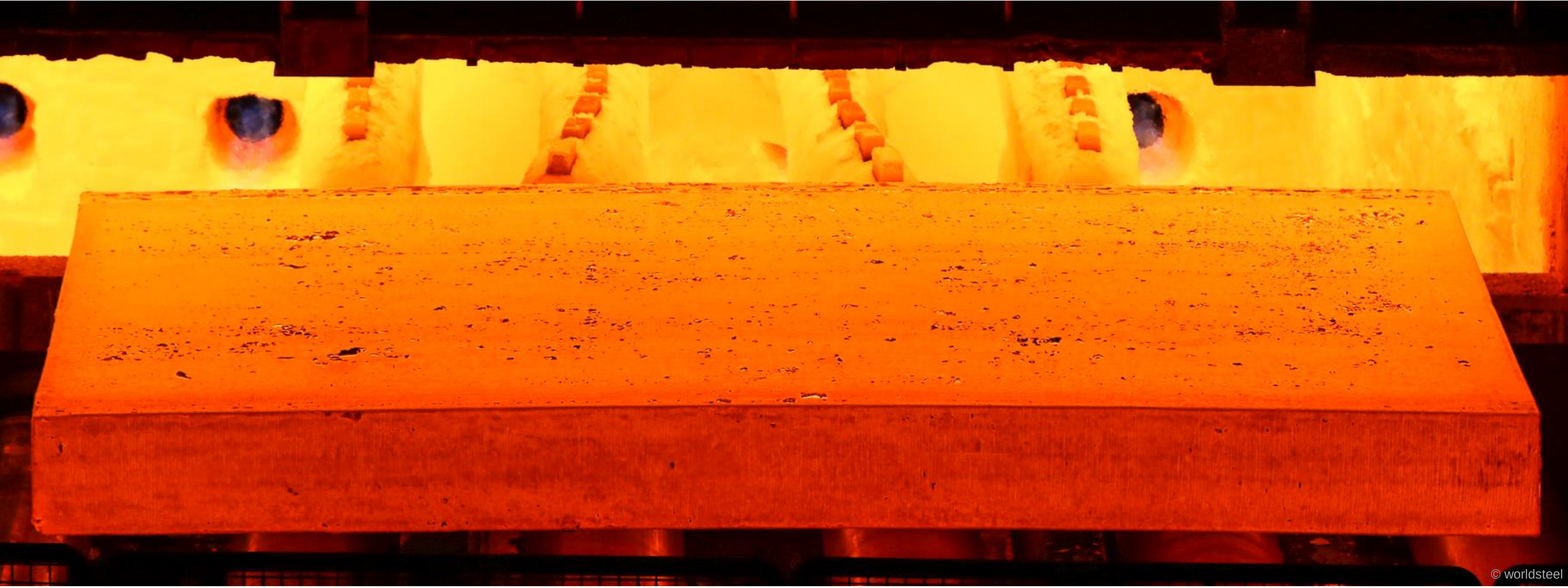


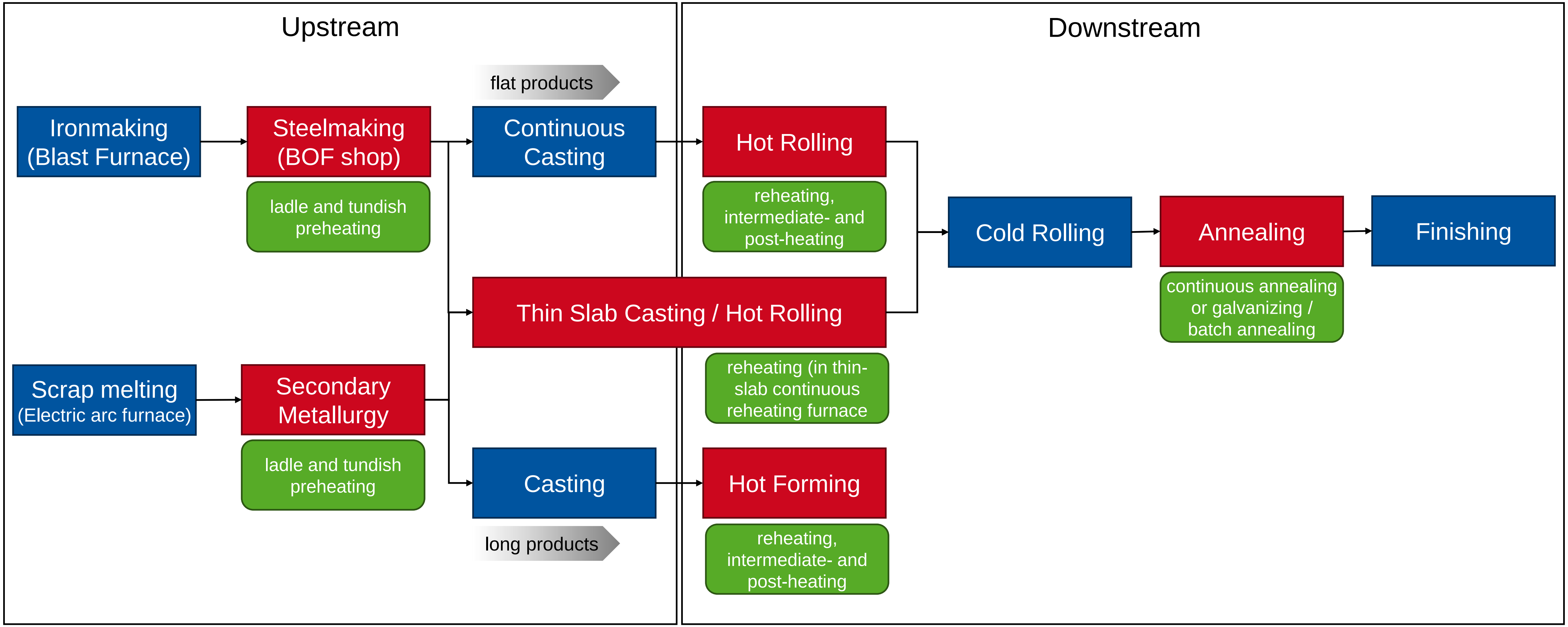
Decarbonizing downstream steel processing with H_2 and NH_3 as alternative fuels

