Life cycle impact assessment for a district heating project with seasonal storage

A case study analysis for a project based in Bracht, Hessen, Germany

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1 Abstract

A Life Cycle Impact Assessment (LCIA) is performed for a solar district heating community project in Bracht, Rauschenberg, Germany.

2 Introduction

Heating is an important topic for energy consumption since it amounts to roughly half of the consumed energy in the EU. Currently, 60% of that energy is generated from fossil fuels as stated in Euroheat & Power (2023). District heating is a setup where one heating generator plant serves many households connected via pipes. District heating works in two ways: Either to utilise surplus heat from sources such as waste incineration plants for heating purposes in residential areas and service centres as described by Swiss Federal Office of Energy (2020), or to use a dedicated source of energy, e.g. biomass or solar thermal collectors. There are 6000 existing district heating systems across the EU according to Euroheat & Power (2023). Process heating uses a similar setup but is targeted at industrial purposes, which usually require higher heat temperature.

Solar thermal collectors (STCs) are devices that absorb solar radiation and convert it into heat. There are different types of solar thermal collectors, including flat plate solar collectors, unglazed water collectors, and evacuated tube solar collectors. They are combined with heat pumps to bridge the gap between solar field produced water temperature and district heating delivery system required temperature as explained in Wikipedia (2025). According to Weiss & Spörk-Dür (2024), there are more than 300 large scale district heating systems globally that are powered with STCs, and more than 1200 STC systems that provide industrial process heat.

STCs are a mature technology. In 2023, the total operational solar thermal capacity reached 560 GWth, which covers roughly 800 km2 of collector area as stated by Weiss & Spörk-Dür (2024). STC-provided capacity varies seasonally depending on available sunlight. Sometimes STCs are used only for parts of the year, e.g. to enable turning off a biomass-powered plant in the summer since it would run at extremely low capacity. STCs can be combined with a short term heat storage acting as buffer or a seasonal heat storage tank (e.g. underground hot water basin) to store extra heat from the hot season for the cold season, which incurs heat losses. If space restrictions require such a setup (or if land is cheaper), the geographical location of an STC can be remote from consumers and plants via pipelines (e.g., 4 km in Priština as described in Euroheat & Power (2023)). However, there is a trade-off since the remote location required laying the necessary pipes underground.

In scientific literature, LCA case studies exist for the district heating system in Milan (see Famiglietti et al. (2021)) and Marseille (see Vauchez et al. (2023)). LCA, in particular the ReCiPe method, has been used to assess the environmental impact of different STC powered district heating configurations by Abokersh et al. (2020). The outcome was that larger systems that serve many households have a lower environmental impact per energy unit served.

Solano et al. (2023) provide an LCA study of a STC plant connected to the Geneva district heat network and find that there is no LCA data available for the coupling of large scale solar thermal installations and district heating networks, and provides suggested numbers that could be used to complement district heat production routes in the KBOB database.

For the community project in Bracht, while the economic viability of the project in comparison to energetic renovation was analysed by Kelch et al. (2024), the environmental impact has not yet been studied in detail. This is the subject of the given study.

3 Methodology and research questions

The foreground data is collected from various online sources and combined with background data from the Ecoinvent v3 database by Wernet et al. (2016) and from the UVEK LCI database DQRv2:2025 database by Federal Office for the Environment (FOEN) (2025). The environmental impact is assessed using the mid-point level Environmental Footprint (EF) method recommended in European Commission (2021), and the Ecological Scarcity 2021 v1.04 method defined in Federal Office for the Environment (FOEN) (2021) at the single score level (with UVEK LCI weighting set). The LCIA is performed using the SimaPro 9.6.0.1 software provided by PRé Sustainability (2024).

The research questions are formulated as follows:

(1) How does the STC based system with seasonal heat storage compare to other heating technologies in terms of environmental impact? The comparison will include district heating from other sources that would be available in small communities (such as a

heat pump or wood chips), and consumer side heating installations such as oil or gas boilers. The hypothesis is that the STC based system will have a lower environmental impact compared to other district heating setups and to fossil energy based consumer installations.

(2) What is the environmental impact contribution of the seasonal heat storage unit for the production, construction, and use stages in the life cycle? The benefits of the STC based system with a seasonal heat storage component included will be assessed in comparison to the same system without seasonal heat storage under several assumed loss coefficients for the storage component (sensitivity analysis). The hypothesis is that the seasonal storage component will lower the environmental impact.

(3) What is the relevance of the additional electricity required in the setup (amounting to 6% of overall energy consumed) and the supplemental biomass boiler (amounting to 26% of overall energy consumed) with respect to the overall environmental impact? The hypothesis is that the additional electricity and biomass required will amount to a sizable part of the overall environmental impact.

4 Goal and scope

The goal and scope definition of an LCA provides a description of the product system and its system boundaries, and a functional unit.

The district heating project that is the topic of this analysis is led by a cooperative comprising future household consumers and the local council. The project setup consists of a solar thermal collector field, a seasonal storage unit also called Pit Thermal Energy Storage (PTES), a heat pump which is using power from the grid, a buffer storage unit, a backup biomass combustion unit that if required can be used as an alternative source of heat (for the cases where there is no availability of heat from neither the solar collector nor the storage), and a distribution network for the customer households (see Figure 1). A receiver unit is installed in each participating household. There are at least 180 consumer households expected, which is roughly 60% of all households in the community.

