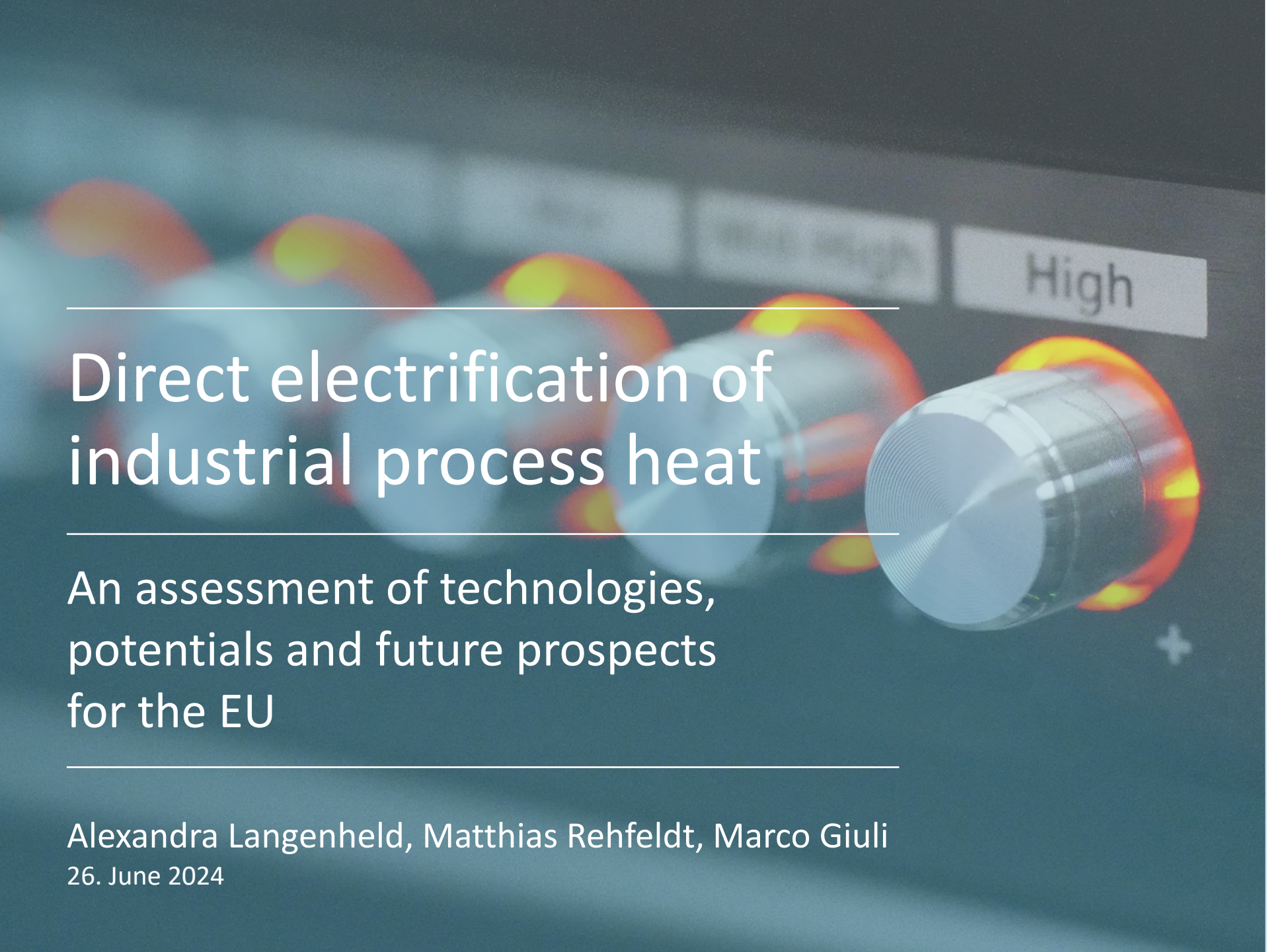


# Direct electrification of industrial process heat

## An assessment of technologies, potentials and future prospects for the EU

Alexandra Langenheld, Matthias Rehfeldt, Marco Giuli

26. June 2024

Agora Industry

Fraunhofer ISI

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ENERGY INNOVATION POLICY & TECHNOLOGY LLC

# Agora Industry – about us

**Who we are:**
Agora Industry is a think tank, policy lab and part of the **Agora Think Tanks**

**What we do:**
We develop **scientifically sound** and **politically feasible strategies** for a successful pathway to **climate-neutral industry** – in Germany, Europe and internationally

**How we work:**
We are independent and non-partisan, with a diverse financing structure – **our only commitment is to climate action**

**Where we take action:**
Agora Industry has offices in Berlin, Brussels, Beijing and Bangkok, and cooperates with a wide network of partner think tanks on the ground



