

Global Syngas Technologies Council
Annual Conference 2024

GSTC

Blue before Green?

Syngas for Decarbonization Solutions

07-09 October 2024

Rancho Bernardo, California

Karsten Radtke

thyssenkrupp Uhde

engineering. tomorrow. together.



thyssenkrupp

thyssenkrupp – a global conglomerate

~37 bn EUR sales

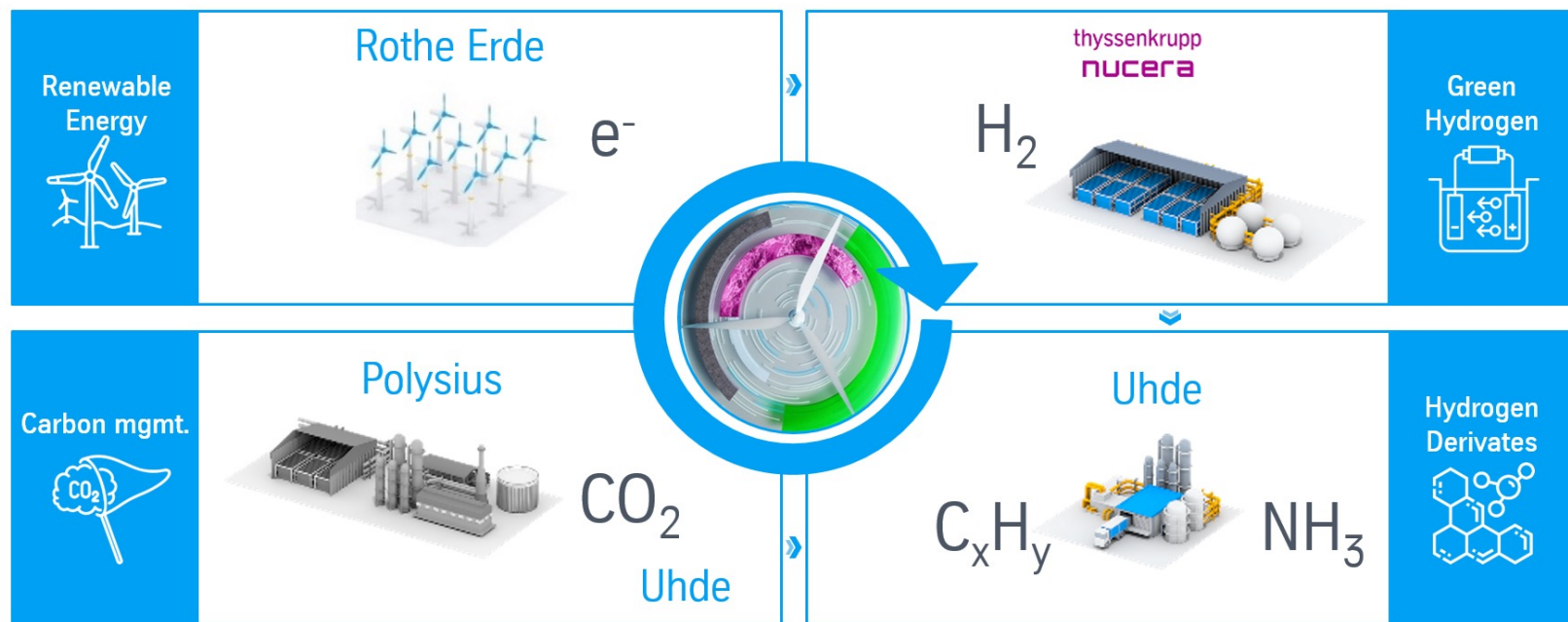
~100,000 employees

present in ~50 countries at ~800 locations

founded 213 years ago in Essen, Germany



Segment Decarbon Technologies



“Green Transformation” is the biggest economic paradigm shift since the industrial revolution

Climate change challenge

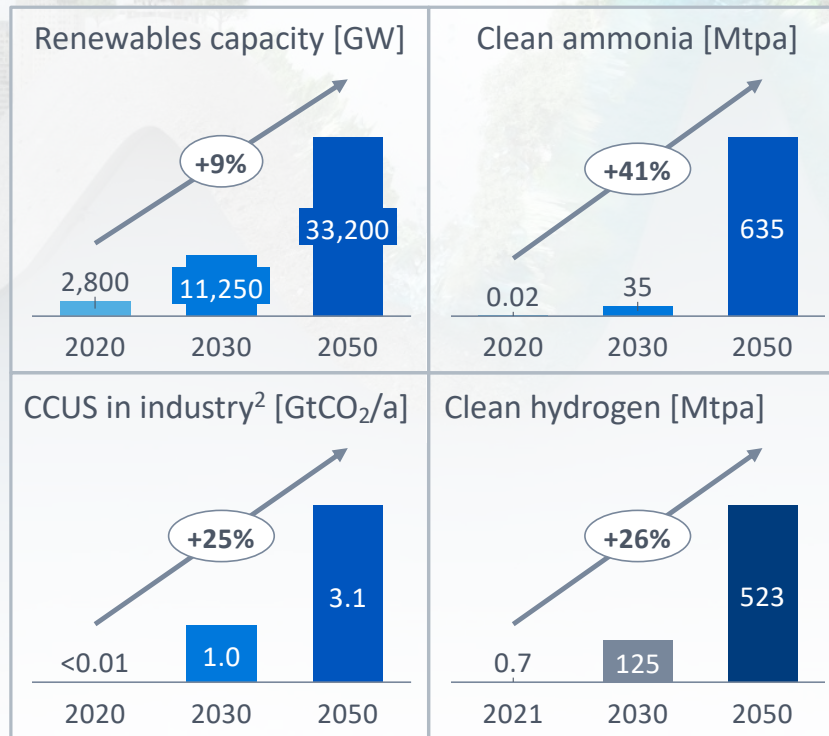
Call for urgent actions



- Tripling renewables & doubling energy efficiency by 2030
- Accelerating efforts towards phase-down of unabated coal power & transitioning away from fossil fuels

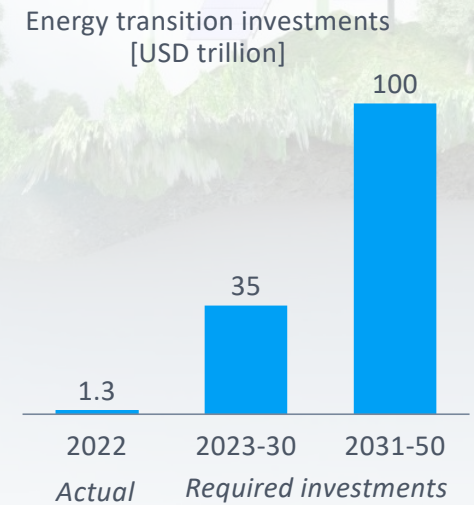
...needs an accelerated industrial green transformation...

