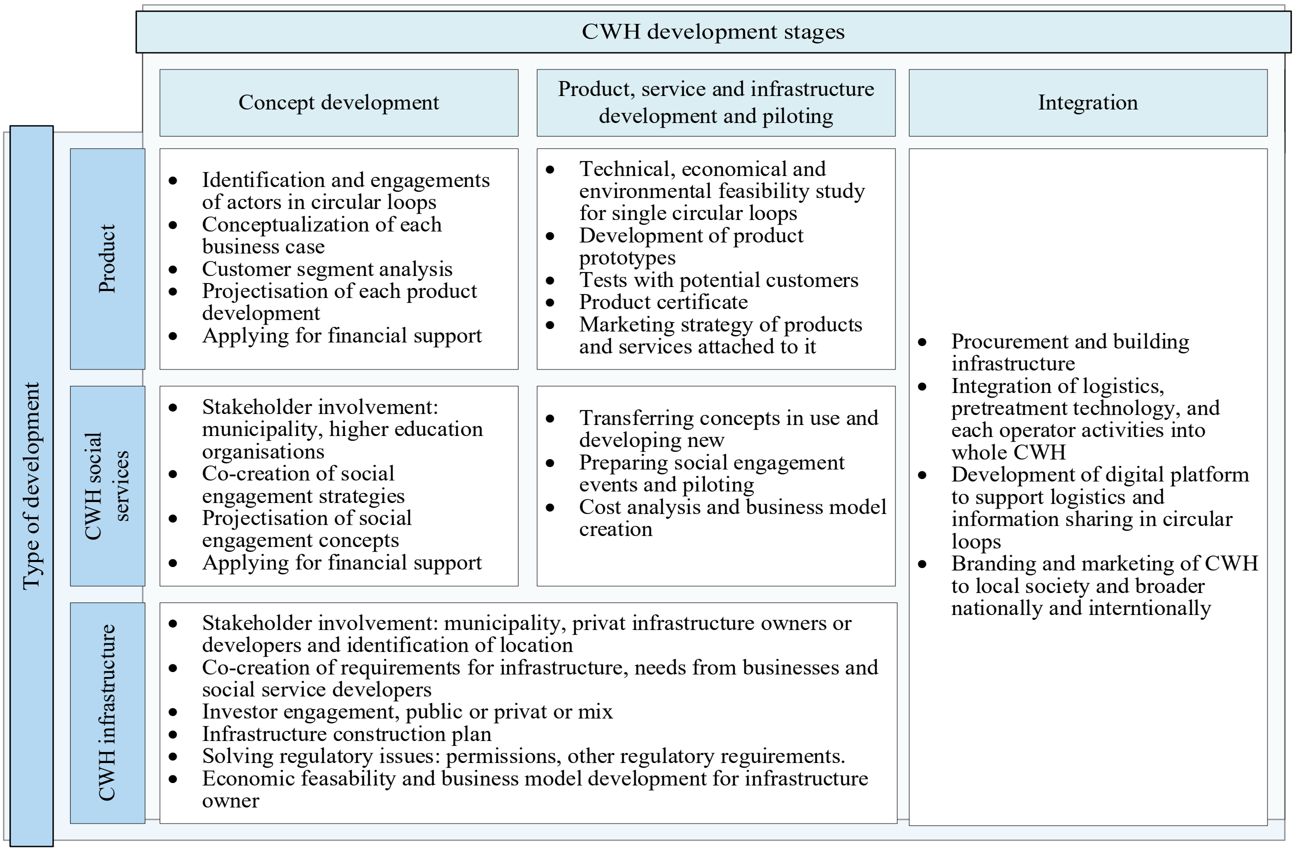
4.3.8.1 Services of orchestrator

The development of CWH progresses through several stages before reaching full operation. The requirements of the service orchestrator vary at each stage, evolving further when the CWH is fully operational. The orchestrator faces its most versatile and challenging role during the developmental phase of CWH. Figure 30 illustrates the primary activities that orchestrators can undertake to facilitate the development and integration of CWH infrastructure and operations into a cohesive system.

