ETP Institute of Electrotechnology

Leibniz Universität Hannover

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Decarburization of industrial heating processes using electrotechnologies: potentials and challenges

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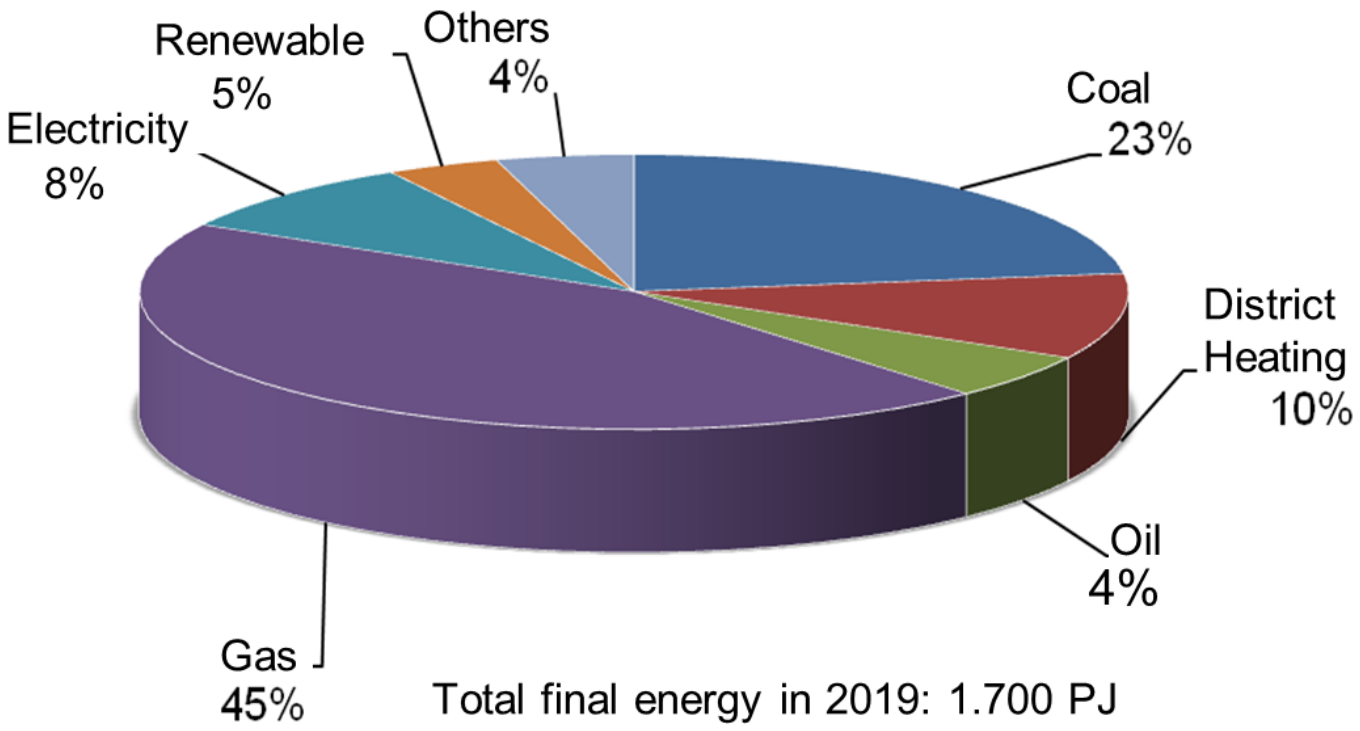
Outline

- Introduction
- Industrial energy demand
- Renewable energy sources for heating processes
- Process requirements and challenges
- Applications and examples
- Conclusions and Outlook

Current situation and potentials for defossilisation of industrial heating processes

