Hydrogen for circular industrial high-temperature processes

Opportunities and challenges

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MateQ PROCESS

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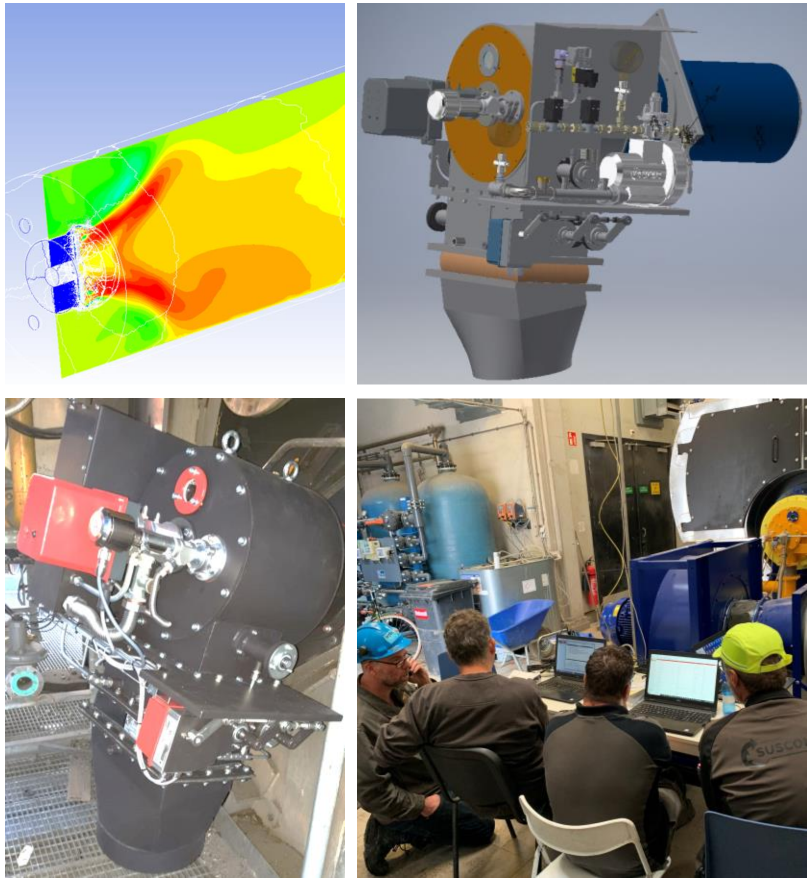
About Mateq Process

Mission: facilitating the energy transfer for industrial high-temperature processes

Focus:

- *Process design of circular heat transfer equipment*
- *Development of tools and models for product and process analysis*
- *Support of startups and other companies in the energy transition*



Overview of activities

Development of hybrid hydrogen – natural gas burner

- Joint venture with SUSCOMB (Heteren, GLD): Combustion2 B.V.

Development of circular Iron fuel combustion system

- Technology and Management Consultancy to RIFT | Renewable Iron Fuel Technology B.V.

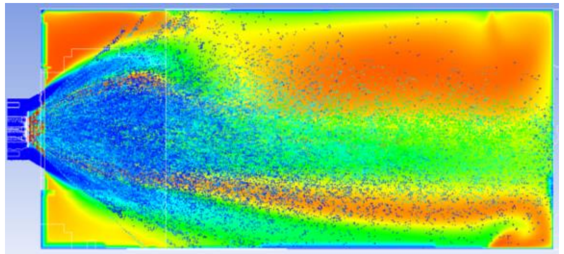
Facilitating transfer to Hydrogen for high-temperature industrial processes

