

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 [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 LCIA 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.

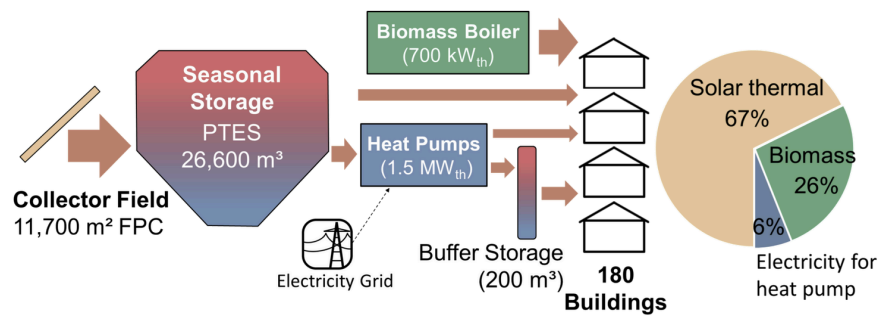


Figure 1: System overview for the Bracht community district heating network. (Source: University of Kassel)

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.

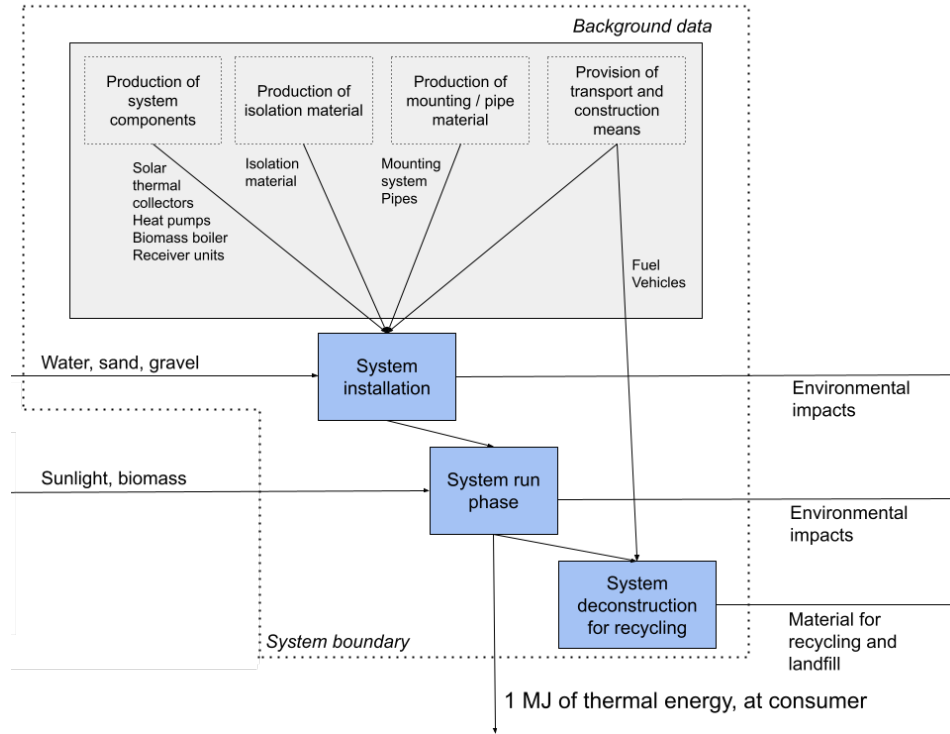


Figure 2: System diagram for the Bracht community district heating network, with functional unit as stated.

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 (LCI)

This section outlines the foundational data used to support system modelling. Extensive project-related information for the Bracht community district heating system is available on the project website ([16]). This was used extensively as a key source for detailed LCI data.

It provided detailed data on the solar thermal collector field, the seasonal storage unit, and heat preparation systems comprising the heat pump, buffer storage, installation facility, and consumer installations.

The comparison datasets and the heat transport network were modelled based on UVEK LCI data [12], an existing resource for conducting LCIA of energy systems and infrastructure within Switzerland and the broader European context provided by the Swiss Federal Office of Energy (abbreviated in English as SFOE, and in German as UVEK). For electricity input, the modelling assumed the ENTSO-E (European Network of Transmission System Operators for Electricity) production mix also provided by the UVEK dataset to ensure the model reflects conditions typical of a plant operating within the European region.