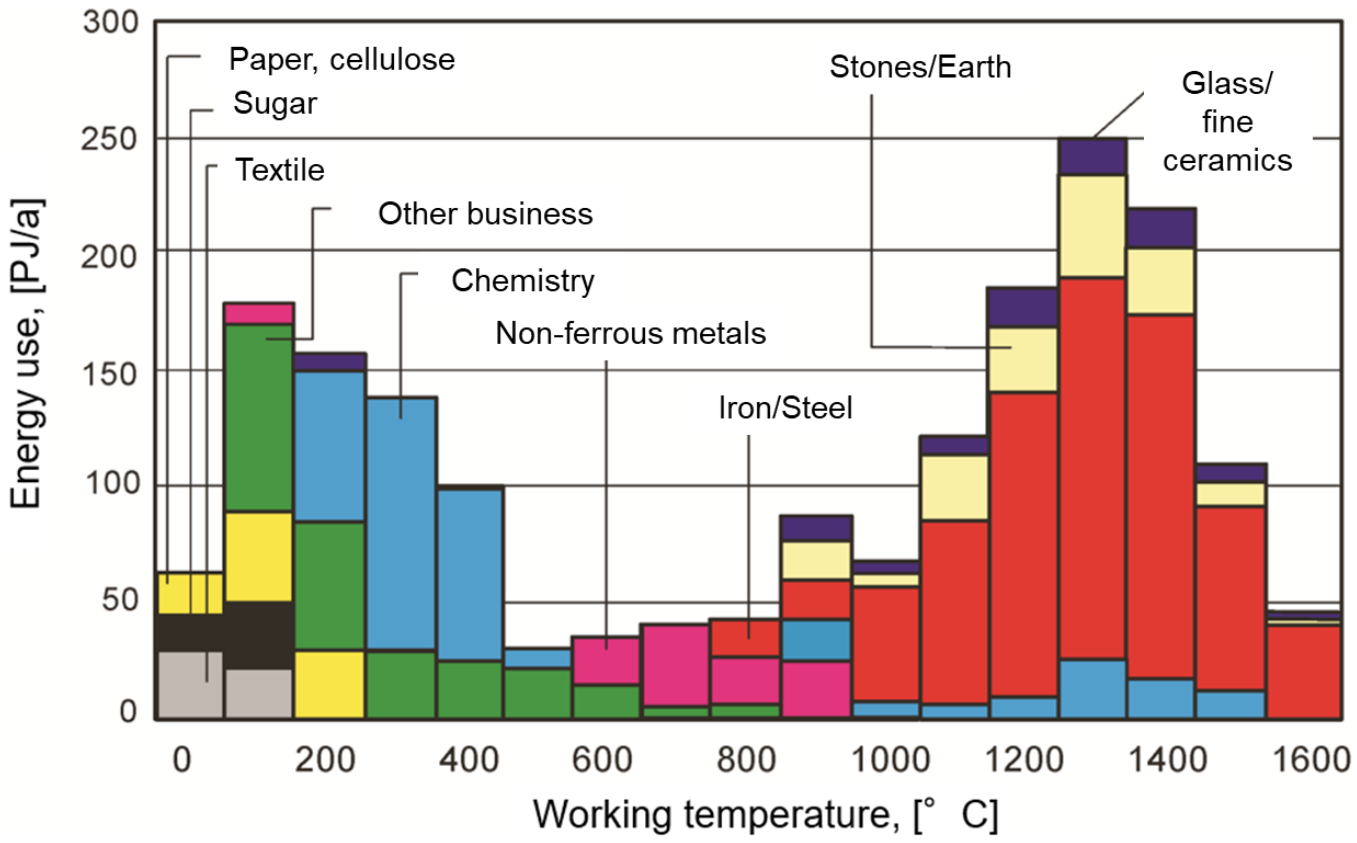
Final energy sources in the sector industrial process heat in Germany



Source: Arbeitsgemeinschaft Energiebilanzen 09/2020

- Appr. 2/3 of the total final energy in industry is used in the sector industrial process heat
- Today more than 80% of the final energy for industrial process heat is based on fossil fuels
- 15% of the annual CO_2 emissions in Germany are caused by industrial thermal processes
- Decarburization and defossilisation of industrial thermal processes by using of climate neutral energy carrier like: green hydrogen, bio/synthetic methane, bio mass or **renewable electricity**

Challenges for the application of renewable energy sources in industrial heating processes



