

Electrification of industrial process heating as foundation for an efficient, clean, and competitive European industry

– A techno-economic perspective on policy needs

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Rome, eceee zero carbon industry conference, February 6, 2025



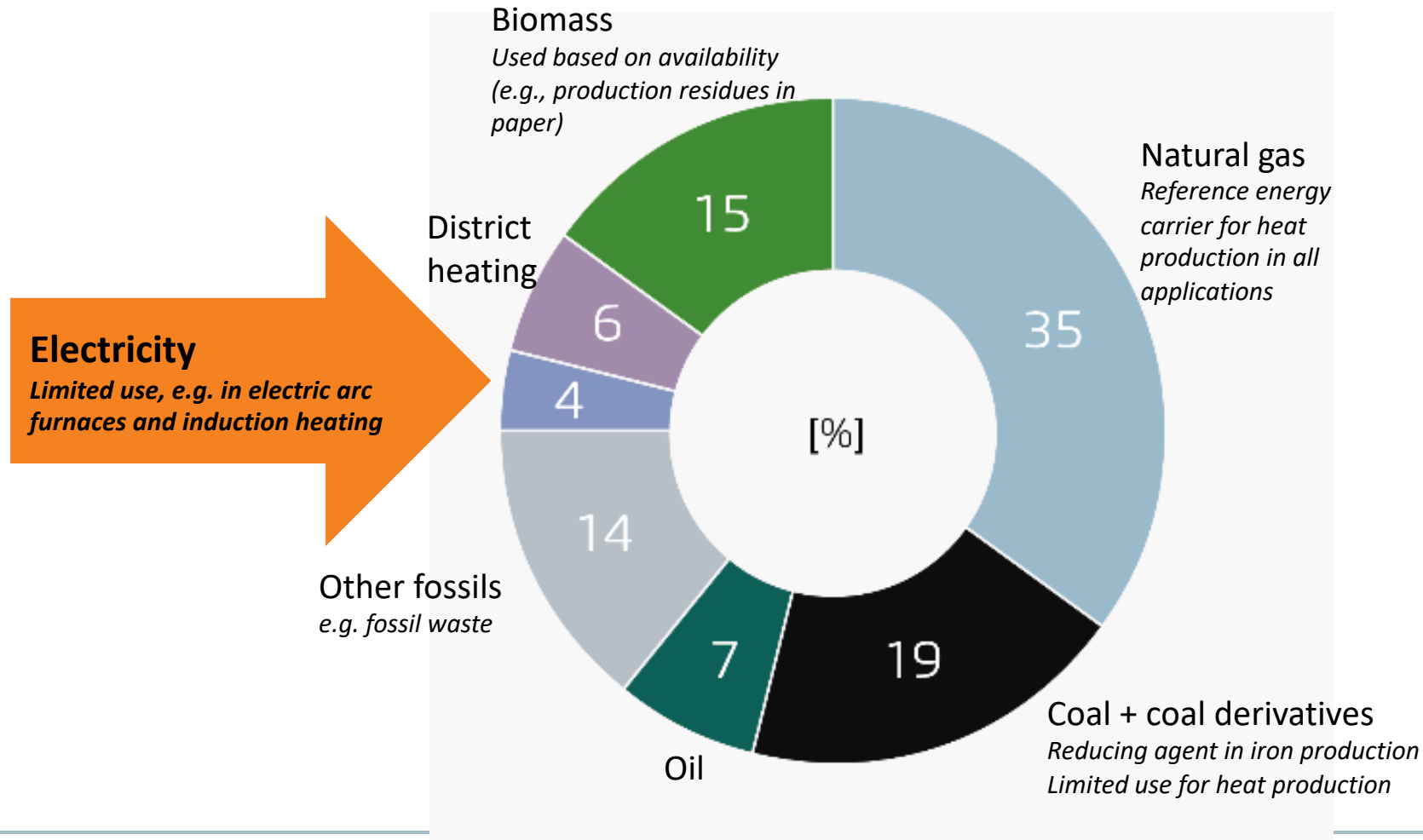
Agenda

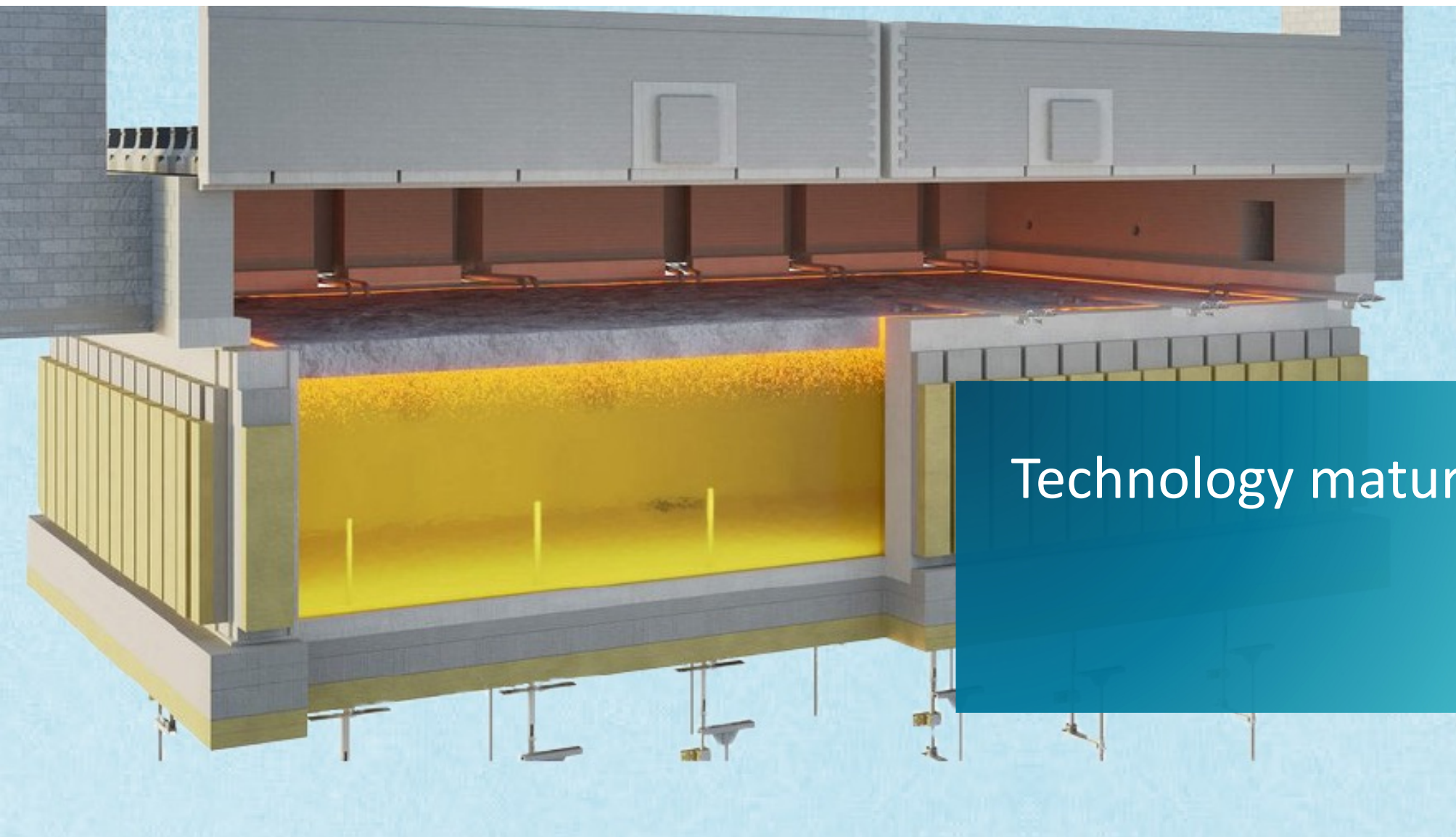
1. Technology maturity
2. Cost competitiveness of electrification and hybrid systems
3. CO2 reduction