The functional unit is 1 MegaJoule (MJ) of thermal energy provided to the consumer directly at the consumer site during the heating period. Using MJ instead of kilowatt-hours of thermal energy (kWh_{th}) ensures consistency with the UVEK processes for other forms of district heating in SimaPro that the comparison will be performed against.

The lifetime of the installation is assumed to be 50 years. The system diagram shown in Figure 2 describes the product system and its boundaries.

System deconstruction was modeled for the solar thermal collector field and the seasonal storage unit. Disposal (via municipal waste incineration) of the plastic material used for seasonal storage unit sealing and insulation was included in the modelling.
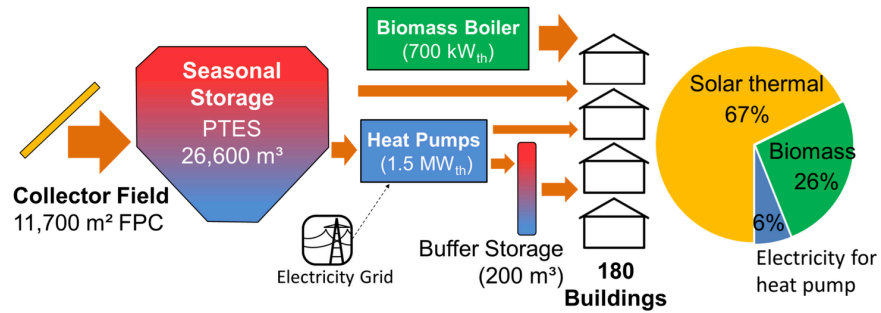
Figure 1: Overview of system setup for the Bracht district heating. Source: University of Kassel.
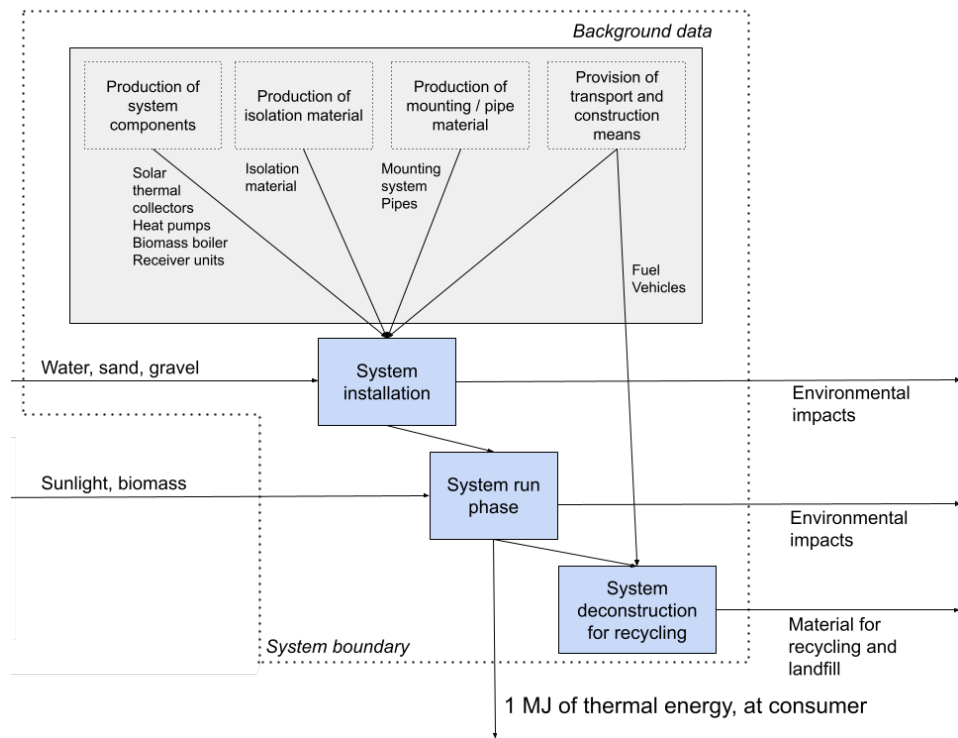

Figure 2: System diagram, with functional unit.

4

5 Life Cycle Inventory

There is a lot of information available on the project website by City of Rauschenberg (2025c). The website has been used as a resource to gather the life cycle inventory data for the five relevant components that are described in the following: solar thermal collector field, seasonal storage unit, heat preparation, distribution infrastructure, and consumer installations.

The planned lifetime for the Bracht plant is 50 years. The assumed individual component lifetimes and the resulting relevant multipliers are shown in Table 1. The assumed individual component lifetimes are in line with the assumptions used in Kelch et al. (2022).

Table 1

Component	Years	Multiplier	Source
Solar thermal collector	30	1.666667	(Große et al., 2017)
Seasonal storage unit	30	1.666667	(Kelch et al., 2022)
Heat pump	20	2.5	(Wolf, 2017)
Heat buffer storage	20	2.5	(Große et al., 2017)
Heat installation facility	50	1	(VDI, 2012)
Heat exchange station at consumer	20	2.5	(Kelch et al., 2022)
Heat transport network	50	1	(Kelch et al., 2022)

The detailed life cycle inventory information can be found in the supporting information appendix in Section 9.1.

5.1 Electrical power requirements and loss coefficient assumptions

Several estimations of annual collector output can be found in the relevant performance data from TÜV Rheinland (2021) for the solar thermal collectors used in this project. They are based on geographical location and on the desired output temperature. The geographically closest matching entry is 5283 kWh per collector per year for the Würzburg location and 75 degrees output. For the given 855 collectors this amounts to an estimated 4.517 MWh per year.