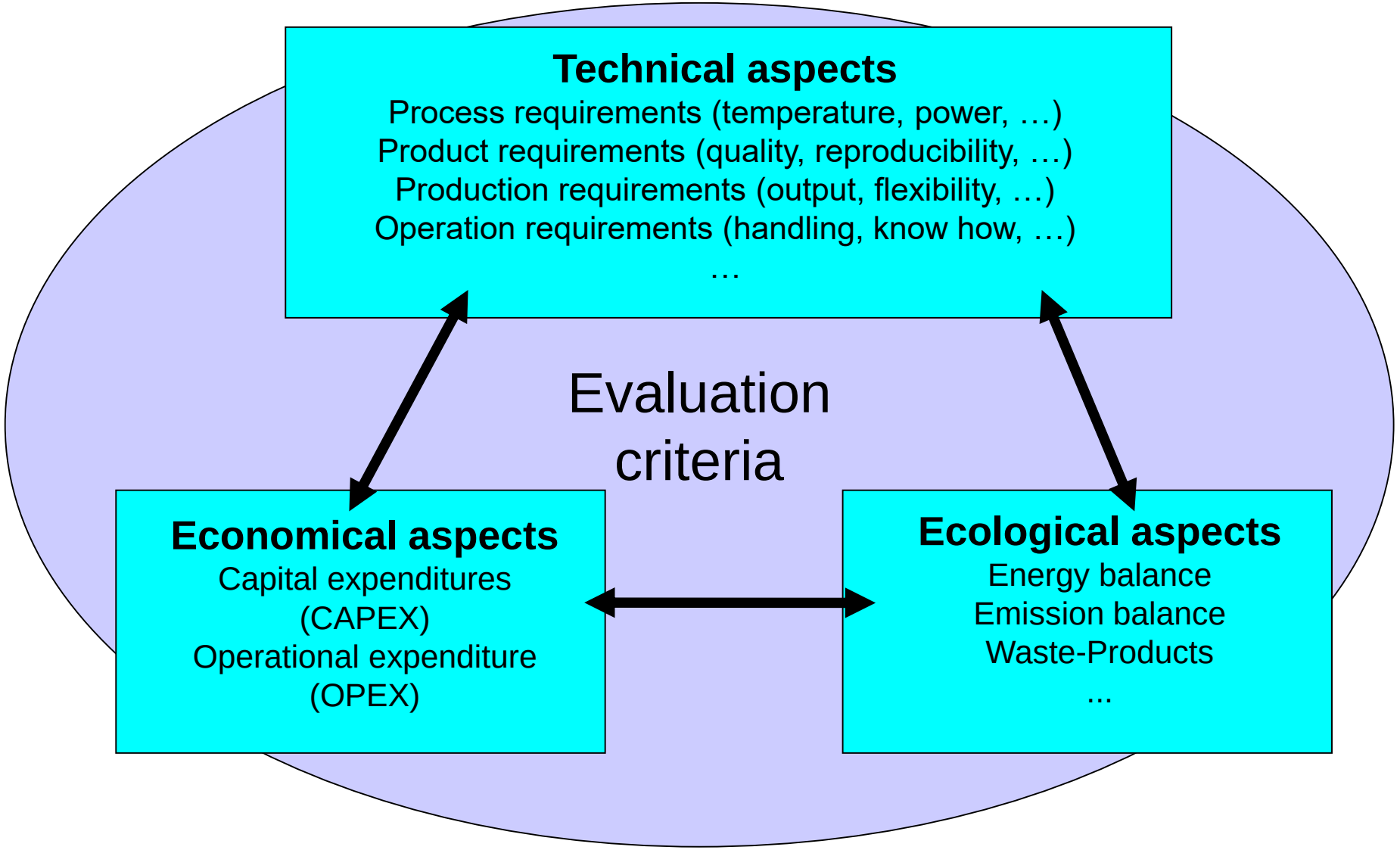
Source: Praxishandbuch Thermoprozesstechnik, Band 1, 3. Auflage, Vulkan-Verlag 2018

- Industrial heating processes cover a wide range of temperatures
- Different applications, materials and products
- A wide range of power and energy demand
- Specific furnace atmospheres, chemical reactions required
- Different operation modes, e.g. batch or continuous processes
- Different furnace dimensions and technologies
- Reliability and volatility of energy supply, possibilities of energy storage
- Economical aspects, e.g. capital and operational expenditure
- Uncertainty of technology changes
- Political boundary conditions

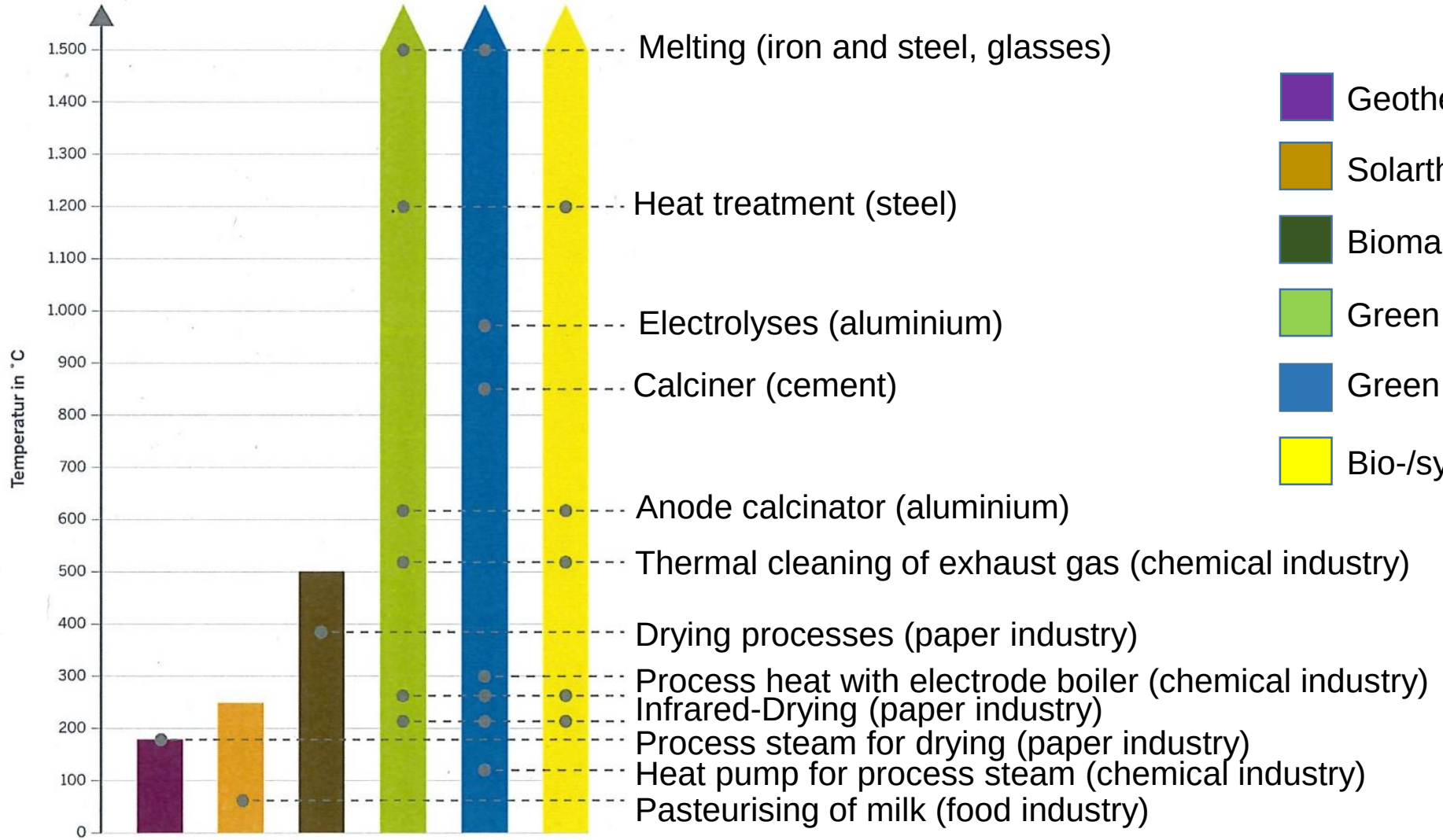
Examples of industrial heating processes, technologies and energy carrier

