



# AMMONIA GAS TURBINE UPDATE

Dr. Jeffrey Goldmeer

Senior Director, Energy Transition Technology Strategy & Global H<sub>2</sub> Leader

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# For the new era of energy...a new company with full focus on the energy transition



# 75K

Global employees

# 100+

Countries

## POWER

Gas Power, Hydro Power, Nuclear, Steam Power

## WIND

LM Wind Power, Onshore Wind, Offshore Wind,

## ELECTRIFICATION

Electrification Software, Grid Solutions, Power Conversion, Solar & Storage Solutions,

## ACCELERATORS

Advanced Research, Consulting Services, Financial Services

# Strength + reach



**~25%**

World's electricity generated with the help of our technology



**2,200GW**

Global Installed Base



**\$33B**

2023 revenue  
~45% services



**7K**

Gas turbines installed...  
world's largest fleet



**1st**

Small Modular Reactor  
commercial contract  
signed in North America



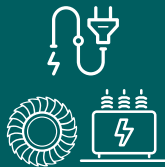
**+\$4B**

Financial Services -  
enabled orders



**54K**

Wind turbines installed  
in >50 countries...  
#1 Onshore Wind in US<sup>a</sup>



**1st**

Enhanced Electric Gas Turbine (EGT)  
Aero + Storage + Hybrid Control



**~\$1B**

Annual Investment  
Advanced Research  
+ Businesses  
~3% of revenue



**30%**

Global utilities served  
by our software



**220M**

Haliade-X rotor size



**\$116B**

Backlog<sup>b</sup>

# Expanding opportunities of Ammonia (NH<sub>3</sub>) fueled gas turbine utilization

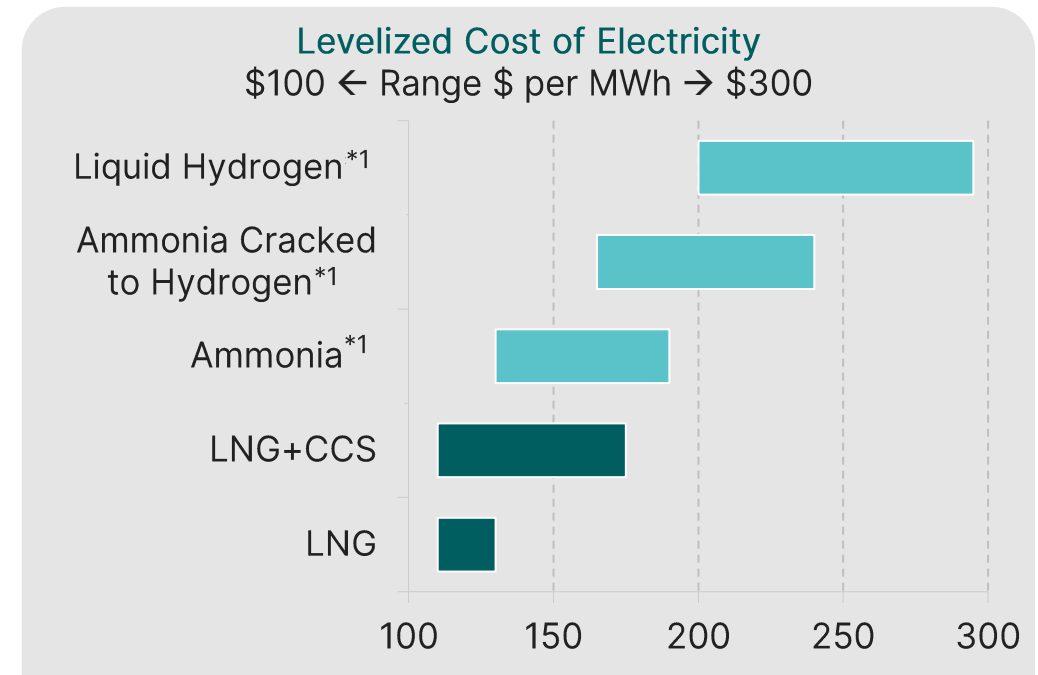
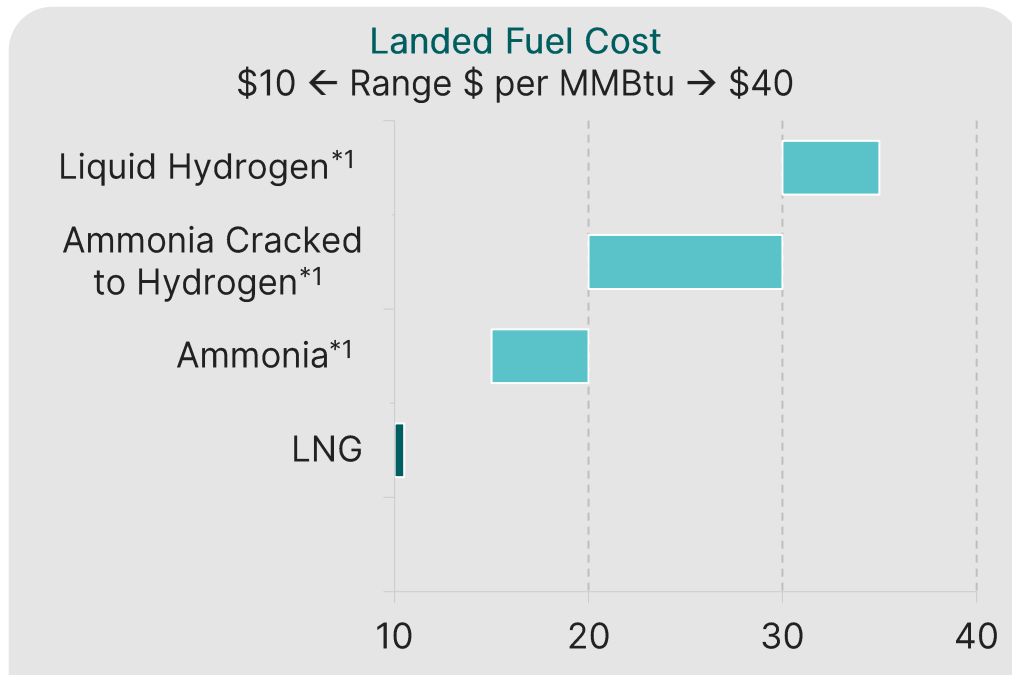


