



# Empowering Transition<sup>SM</sup>

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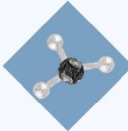
## H2ACT<sup>SM</sup>

Ammonia Cracking Technology:  
A pathway to sustainable energy

# Key Messages



Delivering Solutions,  
Changing the World.<sup>SM</sup>



## Ammonia

The most promising clean hydrogen carrier today



## Ammonia Cracking

Ready today for large scale commercial application, 10-1200 MTPD clean H<sub>2</sub>



## Value Chain Economics

Control of ammonia value chain/ feedstock price is key to profitability

H2ACT<sup>SM</sup>: Efficient, Reliable, Market Leading

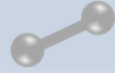
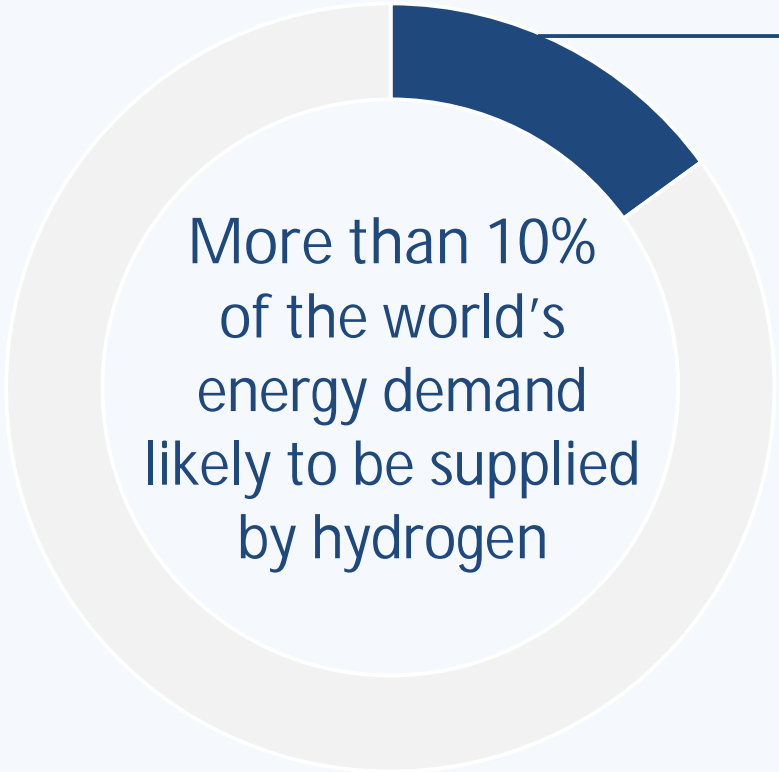




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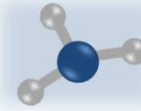
# Potential of Ammonia as Energy Carrier

# The Journey Towards Net Zero



## Hydrogen is a key molecule

+500 hydrogen projects globally  
125 GW electrolysis capacity  
announced by 2030

