2023 WTUI USERS CONFERENCE

Special Breakout Session:

LM2500+G5
Digital Solutions
Hydrogen

GE Gas Power
2023 WTUI LM2500 Users Conference
March 13, 2023

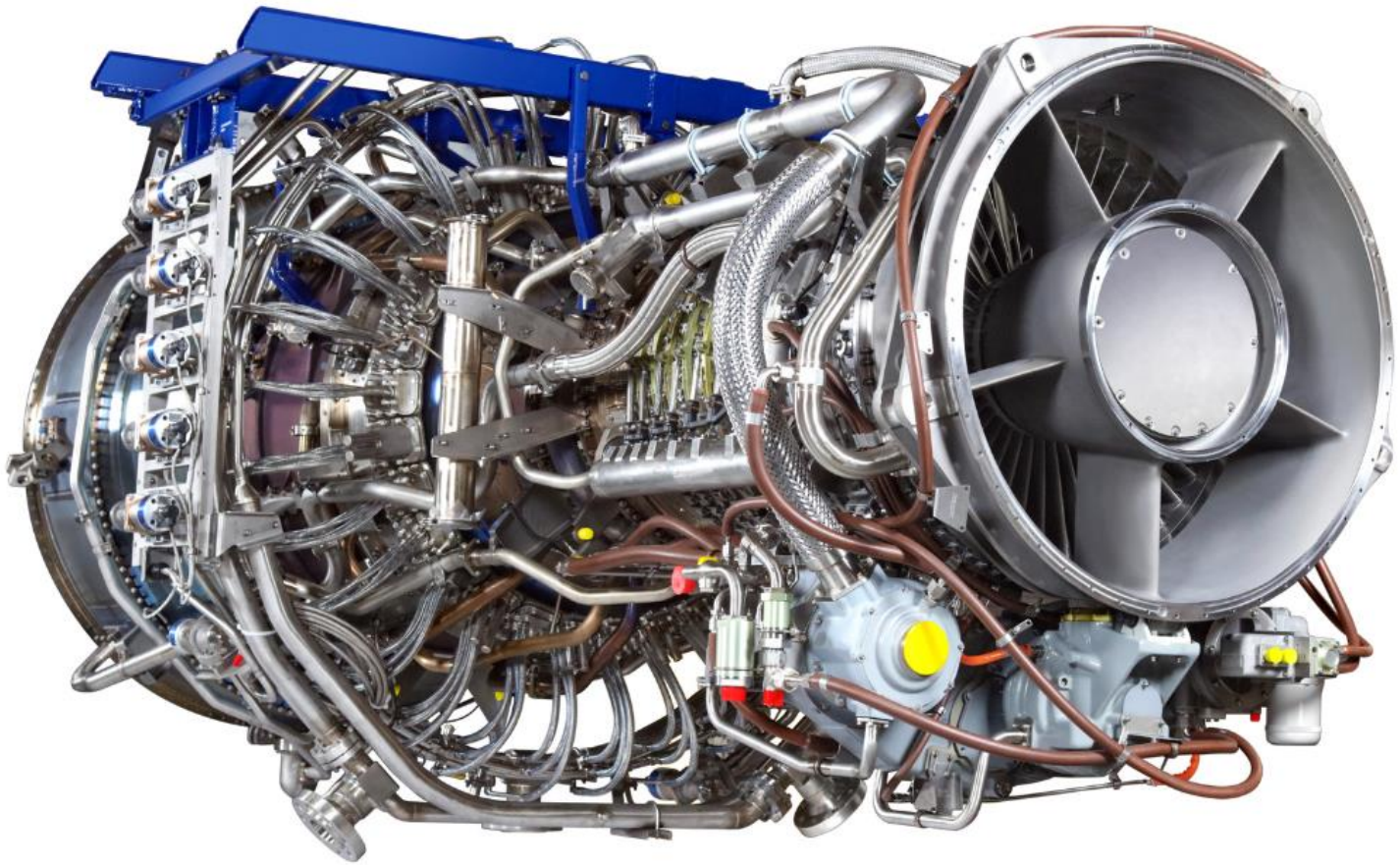
Welcome

Nam Tran

LM2500/TM2500 Product Leader

- 17+ years at GE Power Aeroderivatives
- New product introduction and project engineering background
- Texas A&M BS in electrical engineering
- University of Houston MS in electrical engineering
- Six Sigma GB

