



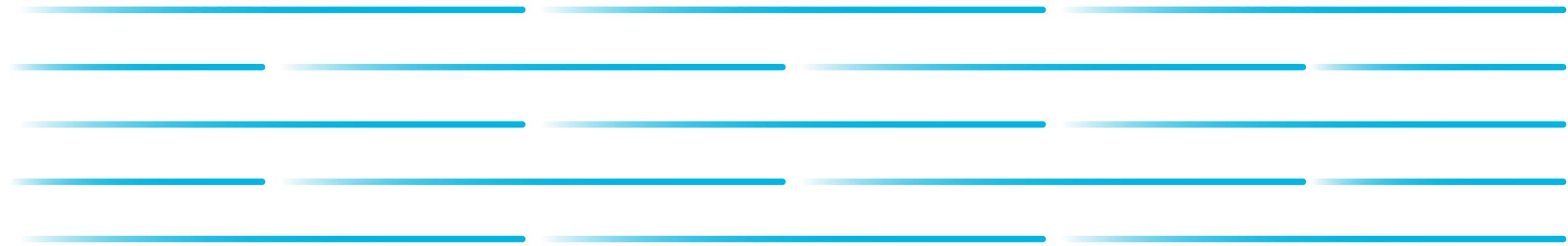
Gas Turbines: Hydrogen Capability and Experience

A presentation to the DOE Hydrogen and Fuel Cell Technology Advisory Committee

Dr. Jeffrey Goldmeer

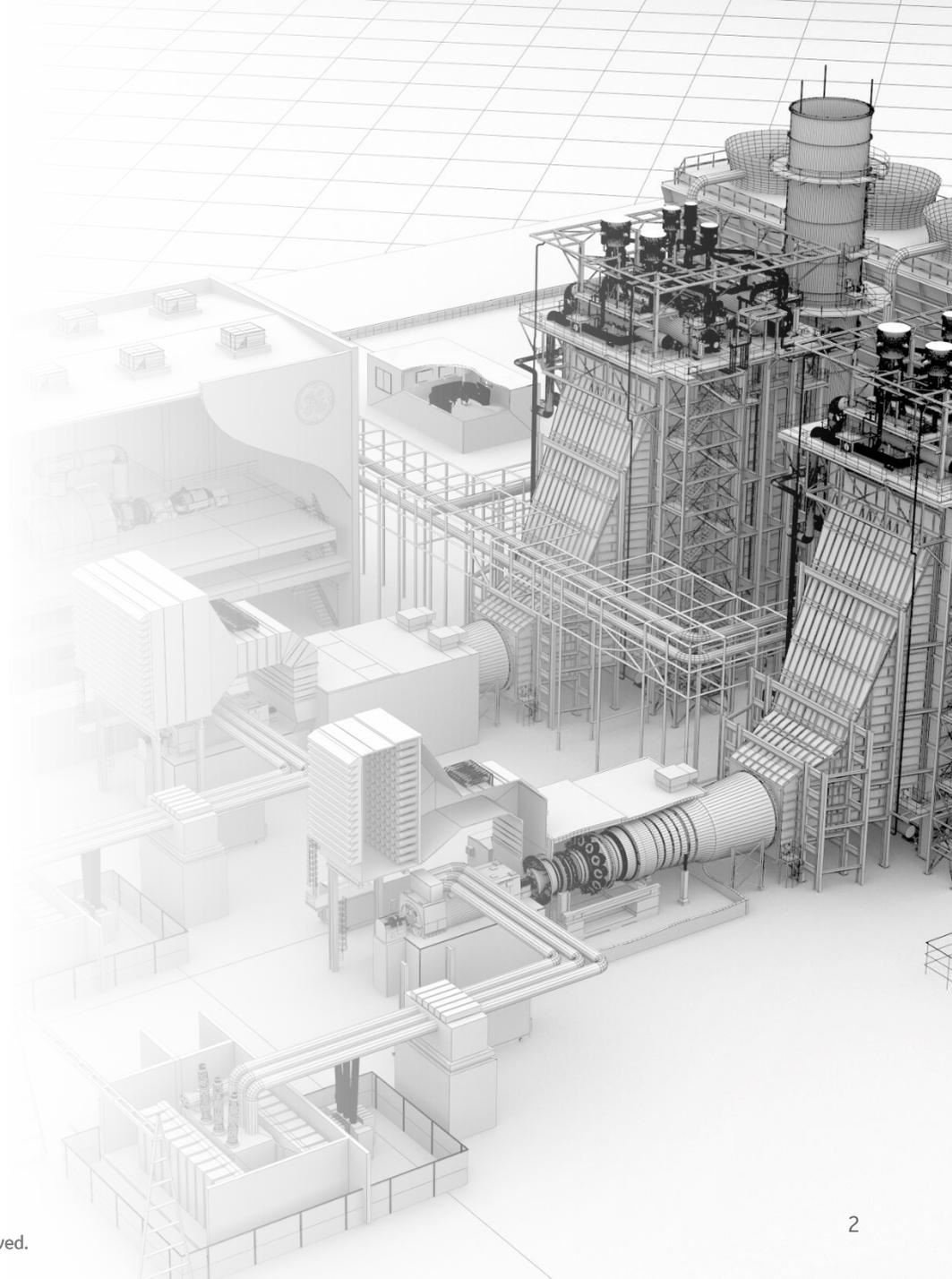
Emergent Technology Director, GE Gas Power