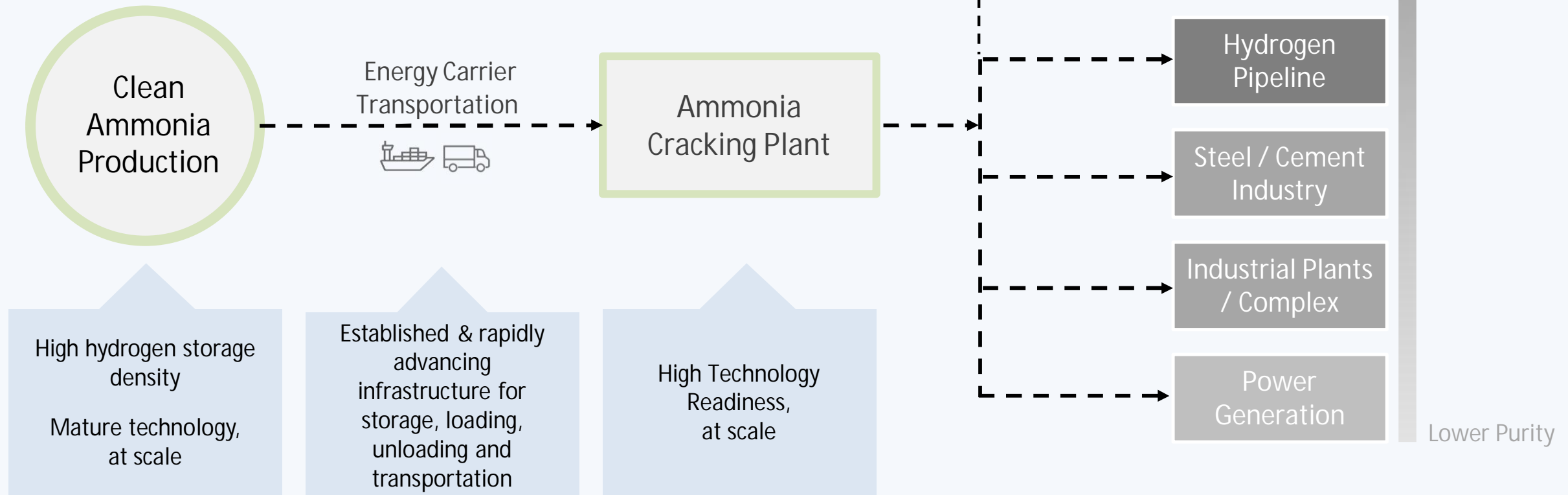


## Ammonia is a key carrier

Existing infrastructure which can be  
expanded  
+100 MTPA to be traded via ships in  
2050

# Ammonia as Energy Carrier

The most promising clean hydrogen carrier for long distances in the short to medium-term



An aerial photograph showing a dense green forest on the left and a body of water on the right. The water is a deep blue-green color. The image is framed by a dark blue border with a yellow accent line at the top.