Massive & rapid deployment of clean solutions¹



...with exponential funds

Huge financial requirements¹



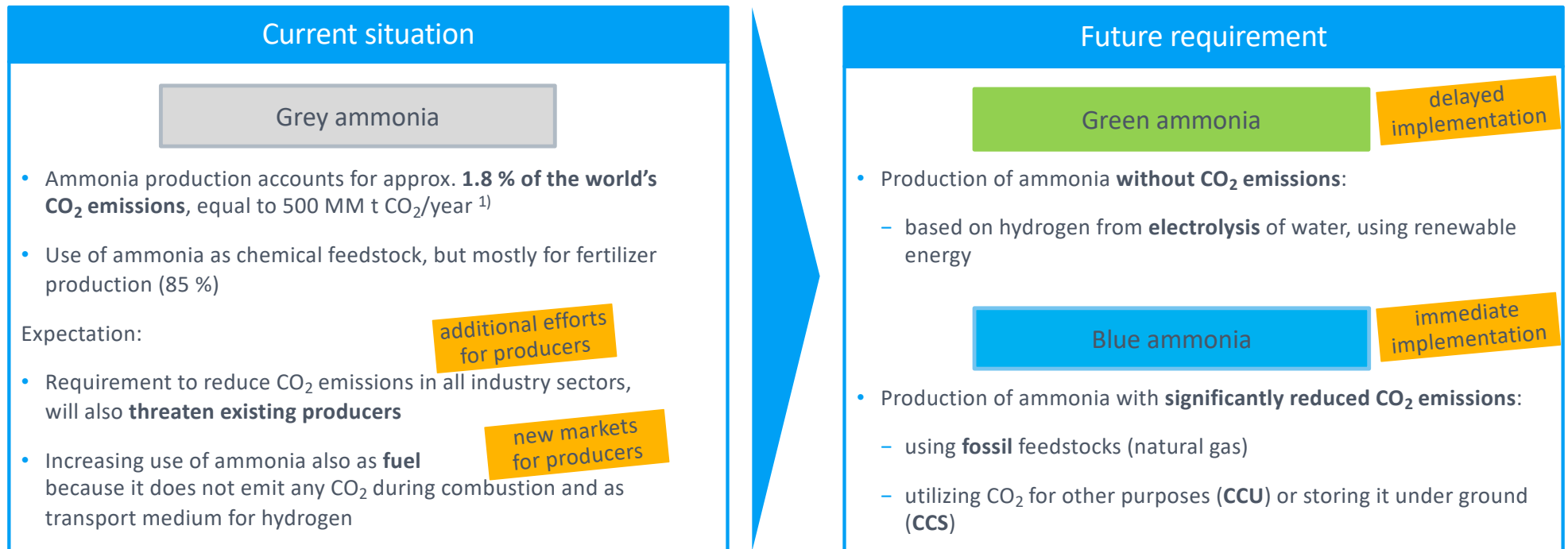
...to achieve the Paris climate targets

Sources: IRENA (2023) | 1. IRENA 1.5°C scenario | 2. Includes iron & steel, cement & lime and chemicals & petrochemicals



Grey, Blue and Green will co-exist for a long time period

Example: focus area ammonia



Fossil Feedstock based Hydrogen and its Key Derivatives (ammonia, methanol, synfuels) will remain. New investments will include grey and blue, later green

1. The Royal Society: Ammonia: Zero-carbon fertiliser, fuel and energy store

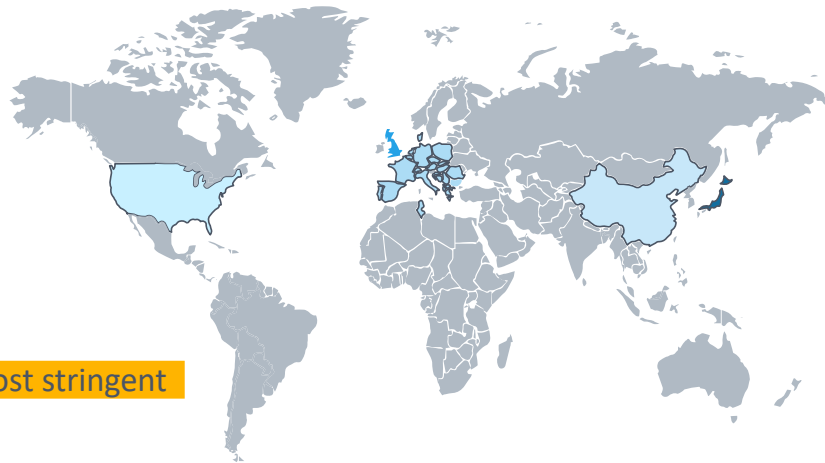


Regulatory Requirements: Carbon Intensity

Even most stringent carbon intensity threshold can be achieved with **blue solutions** today

Global Clean Hydrogen Standards
US Clean Hydrogen Production Standard ≤ 4 kg CO ₂ e per kg H ₂ Four levels in the IRA
China Hydrogen Alliance ≤ 4.9 kg CO ₂ e per kg H ₂
Expected EU regulations ≤ 3.3 kg CO ₂ e per kg H ₂
UK Low Carbon Hydrogen Standard ≤ 2.4 kg CO ₂ e per kg H ₂
Japan Clean Hydrogen Standard ≤ 3.4 kg CO ₂ e per kg H ₂ and 0.84 kg CO ₂ e per kg NH ₃ *
S. Korea Clean Hydrogen Certification Four grades – < 4.0 kg CO ₂ e per kg H ₂
CertifHy Voluntary international standard ≤ 4.4 kg CO ₂ e per kg H ₂