INTRODUCING LM2500+G5



POWER
38 MW
ISO GROSS POWER

EFFICIENCY
41%

MAINTENANCE
INTERVAL (hours)
25k hot section | 50k overhaul

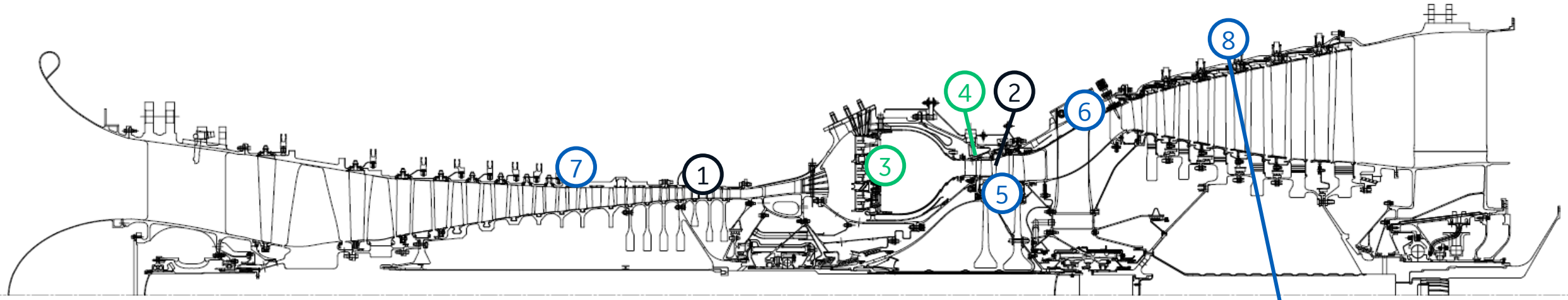
EMISSIONS
25 ppm NOx | 25 ppm CO

Next-Generation LM2500 … 10% more hot-day power

- Updated hot-section with lower parasitic flow
- HPC and bearing durability improvements
- Universal Power Turbine upgrade
- DLE1.5 combustor update to achieve 15-25 ppm capability on gas

EVOLUTION OF THE LM2500 FAMILY
LM2500+G5 DESIGN IMPROVEMENTS

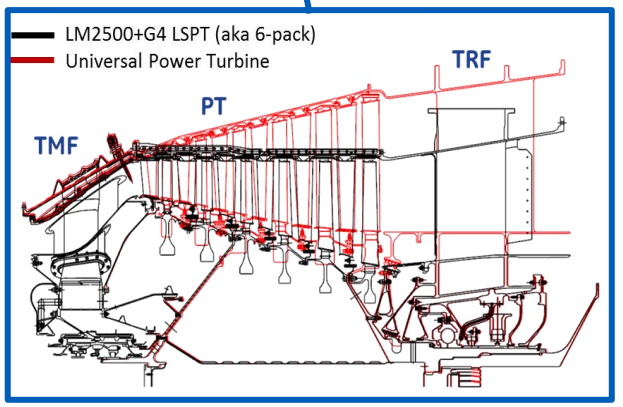
10% Power Increase
Improved Durability
15 and 25-ppm Capability



Durability Improvements
1. HPC vanes/blades
2. HPT stage-1 blade

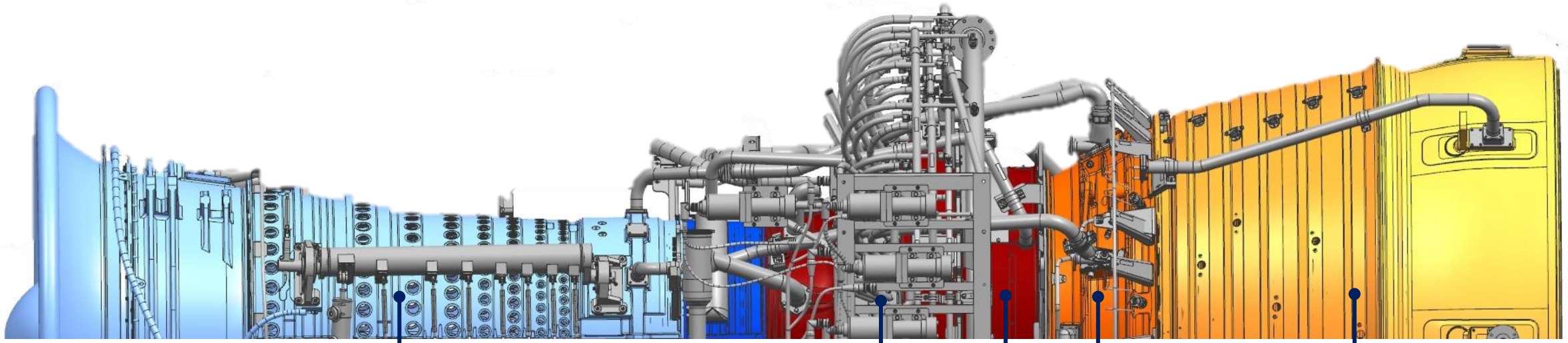
15-ppm Capability
3. Combustor upgrades with new flow splits
4. HPT S1N redesigned to save CDP air

10% Power Increase at 25ppm
5. HPT airfoils
6. TMF liners
7. HPC ultra-polished airfoils
8. Universal Power Turbine



EVOLUTION OF THE LM2500 FAMILY
LM2500+G5 DESIGN OVERVIEW

10% Power Increase
Improved Durability
15 and 25-ppm Capability



HP Compressor
Upgraded G4 design with updated airfoil materials & configuration for better aero-mechanics to improve durability

Combustor
Enhanced DLE 1.5 technology for lower emissions and power

HP Turbine
Updated with latest Aviation HPT technology for power

Turbine Mid-Frame
Upgraded materials and aerodynamic design for G5 requirements

Universal PT
Optimized design for power and efficiency for 50Hz and 60Hz applications