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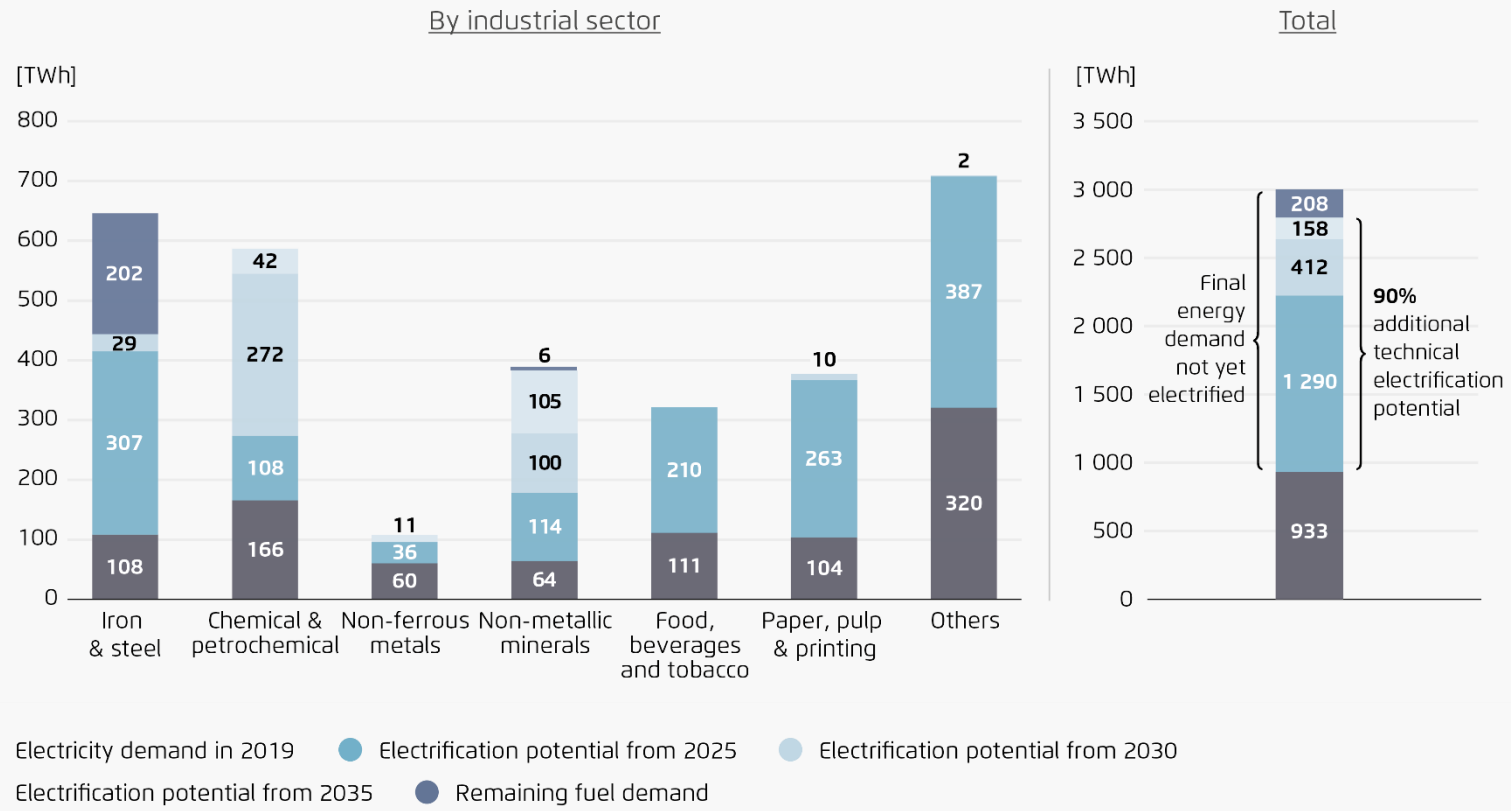
# 90 percent of the remaining industrial final energy demand can be electrified with already existing or soon to be mature technologies

Technical potentials for direct electrification in the EU27 by industrial sector (left) and total (right)




- Electricity already accounts for one third of the industrial final energy demand (933 TWh).
- Of the remaining final energy demand (2 067 TWh) 90% can be electrified with technologies we expect to be mature before 2035.
- Of this remaining final energy demand 60 percent could already be electrified with technologies that exist at large scale today.



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# Imprint


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Energy Innovation



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# Electrifying Europe's industry: Future prospects for process heat decarbonisation

Matthias Rehfeldt, Tobias Fleiter, Simon Lukas Bußmann

Electrification Academy #23

26th of June 2024

# Agenda

1. **Overview of industrial applications**
   1. Industrial structure (GHG, FED)
   2. Important processes and products
2. **Potential technologies for process heat electrification**
   1. Readily available technologies
   2. Potential capability gap
   3. Novel technologies to fill this gap
   4. Summarized potential for electrification
3. **Main barriers to diffusion**
4. **Discussion: Policy measures**

# Basic material industry creates things you like to use

## EU27, 2021

Approximate structure of GHG emissions in the European industry sector, 2018 (based on National Inventory Reports, extended with Germany-based model data from Fraunhofer ISI)

→ Fig. 3


Fraunhofer ISI





Images: Leube Baustoffe, NLMK Group, BASF, Shutterstock

Data: UNFCCC, Fraunhofer ISI

# Basic materials and their process heat demand will stay around...

## EU27, 2019

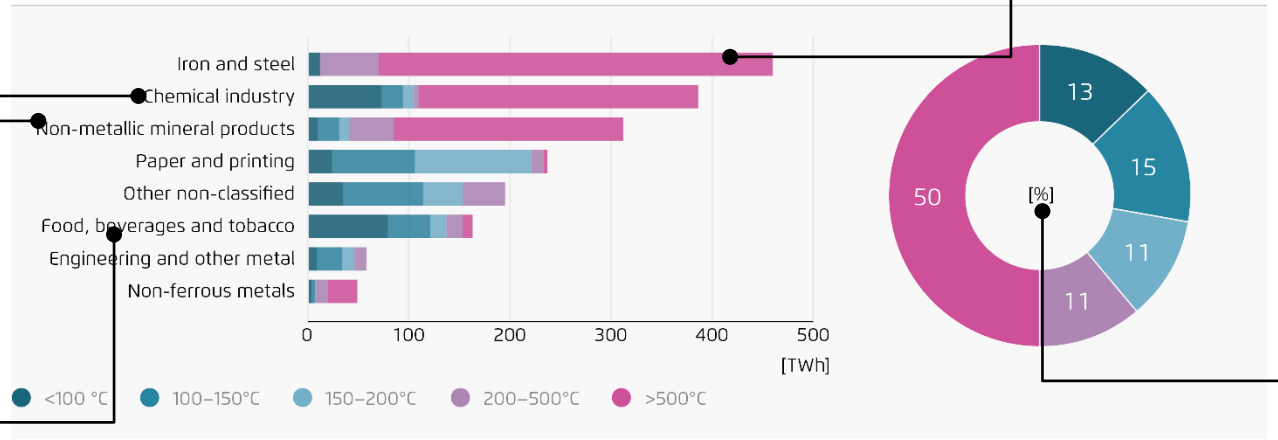
Steel production
*Blast furnace/basic oxygen furnace, electric arc furnace*

