Lessons Learned on H_2 Conversion Gas Turbine Demonstrations

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What can we learn from demonstrations?

Codes and Standards

Key Codes and Standards

Organization →	ASME		CGA	NFPA			
Code	**B31.12**	**BPVC.VIII.1**	**G-5.5**	**2**	**55**	**70**	**497**
Electrical/Grounding						X	*
H_2 Supply	X		X	X	X	X	
H_2-NG Mixing	X						
Overpressure Protection	X	X	X	X			X
Safety Measures	X		X	X	X	X	
Spacing	X		X	X	X	X	
Vent Configuration	X	X	X	X			X

and more (Appendix A)
https://www.epri.com/research/products/000000003002028335

NOTE: These codes and standards are US-centric

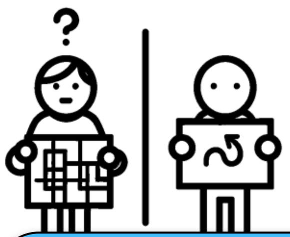
- Asia- or Europe-specific equivalents should be consulted in those regions.

Slide Courtesy of Alex Gupta, EPRI

- Early ID & communication of applicable codes and hazardous area classifications are key
- Always aim to exceed minimum code requirements; verify early
- Unclear codes? Choose closest fit, add requirements, ensure understanding
- Temporary setups should meet or surpass permanent standards
- Compliance should be verified by SMEs
- Stakeholders should establish “internal” codes – more stringent than official ones
- Understand state/local regs; legacy codes may still apply if cited

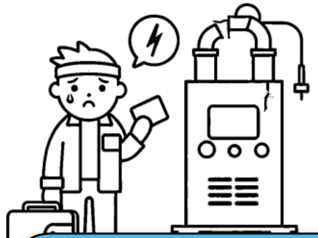
Importance of Comprehensive Procurement Contracts

Project Risks



Misaligned Expectations

- Quality
  - ➢ Defective or noncompliant equipment arriving on site
- Performance
  - ➢ Operational profiles/variability



Potential Project Impacts

- Project delays during shipment or construction/commis sioning
- Cost overruns due to rework or component replacements
- Performance shortfalls
- Operational reliability issues

Lessons Learned

Robust Procurement Contracts

- Set clear expectations quality & performance
- Agree on realistic timelines
- Performance guarantees

Stakeholder Communication

- Frequent updates
- Transparent reporting

Risk Management

- Collaboratively identify risks early and develop mitigation plans

Supported Demonstrations of H_2 for Power Generation

H_2 Demonstration Objectives

- Operate unit without major modifications
- Measure impacts on CO_2, NOx, CO, and unit performance
- Develop best practices for H_2 blending

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

44%v | GE LM6000
(45 MWe - Aeroderivative)

Executive Summary Report

Full Report Version

Georgia Power

20.9%v | Mitsubishi 501G
(265 MWe – Heavy Frame)

White Paper Report

Full Report Version

WEC Energy Group

25%v | Wärtsilä RICE
(18 MWe - RICE)

Executive Summary Report

Constellation.

38%v | Siemens Energy SGT6-6000G
(246 MWe – Heavy Frame)

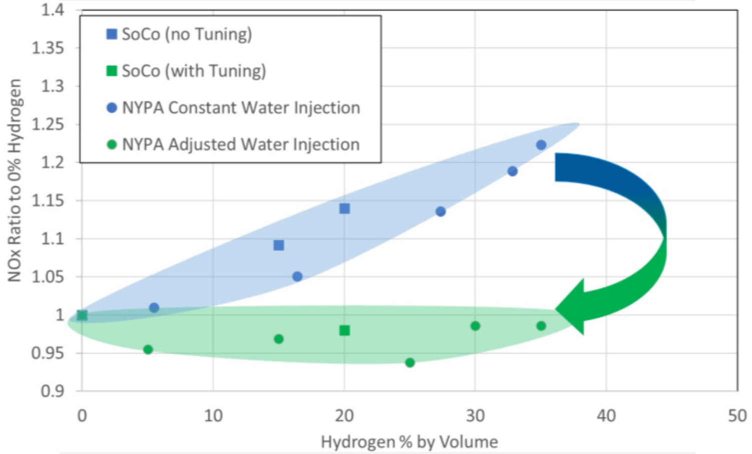
Press Release

Results: Environmental

[1]Mitsubishi Power 501G 20% Hydrogen Test

[2]Hydrogen Cofiring Demonstration at New York Power Authority's Brentwood Site: GE LM6000 Gas Turbine

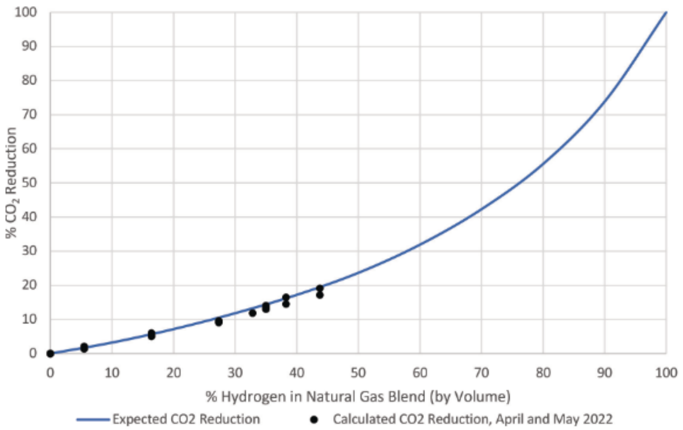
NO_x Emissions[1]



