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 [1]. 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 centers [2], 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 [1]. Process heating uses a similar setup but is targeted at industrial purposes, which usually require higher heat temperature. Studies like [3] have shown that using a centralized heating component together with heat transport pipes to reach participating consumers has lower environmental impact compared to standalone heating component for each consumers.

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 [4]. According to [5], 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 [5]. 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 [1]). 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 [6] and Marseille [7]. LCA, in particular the ReCiPe method, has been used to assess the environmental impact of different STC powered district heating configurations by [8]. The outcome was that larger systems that serve many households have a lower environmental impact per energy unit served.

In [9], the authors 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 [10], 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 [11] and from the UVEK LCI database version DQRv2:2025 database [12]. Environmental impacts are assessed using the mid-point level Environmental Footprint (EF) method [13], and the Ecological Scarcity 2021 v1.04 method [14] at the single score level with UVEK LCI weighting set. The LCIA is performed using the SimaPro 9.6.0.1 software [15].

The research questions are formulated as follows:

(1) 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.

(2) 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.

(3) What is the environmental impact contribution of the seasonal heat storage unit in the production, construction, and use stages in the life cycle? A sensitivity analysis will be performance to assess the benefits of the STC based system with a seasonal heat storage component included under several assumed loss coefficients for the storage component and the transport pipes system. The hypothesis is that the seasonal storage component will lower the 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.
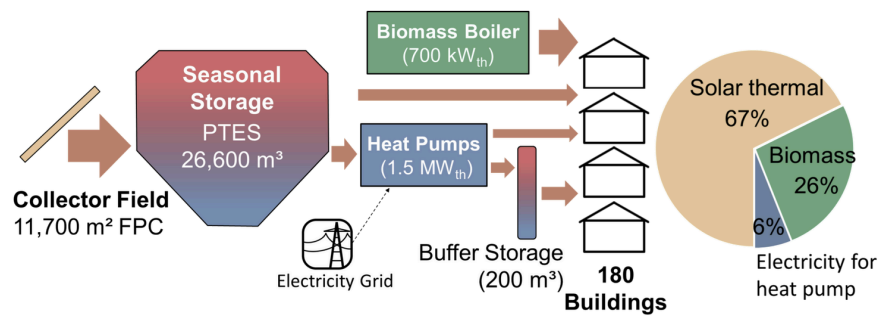

Figure 1: System overview for the Bracht community district heating network. (Source: University of Kassel)

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The functional unit is defined to be 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.
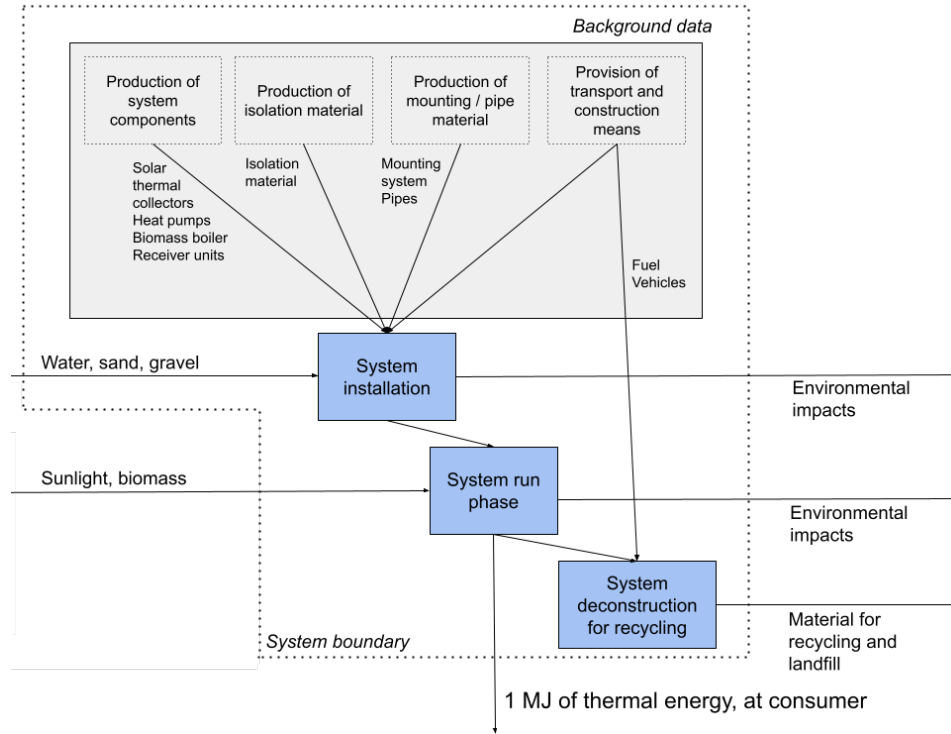

Figure 2: System diagram for the Bracht community district heating network, with functional unit as stated.

