

# Decarbonization of Process Heat in Germany: an Overview of Existing Studies

Javier Inigo Labairu<sup>\*1</sup>, and Tobias Hirsch<sup>2</sup>

<sup>1</sup>German Aerospace Center (DLR), Institute of Solar Research, Linder Höhe, 51147 Köln, Germany

<sup>2</sup>German Aerospace Center (DLR), Institute of Solar Research, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany

\*javier.inigolabairu@dlr.de

## Background

Industrial process heat represents **around 21 % of the final energy demand in Germany**, making it a key sector for achieving national climate targets.

Numerous studies analyse pathways toward **CO<sub>2</sub>-neutral process heat**, focusing mainly on electrification and hydrogen technologies. However, the **system boundaries, methodologies and technology coverage vary widely**, making cross-study comparison difficult.

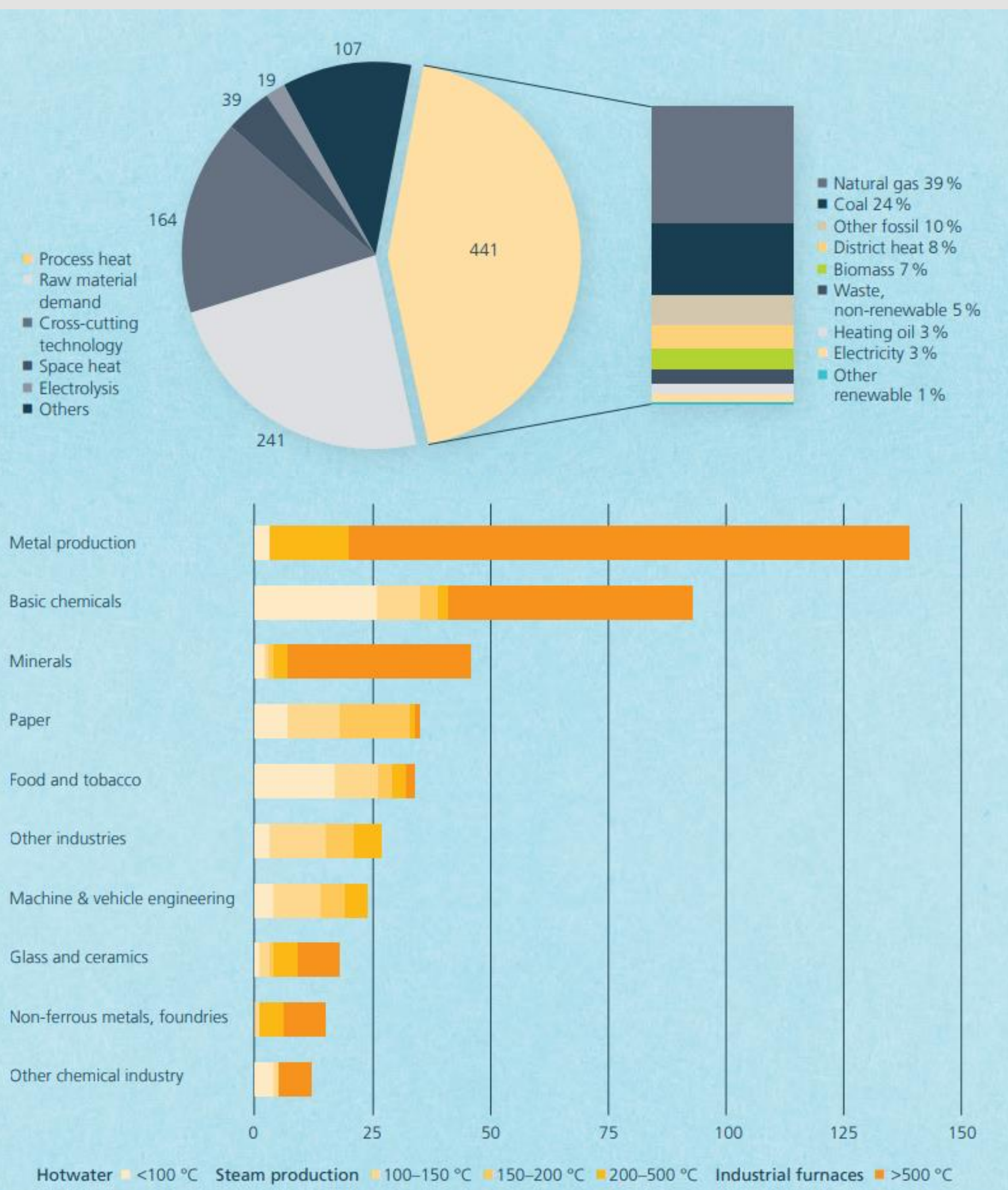


Figure 1: Industrial energy demand in 2019 (TWh) and energy sources used for process heat in Germany (top). Final energy demand for process heat by temperature level and sector in 2019 (bottom). Source: Fraunhofer ISI [1]

## Objectives

This work provides a **structured overview of more than 20 studies** on industrial process heat decarbonization in Germany and identifies key gaps in the literature.

