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# Analyse der bestverfügbaren Technologien und Ausblick auf zukünftige Entwicklungen für Erwärmungsöfen der Stahlindustrie


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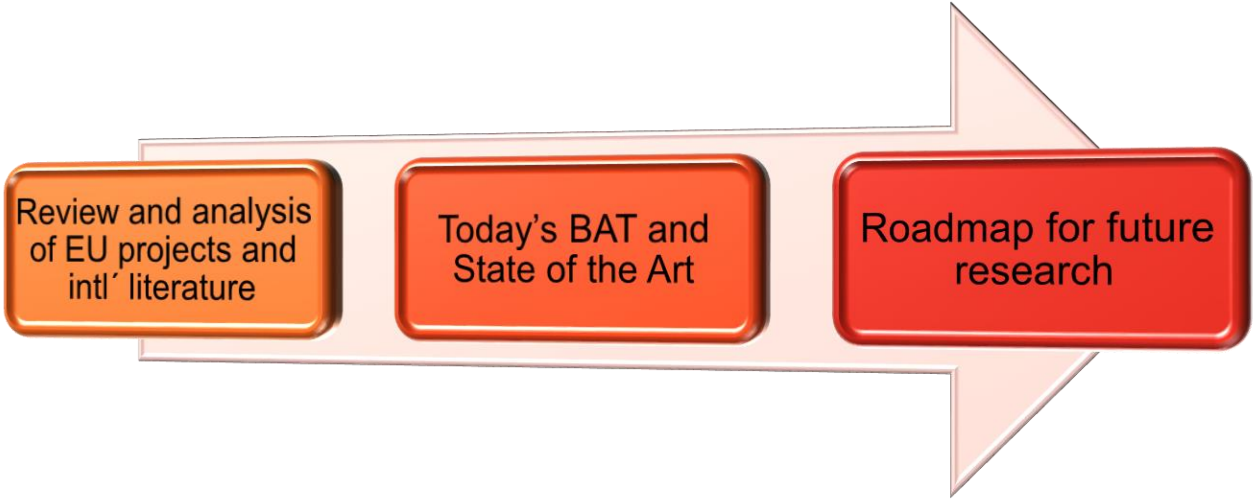
# dissHEAT in a nutshell

**Dissemination of the heating technology research results for emission minimization and process optimization towards todays fossil-free heating agenda – dissHEAT (G.A. 101057930)**

*Coordination: Andreas Johnsson (SWERIM)*

*Partners: SWERIM, BFI, CRM, RINA CSM, RWTH-IOB*



# Methodology

**Analysis of RFCS projects, Horizon Europe projects and international literature over the last 25 years based on the main topic ”*reheating furnace*”.**

Classification into five main topics:

- Heating and burner technology
- Modeling of entire furnaces, Level-2 control
- Sensors and controls, standards, regulations
- Materials in the furnace and product quality
- Heat transfer, heat recovery, CAPEX, OPEX

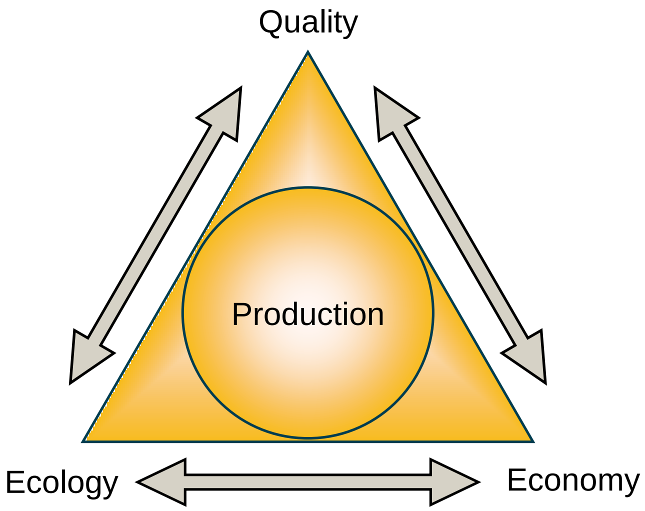
Comprehensive analysis and evaluation, classified into KPIs and categorized with a special focus on low-$CO_2$ heating

