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Draft roadmap for future research

Hugo Uijtdebroeks

CRM Group, hugo.uijtdebroeks@crmgroups.be

- **Global focus of the roadmap for future research**

- **Future research needs for:**
  - **"Heating and burner technology"**
  - **"Modelling and control (level 2) of entire furnaces"**
  - **"Sensors and control (level 1), standards, regulations"**
  - **"Materials in the furnace and product quality"**
  - **"Heat transfer, heat recovery, productivity economy**

Global focus of research

- Global focus of the roadmap for future research is reducing CO2 emissions by 35 per cent by 2030, and of achieving carbon-neutral steelmaking by 2050.

ArcelorMittal

Future research need: heating and burners
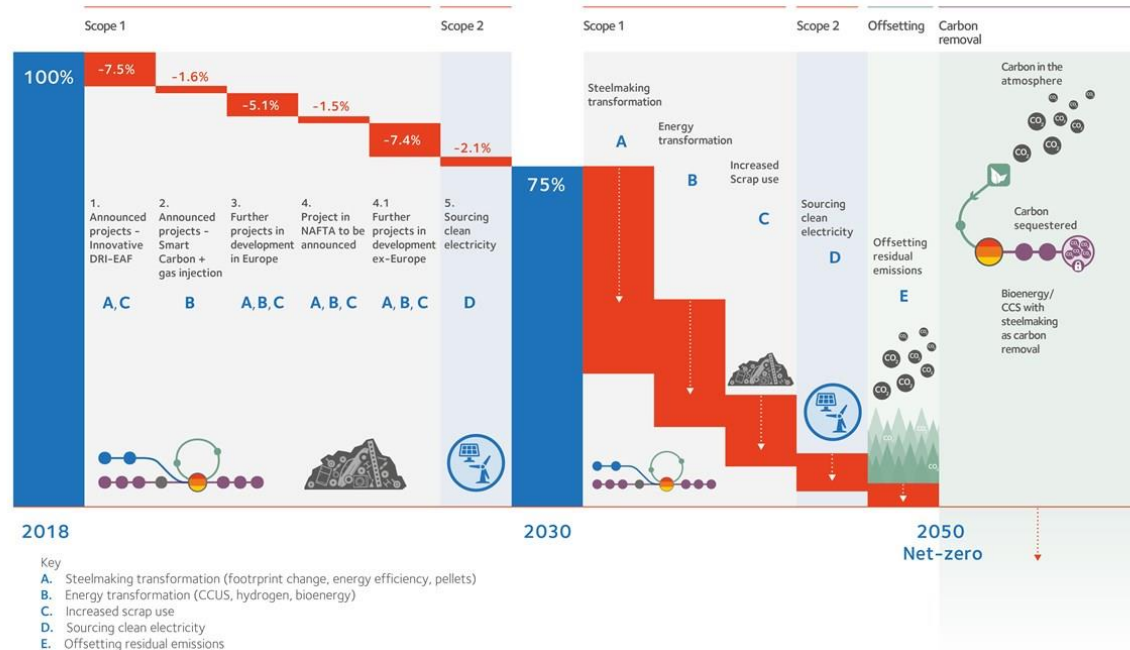
Technology impact and integration research:

- **Heating** with new fuels, hybrid and combinations:
  Hydrogen, biofuels, oxy-fuel, electrical heating (Topic 5)
  => Flameless or ultra LowNO$_x$ combustion

- **Efficiency** with new technologies and heat revovery if applicable
  Dark zone / heating with off gas
  from new fuels, hybrid and combinations

Oxidizer	Preheating oxidizer	Dark zone
Air	🟩	🟩
Oxygen enhanced combustion (OEC)	🟨	🟩
Oxy-fuel (100 % Oxygen)	🟥	🟩

Technology impact and integration research:
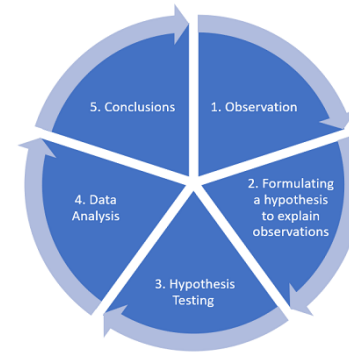
Impact on **product and plant**