Aero RM&D & Digital

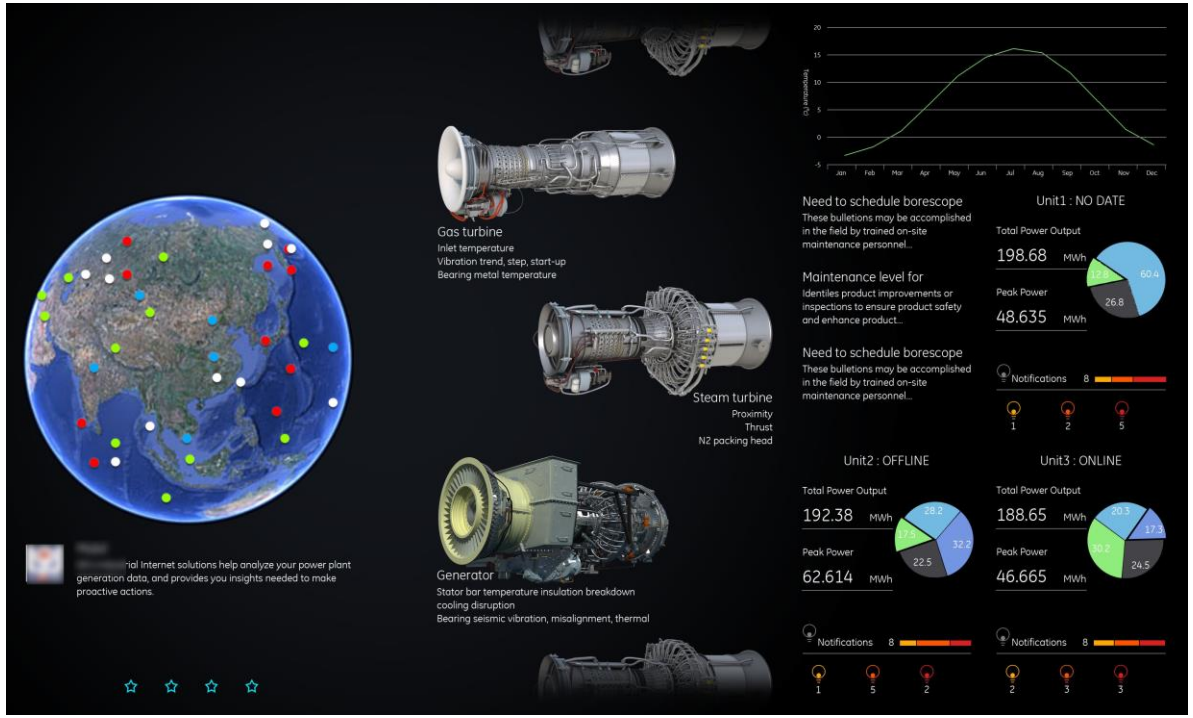
Theo Sanchez

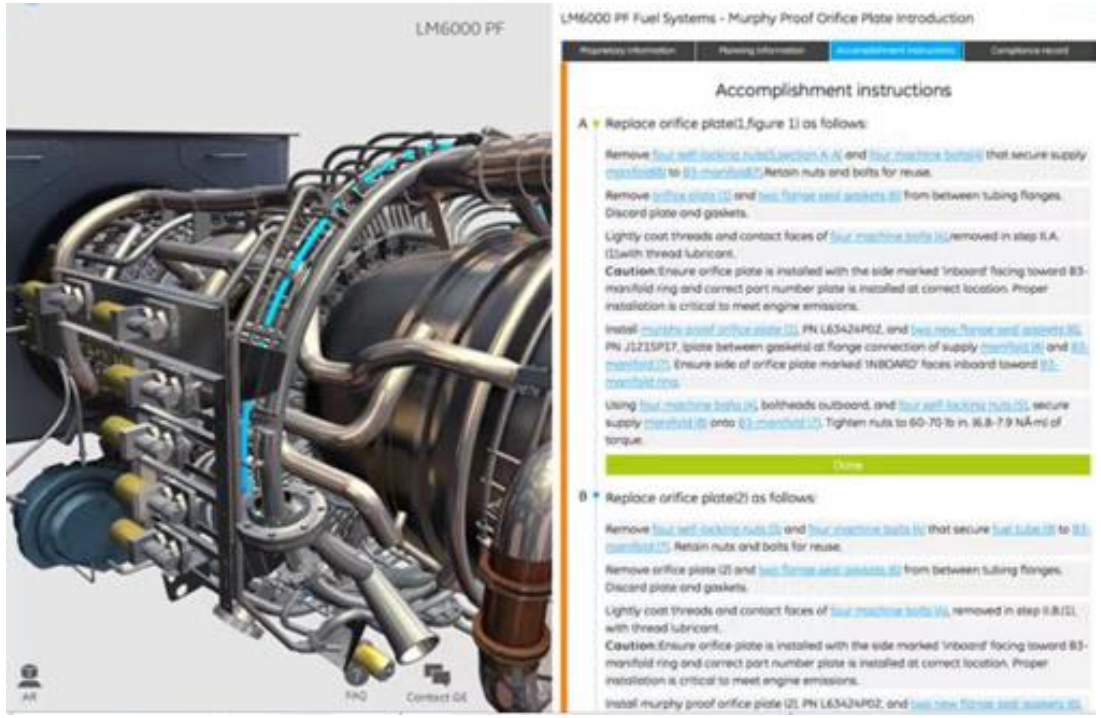
Aero Services Lifecycle

- 18+ years in the power industry
- Services and digitalization background
- GA Tech BS in mechanical engineering
- Emory University MBA
- Lean Six Sigma Black Belt

Aero Digital Solutions

Aero digital solutions help customers break away from the traditional “Break-Fix” model and have more intelligence at the palm of their hands for critical day to day decision making affecting the operation of their assets.