Industrial Heating Processes	Temperature-Level	Heating Installation	Energy Carrier (Today)
Process steam generation (water)	100°C – 500°C	Steam boiler with burner, electrode boiler	gas, oil, coke, electricity
Drying processes (e.g. paper, coating, lacquering)	100°C – 400°C	Hot air furnaces, Infrared dryer,	gas, electricity
Heating for deforming, pressing, joining, heat treatment (steel, iron, non-ferrous metals, plastics)	400°C – 1300°C	Conventional furnaces, inductive/conductive heating installations	gas, oil, electricity
Calcination (ceramics, clinker, cement)	up to 1600°C	Industrial furnaces (chamber- or rotary furnaces)	waste based heating material, gas, oil
Melting processes (iron and non-ferrous materials, glasses)	up to 1650°C	Melting furnaces	coke, gas, oil, electricity

Evaluation criteria for industrial process technologies



Potentials of renewable energy sources for industrial heating processes



Source: IN4climate.NRW (Hrsg.) 2021 Industriewärme klimaneutral: Strategien und Voraussetzungen für die Transformation.

Requirements and strategies for climate neutral process heat

How can we archive the targets for climate neutral heating processes?

Measures and strategies for climate neutral process heat technologies

Technical and economical available and reasonable	Technical available but economical not yet profitable	Technical not yet available
Task: Knowledge transfer to industry and politics	**Task:** Influence to politics for implementation of a decarburisation electricity price	**Task:** Mediation in politics and science on research and development needs

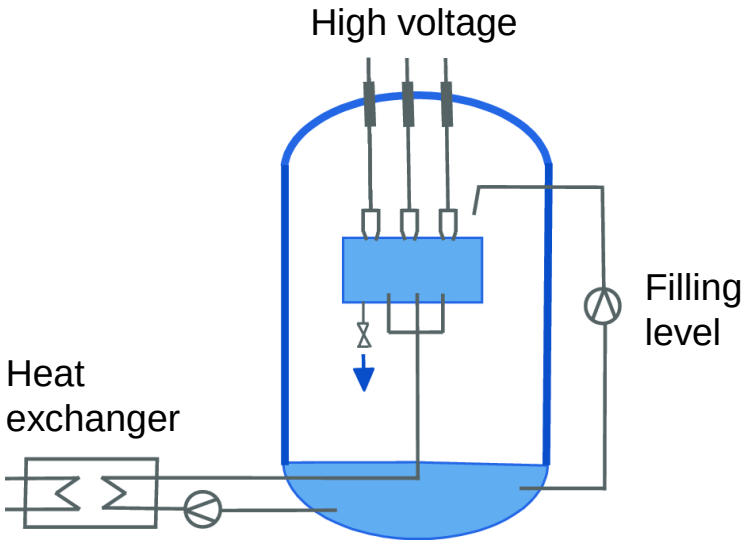
Electrification of industrial heating processes
Example: Generation of process steam

- Steam is widely used in industrial heating processes (chemical, textile, food industry)
- Today steam is mainly produced by gas or coal fired boilers
- Different temperature and pressure levels are used