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.

5 Life Cycle Inventory

There is a lot of information available on the project website [16], which has been used as the source for detailed life cycle inventory information for solar thermal collector field, seasonal storage unit, and heat preparation (heat pump, buffer storage, installation facility, and

consumer installations) can be found in the supporting information appendix in Section 9.1. The heat transport network was modeled based on existing UVEK LCI data. The modelling default electricity source was chosen to be the European Network of Transmission System Operators for Electricity (ENTSO-E) production mix [12], aiming to make the model representative for a plant located in the European region.

The remainder of this section describes the assumptions for component lifetimes, electricity requirements and loss coefficients.

5.1 Component lifetimes

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 [17].

Table 1

Component	Years	Multiplier	Source
Solar thermal collector	30	1.67	[18]
Seasonal storage unit	30	1.67	[17]
Heat pump	20	2.5	[19]
Heat buffer storage	20	2.5	[18]
Heat installation facility	50	1	[20]
Heat exchange station at consumer	20	2.5	[17]
Heat transport network	50	1	[17]

5.2 Electrical power requirements and loss coefficient assumptions

Several estimations of annual collector output can be found in the relevant performance data from [21] 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 5.283 kWh per collector per year for the Würzburg location and 75 degrees output. For the given 855 collectors, this leads to an estimate of 4.517 MWh per year.

The Bracht documentation [22] 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 is generated to 67% from the solar thermal collectors and stored (2.258 MWh), to 26% from biomass (904 MWh), and to 6% from the grid (209 MWh). This is the percentage distribution included 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 7.3.

6 Results

For answering the first research question about the relative environmental impact of the additional electricity and the supplemental biomass boiler, the influence of the different components of the solar thermal district heating system on environmental impact was assessed using the Ecological Scarcity 2021 v1.04 method at the single score level with UVEK LCI weighting set.
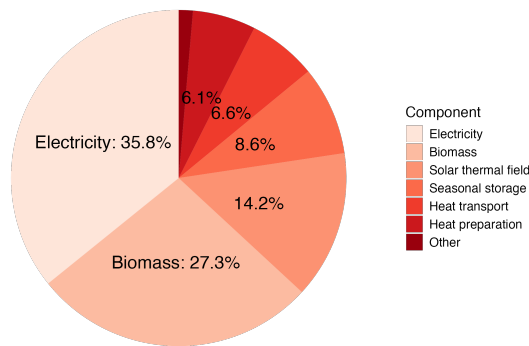

Figure 3: Relative environmental impact of Bracht community district heating network system components using the Ecological Scarcity 2021 v1.04 method at the single score level, using the UVEK LCI weighting set.

The results are shown in Figure 3. While the solar thermal collectors contribute two thirds of the energy production (see Figure 1), their relative environmental impact amounts to less than 15%. The biomass and electricity (ENTSO-E production mix as discussed in Section 5) required in the setup for one third of the energy production contribute two thirds of the environmental impact. This is the combined environmental impact based on the UVEK LCI weighting for the relative importance of the damage categories.

For further detail on the damage categories involved, Figure 4 provides the results for the most relevant damage categories *Climate change*, *Particulate matter*, *Eutrophication, marine*, *Land use*, *Resource use, minerals and metals* and *Resource use, fossils*, as individual results in each category without the weighing provided by UVEK. It reveals that the biomass required