← most stringent



Note: some values are for well to gate emissions, others are well to port

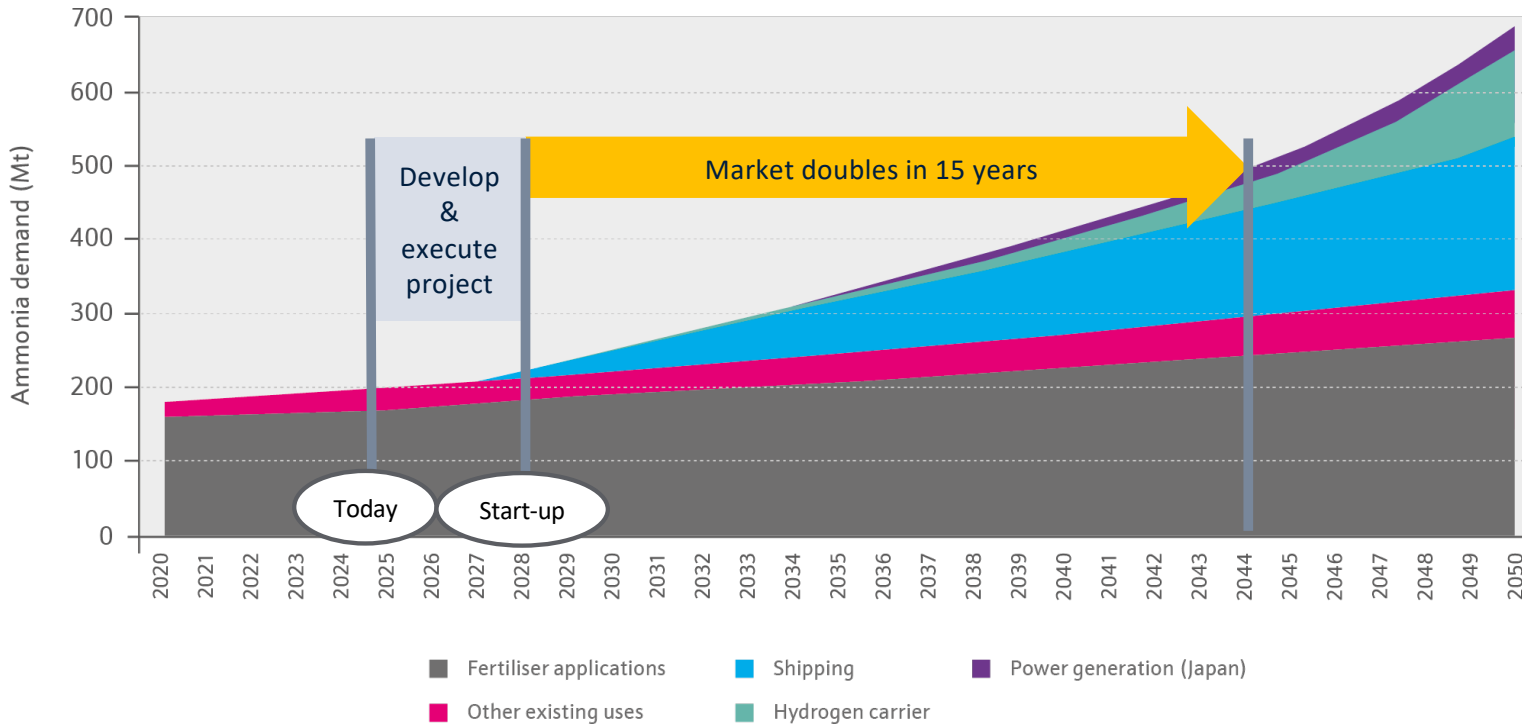
1 Hydrogen Insights December 2023, Hydrogen Council & McKinsey Company
 2 BNEF, Hydrogen Strategies, Dec 2023
 * Only Japan has announced a threshold for ammonia carbon intensity for gate-to-gate

<p>1,418 Clean hydrogen projects announced ¹</p>	<p>51 Hydrogen strategies around the world ²</p>
<p>+30% Investment growth last year</p>	<p>\$570bn Total announced investment ¹</p>



The need for low carbon intensity ammonia is growing

The pull of new opportunities emerging for ammonia, that positively affect demand



Source: Innovation Outlook, Renewable Ammonia; IRENA in partnership with Ammonia energy Association; 2022

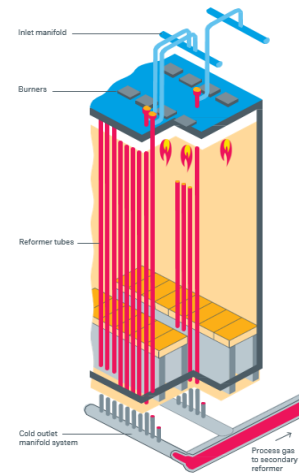


Technical Options for Large Scale Blue Ammonia Plants

SMR or ATR solutions

Tubular steam reformer (SMR):

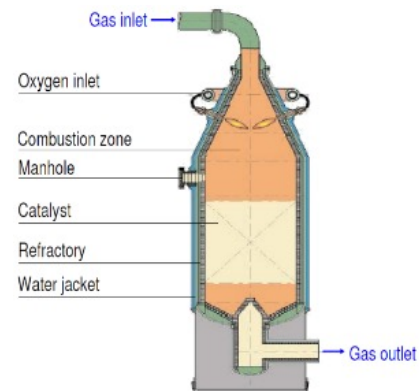
- State-of-the-art technology for ammonia plants: 5 largest running plants by Uhde, all with capacity of 3,300 mtpd or more
- 6th and 7th plant in execution
- With further size increases, maintaining equal temperature distribution can be challenging. However, up to 5,000 mtpd, our design ensures it is effectively manageable



... for blue plants, >75 % CO₂ capture needs CO₂ removal from flue gas (PCCC)

Autothermal reformer (ATR):

- References for methanol plants exist, comparable in size to >5,000 mtpd ammonia
- Basic engineering incl. modularization completed for plant size of 3,500 mtpd
- Needs air separation for O₂ and N₂ supply
- In development for capacities up to 6,000 mtpd with high levels of confidence in scalability
- New cooperation with JM recently announced



... little CO₂ from fired heaters only, almost all CO₂ can be directed to process, easy to capture at ≥90 %