9 March 2020



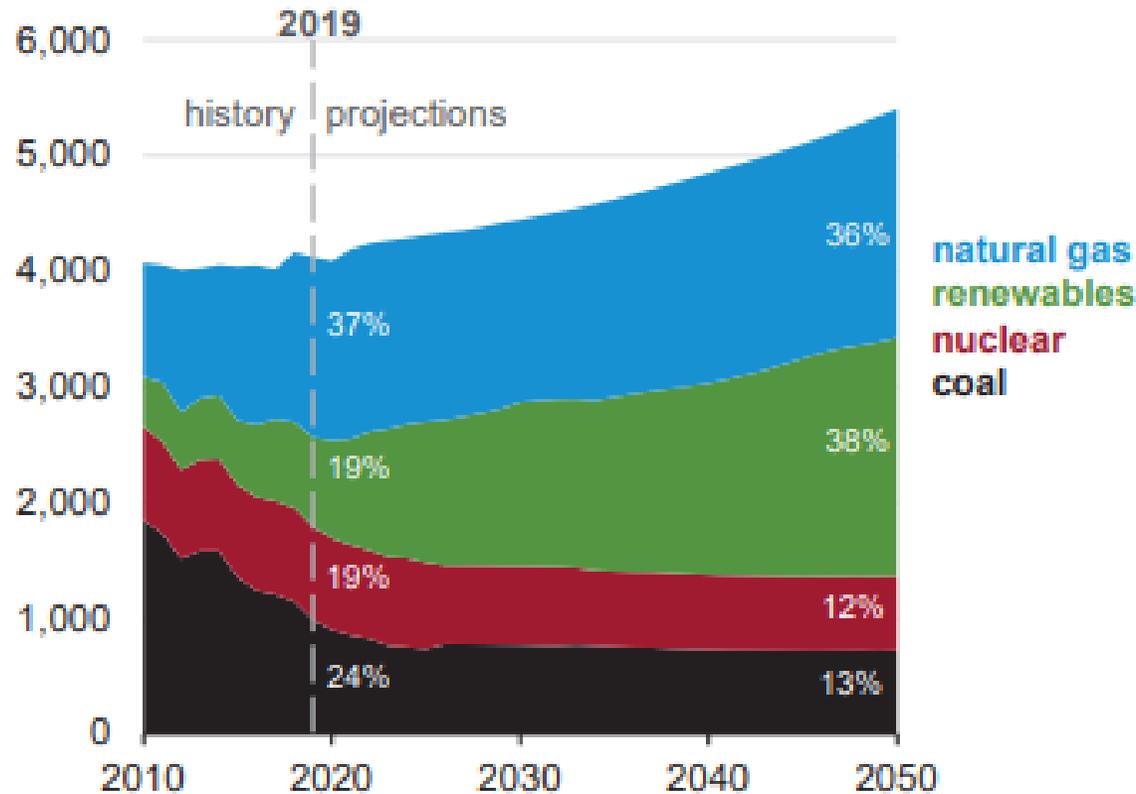
Overview

- Gas turbines are capable of operating on a wide variety of fuels, including hydrogen and other low heating value fuels
- Hydrogen and other low heating value fuels have been used to power gas turbines for decades
- Gas turbine based power plants can be configured to operate on these fuels as a new unit, or upgraded at a later date



The role of gas turbines

**Electricity generation from selected fuels
(AEO2020 Reference case)**
billion kilowatthours



Source: EIA AEO 2020

- Today, natural gas provides 37% of electricity generated in the US
- The EIA's forecast shows this percentage staying effectively the same for the next three decades
- Therefore as we look at a transition to decarbonized energy ecosystem, we need to include the current gas turbine fleet



