MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Approach for Hydrogen Powered Utility Projects

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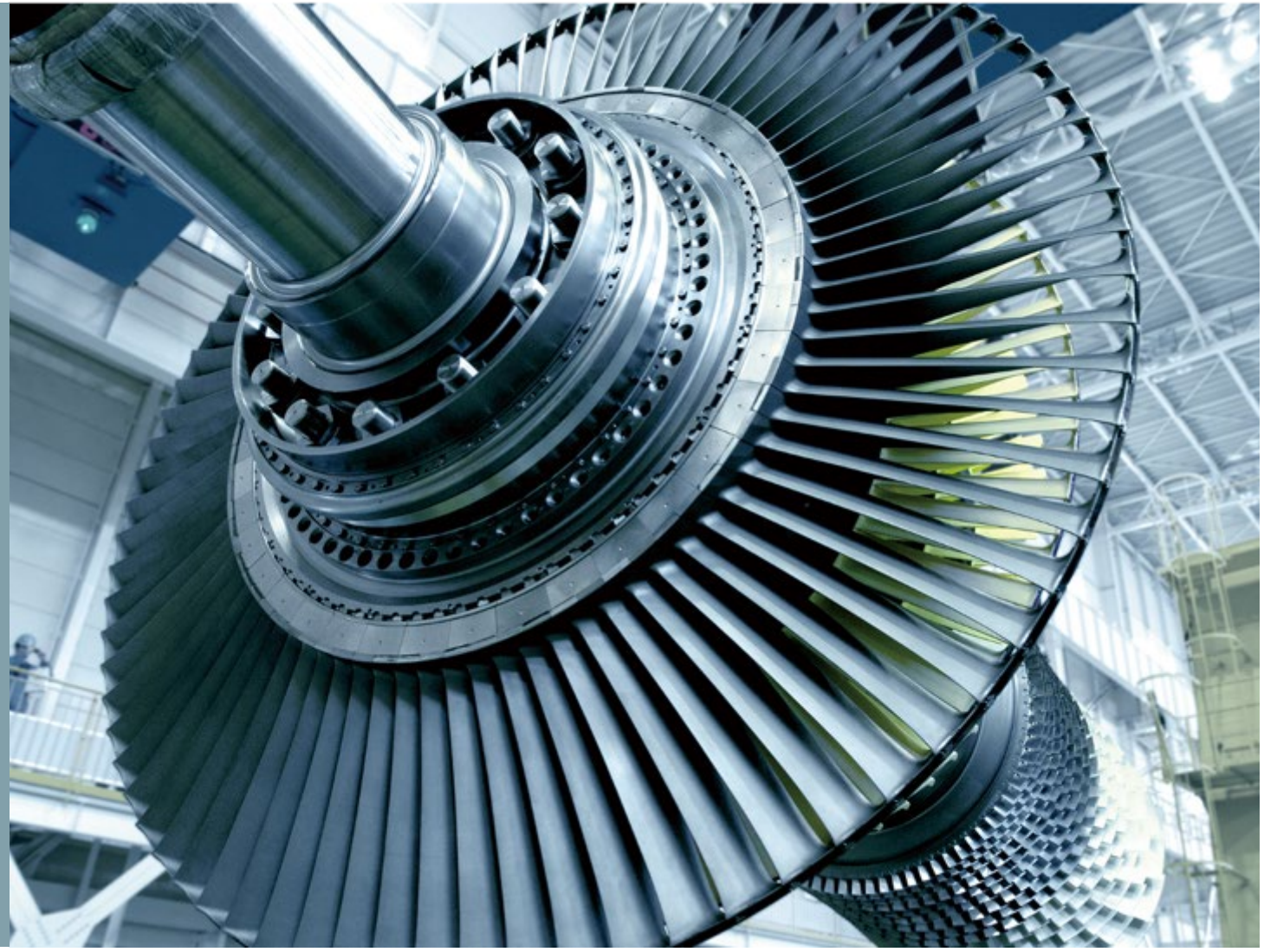

