SOEC for hard-to-abate sector: decarbonizing ammonia production in Europe

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Contents

Hydrogen for chemicals

CO_2 capture
from flue gases or
direct air capture

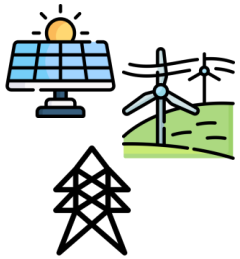
CO_2

C-H conversion

E-fuels
or other e-chemicals

H_2

Heat



Electricity

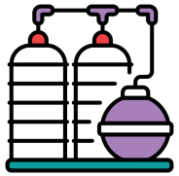
SOEC
or other electrolyser

Heat

H_2

Haber-Bosch

E-ammonia



N_2

Air separation unit

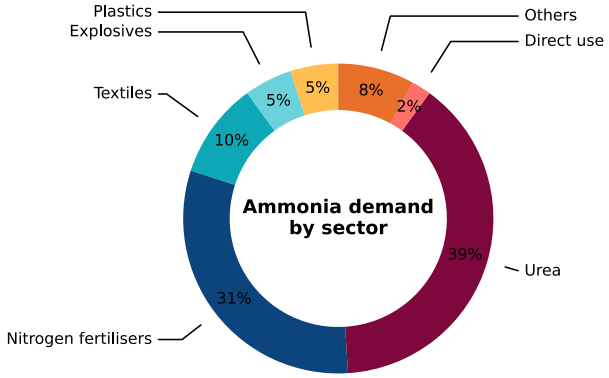
Ammonia demand

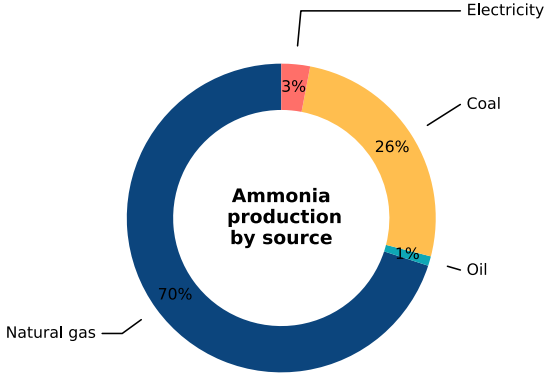
Ammonia demand is well-established in EU and expected to grow.

1.9–2.6 tCO_2/tNH_3

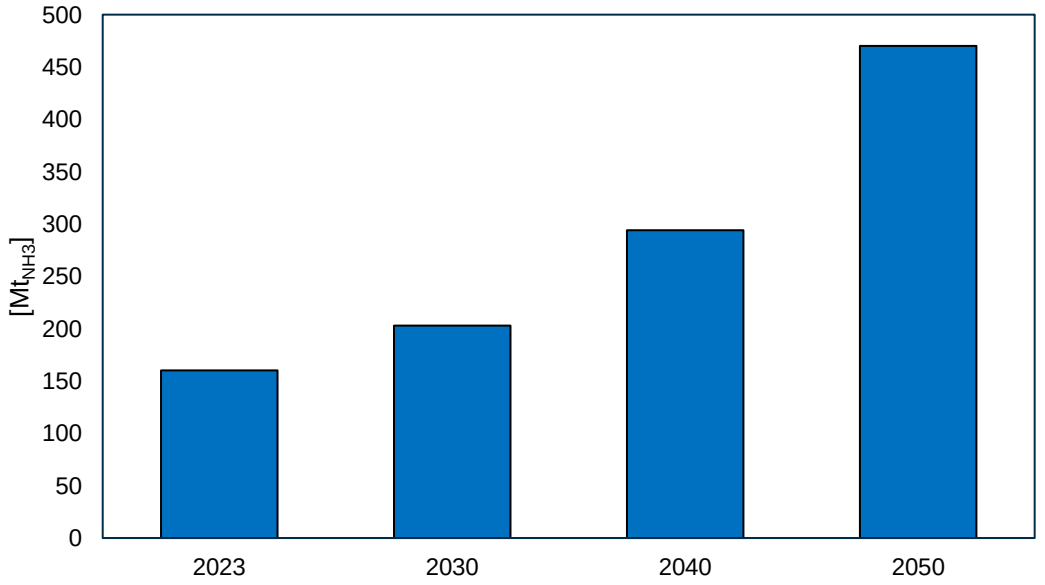
Ammonia production is strongly based on **fossil fuels**, in particular coal and natural gas

EU needs to decarbonise its ammonia production.