Steel processing
*Reheating furnace*

Olefins
*Steam cracker*

Ammonia
*Steam reforming, Haber-Bosch process*

Estimated total final energy demand for process heating in 2019 by temperature and energy carrier in the EU27 countries → Fig. 5




FORECAST model

Cement
*Rotary kiln*

Lime
*Shaft furnace*

Food
*Steam generation, steam-drying, sterilization, cooking ...*

Total: 1861 TWh (17% of EU27 total FED)

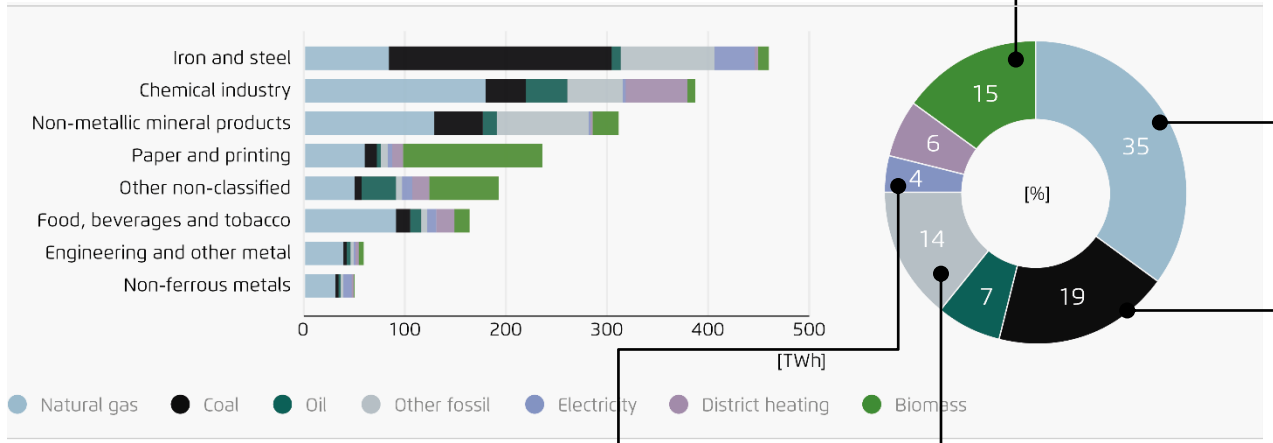
# … but not how they are made.

## EU27, 2019

Biomass
*Used by availability (e.g. production residues in paper, wood processing).*

Natural gas
*~1/3 of energy use.*
*Reference energy carrier for heat production in all applications.*

Estimated total final energy demand for process heating in 2019 by temperature and energy carrier in the EU27 countries → Fig. 5



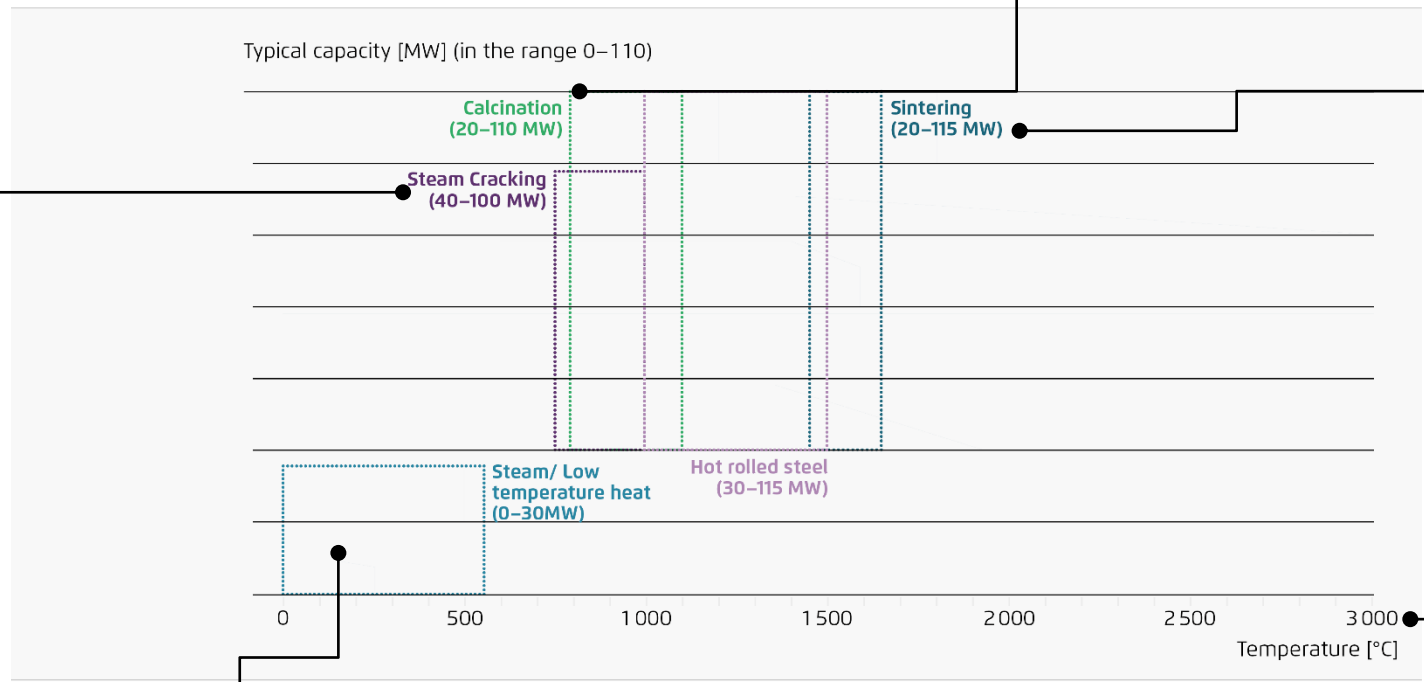

FORECAST model

Electricity
*Limited use, e.g. in electric arc furnaces and induction heating.*

Coal + coal derivatives
*~1/3 of energy use.*
*Reducing agent in iron production.*
*Limited use for other heat production.*