Transformative journey towards a cleaner energy future with our innovative developments aiming to decarbonize the power sector worldwide using revolutionary carbon-neutral<sup>\*1</sup> ammonia-fueled gas turbines

Ammonia - NH<sub>3</sub>; Hydrogen - H<sub>2</sub>; MT - Million Tonne; \*1) Where combusted at 100%; Sources: (a) IEA Ammonia Roadmap NZE scenario, (b) IEA Hydrogen production projects database October 2023 and GE - IHI estimates

# GE Vernova - IHI study: Current analysis

- Ammonia has potential to be lower cost vs. hydrogen when importing over very large distances.
- LNG+CCS could be a lower cost option vs. ammonia, however, requires CCS to be allowed by local regulations, and room for power plants to add CCS systems.
- In circumstances where pipeline transport is viable, hydrogen is likely the lower cost option.



Potential to be low-cost carbon-neutral<sup>\*2</sup> fuel when importing for NH<sub>3</sub> direct use over large distances by vessels where renewables not feasible

CCS – Carbon Capture Storage; \*1) Importing fuel, \*2) Where combusted at 100%

# Joint goals: F-class technology readiness by 2030

## Up to 100%

2-Stages (Rich & Lean) combustion system

- ✓ Configured to burn up to 100% of ammonia @ normal operation with 99+% GHG reduction
- ✓ Start-up with Natural Gas or carbon neutral fuel