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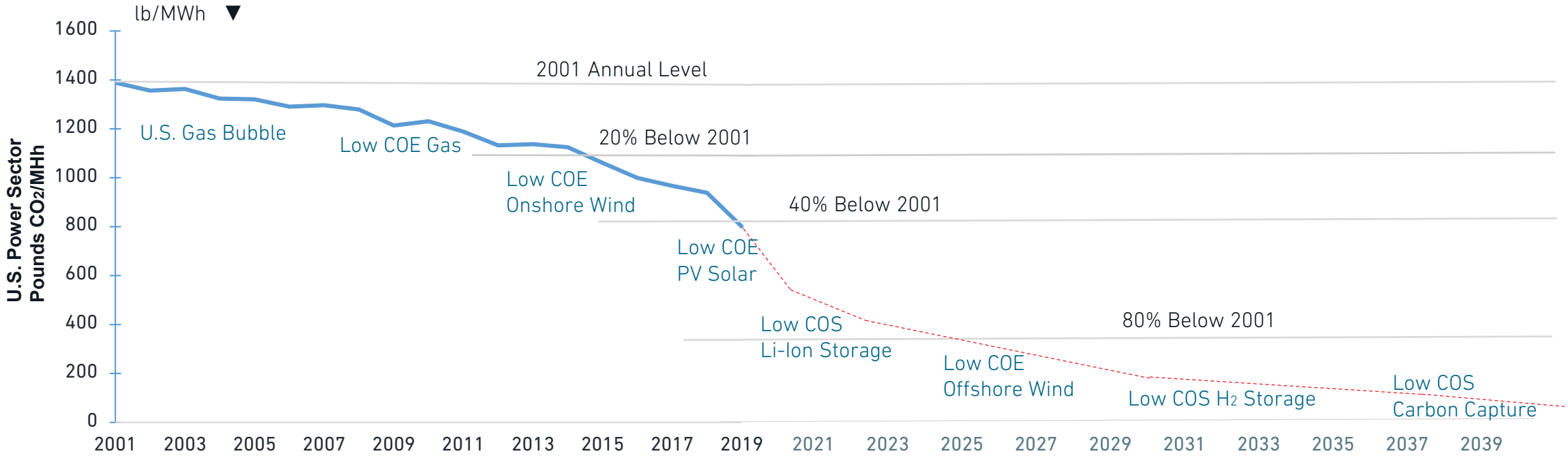
What's Happening With Decarbonization?

POWER SECTOR CARBON INDEX



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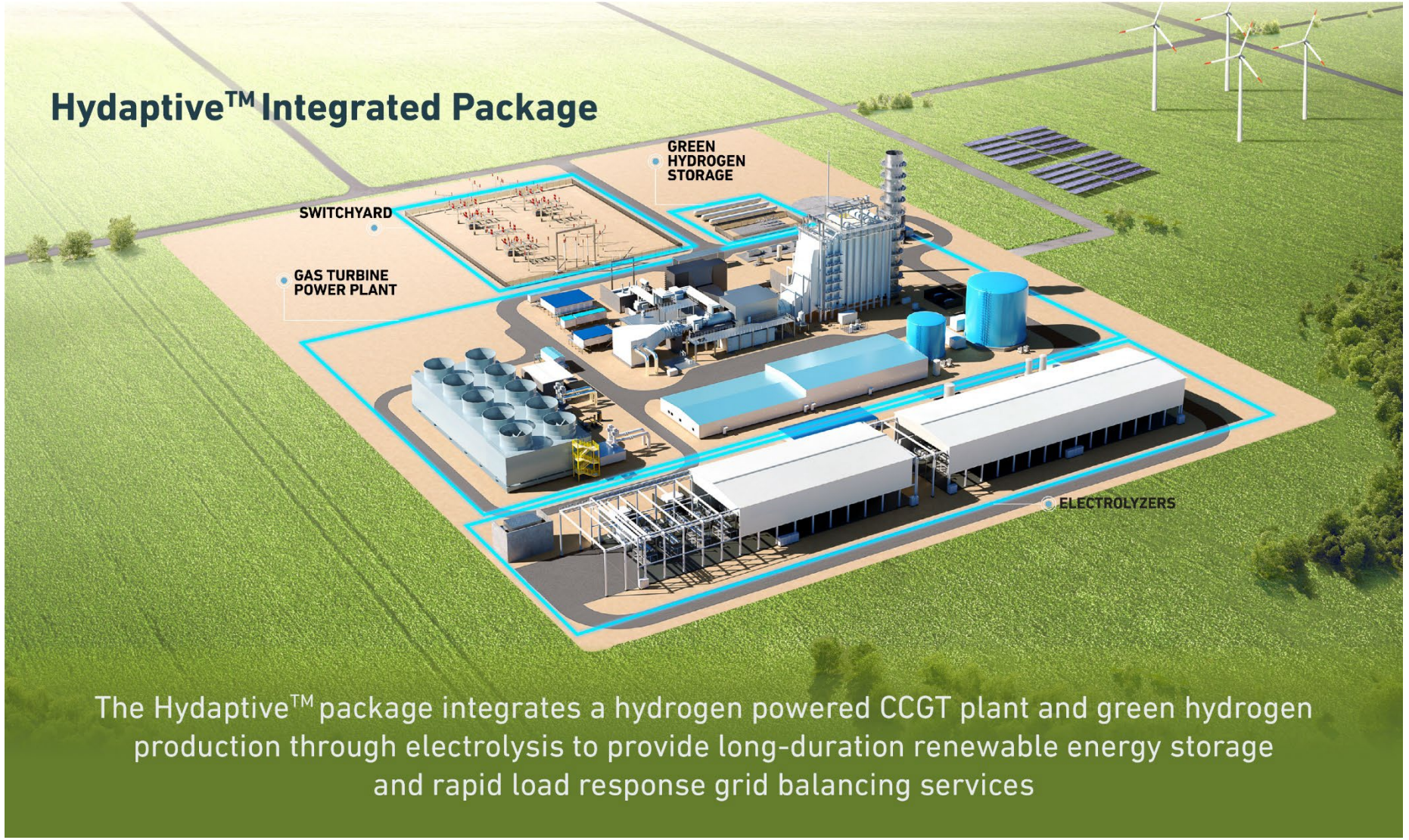
Hydrogen Plant – Combined JAC with 220 MW Hydrogen Plant