A fraction of process heat is electrified in the EU

Graph shows total final energy for process heating in EU27 in 2020

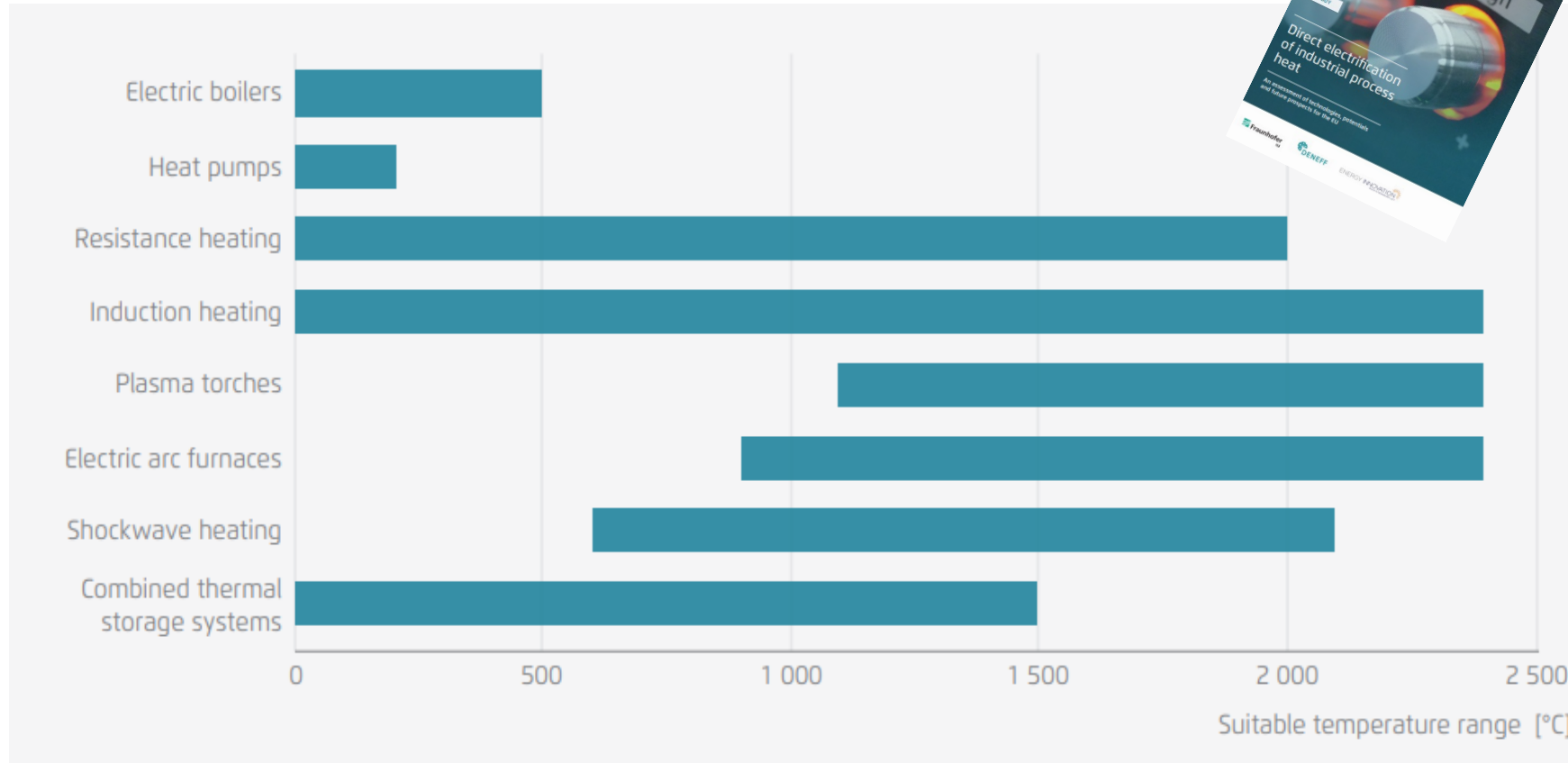
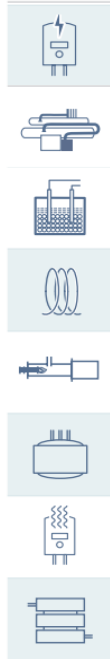




Technology maturity

Electrification technologies available at all temperature levels

With different R&D needs



- Electrification technologies are available at all temperature levels
- Major share of industrial heat can be electrified
- R&D need for integration of electrification technologies into specific industrial applications

Technology development through R&D still necessary

Important directions for R&D



The heterogeneity of process heat applications requires the use of different heating technologies and results in specific research and development needs:

- **Electric resistance heating elements:** increasing power density, application temperature, and service life -> technology available, incremental improvements
- **Induction heating:** targeted design of the heating system for new applications. System characteristics and coil geometry must be adapted to the material (workpiece, melt)
- **Plasma torches:** high potential and power density; however, not tested and disadvantages such as frequent maintenance, complex cooling, and thermal stress on components -> commercial application not expected until after 2035
- **Direct electrical resistance heating:** limited to individual applications (glass, iron, steel, and non-ferrous metals)
- **Arc heating:** New applications beyond the melting of steel scrap
- **High-temperature heat pumps:** higher power ratings (compressors), temperatures (refrigerants), natural refrigerants, overall integration

Application perspective shows diverse technology readiness

Technology readiness of full electrification by application/process (~2022)

