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RECENT TECHNOLOGICAL ADVANCES IN POWER-TO-AMMONIA-TO-POWER (P2A2P)

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SCOPE

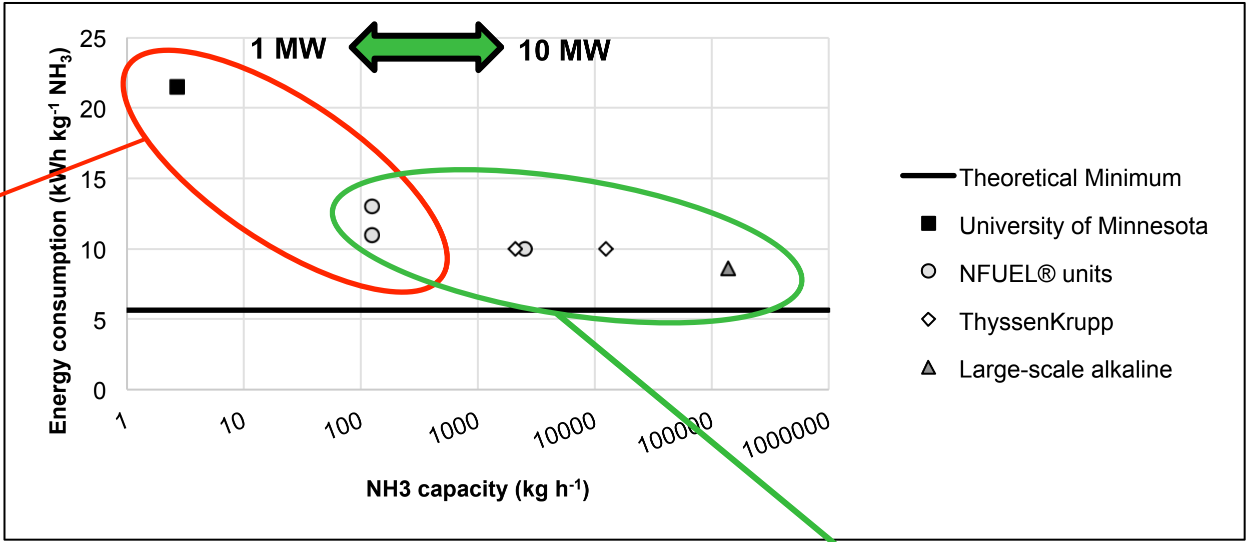
- Decentralized P2A2P (**1-10 MW range**, ~100-1000 kg h^{-1} NH_3)
- Islanded system (100% renewables, off-grid)

- Focus on technological advances
  - Focus on systems with potential for large-scale application
  - No feed compression

[1] MSc thesis '*Power-to-ammonia-to-power for local electricity storage by 2025*'

DECENTRALIZED HABER-BOSCH?