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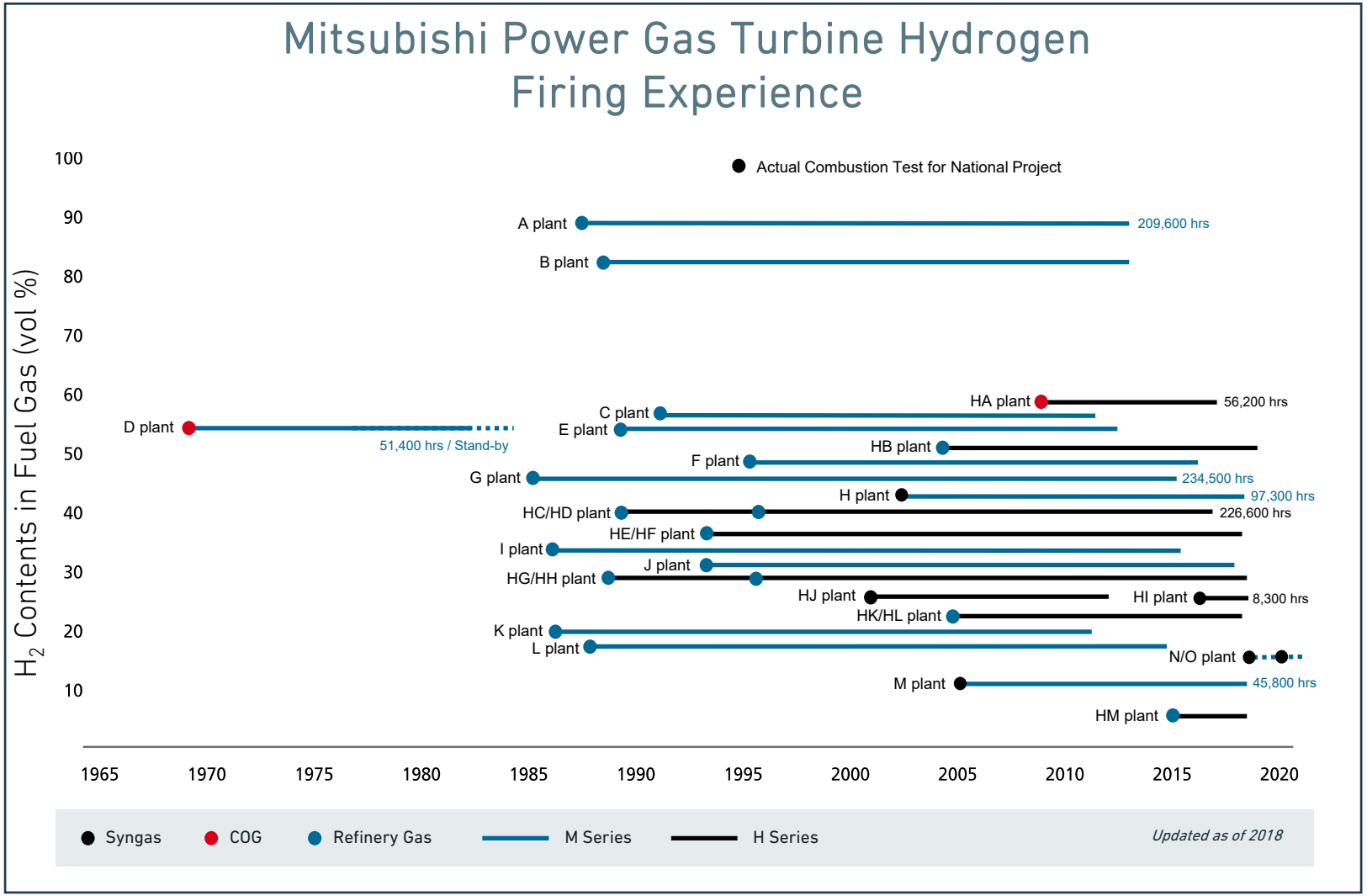
More Than 3.5 Million hours of Hydrogen Co-Firing