The Bracht documentation City of Rauschenberg (2025a) states that in total, 2.700 MWh per year are expected to reach consumer households. This means that the assumed loss coefficients for the storage unit and in the pipes together is estimated to amount to a significant factor of 40% loss. The electrical power that reaches consumer households is generated to 67% from what the solar thermal collectors generated for storage (2258 MWh), to 26% from biomass (904 MWh), and to 6% from the grid (209 MWh) using the percentage distribution given in Figure 1. There is no detailed information how the expected loss was estimated. However,

based on the published numbers and an assumed 20% loss coefficient in the pipes, the resulting expected loss in the seasonal storage unit can be calculated at 50%. These assumptions were used in the modelling. Further discussion of loss coefficients and a related sensitivity analysis can be found in Section 7.1.

6 Results

The results for comparing the solar thermal based district network heat it to other forms of district heating (DH) that are available in small communities such as wood chips (biomass), geothermal heat pump, and also to the usually available consumer side heating installations (CI) such as a oil or gas boiler are shown in Figure 3 and Figure 4.
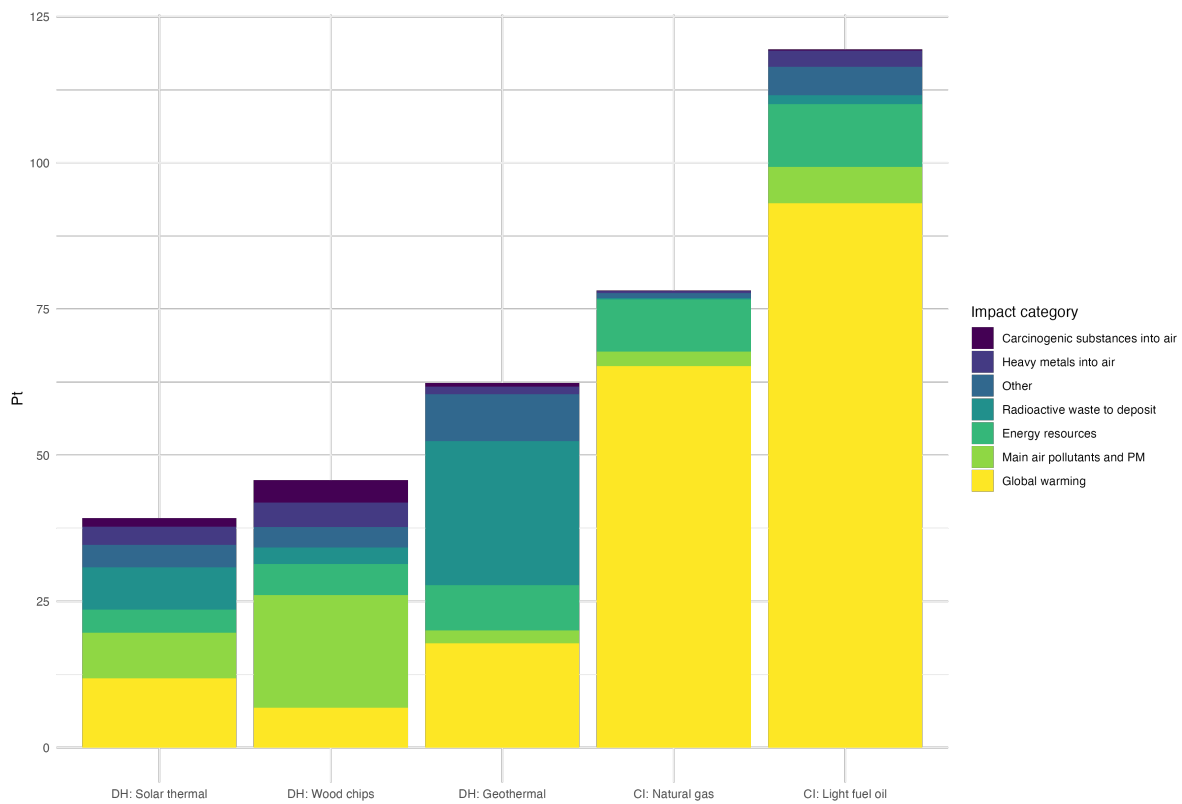
Figure 3: Comparison to other energy sources for district heating (wood chips, heatpump) and consumer installations (gas, oil), based on the Ecological Scarcity 2021 v1.04 method with UVEK LCI weighting set at the single score level.

The relative influence of the district heating system components can be seen in Figure 5. *TBD add for all midpoints (like for the lawns but with components instead of phases)*

Figure 4: Damage assessment using the Environmental Footprint Method, visualized as relative impacts in comparison.

Figure 5: Relative influence of the system components using the Ecological Scarcity 2021 v1.04 method with UVEK LCI weighting set at the single score level.

TBD expectation: heat storage should be 2x heat pump How much HDPE in kg? Compare with weight of heat pump

7 Discussion

As shown in Figure 3, the Bracht setup compares positively to other heating technologies in terms of environmental impact. Based on the analysis using the Ecological Scarcity 2021 v1.04 method with UVEK LCI weighting set, it shows a lower environmental impact compared to other relevant district heating setups and to fossil energy based consumer installations. The results visualize that the Bracht system fares better in the "Main air pollutants and Particulate Matter (PM)" category in comparison to a completely wood chips based energy source for district heating, while the impact from the biomass energy used in the Bracht system is still visible in the results. The geothermal based district heating would perform better if there wasn't as much radioactive waste to deposit. The gas and oil based customer installations compare the least well in the selection because of the high impacts in the global warming category.