- Analyse existing research on industrial heat decarbonization
- Identify **methodological gaps**
- Evaluate the **coverage of different technologies**
- Highlight the **potential role of concentrating solar thermal (CST)**
- Provide insights for **industry and policy makers**

## Key Findings from Literature

Large system studies conclude that **electrification and hydrogen will be the main drivers of industrial decarbonization in Germany**, showing by far the largest technical potential.

### Electrification

- Suitable for low- to medium-temperature processes
- Includes heat pumps, electric boilers and induction technologies

### Hydrogen

- Suitable for high-temperature applications
- Compatible with existing combustion-based infrastructures

However, this strong prioritization often leads to other viable technologies being relegated to niche applications.

## Missing Technologies in Many Studies

A major gap in the literature is the limited consideration of solar thermal technologies, particularly **concentrating solar thermal (CST)**.

### Solar process heat can:

- Provide industrial heat up to **~400°C**
- Achieve **20–50% solar coverage** in industrial systems
- Deliver **payback times of 3–8 years** in Germany
- Enable **significant CO<sub>2</sub> reductions**

**Thermal energy storage (TES)** is also seldom analysed systematically, despite its importance for **flexibility, cost reduction and renewable integration**.

## Example Applications of CST

- Packaging industry (Turkey):** Parabolic trough collectors producing 180°C saturated steam (3 MW)
- Brewery (Spain):** Steam generation via Fresnel collectors (220°C) and parabolic troughs (30 MW)
- Enhanced oil recovery (Oman):** Parabolic trough solar steam plant (~330 MW) for oil extraction.
- District heating (Denmark):** Hybrid solar-biomass system with a 16.6 MW parabolic trough field

## Additional Research Gaps

The literature review reveals several structural challenges:

- Limited technology comparison:** Many studies focus mainly on electrification and hydrogen.
- Methodological heterogeneity:** Different assumptions on costs, lifetimes and temperature ranges complicate cross-study comparison.
- Limited accessibility of results:** Some studies are very extensive and difficult for companies to use in decision-making.
- Missing industrial case studies:** Few analyses are based on real industrial applications.

## Conclusions

Industrial process heat decarbonization is essential for achieving climate neutrality in Germany.

Existing studies provide valuable insights but show **significant gaps in technology coverage and methodological consistency**.

**Technology-neutral comparisons including solar thermal and thermal storage are needed** to identify effective decarbonization pathways.

Study	CST considered	CST compared with alternatives	Based on case studies	Economic comparison	Compact / industry-friendly
Fraunhofer ISE and BSW (2025)	✓	✗	●	✓	✓
Uni Kassel (2011)	✓	✗	✗	✗	✗
DLR et al. (2021)	✓	✗	●	✓	✓
Fichtner (2023)	✓	●	✓	✓	✓
Fraunhofer ISI and IOB RWTH (2023)	✗	✗	✓	✓	✗
Fraunhofer ISI and IOB RWTH (2024)	✗	✗	✗	●	✓
Fraunhofer UMSICHT, Wuppertal Ins. (2023)	✗	✗	✓	✗	✓
IREES and Path to Zero (2023)	●	✓	●	●	✗
Adelphi and Leibniz Universität (2022)	✗	✗	✗	✗	✗
Fraunhofer ISE and Fraunhofer IEE (2022)	✗	✗	●	✗	✗
Gas- und Wärme-Inst. Essen, et al. (2024)	✗	✗	✗	✗	✗
Hamburg Institut (2012)	✓	✓	✗	✗	✗
Kleinkraft (2024)	✗	✗	✗	✗	✗
U.S. Department of Energy (2022)	✓	✓	✗	✗	✗
Columbia SIPA (2019)	✓	✓	✗	✗	✗
Hochschule Niederrhein (2022)	✗	✗	✗	✗	✗
Agora Energiewende, Wuppertal Inst. (2019)	✗	✗	✗	✗	✗
Fraunhofer ISI (2024)	✗	✗	✗	✗	✗
Kopernikus-Projekt Ariadne (2021)	✗	✗	✗	✗	✗
Kopernikus-Projekt Ariadne (2021)	✗	✗	✗	✗	✗
Kopernikus-Projekt Ariadne (2025)	✗	✗	✗	✗	✗
FÖS (2025)	✗	✗	✗	✗	✗
NRW.Energy4Climate (2023)	✓	✓	✗	✗	✓
IN4climate.NRW (2021)	✓	✓	✗	✗	✓

Table 1: Overview of existing studies and identified research gaps (Full references available in the abstract or upon request).



[1] Fraunhofer Institute for Systems and Innovation Research ISI and Department for Industrial Furnaces and Heat Engineering (IOB) RWTH Aachen University. CO<sub>2</sub>-neutral process heat using electrification and hydrogen (Policy Brief)