

System Evaluation of Power to Ammonia

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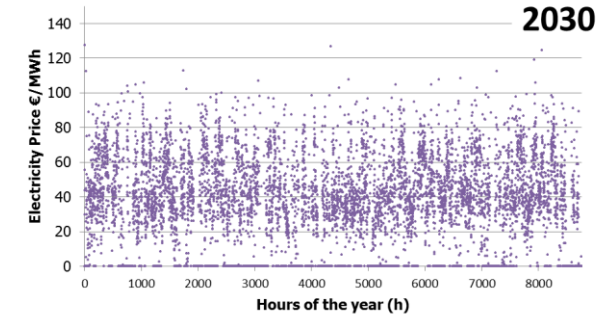


System Evaluation of Power to Ammonia

A Dutch Perspective

Rotterdam
19/05/2017

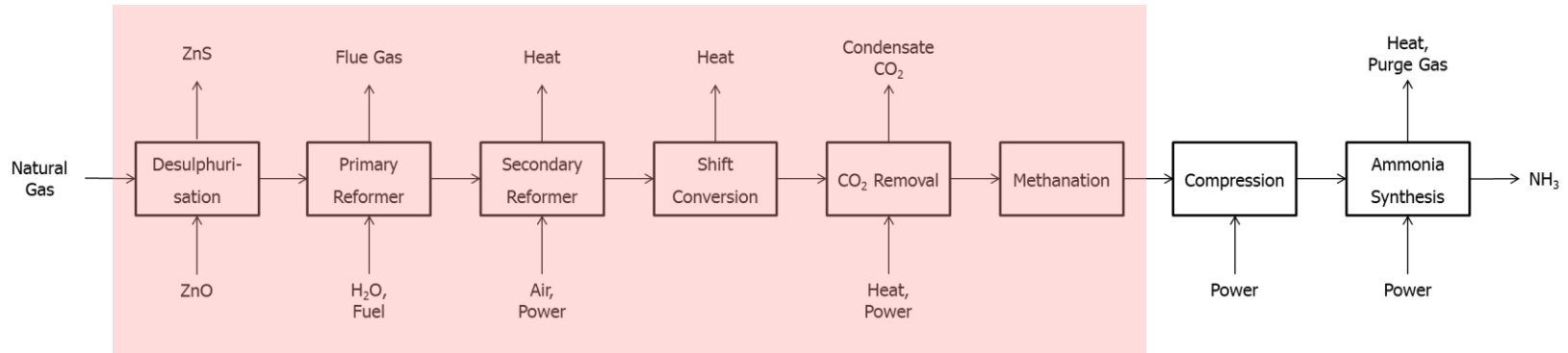
Introduction



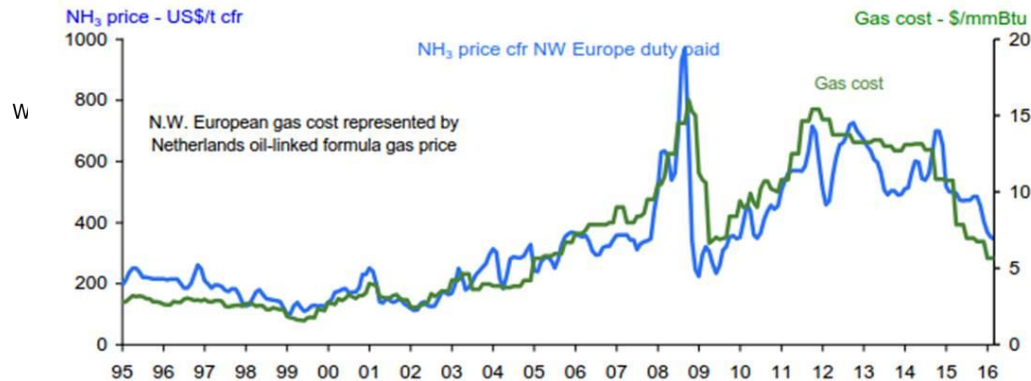
- Increasing levels of CO₂ in the atmosphere
- Source of CO₂ emission:
 - Electricity Generation
 - Transport
 - Industrial

- Increased electricity market volatility
 - Fossil power plants shut down due to increased hours of low electricity prices
- Mismatch in supply and demand of electricity