- H2Hub Twente: Program leader of high-temperature working group

2nd year coordinator International Master in Sustainable Energy Technology

- Part-time position at University of Twente

Consultancy on analysis and improvement of complex high-temperature processes



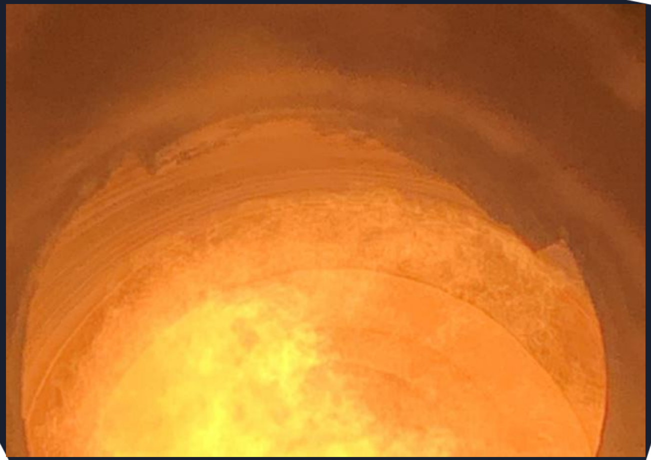
Opportunities for Hydrogen in circular high-temperature industrial processes

For high-temperature industrial thermal processes (> 650 °C), combustion is the sole economically feasible means of achieving the required temperatures, at the requested total heat input in MW or gas flow volume

Electrical systems either do not reach the required temperature levels, or cannot handle the desired total heat input, or both

Hydrogen is the logical candidate for a circular fuel for these processes

- Its (future) availability
- Lack of carbon in cycle
- Excellent combustion properties

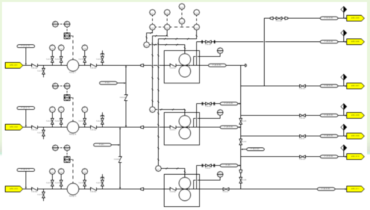


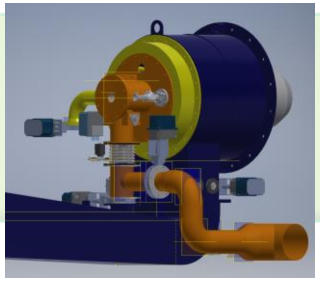
Transition to Hydrogen in practice

In the transition to hydrogen for an industrial process, two main subjects need to be assessed:

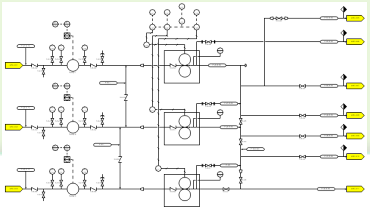
The (continuous) **availability** of green hydrogen

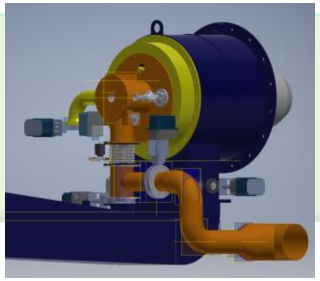
Consequences for the **use** of Hydrogen for the thermal process and its equipment