Gas fired industrial boiler for process steam

Source: www.getec-energyservices.com

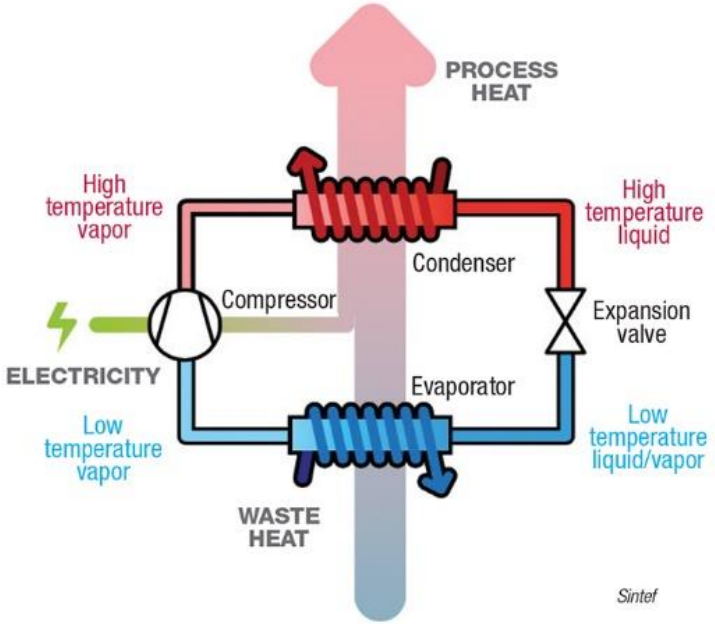
- Direct electrical heating of water by submerged electrodes
- High efficiency (up to 99%), fast and flexible heating mode
- Relative simple and robust technology



Electrode boiler for hot water and process steam

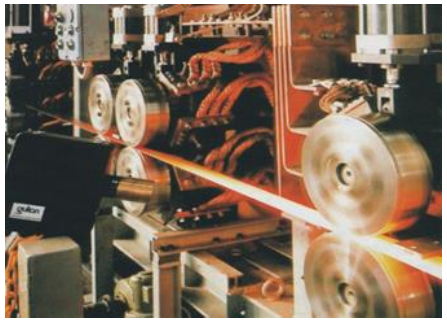
Source: www.springer.com

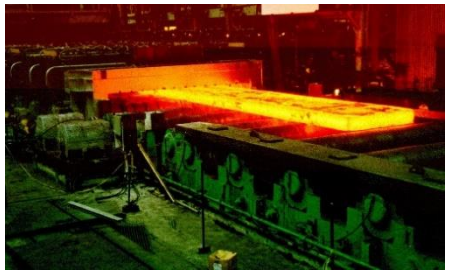
- Heat pumps with high coefficient of performance (COP>3) for temperature up to 150°C
- High temperature heat pumps are under development