Technical Options for Large Scale Ammonia Production

Comparison Steam Reformer vs. SMR

No additional CO₂ recovery from flue gas

Smaller front end due to later N₂ addition

Smaller synthesis loop by fewer inert gas purges

Lower capex for large plants

Lower construction effort, easier mobilization

No air separation unit, no oxygen handling



Smaller syngas compressor (in case of steam reformer)

Higher number of references, leading to lower risk

Easier turndown operation

Lower operating cost

Blue hydrogen as additional (by-)product

Joint press release

thyssenkrupp Uhde
May 20, 2024
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thyssenkrupp Uhde and Johnson Matthey join forces to offer an integrated solution for blue ammonia technology

- Johnson Matthey and thyssenkrupp Uhde to combine expertise to offer integrated technology to produce low carbon (blue) ammonia that is more climate-friendly than current production methods.
- Demand for ammonia is growing because it's easier to store and transport than pure hydrogen and is key to decarbonising the world's power, shipping, and industrial processes.

thyssenkrupp Uhde, a leading provider for engineering, construction and service of chemical plants, and Johnson Matthey (JM), a global leader in sustainable technologies, today announced they have signed a Memorandum of Understanding to jointly offer a fully integrated low carbon (blue) ammonia solution, building on a nearly 25-year ammonia relationship between the companies.

In the drive to reduce CO₂ emissions, the role of ammonia has expanded from a vital ingredient used to produce fertilizer for the agricultural sector, to a decarbonized carrier and supplier of hydrogen energy that's easier to store and transport than pure hydrogen. The movement of low carbon ammonia can utilize existing infrastructure making it a leading energy transition solution that's ready to capture, store, and ship vast quantities of hydrogen for use in the power and shipping sector, and industrial value chains globally.

By joining forces thyssenkrupp Uhde and JM can access the blue ammonia market together offering proven technologies combining the uhde® ammonia process and JM's hydrogen expertise through its LCHTM technology, which will enable the production of blue ammonia with up to 99% CO₂ capture.

thyssenkrupp Uhde has licensed, engineered, or constructed over 130 ammonia plants worldwide since 1928 and is market leading in plants greater than 3,000 metric tonnes per day with its unique uhde® dual pressure technology. JM's LCH technology, which utilizes JM's autothermal reformer alone, or in conjunction with JM's gas heated reformer, has been selected for several of the world's first large scale blue hydrogen projects including bp's H2Teesside, a 700-megawatt low carbon hydrogen production plant, and the H2H Saltend project with Equinor and Linde for a 600-megawatt low carbon hydrogen production plant.

Lucretia Löscher, COO thyssenkrupp Uhde, said: "At thyssenkrupp Uhde, we are committed to our purpose, 'we create a livable planet'. With this strong partnership we further broaden our portfolio of climate-friendly solutions and can help our customers even better to reach their sustainability goals."

Alberto Giovanzana, Managing Director – Catalyst Technologies at Johnson Matthey, said: "We know multiple routes are needed in the energy transition, and ammonia provides several options because it can be used directly in power and shipping industries, and as a hydrogen carrier to safely transport hydrogen to areas it is not easy to produce. Combining our expertise and over two decades worth of partnership with thyssenkrupp Uhde, we are excited to offer this technology which will allow our customers to produce ammonia with significantly lower CO₂ emissions."

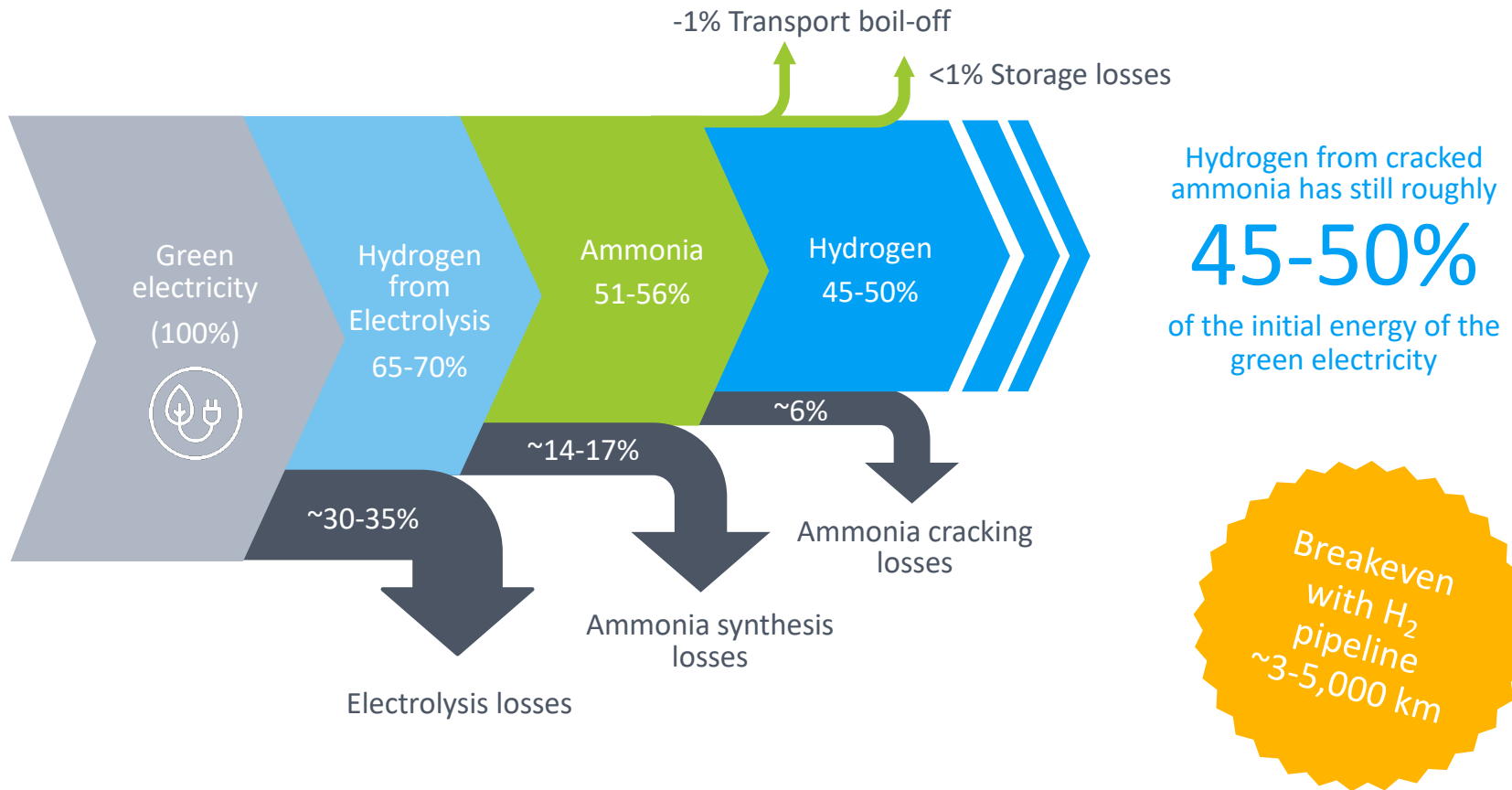
SMR	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	ATR ¹
SMR	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	ATR
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MR	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	ATR