KEY THEMES

1

**Gas turbine intro
& combustion
technology**

2

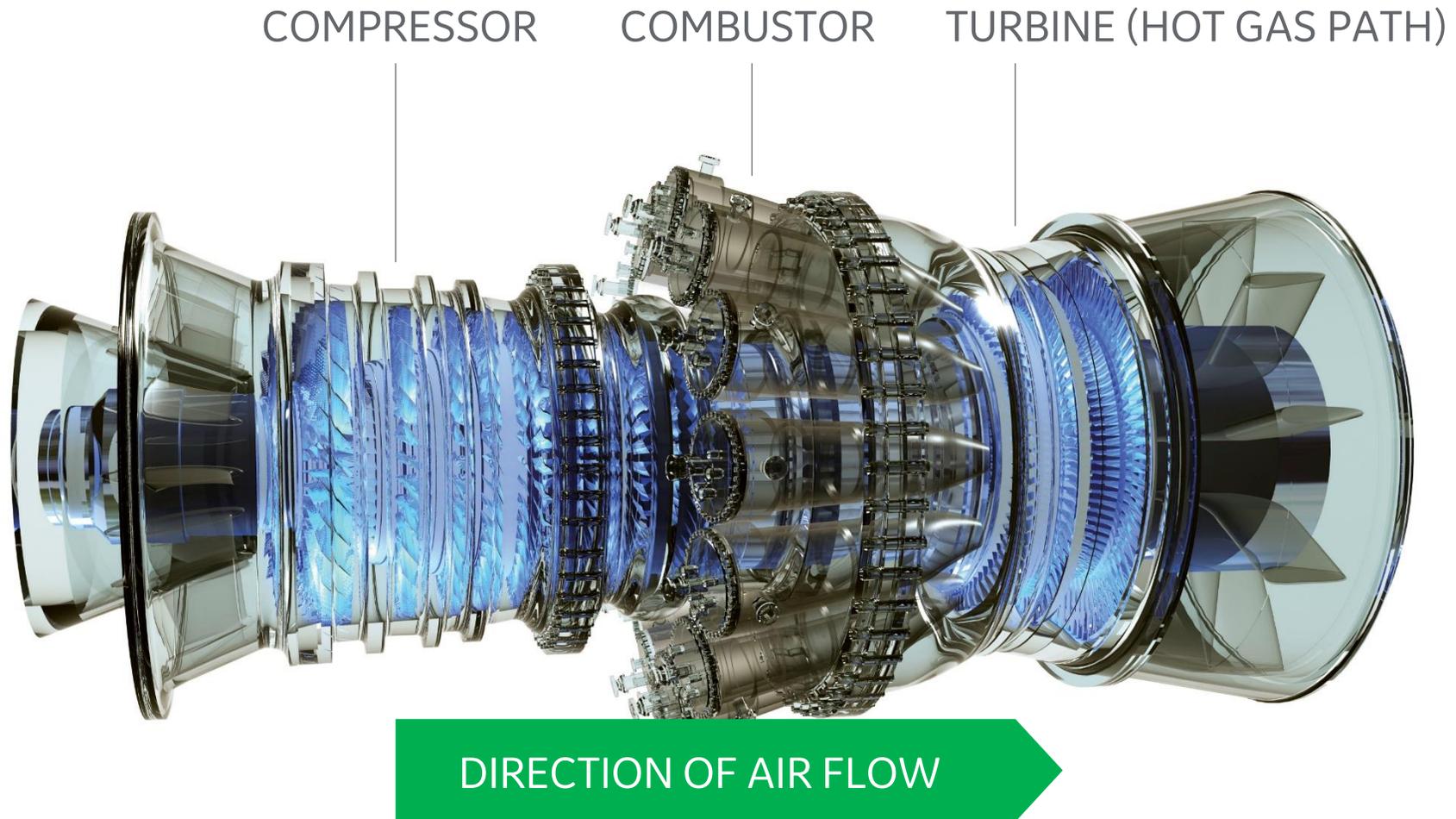
**Gas turbine
experience &
capabilities**