Sector	Industry	Application (grouped)	Electrification
Metals	Steel	Production of crude steel (primary)	<3
		Rolling mill: tempering flat steel	<4
		Rolling mill: continuous heating flat/long steel	<3
	Foundries	Melting aluminum	9
		Melting cast iron (cupola furnace)*	<4/9
	Hardening	Carburization and austenitization	9
	Forming processes	Continuous heating forged parts	<5
		Discontinuous heating forged parts	<3
		Continuous heating steel plates	9
	Aluminum	Melting/warming, homogenizing/heating	9
Minerals	Copper	Melting, warming, tempering semi-finished products	9
	Glass	Melting container glass**	<4/9
		Melting flat glass	<3
	Bricks, ceramics	Firing bricks	<4
		Firing refractory bricks	<4
	Cement	Burning cement clinker	<3
	Lime	Burning in a shaft kiln	<2
		Burning in a parallel flow regenerative kiln	<3
		Burning in a rotary kiln	<3
Steam	Chemicals	Chemical park steam supply***	9/5-6
	Paper	Paper drying***	9/7-8
	Food	Milk powder production***	9/7-8

Figure 4: Technology readiness level (TRL) of climate-neutral technologies

Figures are based on 100 % electricity or hydrogen supply, *TRL <4 for substituting large installations, TRL 9 for small ones such as...
TRL <4 for large installations, TRL 9 for small ones, *TRL 7-8 for high-temperature heat pumps and TRL 9 for electrode boiler

Source: Fleiter, T.; Rehfeldt, M.; Hirzel, S.; Neusel, L.; Aydemir, A.; Schwotzer, Ch. et al. (2023): [CO₂-neutral process heat generation](#).
Conversion of industrial plants as part of the energy transition: Determination of the current SdT and further action required for the use of electricity-based process heating systems. Published by the Federal Environment Agency (UBA): Dessau-Roßlau.