Identification of market needs and defintion of a roadmap for future research

# What it's all about…

**Production is always the main target of reheating furnaces, considering ...**

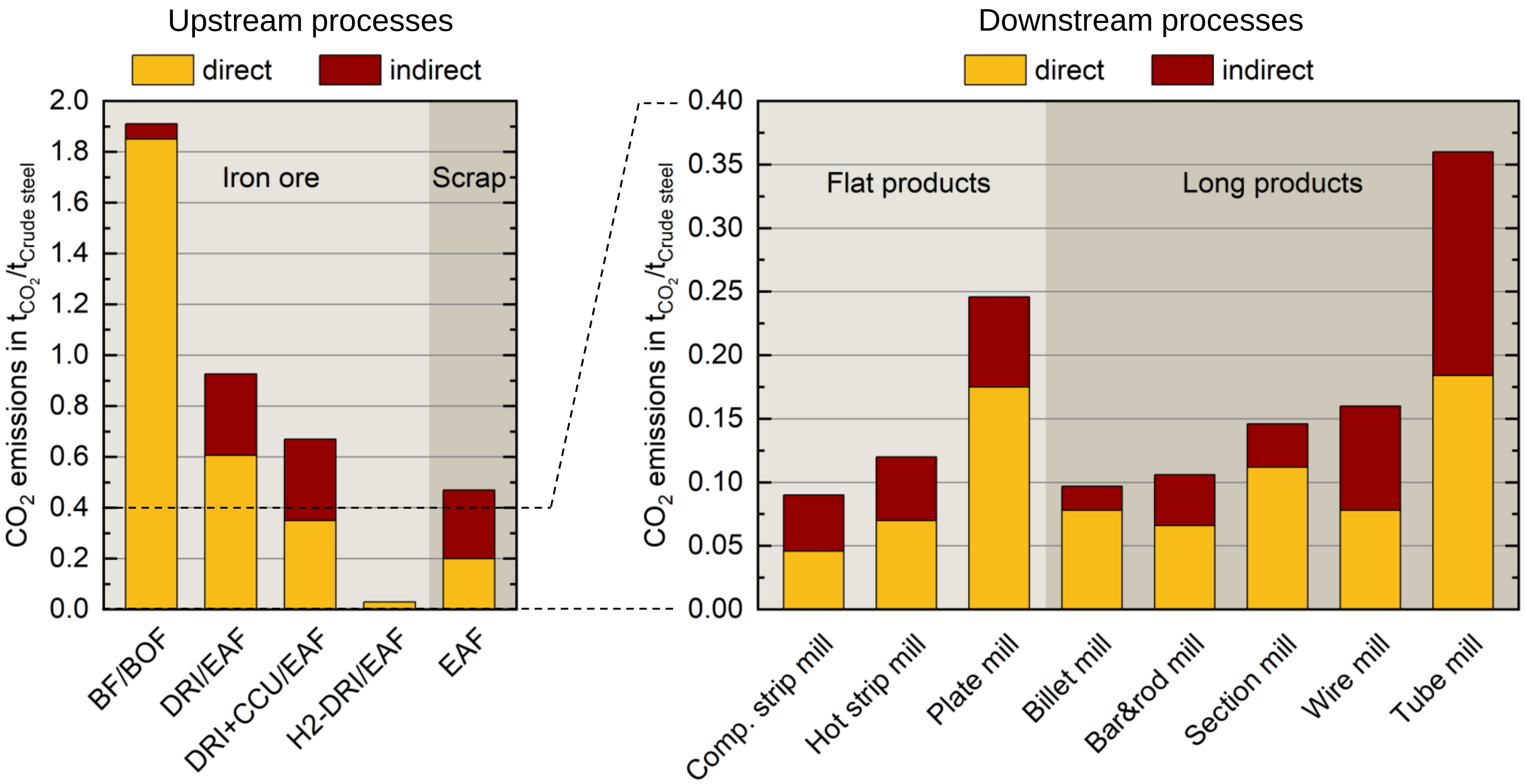
- the best product quality
  min. temperature gradient, min. thermal stress, low scale formation, low decarburization, …
- at minimum costs
  low CAPEX, low OPEX through energy efficiency and digitalization
- with minimum carbon footprint
  energy efficiency, digitalization, alternative fuels, electrification?
- and lowest air pollutant formation
  ultra low $NO_x$ burners, low CO emissions