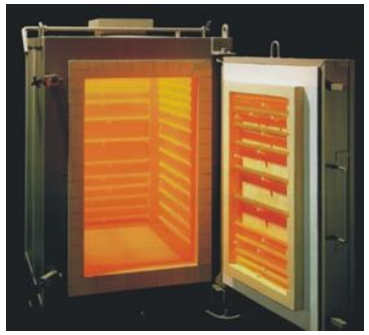


Heat pump for hot water and process steam

Electric heating: multifunctional industrial applications



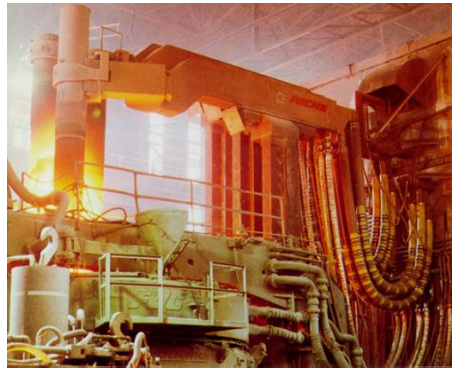




Inductive Heating

Resistance Heating

Inductive Melting



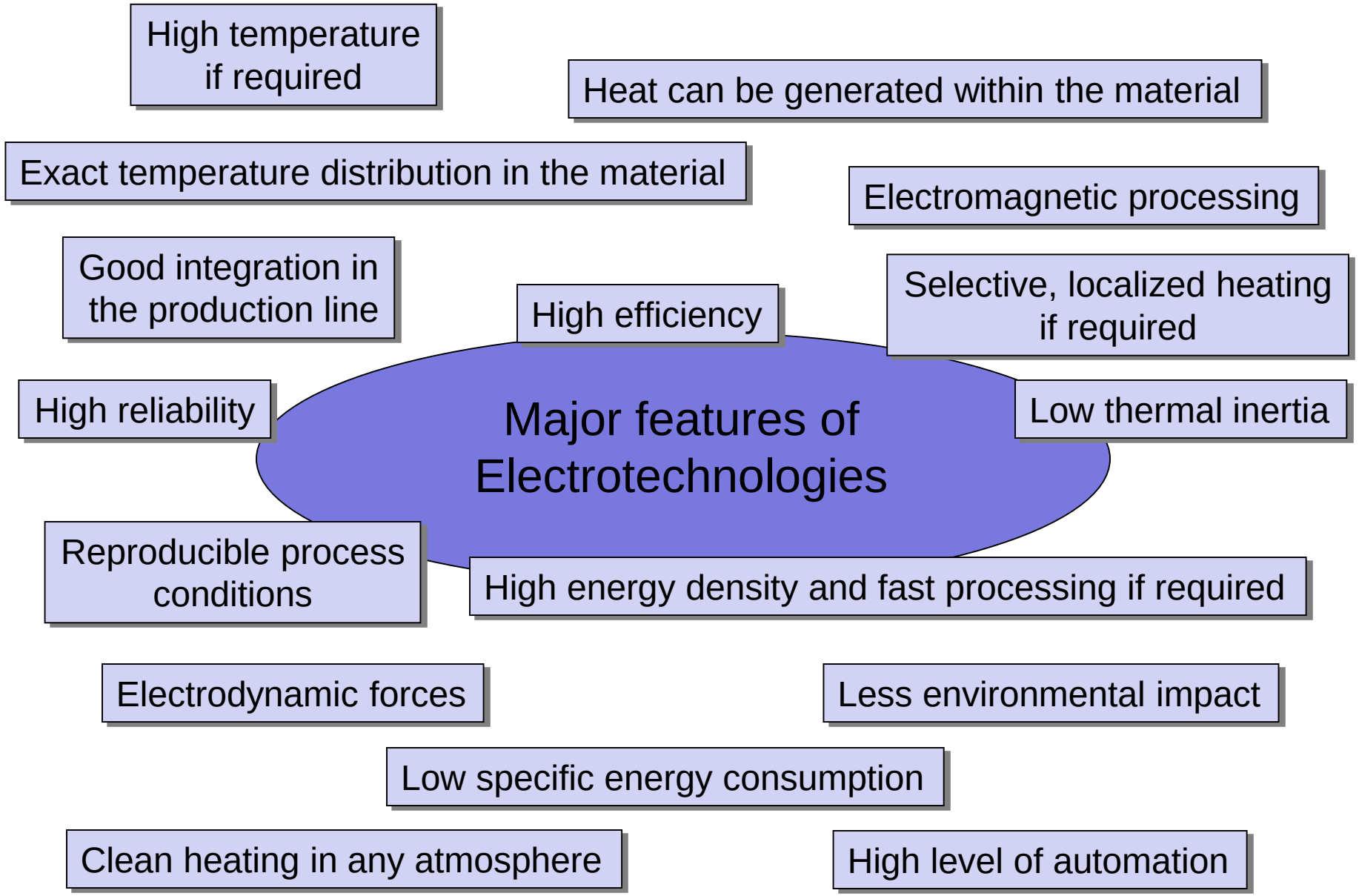
Electrothermal processes
(examples)