CWH operates through a multifaceted approach, involving multiple concurrent solutions and engaging a diverse array of actors. This not only facilitates the production of new goods but also ensures their consumption, supported by a range of complementary services. Moreover, educational initiatives targeting various demographics are integral to the CWH framework.

In contrast to the primarily supply chain-oriented resource orchestration described by Palmié et al. (2021), the role of the CWH orchestrator extends beyond logistical organization to encompass the development of social activities. Consequently, actions within the CWH necessitating interfirm coordination can be categorized into three main groups:

1. **Supply Chain Activities:** These include preparing by-products for their next utilization stage and managing their distribution within the circular loops to optimize resource efficiency.
2. **Organizing Social Engagement:** The orchestrator is responsible for arranging and promoting various social engagement initiatives within the community, fostering cohesion and participation among residents and businesses alike.
3. **Promotion of CWH:** Lastly, the orchestrator plays a crucial role in promoting the CWH concept, raising awareness about its benefits, and encouraging broader community involvement and support.



Type of development	CWH development stages		
	Concept development	Product, service and infrastructure development and piloting	Integration
Product	• Identification and engagements of actors in circular loops • Conceptualization of each business case • Customer segment analysis • Projectisation of each product development • Applying for financial support	• Technical, economical and environmental feasibility study for single circular loops • Development of product prototypes • Tests with potential customers • Product certificate • Marketing strategy of products and services attached to it	• Procurement and building infrastructure • Integration of logistics, pretreatment technology, and each operator activities into whole CWH • Development of digital platform to support logistics and information sharing in circular loops • Branding and marketing of CWH to local society and broader nationally and interntionally
CWH social services	• Stakeholder involvement: municipality, higher education organisations • Co-creation of social engagement strategies • Projectisation of social engagement concepts • Applying for financial support	• Transferring concepts in use and developing new • Preparing social engagement events and piloting • Cost analysis and business model creation	
CWH infrastructure	• Stakeholder involvement: municipality, privat infrastructure owners or developers and identification of location • Co-creation of requirements for infrastructure, needs from businesses and social service developers • Investor engagement, public or privat or mix • Infrastructure construction plan • Solving regulatory issues: permissions, other regulatory reguirements. • Economic feasability and business model development for infrastructure owner		

FIGURE 30. Services of orchestrator in CWH product, social activities, and infrastructure development stages

Many authors have identified that one main component of the circular economy is the importance of collaboration and co-creation with the stakeholders of any given solution or business, e.g., Walker et al (2021), Jesus & Jugend (2023), etc. Additional tasks for the orchestrator include initiating a shift in stakeholder mindset, encouraging willingness to collaborate, embrace change, and experiment with new approaches. Since the proposed CWH concept is novel and lacks existing linkages between stakeholders, a motivated orchestrator is essential to champion the vision and inspire widespread sharing of it among a diverse array of stakeholders.

Although many solutions and products are feasible and implemented elsewhere, their transfer requires product adjustment to the needs of customers in Kokkola. Co-creation of products with customers at the early stages would additionally be a marketing tool and would promote use of services. The orchestrators' role is to assist in product development by e.g., identifying, and engaging knowledge of experts for product type, assisting in projectisation of the ideas and applying for financial support from public or private funding to develop and pilot products and services, and manage projects when and if needed.

The process of developing and implementing infrastructure involves several stages. One critical aspect is the role of the orchestrator in securing investment for the infrastructure. This involves assessing the technical, economic, and environmental feasibility of the products and services within the CWH, as well as the requirements of social activity organizers. Based on these assessments, the viability of the infrastructure, particularly its technical and economic aspects, is evaluated to inform investment decisions. Seeking funding from sources beyond private investors can facilitate the realization of the concept. Therefore, in addition to engaging suitable and motivated stakeholders, the orchestrator's responsibilities include advocating for the concept to receive support from European Union funding bodies, governmental agencies such as Sitra, Business Finland, the Ministry of Economic Affairs, and municipal authorities.