→ Highly relevant for greenfield projects, brownfield retrofits and operating furnaces in rolling mills and forging lines

Illustration adapted from: E. Malfa: Sustainable heating technologies for today's and tomorrow's metal industry, dissHEAT workshop at ESTAD 2023, 15/06/2023, Duesseldorf

# Where do we stand today…




Data from: E. Malfa: Sustainable heating technologies for today's and tomorrow's metal industry, dissHEAT workshop at ESTAD 2023, 15/06/2023, Duesseldorf
based on EUROFER, Determination of GHG emissions in energy-intensive industries, 2020; ENERGIRON process data, 2015; Internal Tenova evaluations, 2022.
$CO_2$ intensity for grid electricity 0.376 t/MWh

# Heating and burner technology

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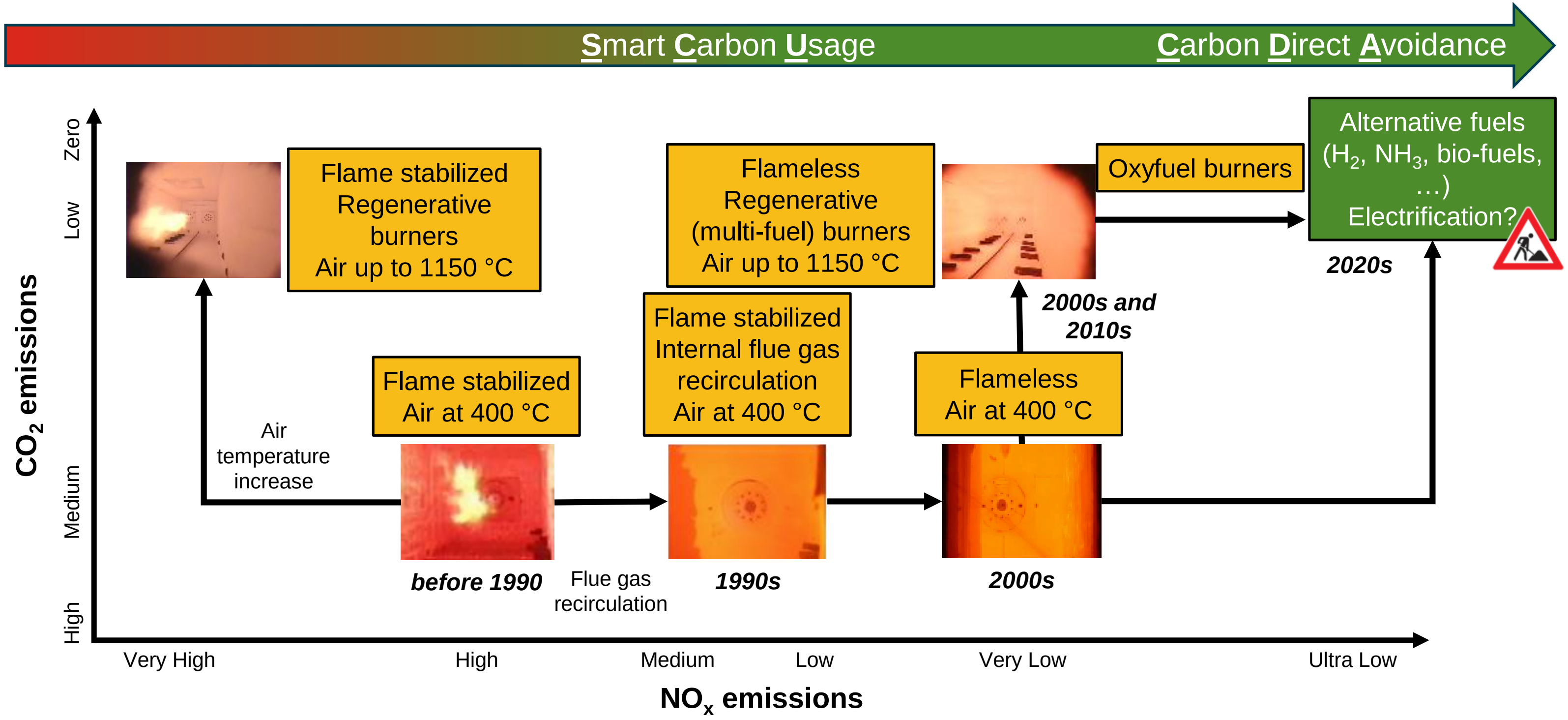
## Combustion system developments in the last 25 years