Update 2025: Selection of publicly supported recent projects

Source: KEI - <https://www.klimaschutz-industrie.de/>



laufend
DHC



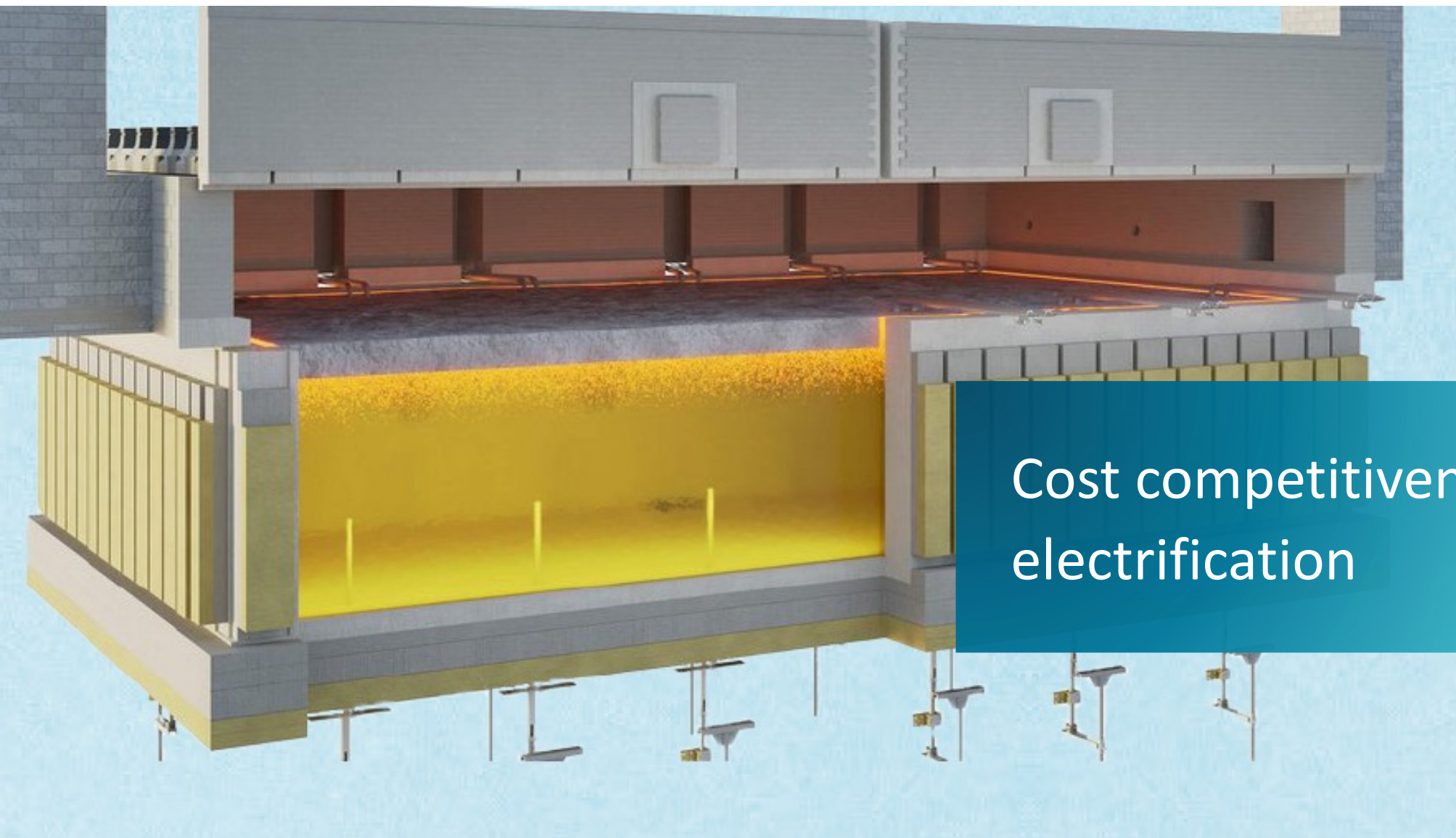
laufend
E-FLOAT WEIHERHAMMER 1



laufend
ECHSTO



abgeschlossen
NextGen Furnace



Cost competitiveness of electrification

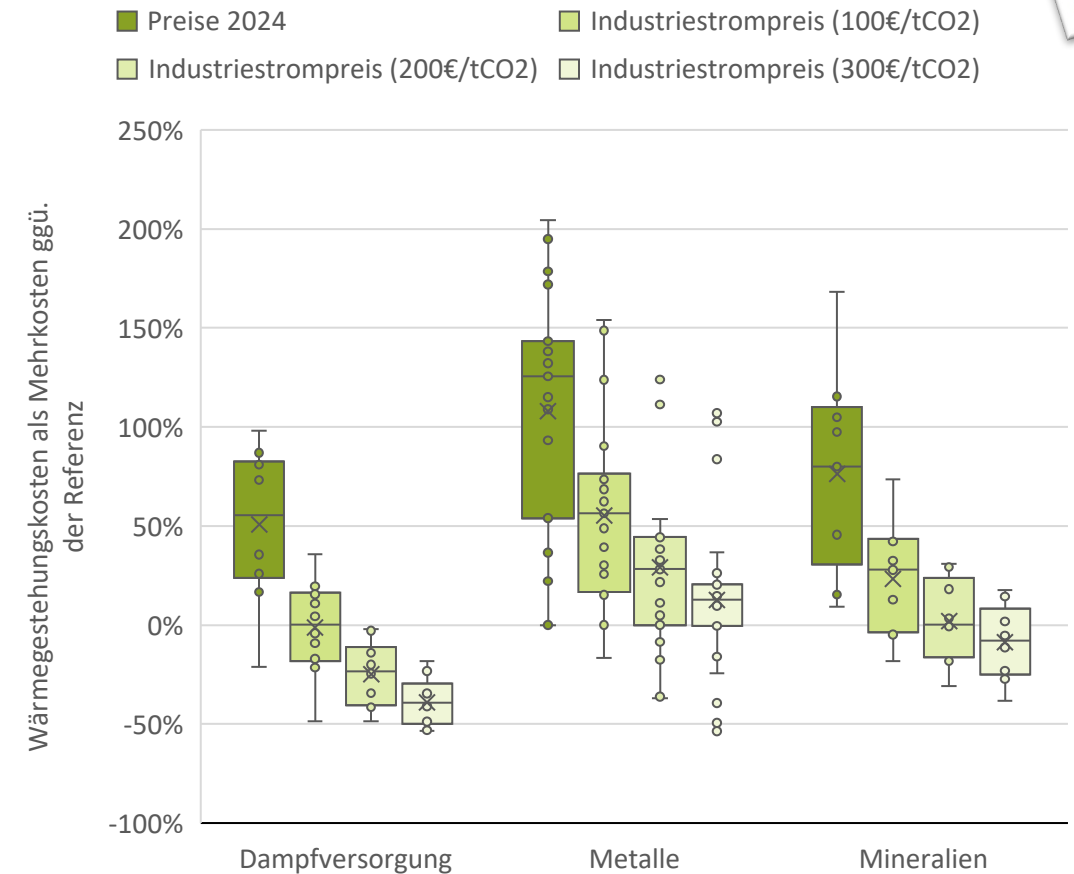
How cost-competitive is full electrification in Germany?

Definition of four variants

Scenario	CO2 [EUR/t]	Natural gas [EUR/MWh] IS Band	Electricity [EUR/MWh] IF Band
1 Prices 2024	75	41	138
2 Industry electricity price (€100/t)	100	31	76
3 Industry electricity price (€200/t)	200	31	76
4 Industry electricity price (€300/t)	300	31	76

- Assuming current electricity and natural gas prices and a CO₂ e price of €75/t CO₂, **full electrification is not economical for most applications in Germany.**
- Economical operation** requires that the price of electricity be at a similar level to the price of natural gas including the CO₂ price OR that high efficiency gains be achieved, e.g., through heat pumps.

Heat production costs for 34 applications (additional costs compared to fossil fuel reference)

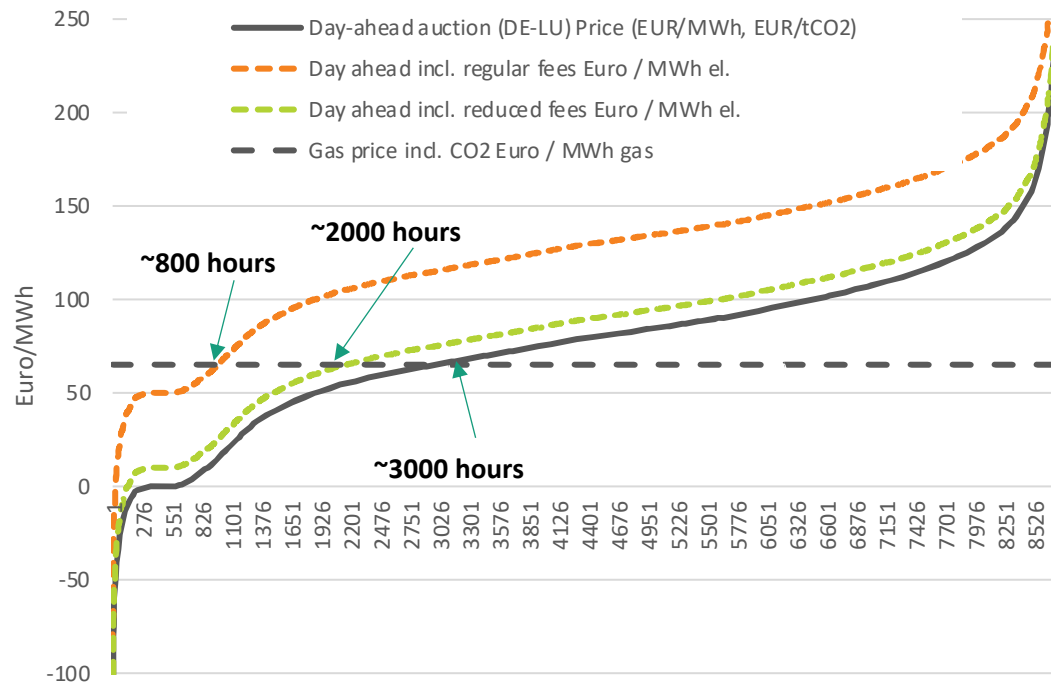


Source: Fleiter, T.; Gerhardt, N.; Kost, C.; Pfluger, B.; Wietschel, M.; Lux, B.; Neuwirth, M.; Lütz, L.; Ragwitz, M.; Braun, M.; Henning, H.-M. (2025): [How do investments in renewable energies and energy infrastructures support a climate-neutral and competitive industry in Germany and Europe? - Policy recommendations from Fraunhofer energy systems research.](#)

Competitive operation only possible with reduced grid fees

Hybrid process heat with electric + gas boiler

Hourly day-ahead electricity prices for 2024, sorted



Source Day-ahead prices: Energy Charts from FH ISE

Assumptions

- Electrode boiler supplements existing gas boiler
- 100 euros/t CO₂, 45 euros/MWh gas
- Grid fees: 50 euros/MWh (regular) and 10 euros/MWh (discount)