# Basic materials installations are huge and hot

Potential development of electric heating technologies by 2035 and industrial applications – Expected capacity versus temperature → Fig. 18




**Capacity**
*Basic materials are usually produced with high throughput and installed power.*

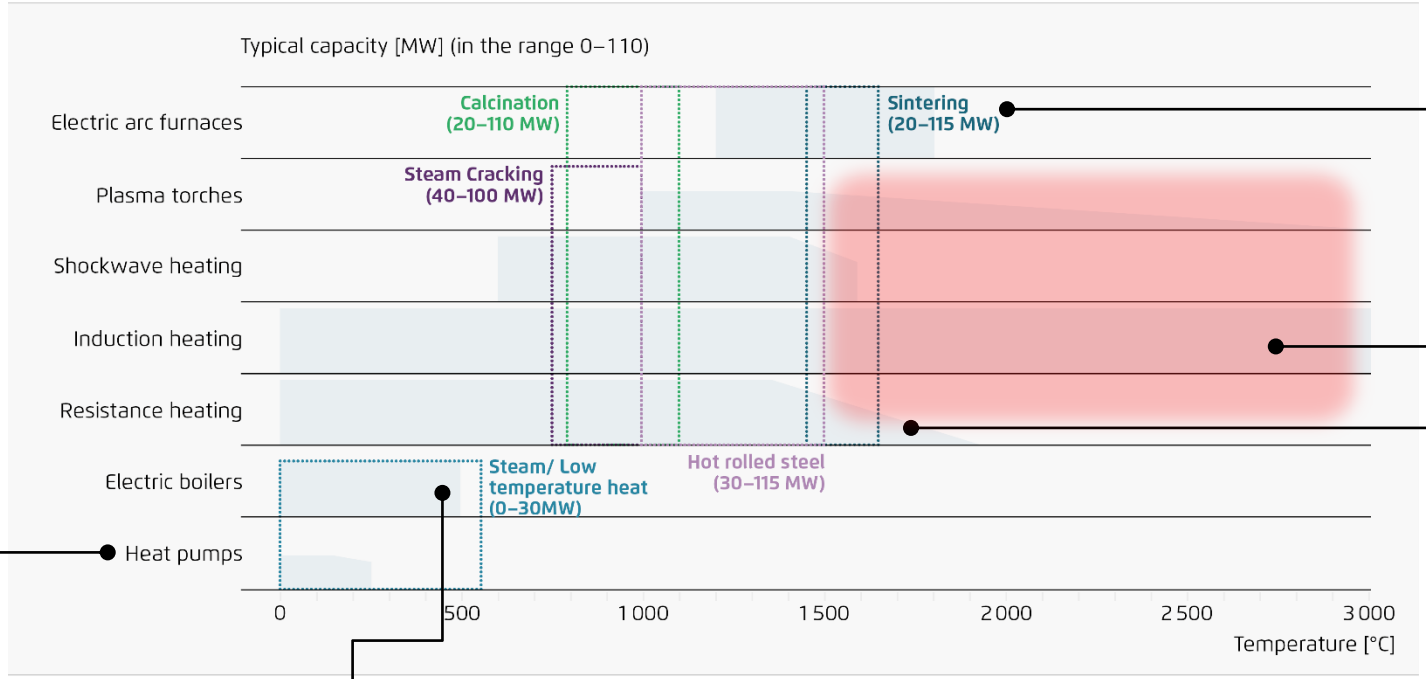
**Cement (lime) production**
*Two-stage process with potential for temperature differentiation.*

**Steam generation**
*The generation of steam and its use are separated. Steam demand is more homogeneous than furnaces. Individual installations may be larger (>200MW).*

**Temperature**
*Many basic materials need high temperatures.*

# Available technologies are challenged in high temperatures

Potential development of electric heating technologies by 2035 and industrial applications – Expected capacity versus temperature → Fig. 18