IEA, Ammonia Technology Roadmap, Paris, 2021



US Geological Survey, Production of ammonia worldwide from 2010 to 2023, 2024

EU legislation context

European Union posed challenging targets to pursuit withing 2030 for hydrogen-related products and their uses:

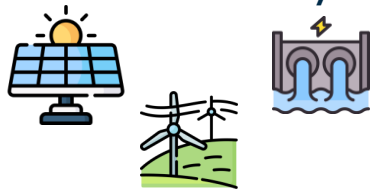
Strict requirements on **RFNBO production**

Additionality

Temporal correlation

Geographical correlation

Renewability



Delegated Regulation 2023/1184

Ambitious targets on **RFNBO uses**

42% in industrial sector by 2030

2% in aviation sector by 2032

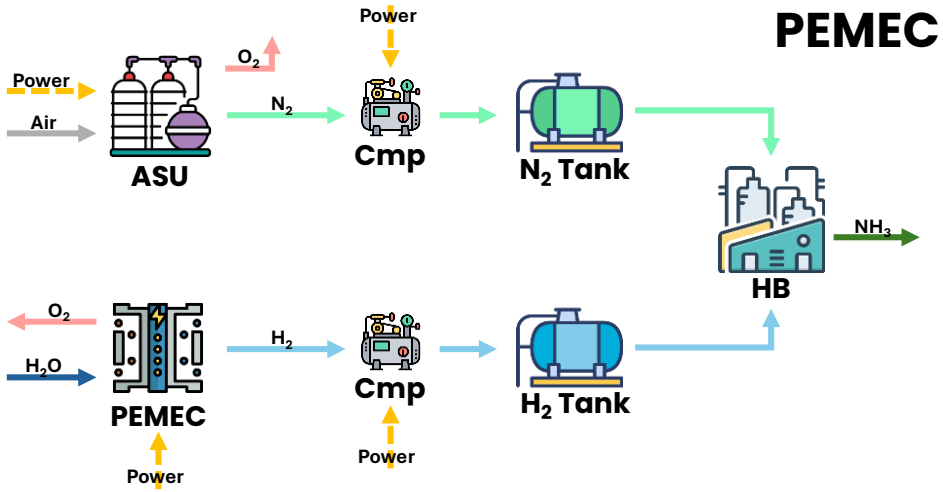
2% in maritime sector by 2032

Directive 2023/2413 (RED III)