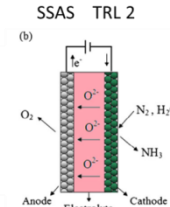
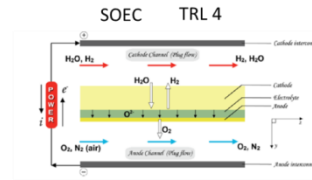
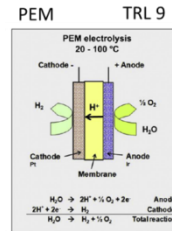
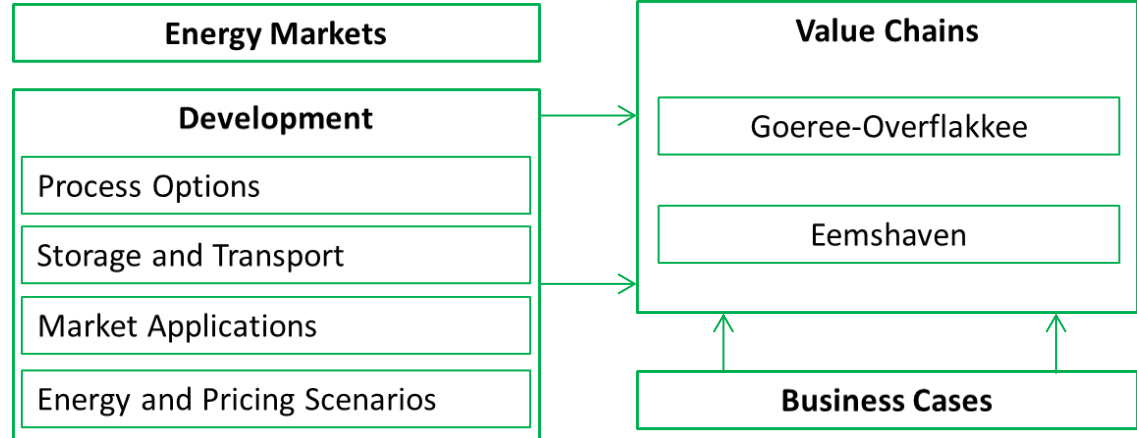
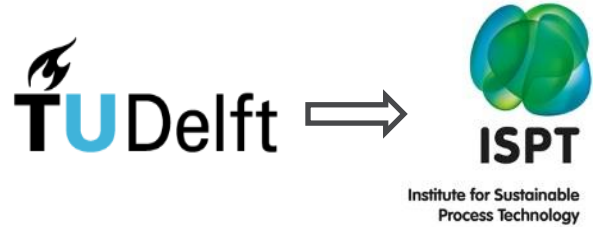
Introduction



NORTHWEST EUROPE: GAS COSTS AND AMMONIA PRICE

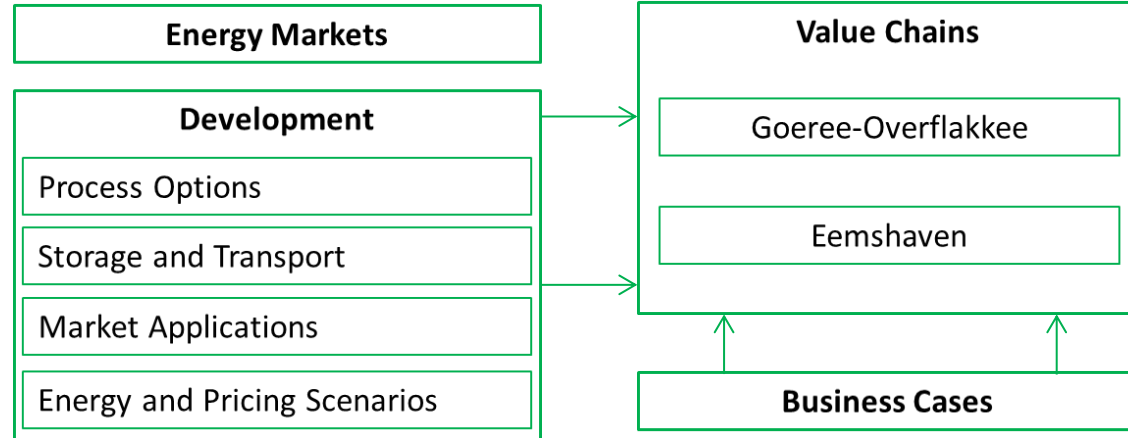


Background



Year	Renewables	Fuel Price
2023	Normal	High
		Low
2030	Normal	High
		Low
2030	High	High
		Low

Background



Approach – Development

- Techno-economic study

- Technical feasibility and process line up
- Flexibility assessment
- CAPEX and OPEX estimation

- Benchmarking

- Ammonia production – Compare against Steam Methane Reforming (SMR)
- Energy Storage – Compare against mechanical, electrical and chemical energy storage systems

- R&D Roadmap

$$Cost\ of\ Ammonia\left(\frac{\text{€}}{t}\right) = \frac{C_{manufacture}\left(\frac{\text{€}}{y}\right) - R_{Products}\left(\frac{\text{€}}{y}\right)}{M_{NH_3}\left(\frac{t}{y}\right)}$$

- Cost to Manufacture:

- CAPEX (Annualized: 7% and 15 yrs)
- O&M
- Feedstock costs (Day Ahead Market)

