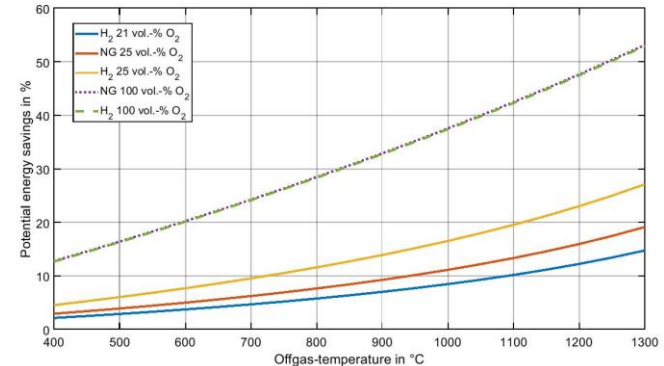
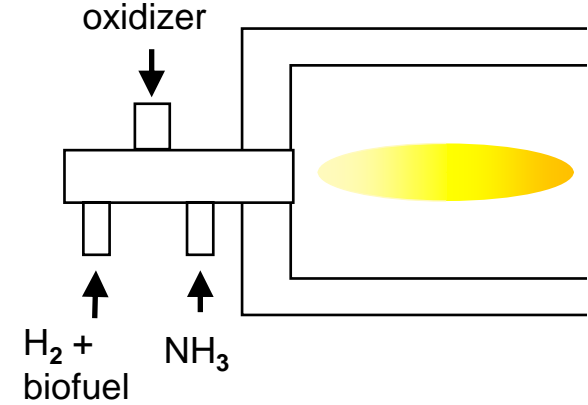


ROADMAP presentation for low carbon future for steel reheating furnaces

Technology impact and integration research:

- **Combustion heating**
with fuel flexible burners for future **fuels**:
Hydrogen, biofuels, ammoniac
Oxidizers: air, OEC, oxy-fuel – 100% O₂
NO_x-emissions:
Flameless or ultra LowNO_x burners
- Impact on product heating:
 - Flame temperature and shape
 - Radiative heat transfer of combustion gases (H₂O)

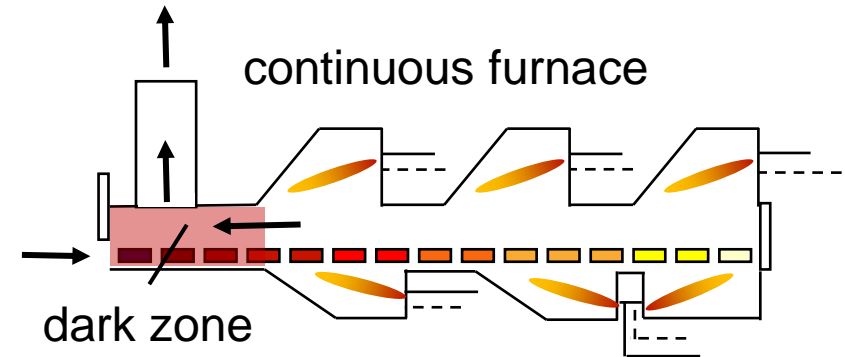


Technology impact and integration research:

- **Efficient** heating with new technologies by heatrecovery from exhaust to preheat:
 - Oxidizer, future fuels or mixtures with exhaust
 - Product in dark zone / heating with off gas from new fuels, hybrid and combinations
- Impact of measures on efficiency in specific plants / use cases

Oxidizer	Preheating oxidizer	Dark zone
Air	Green	Green
OEC*	Yellow	Green
100 % O ₂	Red	Green

* OEC: oxygen enhanced combustion



Technology impact and integration research:

Impact on **product and plant**

- Hydrogen combustion, electrical heating and combinations:
 - Influence on product-material, temperature uniformity, scaling
 - Influence on furnace and heating equipment when technologies are combined: i.e. high H₂O content in exhaust gas
=> influence on resistance heaters
=> influence on refractory and insulation
- Security when handling H₂ and/or O₂



Technology impact and integration research:

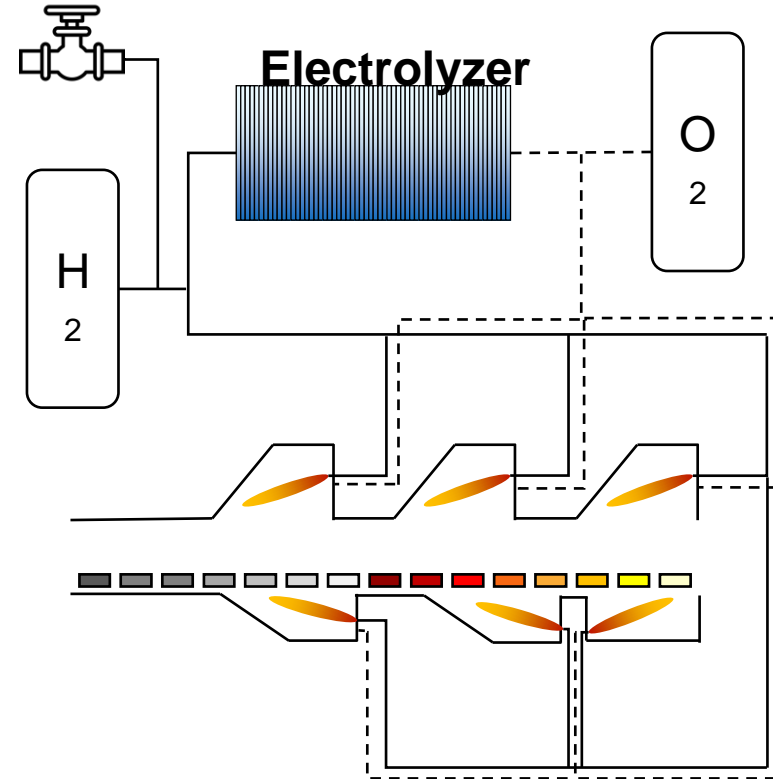
Specific combinations of combustion and electric heating driven by

- Availability of future fuels and renewable energy:
 - Impact on use of H₂ produced by electricity or direct use of electricity for heating
 - Local availability of biofuels
- Product geometry and material:
 - Efficient induction heating not possible for all formats of casted steel by current induction heating technology
 - Impact of heating method on materials / product



Hydrogen combustion

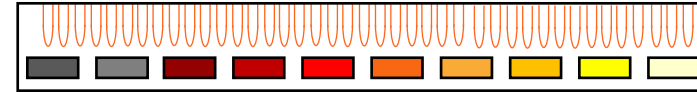
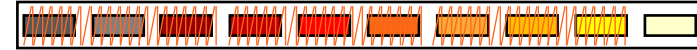
- Most simple retrofitting option, can preserve current infrastructure to a large degree
- Needs investment in electrolyzer or bought from market, preferably through gas grid
 - Electrolyzers currently undergoing upscaling to levels matching reheating furnaces
 - Gas grid a possible H₂ storage



Electrical heating from industrial PoV

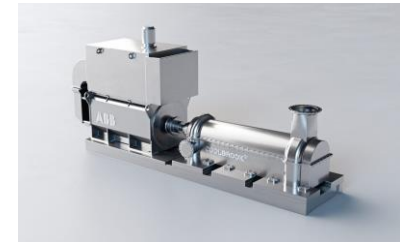
Greenfield installations

- New electrical furnace
- Induction furnace pre-heating for productivity
- Resistive for soaking
- Possible to use protective atmosphere



Retrofitting of existing furnaces

- Induction heating, but with relatively large losses
- Due to power density of resistive heating, only partial replacement of fuel possible
- RDH possible future market competitor with higher power density



Coolbrook RDH

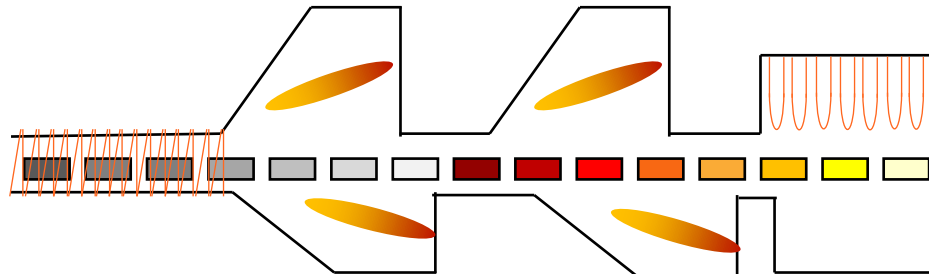


Flexifuel strategies

- Optimization of hybrid fuel usage (H_2 , NG, O_2 , electricity)

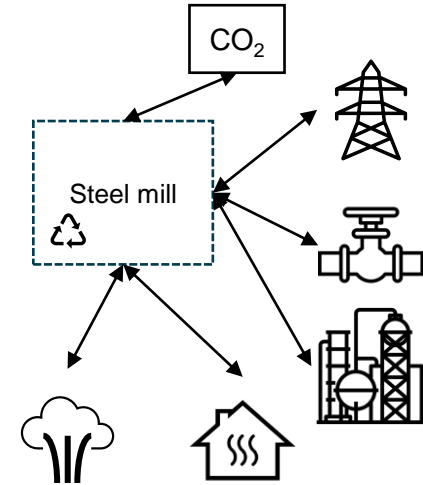
Technology integration research

- Hybrid furnace operation (induction, combustion, resistive)
 - Retrofit
 - Greenfield



