EuroSun 2026

CORRELATION-BASED PRE-ASSESSMENT OF THE LEVELIZED COST OF HEAT OF LOW-TEMPERATURE INDUSTRIAL HEAT SUPPLY TECHNOLOGIES

Summary

Low-temperature industrial process heat (< 100 °C) can be supplied by several efficient and low-carbon technologies, yet these options are often not fully considered in early project phases due to limited familiarity and the effort required for techno-economic assessments. This contribution presents a correlation-based approach for the rapid pre-assessment of the levelized cost of heat (LCoH) for four heat supply technologies: solar thermal collectors, heat pumps for waste heat utilization, biomass boilers, and natural gas boilers as reference or backup systems.

The approach is based on harmonized methodological assumptions and explicitly defined system boundaries, ensuring direct comparability between technologies. Generic contour plots are derived to express the LCoH as a function of two dominant parameters for each technology, complemented by additional correlations that allow key parameters such as solar collector yield and full-load hours to be estimated without detailed simulations. The full-load hour correlations are further extended to hybrid systems, combining solar thermal collectors and one or several dispatchable heat generator(s). Overall, the results support early-stage decision-making by allowing stakeholders to quickly compare technology options on a consistent basis and to identify promising solutions for more detailed analysis.

Keywords: industrial process heat, levelized cost of heat, solar thermal, heat pumps, biomass boilers

1. Introduction

Industrial process heat and space heating in industrial buildings account for 20 % of global energy consumption and a significant share of global CO_2 emissions (Bellevrat and West, 2018). For applications below 100 °C, commercially available technologies such as solar thermal collectors, heat pumps using waste heat, and biomass boilers can significantly reduce fossil energy use and emissions.

In practice, technology selection is often driven primarily by economics, but promising options may not be considered early due to limited familiarity among decision-makers. One reason is the lack of simple methods that allow decision-makers to quickly assess the economic competitiveness of alternative heat supply options without performing detailed simulations and cost calculations.

This contribution addresses this gap by presenting correlation-based methods that enable a rapid pre-assessment of the heat cost of the three low-temperature industrial heat supply technologies introduced above. The results are derived from a report currently in preparation within the framework of IEA SHC Task 71, Subtask D (Louvet and Pag, 2026). The analysis follows the harmonised methodological guidelines developed within the same Task, Subtask B (Itten et al., 2025), ensuring consistent assumptions and system boundaries, and allowing direct comparison between technologies.

2. Methodological framework and assumptions

The economic assessment is based on the levelized cost of heat (LCoH), which accounts for investment, operation and maintenance and replacements, over the system lifetime. To ensure broad applicability, country-specific subsidies, disposal costs and VAT are excluded. For all systems, a period of analysis of 30 years, a nominal discount rate of 5.5 %/a, and an inflation rate of 2 %/a are assumed. Further technology-specific assumptions are made, which will be presented in the full contribution.

System boundaries are defined in accordance with IEA SHC Task 71. The assessed technologies are assumed to feed heat into the main distribution network of an industrial site. Costs include turnkey supply of the heat generation technology, thermal storage, and hydraulics up to the feed-in point, while 10 % distribution losses are assumed between the generator outlet and the reference energy boundary.

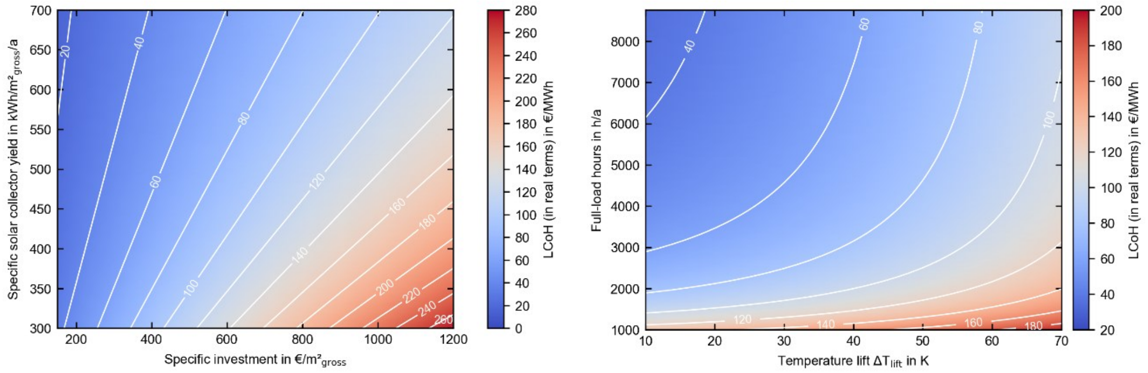
The three renewable technologies analysed are solar thermal collectors, heat pumps for waste heat utilisation, and biomass boilers. Natural gas boilers are also considered, serving as backup heat generators or as reference system.