Related results are shown in Figure 4 when looking at the Environmental Footprint Method. Again the wood chips based energy source for district heating fares worst in the particulate matter category. It is also returning the worst results for land use, euthrophication (marine and terrestrial), human toxicity (cancer), and photochemical ozone formation. The oil burner returns the worst results for acidification, climate change, freshwater ecotoxicity, human toxicity (non-cancer), and fossil resource use. The gas burner shows bad results for climate change and ozone depletion. The geothermal heat pump district heating is performing badly for euthrophication (freshwater) and for ionising radiation. The solar thermal based district heating returns the worst results for resource use (minerals and metals).

Figure 5 reveals that the environmental impact contribution of the seasonal heat storage unit are minimal. The only component that is listed is the Polystyrene from the floating cover of the seasonal heat storage unit, which amounts to 2% of the overall impact. The seasonal storage component lowers the environmental impact very significantly since it avoids using more heat from wood chips and electricity, which are the two biggest contributors to overall environmental impact. The plan for this research was to assess the impact of not using a seasonal storage component in the setup. However, the results shown in Figure 5 make it very clear that the seasonal storage component is essential for the overall system while its environmental impact is minimal. Therefore, the effects of not using a seasonal storage component in the setup were not analysed further.

The additional electricity and biomass required were expected to play a big role with respect to the overall environmental impact. But it is surprising to see that these two are the biggest contributors. The electricity use can not be avoided since it is required to run the heat pump. Its impact can be lowered by using green energy *TBD should it be assessed too? (It's clear that using green energy will make the results much better. Electricity modelling currently very*

simple, using "electricity mix, winter 2018/CH"). The opportunities and effects of using less biomass by lowering heat loss coefficients is assessed in detail in Section 7.1.

7.1 Loss coefficients and sensitivity analysis

Heat is harder to transport than electrical power since even good insulation cannot avoid losses of radiating heat. There are two main areas where heat losses occur in the setup: in the pipes, and in the seasonal storage unit. Therefore, the loss coefficients assumed for the pipes and for the storage unit are highly relevant to the modelling.

As summarized by Werner (2017), the relevant parameters affecting heat loss in the pipes are the length of the network which depends on the transmission distance relative to demand, the system age, and the operating temperature. The cited loss coefficient numbers for pipe loss range between 5% and 35%. The Bracht setup has a long transmission distance of 8800 meters because of the rural setup, and a planned operating temperature of 85 degrees Celsius. Both of these factors affect performance negatively. Therefore, even if the system is brand new and therefore modern, assuming a 20% heat loss is realistic. The open source modelling tool Energy Transition Model by Quintel (2025) suggests 15% as a sensible default for modelling heat loss in the pipes of modern district heating networks based on real world numbers. Note that in the comparison in Figure 3, the data for the other energy sources for district heating (wood chips, heatpump) used a 5% to 10% assumption which means that the solar thermal data with the 20% assumption is disadvantaged in the comparison.

If the heat loss in the Bracht pipes could be lowered to 10% by using a lower operating temperature, that would result in efficiency savings of 335 MWh per year which would in turn not require production from the biomass boiler. This is significant since it amounts to roughly one third of the energy coming from biomass. Figure 6 shows that this results in a reduction from 39 to 34 Ecopoints per MJ of district heat, which amounts to a 12% reduction. The main impact factor changed is in the "Main air pollutants and Particulate Matter (PM)" category.