The availability of green Hydrogen





Conversion of Hydrogen using electricity

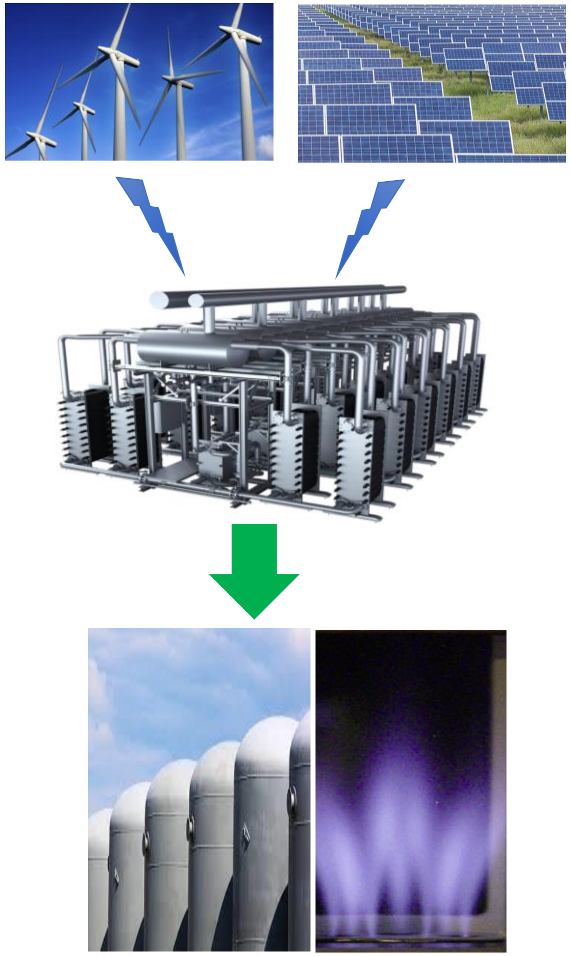
Water is converted to Hydrogen in an electrolyzer

- For every kg of water, 0.11kg of Hydrogen can be produced
- 1 kg of Hydrogen (11m^3) represents 120MJ of thermal energy
- For every kg of Hydrogen, 8kg of Oxygen (5.6m^3) is produced

Electrolyzers have typically 67% energy conversion efficiency

Electrolyzers need continuous operation to be efficient. They also need a threshold power input to be able to produce Hydrogen

This means electricity needs to be continuously available, and of sufficient amount, for optimum electrolyzer performance



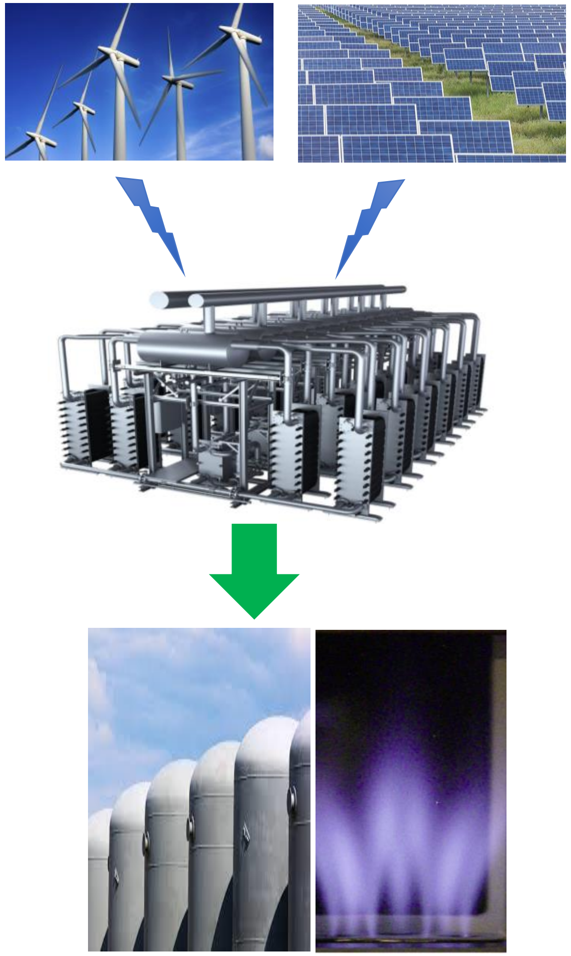
The availability of green energy

Solar and wind energy are currently seen as feasible means for local green energy production

- Solar is seen as less intrusive, especially when applied on existing infrastructure
- Wind has a larger peak electricity output (e.g., 10MW for 150m wind turbine)

Wind and sun are more prevalent during the day, where solar shows a more modulating power supply than wind