Additional LCI details for all components are provided in the Supporting Information appendix (Section 9.1). Further specifications and parameters of the resulting system model are described in section Section 9.2. The remainder of this section outlines the key assumptions regarding component lifetimes, expected electricity demand, and thermal 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 collectors | 30 | 1.67 | [18] |
| Seasonal storage unit | 30 | 1.67 | [17] |
| Heat pumps | 20 | 2.5 | [19] |
| Heat buffer storage | 20 | 2.5 | [18] |
| Heat installation facility | 50 | 1 | [20] |
| Heat exchange stations at consumer | 20 | 2.5 | [17] |
| Heat transport network | 50 | 1 | [17] |

5.2 Electrical power requirements and loss coefficient assumptions

Performance data from [21] provides several estimates of the annual output for the solar thermal collectors used in this project. These estimates vary by geographic location and desired output temperature. The most geographically relevant data point is for Würzburg, with an output of 5.283 kWh per collector per year at a target output temperature of 75 °C.

Given a total of 855 collectors, the estimated gross thermal energy production is approximately 4.517 MWh per year.

According to the project documentation [22], 2.700 MWh per year are expected to reach end-user households. This implies a total system loss of approximately 40%, accounting for thermal losses in the storage unit and distribution piping.

The energy distribution for heating supply is reported in Figure 1 as follows:

- 67 % from stored solar thermal energy (approximately 2.258 MWh),
- 26 % from biomass sources (904 MWh), and *. 6 % from the electricity grid (209 MWh).

While detailed methods for estimating losses are not provided in the documentation, the modelling assumes a 20% loss coefficient for the pipe network. This estimate was chosen based on an initial literature study and previous experience. Given this assumption, the implied thermal loss within the seasonal storage unit would be approximately 50% to align with the reported figures from [22]. These assumptions were incorporated into the system model as the default values. A more detailed discussion of thermal loss coefficients and their influence on system performance is presented in the sensitivity analysis in Section 7.3.

6 Results

The system model, as detailed in Section 9.2, was implemented using SimaPro version 9.6.0.1 ([15]). This model served as the foundation for generating LCIA results using two established methodologies: the Environmental Footprint (EF) method ([13]) and the Ecological Scarcity 2021 v1.04 method ([14]). The corresponding results derived from these assessments are presented in this section.

To address the first research question regarding the environmental impact of the additional electricity and the supplemental biomass burnt in the wood boiler, the relative influence of the individual components of the solar thermal district heating system on overall environmental impact was evaluated using the Ecological Scarcity 2021 (version 1.04) method. The assessment was conducted at the single-score level, applying the UVEK LCI weighting set to define the relative importance of the different damage categories. The results are presented in Figure 3.

Although the solar thermal collectors account for two-thirds of the total energy production (see Figure 1), their relative contribution to the overall environmental impact is less than 15%. In contrast, the biomass and electricity sourced from the ENTSO-E production mix (as described in Section 5) supply only one-third of the energy delivered to end consumers, but are responsible for approximately two-thirds of the environmental impact.

For a more detailed view of the environmental impact by individual damage categories, Figure 4 presents the drilled-down individual results for the most relevant impact categories *Climate change*, *Particulate matter*, *Eutrophication (marine)*, *Land use*, *Resource use*

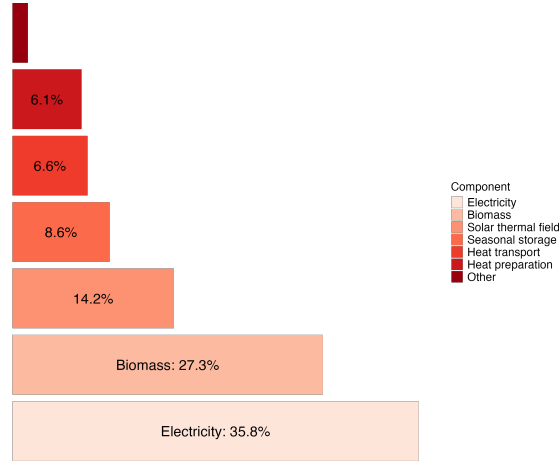


Figure 3: Relative environmental impact of Bracht community district heating system components (Ecological Scarcity 2021, v1.04, UVEK LCI weighting)

(*minerals and metals*), and *Resource use (fossils)*. The figure shows that biomass combustion is the dominant contributor to Land use, Particulate matter, and Marine eutrophication. In contrast, electricity use is the primary driver of impacts in *Fossil resource use* and *Climate change*. The environmental impact in the *Minerals and metals resource use* category is most significantly influenced by heat preparation and the solar thermal collectors. The seasonal storage unit contributes notably to the *Climate change* category.