Plant layouts

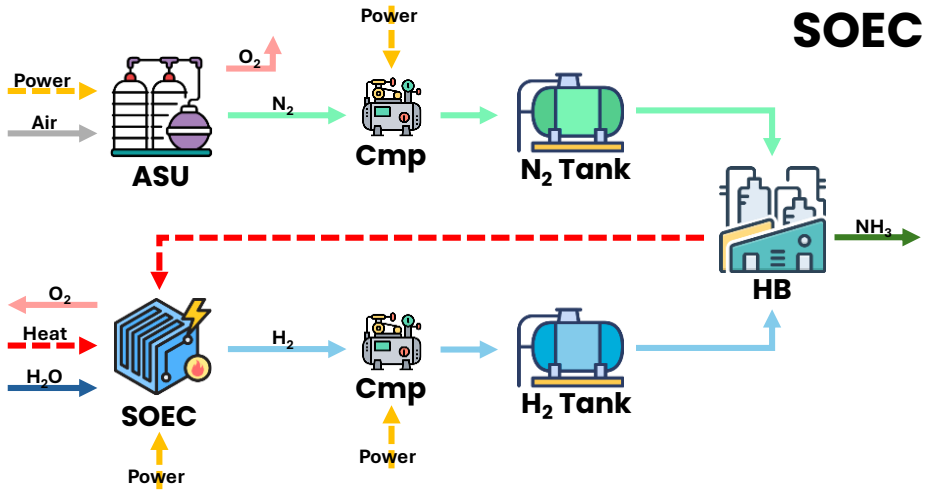
Low-temperature electrolysis

- Better operation flexibility
- Lower capital costs
- Higher maturity

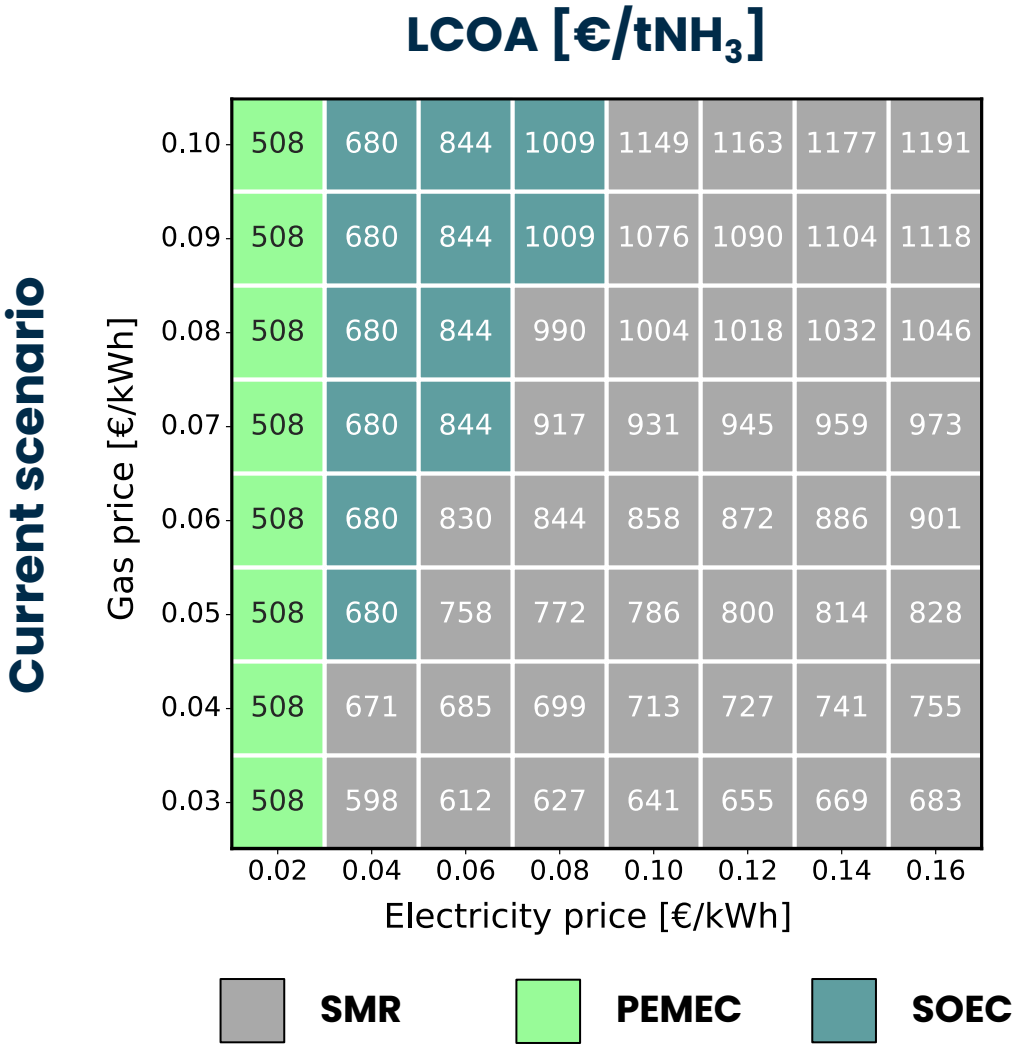


High-temperature electrolysis

- Better efficiency
- Possibility of heat integration with HB
- Lower use of expensive materials



Cost competitiveness of the technologies



In current scenario, electrolysers appear to be competitive with fossil-based production **only if electricity prices are low enough**.

However, when SOEC prices will decrease in next years, **competitiveness with natural gas will improve**, making it convenient if electricity price is kept below 0.10 €/kWh.