- Solar: Day/night; summer/winter rhythms



Energy demand of production processes

Production processes typically have a modulating energy demand

- Day / night
- Week / weekend

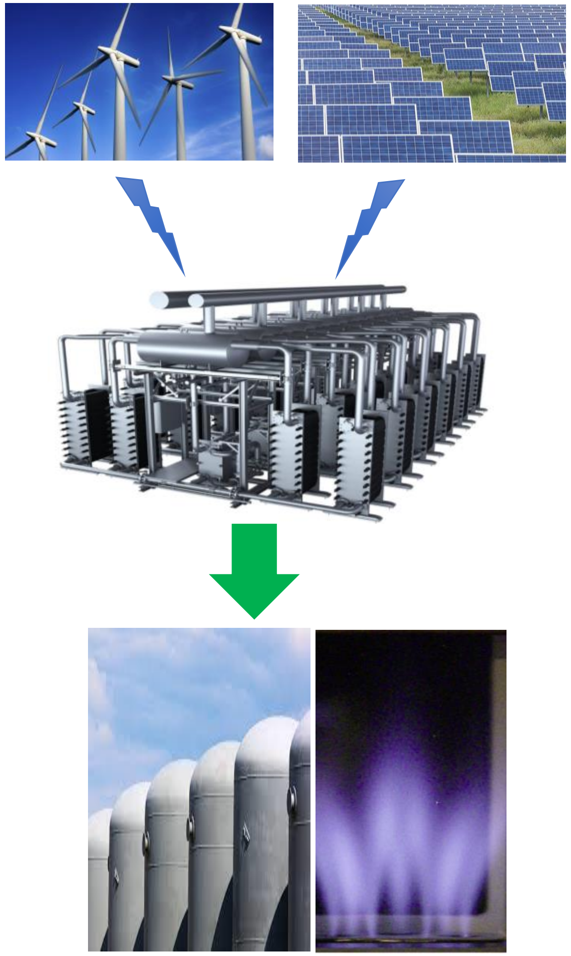
The demand is driven by the process but to a large extent also by operator planning

Process:

- continuous vs batch process

Operator planning:

- cost vs benefits of machine / staff availability
- Production capacity vs product demand



The availability of green Hydrogen

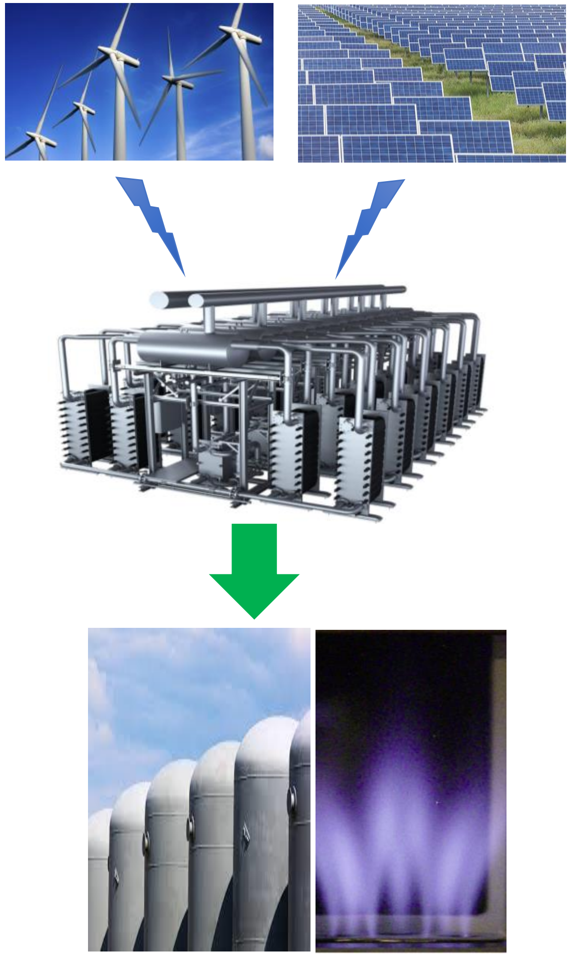
Hydrogen production via green sources is often dependent on the availability of these sources (mostly sun and wind)