Laser beam Heating

Arc furnace Melting

Dielectric Heating

Infrared Heating

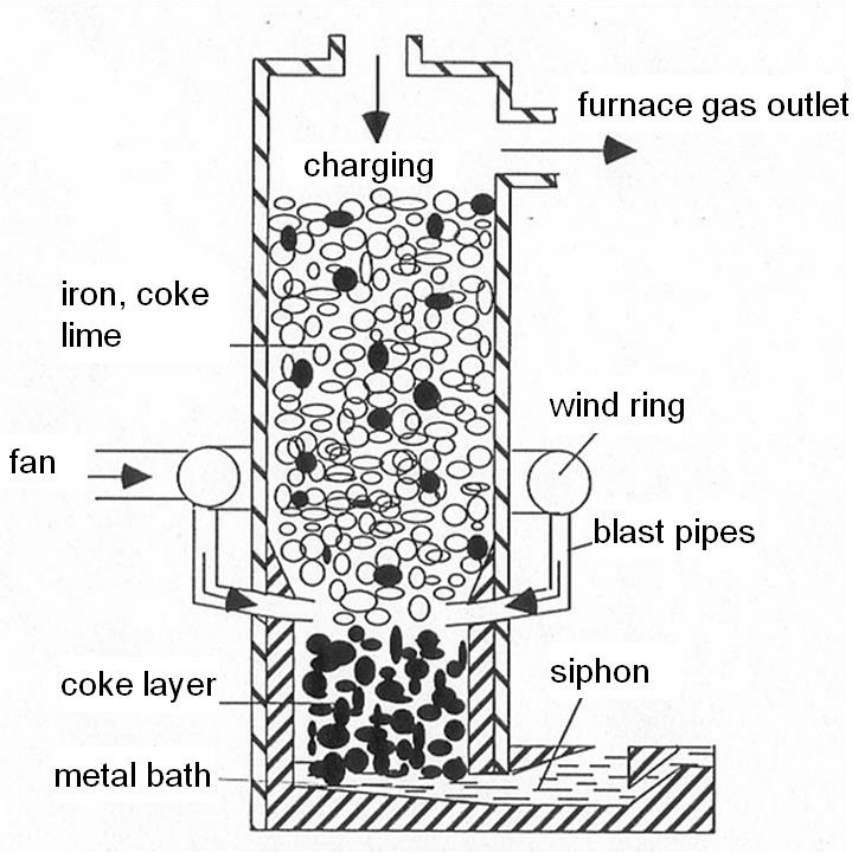

High temperature if required
Heat can be generated within the material
Exact temperature distribution in the material
Electromagnetic processing
Good integration in the production line
High efficiency
Selective, localized heating if required
High reliability
Major features of Electrotechnologies
Low thermal inertia
Reproducible process conditions
High energy density and fast processing if required
Electrodynamic forces
Less environmental impact
Low specific energy consumption
Clean heating in any atmosphere
High level of automation

Hybrid heating solution in industrial thermal processes

Combination of different heating technologies using different energy carrier, e.g. electricity & gas
Technical, energetic and economical advantages:

- Flexible use of different energy carrier depending on disposability and costs, e.g. renewable electricity
- Flexible fuel-based and electrothermal processes in heating and melting plants, e.g. iron and steel industry, cement production, glass industry
- Increasing of energy efficiency, productivity and quality of the heating process
- Increasing of the reliability and flexibility of the heating process

Example for decarburization: Melting process in the cast iron industry



Hot blast cupola furnace (share: 50%)

- Continuous operation mode
- Low flexibility
- Low energy costs (coke)

Hot blast cupola furnace)

Energy balance:

900 kWh/to coke
20 kWh/to gas
30 kWh/to electrical energy
140 kWh/to oxidation losses

Total energy: 1070 kWh/to

Total CO2 emission: 810 kg/to (electricity mix 2022)

Induction crucible furnace

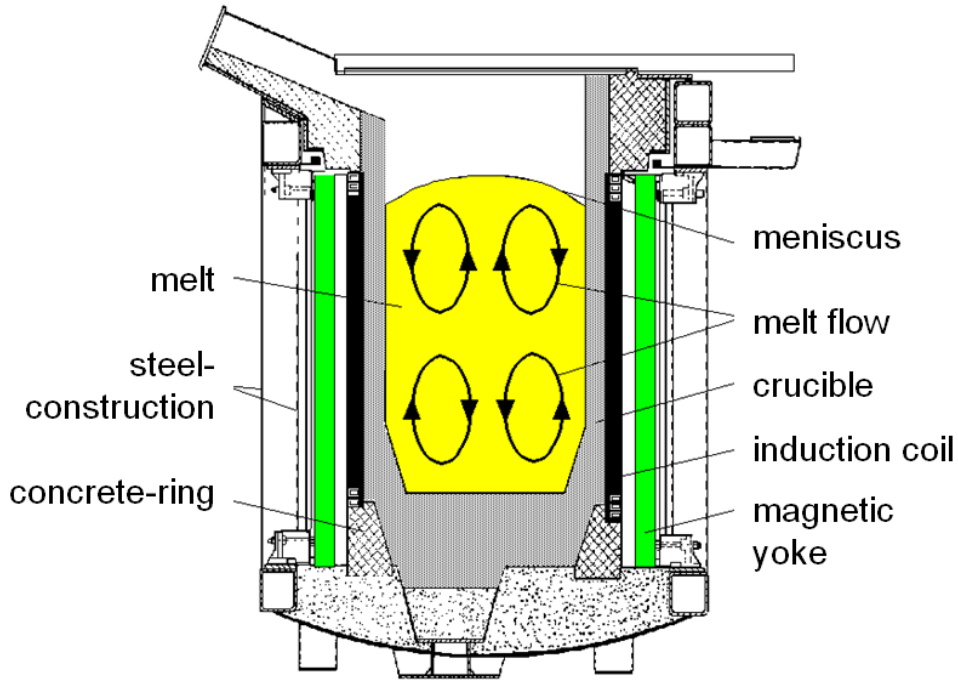
Energy balance:

415 kWh/to electrical energy
45 kWh/to oxidation losses
75 kWh/to carburization

Total energy: 535 kWh/to

Total CO2 emission: 220 kg/to (electricity mix 2022)