**Induction, arc furnaces**
*Limited to specific materials and geometries*

**Heat pumps**
*Limited to ~200°C*
*Efficiency declines sharply with higher temperature differences.*

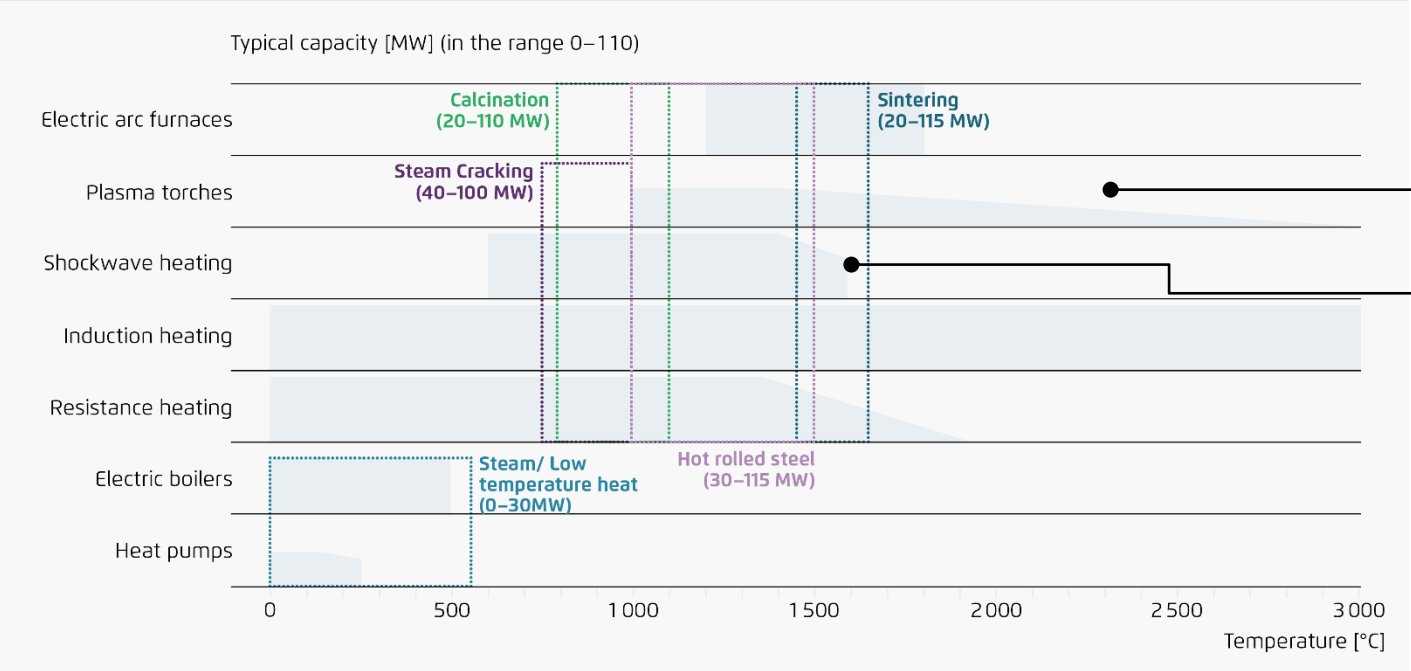
**Electric boiler**
*Able to supply entire steam demand range. Limited efficiency gains.*

**Resistance heating**
*Versatile and most relevant available technology for high temperatures. Limited by energy density.*

# Novel technologies can extend temperature ranges

Potential development of electric heating technologies by 2035 and industrial applications – Expected capacity versus temperature

→ Fig. 18

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**Plasma torches**
*Direct electricity in highly-concentrated burner-like delivery. Challenged by power range per torch lifetime of torches.*

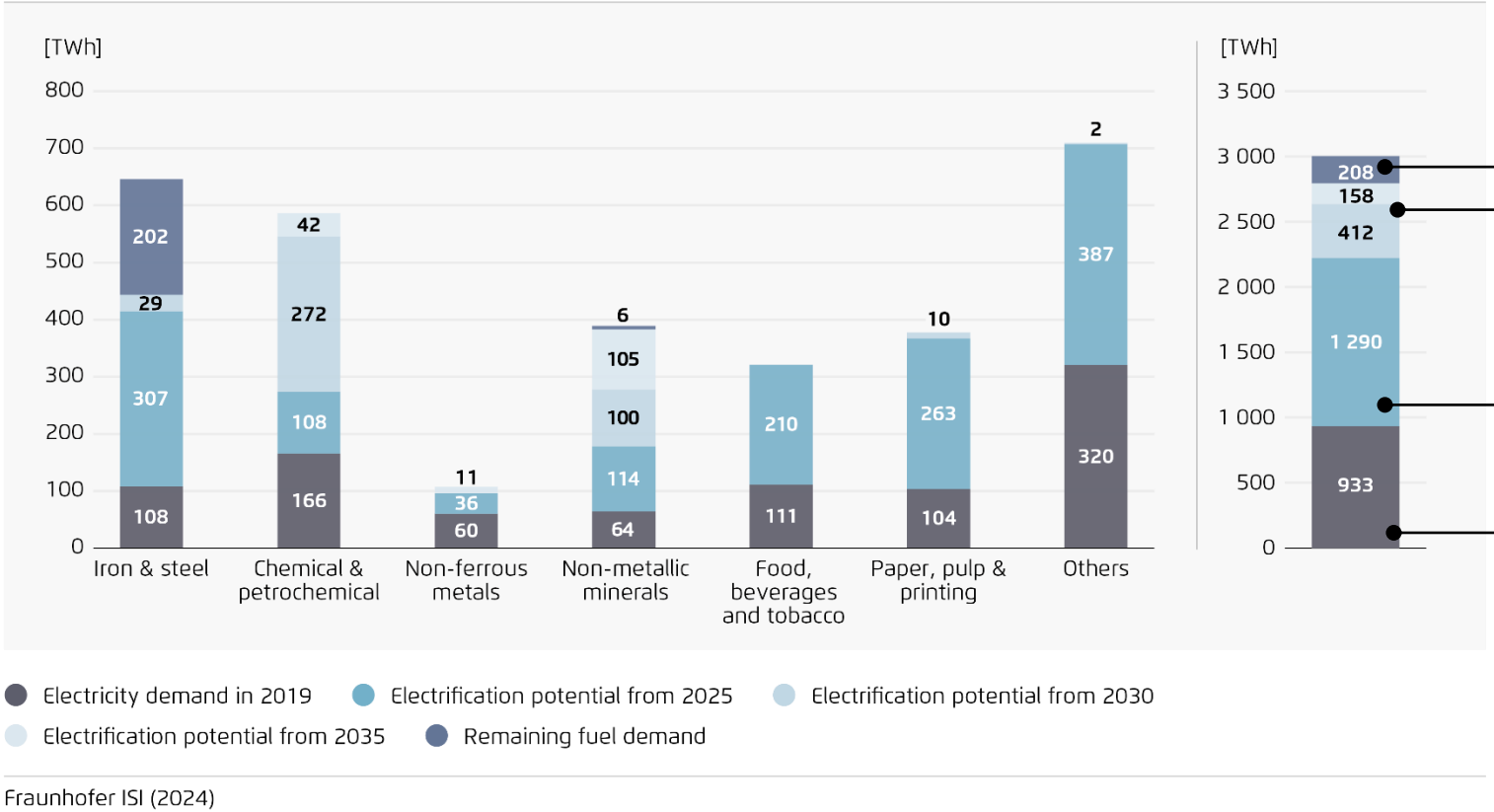
**Shockwave heating**
*Direct electricity use, generates hot fluid. High temperatures, broad application possible. But limited efficiency gains.*