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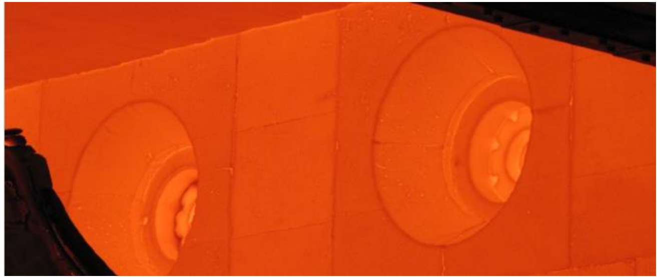
SWERIM
European Commission
Research Fund for Coal & Steel

# Heating and burner technology

## Today's Best Available Technologies



- Regenerative burner technology
- Flameless/Ultra Low-$NO_x$ combustion
- Oxyfuel combustion
- Multi-fuel burner configurations for integrated steel plants
- Productivity boosting with oxygen-enriched combustion

➡

- Optimized utilization of steel plant gases and fuel
- Improved energy efficiency by high air preheating or oxyfuel combustion
- Lowest $NO_x$ emissions (in the range of 100 mg/m³)

# Modeling and Level-2 control

**Today's Best Available Technologies**

- Prediction quality of combustion simulations has massively increased, but ongoing work – especially for new fuels
- Full furnace CFD simulations are possible with smart modeling approaches and reduced kinetic mechanisms/tabulated chemistry