1. for ATR in combination with Uhde's selection of downstream gas cleaning steps



Green Hydrogen from Ammonia Cracking

Energy Flow Diagram shows: Cracking is the smallest energy loss

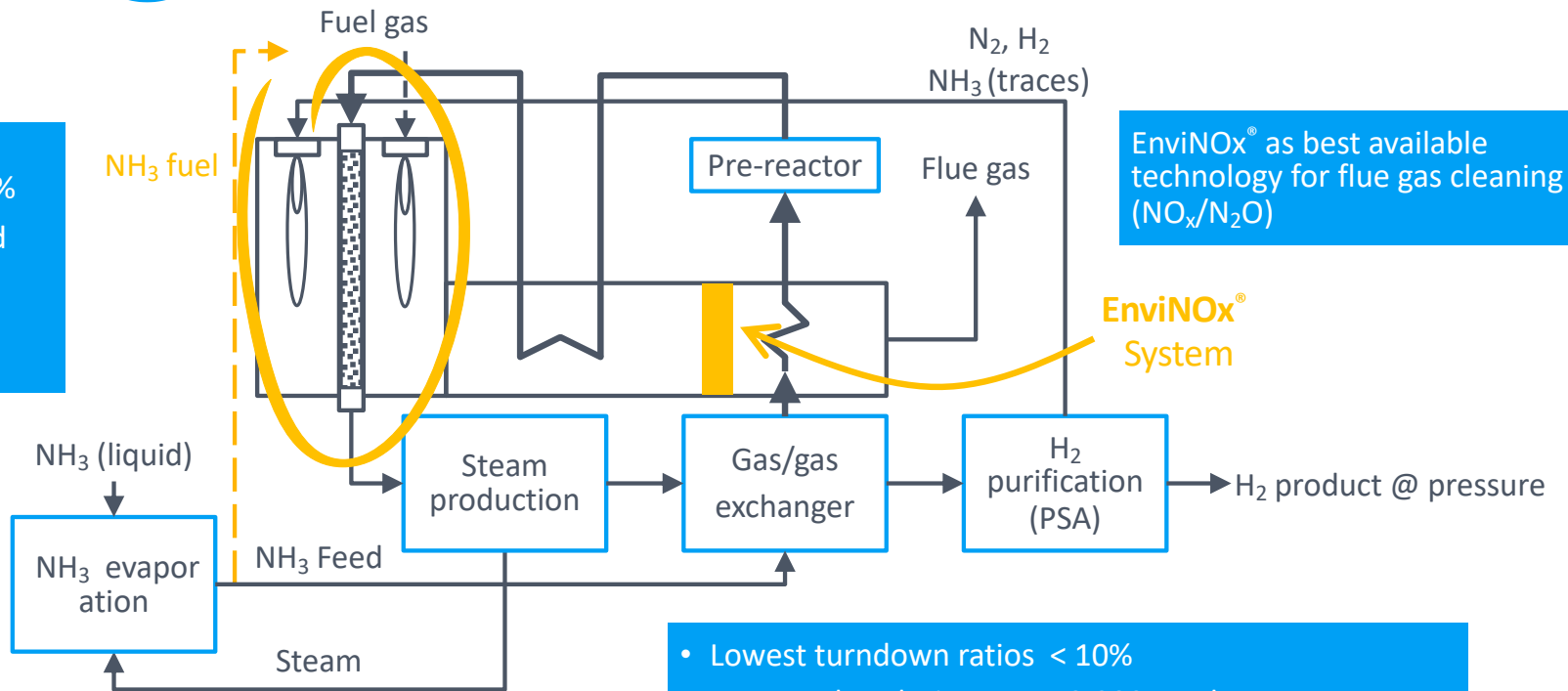


Ammonia Cracking: Based on Proven Steam Reformer Design – including EnviNOx System



Uhde's well proven SMR prop. equipment with more than 100 large-scale installed units

- High catalytic NH_3 conversion to $\text{H}_2 > 98\%$
- Catalyst can withstand water content
- Purities adaptable to requirements of user



EnviNOx[®] as best available technology for flue gas cleaning ($\text{NO}_x/\text{N}_2\text{O}$)

EnviNOx[®] System

- Lowest turndown ratios $< 10\%$
- Large scale solutions over 3,000mtpd NH_3
- Highest energy efficiency