Fast Facts:	Hydrogen Generation

- Long history (50 years) of operating on Hydrogen fuel blends in gas turbines
- Many projects with fuels greater then 50%
- Projects with over 80% hydrogen with hundreds of thousands of hours of operation
- Many different projects with different fuel characteristics
- Over 3.5 million hours of experience with hydrogen fuels on gas turbines
- Impacts to gas turbine materials are well understood with decades of experience

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Scope Changes for 100% Hydrogen at COD (Compared to 0%)

SCENARIO

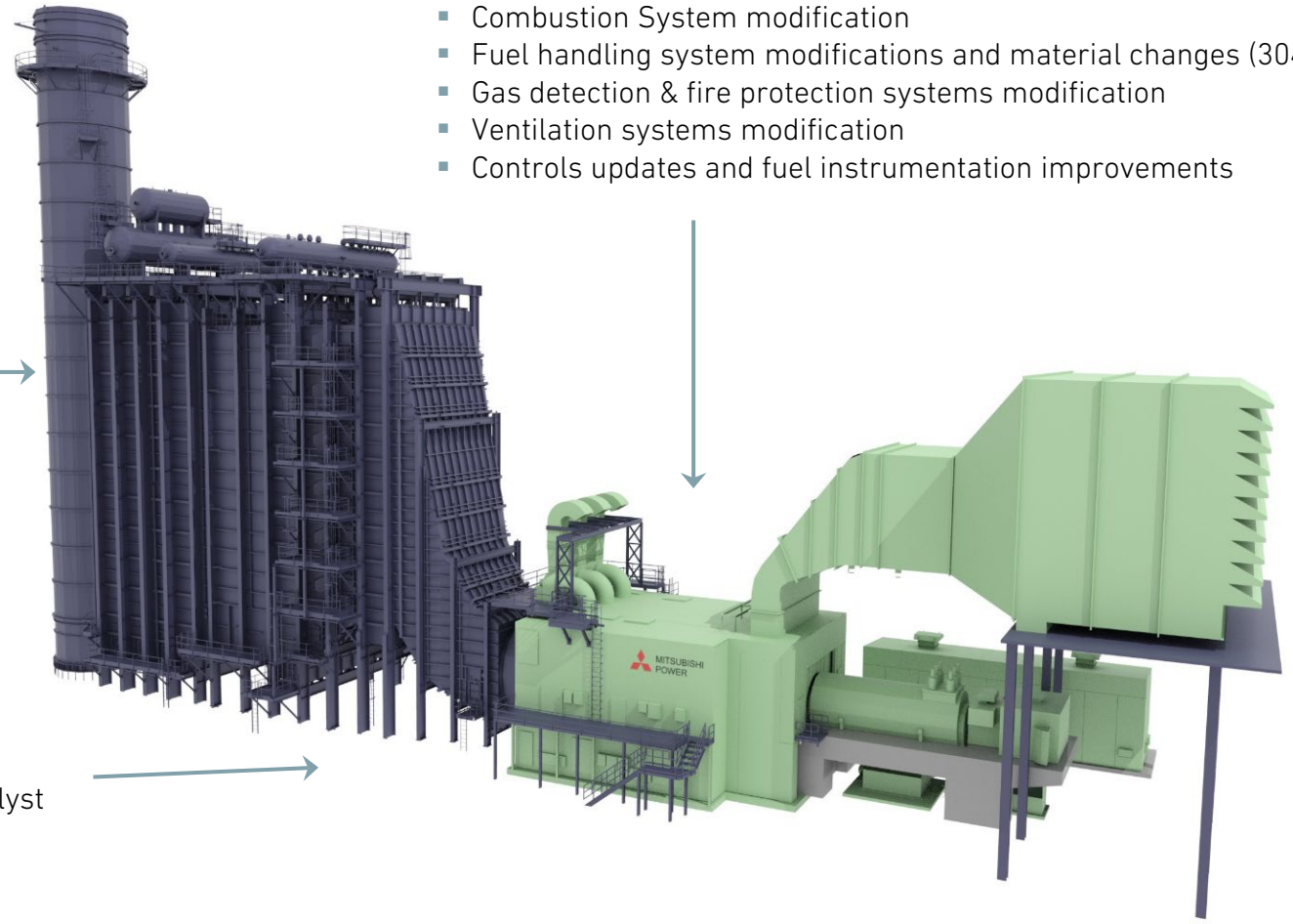
- Customer considering up to 100% hydrogen on or after commercial operation date (COD)
- How do we get there?