➡ Tools for design optimization and in-depth analysis of furnaces

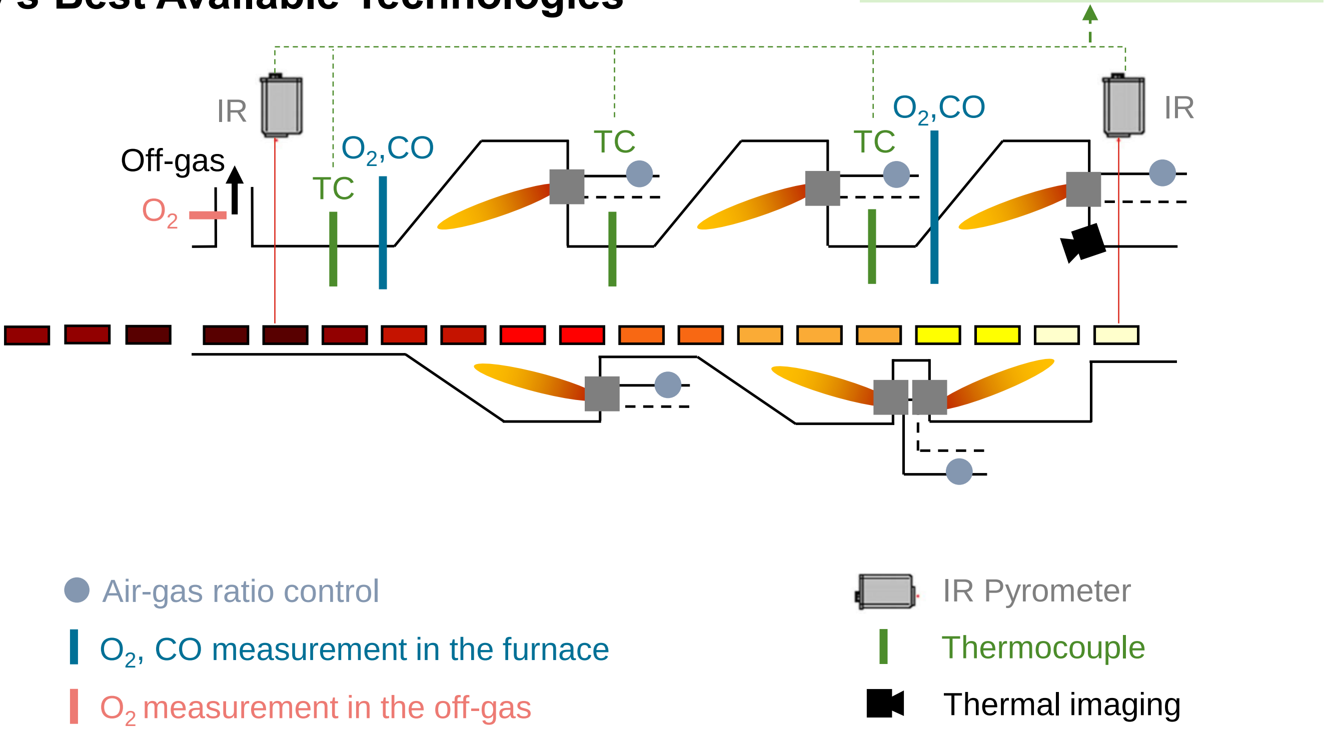
- Dynamic temperature control by Level-2 models
- Connection to other parts of the plant (roughing mill) and Level-3 systems
- First integration of Artificial Intelligence (AI) for predictive maintenance etc.

➡ Tools for process optimization, control and OPEX minimization

# Sensors/controls, standards, regulations

level-2 systems for optimized temperature control

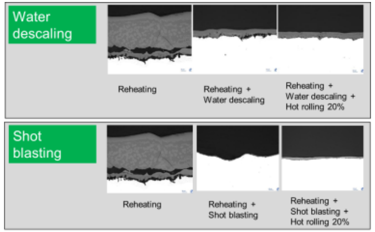
## Today's Best Available Technologies

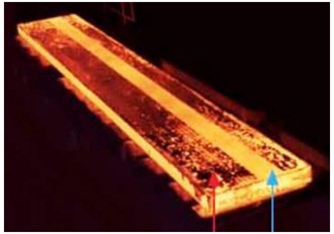


# Materials and product quality

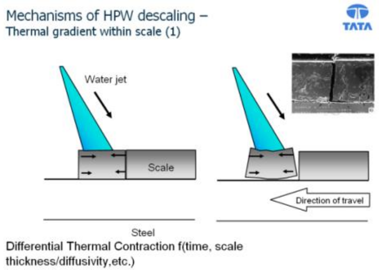
## Investigations and research in the last 25 years

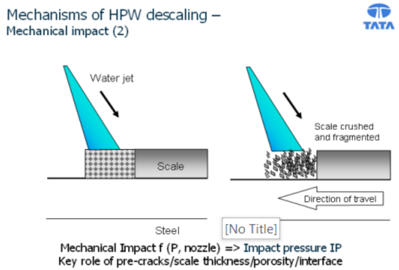
- Focus of investigations on surface properties of the product:
  - Scale
  - Decarburization
  - Interfaces
  - Defects

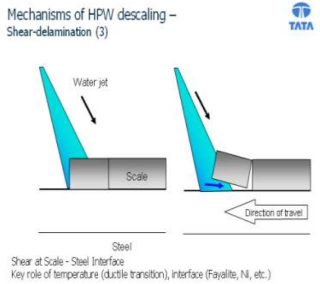


- Research in the past 25 years focusing on scale growth, descaling and application of coatings