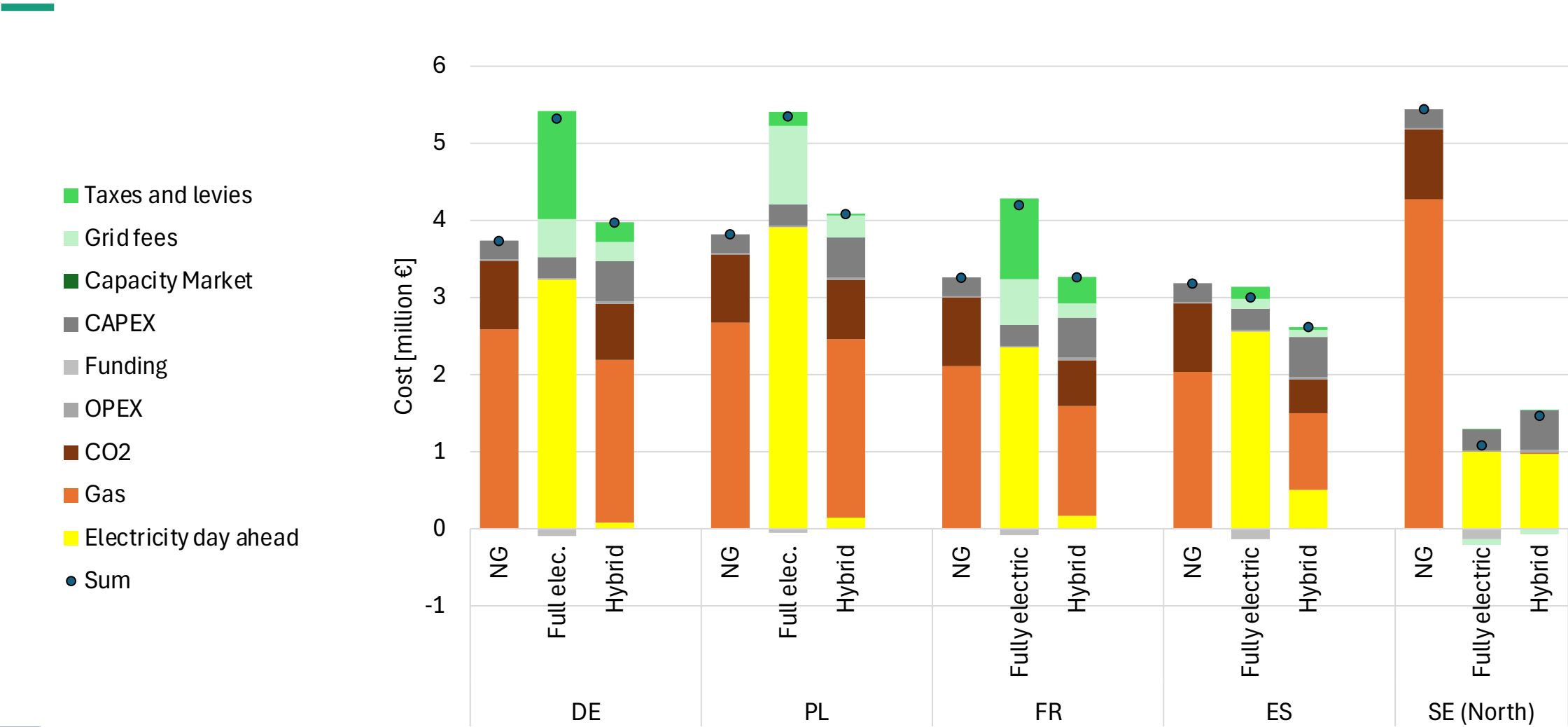
Approximate cost-effectiveness

Output	20 MW
Investment	10 million euros
Power price	0.4 million euros / a
Savings compared to natural gas	1.4 million euros / a
Amortization	~7 years
Operating hours	~2500 h/a

-> Competitive only with reduced grid fees!

-> Additional revenue opportunities on reserve markets

Cost competitiveness of hybrid process heat for selected countries



Flexible hybrid process heat as a key technology

Why should all sites consider investing in hybrid electrification?



1

Available and proven technology



2

Economic investment; reduces energy costs in the company

Amortization periods of 3-10 years are possible with 1,000 to 2,000 full-load hours



3

Strengthens security of supply by protecting against plant failure and future price risks



4

Low-risk entry into the transformation and possible market-driven "ramp-up" and gradual learning



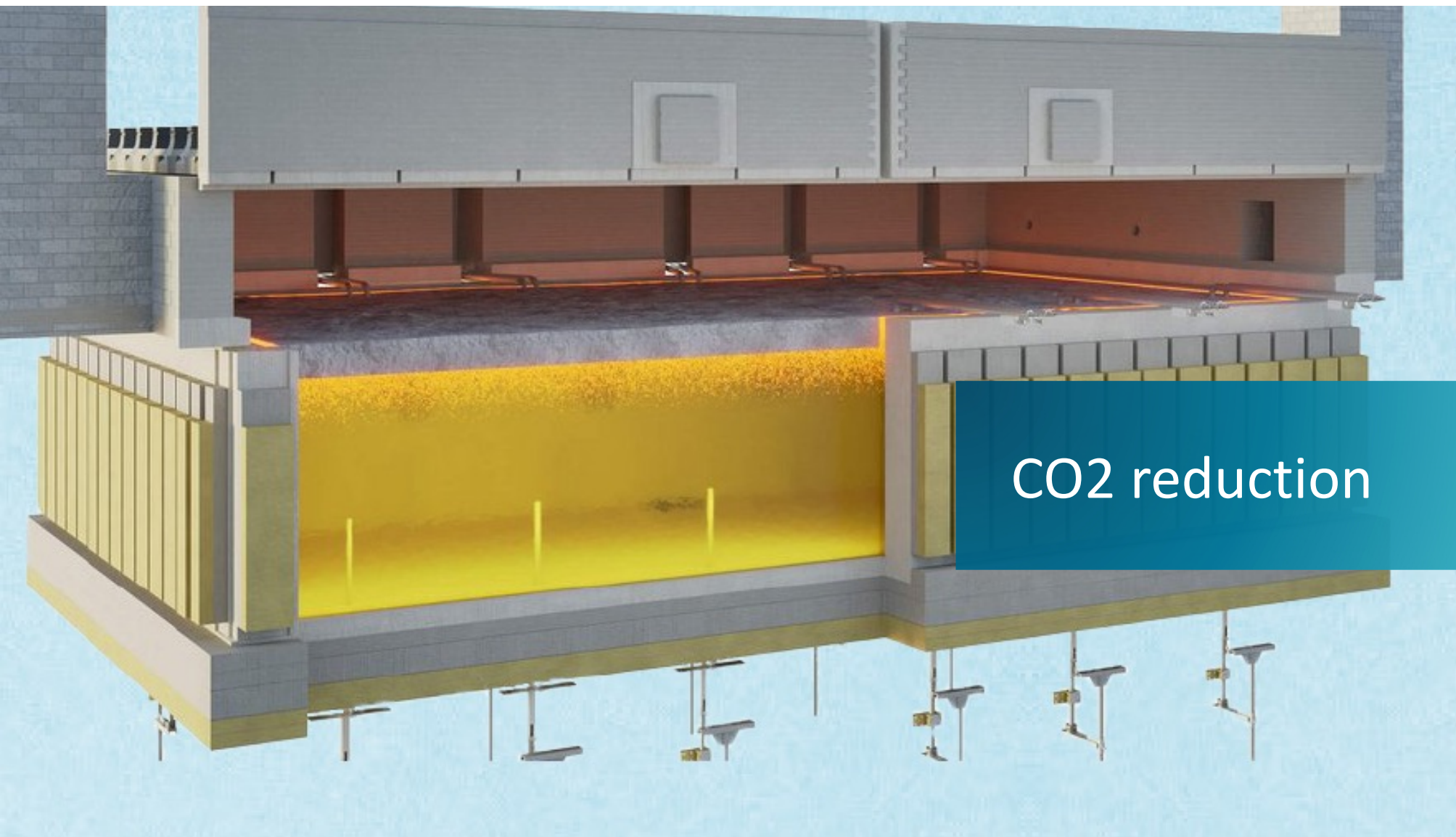
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High system benefits through contribution to the integration of renewable energies