Benefits:

Planning for the unplanned

Better forecasting of events

Proactively engage with Product Services Engineering using real-time data

Better visibility of fleet operational profile

Strategy:

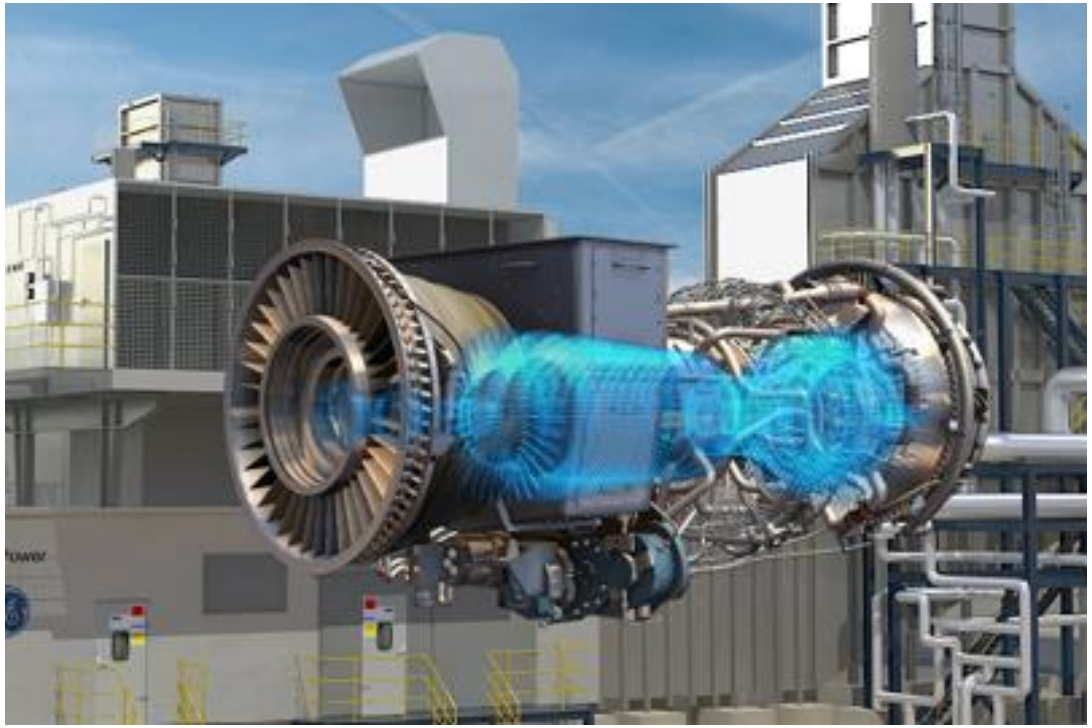
Coordination through a designated Service Manager

Implementation of continuous operational improvements on customer assets

Bundle services that complement the specific operations and maintenance practices of each customer.

Aero Digital Solutions

Aero digital solutions provide a tangible return to the customer to easily understand the return on investment the solutions offer. GE is not only focused on the data collection piece but also in bringing subject matter experts in analyzing the data to provide recommendations on optimizing the operation of assets.



Focus:

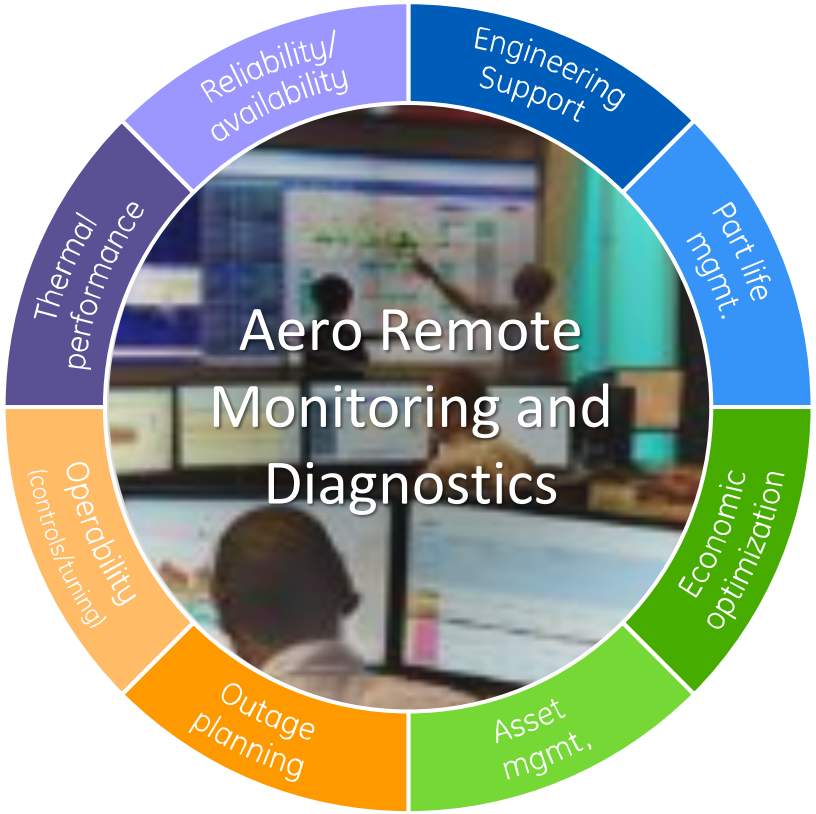
Asset diagnostic

Equipment Management

Equipment Care

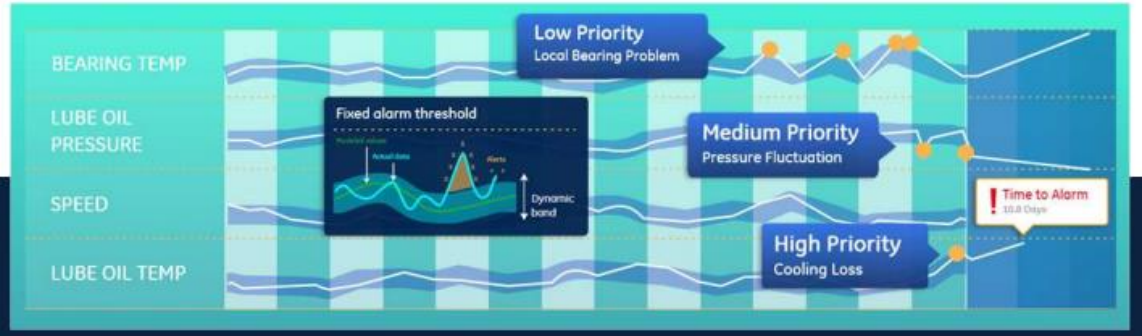
Operational Excellence

Sustainability



Aero Customer Portal

As we think of improving the way we communicate with customers and have better visibility of asset health, Aero is currently developing a customer portal that will be used by the regional teams to engage with customers. The customer portal will provide a snap-shot of the condition of the asset at any point in time and will contain operational data to help operators optimize the way they run their assets.



BENEFITS

- **Library of manuals available**
- Real-time data showing trends
- **Information in the portal will be used to trouble shoot problems**
- Asset data will be summarized graphically to help

FOCUS

- **Customers sharing operational data through the portal will plan better for the unplanned**
- Engineering reports generated by GE will be linked to the portal
- **The portal can be customized based on the customer's needs and operational profile**

Powering to a

CLEANER ENERGY FUTURE WITH HYDROGEN

GE Gas Power

2023 WTUI Users Conference

March 15, 2023

Decarbonization Overview

Nethra Subramanya

Emerging Technologies & Competitiveness Leader

- 6+ years with GE
- Experience: Engineering, Pricing, Marketing, Product Management
- Texas A & M University, College Station (Civil & Env. Eng.)
- Cornell University, Ithaca (MBA)

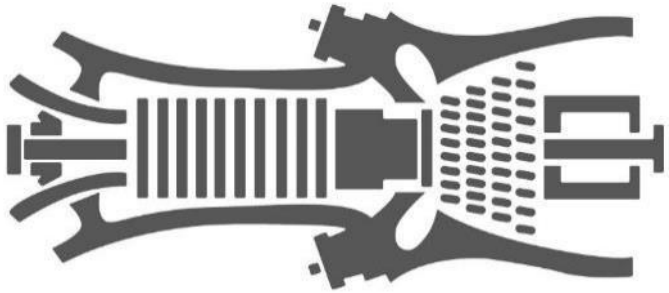
Contents

- Decarbonization and the Future of Energy
- Using H_2 for Powergen
- GE's Aeroderivatives and H2 capability
- GE's H_2 experience

DECARBONIZATION AND THE FUTURE OF ENERGY

Multiple ways to decarbonize* existing & future gas power plants

Pre-combustion



Post-combustion

Use a near zero or carbon neutral fuel

- Hydrogen (blue, green, pink)
- Synthetic (renewable) methane
- Ammonia (NH_3)
- Biofuels

Remove carbon from the plant exhaust

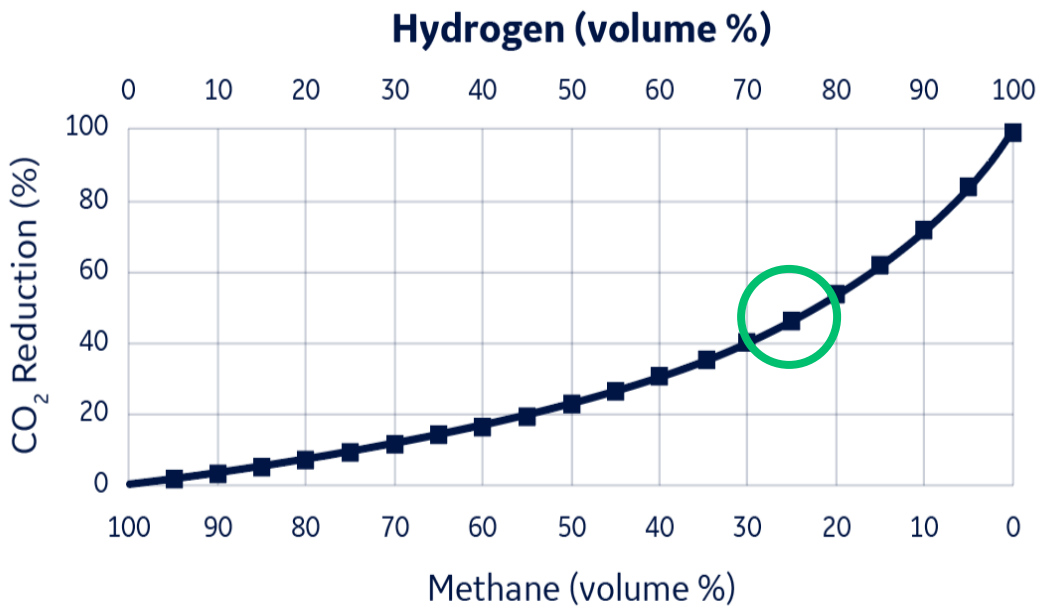
- Carbon capture (liquid solvents)

*Decarbonization as used herein is intended to mean the reduction of carbon emissions on a kilogram per megawatt hour basis.