GAS TURBINE, ENCLOSURE & AUXILIARY EQUIPMENT

- Combustion System modification
- Fuel handling system modifications and material changes (304SS & 316SS)
- Gas detection & fire protection systems modification
- Ventilation systems modification
- Controls updates and fuel instrumentation improvements

HRSG

- Additional catalyst



FOUNDATIONS

- Larger foundations to accommodate additional catalyst

Project specific scope changes may differ

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Major Materials Used in Gas Turbine

Section	Component	Fuel	
		Natural Gas	Hydrogen
Turbine	Disk (1 - 4)	NiCrMoV	NiCrMoV
	Blade (1 - 4)	MGA1400*	MGA1400*
	Vane (1 - 4)	MGA2400*	MGA2400*
Combustor	Casing	CrMo	CrMo
Turbine	Casing	CrMo	CrMo
Exhaust	Casing	CrMo	CrMo
	Manifold	SS	SS

*MGA1400 & MGA2400 are Mitsubishi developed Ni-base superalloys

Mitsubishi Power Does Not Use Single Crystal Blades in our Gas Turbines

No Material Changes Required for Hydrogen Fuel

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Hydrogen Conversion Project in the Netherlands

Project Organization

Energy Supplier	Owner of Nuon Magnum	Gas Infrastructure and Transporter
Upstream part: NG supply, H_2 production and, CO_2 Transport and Storage		**Mid-stream part:** H_2 Transport and Storage

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GTCC OEM

Nuon & Mitsubishi Power: Downstream part Magnum modifications

Vattenfall's gas power plant Magnum. (Photo: Koos Boertjens / Vattnfall)

KICK-START H_2 ECONOMY BY:

- Realization of hydrogen infrastructure
- Development of hydrogen demand CO_2 emission reduction: up to 2 Mt/yr

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Cluster Combustor Experience With High Hydrogen Fuel

- The multi-cluster combustor has been operating at an O2-blown IGCC demonstration plant of Osaki CoolGen (OCG) Corporation in order to evaluate its long-term Operational reliability.

Multi-Cluster Combustor Major Specification	
Plant Output	166 MW (gross)
Plant Efficiency	42.7% (LHV, Net)
Fuel H2 content	Up to 80%
Gas Turbine	H-100 GT (1 on 1)
Operation Started	March 2017