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in the setup is the dominant influence in the damage categories land use, particulate matter (PM), and marine eutrophication. Electricity dominates the impact for fossil resource use and climate change. The resource use is most heavily influenced by heat preparation and the solar thermal collectors. The seasonal storage unit impacts climate change and fossil resource use.
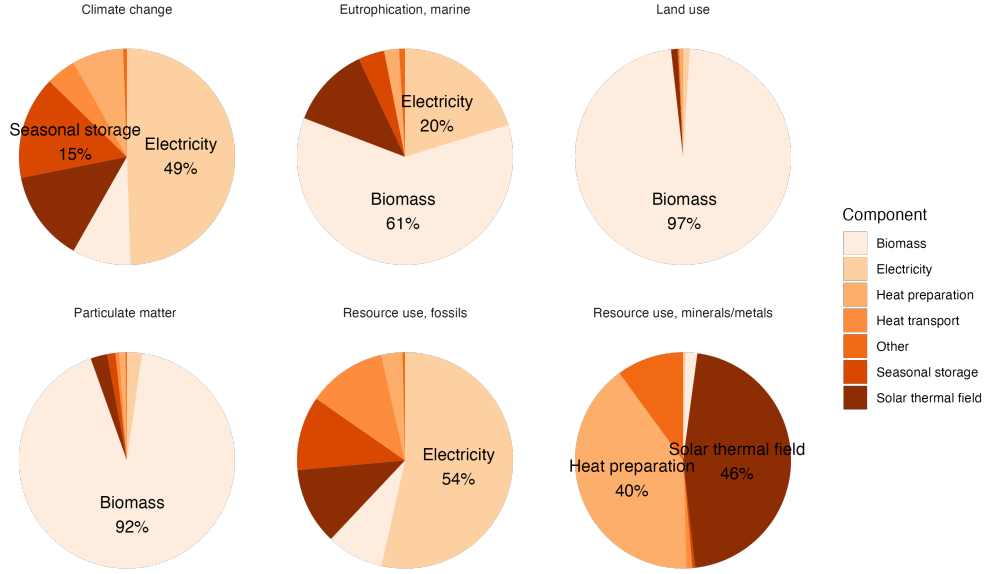

Figure 4: Relative environmental impact of Bracht community district heating network system components using the Environmental Footprint Method

To summarize, the electricity and biomass required to power and supplement the system play the dominant roles with respect to the overall environmental impact.

The electricity use is not avoidable since it is required by the heat pump. Its impact can be lowered by using green energy, which will be investigated in Section 7.2. The opportunities and effects of using less biomass by lowering heat loss coefficients are assessed in Section 7.3.

To address the second research question, a comparison of the environmental impact of the heat generated from the STC based district heating system with seasonal heat storage to other heating technologies is performed. Figure 5 shows the results for comparing the environmental impacts of solar thermal based district network heat to other forms of district heating (DH) available in small communities with energy sources such as wood chips (biomass) or geothermal heat pump, and to the usually available consumer side heating installations (CI) such as a oil or gas boiler. This was assessed using the Ecological Scarcity 2021 v1.04 method at the single score level with UVEK LCI weighting set. The results are shown in environmental impact points (Pt) per kilowatt-hour (kWh) of heat.

The result is that the heat produced by the Bracht plant with 170 Pt per kWh of heat shows the second lowest environmental impact compared to the other heating technologies. The
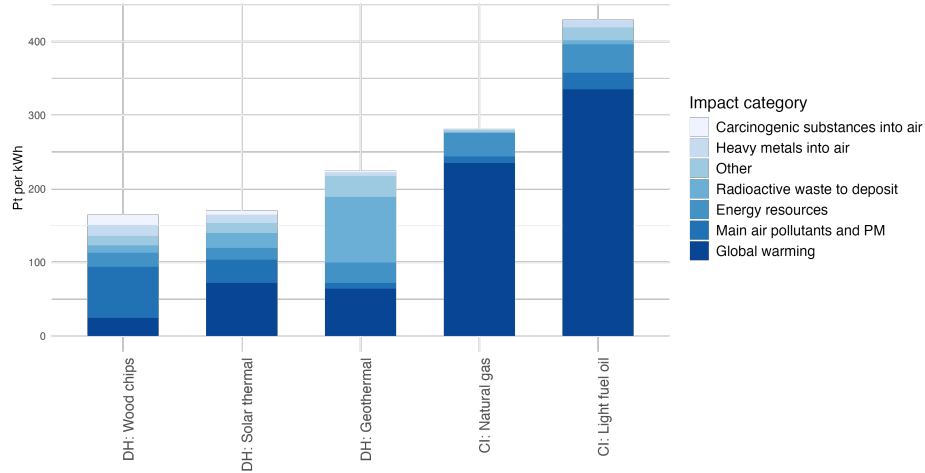
Figure 5: Comparison of environmental impact of Bracht community district heating network to other energy sources for district heating (wood chips, heat pump), and to other types consumer installations (gas, oil). This analysis is based on the Ecological Scarcity 2021 v1.04 method at the single score level, with UVEK LCI weighting set.

largest contributor is the "Global warming" category, dominantly caused by the electricity required (ENTSO-E production mix as discussed in Section 5) and to a lesser extent by the seasonal storage unit and the solar thermal collectors (cf. Figure 4).