During the integration stage, the focus extends beyond the physical construction of infrastructure to encompass the orchestration of various complementary elements essential for the smooth functioning of the CWH. In addition to building the necessary physical infrastructure (or in this case modification of existing infrastructure to suit the needs of the CWH), this phase involves the development and implementation of digital tools aimed at bolstering the efficiency and effectiveness of circular loops within the CWH ecosystem. These digital tools may include platforms for tracking and managing resource flows, optimizing logistics, and facilitating communication among stakeholders.

Furthermore, the integration stage entails concerted efforts towards social engagement, fostering a sense of community ownership and participation within the CWH framework. This may involve organizing educational workshops, community events, and outreach programs aimed at raising awareness about the benefits of the CWH and encouraging active involvement from various stakeholders.

Another crucial aspect of the integration stage is the branding and marketing of the CWH. This involves crafting a distinctive identity for the hub, highlighting its unique value proposition, and effectively communicating its benefits to potential users, investors, and the wider community. Through strategic branding and marketing initiatives, the CWH can attract interest, build credibility, and ultimately establish itself as a trusted and indispensable resource within the region. This can boost the regions image, but also highlight the strengths and knowledge base of the region further.

When the CWH is in operation, orchestrator's activities are shifting from development project manager type of activities to usual business operator's activities, what includes supply chain management, organisation of social events, daily work with stakeholders and promotion of CWH concept. Furthermore, the orchestrator is monitoring and evaluating CWH environmental and social impact and further develops new circular loops with engagement of existing or new stakeholders. Also, with time the orchestrators' role will also include possible sustainability reporting and other indicators to ensure transparency of the operations to a larger public and public entities.

4.3.8.2 Type of orchestrator's organisation

The role of the orchestrator is versatile, it changes depending on the stage and type of CWH development point and requires multiple skills. Therefore, the orchestrator is an organisation, rather than individual person. The orchestrator service provider can be public organisation or NGO, private business for profit or e.g., eco- and social entrepreneurs (Santini 2017, Henriksson et al 2019).

CWH contains many actors, including small businesses, such as the brewery, beauty and wellness service providers, catering and other food businesses, small scale cultivation, circular product vendors, also the owner of the infrastructure and therefore their capacity to take on orchestrator's role is investigated. Capacity and businesses cases for possible orchestrator for CWH in operation are analysed using scenario planning methodology. Scenario planning is one of methodologies to deliver alternative views and elaborate various possible paths. Although it is mostly used as predictive tool to evaluate future possibilities, it suits also in this context.

Scenario Planning

Scenario 1- self -organised model. One of the small businesses in the circular loops taking up the role of orchestrator by expanding their own operations. The brewery at the core of the CWH on the surface seems like the obvious choice, but as the interview with Kahakka brewery and research has found, small enterprises find it often difficult to allocate resources to the necessary business activities and to ass the role of orchestrator on top is too much for them. The interview with Kahakka revealed that their passion is in producing beers with various tastes and developing of new recipes in collaboration with their customers. While exploring solutions for effectively utilizing residual streams would be beneficial, orchestrating the entire CWH solely for a small brewery is deemed impractical due to the considerable allocation of resources, including manpower and capital, it would entail. However, the brewery's contribution to circular loops can still be enhanced by pre-treating waste streams for potential reuse in other processes if necessary. This approach allows the brewery to play a part in maximizing resource efficiency within the circular economy model without shouldering the extensive burden of orchestrating the entire CWH.

Many authors, e.g., Schlüter et al (2022), have also noticed, that small companies need support in orchestration which is also confirmed by interviewing Kahakka. It is also difficult to believe, that any of micro businesses in CWH would be willing to orchestrate all activities in CWH. Clearly external organization is needed to provide orchestrator’s services for the circular system to function.

Scenario 2 – organised by external private organisation. The owner and maintainer of the infrastructure is a private company, and the orchestrator's activities are seamlessly integrated into the company's business operations. The company generates revenue from two primary sources:

1. Renting premises within the infrastructure: This constitutes a for-profit business endeavour, where the company leases out spaces within the infrastructure to various tenants or businesses.
2. Orchestrating circular loops and social activities: This aspect involves integrated eco-entrepreneurship and/or social entrepreneurship, wherein the company oversees the coordination of circular resource flows and social engagement initiatives within the CWH. These activities generate revenue through various means, such as service fees, partnerships, or grants aimed at supporting sustainable practices and community development.