In summary, electricity and biomass used to operate and supplement the system are the primary contributors to the overall environmental impact. Electricity consumption is unavoidable due to the operation of the heat pump. However, its impact can potentially be mitigated by sourcing electricity from renewable sources, an option explored in more detail in Section 7.2. Strategies to reduce biomass consumption by improving thermal efficiency, such as lowering heat loss coefficients, are examined in Section 7.3.

To address the second research question, the environmental impact of heat generated by the solar thermal collector based district heating system with seasonal heat storage was compared to that of other heating technologies. The results, presented in Figure 5, show a comparison of the environmental impacts of STC-based district heating with other district heating (DH) options commonly available in small communities, such as systems powered by wood chips (biomass) or geothermal heat pumps. Additionally, the analysis includes consumer-side heating installations (CI), such as oil and gas boilers. The assessment was conducted using the Ecological Scarcity 2021 (v1.04) method at the single-score level, applying the UVEK LCI weighting set. Results are expressed in environmental impact points (Pt) per kilowatt-hour (kWh) of heat delivered.

The result is that the heat produced by the Bracht plant with 170 Pt per kWh of heat shows

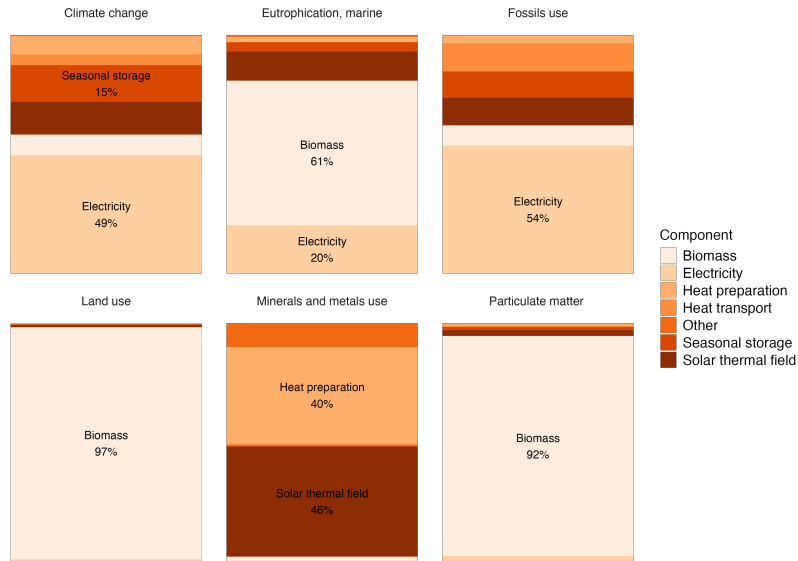


Figure 4: Relative environmental impact of Bracht community district heating network system components (Environmental Footprint Method)