Decarbonization and the colors of hydrogen

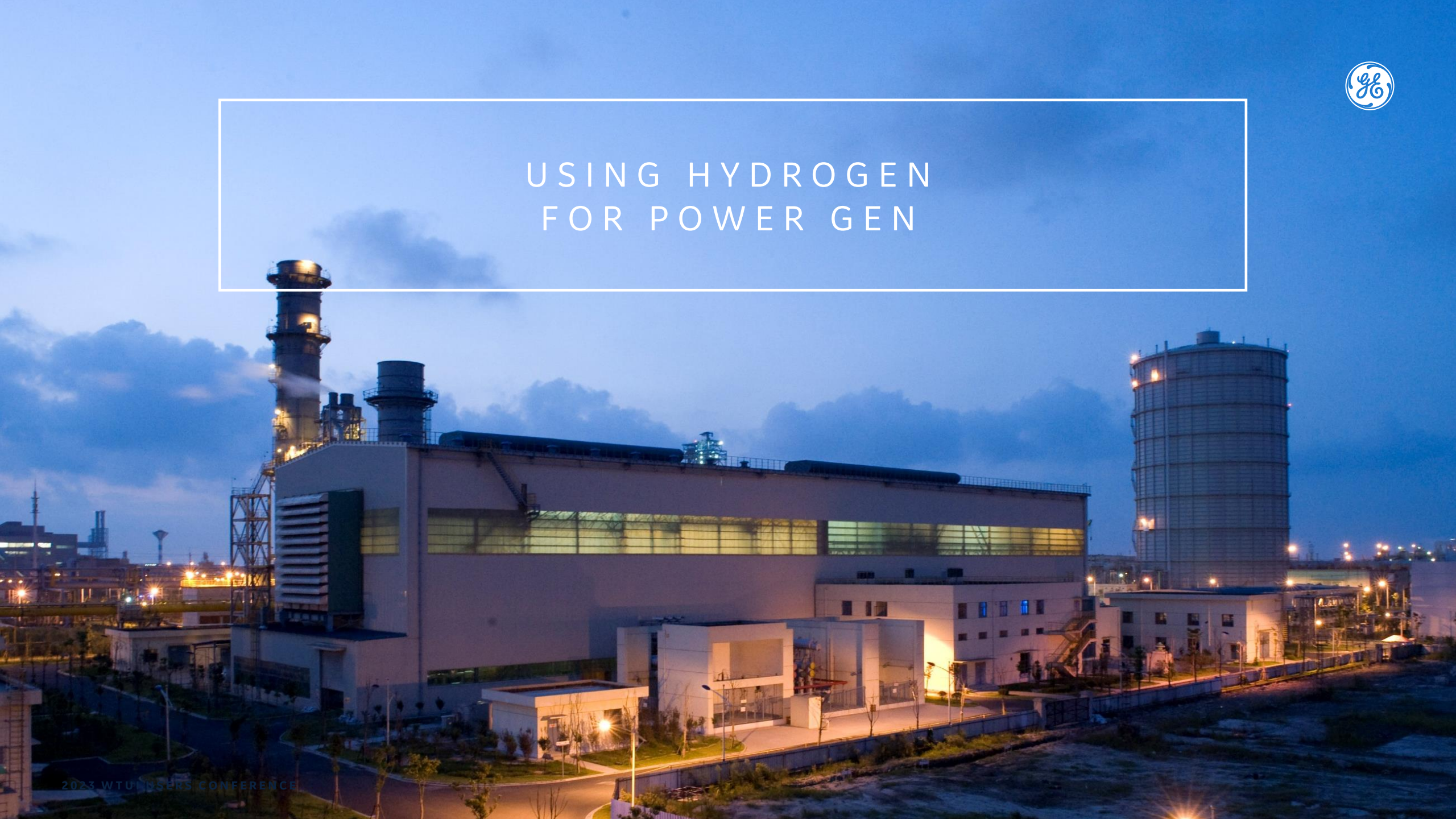
LOWER CO2	HYDROGEN COLOR	TECHNOLOGY READINESS
	GREY/BLACK: Gasification of **coal or reforming natural gas** without CCS	Mature Today's standard
	BLUE: Grey + CCS	Mature (SMR)
	TURQUOISE: **Pyrolysis of methane** which produces H2 and solid carbon	Early tech development
	GREEN: Electrolysis of water using **renewable power;** zero carbon from process	Available
	RED/PINK: Electrolysis of water using **nuclear power;** zero carbon from process	High temp electrolysis in development
	WHITE: Gasification of **100% biomass**	Available (limited)

DECARBONIZATION WITH H2 BLENDING IN NATURAL GAS



To get to 50% reduction in carbon emissions, ~77% H_2 by volume

USING HYDROGEN FOR POWER GEN



Use of hydrogen as a gas turbine fuel requires system changes

Fuel System

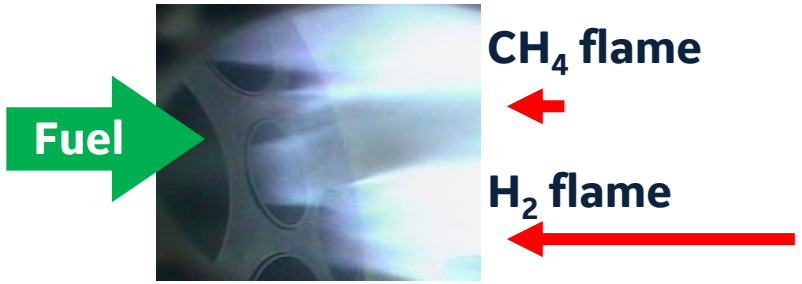
Methane (CH_4): 912 lb/ft^3
Hydrogen (H_2): 275 lb/ft^3