# Large-scale electrification can be technically possibly

## ...if technologies are improved and deployed

Technical potentials for direct electrification by industrial sector (left) and total (right) in the EU 27 based on 2019 energy demands

→ Fig. 1




Fraunhofer ISI (2024)

**Less than 10%**
*depends on molecules by 2035 (additional technologies to reduce this value are possible beyond 2035).*

**Additional 20%**
*requires relevant technology development (after 2030/35), often high temperatures and energy densities. (Novel technologies)*

**Additional 40%**
*could be electrified with already or soon-available technologies (after ~2025); in particular low- to medium-temperature applications. (Available technologies)*

**About 1/3 of energy demand**
*is existing electricity use: fans, pumps, lighting, limited process heat.*

# Primarily economic and organizational barriers must be addressed

**Limited technical barriers**
*exist to direct process heat electrification after 2035.*

**They are present in**
*demand for feedstock, reducing agents and very high energy densities.*

Dimensions and modes of action of barriers → Fig. 32




Fraunhofer ISI (2024)

**On-site production systems**
*the integration of electric systems may create challenges around changed logistic and space demand.*

**Electricity infrastructure**
*must be extended. Beyond transmission grids, upgrades to site-specific connections are necessary.*

**OPEX**
*for energy are the largest component in total cost of ownership of process heat installations.*

**Energy efficiency improvement**
*as a result of direct electrification can - in some applications – offset higher energy prices for electricity (compared to natural gas).*

**Attractive direct electrification**
*in many applications though requires changed market conditions, e.g. higher CO2-prices and reduced electricity prices.*

**Technical lifetime**
*of existing installations is too long – many installations will have to be replaced earlier than planned.*

**Enabling direct electrification**
*also has to address organizational barriers:*
*Electricity infrastructure*
*On-site production systems*
*Technical lifetimes of installations*
*Knowledge about solutions*
*Uncertainty.*

**Uncertainty**
*hinders or stops investment decisions that are needed for market entry of important technologies.*

**Knowledge**
*about already available and upcoming solutions can be scarce.*

# Electrifying Europe's industry: Future prospects for process heat decarbonisation

| | |
|---|---|
| 3 | Basic material industry creates things you like to use. |
| 4 | Basic materials and their process heat demand will stay around... |
| 5 | ... but not how they are made. |
| 6 | Basic materials installations are huge and hot. |
| 7, 8 | Available technologies are challenged in high temperatures.<br>Novel technologies can extend temperature ranges. |
| 9 | Large-scale electrification can be technically possibly, if technologies are improved and deployed |
| 10 | Primarily economic and organizational barriers must be addressed |

**Contact**

FORECAST FORecasting Energy Consumption Analysis and Simulation Tool | eLOAD energy LOad curve ADjustment tool

http://www.forecast-model.eu/forecast-en/index.php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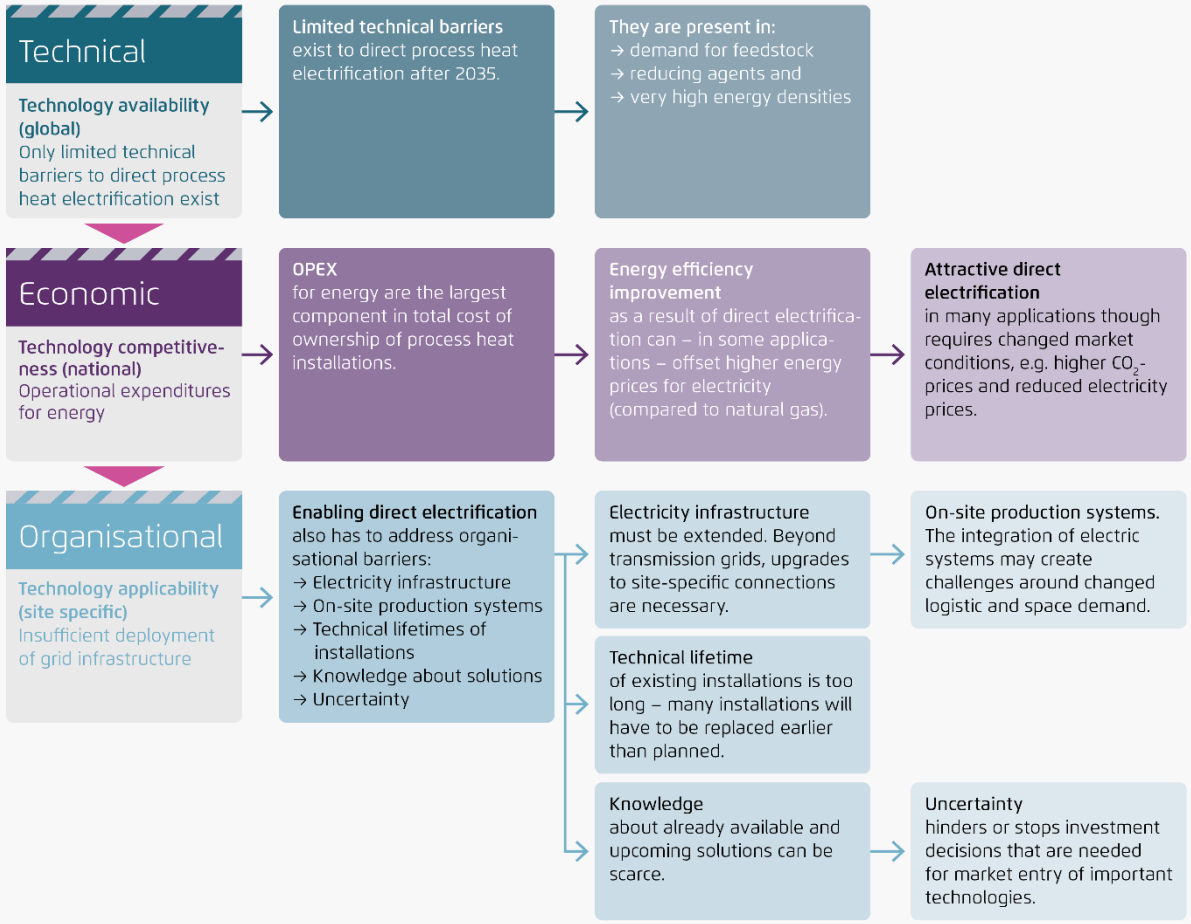
# Limited technical barriers exist to scale up the direct use of renewable electricity; economic and organizational barriers need full political focus