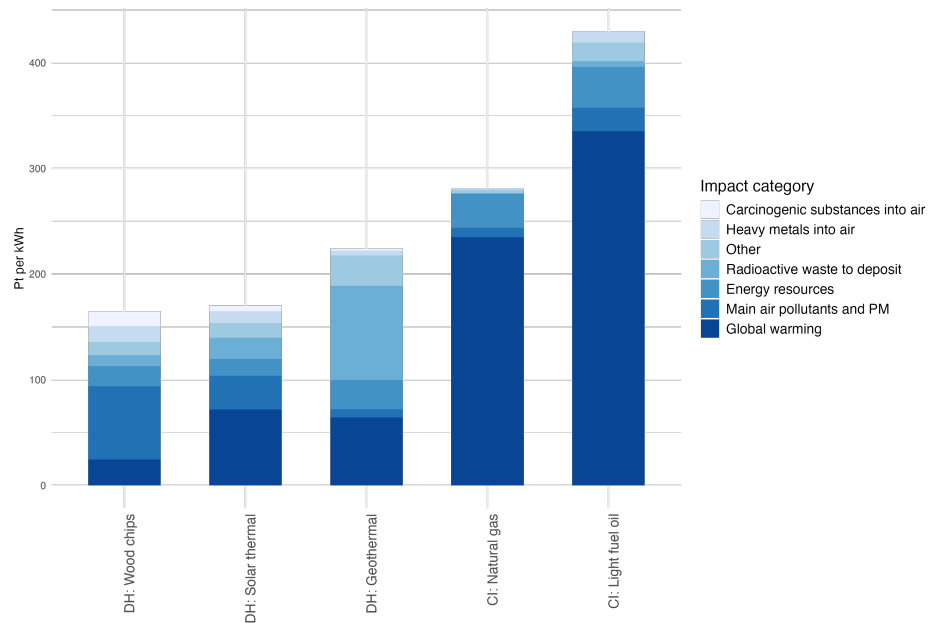


Figure 5: Comparison of environmental impact of Bracht community district heating network to other energy sources for district heating such as wood chips and heat pump, and to consumer installations such as gas and oil burners (Ecological Scarcity 2021, v1.04, UVEK LCI weighting)

the second lowest environmental impact compared to the other heating technologies. The 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 results indicate that heat produced by the Bracht plant, with an environmental impact of approximately 170 Pt per kilowatt-hour, exhibits the second lowest impact among the heating technologies assessed. The dominant contributor to this impact is the *Global warming* category, primarily driven by electricity consumption, based on the ENTSO-E production mix as detailed in Section 5, and to a lesser extent by the seasonal storage unit and the solar thermal collectors (see 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 presents the individual results for the most relevant damage categories, comparing them relative to the highest value in each category, which is shown as the longest bar representing 100% relative impact. This analysis confirms the findings from Figure 5, clearly demonstrating that oil and gas boilers have extremely high impacts in the *Climate change* category which is equivalent to Global warming in the Ecological Scarcity method with relative impacts of 100% and 70%, respectively. Additionally, oil and gas boilers exhibit the highest fossil resource use, at 100% and 80%.

A clear trade-off exists because each heating technology performs worst in different impact categories. For example, the district heating network using wood chips shows lower climate change impacts but the highest relative impacts in *Marine eutrophication*, *Land use*, and *Particulate matter* (PM). While PM impact was visible in Figure 5, *Marine eutrophication* and *Land use* impacts were not significant in the single score results. Similarly, solar thermal and geothermal-based district heating systems have the highest relative impacts in Minerals and metals resource use, at 100% and 83%, respectively. These trade-offs imply that selecting a heating technology depends on which environmental impacts are prioritized for a given use case. This highlights the need to weigh and balance different categories manually, or to rely on a single score method if applicable.