To deliver the same energy content, hydrogen requires 3X more volume flow

Hydrogen has a higher propensity to leak and requires improved sealing

Combustion System

Methane (CH_4): ~30–40 cm/sec
Hydrogen (H_2): ~200–300 cm/sec

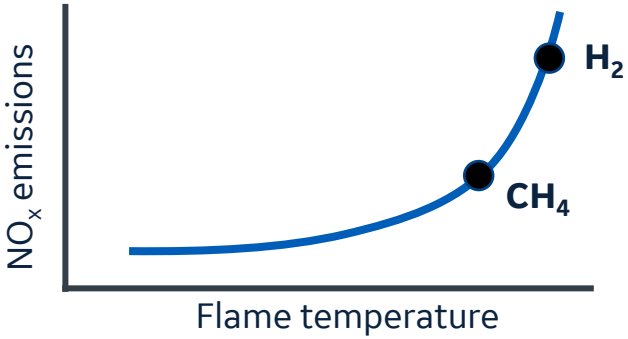


Hydrogen produces higher flame temperatures potentially impacting combustor hardware temperatures

The wider flammability range of hydrogen requires upgrades to safety systems

Emissions Aftertreatment

Methane (CH_4): ~3,565 °F
Hydrogen (H_2): ~4,000 °F



Operating on hydrogen may increase NO_x emissions

Operating a gas turbine on blends of hydrogen or on 100% hydrogen may require changes to key power plant systems, but this has been successfully demonstrated

Impact of hydrogen on new and existing power plant systems

Emissions after treatment

Gas turbine & plant controls

Hydrogen transport & storage

Gas turbine combustion system

Fuel accessory system:
- Valves & Piping
- Purge systems

Gas turbine enclosure modifications:
- Ventilation
- Haz gas detection
- Fire protection

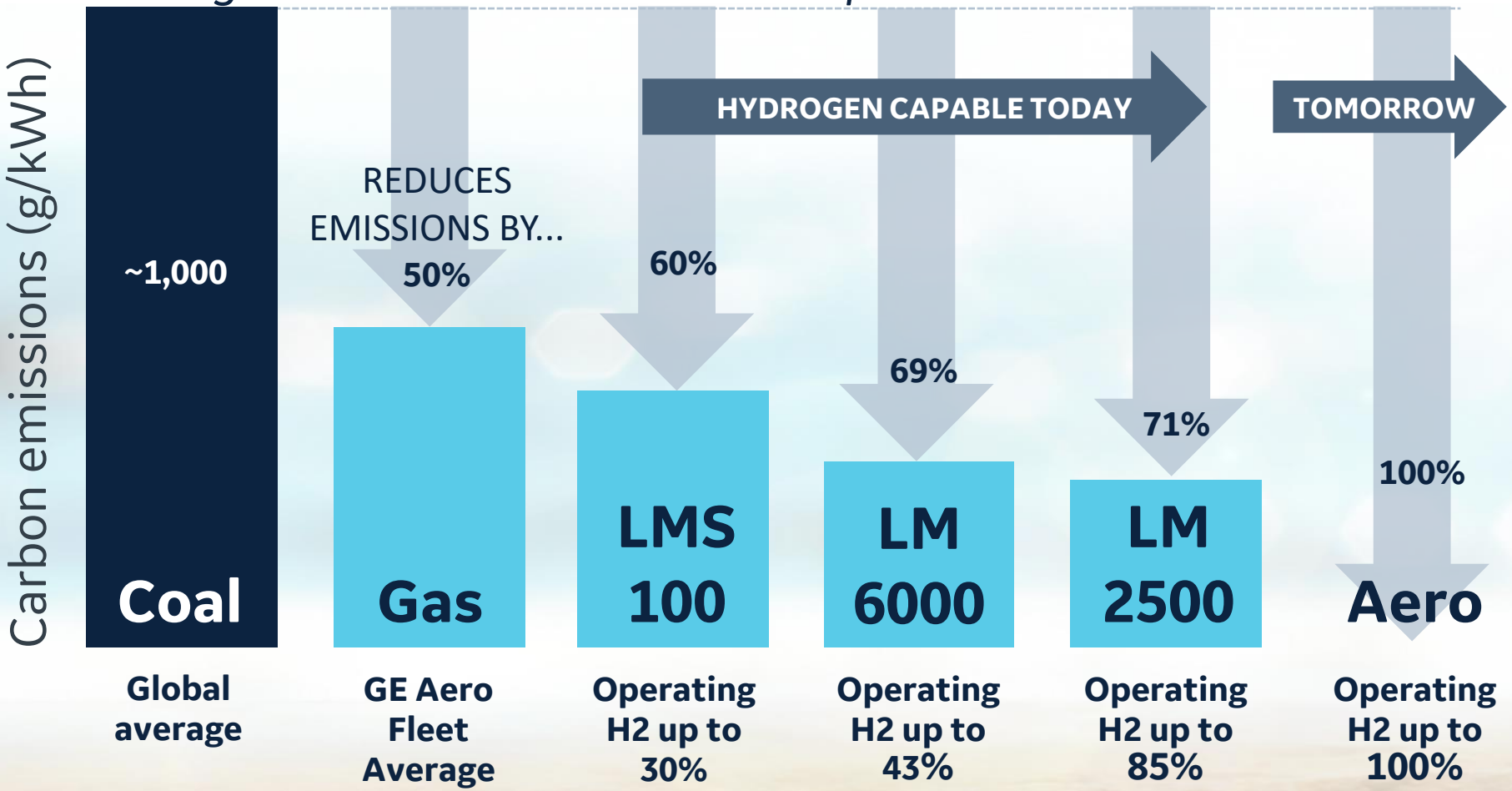
These modifications/upgrades can be implemented at both new and existing power plants