## Retrofittable

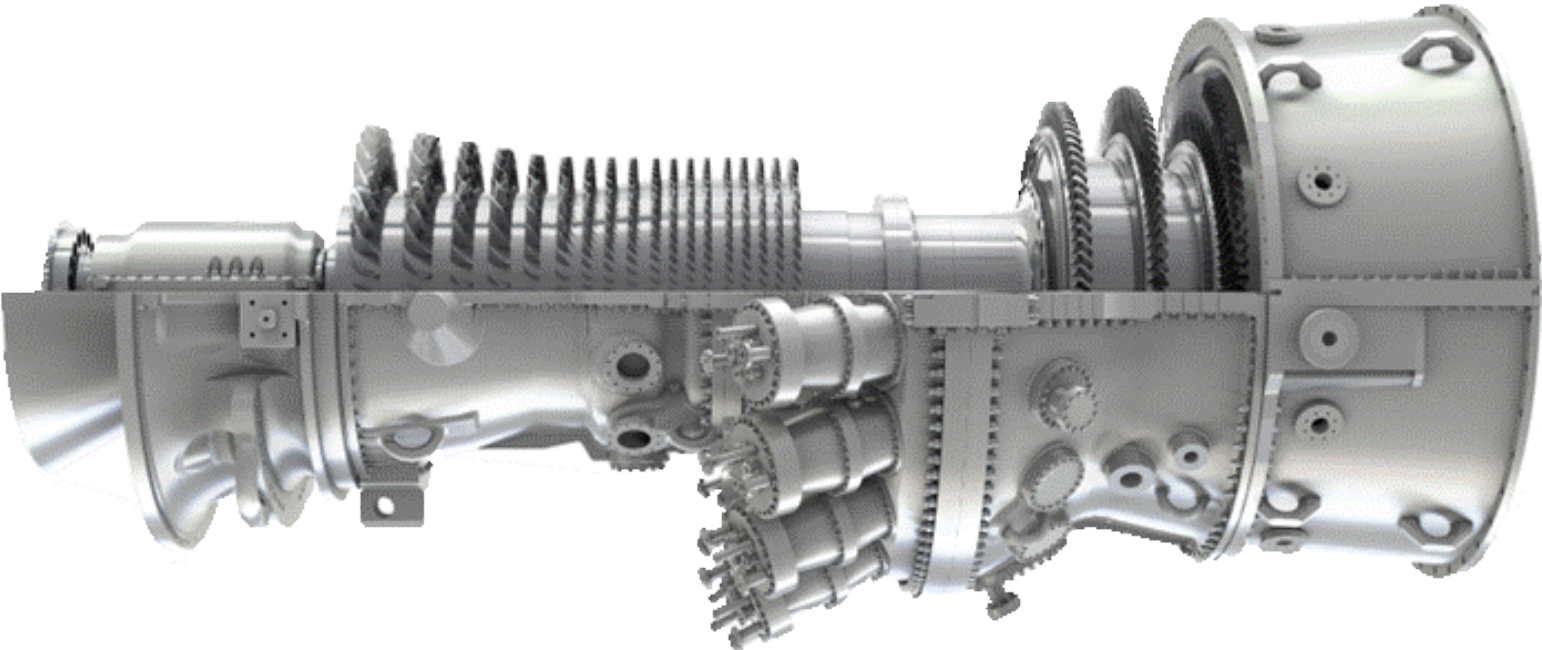
Reduced investment & same life as existing

- ✓ Utilize existing power plant assets with smaller modification for fuel conversion from natural gas to ammonia
- ✓ Target to maintain component durability and existing F-class life

## NOx emission

Comply with stringent emission requirement (lower single digit ppm)

- ✓ New combustion technology with conventional NOx after treatment systems
- ✓ Target to meet Japan's regulation for NOx



# GE Vernova - IHI collaboration & milestones

## IHI

- Development of ammonia combustion system
- Configuration and validation including component & engine test
- Ammonia value chain development

## GE Vernova Gas Power

- Support development of ammonia combustion system
- Integrate ammonia combustion system to GE Vernova F-Class GT
- Control system modification for operation with fuel ammonia

2021

GE IHI MOU  
Techno-economic study

2022

IHI 100% NH<sub>3</sub> firing in 2MW gas turbines achieving 99% CO<sub>2</sub>-free power generation

2023

GE IHI MOU  
100% ammonia combustor development & timeline

2023

Sembcorp, IHI, GE Vernova MOU  
Explore retrofitting of Sakra Plant with ammonia-firing

2024

GE Vernova IHI JDA  
Proceed to next phase of engineering & technology development

Way forward  
Leverage technology to further collaborations



Product Introduction\*  
Offer solutions worldwide

2030

Development & Validation\*  
Power plant systems development, continued testing and validation