- Hydrogen combustion, electrical heating and combinations:
    - Influence on product-material, temperature uniformity, scaling
    - Influence on furnace and heating equipment when technolgies are combined: i.e. high H_2O content in exhaust gas
      => influence on resistance heaters
      => influence on refractory and insulation
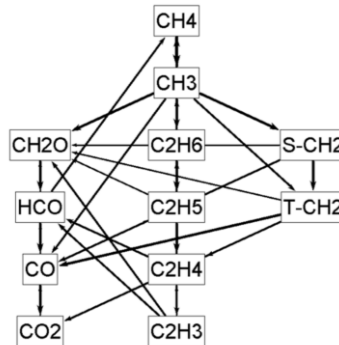   - Security when handling H_2

- Extended satistical approach

- Artificial Intelligence and Machine Learning approach

- Improved kinetic schemes

Future research need Modelling and control (level 2) Technology impact and integration research

- Use of machine learning and/or joining of statistical models and physical models (physical-injected neural network)

- Dynamic and/or auto-adaptive modeling for process control

- Flame monitoring

- Kinetic scheme for pollutant prediction (including the formation of NOx and particulate emissions)
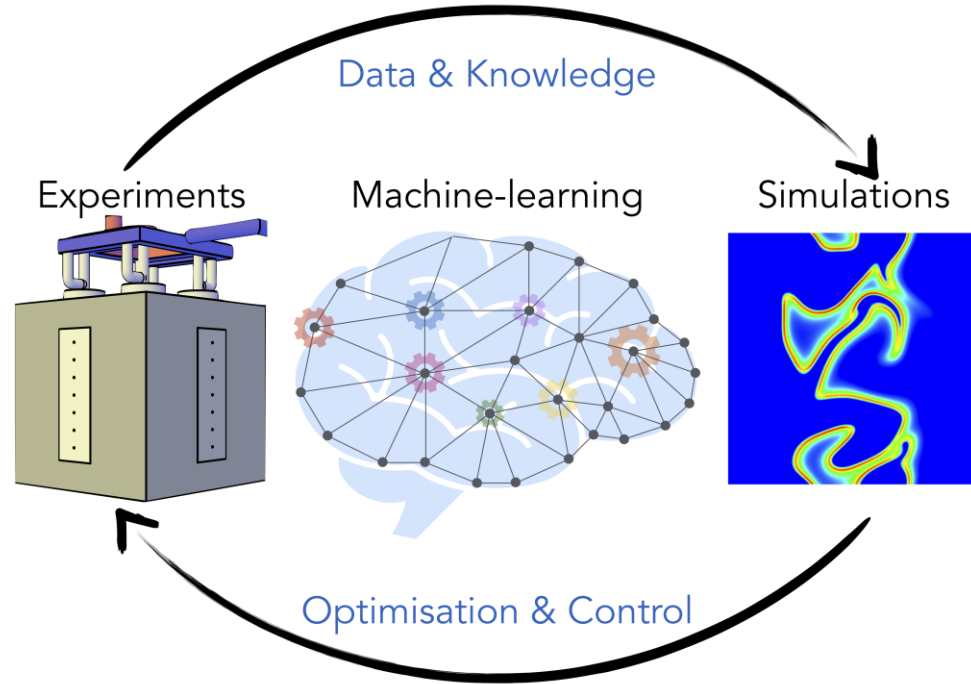
1. Research gaps for alternative heating systems for sensors and control:

- Influence of fuel blends on **flow measurement**
- Influence on **fuel quality measurement**
- Optimization of **air-to-fuel ratio** for new fuels, oxidizers and fuel flexible operation
- Influence on **off-gas composition** and **pollutant emission** measurements → Development of emission measurement system
- **Temperature measurement** for process control for electrical and hybrid heating systems

Sensors and control (level 1)

2. Open topics concerning legislation for alternative heating systems:

- NO_x limit definitions
- Revision of BREF FMP to new limit definitions
- Emission measurement standards

Materials and product quality

1. Study the impact of residuals on product quality
   - Cu: diffuses quickly leading to segregation, roughening and intergranular oxidation
   - Mo: above 0,25% will increase scale adhesion
2. Perform a full screening of all grades related to the different reheating alternatives (e.g. 100% Hydrogen combustion)