A. Magnino, P. Marocco, M. Santarelli, M. Gandiglio, "Economic viability and CO_2 emissions of hydrogen production for ammonia synthesis: A comparative analysis across Europe", Advances in Applied Energy

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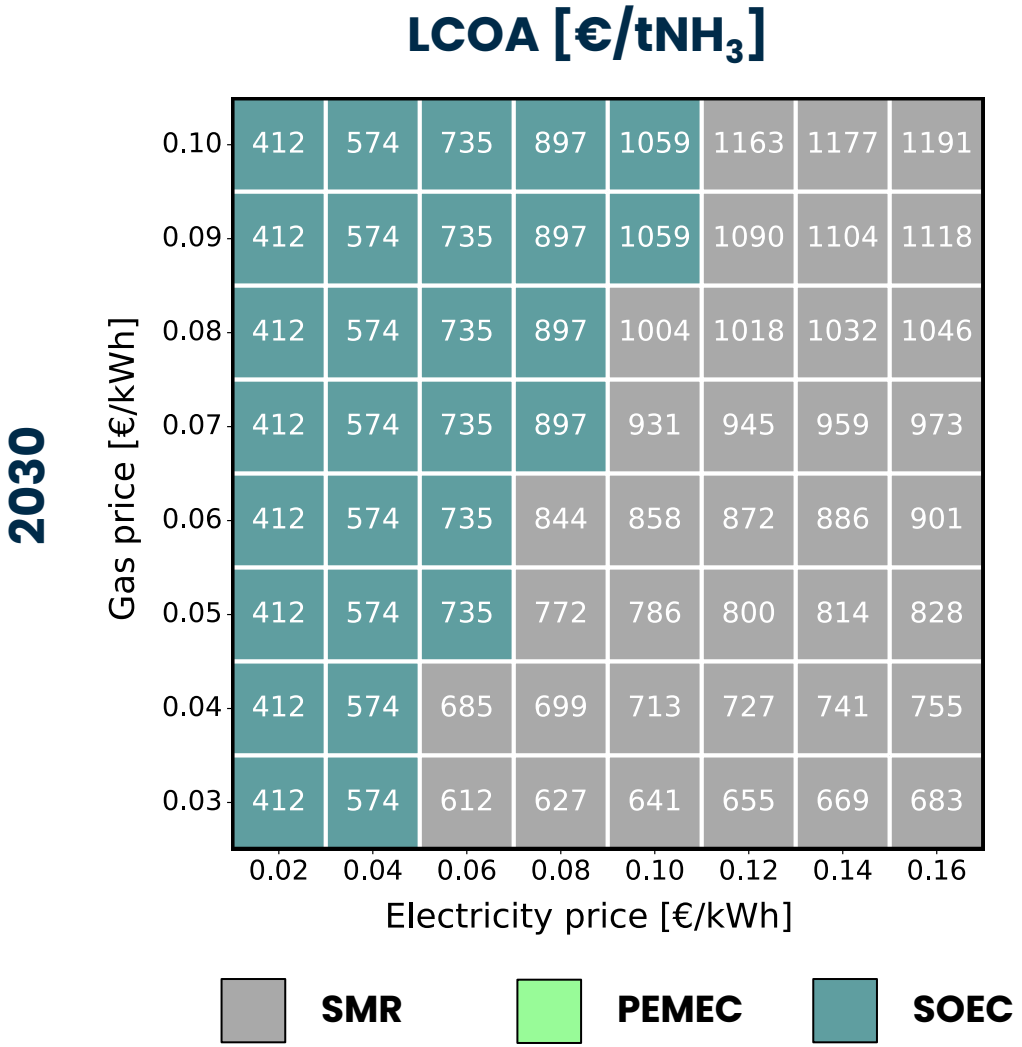