Penttinen et al. (2021) report a 26% loss of heat production in the storage unit amounted to of heat production. The Energy Transition Model by Quintel (2025) suggests 30% as a sensible default for modelling heat loss in the storage unit. Xiang et al. (2022) provide a comprehensive review and find that 30% to 50% heat loss are common for Pit Thermal Energy Storage and that the majority of losses are caused by floating cover. The assumption for Bracht, which is 50% loss, seems to be on the conservative side. If it can be lowered to 30%, which seems feasible given the scientific results cited, that would cancel out the entirety of energy from biomass required. This would reduce the environmental impact from 39 to 26 Ecopoints per MJ of district heat, which is a reduction of 33%, as shown in Figure 7.
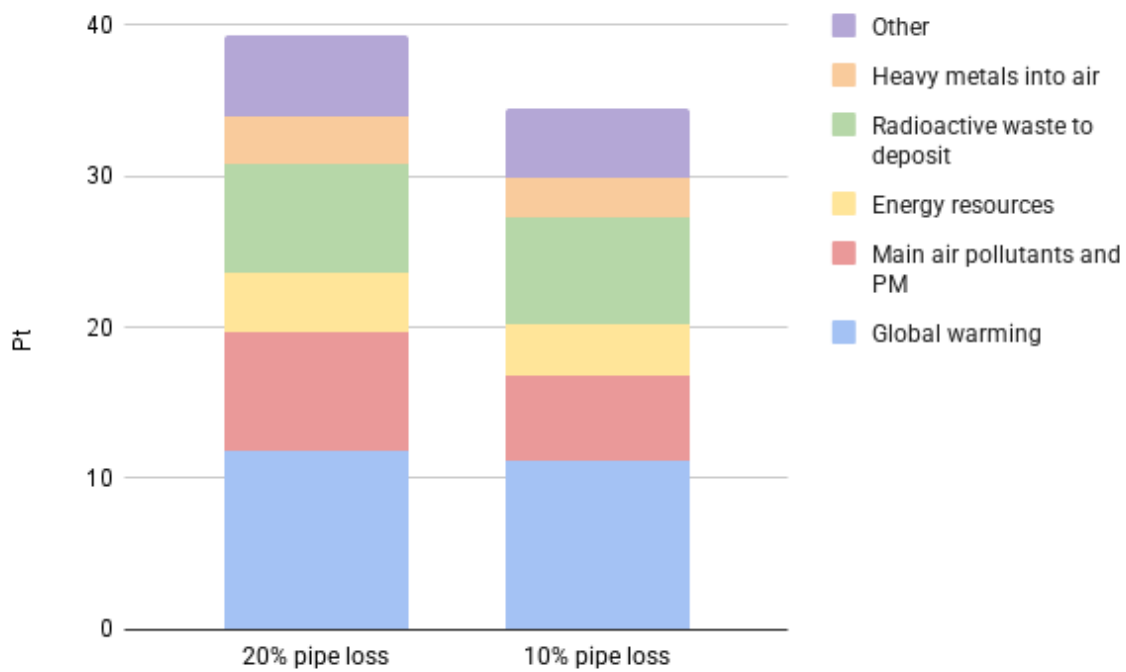
Figure 6: Potential savings when halfing heat loss in pipes.
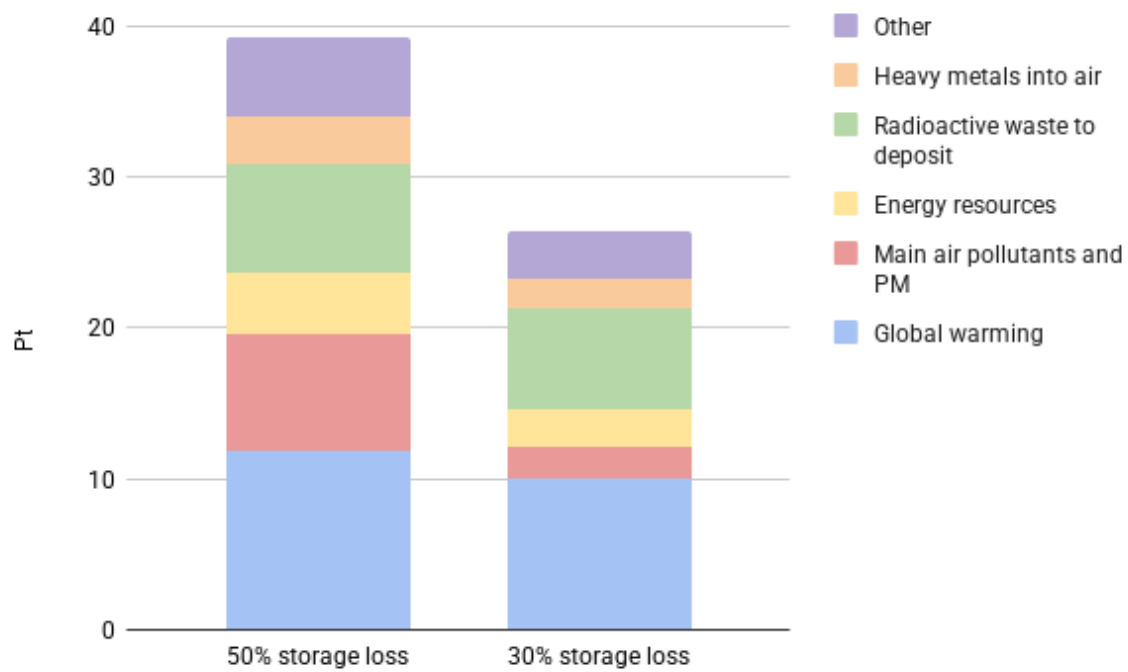
Figure 7: Potential savings when lowering heat loss in storage from 50% to 30%.

8 Conclusion

A case study life cycle assessment was performed for the solar district heating community project in Bracht, Rauschenberg, Germany. The results compare favorably to other heating technologies in terms of environmental impact. To further improve, the recommendations are (1) to consider a lower operating temperature for the system to achieve better overall efficiency through avoided heat losses, (2) to use green energy for running the heat pump, and (3) to lower or event completely remove the amount of biomass burnt by improving the heat loss coefficients for storage unit and transmission pipes.

9 Supporting information

This section documents the supporting information related to the life cycle inventory in Section 9.1, the exact data used for process modelling in SimaPro in Section 9.2, and the project organization in Section 9.3.

9.1 Life Cycle Inventory

There are several components described in the following sections: solar thermal collector, seasonal storage unit, and heat preparation.

9.1.1 Solar thermal collector

The relevant data for the solar thermal collector can be found in Table 2.

<div align="center">Table 2</div>

Dimension	Value	Source
Size	11'638 m^2 (855 x 13.6 m^2)	(Viessmann Climate Solutions, 2024)
Type	Flat-plate collectors Vitosol 100-F XF13 Viessmann	(Viessmann Climate Solutions, 2024) (Viessmann Climate Solutions, 2021) (TÜV Rheinland, 2021)
Land use	23.500 m^2	(Viessmann Climate Solutions, 2024)

Dimension	Value	Source
Mounting infrastructure material	15 t steel	(City of Rauschenberg, 2025c)
Collector weight	50 kg / m^2	Own assumption
Production country	China	Own assumption
Transport per container ship	8000 km	Own assumption
Transport per lorry	1000 km	Own assumption
Total transport km per container ship	(11638 m^2 * 50 kg / m^2 * 1.666667 + 15000 kg) / 1000 * 8000 km = 7'878'668 tkm	Calculation
Total transport km per lorry	(11638 m^2 * 50 kg / m^2 * 1.666667 + 15000 kg) / 1000 * 1000 km = 984'834 tkm	Calculation