2026-2029

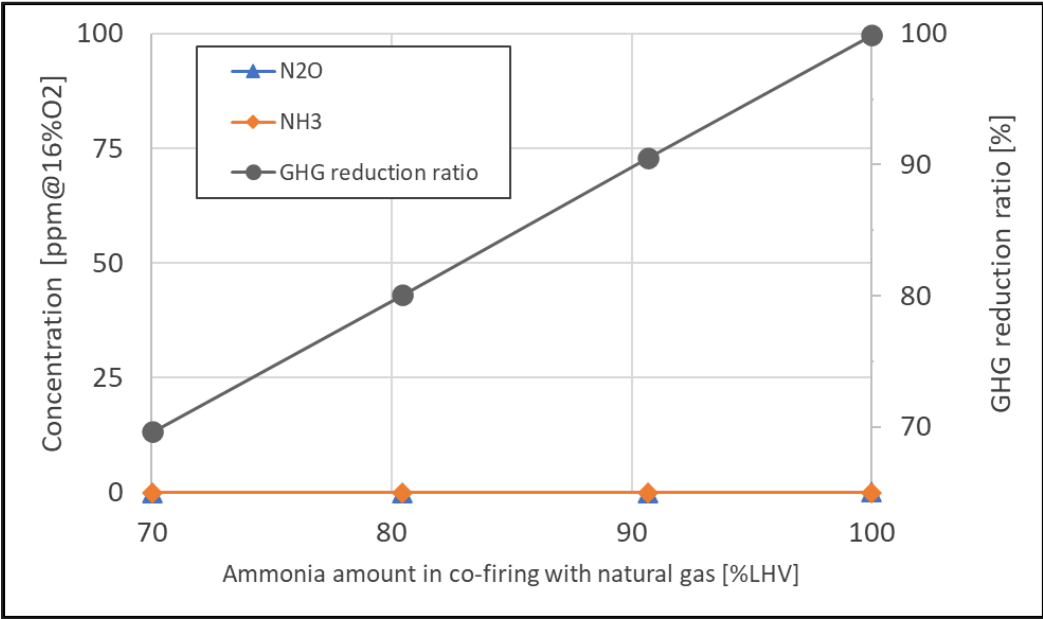
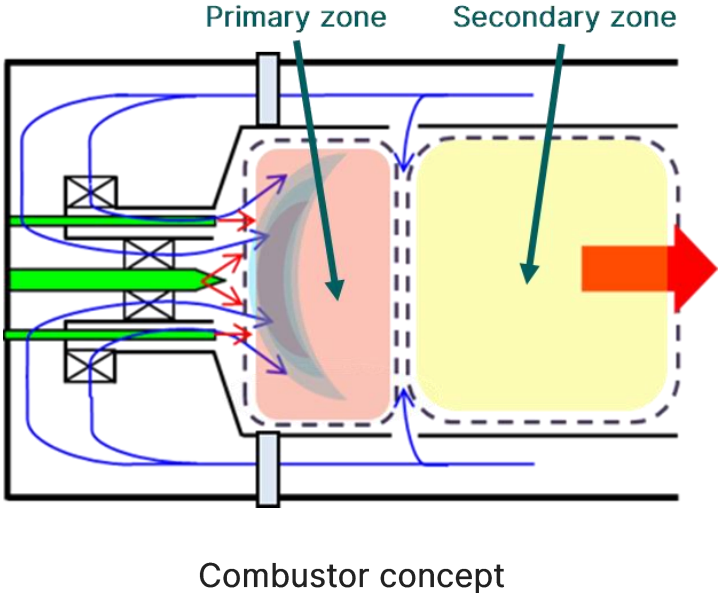
Configuration Maturation\*  
F-class combustor configuration maturation through testing