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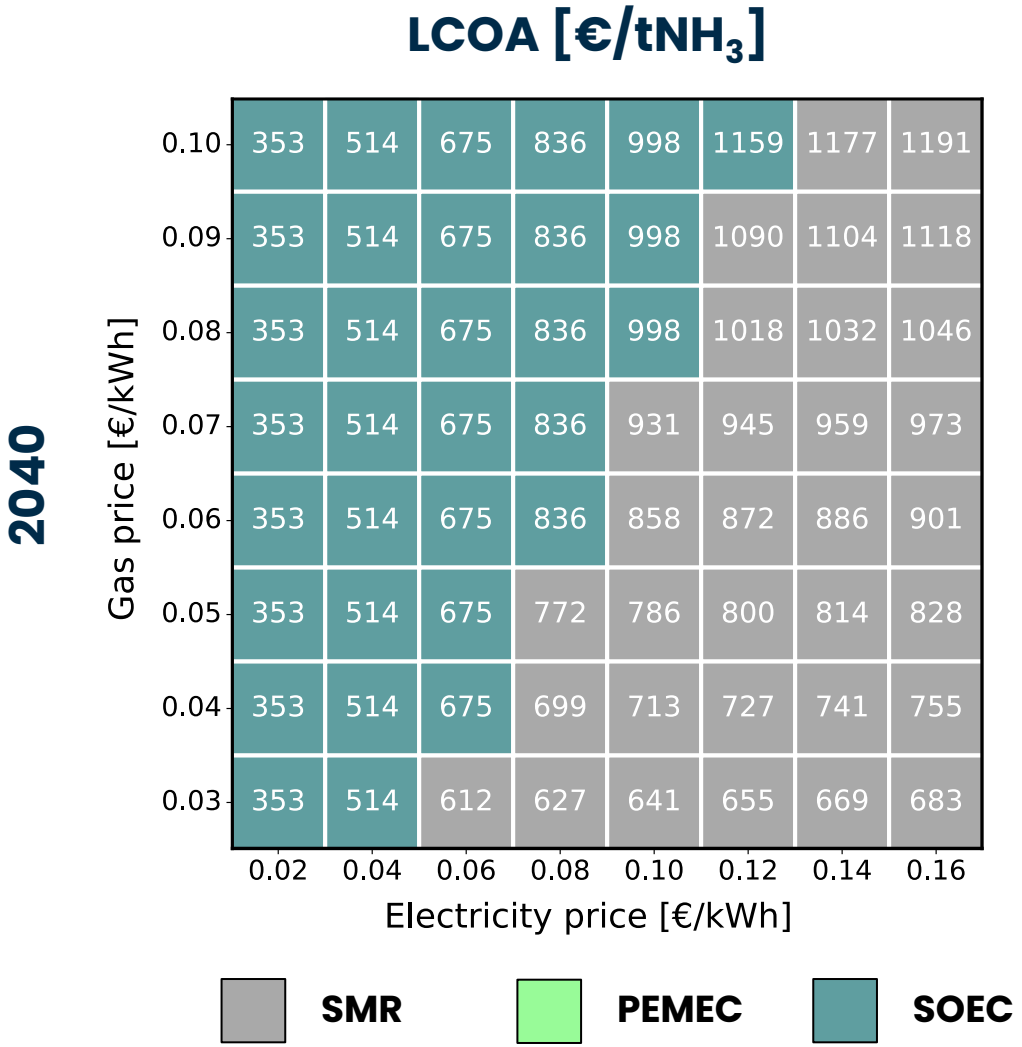