In essence, the company operates both as a landlord, leasing out space within the infrastructure, and as an orchestrator, facilitating circular economy initiatives and social engagement activities as part of its broader business model.

Scenario 3 – organiser is public organisation. In this scenario, the organizer of the CWH is a public organization, specifically the municipality. The municipality provides the premises for the hub, and the orchestrator is an integral part of the municipality's activities, operating within its framework. This model is particularly suitable for circular economy cases where social engagement is a key consideration.

However, a notable challenge arises with the inclusion of a brewery and a restaurant holding an A-license, which permits the serving of alcoholic beverages with alcohol content exceeding 2.8% by volume. There is a prevailing sentiment that leasing premises for these two businesses from the municipality would not align with ethical standards.

This ethical concern likely stems from potential conflicts of interest or perceptions of impropriety associated with a public organization, such as the municipality, engaging in business arrangements involving the sale of alcohol. As a result, alternative solutions or partnerships may need to be explored to address this challenge while still advancing the objectives of the CWH and promoting sustainability within the community.

Scenario 4 – mixed private-public model. In this scenario, the ownership structure of the infrastructure is mixed. The infrastructure designated for private sector activities, such as commercial ventures or for-profit enterprises, is owned by a private company. Conversely, the premises designated for social engagement activities are owned by the municipality.

Revenue generation occurs through different channels for each entity involved. The private business earns revenue by renting out premises within the infrastructure to tenants or businesses engaging in commercial activities. On the other hand, the municipality generates revenue by renting out premises specifically designated for social activities, such as community events or educational workshops.

Despite the mixed ownership structure, the orchestrator responsible for coordinating activities within the Circular Waste Hub (CWH) operates as part of the municipality's operations. This arrangement allows for a collaborative approach, leveraging both private and public resources to promote sustainability and community engagement within the CWH framework.

Scenario 5 – organisers are several public organisations; infrastructure is own by private organisation. Orchestration is combined effort of various organisations in Kokkola. The most knowledgeable orchestrator can be chosen for each stage of development. The CWH concept development step could be orchestrated by collaborative effort of KOSEK (public business support organisation), Centria UAS and KYC. CWH development can be started as project and new business entity established to orchestrate CWH when it is integrated and operates on a routine basis. This business entity business type could be eco-entrepreneurship or social entrepreneurship.

Conclusion

The analysis indicates that scenarios 4 and 5 are the most likely outcomes, necessitating a collaborative interplay between public and private coordinators, particularly in the operational aspects of the infrastructure. A public organization is best positioned to cultivate an inspiring environment conducive to the creation of numerous value chains within the CWH, initiating collaboration between companies and co-developing the concept.

Subsequently, business operators will facilitate the establishment of B2B exchanges for side streams and essential knowledge transfer. Concurrently, the public organization will continue to play a vital role in advancing social engagement initiatives and serve as a prominent ambassador to promote the CWH model and bolster the Kokkola brand. This multifaceted approach ensures the sustainable growth and success of the CWH while enhancing its societal impact and brand recognition.

4.3.9 The Circular Wellness Hub value-chain framework

Finally, we present the CWH value-chain framework that looks beyond the hub's own activities at other aspects that need to be figured out for the Hub to operate smoothly once the internal activities and orchestrating party is selected.