2025

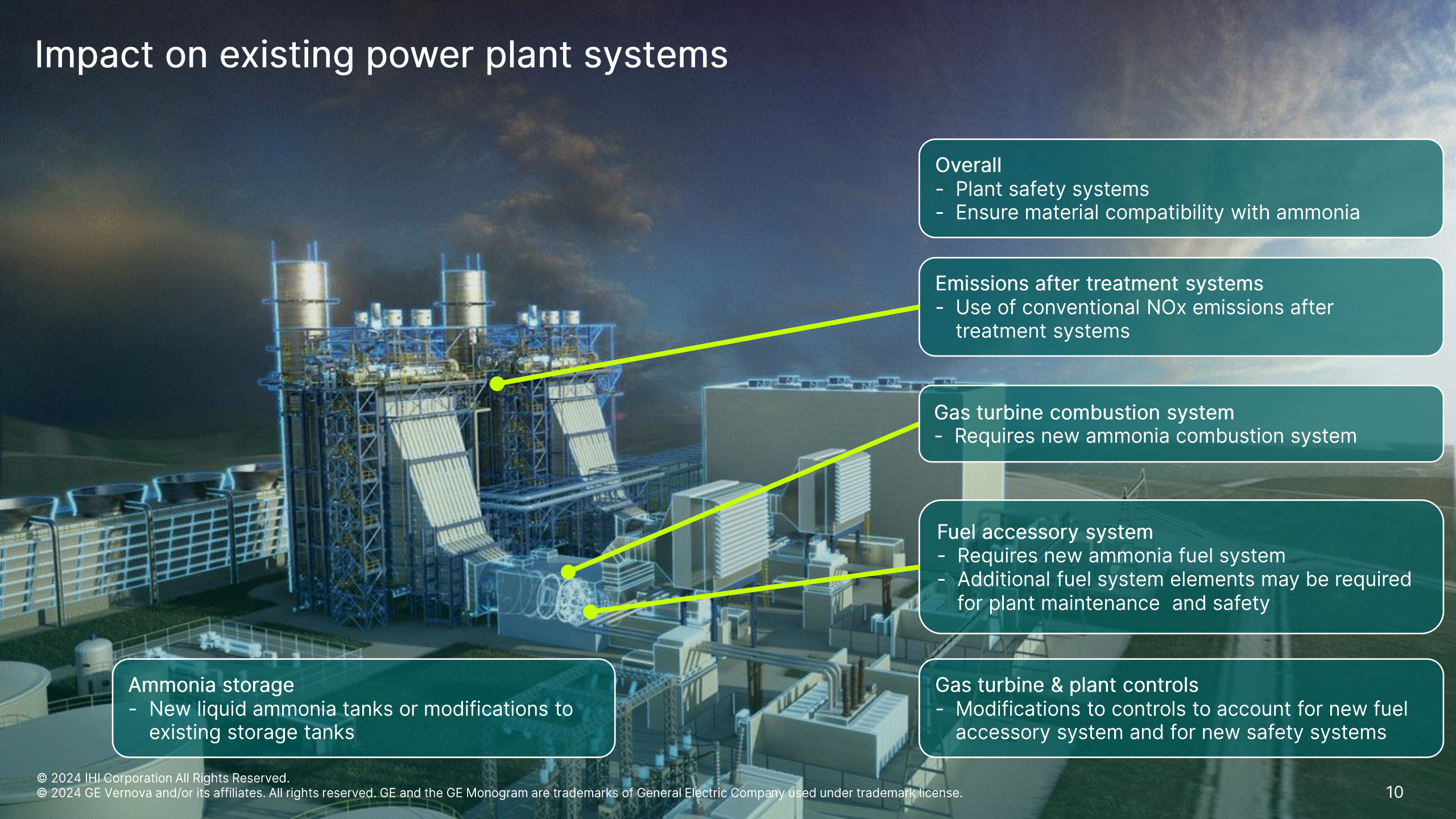


# IHI Ammonia 100% IM270 gas turbine current achievements

- Two-stage combustor configuration.
- 99+% Reduction of Green House Gas ( $\text{CO}_2$  &  $\text{N}_2\text{O}$ ) from natural gas operation.
- Regulatory compliant  $\text{NO}_x$  emission level with conventional  $\text{NO}_x$  after treatment systems.
- Safely handled ammonia for these series of tests.