thyssenkrupp Uhde Ammonia Cracking

Current Status

Demo Plant Start-up in early 2026

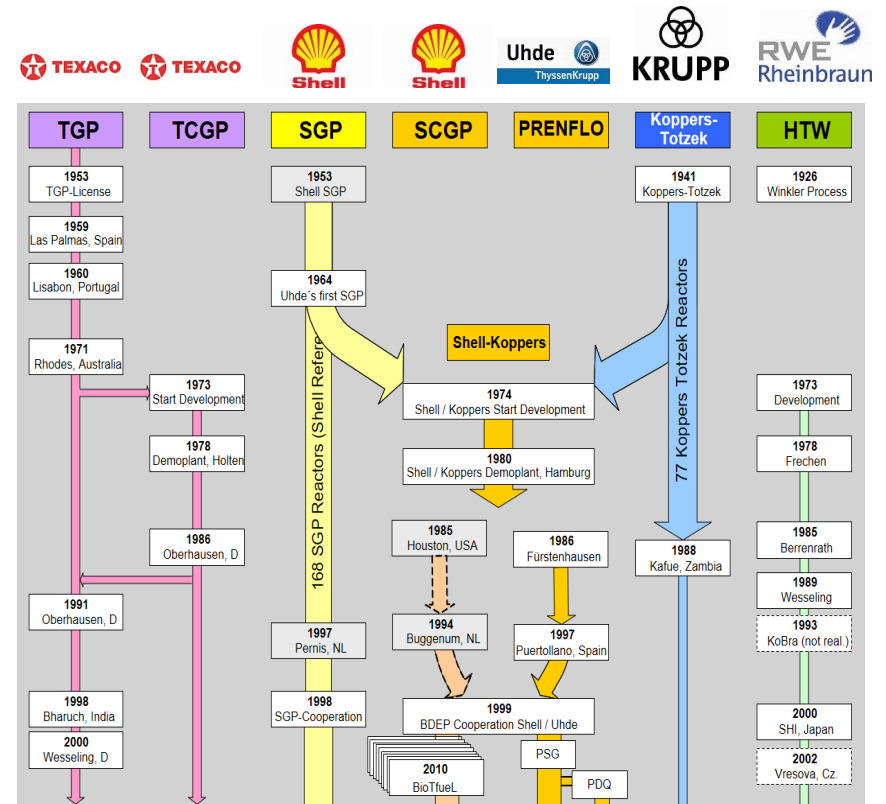
- Capacity of 28 mtpd ammonia
- Commercial size tubes; numbering-up to large scale application
- Flexibility in operation (pressure, temperature, throughput)
- Flexibility in design (burner and catalyst type, material)
- Flexibility in firing (ammonia and hydrogen)

- Demo Plant is a “cut out element” of future large scale crackers
- Tubes with industrial length
- No scale-up but numbering-up
- Reaching TRL 9 directly



A new era for Gasification emerging

Focus: green biomass based syngas products – and CCS



over 100 gasifiers built by Uhde based on 8 different technologies

TGP: Texaco Gasification Process
TCGP: Texaco Coal Gasification Process
SGP: Shell Gasification Process

SCGP: Shell Coal Gasification Process
PRENFLO: Pressurized Entrained Flow Gasification
HTW: High-Temperature Winkler Gasification

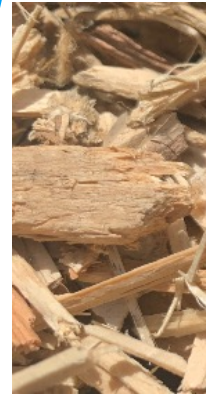


BioTfuel[®] Project

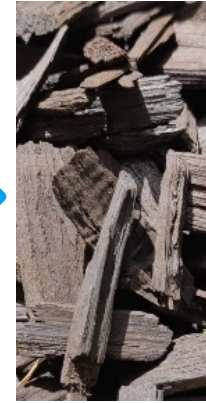


1 Drying + Torrefaction unit
Venette, France

2 Gasification + Syngas + FT unit
Dunkirk, France



Raw Wood



Torrefied Wood

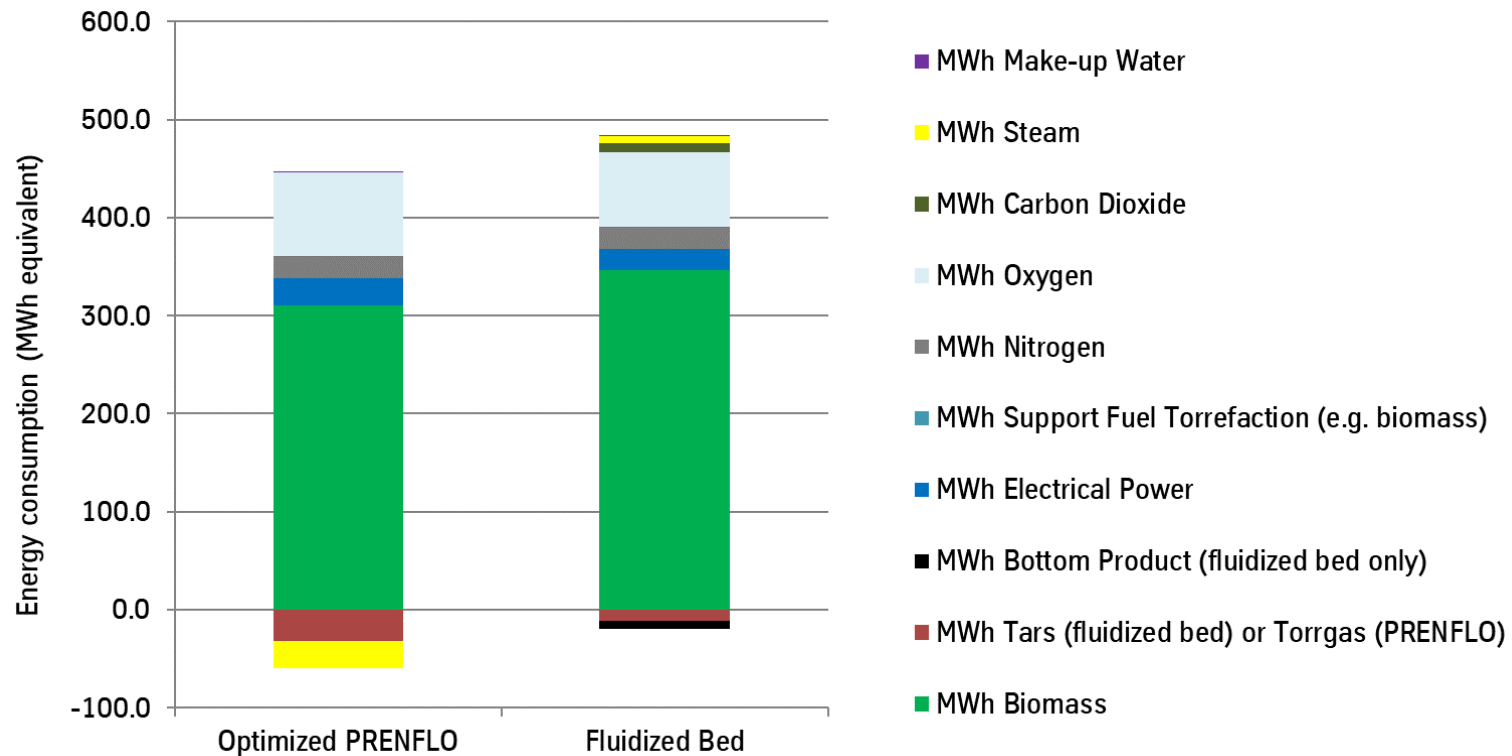


FT Liquids



Why did we select Entrained-Flow for Biomass?