# Challenges of Ammonia Energy Carrier Value Chain

# Ammonia Value Chain - Key Challenges



VALUE CHAIN  
ECONOMICS



VALUE CHAIN  
CARBON INTENSITY



VALUE CHAIN  
SAFETY

# Challenges – Value Chain Economics



VALUE CHAIN ECONOMICS



VALUE CHAIN CARBON INTENSITY



VALUE CHAIN SAFETY





# Challenges – Value Chain Carbon Intensity (CI)



# Challenges – Value Chain Safety



VALUE CHAIN ECONOMICS



VALUE CHAIN CARBON INTENSITY



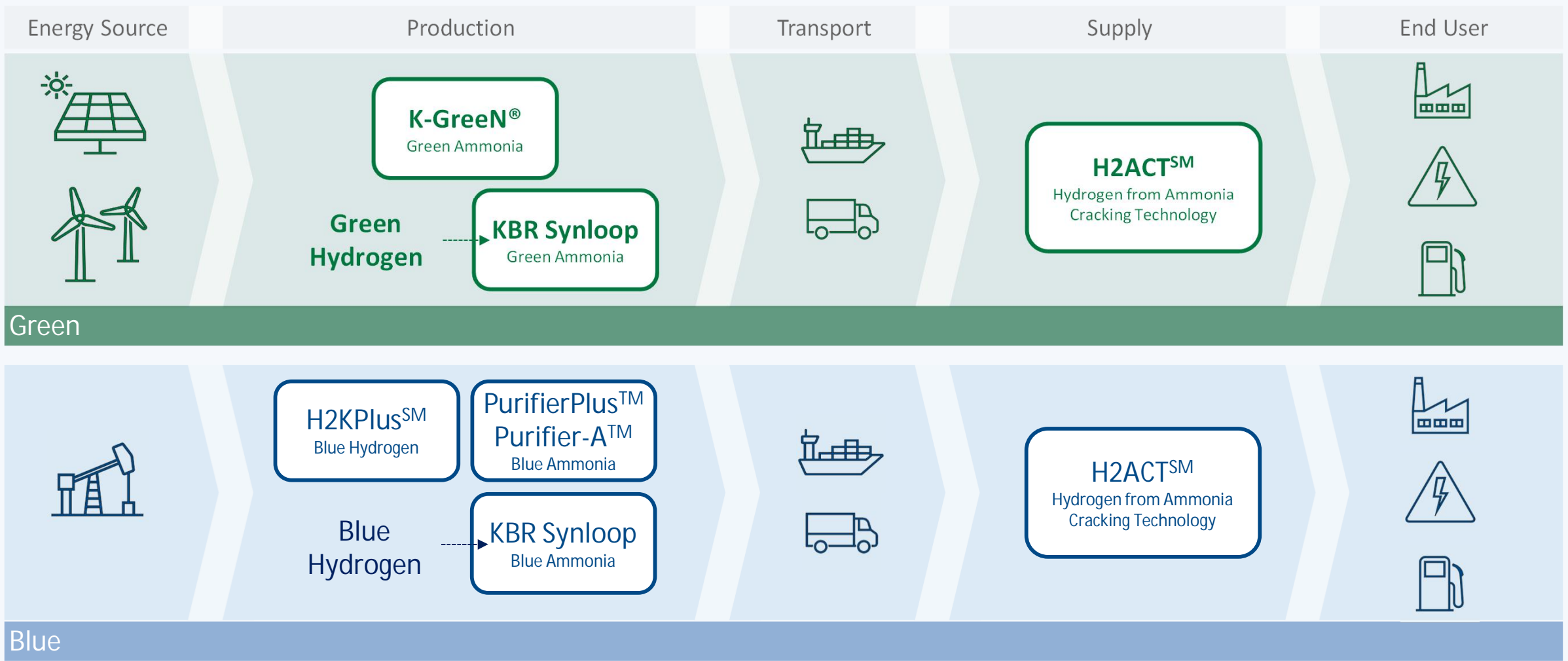
VALUE CHAIN SAFETY



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# H2ACT<sup>SM</sup> New Market, Reliable Technology

# KBR Technologies across Full Sustainable Hydrogen Value Chain



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**NET ZERO**

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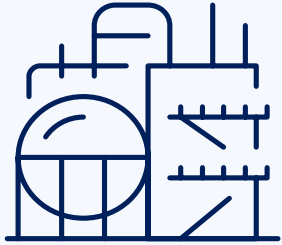
Delivering Solutions, Changing the World.™



# Technology built on strong heritage over 80 years



## SCALE



World's largest ammonia plant with single converter  
+3000 TPD

## EFFICIENCY



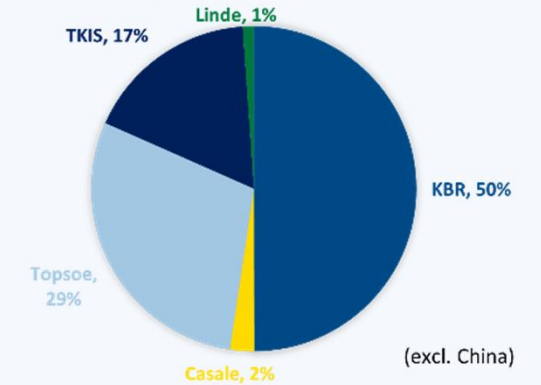
World's most energy-efficient ammonia plant  
6.27 Gcal/MT

## RELIABILITY



World's most reliable ammonia plant 2.162 consecutive days in operation

AMMONIA CAPACITY MARKET SHARE (SINCE 2010)



+50% Market share  
All based on combined reforming

KBR can deliver 1,200 TPD H<sub>2</sub> (8,640 TPD NH<sub>3</sub>) in one train, fully green



# The Ammonia Dissociation Reaction

## Endothermic

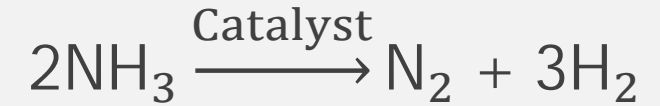
Cracking heat required 0.65 Gcal/MT, 12% ammonia energy