9.1.2 Seasonal storage unit

The relevant data for the seasonal storage unit can be found in Table 3. A picture of the floating cover can be found in Figure 8.
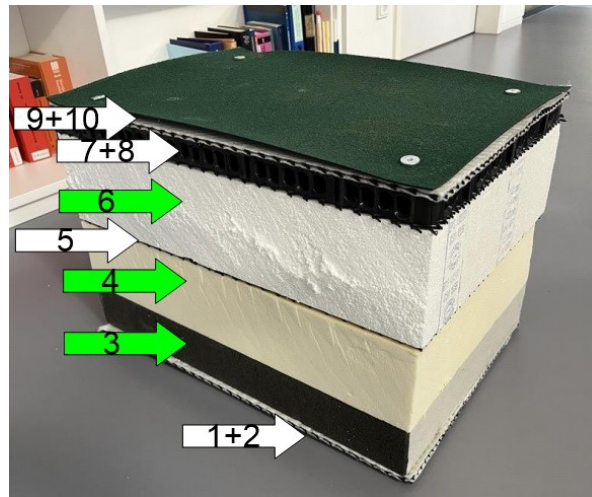
Figure 8: Floating cover profile. Source: Bracht community.

Table 3

Dimension	Value	Source
Volume	26'600 m^3	Figure 1

Dimension	Value	Source
Resource: water	26'600 m^3 filled from local source	(City of Rauschenberg, 2025b)
Cover: layer 1 and 10	Polyethylen (HDPE) sealing membranes 1.5 mm, 1.5 kg / m^2	(City of Rauschenberg, 2025b), weight own assumption
Cover: layer 2 and 9	Fleece (0.1 kg / m^2) laminated plastic grid (HDPE, 0.5 kg / m^2)	(City of Rauschenberg, 2025b), weight own assumption
Cover: layer 3	Foam glass, 8.33 kg / m^2	(City of Rauschenberg, 2025b)
Cover: layer 4	Polyurethane (bauder foam): 3.125 kg / m2	(City of Rauschenberg, 2025b)
Cover: layer 5, 7, 8	Airing gap made of plastic grid, 0.5 kg / m^2 each	(City of Rauschenberg, 2025b), weight own assumption
Cover: layer 6	Polystyrene (XPS), 3 kg / m^2	(City of Rauschenberg, 2025b)
Floating cover dimensions	70 m x 70 m = 4900 m^2	(Top Agrar, 2025)
Floating cover weight	2 * (1.5 + 0.1 + 0.5) + 8.33 + 3.125 + 1.5 + 3 = 20.155 kg / m^2	Calculation
Ground liner	Polyethylen (HDPE), 5 kg / m^2	(City of Rauschenberg, 2025b), weight own assumption
Ground liner dimensions	Bottom 20 m x 20 m, vertical height ca. 15 m, surface area on each of the four sides ca. 5250 m^2	(Top Agrar, 2025)
Ground liner weight	5 kg / m^2	Calculation
Production country	China	Own assumption
Transport per container ship	8000 km	Own assumption
Transport per lorry	1000 km	Own assumption

Dimension	Value	Source
Required construction process	Excavator 26.600 m^3	Own assumption
Total transport km per container ship	(((4900 m^2 * 16.905 kg / m^2) + (5400 m^2 * 5 kg / m^2)) * 1.666667) / 1000 * 8000 km = 1'464'460 tkm	Calculation
Total transport km per lorry	(((4900 m^2 * 16.905 kg / m^2) + (5400 m^2 * 5 kg / m^2)) * 1.666667) / 1000 * 1000 km = 183'058 tkm	Calculation

9.1.3 Heat preparation

The relevant data for the heat preparation unit can be found in Table 4.

Table 4

Dimension	Value	Source
Type of heat pump	2 Carrier Aquaforce 61XWH-ZE heat pump with 630 kW max electrical input power each	(Viessmann Climate Solutions, 2024) (Carrier Klimatisierungs- und Heizsysteme - Deutschland, 2025)
Electricity requirements	209 MWh per year	Own calculation, see Section 5.1 for details
Buffer storage	ca. 200 m^3 = 200'000 l	Figure 1
Biomass boiler	Mawera boiler with 700 kW thermal power	(Viessmann Climate Solutions, 2024)
Controller	Vitocontrol 200-M	(Viessmann Climate Solutions, 2024) (Viessmann Climate Solutions, 2025)
Heat installation facility	50 m^2	Own assumption

9.2 SimaPro Data

Table 5 and Table 6 show the parameters and calculated parameters that were defined as helpers for modelling the solar thermal based district heating process in Simpapro. The data for the process itself is shown in Figure 9.