System integration research

- Internal integration within steel mill
- Options for CCS/CCU
- Flexible interaction with gas and power grids
- Oxygen use
- Integration with chemical industry for synthetic fuel production
- Heat integration with steam production or hot water production
- Steel flow logistics for optimal hot charging

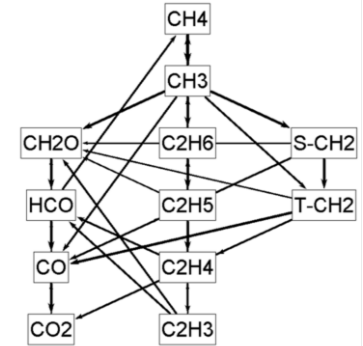


Future research need

Relevant new technologies

dissHEAT

- Improved Kinetic Scheme
- pollutant prediction (including the formation of NO_x and particulate emissions)
- Flame monitoring



Bfi

CRM GROUP

RINA

RWTH AACHEN UNIVERSITY

SWERIM

European Commission

Research Fund
for Coal & Steel

Tools:

- Kinetic scheme interpreter (CHEMKIN, Cantera)
- CFD software (Fluent, OpenFOAM...)
- CPU (Cluster, Servers)



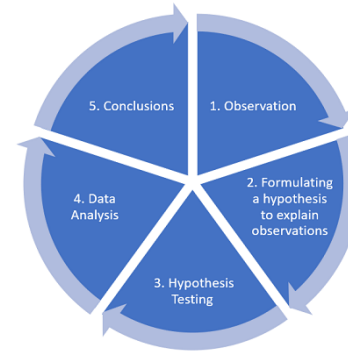
Cantera

ANSYS[®]
FLUENT[®]

Future research need

Relevant new technologies

- Extended statistical approach



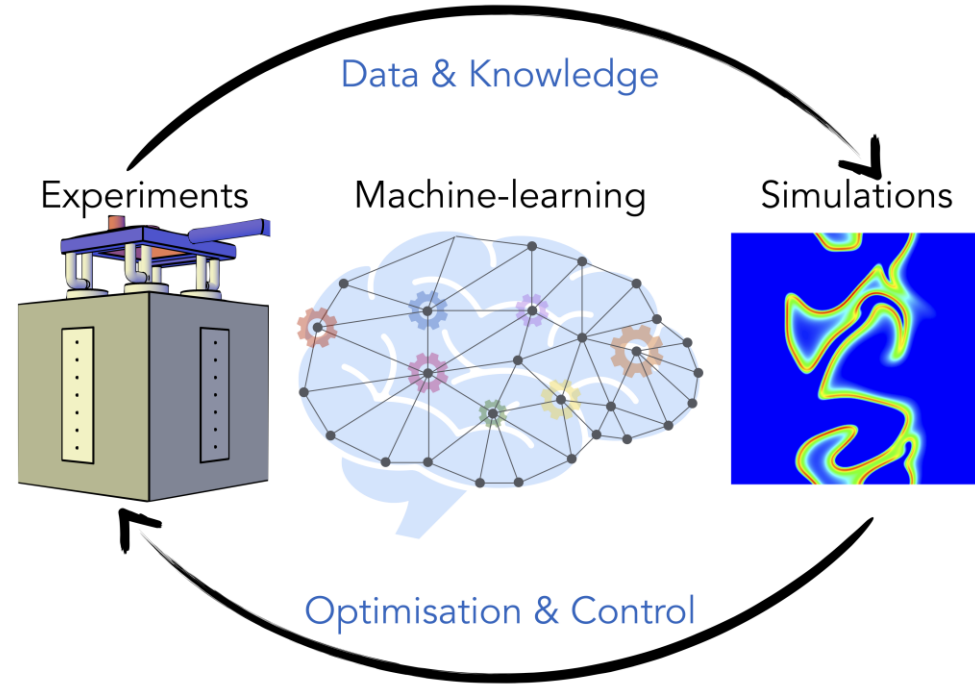
- Artificial Intelligence and Machine Learning approach



Future research need

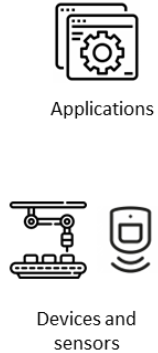
Technology impact and integration research

- Artificial Intelligence and Machine Learning approach
- Physical-injected neural network
- Dynamic and/or auto-adaptive modeling for process control



Future research need

Big Data and Advanced Analytics overview



Ingestion



Store



Data Lake

Preparation
& Training



Analytics Platforms



Machine Learning

Serving



Database



Datawarehouse



Analysis services

Visualization
& Intelligence



Predictive apps



Operational
reports/
dashboards

Ingestion tools:

- Kafka
- MQTT
- IoT/Event Hub

Data Lake:

Centralized repository that holds a large amount of structured and unstructured data at any scale.