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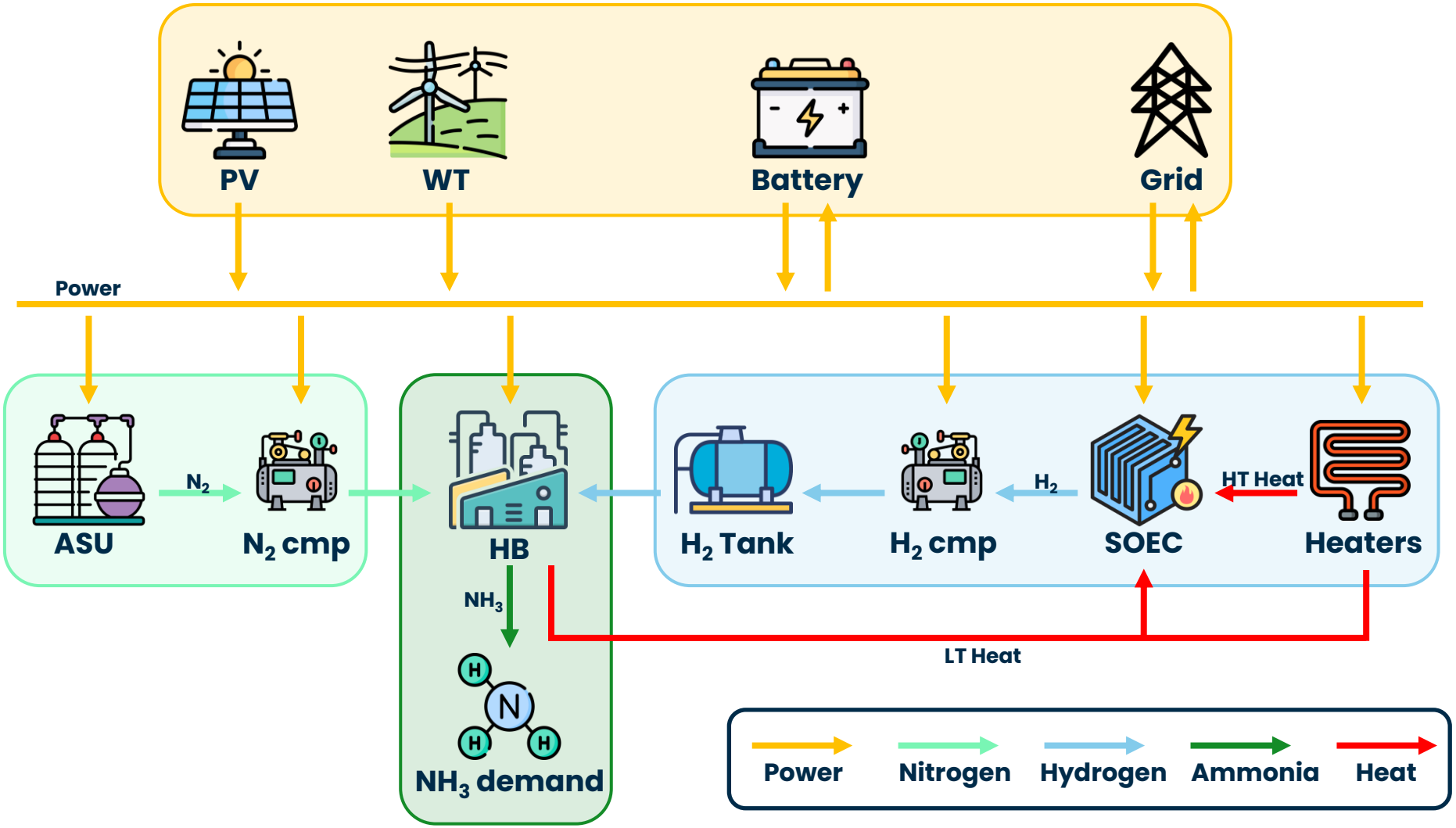
SOEC-based green ammonia production plant



MILP-based approach

Objective function

$$\min_{x,y} \; c^T \cdot x + d^T \cdot y$$

Constraints

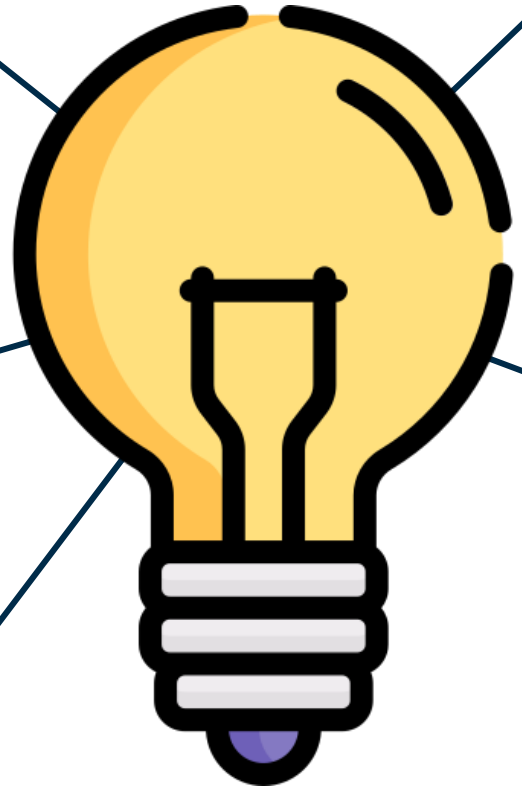
$$\begin{cases} A\,x + B\,y \leq b \\ x \geq 0, x \in \mathbb{R}^n \\ y \in \{0,1\}^m \end{cases}$$

A. Magnino, P. Marocco, M. Santarelli, M. Gandiglio, "SOEC-Based Green Ammonia Cost Competitiveness: A Region-Specific Analysis Across Europe", under review

Conclusions

SOEC-based ammonia is competitive with fossil production only in case electricity prices are very low

Coupling SOEC with HB plant helps increasing efficiency and reducing production costs



Decreasing **SOEC prices will make green ammonia competitive** with traditional routes

Where grid electricity use is allowed, **costs are generally reduced**

Carbon intensity of grid electricity must be taken into account to define ammonia associated emissions