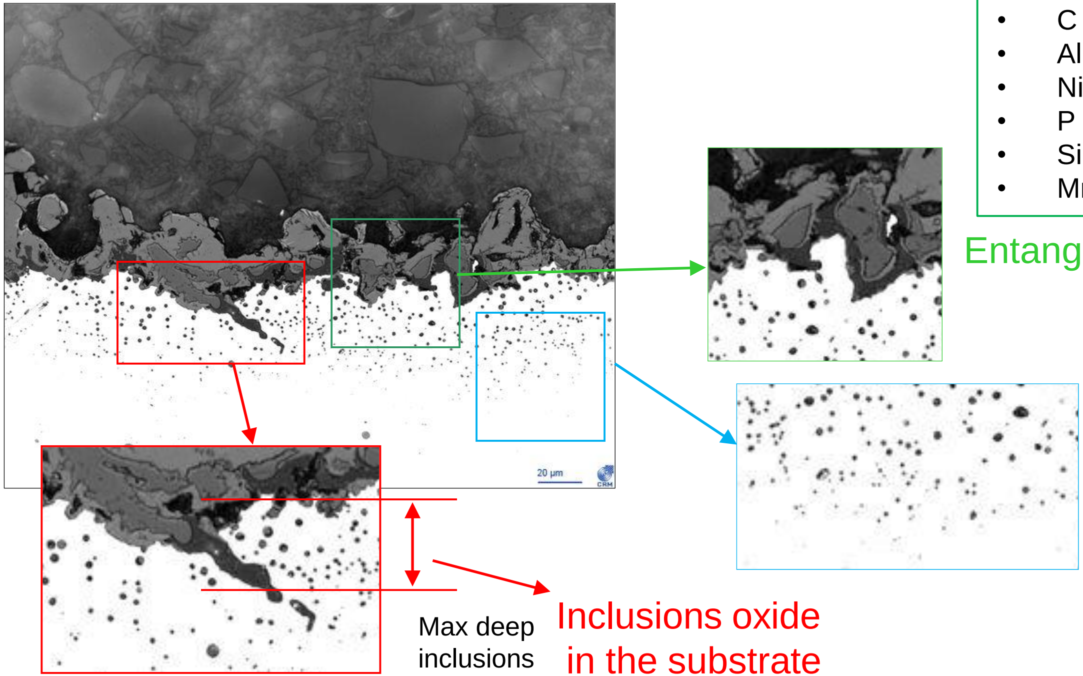



# Materials and product quality

## Example: Impact of alloying elements on scale formation:

Elements with a very high effect on scale are:

| | | |
|---|---|---|
| • | C | Porous and blisters |
| • | Al and Cr | Reduction oxide |
| • | Ni | Metallic particles |
| • | P | Blisters |
| • | Si | Formation of fayalite |
| • | Mn | Low adherence |



# Materials and product quality

**Today's Best Available Techniques – theoretical guidelines**

- Limit alloying elements (e.g. Al, Si, P, B, Cr, Mo, Ti, Nb, Cu, Ni, Sn, As, Sb)
- Limit reheating temperature
- Limit duration in the furnace, especially at high temperatures
- Limit oxygen content of the furnace atmosphere
- Limit humidity of the furnace atmosphere
- Limit transfer time between furnace and descaler
- Assure an optimum descaler performance related to the steel grade
- Apply coatings to avoid decarburization depending on product and steel grade
- Higher scale formation rates are beneficial for reducing decarburization, as these regions are removed by the oxide layer