## Equilibrium

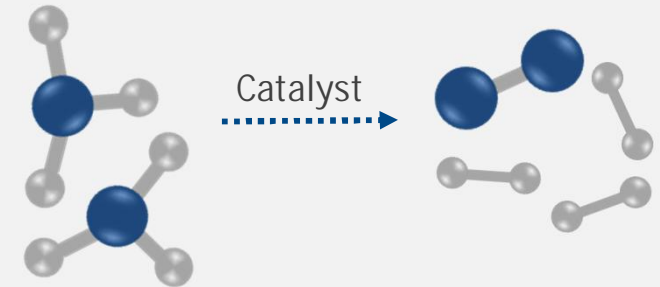
- § Equilibrium favored by high temperature and low pressure
- § Theoretically near complete conversion
  - § At > 550°C @ 1 bara
  - § At > 800°C @ 5 bara
  - § At > 1000°C @ 30 bara

## Catalyst

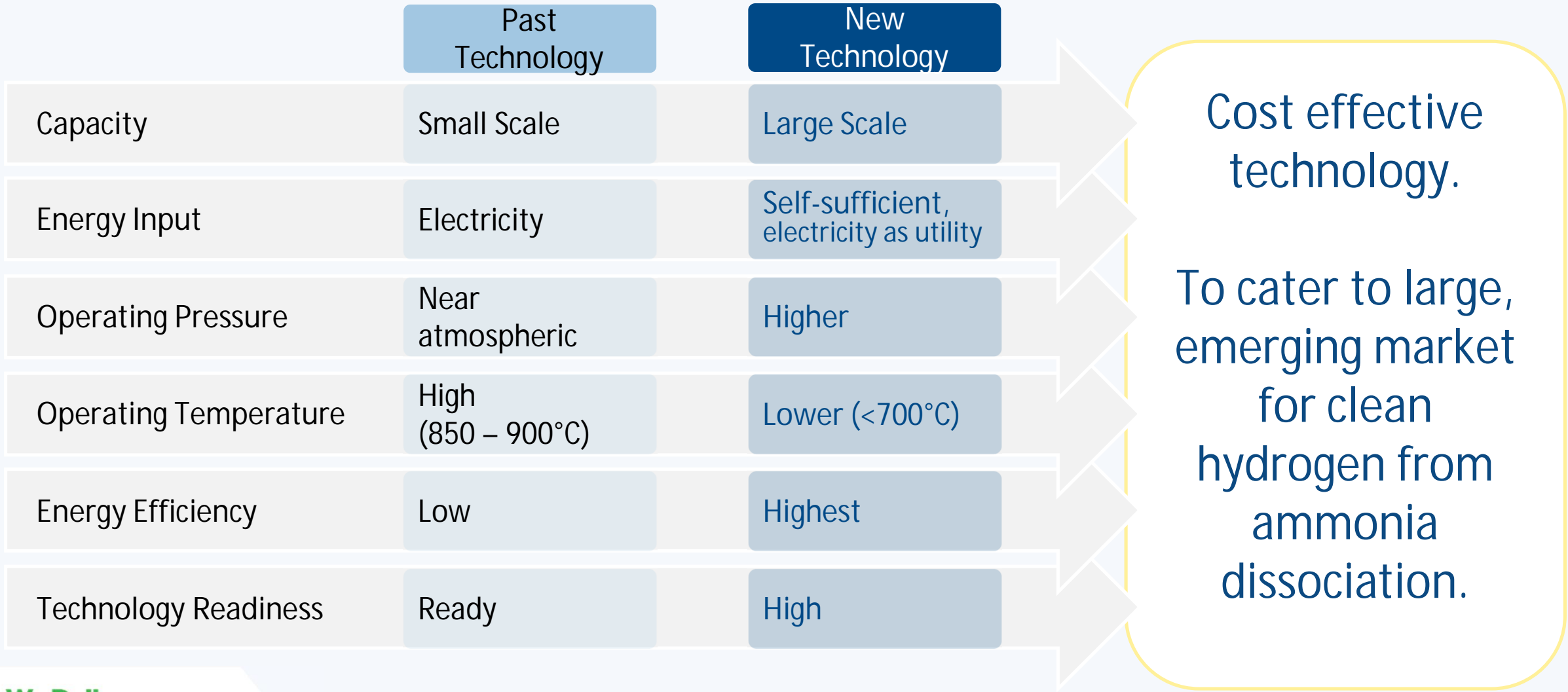
- § Nickel-based: commercialised, enhanced activity
- § Ru-based: high conversion, better equilibrium, rare & expensive



$$\Delta H_{298} = 46 \text{ kJmol}^{-1}_{\text{NH}_3}$$



# Technology Advancement for Clean Hydrogen Market



# KBR Development on Ammonia Dissociation Technology



## Catalyst



Co-operate with world-leading catalyst suppliers, commercial catalysts available

Benchmark and compare both proven and novel catalysts for best fit

## Reactor Design



Well-proven KBR reactor design, with decades of success in design and reliable operation