3

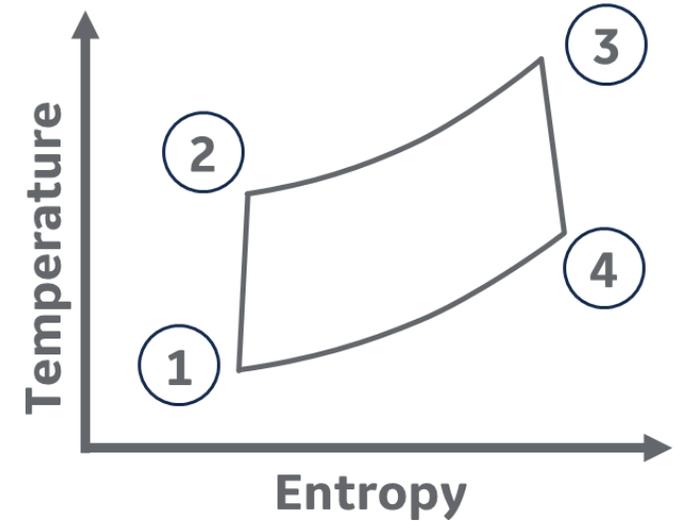
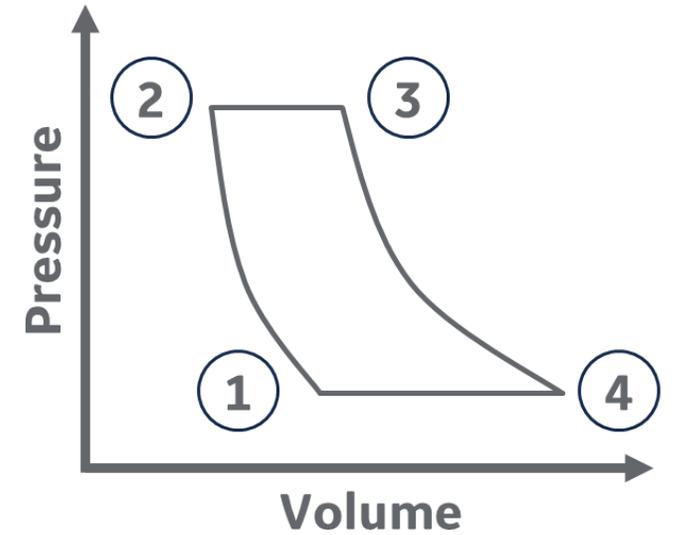
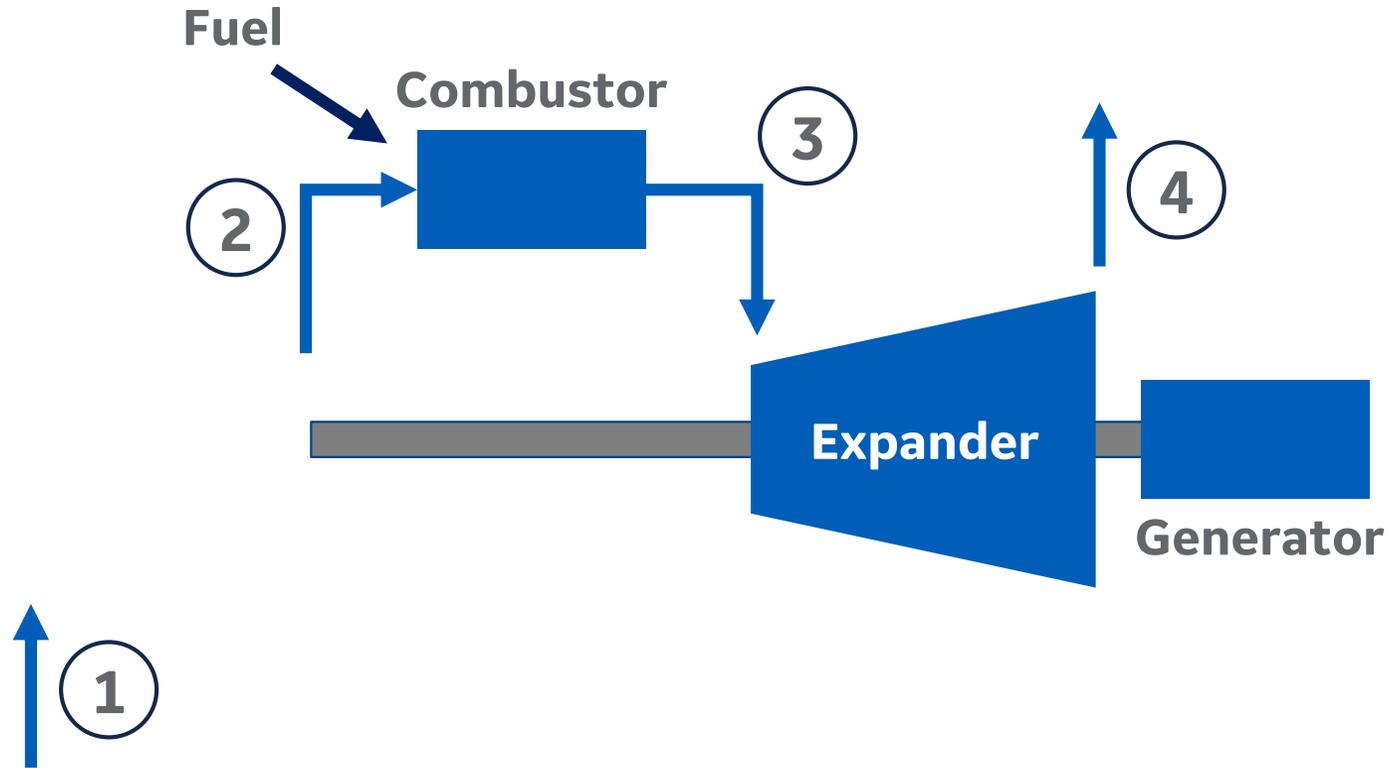
**Implications of
hydrogen for
power gen**