ELECTROLYSIS-BASED HABER-BOSCH SYSTEMS AT VARIOUS SCALES



Heat losses

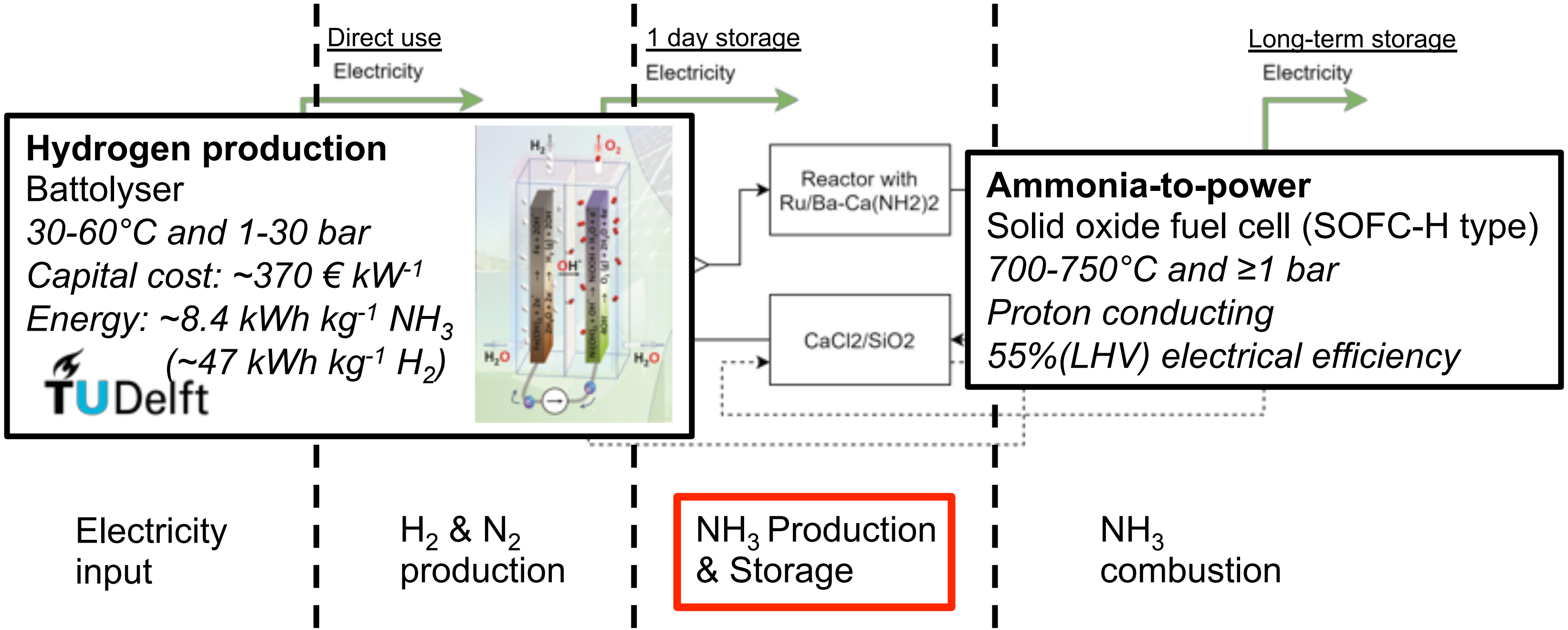
Absorbent-enhanced process

- Improved intermittent operation
- Low-pressure operation

Scale effects

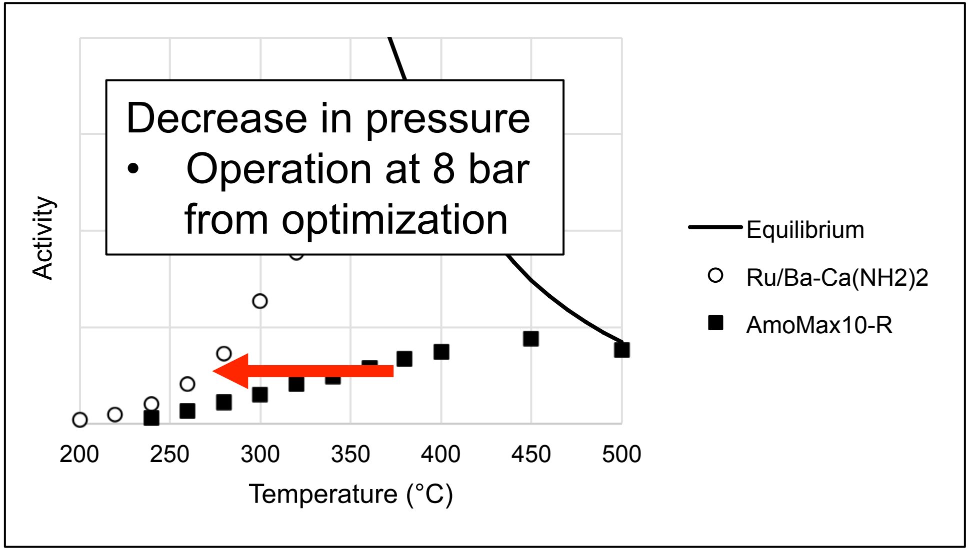
DECENTRALIZED HABER-BOSCH

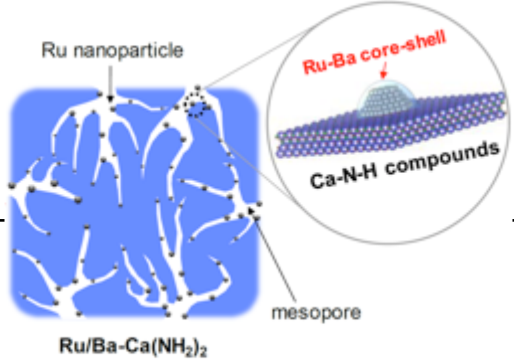
PROCESS CHOICES

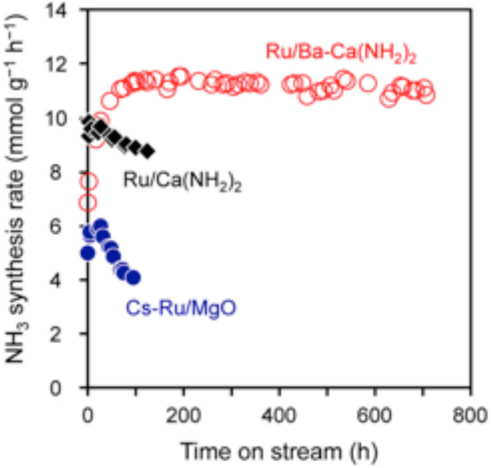


AMMONIA SYNTHESIS CATALYST

RU/BA-CA(NH2)2





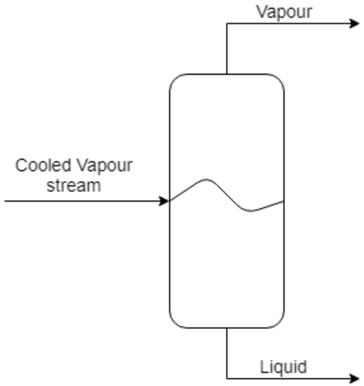


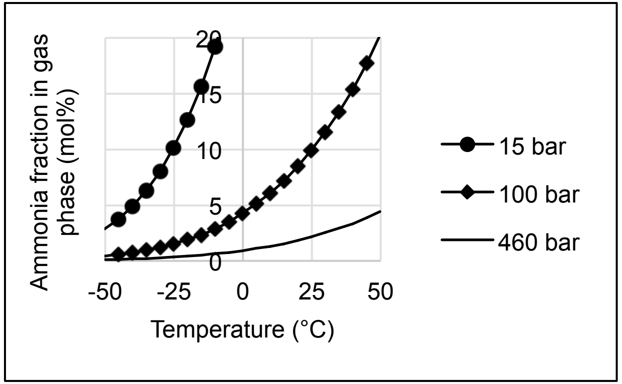
To be used in test facility of Tsubame BHB in Japan by 2021

AMMONIA SEPARATION & STORAGE

CONVENTIONAL SEPARATION

Conventional → **Supported metal halides ($CaCl_2/SiO_2$)**





- No sharp separation at low P
- Low temperatures for separation
- Refrigeration required

- Sharp separation
- High temperatures for separation (150°C)
- Safety

Energy consumption for desorption by TSA: 1.5-2.0 kWh kg^{-1} NH_3

SYNERGIES

Ru/Ba-Ca$(NH_2)_2$ catalyst
- Active @250-300°C

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Absorption enhanced process (16 bar)
- Reaction @370-400°C
- Absorption @200-250°C
- Desorption @300-400°C

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Absorption enhanced process (8 bar)
- Reaction @275°C
- Absorption @150°C
- Desorption @350°C

Same pressure as H_2 production & N_2 production

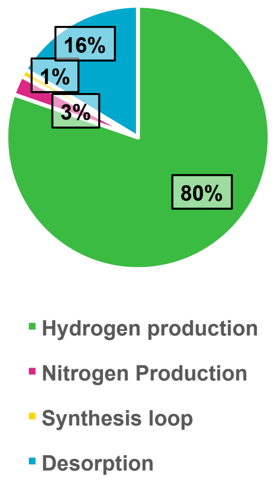
ENERGY CONSUMPTION

Table: Energy consumption of power-to-ammonia plant.