Store raw data without a predefined schema, the schema is applied when the data is read, allowing for flexibility and agility in data exploitation.

Analytics Platforms:

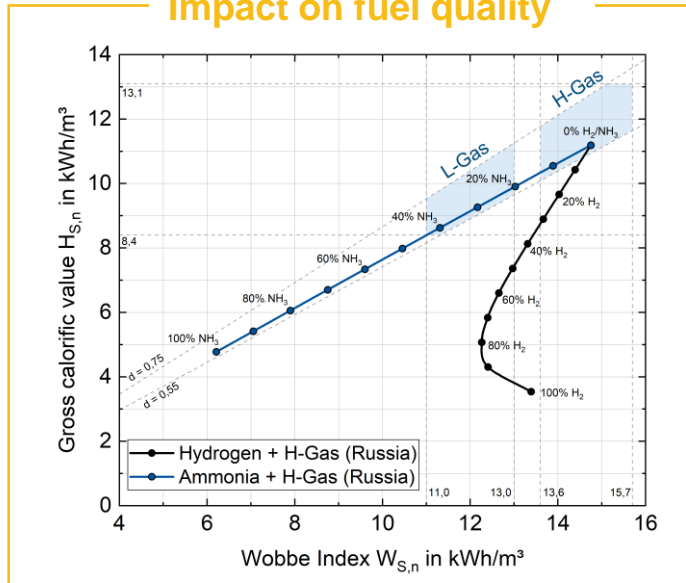
Cloud Software-as-a-Service-like tool for processing massive amounts of data and developing, training and deploying models.

Provide on-demand scalability, based on computational and storage needs with pricing based on the resources consume (no hardware and infrastructure investments are required)

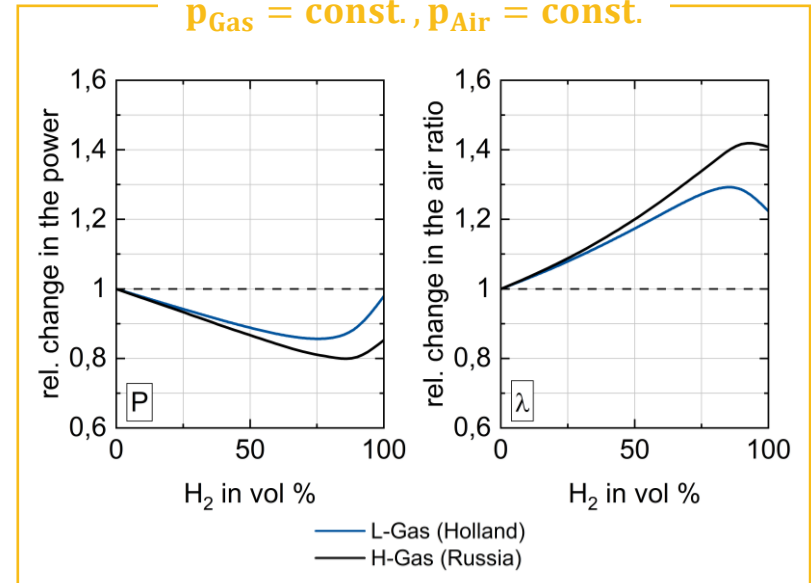
Impact of alternative heating systems on furnace control

- Multi-fuel burners require adapted burner control systems and furnace operation