Evaluate alternative reactor options and configurations, minimize fuel consumption

## Flow Scheme

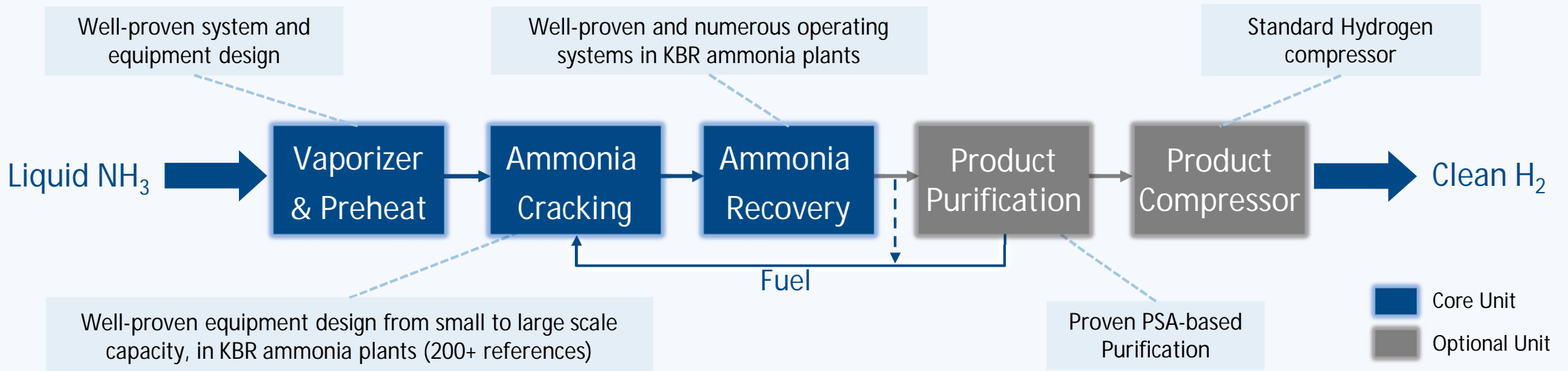


High Efficiency, cost-effective, tailored process

Operating parameter optimization to best meet project specifics (purity, pressure, etc)



# H2ACT<sup>SM</sup> Technology Overview



	Product Specification
Hydrogen Purity	From 75% to 99.97%+
Ammonia Content	As low as < 0.1 ppmv
Water Content	As low as < 1 ppmv
Delivery Temperature	As per Client requirement
Delivery Pressure	As per Client requirement

	Performance
Capacity	10 – 1,200 TPD H <sub>2</sub>
	72 – 8,640 TPD NH <sub>3</sub>
Direct Carbon Intensity [kg CO <sub>2</sub> / kg H <sub>2</sub> ]	0
Typical Yield [H <sub>2</sub> in Product / H <sub>2</sub> in Feed]	78 wt%
Typical Efficiency [HHV out / (HHV in + Power)]	88 %