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

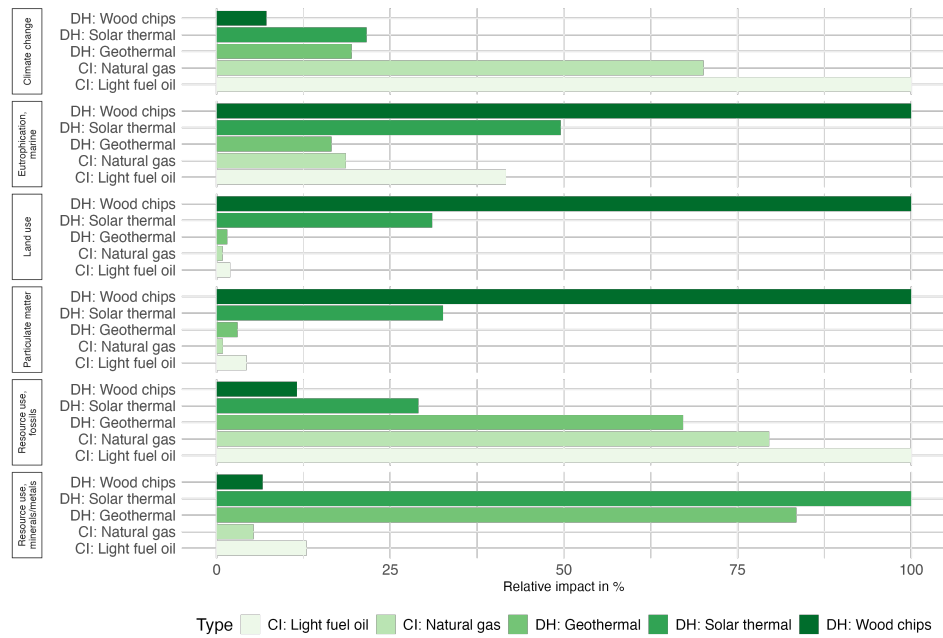


Figure 6: Damage assessment using the Environmental Footprint Method, visualized as relative environmental impacts in comparison.

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 lower-emitting (see Section 7.2) or less energy resources (see third research question and Section 7.3), sensitivity analyses for source of electricity and loss coefficients for the heat loss in the seasonal storage unit and the transport pipes will be performed.

7.1 Modeling limitations

The UVEK data for the other energy sources for district heating (wood chips, heat pump) used an 11 % 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).

Note that there was a problem with the weights for the damage category *Water resources, net balance* in the UVEK LCI weighting set that required excluding this category from the analysis.

7.2 Sensitivity analysis: Source of electricity

Figure 5 has shown that the dominant environmental impact is from electricity. For the default mode, the Electricity (ENTSO-E) production mix [12] was assumed. In this section, the potential savings by using lower-emitting electricity are assessed. Since the electricity is required during the winter months where it is much harder to produce compared to the summer months, the relevant UVEK-supplied data for running storage pumps in Austria, Germany, France, Italy, and Switzerland were used for the analysis. The results are shown in Figure 7.

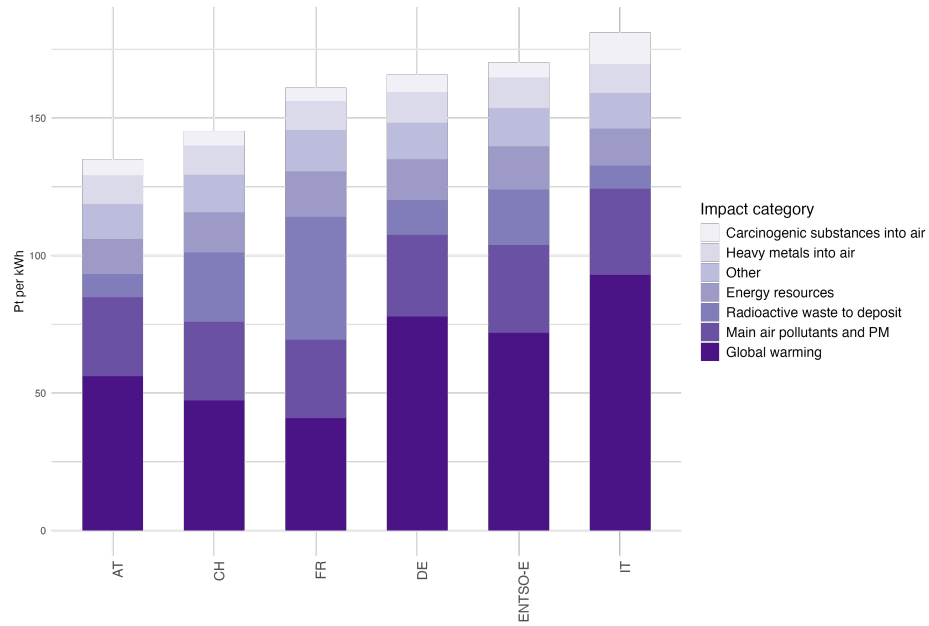


Figure 7: Comparison of environmental impact depending on source of electricity, using UVEK-supplied data for running storage pumps in Austria, Germany, France, Italy, and Switzerland in winter. This analysis is based on the Ecological Scarcity 2021 v1.04 method at the single score level, with UVEK LCI weighting set.

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.