Gas turbine introduction – major systems



Gas turbine thermodynamics – Brayton Cycle



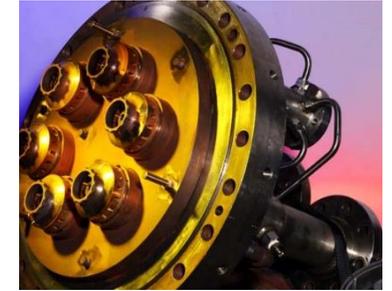
Combustion science: premixed versus diffusion flames

Diffusion flame



Characteristics

- At or near stoichiometric proportion
- Increased flame stability
- High peak flame temperature
- NOx: 200–600 ppm



GE Multi-nozzle quiet combustor

Premixed flame

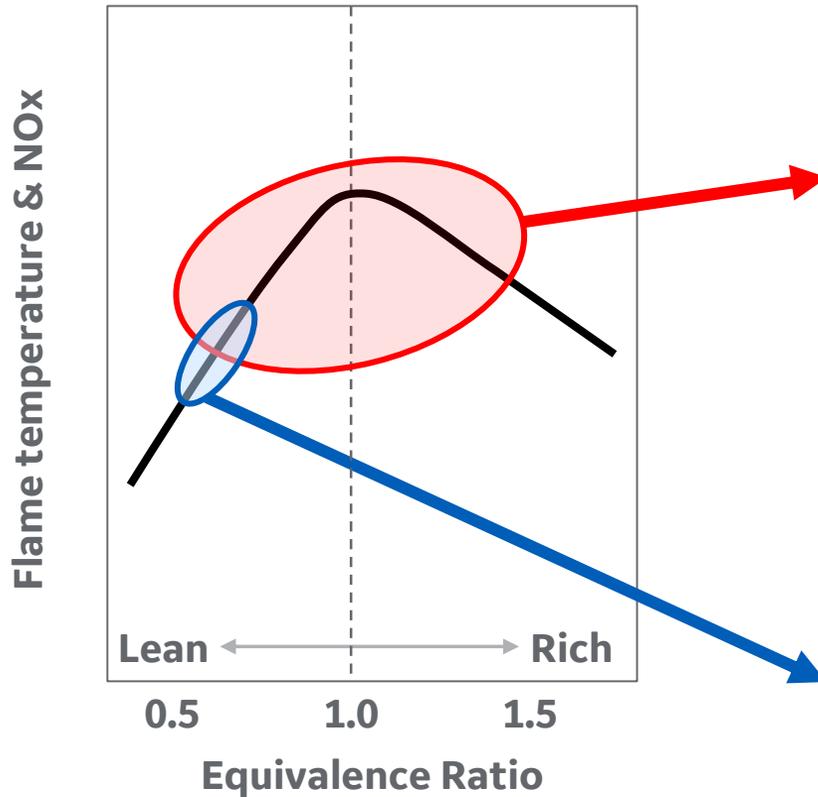


Characteristics

- Air rich (fuel lean) conditions
- Low NOx without diluent
- More susceptible to combustion dynamics
- NOx: single digit ppm



GE DLN2.6+



Example of stoichiometric reaction



Advanced premixer technology development

2005



Swizzle based architectures

Target premixing and flashback tolerance for NG

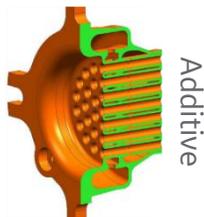
Hydrogen limits

- DLN 2.6 ~5% (vol)
- DLN 2.6+ ~15-18% (vol)