# Efficiency, productivity and economy

## Today's Best Available Technologies for Efficiency improvement

Recuperative systems

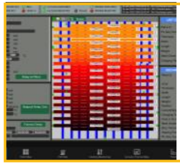
air preheating up to 650 °C

4-8% $CO_2$ reduction

Regenerative burners

air preheating up to 1150 °C

8-12% $CO_2$ reduction



Level-2 control system

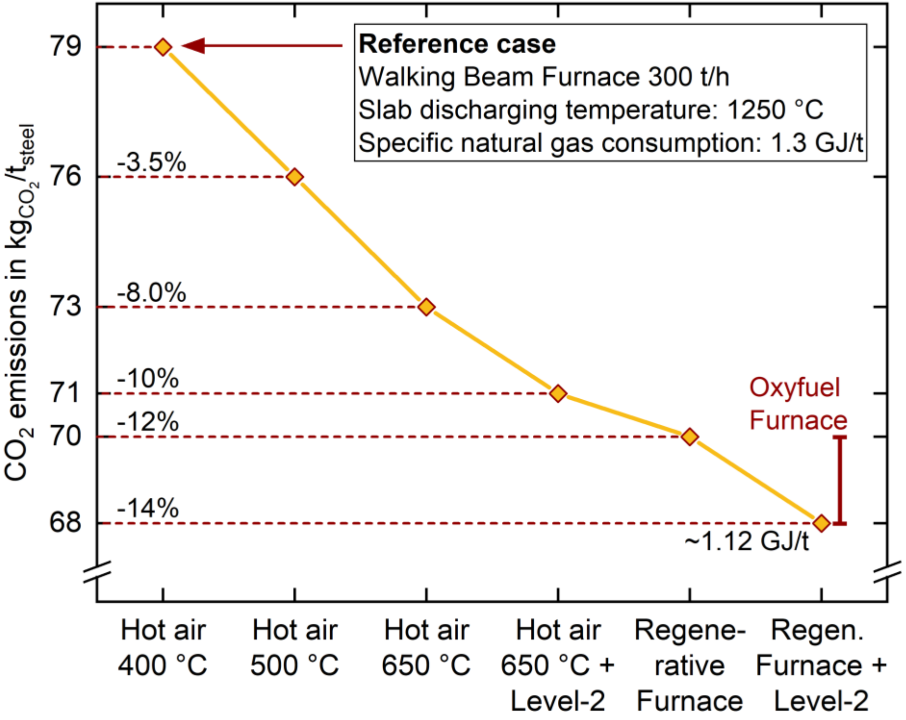
optimized heating strategies

1-3% $CO_2$ reduction

Waste gas heat recovery

Steam for use/power generation

7-20% $CO_2$ reduction




Data from: E. Malfa: Sustainable heating technologies for today's and tomorrow's metal industry, dissHEAT workshop at ESTAD 2023, 15/06/2023, Duesseldorf

# Future research needs

## Heating and burner technology

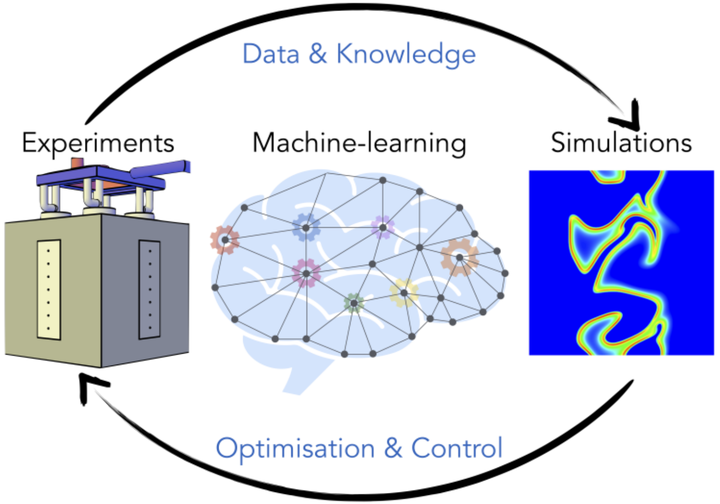
- Flexible heating with alternative fuels and oxidizers:
  - Hydrogen, bio-fuels, ammonia and combinations with well-known fuels
  - Air, oxygen-enriched and pure oxygen combustion
- Electrification and hybrid heating concepts
  - Tailored and well investigated concepts for resistive and induction heating in industrial environment

➡ Impact on process, product and plant!