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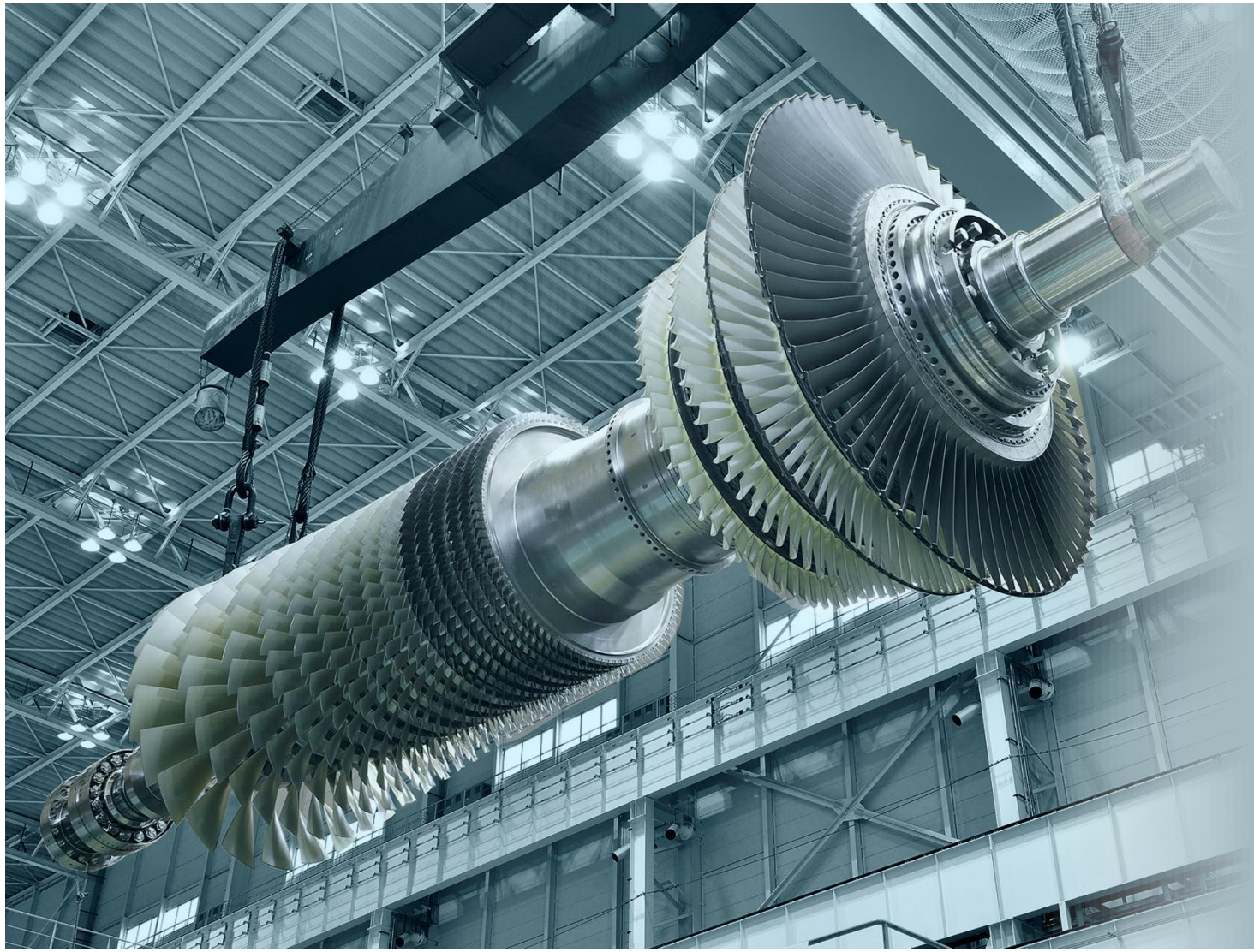
Hydrogen Fuel Impact on Parts Life



Fast Facts: Hydrogen & Parts Life

- When operating on 100% hydrogen fuel, the exhaust contains additional water content, and no CO_2
- Based on decades of experience with water / steam injection, there is no expected effect on the parts life

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Intermountain Power Project: Meeting California's 100% Carbon-Free Goals

- March 10, 2020 - Mitsubishi Power awarded contract for 2 hydrogen gas turbines
- The **1st Advanced Class Gas Turbine project** specifically **designed for Green Hydrogen fuel**
- **840MW of reliable energy** to Los Angeles and municipalities in other parts of California and Utah
- Commercial Operation in **2025** using mix of **30% hydrogen & 70% natural gas fuel**
- By **2045**, **100% Green Hydrogen** capable to support California carbon-free goals

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Summary

- Mitsubishi Power Americas views long duration storage through green hydrogen fueled turbines as essential for U.S. power sector decarbonization and has developed a standard package called Hydaptive™ to meet this market need
- We have used higher hydrogen content fuels in turbines for decades, with millions of hours of experience, and understand the impact on GT alloys/coatings
- For 100% hydrogen, the only change to materials is the conversion of the external fuel system piping to stainless steel. No change to gas turbine hot path materials
- Our multi-cluster combustor in development for the 100% hydrogen application is already in commercial operation at an IGCC plant
- Conversion to 100% hydrogen is being planned in the Netherlands, and a new build 100% hydrogen project is being built by Intermountain Power Agency in the U.S.

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