Dr.-Ing. Nico Schmitz

CORALIS workshop „Thrive in the energy transformation“, 19/12/2022

CORALIS Industrial Symbiosis in Energy Intensive Industries | IOB Department for Industrial Furnaces and Heat Engineering | RWTH AACHEN UNIVERSITY

Production flow for flat and long steel products



Reheating furnaces for flat/long products – decarbonization options for retrofit installations

Property	Value
Process	reheating of steel slabs and bars
Mode of operation	continuous
Typical productivity	80-450 t/h
Typical heating capacity	30-250 MW
Process temperature	1100-1300 °C
Heating principnle	combustion, direct
Fuel	natural gas, steel plant gases

Electrification

Challenges: power density, high process temperature

Lower TRL, especially for flat products

Combustion of sustainable fuels

Challenges: availability and transport of fuels, NO_x emissions

High TRL, demonstrations pending

source: Danieli, https://www.danieli.com/media/formato4/reheating-furnaces-for-slabs-2.jpg

Continuous annealing/galvanizing lines for flat products – decarbonization options (retrofit)

Property	Value
Process	Heat treatment of steel strip
Mode of operation	continuous
Typical productivity	50-110 t/h
Typical heating capacity	15-30 MW
Process temperature	750-1000 °C
Heating princinple	combustion, indirect
Fuel	natural gas, steel plant gases

Electrification

Challenges: electrical supply, long-term experience

High TRL, first lines in commissioning

Combustion of sustainable fuels

Challenges: availability and transport of fuels, NO_x emissions

High TRL, demonstrations pending

source: John Cockerill, https://johncockerill.com/wp-content/uploads/2019/05/CMI-four-de-ligne-de-galvanisation-1024x768.jpg

Bell annealing furnaces for flat/long products – decarbonization options (retrofit)

Property	Value
Process	Heat treatment of steel strip
Mode of operation	batch
Typical productivity	1.0-2.5 t/h
Typical heating capacity	0.6-1.8 MW
Process temperature	700-800 °C
Heating principnple	combustion, indirect
Fuel	natural gas, steel plant gases

Electrification

Challenges: electrical supply

High TRL, furnaces in operation

Combustion of sustainable fuels

Challenges: availability and transport of fuels, NO_x emissions

High TRL, demonstrations pending

source: Tenova LOI, https://tenova.com/sites/default/files/images/solutions/headers/LOI_HPH-Bell-type_Annealing-Furnace_Steel-Strip_2_0.jpg

Hydrogen and Ammonia – fuel properties in comparison to CH_4 and C_3H_8

- H_2 → higher adiabatic flame temperature → potential issues with thermal NO formation
  → higher burning velocity → potential issues with shorter flame length and heat transfer

- NH_3 → lower adiabatic flame temperature → potential issue for high temperature processes
  → low laminar burning velocity → potential issues to allow a complete combustion
  → NO formation → potential issues with Fuel-NO formation