6

Effective reduction of GHG emissions – even when using "gray" electricity



CO2 reduction

Emission intensity for all EU countries for 2023

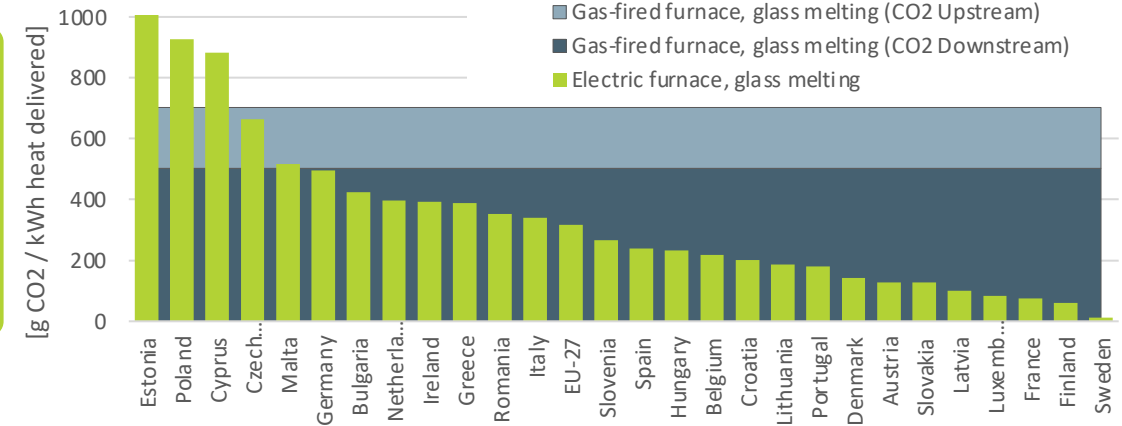
Observations

- **Electrification results in net emission reduction in most cases**, but the pattern is very diverse across the individual countries
- When electrification brings large **efficiency gains**, such as through heat pumps, it results in (mostly substantial) net emission reductions in all countries—even in Estonia, Poland, and Cyprus, which have very high CO2 intensity in domestic power generation
- **In a few countries, the power mix is still very CO2-intensive** and electrification might result in substantial emission increase compared to natural gas heating: Estonia, Poland, Cyprus, Czech Republic
- **Declining emissions in power supply** will improve the picture in the years to come (decline from 2023 to 2024 alone is estimated at 10%).

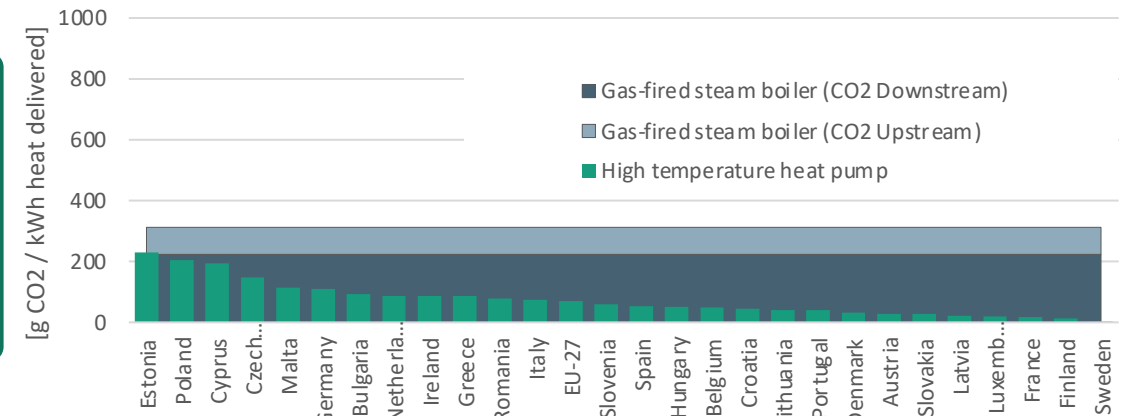
Data

- 2023 CO2 emission data by country from <https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1>
- Natural gas upstream emissions based on IEA report: [Assessing emissions from LNG supply and abatement options](#)