7.3.1 Pipe heat loss

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 8.800 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 for the given modeling is a realistic number. However, 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, and the UVEK assumptions for district heating are also lower with 11%. Using the UVEK assumption for the Bracht setup would result in efficiency savings of approximately 300 MWh per year, leading to a reduction from 170 Pt per kWh of heat to 155 Pt per kWh of heat (9% reduction) which is lower environmental impact compared to the district heating with wood chips as the energy source. The main impact factors changed are the *Climate change* and the *Main air pollutants and Particulate Matter (PM)* category.

7.3.2 Seasonal storage unit heat loss

In [25], the authors report a 26% loss of heat production in the storage unit amounted to of heat production. The Energy Transition Model [24] suggests 30% as a sensible default for modelling heat loss in the storage unit. Another study [26] provides a comprehensive review and finds that 30% to 50% heat loss are common for Pit Thermal Energy Storage and that the majority of losses are caused by floating cover.

Given these reference numbers from literature, the 50% loss assumption for Bracht is on the conservative side. For the sensitivity analysis, the assumption made is that it can be lowered to 30% based on two different scenarios: (1) without any changes in the setup but an understanding that the original assumptions were not accurate, and (2) by using twice the cover for the top of seasonal storage unit and therefore better insulation. The sides and the bottom of the seasonal storage unit remain unchanged.

In both scenarios, a higher amount of energy is supplied from the seasonal storage unit (3.160 MWh). That consequently results in an increase of electrical energy requirements for the heat

pump. A rough estimate of the heightened energy requirements was performed based on using the same factor between energy from the seasonal storage unit and energy from electricity as in the original assumptions (see Section 5.2): 209 MWh divided by 2.258 MWh, which returns a 9 % electricity requirement factor. This results in a 293 MWh electricity demand for the heat pump. With an assumed 20% heat loss in the pipes as in the default assumptions, a remaining amount of 2.764 MWh of energy is available for consumers. This meets the consumer heating demands of 2.700 MWh and therefore, no supplemental energy from biomass is required.

For scenario (1 - *no changes*), a 15 % reduction from 170 Pt per kWh of heat to 146 Pt per kWh of heat can be achieved. For scenario (2 - *double cover*), a 9 % reduction to 155¹ Pt per kWh of heat can be achieved.

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, but the solar thermal based district heating is not the best available options without further improvements. To further improve, the recommendations are to use green energy for running the heat pump, and to lower or event completely remove the amount of biomass burnt by improving the heat loss coefficients for storage unit and transmission pipes with better insulation.

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.

¹This is coincidentally the same result as in Section 7.3.1.

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) | [27] |
| Type | Flat-plate collectors Vitosol 100-F XF13 Viessmann | [27] [28] [21] |
| Land use | 23.500 m^2 | [27] |
| 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 8.

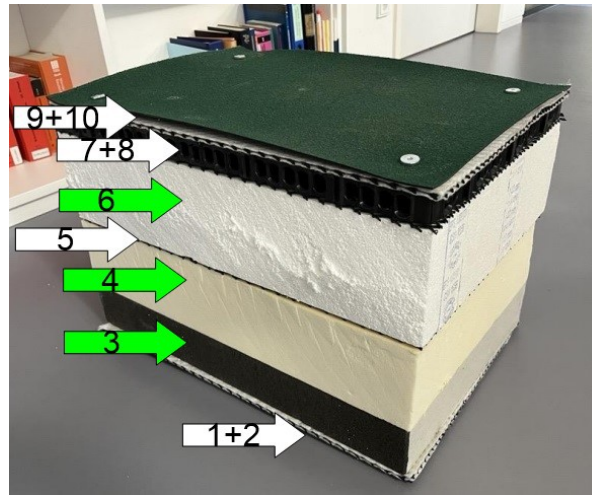


Figure 8: Floating cover profile. Source: Bracht community.