Table 5

Name	Value	Comment
Plant-size-m2	23500	The total size of the plant in sqm
STC-size-m2	11638	The total size of the STC panels in sqm
STC-weight-per-m2	50	The weight of the STC per sqm
STC-prod-MWh-per-a	2700	Production from the STC per year in MWh
Lifetime	50	The lifetime of the plant
MWhtoMJ	3600	Conversion from MWh to MJ
Mult30To50	1.666666667	Multiplier for components with 30 years lifetime
Mult20To50	2.5	Multiplier for components with 20 years lifetime
SSU-volume-m3	26600	The volume of the SSU
SSU-top-m2	4900	The size of the SSU at the top (floating cover) in sqm
SSU-side-m2	5250	The size of the SSU at each of the four sides in sqm
SSU-bottom-m2	5400	The size of the SSU at the ground in sqm
Steel-kg	15000	The weight of the required steel for the STC foundation
Freight-ship-dist-km	8000	The transport distance per freight ship in km
Lorry-dist-km	1000	The transport distance per lorry in km

Table 6

Name	Value	Comment
STC-prod-MJ-lifetime	STC-prod-MWh-per-a * Lifetime * MWhtoMJ	The total production from the STC over the plant lifetime in MJ
STC-weight-t-total	(STC-size-m2 * STC-weight-per-m2 * Mult30To50 + Steel-kg) / 1000	The total transport weight of the STC over the plant lifetime in tons
SSU-ground-m2	SSU-bottom-m2 + 4 * SSU-side-m2	The total size of the SSU that is touching the ground on the bottom and sides in sqm

#	Name	Formula	Unit	Comment
1	**Products**			
2	district heat, at consumer, solar thermal, 1MW/MJ/DE U		1 MJ	
3	**Resources**			
4	Water, cooling, unspecified natural origin, DE	SSU_volume_m3/STC_prod_MJ_lifetime	m3	SSU
5	Land use II-III	Plant_size_m2a*Lifetime/STC_prod_MJ_lifetime	m2a	Total plant
6	**Materials/fuels**			
7	steel, electric, unalloyed, at plant/CH U	Steel_kg/STC_prod_MJ_lifetime	kg	STC
8	flat plate collector for PVT, aluminium copper absorber, at plant/CH/I U	(STC_size_m2*Mult30To50)/STC_prod_MJ_lifetime	m2	STC
9	transport, transoceanic freight ship/tkm/OCE U	(STC_weight_t_total * Freight_ship_dist_km)/STC_prod_MJ_lifetime	tkm	STC
10	transport, freight, lorry 40-50 metric ton, EURO 5/RER U	(STC_weight_t_total * Lorry_dist_km)/STC_prod_MJ_lifetime	tkm	STC
11	Polyethylene, HDPE, granulate, at plant/RER U	(SSU_top_m2*1.5*2*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 1 and 10: Sealing membrane
12	Polyethylene, HDPE, granulate, at plant/RER U	(SSU_top_m2*0.5*2*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 2 and 9: Plastic grid
13	Fleece, polyethylene, at plant/RER U	(SSU_top_m2*0.1*2*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 2 and 9: Fleece
14	Foam glass, at plant/RER U	(SSU_top_m2*8.33*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 3: Glapor
15	Polyurethane, rigid foam, at plant/RER U	(SSU_top_m2*3.125*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 4: Bauder Foam
16	Polyethylene, HDPE, granulate, at plant/RER U	(SSU_top_m2*0.5*3*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 5, 7, 8: Plastic grid
17	Polystyrene, extruded (XPS), at plant/RER U	(SSU_top_m2*3*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 6: XPS
18	Polyethylene, HDPE, granulate, at plant/RER U	(SSU_ground_m2)/STC_prod_MJ_lifetime	kg	SSU ground liner
19	transport, transoceanic freight ship/tkm/OCE U	((((SSU_top_m2*20.155) +(SSU_ground_m2*5))*Mult30To50)/1000 * Freight_ship_dist_km)/STC_prod_MJ_lifetime	tkm	SSU transport
20	transport, freight, lorry 40-50 metric ton, EURO 5/RER U	(((((SSU_top_m2*20.155) + (SSU_ground_m2*5))*Mult30To50)/1000 * Lorry_dist_km)/STC_prod_MJ_lifetime	tkm	SSU transport
21	excavation, hydraulic digger, average/m3/CH U	26600/STC_prod_MJ_lifetime	m3	SSU excavation
22	heat pump, brine-water, 50kW/RER/I U	(24*Mult20To50)/STC_prod_MJ_lifetime	p	HP heat pump
23	Heat storage 2000l, at plant/CH/I U	(100*Mult20To50)/STC_prod_MJ_lifetime	p	HP heat pump
24	Building, hall/CH/I U	50/STC_prod_MJ_lifetime	m2	HP building
25	heat, mixed chips from forest, at furnace 1000kW/MJ/CH U	(904*Lifetime)/STC_prod_MJ_lifetime	MWh	HP biomass, includes the furnace
26	Heat exchanger of Mini CHP plant/CH/I U	(180*Mult20To50)/STC_prod_MJ_lifetime	p	Distribution infrastructure
27	transport, district heat, large area network, for warm water/MJ/CH/I U	(STC_prod_MWh_per_a*Lifetime)/STC_prod_MJ_lifetime	MWh	Lifetime 30 years
28	**Electricity/heat**			
29	electricity, production mix ENTSO/kWh/ENTSO U	(209*Lifetime)/STC_prod_MJ_lifetime	MWh	
30	**Waste to treatment**			
31	deconstruction, average/CH U	(STC_weight_t_total*1000 + (((SSU_top_m2*16.905) +(SSU_bottom_m2*5))*Mult30To50))/STC_prod_MJ_lifetime	kg	
32	disposal, polyethylene, 0.4% water, to municipal incineration/kg/CH U	((SSU_top_m2*20.155 +SSU_ground_m2*5)*Mult30To50) / STC_prod_MJ_lifetime	kg	

Figure 9: SimaPro data excerpt.

9.3 Project organization

In this section, the time plan and the meeting notes are documented.