## Dimensions and mode of action of barriers




- → Electricity as the new primary energy carrier needs to be competitive vs. gas. Carbon pricing or electricity tariff design provide options.
- → Developing and upscaling technologies must be supported.
- → Technology learning must be facilitated by early market introduction and platforms transporting the knowledge.
- → Infrastructure access is a key challenge.
- → Striking a balance between quality and quantity – allow for full integration and standardized drop-in solutions.



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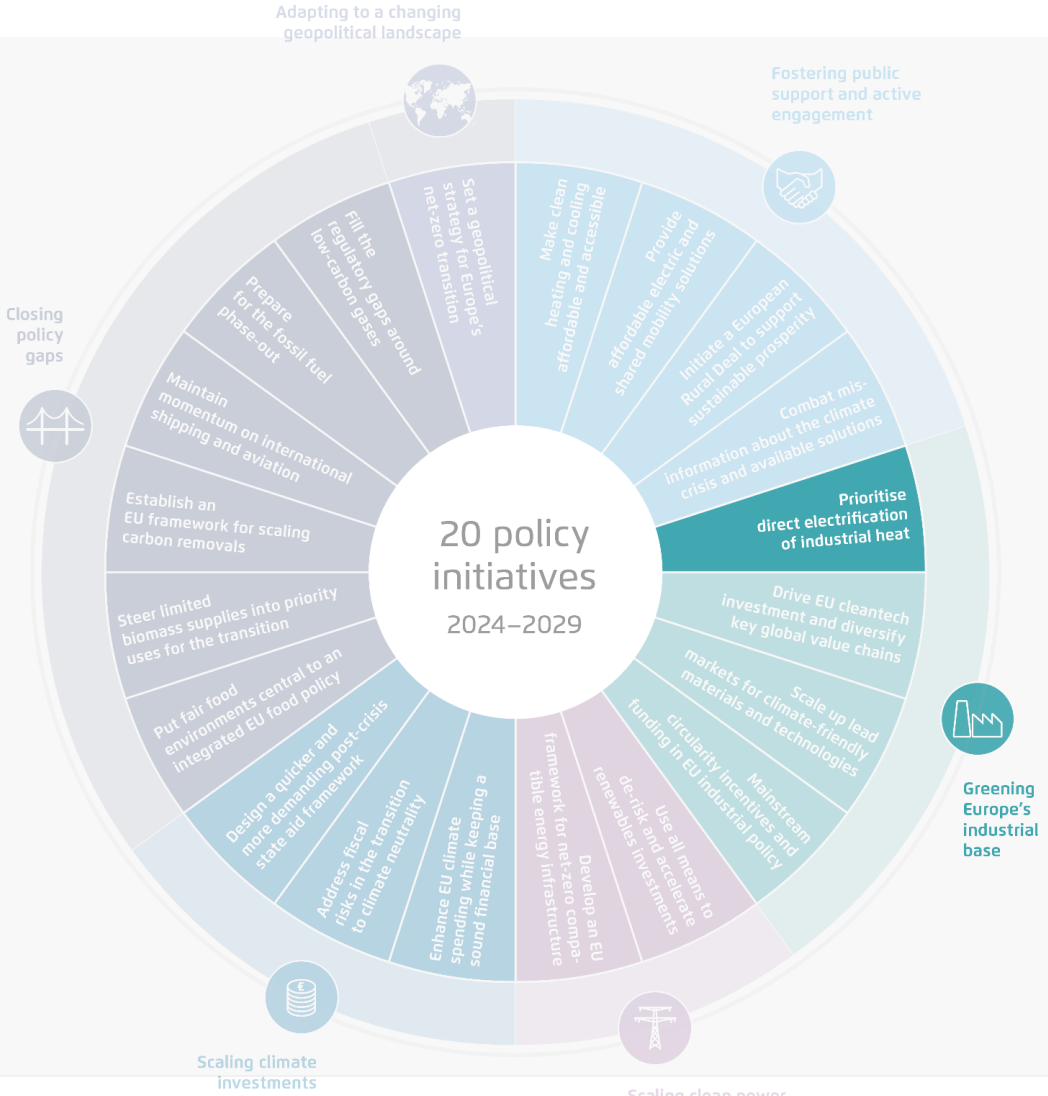
# Our latest EU policy proposal addressing the upcoming EU legislative cycle sees a priority for supporting direct electrification of industrial heat




**An EU industrial electrification action plan should:**

- Establish an industrial alliance to facilitate market introduction of technologies.
- Set deployment targets to enable investments.
- Develop funding schemes to explicitly support direct electrification projects.
- Enable regulators to integrate strong industrial electrification in grid planning.
- Allow industry easy grid access.