By controlling GT flame temperature (DLN or WLE), NO_x emissions ≤ NG case

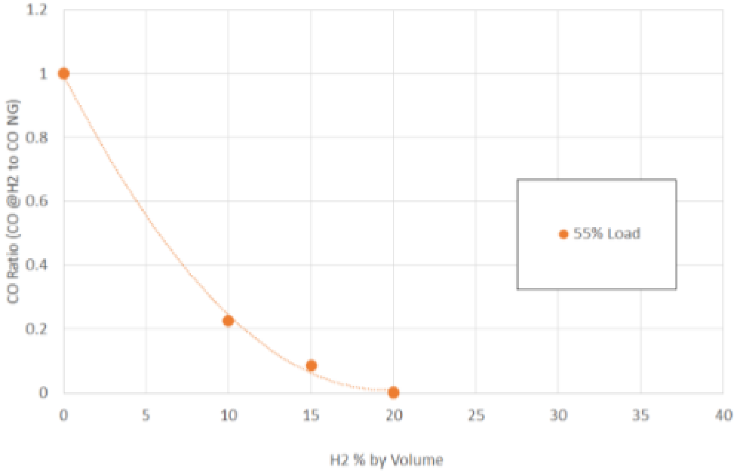
- ➢ Decrease RICE NO_x emissions by reducing charged air pressure or retarding ignition timing.

CO_2 Emissions[2]



As %H_2 increases, CO_2 and other carbon emissions decrease

CO Emissions[1]



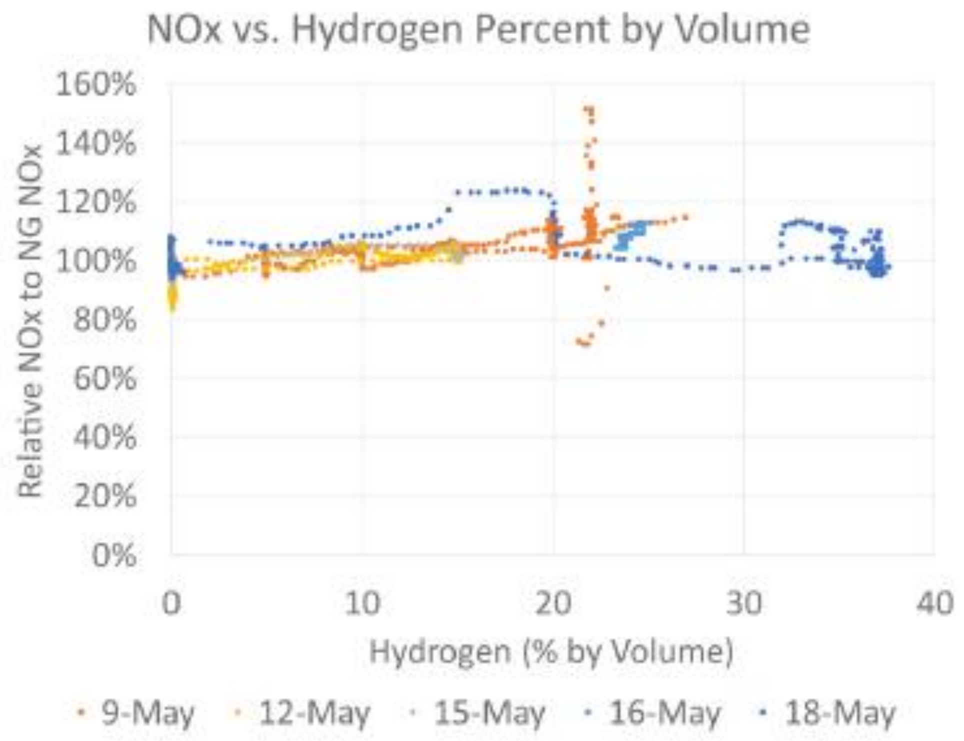
H_2 caused more complete combustion, reducing CO emissions