A deep-dive techno-commercial analysis shows that entrained-flow beats fluidized-bed solutions by 10-20 %



Full consideration of all parameters: feedstock consumption, byproducts, power consumption, support fuel consumption, inert gas consumption, oxygen consumption, steam production and consumption and make-up water consumption. All consumption and production figures converted to energy equivalents (MWh) for better comparability.




PRENFLO Gasification

Broad Feedstock Applicability




 Coal (hard/brown/lignite) **proven**

 Petcoke **proven**

 Wastes **partially tested**

 Biomass **proven**

Different hard woods, soft woods, forest residues
grassy biomasses (e.g. straw or miscanthus) and
waste wood as potential feedstocks



Multi-fuel concept available due to multiple burners:

Each burner can be operated with individual gaseous, liquid or solid feedstock or feedstock mixtures.



BioTfuel[®] Key Advantages

Single-Point of Responsibility

Licensing of complete chain



BioTfuel



End to End Guarantees

From biomass intake to final fuels

Axens



thyssenkrupp

Full Process Integration

Reliable & flexible technologies
Process efficiency & integration

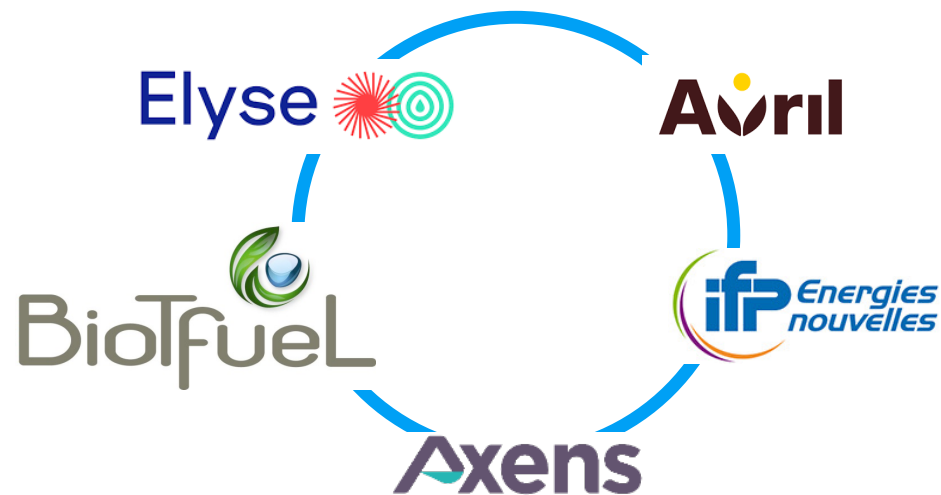


Proven Technologies

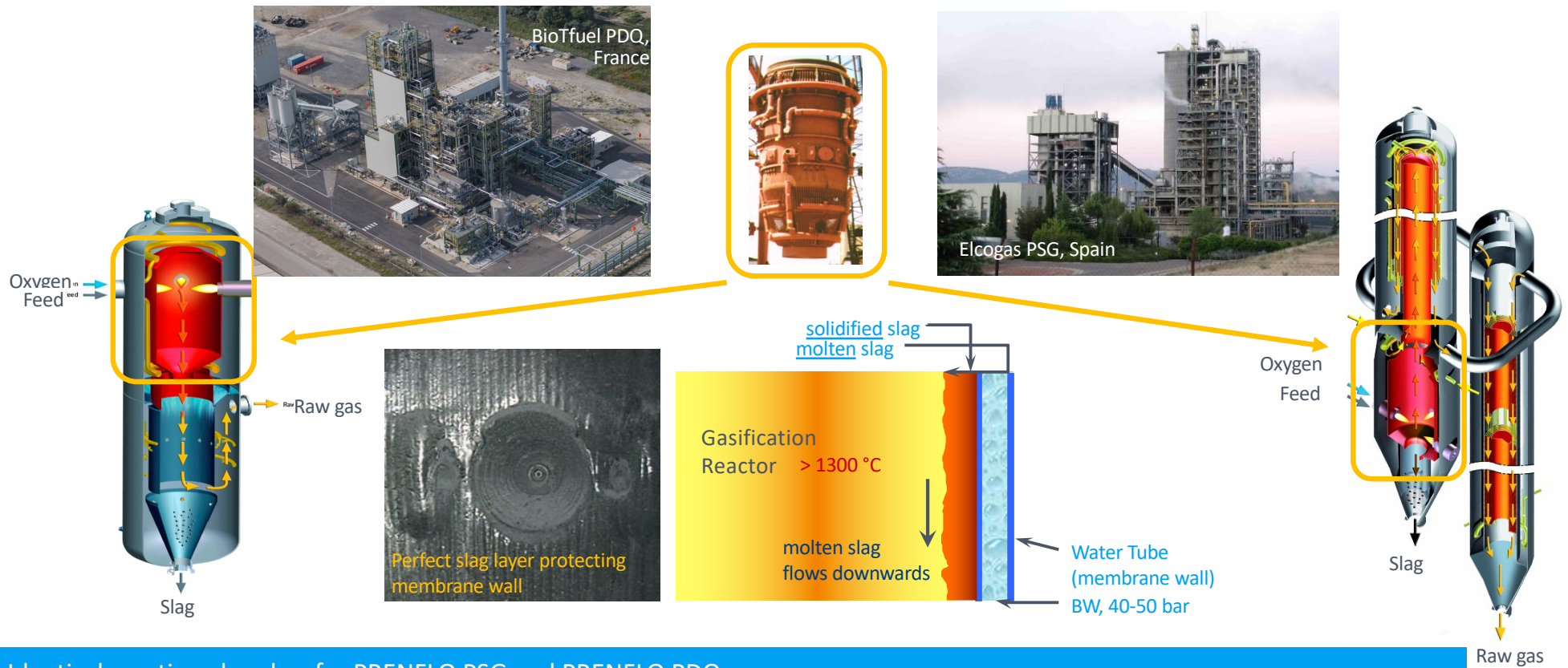
BioTfuel[®] is validated and based upon existing commercial technologies