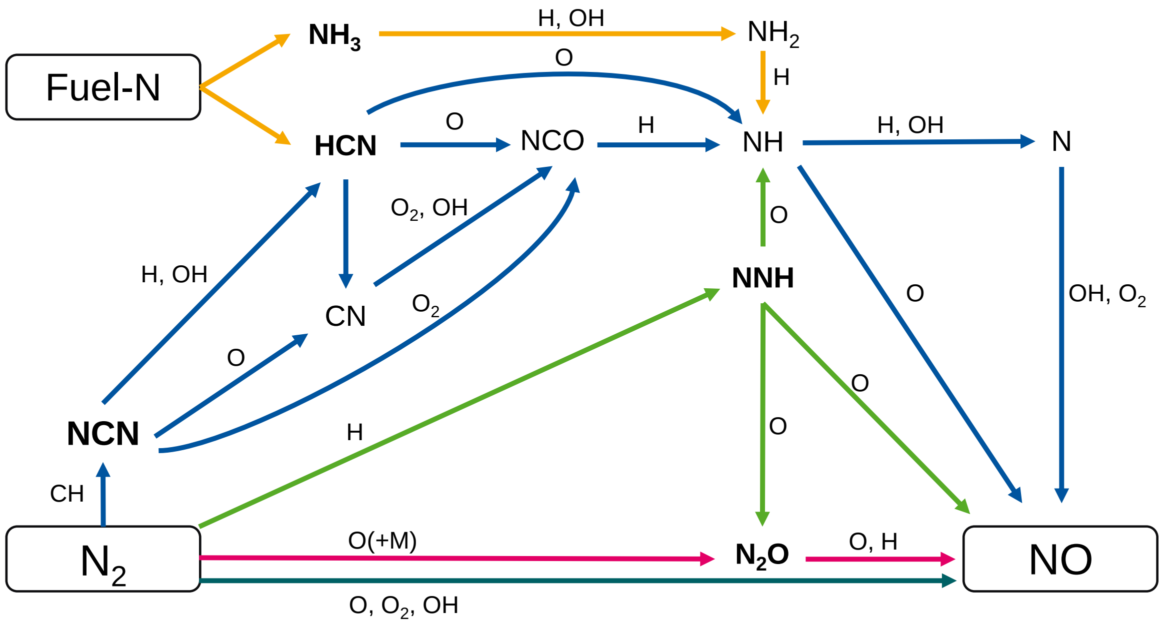
Property	CH_4	C_3H_8	H_2	NH_3
Lower heating value in MJ/kg	50.0	46.4	120.0	18.6
Flammability limits (air ratio λ)	0.58-2.00	0.40-1.96	0.14-10.00	0.71-1.59
Adiabatic flame temperature in °C	1950	2000	2110	1800
Max. laminar burning velocity in m/s	0.37	0.43	2.91	0.07
Density (at 25 °C) in kg/m³	0.66	1.81	0.08	0.73
Boiling temperature at 1 atm in °C	-161.0	-42.1	-253.0	-33.4
Condensation pressure at 25 °C in atm	N/A	9.4	N/A	9.9

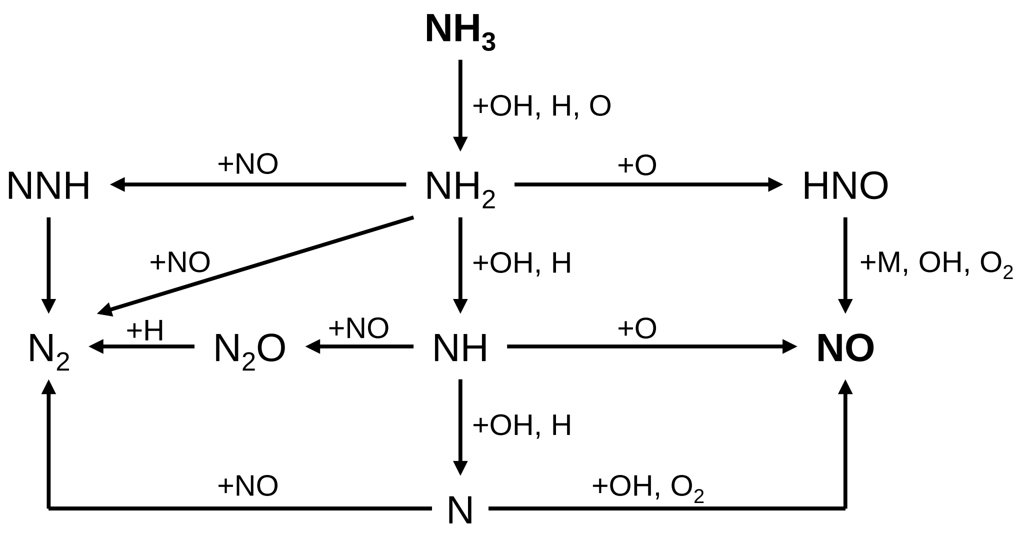
source: Kobayashi, H.; Hayakawa, A.; Somarathne, K. D. K. A.; Okafor, E. C.: Science and technology of ammonia combustion, Proceedings of the Cumbustion Institute Vol. 37 (2019), No. 1, pp. 109-133