Impact on fuel quality

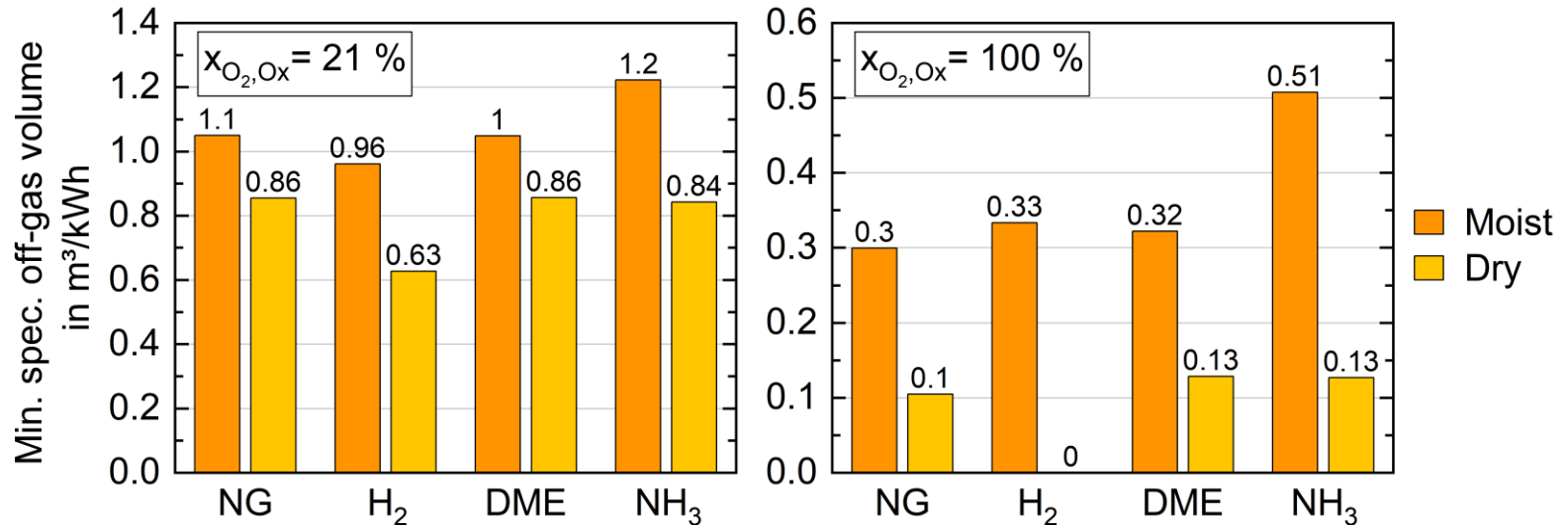


$p_{Gas} = const., p_{Air} = const.$



Impact of alternative heating systems on off-gas measurements

- Water content in off-gas using alternative fuels and oxyfuel



➔ For a fair comparison of NO_x emission, measurement on moist basis is recommended

Impact of alternative heating systems on standards and regulations

- Revision of emission measurement standards for measurement on moist basis

EN 14792

Stationary source emissions – Determination of mass concentration of nitrogen oxides – Standard reference method: chemiluminescence

EN 14181

Stationary source emissions — Quality assurance of automated measuring systems

EN 15267-3/-4

Assessment of air quality monitoring equipment –Part 4: Performance criteria and test procedures for stationary/portable automated measuring systems for periodic measurements of emissions from stationary sources



Impact of alternative heating systems on standards and regulations

- Revision of NO_x limit definitions for flexible operation
 - for flexible fuel operation
 - for hybrid heating operation (electric & gas)
- Revision of BREF Ferrous Metals Processing to include new BAT-AELs definitions
 - To date, BAT AELs for the heating of feedstock in hot rolling are only defined for two fuel categories: "100% natural gas" and "other fuels"



Impact of alternative heating systems on standards and regulations

- Use of alternative fuels according to ISO 13577-2
“Industrial furnaces and associated processing equipment - Safety - Part 2: Combustion and fuel handling systems”:
 - *“When other fuels like e.g. hydrogen are used additional risk assessment is conducted to prove suitability of components”*
 - *“Where fuel gas with a volume fraction of more than 80 % hydrogen (H_2) is used additional risk assessment shall prove suitability of components etc. and procedures”*
 - *“In case of hydrogen and fuel gases with a volume fraction of more than 80 % hydrogen the safety time for ignition shall be limited to 3 s”*
 - *“In case of gaseous fuels with a volume fraction of more than 80 % hydrogen or acetylene (C_2H_2) residual fuel from the automatic shut-off valves to the burners shall be safely discharged or burned”*



- The project runs until end of 2023 and all following material is available on the homepage www.dissheat.eu
 - Reports
 - Abstracts
 - Recorded webinars with one webinar per main topic incl guest speakers
 - Heating and burner technology
 - Modeling of the entire furnace
 - Measurement technology and standards, regulations
 - Materials in the furnace and product quality
 - Heat transfer, heat recovery, productivity and CAPEX, OPEX
 - Recorded webinar of this event- Roadmap
 - Presentation material from Workshop at ESTAD 2023



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Thank you for the attention!

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