3. Contour plots for estimating the LCoH of four heating technologies

For each technology, the LCoH is expressed using generic contour plots as a function of two dominant parameters:

- Solar thermal collectors: specific investment (€/m²$_{gross}$) vs. specific collector yield (kWh/(m²$_{gross}$ ·a))
- Heat pumps: temperature lift (K) vs. full-load hours (h/a)
- Biomass boilers: specific investment (€/kW$_{th}$) vs. full-load hours (h/a)
- Natural gas boilers: specific investment (€/kW$_{th}$) vs. full-load hours (h/a)

These contour plots allow a rapid estimation of the LCoH once approximate values for the two parameters are known. Fig. 1 shows the contour plots for solar thermal collectors (a) and heat pumps (b) under the assumptions used in this work. For heat pumps and boilers, additional sensitivity analyses are conducted to assess the impact of the fuel and electricity prices.



(a) (b)

Fig. 1: Contour plots of the LCoH for heating systems with solar thermal collectors (a) and heat pumps for waste heat utilization (b) in process heat applications, under the assumptions considered in this work.

4. Correlation-based estimation of key parameters

In practical applications, one of the two parameters required for the contour plots (solar collector yield or full-load hours) cannot be determined without simulation. To overcome this limitation, additional correlations are provided.

Solar collector yields are estimated using correlations from the VDI 3988 guideline (VDI, 2020) for five collector types and two climate zones (Northern/Central Europe and Southern Europe), with correction factors for weekly load profiles and collector orientation.

Full-load hours of dispatchable heat generators are estimated using representative industrial heat-demand profiles developed in IEA SHC Task 64 (Jesper et al., 2021; Pag et al., 2021). Three characteristic yearly profiles with different degrees of seasonality and two daily profiles ("constant" and "daytime") are considered. Based on these profiles, characteristic curves relate full-load hours to the ratio of installed nominal capacity ($\dot{Q}_{gen,nom}$) to peak heat demand ($\dot{Q}_{dem,peak}$).

The approach is extended to hybrid systems combining solar thermal collectors with one or more dispatchable generators. A simplified hourly solar yield allocation method and a simplified energy-based storage model are used to estimate how solar thermal integration reduces the operating hours of the other heat generators. The resulting full-load hour characteristic curves depend on the heat demand profile, the collector type, and the operating temperature level of the solar thermal system. Fig. 2 illustrates exemplary full-load hour characteristic curves of the dispatchable heat generator for such hybrid systems. In the figure, the tuples (e.g. (0,1)) denote the combinations of weekday and weekend heat demand profile clusters as defined in IEA SHC Task 64, while the indicated temperatures correspond to the mean solar collector temperature.

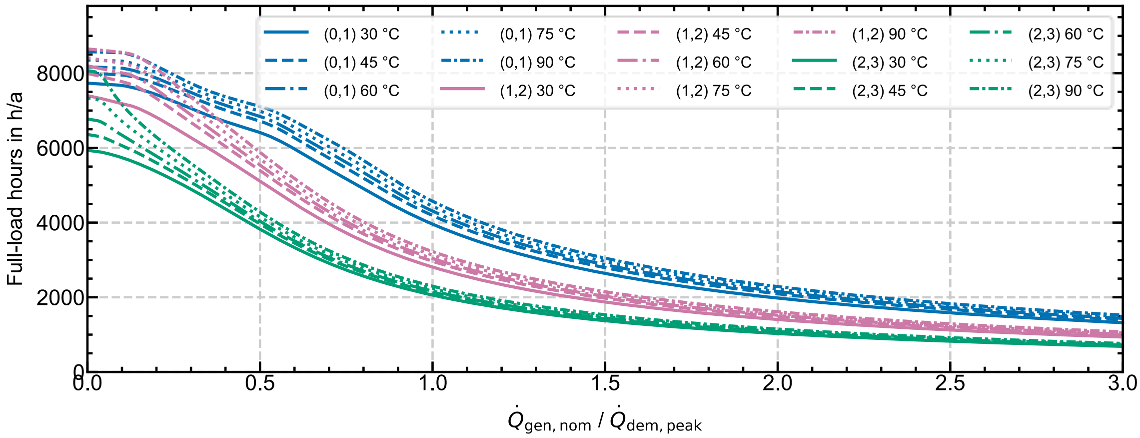


Fig. 2: Full-load hour characteristic curves for dispatchable heat generators combined to flat-plate collectors in Northern and Central Europe for a "constant" daily heat demand profile.

5. Conclusions and outlook

This contribution presents a set of harmonised correlations that enable a rapid pre-assessment of the LCoH of four low-temperature industrial heat supply technologies and their combinations. The correlations allow stakeholders to quickly compare options on a consistent basis, identify non-competitive solutions early, and focus planning efforts where detailed analyses are most valuable.

Additional sensitivity analyses show that the economic performance of the technologies is influenced by key parameters such as discount rate, service lifetime, temperature lift, and fuel or electricity prices. The result of these sensitivity analyses will be presented in the full contribution. They underline the importance of transparent assumptions and consistent system boundaries when comparing results.

At the conference, the methodology, as well as selected contour plots, full-load hour correlations, and sensitivity results will be presented and discussed. Future work could extend the methodology to additional technologies (e.g., direct electric boilers, geothermal, air-source heat pumps), broaden climate coverage for solar thermal, and verify the correlations against data from realised industrial projects.

6. References

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