# Impact on existing power plant systems



**Overall**

- Plant safety systems
- Ensure material compatibility with ammonia

**Emissions after treatment systems**

- Use of conventional NOx emissions after treatment systems

**Gas turbine combustion system**

- Requires new ammonia combustion system

**Fuel accessory system**

- Requires new ammonia fuel system
- Additional fuel system elements may be required for plant maintenance and safety

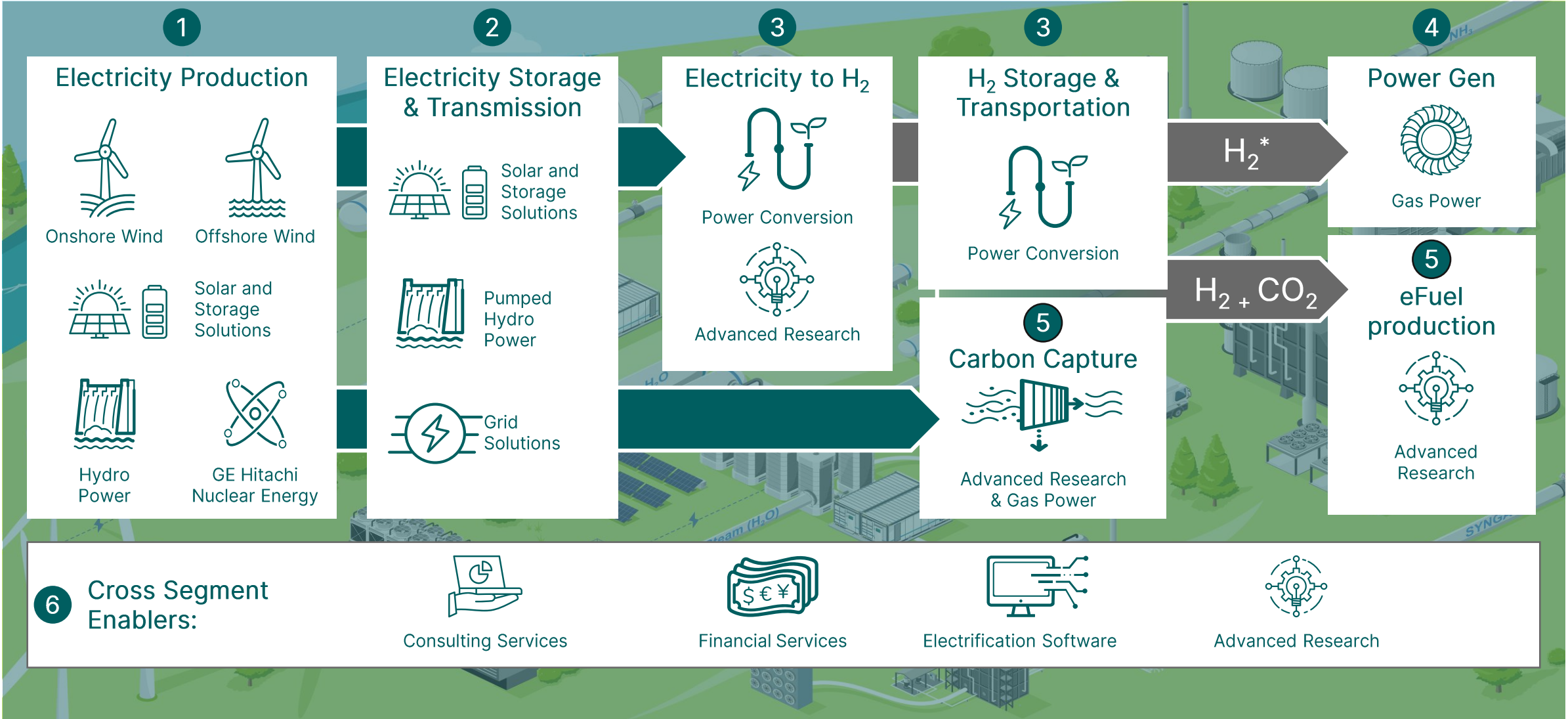
**Ammonia storage**

- New liquid ammonia tanks or modifications to existing storage tanks

**Gas turbine & plant controls**

- Modifications to controls to account for new fuel accessory system and for new safety systems

# GE Vernova play across the lower carbon fuel value chain



\* Could include hydrogen and hydrogen derivatives, i.e., ammonia



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