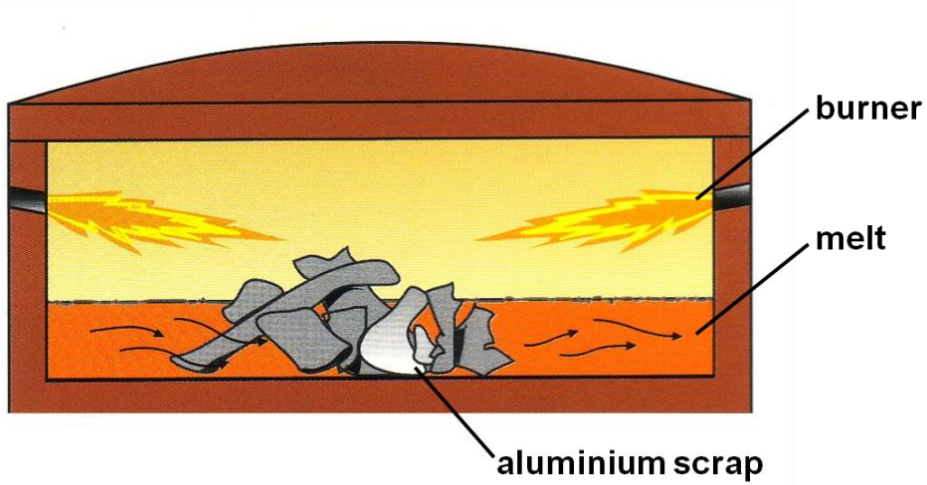
Total CO2 emission: 20 kg/to (green electricity)



Induction crucible furnace (share: 50%)

- Batch operation mode
- High flexibility
- High energy costs (electricity)

Example for decarburization: Melting process in the aluminium industry



Gas fired furnace (share: 92%)

- Gas burner direct on melt surface
- Low efficiency
- High oxidation losses
- Low energy costs (gas)

Gas fired melting furnace

Energy balance:

715 kWh/to gas

775 kWh/to oxidation losses

Total energy: 1490 kWh/to

Total CO2 emission: 490 kg/to

Induction channel furnace

Energy balance:

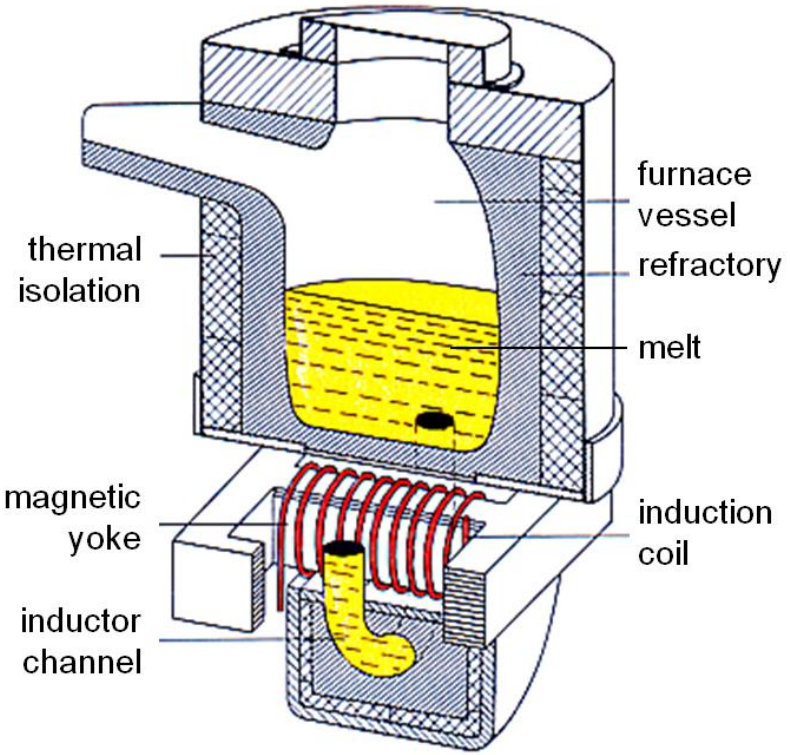
520 kWh/to electrical energy

200 kWh/to oxidation losses

Total energy: 720 kWh/to

Total CO2 emission: 340 kg/to (electricity mix 2022)

Total CO2 mission: 90 kg/to (green electricity)



Induction channel furnace (share: 8%)

- Induced power in the channel
- High efficiency
- Low oxidation losses
- High energy costs (electricity)

Conclusions and Outlook

- Appr. 2/3 of the total final energy in industry is used in the sector industrial process heat and today more than 80% of these heating processes are based on fossil fuels
- Process heating based on renewable electrical energy offers great potential for energy saving and climate-neutral thermal processes in industry
- But: industrial heating processes cover a wide range of technological and application depending requirements, like process temperatures, heating power and energy demand, furnace dimensions and atmospheres, operation modes and many others
- Electrotechnolgies enable the direct, efficient, versatile use of renewable electrical energy and can thus make a significant contribution to the sustainable decarburization and defossilization of industrial heating processes in the future
- Decarburization of the electrical energy supply so that climate-neutral technologies for industry, like electrothermal processes or green hydrogen production become a real option
- Subsidization of climate-neutral technologies as well as a generally higher CO_2 price to favor the currently disadvantaged climate-neutral options and at the same time to get the industry to rethink


Thank you very much for you attention!