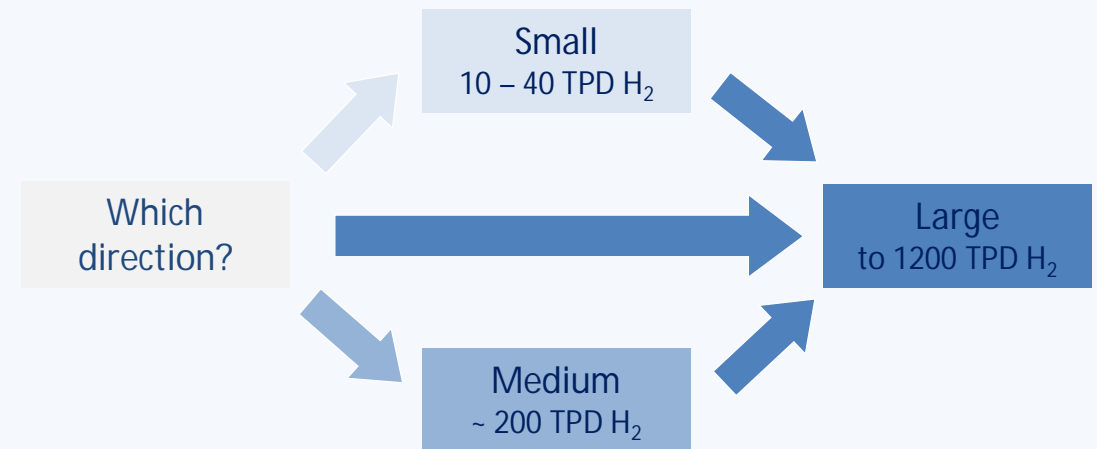
# Technology at Large Scale



Cost Effective Designs for Range of Capacities

Small Scale (Demo Plant)	10 – 40 TPD H <sub>2</sub>
Medium Scale	40 – 200 TPD H <sub>2</sub>
Large Scale	Up to 1200 TPD H <sub>2</sub>

Extensive Experience in Scale-up & Commercialization



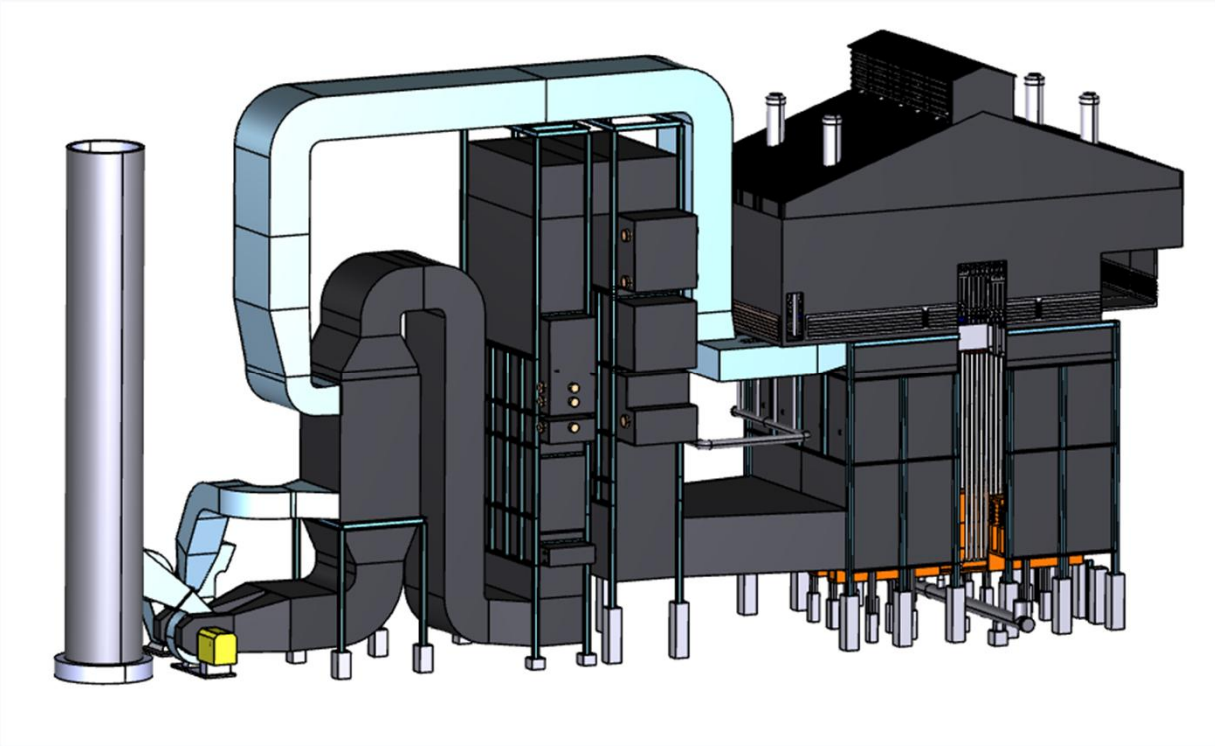
KBR Ammonia Reformers



Different routes to reach large-scale capacity

KBR can offer all the three routes.