The lowest environmental impact with 165 Pt per kWh of heat is returned for the district heating system based on wood chips as the energy source, even with the impact on main air pollutants and particulate matter (PM) having a significant impact on the overall results for this setup. The district heating system based on a geothermal heat pump as the energy source has the third lowest impact with 225 Pt per kWh of heat, to the largest extent from impact on radioactive waste to deposit. Oil and gas based consumer installations fare worse with 430 Pt and 281 Pt per kWh of heat, dominantly from impact on climate change.

As before, Figure 6 provides the individual results for the most relevant damage categories. These are compared against each other, where the highest result in each damage category is shown as longest bar with 100% relative impact. The analysis confirms the numbers from Figure 5, again demonstrating that oil and gas boilers have extremely large impacts in the damage category climate change, which is equivalent to global warming in the Ecological Scarcity method, with 100% and 70%, respectively. It also reveals that oil and gas boilers have the highest fossil resource use with 100% and 80% The district heating network with wood chips as the energy source has the relative worst impact in three categories: marine eutrophication, land use, and particulate matter (PM). While the latter has a sizable impact that was visible already in Figure 5, the former two exhibit no significant effects in the single score results. The district heating systems with solar thermal based and geothermal energy source return the highest amounts of metal and minerals resource use with 100% and 83%.
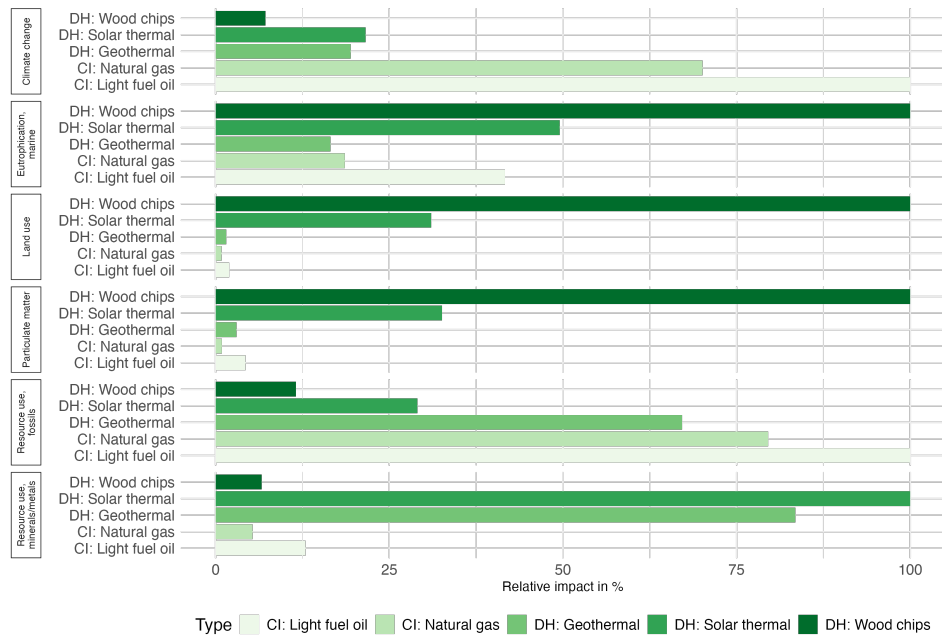
Figure 6: Damage assessment using the Environmental Footprint Method, visualized as relative environmental impacts in comparison.

7 Interpretation and discussion

This chapter discusses the results introduced in Section 6. They revealed that the district heating system based on solar thermal energy and seasonal storage compares favorably to other means of heating. However, in the given modelling, with limitations as documented in Section 7.1, it exhibits higher environmental impact compared to the district heating system based on wood chips as the energy sources. The electricity and the supplemental biomass required were found to be the two top single contributors to the overall results. To understand the saving potential from using less or lower-emitting energy resources, sensitivity analyses for source of electricity (see Section 7.2) and loss coefficients for the heat loss in the seasonal storage unit and the transport pipes (see third research question and Section 7.3) will be presented.