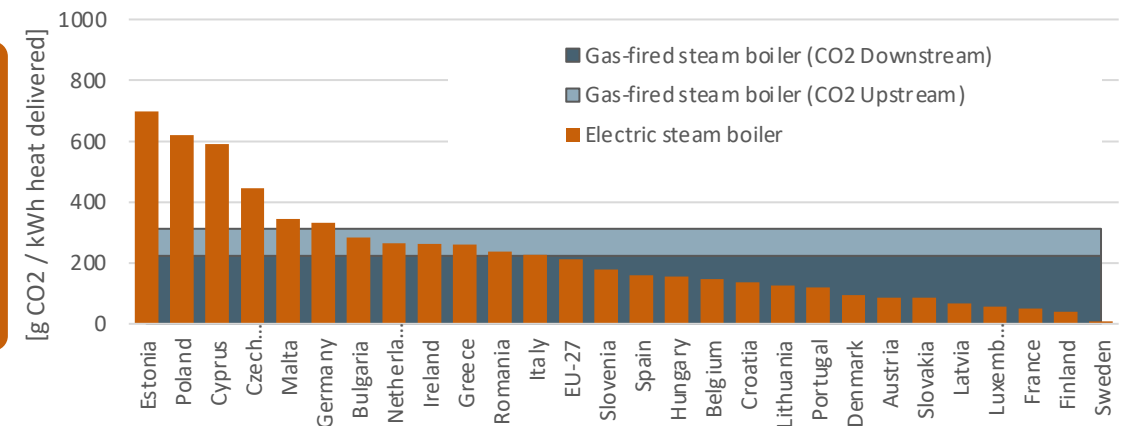
Glass melting



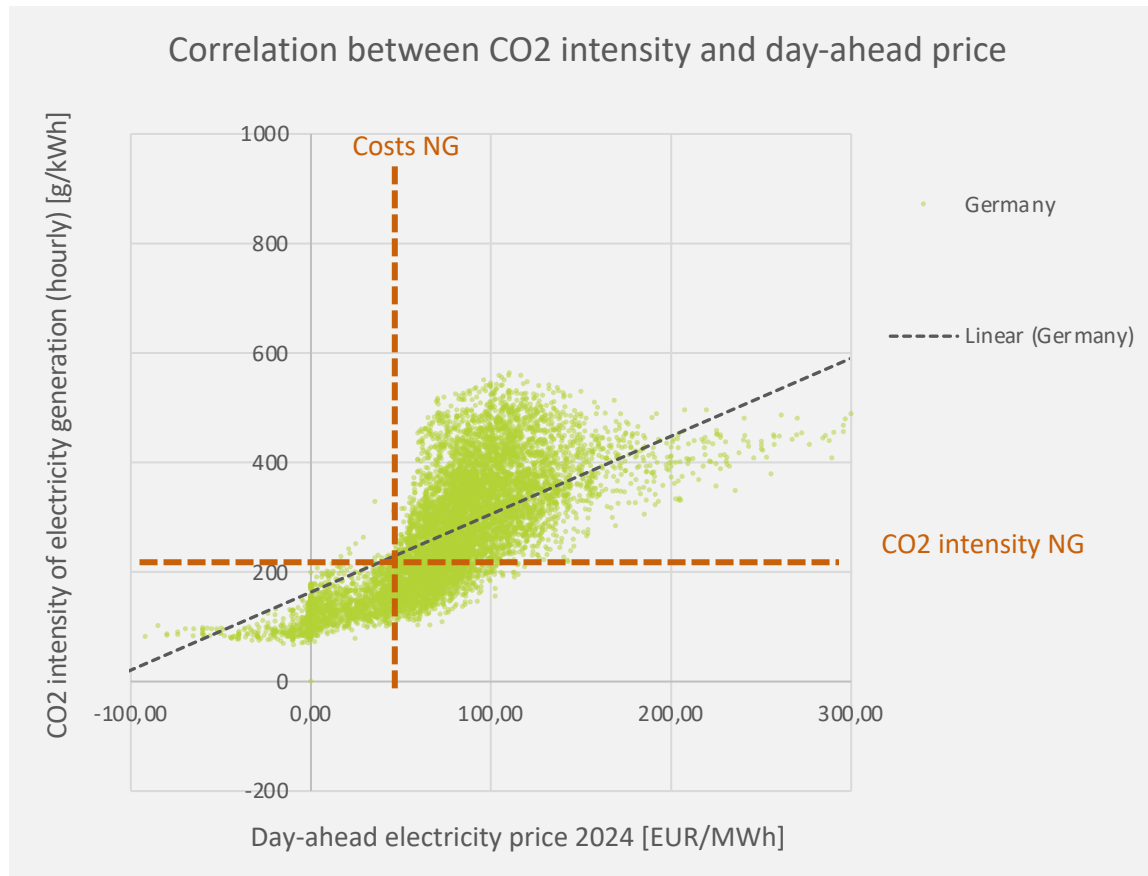
Heat pump



Electric boiler



Correlation of hourly emissions and prices for four selected countries



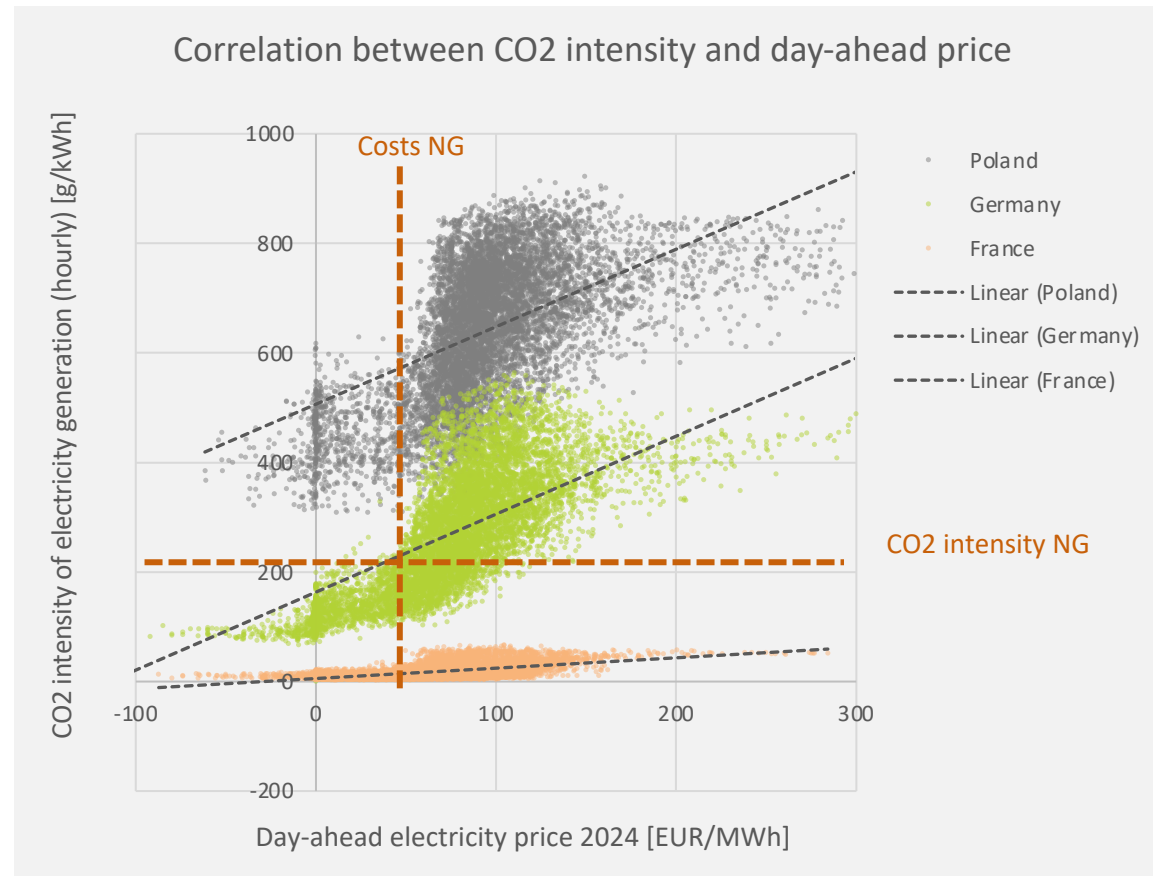
Insights

- Clear correlation: Hours with lower prices also have lower CO2 intensity
 - Comparison to natural gas:
 - In **Germany**, electrification reduces CO2 in all hours when it is cost-competitive compared to NG
 - In **France**, electrification reduces CO2 emissions in all hours
 - In **Poland**, in none
- > In the short term, electrification via flexible hybrid systems may be more suitable than instant full electrification

Data

- Hourly specific CO2 emissions of electricity generation from <https://app.electricitymaps.com/> for 2024
- Hourly day-ahead prices for 2024
- Natural gas: Downstream emissions only