9.3.1 Time planning

Figure 10 documents the time plan that was followed for this project. The live version can be found here. Access is given upon request.
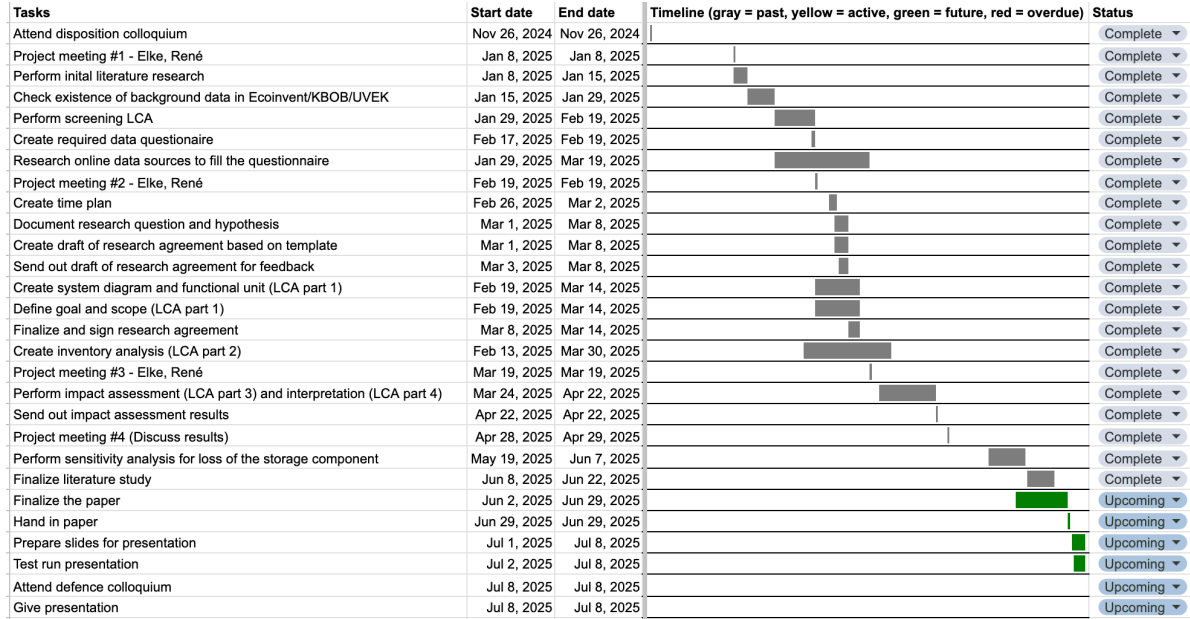
Tasks	Start date	End date	Timeline (gray = past, yellow = active, green = future, red = overdue)	Status
Attend disposition colloquium	Nov 26, 2024	Nov 26, 2024		Complete
Project meeting #1 - Elke, René	Jan 8, 2025	Jan 8, 2025		Complete
Perform inital literature research	Jan 8, 2025	Jan 15, 2025		Complete
Check existence of background data in Ecoinvent/KBOB/UVEK	Jan 15, 2025	Jan 29, 2025		Complete
Perform screening LCA	Jan 29, 2025	Feb 19, 2025		Complete
Create required data questionaire	Feb 17, 2025	Feb 19, 2025		Complete
Research online data sources to fill the questionnaire	Jan 29, 2025	Mar 19, 2025		Complete
Project meeting #2 - Elke, René	Feb 19, 2025	Feb 19, 2025		Complete
Create time plan	Feb 26, 2025	Mar 2, 2025		Complete
Document research question and hypothesis	Mar 1, 2025	Mar 8, 2025		Complete
Create draft of research agreement based on template	Mar 1, 2025	Mar 8, 2025		Complete
Send out draft of research agreement for feedback	Mar 3, 2025	Mar 8, 2025		Complete
Create system diagram and functional unit (LCA part 1)	Feb 19, 2025	Mar 14, 2025		Complete
Define goal and scope (LCA part 1)	Feb 19, 2025	Mar 14, 2025		Complete
Finalize and sign research agreement	Mar 8, 2025	Mar 14, 2025		Complete
Create inventory analysis (LCA part 2)	Feb 13, 2025	Mar 30, 2025		Complete
Project meeting #3 - Elke, René	Mar 19, 2025	Mar 19, 2025		Complete
Perform impact assessment (LCA part 3) and interpretation (LCA part 4)	Mar 24, 2025	Apr 22, 2025		Complete
Send out impact assessment results	Apr 22, 2025	Apr 22, 2025		Complete
Project meeting #4 (Discuss results)	Apr 28, 2025	Apr 29, 2025		Complete
Perform sensitivity analysis for loss of the storage component	May 19, 2025	Jun 7, 2025		Complete
Finalize literature study	Jun 8, 2025	Jun 22, 2025		Complete
Finalize the paper	Jun 2, 2025	Jun 29, 2025		Upcoming
Hand in paper	Jun 29, 2025	Jun 29, 2025		Upcoming
Prepare slides for presentation	Jul 1, 2025	Jul 8, 2025		Upcoming
Test run presentation	Jul 2, 2025	Jul 8, 2025		Upcoming
Attend defence colloquium	Jul 8, 2025	Jul 8, 2025		Upcoming
Give presentation	Jul 8, 2025	Jul 8, 2025		Upcoming

Figure 10: Gantt chart used for time planning.

9.3.2 Meeting notes

The notes for the meetings can be found here. Access is given upon request.

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