DOE High-H₂ program*

Target premixing and flashback tolerance for H₂

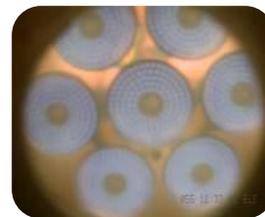
Small prototype



Prototype fuel nozzle



Full head end combustion test



Demonstrated single digit NO_x emissions at F-class temperatures and pressures

2016



Demo
7HA.01 TS7

2018



DLN 2.6e
1st commercial shipment in 2018

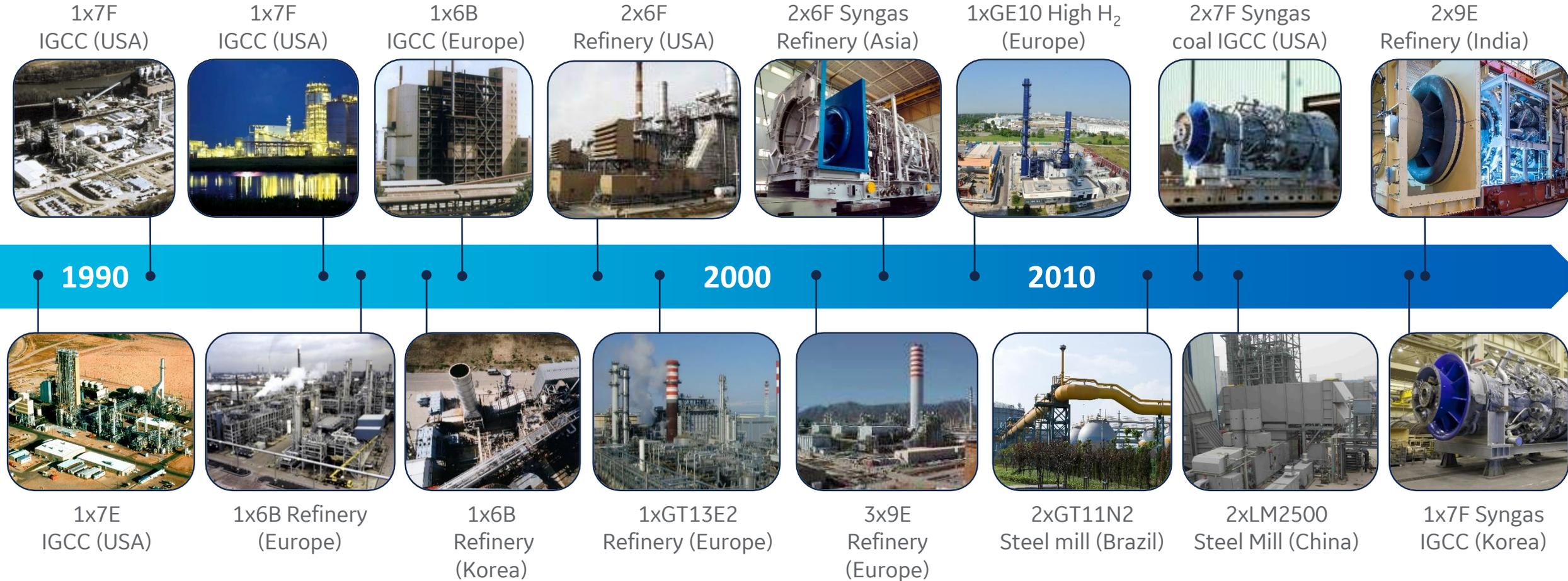
- This technology can be applied to natural gas or H₂ fuels... decouples flashback, premixing and dynamics
- Demonstrated capability to **50%** (by vol) H₂



GE gas turbine experience and capabilities



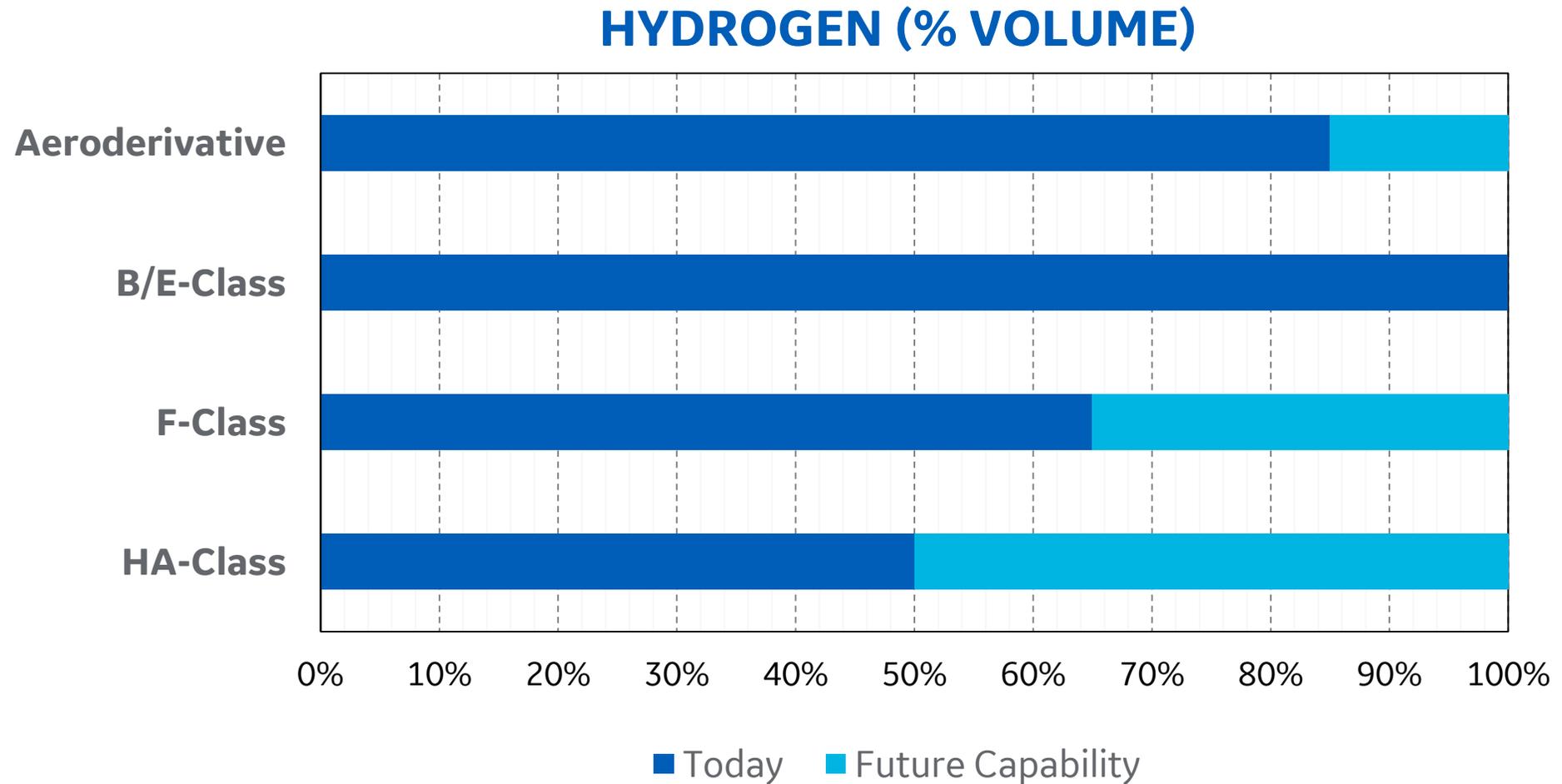
Timeline of GE experience with H2 and associated fuels