Table 3

| Dimension | Value | Source |
|-------------------------------|---|------------------------|
| Volume | 26'600 m^3 | Figure 1 |
| Resource: water | 26'600 m^3 filled from local source | [29] |
| Cover layer 1, 10 | Polyethylen (HDPE) sealing membranes 1.5 mm, 1.5 kg / m^2 | [29], estimated weight |
| Cover layer 2, 9 | Fleece (0.1 kg / m^2) laminated plastic grid (HDPE, 0.5 kg / m^2) | [29], estimated weight |
| Cover layer 3 | Foam glass, 8.33 kg / m^2 | [29] |
| Cover layer 4 | Polyurethane (bauder foam): 3.125 kg / m^2 | [29] |
| Cover layer 5, 7, 8 | Airing gap made of plastic grid, 0.5 kg / m^2 each | [29], estimated weight |
| Cover layer 6 | Polystyrene (XPS), 3 kg / m^2 | [29] |
| Floating cover dimensions | 70 m x 70 m = 4900 m^2 | [30] |
| 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 | [29], 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 | [30] |
| 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) | [27] [31] |
| Electricity requirements | 209 MWh per year | Own calculation, see Section 5.2 |

| Dimension | Value | Source |
|----------------------------|---|----------------|
| Buffer storage | ca. 200 $m^3 = 200'000$ l | Figure 1 |
| Biomass boiler | Mawera boiler with 700 kW thermal power | [27] |
| Controller | Vitoccontrol 200-M | [27] [32] |
| 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 Simapro.

The data for the process *district heat, at consumer, solar thermal, 1MW/MJ/RER U* is kept in an external spreadsheet [accessible here](#)

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 |

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 |

For the comparison, the following SimaPro processes were employed (all of them part of the UVEK dataset):

- *district heat, at consumer, borehole heat pump, 50kW/MJ/CH U*
- *district heat, at consumer, wood chips in industrial furnace, 1MW/MJ/CH U*
- *heat, light fuel oil, at boiler 10kW, average/CH U*
- *heat, natural gas, at boiler condensating modulating, 15kW/CH U*

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.

9.3.2 Meeting notes

The notes for the meetings can be found [here](#). Access is given upon request.

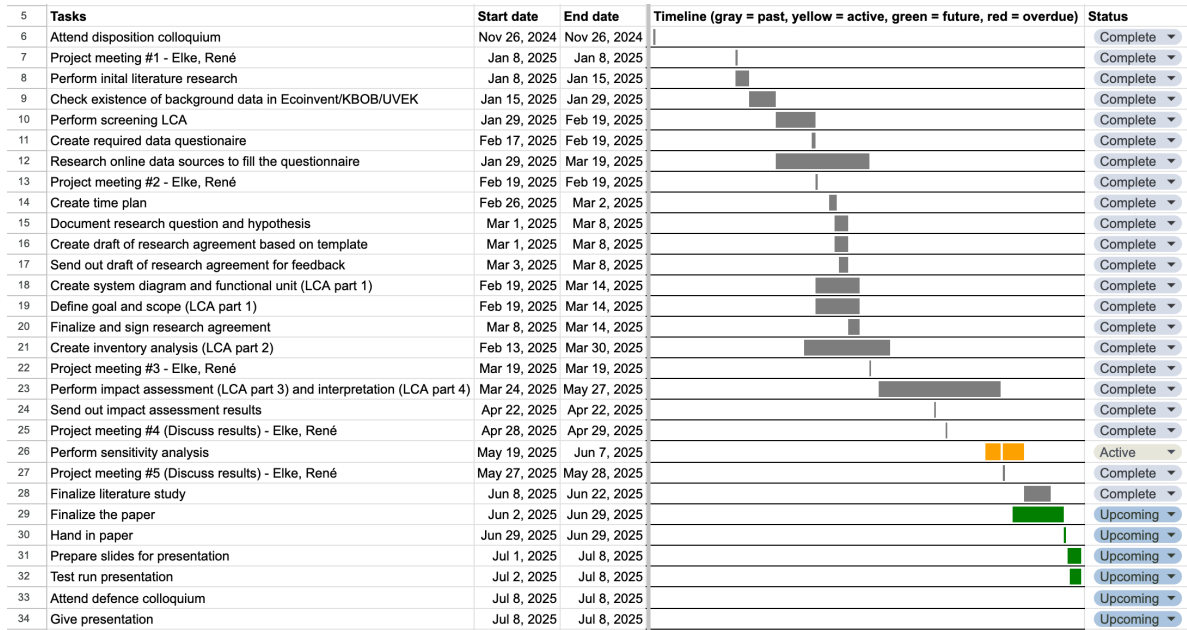


Figure 9: Gantt chart used for time planning.

References

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