GE'S AERODERIVATIVE GAS TURBINE TECHNOLOGY AND H_2 CAPABILITY

Photo: American Public Power Association - Unsplash

A decade of action with our **Aeroderivative Gas Turbines**

Pathway to low or near-zero carbon power

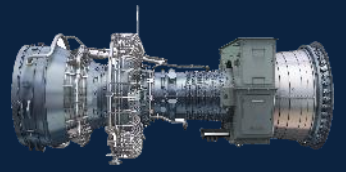


Burning Hydrogen

A viable pathway to low or zero carbon power

Source: GE Future of Energy White Paper Dec 2020

Aeroderivative Hydrogen Capability Roadmap (%vol H_2)

	Today	Phase 1 3-4 years	Phase 2 5+ years	Phase 3 7+ years
LM2500 	SAC 85% DLE 35%	SAC 100% DLE 50+%	DLE 50-70%	DLE ~100%
LM6000 	SAC 43% DLE 35%	SAC 100% DLE 50+%	DLE 50-70%	DLE ~100%
LMS100* 	SAC 30%		SAC 90%	SAC ~100%

Expected path to 100% hydrogen capability to support decarbonization and energy transition

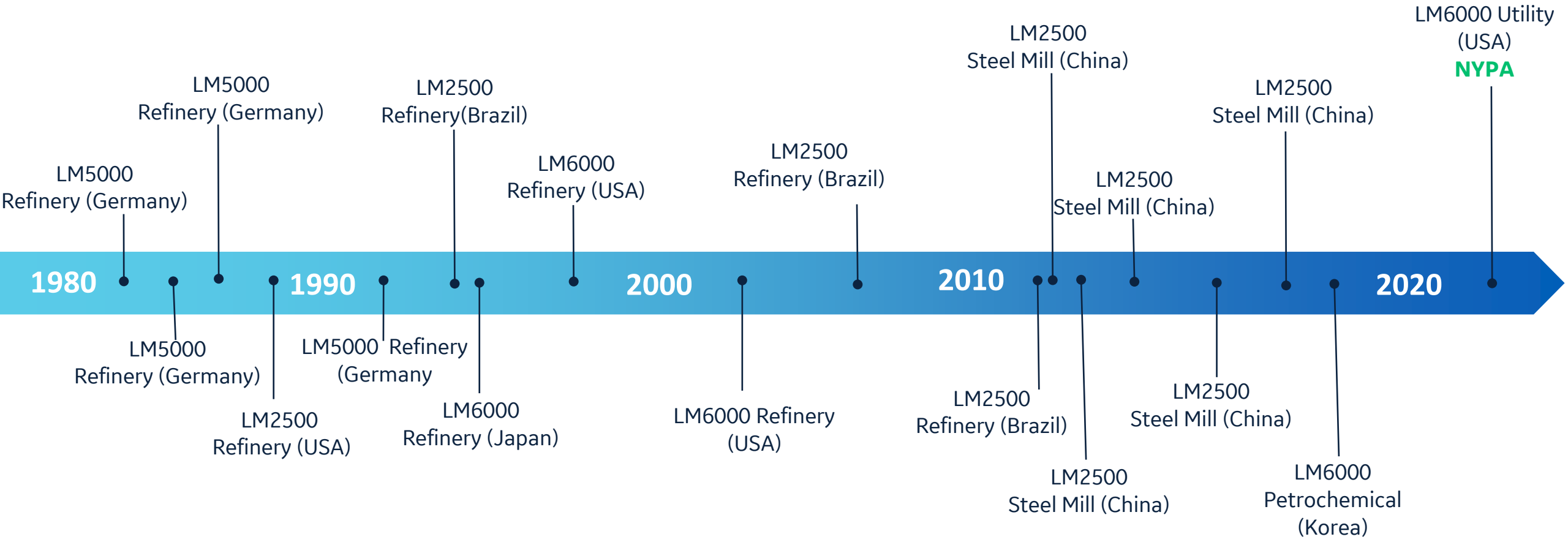
*LMS100 development follows development of LM2500 and LM6000 product lines

Higher H2% can be achieved on a case-by-case basis - Dependent on fuel content, certifications, and other factors. Requires additional investment to support technology & product development & testing

GE GAS TURBINE EXPERIENCE WITH H_2 AND OTHER LOW BTU FUELS

Decades of experience with hydrogen and similar low BTU fuels

>25 units…over 2.2 mil operating hours



GE has 40 years of operating experience with Aeros on hydrogen fuels

New Hydrogen projects with Aero gas turbines

New York Power Authority (NYPA) – Brentwood Power Station (NY, USA)

- A NYPA-led, first-of-its-kind demonstration project
- **LM6000 PC** combustion turbine currently fueled by natural gas.
- Demonstration successfully completed at 43% H2 by volume
  - **Different concentrations of H_2 blended with natural gas** upto 43% were evaluated
  - **The blend's effect on reducing GHG emissions** were assessed with CO_2 emissions reduced by 14% and a 24% increase in NO_x at the same water injection rate as NG
  - CO decreased by 88% and NO_2/NO_x decreased by 61%
  - The detailed report can be found on the EPRI site at this link.

https://www.newsday.com/long-island/suffolk/green-hydro-nypa-lipa-1.50300496

Black Hills Energy – Cheyenne Prairie Generating Station (WY, USA)

- The Wyoming Energy Authority announced that it will provide an award to Black Hills Energy under a recent RFP for the **development of hydrogen pilot projects**.
  - GE's scope will be to support a conceptual engineering assessment of equipment modifications of **GE LM6000** combustion turbines to accommodate blended fuel mix of hydrogen and methane.