# Future research needs

## Modeling and level-2 control

- Extended use of AI and machine learning approaches
- Joining statistical and physical models (e.g. physics-informed neural networks, hybrid models)
- Dynamic and auto-adaptive modeling approaches for flexible process control
- Improved kinetic schemes and turbu-lence-chemistry interaction models for the prediction of new combustion regimes



# Future research needs

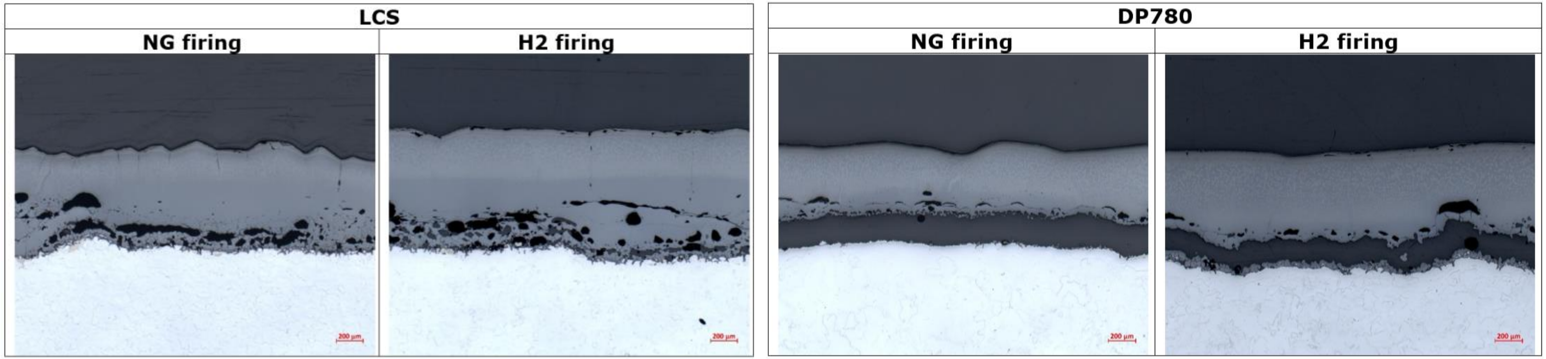
**Sensors and level-1 control, standards, regulations**

- Impact of alternative heating systems on measurement and control:
  - Flow measurement
  - Fuel quality measurement
  - Online air-to-fuel ratio control for flexible operation
  - Off-gas composition and pollutant emission measurement
  - Temperature measurement for process control
- Impact on standards and regulations:
  - $NO_x$ limit definitions for flexible operation
  - Revision of BREF Ferrous Metals Processing to new limit definitions
  - Revision of emission measurement standards

# Future research needs

## Materials and product quality

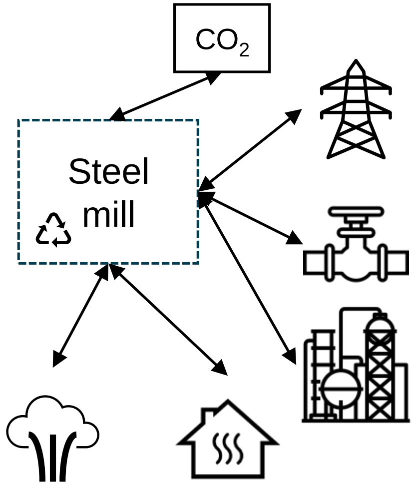
- Study of the impact of residuals on product quality (higher scrap rates):
  - Cu: diffuses quickly leading to segregation, roughening and intergranular oxidation
  - Mo: Increases scale adhesion above 0.25%
- Full screening of steel grades in new furnace atmospheres



# Future research needs

**Heat recovery, heat transfer, productivity and economy**

- System integration research:
  - Internal integration of new heating concepts within steel mill
  - Options for CCS/CCU
  - Flexible interaction with gas and electricity grids
  - Integration with chemical industry for synthetic fuel production
  - Heat integration with steam production or alternatives
- Flexible oxygen utilization for productivity and from an economic perspective



# Thank you for the attention!

**Stay informed**
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