7.1 Modeling limitations

The detailed data of the SimaPro process named *district heat, at consumer, solar thermal, 1MW/MJ/RER U* that was defined for this analysis can be found in Figure 8.

The UVEK data for the other energy sources for district heating (wood chips, heat pump) used a 5% to 10% assumption which means that the solar thermal data with the 20% assumption as described in Section 5.2 is disadvantaged in the comparison in Figure 5. The effect of these assumptions on the results will be investigated in Section 7.3.

Data availability was generally satisfactory with one notable exception for the modelling of the heat pumps used in the system (see Section 9.1.3 for specifications). There are two heat pumps with 630 kW max electrical input power each used in the system, but in the UVEK data, the largest sized heat pump available has a maximum of 50 kW power. The best possible assumption in this situation was that the two large heat pump have the same impact as 25 units of the 50 kW heat pump, but this is likely leading an overestimation of the resource use for minerals and metals. This is acceptable since with 6.1 %, the heat preparation system which includes the heat pump showed only minor impact on the overall results (see Figure 3).

Worth mentioning is that the UVEK data for the transport system district heat has a lifetime assumption of 30 years whereas the Bracht setup assumes 50 years. This is acceptable since with 6.6 %, the heat transport system showed only minor impact on the overall results (see Figure 3).

7.2 Sensitivity analysis: Source of electricity

This is an additionally performed analysis for the first research question

- Winter electricity
- Future production mix (to plan ahead)

TBD: Add results for a couple of different electricity sources

7.3 Sensitivity analysis: Loss coefficients

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 in [23], 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 [24] suggests 15% as a sensible default for modelling heat loss in the pipes of modern district heating networks based on real world numbers.

TBD: Add results for lower loss in pipes and lower loss in SSU

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 (STC)

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

Table 2

Dimension	Value	Source
Size	11'638 m^2 (855 x 13.6 m^2)	[25]
Type	Flat-plate collectors Vitosol 100-F XF13 Viessmann	[25] [26] [21]
Land use	23.500 m^2	[25]
Mounting infrastructure material	15 t steel	[16]
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

9.1.2 Seasonal storage unit (SSU)

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 7.

Table 3

Dimension	Value	Source
Volume	26'600 m^3	Figure 1
Resource: water	26'600 m^3 filled from local source	[27]
Cover layer 1, 10	Polyethylen (HDPE) sealing membranes 1.5 mm, 1.5 kg / m^2	[27], estimated weight
Cover layer 2, 9	Fleece (0.1 kg / m^2) laminated plastic grid (HDPE, 0.5 kg / m^2)	[27], estimated weight
Cover layer 3	Foam glass, 8.33 kg / m^2	[27]

Dimension	Value	Source
Cover layer 4	Polyurethane (bauder foam): 3.125 kg / $m2$	[27]
Cover layer 5, 7, 8	Airing gap made of plastic grid, 0.5 kg / m^2 each	[27], estimated weight
Cover layer 6	Polystyrene (XPS), 3 kg / m^2	[27]
Floating cover dimensions	70 m x 70 m = 4900 m^2	[28]
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), 2.5mm, 2.5 kg / m^2	[27], estimated weight
Ground liner dimensions	Bottom 20 m x 20 m, vertical height 15 m, surface area on each of the four sides 5250 m^2	[28]
Ground liner weight	2.5 kg / m^2	Assumption
Production country	China	Assumption
Transport per container ship	8000 km	Assumption
Transport per lorry	1000 km	Assumption
Required construction process	Excavator 26.600 m^3	Figure 1