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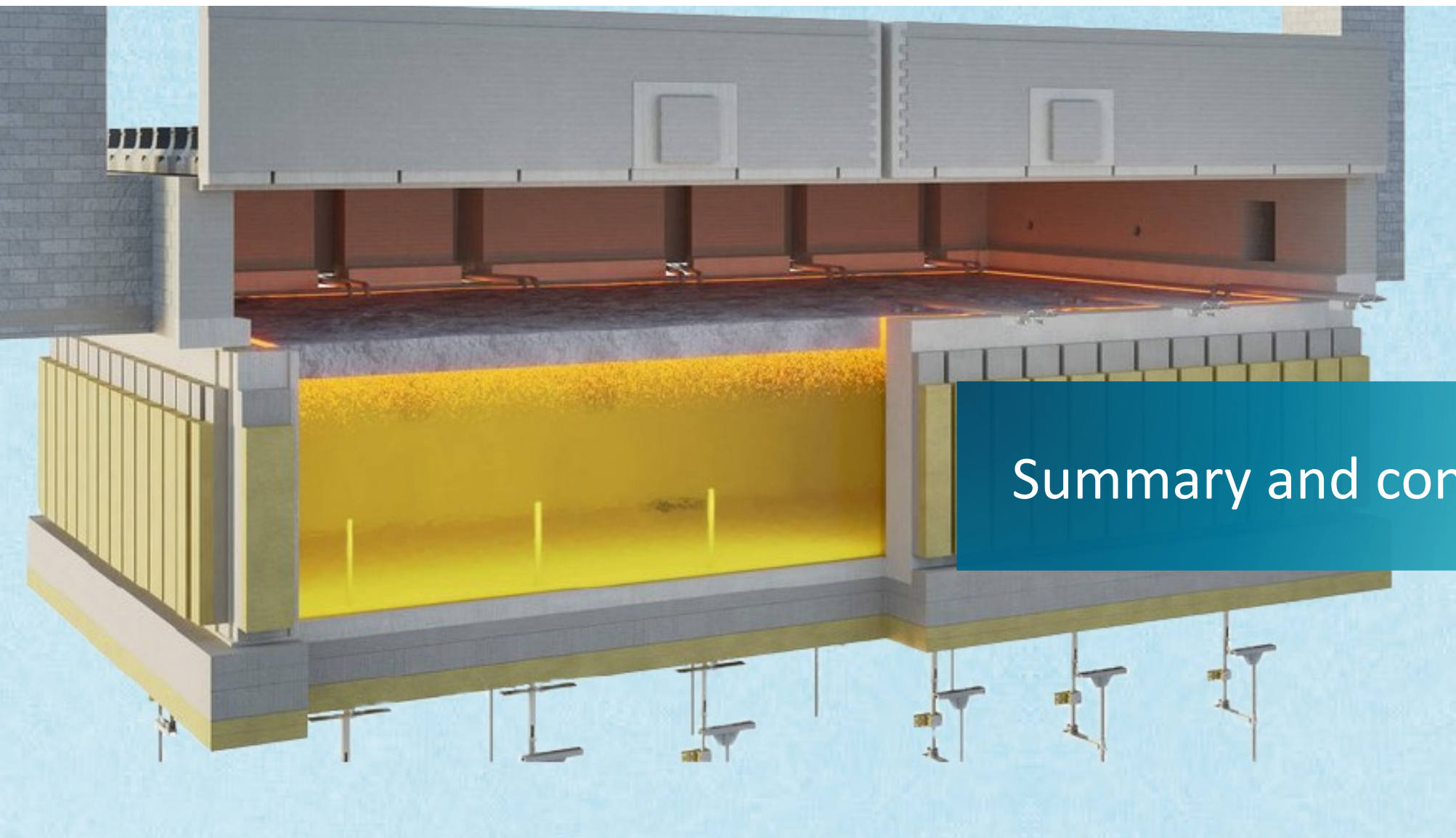
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High system benefits via flexible operation that follows wind and solar generation



6

Effective reduction of GHG emissions – even with "grey" electricity



Summary and conclusions

Summary

Technology

- **Technologies are available** to adress all temperature levels
- **Need for process integration**, demonstration, upscaling and further improvement

Economics

- **Full electrification** not cost-competitive in many countries. Main reason: electricity price too high compared to gas
- **Hybrid systems** are an enabler for companies to invest in the short-term

CO2

- **Electrification enables emission reduction** in most cases (few exceptions: Estonia, Poland, Cyprus, Czech Republic)
- **Grid emissions are falling quickly** in most countries, making electrification more and more attractive

Towards a strategy for "Electrification of process heat for climate neutrality and competitiveness"



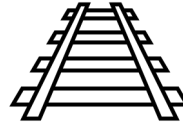
Enabling hybrid electrification in the short term:

- Reform grid fees
- Adjust subsidy conditions
- Prioritize grid connection requests

Enable upscaling:

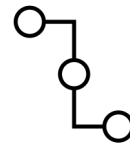


- Develop key technologies: HT heat pumps, thermal storage, HT solutions
- Demonstrate technology maturity and process integration
- Strengthen grid connection for industrial sites
- Rapid expansion of renewable energies



Create long-term stability to enable investments

- Provide competitive electricity price
- Phase-out subsidies for natural gas and fossils
- Robust CO2 price in ETS 1 and ETS 2
- Solutions for processes that are difficult to electrify: hydrogen, CO2 capture, biomass, etc.



Tapping into synergies

- Modernization of (partly outdated) plant facilities
- Digitization in production
- Security of supply
- Growth impulses through cleantech

Thank you for your attention!

Contact

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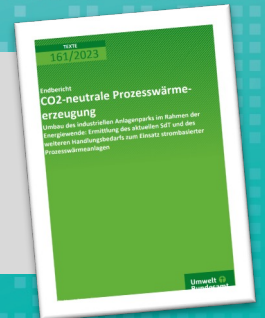
Policy Brief: CO₂-neutral process heat through electrification and the use of hydrogen

- ❖ Compact policy recommendations
- ❖ Technologies and economic efficiency
- ❖ Link: [Perspectives – Policy Briefs – Fraunhofer ISI](#)



CO₂-neutral process heat generation, 2023 (Federal Environment Agency)

- ❖ Focus on electrification potential EU27
- ❖ Link: [Direct electrification of industrial process heat](#)



Flexibilization of electrified industrial processes, 2024 (KEI)

- ❖ Technical potential for flexibility
- ❖ Economic efficiency and recommendations for regulation
- ❖ Link: [Study "Flexibilization of electrified industrial processes" | Competence Center for Climate Protection in Energy-Intensive Industries \(KEI\)](#)



More material available:

Direct Electrification of industrial process heating, 2024 (Agora Industry)

- ❖ Focus on electrification potential EU27
- ❖ Analysis of electrification technologies
- ❖ Link: [Direct electrification of industrial process heat](#)