Over **75** gas turbines with more than **5 million hours** on hydrogen and associated low BTU fuels



GE gas turbine hydrogen capability



Implications of using hydrogen for power generation



Impact of hydrogen on power plant systems

SCR

HRSG inlet

Gas turbine
combustion
system

Gas turbine controls

**Gas turbine enclosure
modifications:**

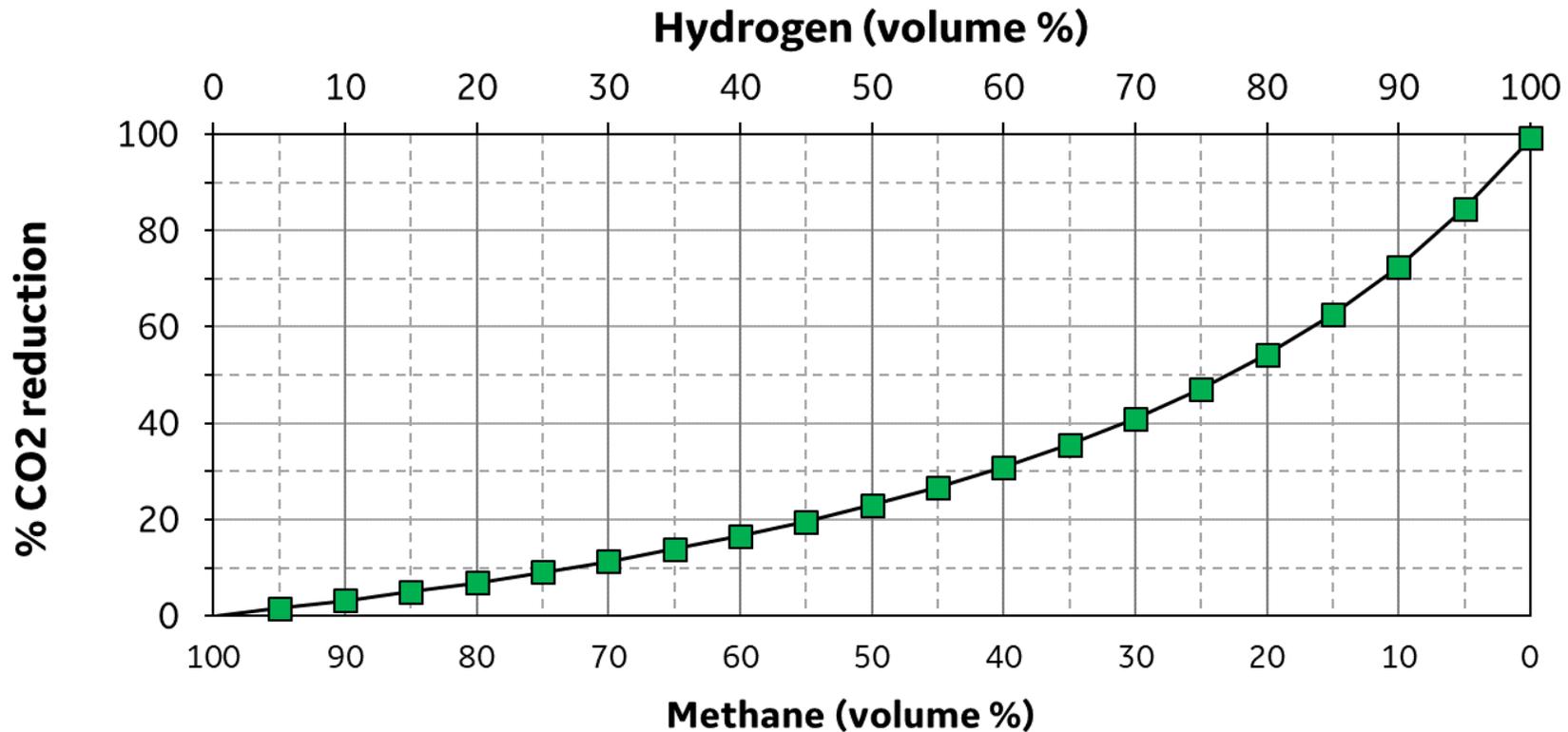
- Ventilation
- Haz gas detection
- Fire protection