Materials and product quality
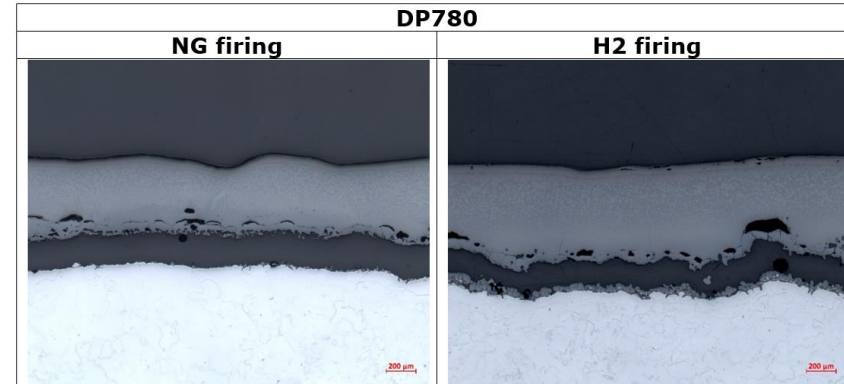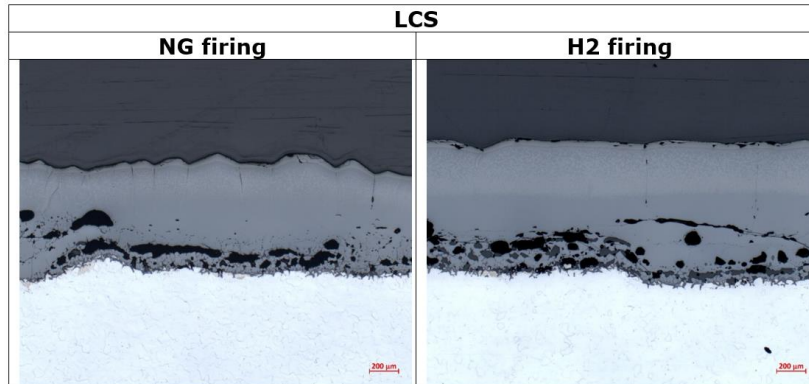
3. Adaptations :

   - Gas flow and composition (e.g. Nitrogen injection at exit)

   - Coatings

   - Alternative metallugical composition
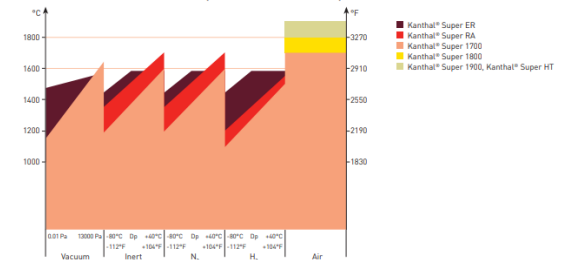

4. Wear of components :

   - Burner nozzle wear by hydrogen flame

   - Wear of electrical resistances

   - Wear / adhesion on ceramics

Maximum recommended element temperature in different atmospheres
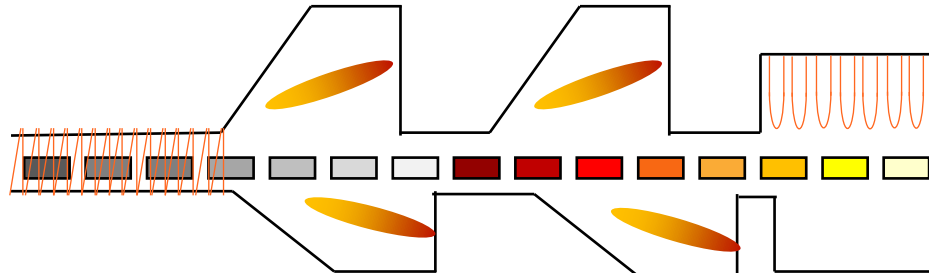
Flexifuel strategies

- Optimization of hybrid fuel usage (H_2, NG)

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
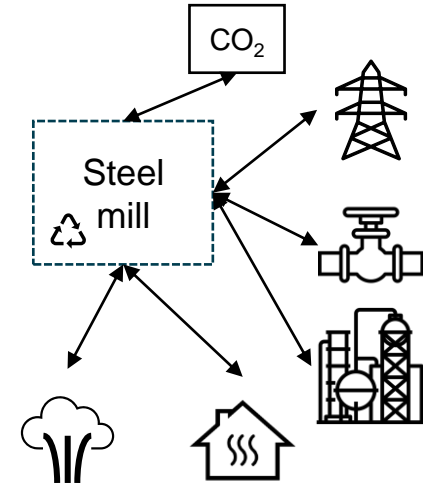
Thank you for the attention!

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