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# Key Findings

1 **Achieving climate-neutral industry requires an efficient decarbonisation of industrial heat.** Three quarters of industrial CO2 emissions result from burning fossil fuels that provide process heat for the production of industrial goods, such as chemicals, steel, paper, food and beverages. Process heat constitutes the single most significant energy use by industry.

2 **Direct electrification technologies expected to be available by 2035 could meet 90 percent of the energy demand not yet electrified by European industry.** Technologies readily available today, such as heat pumps and electric arc furnaces, could already deliver more than 60 percent of this demand. To tap into this potential, quickly ramping up technologies for the direct electrification of process heat at all temperature levels is key.

3 **A broad range of electrification technologies exists to meet specific process needs. Heat pumps and electric boilers can already generate up to 200 and 500 degrees Celsius, respectively, for chemical processes.** Electric arc furnaces are widely employed for steel production at 1 800 degrees. Technologies such as resistance heating, induction heating and electric steam crackers will become available in the coming years and cover all ranges, from 100 to 2 500 degrees.

4 **A targeted EU action plan is needed to address the economic and organisational barriers to direct electrification and ensure it is a key transition strategy for industry across Europe.** Major elements include establishing an industrial alliance to facilitate market introduction of technologies and setting deployment targets to enable investments. Funding schemes should explicitly support direct electrification projects, while regulators should integrate electrification in grid planning and allow industry easy grid access.

# Thank you for your attention!

Do you have any questions or comments?

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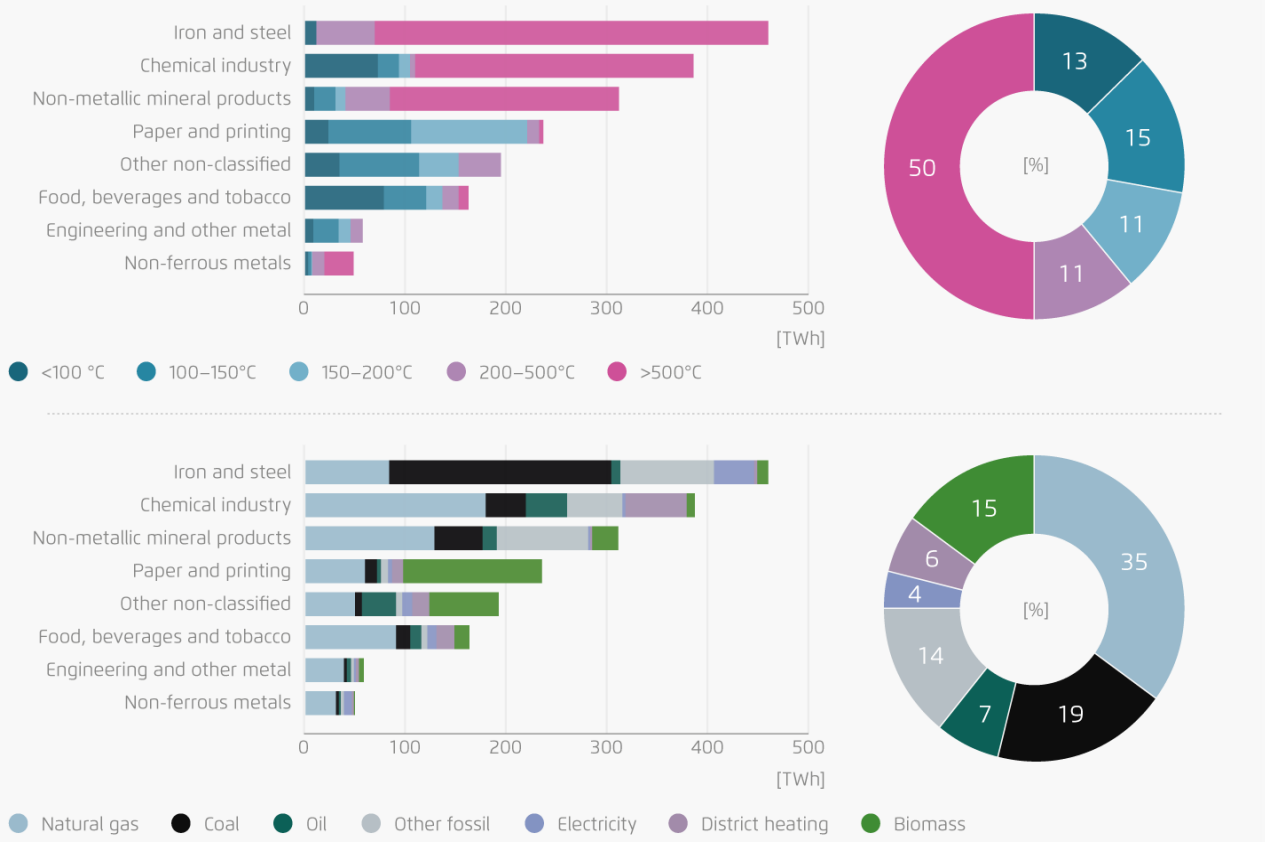
# Next steps: focus on low and medium temperature heat

Estimated total final energy demand for process heating in 2019 by temperature and energy carrier in the EU-27 countries → Fig. 5




Fraunhofer ISI (2024), based on FORECAST model

- Case selection: Germany, Italy, Poland
- Sectoral selection: chemicals (low temperature processes), pulp and paper, food and beverage, textile, industrial space heating.
- Core scenario analysis: emission reduction potential, energy savings potential, relative cost analysis (vs current fossil fuel alternatives and main decarbonization alternatives).
- Identification and discussion of the main sectoral barriers