Unit	Energy consumption (kWh kg^{-1} NH_3)
Hydrogen production	8.4
Nitrogen production	0.25
Synthesis loop • **Recycle compression** • **Cooling** • **Desorption**	1.7 0.05 0.06 **1.6**
Total	~~10.3~~ **8.7**

Thermodynamic Minimum
5.64 kWh kg^{-1} NH_3

~~183%~~ **154%**
Theoretical minimum



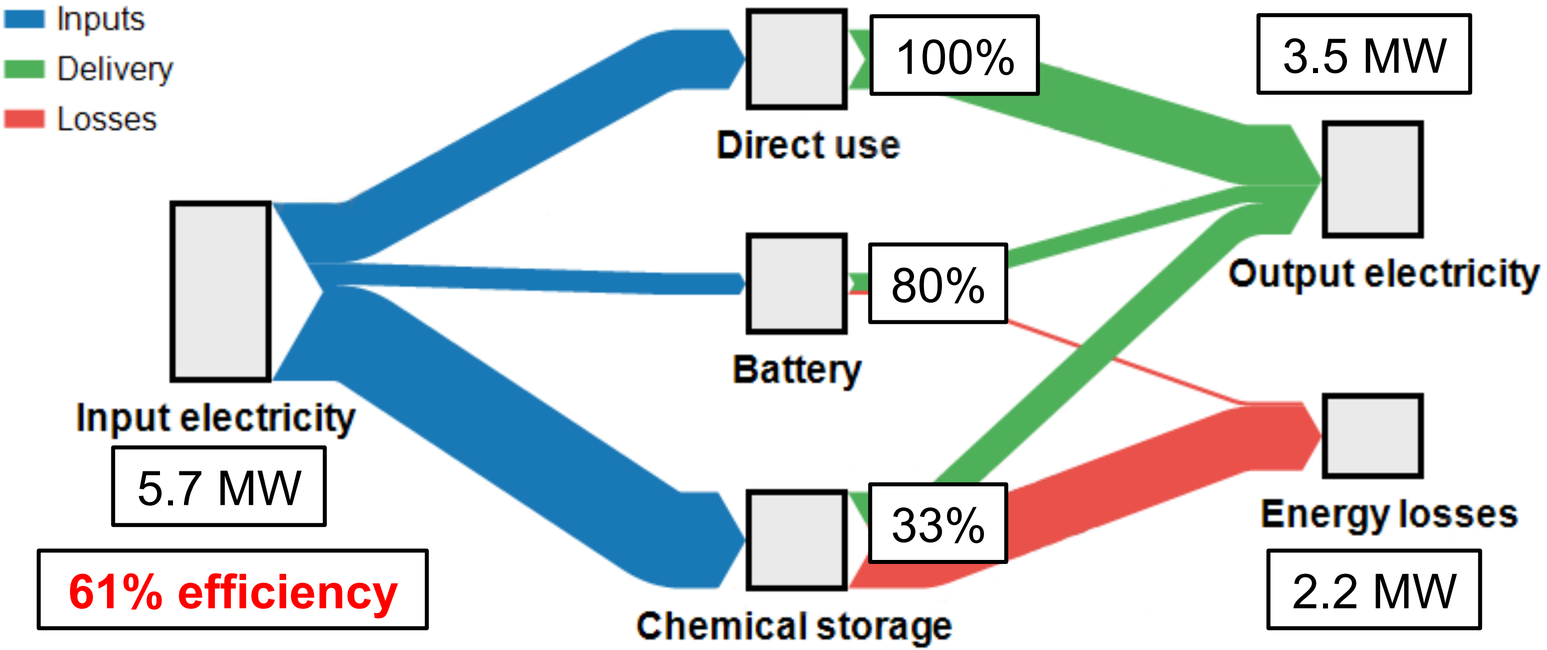
NFUEL® units:
10-13 kWh kg^{-1} NH_3

SOFC-H: 55%(LHV) electrical efficiency

33% P2A2P efficiency

CASE STUDY

HAAKSBERGEN (~25000 INHABITANTS)



CONCLUSION

- Recent technological advances for P2A2P for local energy storage
- Process operating at 275°C and 8 bar
  - Same pressure for H_2 production, N_2 production & NH_3 synthesis
- Applied to case study (Haaksbergen)
  - 61% efficiency in islanded system (electricity cost 0.32 € kWh^{-1})

Thank you for your attention!

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QUESTIONS?