# KBR Ammonia Cracking Furnace Design – Scale at no added risk



Proven, Robust & Compact Mechanical Design of Furnace





# H2ACT<sup>SM</sup> Selected for World's First Commercial NH<sub>3</sub> Cracking Plant

## Hanwha Impact Clean H2 Project

- § KBR awarded license and engineering design contract for a large-scale commercial ammonia cracking unit in Korea
- § Clean hydrogen production of more than 200 MTPD H<sub>2</sub> for use as fuel in Hanwha's Daesan H2GT Power Plant (Ammonia feedstock of ≥1450 MTPD NH<sub>3</sub>)
- § Up to 60% hydrogen can be co-fired with natural gas for clean power generation
- § KBR performing Licensor Basic Engineering Design (LBED) in parallel to FEED by the engineering contractor.
- § Commercial Operation in 2027



Daesan H2GT Power Plant © PSM



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# Ammonia Cracking Project Economics

# Overall Value Chain Economics



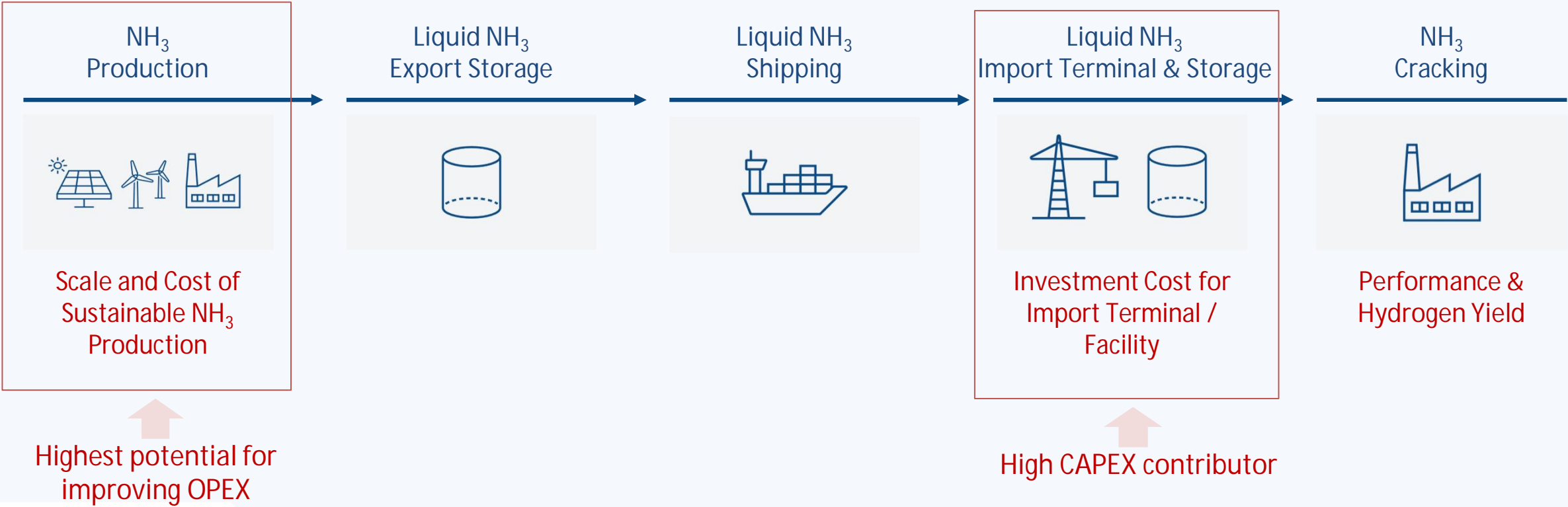
VALUE CHAIN ECONOMICS



VALUE CHAIN CARBON INTENSITY

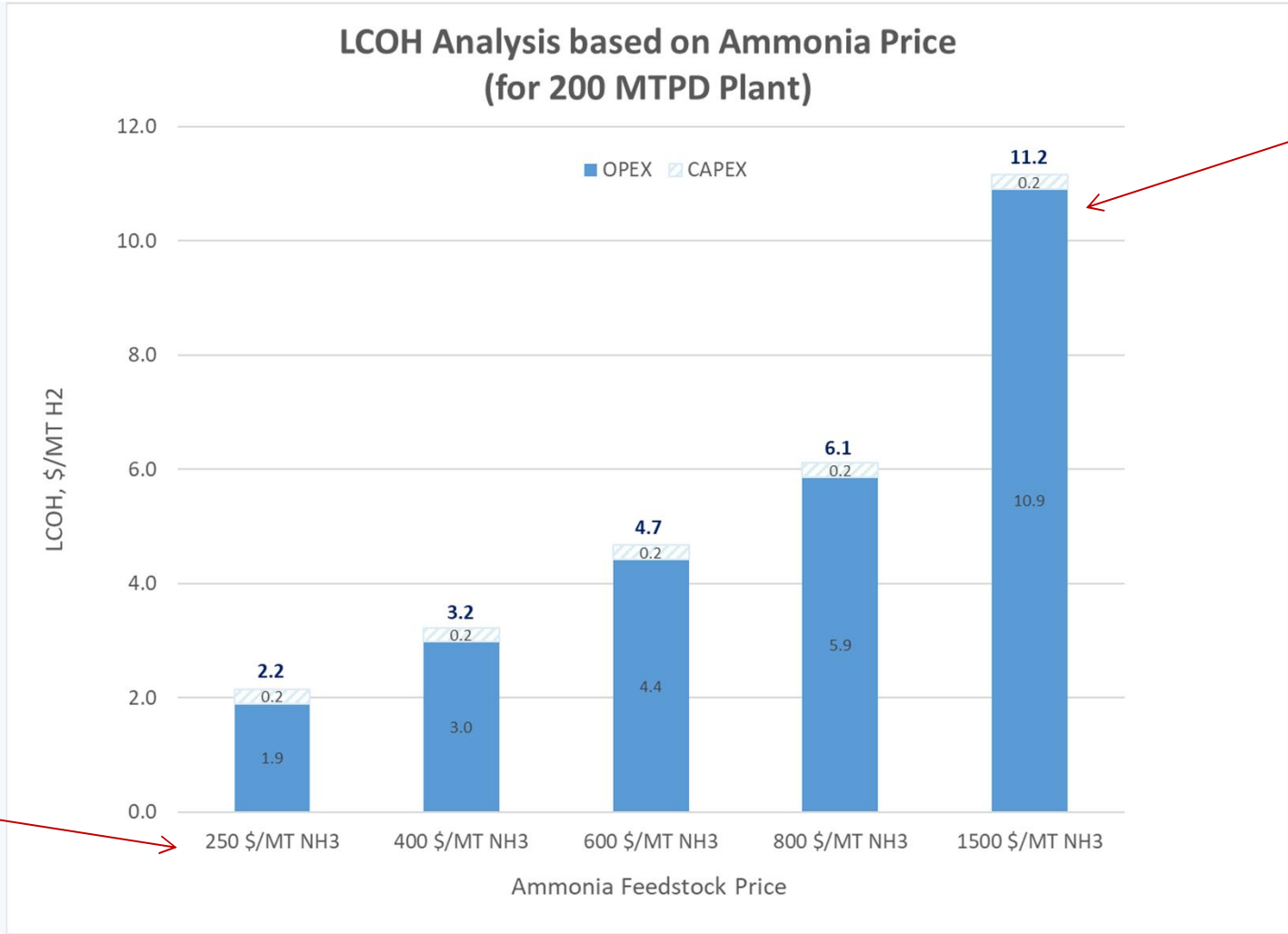


VALUE CHAIN SAFETY



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# Ammonia Cracking Plant Economics



LCOH is heavily dependent on ammonia price

CAPEX contribution to LCOH is small

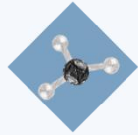
**Plant Economics Dominated by OPEX**



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Changing the World.<sup>SM</sup>



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# Thank You



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