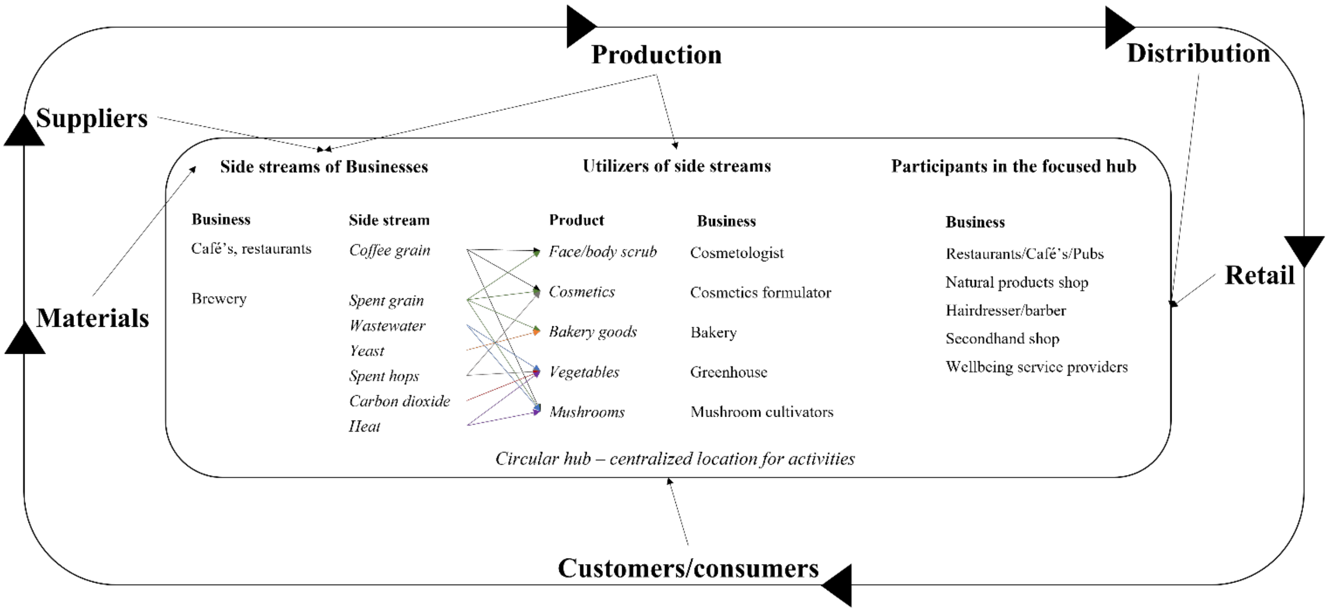


FIGURE 31. Circular Wellness Hub value-chain

Figure 31 illustrates the framework of a circular hub that operates based on the principles of circular economy, which eases the effects of a supply chain by focusing actions in a tightknit area. In the centre of the picture, we have the previously detailed CWH and its activities while on the outer rim we see the other components of the value-chain. Some of these sections can operate within the hub, while others are not directly located within the hub but work together with the actors and others are participants of the hub that need to be attracted to the location. Below we discuss some of the outer rim actors and their importance and role.

Production

At the heart of the CWH value-chain lies the production phase, where goods and services are generated in alignment with circular principles. This includes the cultivation of organic produce, the creation of eco-friendly wellness products, and the development of sustainable solutions for health and fitness.

Distribution

Efficient distribution channels are crucial for ensuring the seamless flow of goods from production facilities to end-users. The CWH leverages innovative approaches such as local sourcing, decentralized logistics, and collaborative partnerships to optimize distribution processes and minimize environmental footprint.

Retail

Retail outlets within the CWH play a pivotal role in connecting consumers with sustainable and ethically sourced products. These establishments prioritize transparency, quality, and eco-consciousness, offering a diverse range of wellness offerings tailored to individual needs and preferences.

Customers/Consumers

Consumers are key stakeholders in the CWH value-chain, driving demand for eco-friendly products and services that promote well-being. Through education, advocacy, and community engagement initiatives, the CWH fosters a culture of conscious consumption, empowering individuals to make informed choices that align with their values.

Materials

Sustainable sourcing and utilization of materials are fundamental principles guiding the CWH value-chain. From renewable resources to upcycled materials, every effort is made to minimize waste and environmental impact while maximizing resource efficiency throughout the production process.

Suppliers

Collaboration with ethical and eco-conscious suppliers is essential for maintaining the integrity of the CWH value-chain. Suppliers adhere to stringent sustainability criteria, ensuring that raw materials and components meet the highest standards of quality, environmental responsibility, and social ethics.

The purpose of this framework is also to act as a more generalizable view on a circular hub, which could be applied to any industry or by-product focus rather than just considering the waste of breweries. Thus, the aim is for this framework to help others in developing circular hubs around Finland and the world in which resources are shared efficiently with existing infrastructure and cultural norms to build sustainable solutions that are unique but in essence circular and collective.

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