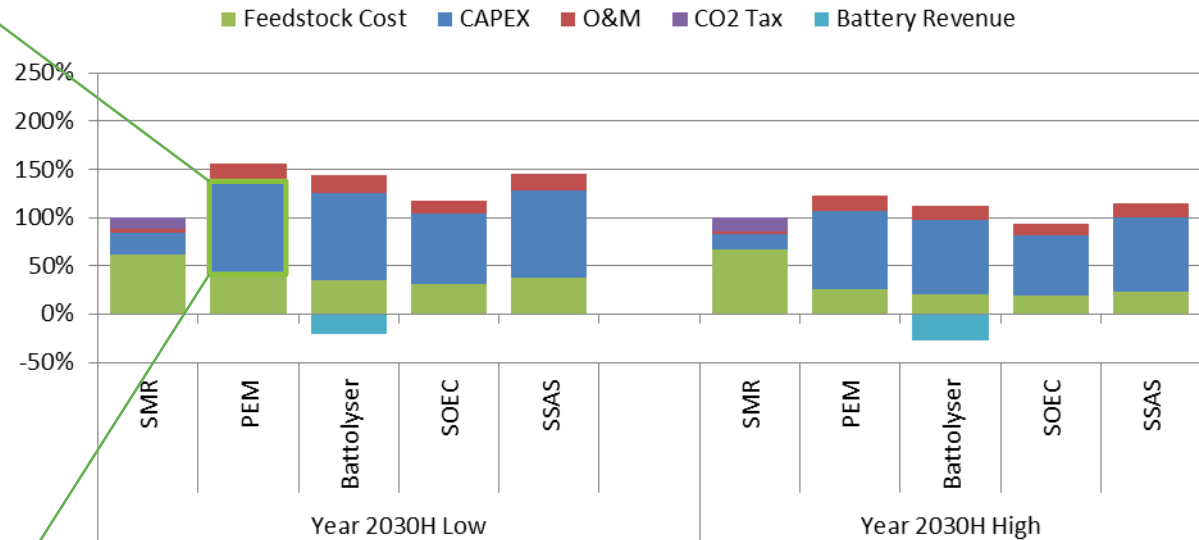
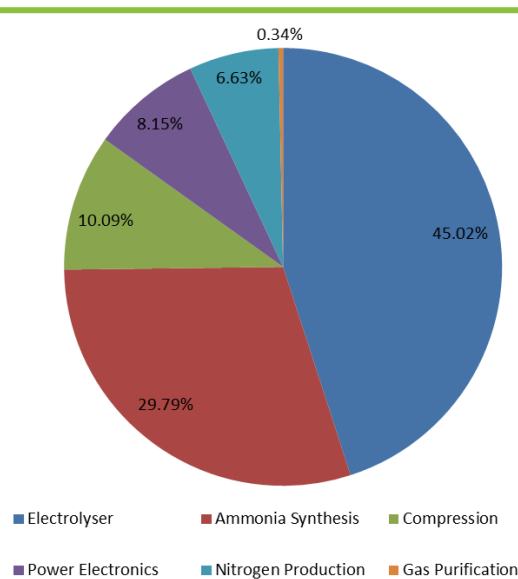
- Revenue from products

- Additional revenue from operation as a battery

$$CO_2\text{Avoided}\ (%) = \frac{\sum m_{CO_2,ref} - \sum m_{CO_2}}{\sum m_{CO_2,ref}}$$

Results

Cost of Ammonia for operating on the Day Ahead Market



100% CO₂ avoided if **green** electricity is used

Results

R&D Roadmap for PEM, Battolyser and SSAS

• PEM

Technology Area	Critical Focus Areas	Importance	Understanding	Opportunity
Membrane	Reduce membrane thickness	9	High	High
	Membrane mechanical reinforcement	5	Medium	Medium
	Improve membrane dimensional stability	9	High	High
Catalyst	Catalyst loading reduction (O ₂)	7	Medium	High
Protection Coating	Alternate lower cost coating materials	7	Medium	High
Accelerated Life Testing	Reduce design and material validation test time	9	Low	High
	Remove barriers for new materials market acceptance	9	Medium	High

• Battolyser

- Power level vs. efficiency optimization
- Scale up technology from Lab to Demo

• Solid State Ammonia Synthesis

- Increasing material durability
- Increasing product selectivity
- Operating conditions (Temperature and Pressures)

Conclusion

- Power to Ammonia (P2A) is technically feasible (has been for ~80 years)
- P2A can be deployed economically with sufficient renewable penetration
- No CO₂ emissions if green electricity is used. 'Grey' electricity leads to ~3x the normal emissions of SMR
- Cost drivers for P2A
 - Feedstock
 - CAPEX of Electrolyzer (+low utilization)
- R&D Roadmap for cost reduction and performance improvement

Further work

- PEM Testing Facility (ECN)
 - Extended duration and accelerated degradation testing
 - Platform to bring together component and Electrolyzer manufacturers
- Field testing cost efficient PEM (ECN)
- Demonstration 6 MW PEM in steel production
- STW Projects (TU Delft)
 - Battolyser and SSAS



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