Fuel accessory system:

Skids, valves, piping,
purge systems



CO₂ emissions reduction when operating on H₂



The use of H₂ as a gas turbine fuel, even if blended with natural gas, can reduce CO₂ emissions



CO2 emission impact – hydrogen

- To help customers determine the impact of using hydrogen on carbon emissions and the economics of carbon emissions, GE has created a new online tool.
- With a few simple selections (gas turbine model, plant configuration, carbon tax rate, etc.) the tool will calculate infrastructure requirements, carbon emissions reduction, and the avoided cost of carbon emissions.

HYDROGEN AND CO₂ EMISSIONS CALCULATOR

LEARN MORE ABOUT HYDROGEN'S POTENTIAL SAVINGS

With the rise in global interest in the use of hydrogen as a zero-carbon fuel, there are still many questions surrounding the real-world numbers around its implementation. What will you need in terms of infrastructure? How will it impact your CO₂ emissions? We've made it easy for you. GE's Hydrogen and CO₂ Emissions Calculator will help you:

- Understand the fuel flow rate required for a gas turbine to operate on hydrogen
- Discover the water and electricity infrastructure needed to make hydrogen
- Get the numbers around the potential savings you could realize

Want to get started? Give us a few pieces of information to see more information around your potential hydrogen project.

The information presented on or through this website and calculator is made available solely for general informational purposes. GE does not warrant (1) the accuracy, completeness, or timeliness of any results, conditions, or information provided by this website or calculator, (2) that any specific operating or performance results will occur from any information provided by the website or calculator, or (3) that any other digital or physical results will result from the website or calculator. Any reliance you place on such information is strictly at your own risk. GE disclaims all liability and responsibility arising from any reliance placed on the results, conditions, or information provided by the website or calculator by any person who may be influenced by any of its content.

1 What kind of gas turbine do you have?
7F.05

2 What are the expected annual operating hours of your gas turbine?
PEAKER MID MERIT FULL LOAD 8000 HRS

3 What's the volume percent of hydrogen you want to run through?
0% 25% 50% 75% 100% 100 %

4 What CO₂ tax rate do you pay today, if any?
Enter in your rate below. Not sure? Simply select your country using the dropdown menu. Rates are in USD/ton.
Choose your country/location OR \$ 25.00

SEE YOUR HYDROGEN POTENTIAL

Ready to get started? **CONTACT GE TODAY** →

HYDROGEN AND CO₂ EMISSIONS CALCULATOR

YOUR HYDROGEN AND CO₂ EMISSIONS RESULTS

These results are based on your estimate of 8,000 annual operating hours at 100% hydrogen on a 7F.05 turbine and a current CO₂ tax of \$25.00 per ton. **RECALCULATE**

Infrastructure Requirements CO₂ Savings Summary

HYDROGEN PRODUCTION AND INFRASTRUCTURE REQUIREMENTS

Choose your process: **Electrolysis** Steam methane reforming

ELECTRICITY REQUIRED
Energy per year
1,109.7 MW
You will need the equivalent of 740 - 1.6 MW wind turbines to create the required energy for your hydrogen infrastructure.

WATER FLOW REQUIRED
Gallons of water per day required
1,044,777
You will consume the equivalent of 1.68 Olympic-sized pools of water every day as part of your hydrogen infrastructure plan.

HYDROGEN FLOW REQUIRED
Cubic feet per day
181.9 million
Amount of hydrogen created

Ready to get started? **CONTACT GE TODAY** →

power.com/h2turbines



Closing thoughts



LOOKING TOWARDS THE FUTURE



The gas turbine industry has **proven experience** operating with H₂ and similar low BTU fuels



Combustion technology exists for operating with H₂ blends and high H₂ fuels



Gas turbines are ready for a world with **low-carbon fuels**