Production processes also typically have a modulating energy demand

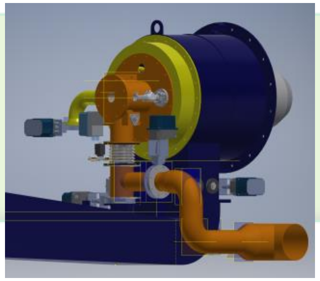
The discrepancies between supply and demand of Hydrogen can be resolved with a mix of

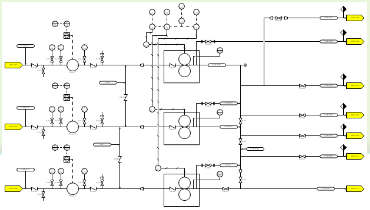
- Optimization of supply and demand by adjusting production process energy cycles
- Using backup energy sources (usually natural gas is seen as a logical alternative)
- Hydrogen / energy storage
- Electricity from the grid

This yields a business case that needs to be assessed and optimized per specific site / process



Consequences for combustion equipment





Hydrogen as energy carrier for high-temperature processes

Hydrogen can very easily be combusted with air in an industrial burner; this technology is actually decades old

However, those designs mostly focused on the safe and complete (co-) combustion of residual Hydrogen of industrial processes, and not necessarily on achieving ultra-low emission levels of NOx

In legislation, Hydrogen is still not considered a reference fuel, such as natural gas, and even has less strict emission level requirements for large installations

Hydrogen as energy carrier for high-temperature processes

Achieving ultra-low NOx levels in Hydrogen combustion, as well as in mixed H2 – natural gas combustion, poses several challenges, due to some specific properties of Hydrogen:

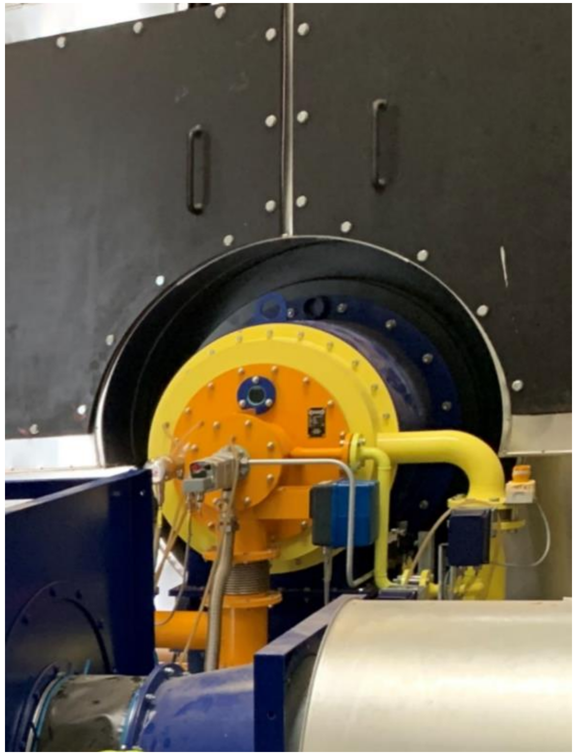
- Extremely high combustion velocities
- High peak temperatures of Hydrogen – air combustion
- Wide flammability envelope
- High diffusivity of Hydrogen compared to other species
- Low density of Hydrogen
- Influence of Hydrogen on materials

These properties have consequences for both the development and the application of ultra-low NOx Hydrogen combustion equipment

Ultra-low NOx design rules for developing industrial burners

- Industrial fuel gas burners usually achieve low NOx emissions by keeping peak flame temperatures low
  - Local lean premixing of fuel and air
  - Staged combustion of fuel and air
  - Use of external flue gas recirculation

- Industrial burners for boilers and furnaces operate with an air excess as low as possible
  - Typically, an air excess of 5 to 15% – contrary to gas turbine combustors which operate at 200 - 300%
  - This means adding additional air to lower peak temperatures is not possible in these types of burners