9.1.3 Heat preparation (HP)

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

Table 4

Dimension	Value	Source
Heat pump	2x Carrier Aquaforce 61XWH-ZE (630 kW max electrical input power)	[25] [29]
Electricity requirements	209 MWh per year	Own calculation, see Section 5.2
Buffer storage	ca. 200 m^3 = 200'000 l	Figure 1
Biomass boiler	Mawera boiler with 700 kW thermal power	[25]
Controller	Vitocontrol 200-M	[25] [30]
Heat installation facility	50 m^2	Own assumption
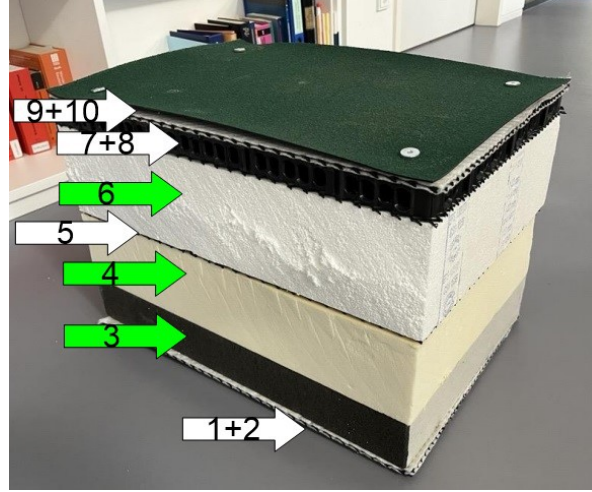
Figure 7: Floating cover profile. Source: Bracht community.

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 8.

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 in years
MWhtoMJ	3600	Conversion from MWh to MJ
Mult30To50	1.67	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

14

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

1	Products			
2	district heat, at consumer, solar thermal, 1MW/MJ/RER U		1	MJ
3				
4	Resources			
5	Water, cooling, unspecified natural origin, DE	SSU_volume_m3/STC_prod_MJ_lifetime	m3	SSU
6	Land use II-III	Plant_size_m2*Lifetime/STC_prod_MJ_lifetime	m2a	Total plant
7				
8	Materials/fuels			
9	steel, electric, unalloyed, at plant/CH U	Steel_kg/STC_prod_MJ_lifetime	kg	STC
10	flat plate collector for PVT, aluminium copper absorber, at plant/CH/I U	(STC_size_m2*Mult30To50)/STC_prod_MJ_lifetime	m2	STC
11	transport, transoceanic freight ship/tkm/OCE U	(STC_weight_t_total * Freight_ship_dist_km)/STC_prod_MJ_lifetime	tkm	STC
12	transport, freight, lorry 40-50 metric ton, EURO 5/RER U	(STC_weight_t_total * Lorry_dist_km)/STC_prod_MJ_lifetime	tkm	STC
13	Polyethylene, HDPE, granulate, at plant/RER U	(SSU_top_m2*1.5*2*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 1, 10: Sealing membrane
14	Polyethylene, HDPE, granulate, at plant/RER U	(SSU_top_m2*0.5*2*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 2, 9: Plastic grid
15	Fleece, polyethylene, at plant/RER U	(SSU_top_m2*0.1*2*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 2, 9: Fleece
16	Foam glass, at plant/RER U	(SSU_top_m2*8.33*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 3: Glapor
17	Polyurethane, rigid foam, at plant/RER U	(SSU_top_m2*3.125*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 4: Bauder Foam
18	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
19	Polystyrene, extruded (XPS), at plant/RER U	(SSU_top_m2*3*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU layer 6: XPS
20	Polyethylene, HDPE, granulate, at plant/RER U	((SSU_ground_m2)*2.5*Mult30To50)/STC_prod_MJ_lifetime	kg	SSU ground liner
21	transport, transoceanic freight ship/tkm/OCE U	((((SSU_top_m2*20.155) +(SSU_ground_m2*2.5))*Mult30To50)/1000 * Freight_ship_dist_km)/STC_prod_MJ_lifetime	tkm	SSU transport
22	transport, freight, lorry 40-50 metric ton, EURO 5/RER U	((((SSU_top_m2*20.155) + (SSU_ground_m2*2.5))*Mult30To50)/1000 * Lorry_dist_km)/STC_prod_MJ_lifetime	tkm	SSU transport
23	excavation, hydraulic digger, average/m3/CH U	26600/STC_prod_MJ_lifetime	m3	SSU excavation
24	heat pump, brine-water, 50kW/RER/I U	(25*Mult20To50)/STC_prod_MJ_lifetime	p	HP heat pump
25	Heat storage 2000l, at plant/CH/I U	(100*Mult20To50)/STC_prod_MJ_lifetime	p	HP heat pump
26	Building, hall/CH/I U	50/STC_prod_MJ_lifetime	m2	HP building
27	Heat exchanger of Mini CHP plant/CH/I U	(180*Mult20To50)/STC_prod_MJ_lifetime	p	Distribution infrastructure
28	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
29				
30	Electricity/heat			
31	electricity, production mix ENTSO/kWh/ENTSO U	(209*Lifetime)/STC_prod_MJ_lifetime	MWh	
32	heat, mixed chips from forest, at furnace 1000kW/MJ/CH U	(904*Lifetime)/STC_prod_MJ_lifetime	MWh	
33				
34	Waste to treatment			
35	deconstruction, average/CH U	(STC_weight_t_total*1000 + (((SSU_top_m2*20.155) +(SSU_bottom_m2*2.5))*Mult30To50))/STC_prod_MJ_lifetime	kg	
36	disposal, polyethylene, 0.4% water, to municipal incineration/kg/CH U	((SSU_top_m2*5.5 +SSU_ground_m2*2.5)*Mult30To50) / STC_prod_MJ_lifetime	kg	
37	disposal, polyurethane, 0.2% water, to municipal incineration/kg/CH U	((SSU_top_m2*3.125)*Mult30To50) / STC_prod_MJ_lifetime	kg	
38	disposal, polystyrene, 0.2% water, to municipal incineration/kg/CH U	((SSU_top_m2*3)*Mult30To50) / STC_prod_MJ_lifetime	kg	