Hydrogen and Ammonia – NO_x emissions

- Higher thermal NO-formation can be tackled by advanced combustion technology (primary measures)

- Minimization of Fuel-NO-formation not possible by primary measures (secondary measures → DeNOx plant)

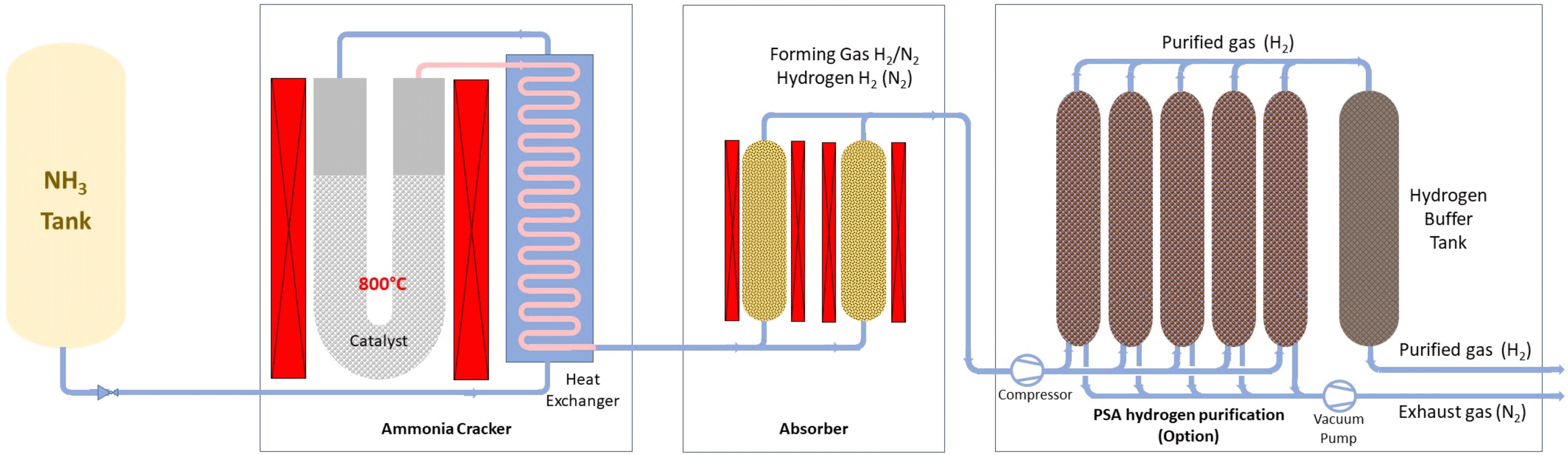




sources: Iavarone, S.; Cafiero, M.; Ferrarotti, M.; et al.: A multiscale combustion model formulation for NOx predictions in hydrogen enriched jet flames, International Journal of Hydrogen Energy Vol. 44 (2019), No. 41, pp. 23436-23457
Glarborg, P.; Miller, J. A.; Ruscic, B.; Klippenstein, S. J.: Modeling nitrogen chemistry in combustion, Progress in Energy and Combustion Science Vol. 67 (2018), pp. 31-68

Alternative for direct NH_3 combustion – NH_3 cracking

- Thermal cracking of NH_3 → combustion of resulting forming gas (H_2/N_2)
  → (purifcation (PSA) and combustion of H_2)
- Additional energy demand (maybe with waste heat from a high temperature process)
- Traces of NH_3 in forming gas might lead to fuel-NO emissions



source: https://www.crystec.com/Ammonia%20cracker_PSA.gif

Conclusions, Outlook, Research needs

- Application of H_2 and NH_3 in downstream steel processing is generally possible – availability at location (!)
- H_2 might lead to higher thermal NO formation → partially solved by combustion technology
- Demonstration of H_2 combustion in furnaces in several European and other projects

research needs: impact on processes and products, demonstration in large scale, long-term experience, standardization, NO_x emission legislation

- NH_3 might lead to higher fuel-NO formation → secondary measures might be needed
- Low reactivity of NH_3 might cause issues reaching a complete combustion → addition of H_2 or partial cracking
- Alternative to direct NH_3 combustion: cracking of NH_3 to forming gas
- Demonstration of NH_3 combustion in downstream steel processing pending

research needs: impact on processes and products, combustion optimization, system development, safety and standards, demonstration in small scale

Thinking the Future
Zukunft denken

contact

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