New Commercial Plant: From BioTfuel to Commercial-Scale BioTJet

- New Commercial-Scale E-SAF Plant
- France, Pardies (nearby Pau)
- Forestry residues and alternative feedstocks. Local Sourcing
- 110,000 t/year SAF + Renewable naphtha
- E-BioTfuel[®] selected
- Start-up: 2028



PRENFLO with Steam Generation (PSG) or with Direct Quench (PDQ)



Identical reaction chamber for PRENFLO PSG and PRENFLO PDQ

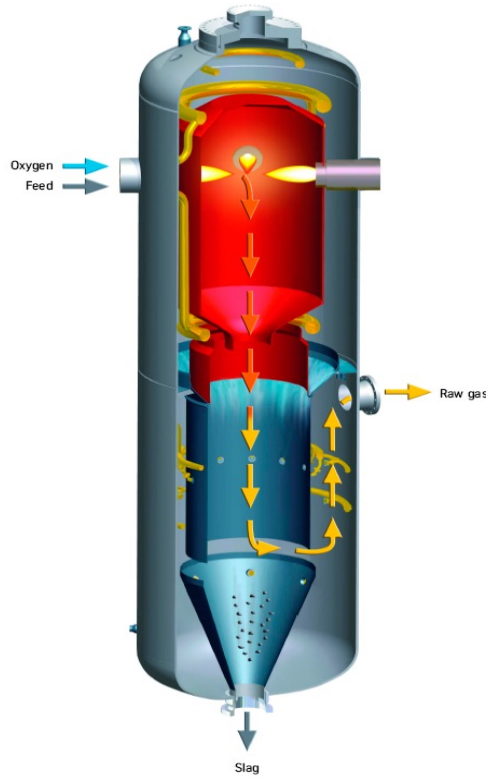
- PSG: PRENFLO with Steam Generation



PRENFLO PDQ Gasification

PDQ Features

- Dry powder feed (coal or biomass)
- Multiple horizontal co-annular burners
- Membrane wall
- Direct water quench
- Operation pressure flexible to requirements (25 - 42 bar)
- Raw gas temperature outlet of quench (200 - 250 °C)
- Compact gasification system with low CAPEX

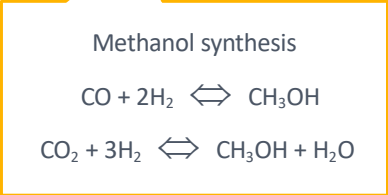
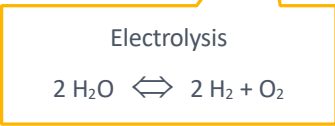
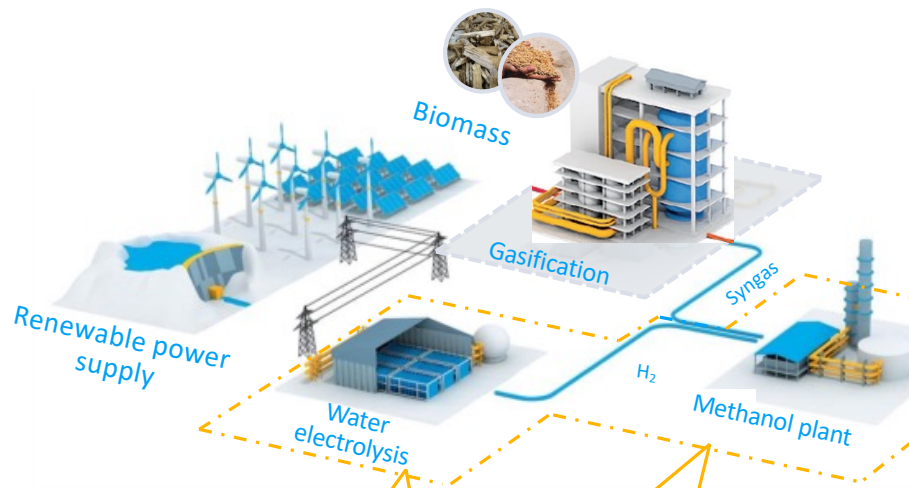


- PDQ: Prenflo with Direct Quench

Erection PDQ Gasifier, Dunkirk



Biomass to green methanol: with or without electrolysis it depends...



CO₂ emissions
 With or without electrolysis
 a water electrolysis
 emissions
 more than

thyssenkrupp Uhde
 53,516 followers
 1mo · Edited

Clean fuel from the forest 🌳 We have signed a Memorandum of Understanding with the Australian low-carbon fuels and chemicals company **HAMR - Fuelling a Sustainable Future** to underpin the development of the \$AUD 2bn Portland Renewable Fuels Project to decarbonise the shipping sector.

The planned large-scale Green Methanol project is intended to produce 300,000 tpa of Green Methanol from biomass, using forest residues.

#thyssenkrupp #Uhde #biomass #greenmethanol #sustainability #cleanfuels

Clean fuel production for HAMR Energy

“We are excited to work alongside HAMR Energy”

	w/o water electrolysis	with water electrolysis
Biomass (dry)	1.8 - 2.4 t/t _{CH3OH}	0.9 - 1.2 t/t _{CH3OH}
Electric power	1.5 - 2.5 MWh/t _{CH3OH}	5.5 - 6.5 MWh/t _{CH3OH}



Summary

- **Blue** projects dominate, **green** is coming up, but with quite some delays – **grey** continues to play a role
- **Ammonia** has established its role as hydrogen carrier, blue solutions with **SMR** and **ATR** meet all current import requirements
- **Ammonia Cracking** comes timely: commercial applications will be ready, when the market is
- **Gasification of biomass** is a true green solution. **Entrained-Flow Gasification** beats **fluidized-bed** for biomass applications
- **BioTfuel** has proven ligno-cellulosic feedstock gasification. **PRENFLO** gasification has been selected by several clients for commercial-scale SAF, methanol and hydrogen generation
- **Blue Technologies** require long-term **CCS** or **CCU** solutions. Market in **Europe** dominating.



Thank you for your attention.

Questions?

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