Figure 8: 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 9 documents the time plan that was followed for this project. The live version can be found here. Access is given upon request.
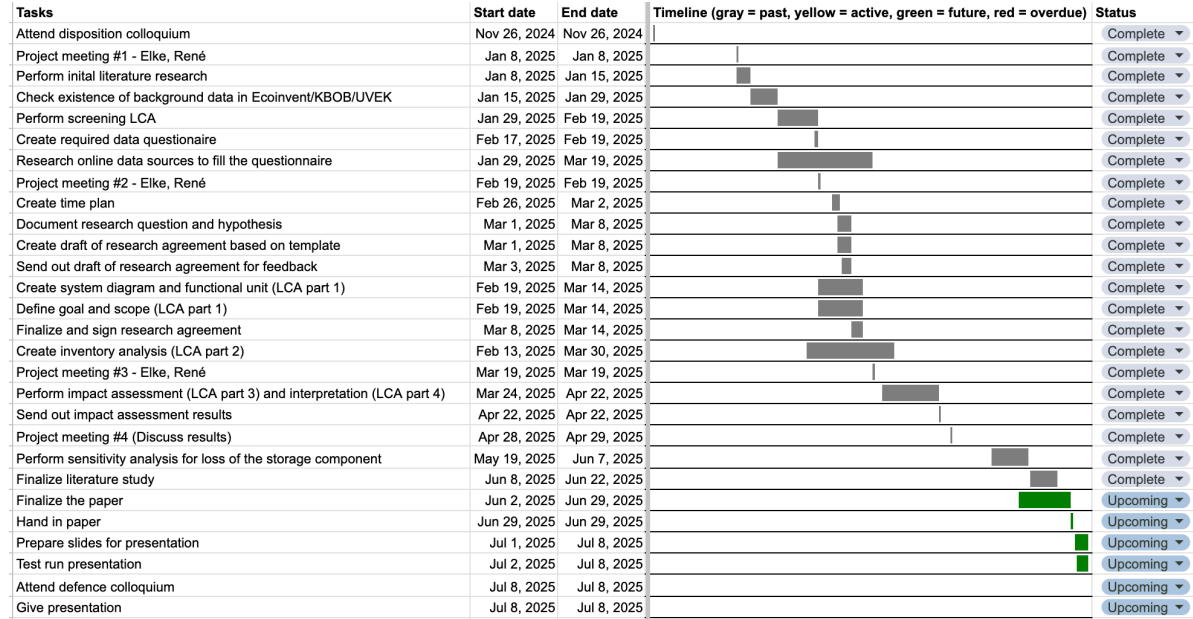
Tasks	Start date	End date	Timeline (gray = past, yellow = active, green = future, red = overdue)	Status
Attend disposition colloquium	Nov 26, 2024	Nov 26, 2024		Complete ▾
Project meeting #1 - Elke, René	Jan 8, 2025	Jan 8, 2025		Complete ▾
Perform inital literature research	Jan 8, 2025	Jan 15, 2025		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 9: 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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