Design challenges for hydrogen-fueled industrial burners

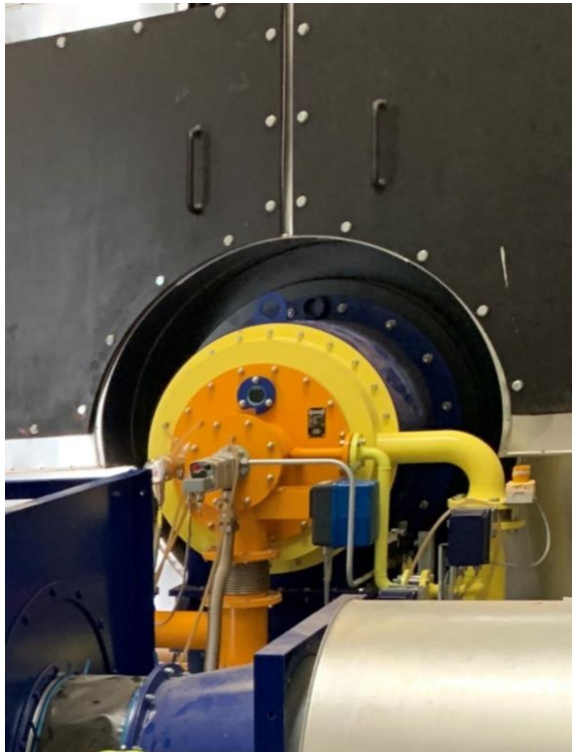
With premixing, there is a higher risk of flash back of the flame into the premixer

Fuel / air staging is more difficult to achieve, due to the large combustion velocity, flammability envelope and diffusivity of Hydrogen

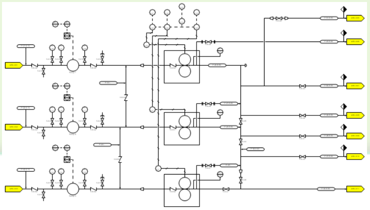
Fuel gas and air volumes are different under Hydrogen than under natural gas combustion

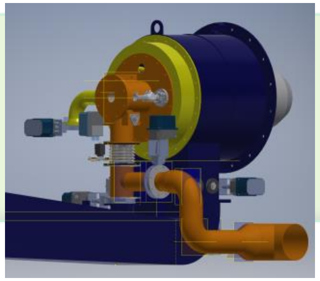
In the material selection / assessment of (existing) equipment, sensitivity to Hydrogen needs to be assessed

- Hydrogen attack / embrittlement
- Hydrogen-tightness



Conclusion





Conclusion

Hydrogen is one of the main circular energy carriers for high-temperature thermal industrial processes

For a successful transition to Hydrogen, an integral approach needs to be taken, incorporating the complete energy supply chain. This will yield a business case that is site and process specific

While Hydrogen is extremely flammable, achieving ultra-low NOx performance in Hydrogen combustion poses real challenges

Combining know-how and co-development will be essential in making the transition a success for industrial high-temperature processes

Thank you for your attention

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Basic properties of natural gas and Hydrogen

Quantity	Natural gas	Hydrogen
Diffusion coefficient at room temperature	0.2 cm^2/s	0.6 cm^2/s
Critical velocity	454 m/s	1.323 m/s
Stoichiometric burning velocity 1)	38 cm/s	330 cm/s
Density	0,8 kg/m_0^3	0,090 kg/m_0^3
Fuel/air ratio at 15% air excess	9.4 m_0^3 air / m_0^3 fuel	2.7 m_0^3 air / m_0^3 fuel
Heating value in volume units	31 MJ/m_0^3	11 MJ/m_0^3
Heating value in mass units	38 MJ/kg	120 MJ/kg
Flammability limits	5 to 15 vol%	4 to 74 vol%

1) Stoichiometric = ideal fuel/air mixture