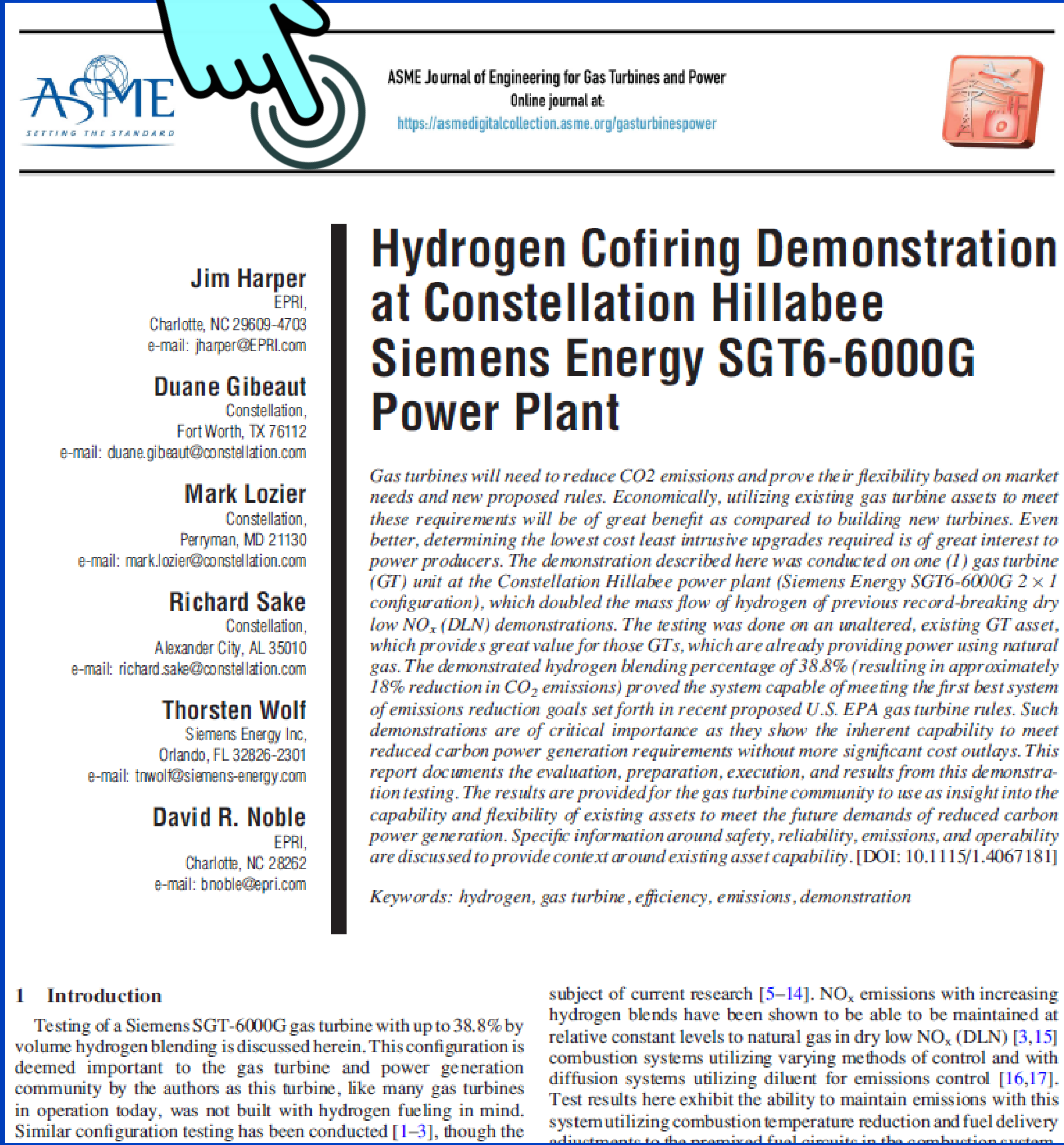
- ➢ However, low-NO_x techniques may cause CO emissions to increase.

To date, existing emissions control systems sufficient to maintain emissions within permissible levels

Hillabee Testing Results in Recent Journal Publication: GTP-24-1572

- NOx emissions could be tuned to NG levels or below
- Blends up to 38% by volume





ASME Journal of Engineering for Gas Turbines and Power
Online journal at:
https://asmedigitalcollection.asme.org/gasturbinespower

Hydrogen Cofiring Demonstration at Constellation Hillabee Siemens Energy SGT6-6000G Power Plant

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Gas turbines will need to reduce CO2 emissions and prove their flexibility based on market needs and new proposed rules. Economically, utilizing existing gas turbine assets to meet these requirements will be of great benefit as compared to building new turbines. Even better, determining the lowest cost least intrusive upgrades required is of great interest to power producers. The demonstration described here was conducted on one (1) gas turbine (GT) unit at the Constellation Hillabee power plant (Siemens Energy SGT6-6000G 2 × 1 configuration), which doubled the mass flow of hydrogen of previous record-breaking dry low NO_x (DLN) demonstrations. The testing was done on an unaltered, existing GT asset, which provides great value for those GTs, which are already providing power using natural gas. The demonstrated hydrogen blending percentage of 38.8% (resulting in approximately 18% reduction in CO_2 emissions) proved the system capable of meeting the first best system of emissions reduction goals set forth in recent proposed U.S. EPA gas turbine rules. Such demonstrations are of critical importance as they show the inherent capability to meet reduced carbon power generation requirements without more significant cost outlays. This report documents the evaluation, preparation, execution, and results from this demonstration testing. The results are provided for the gas turbine community to use as insight into the capability and flexibility of existing assets to meet the future demands of reduced carbon power generation. Specific information around safety, reliability, emissions, and operability are discussed to provide context around existing asset capability. [DOI: 10.1115/1.4067181]

Keywords: hydrogen, gas turbine, efficiency, emissions, demonstration

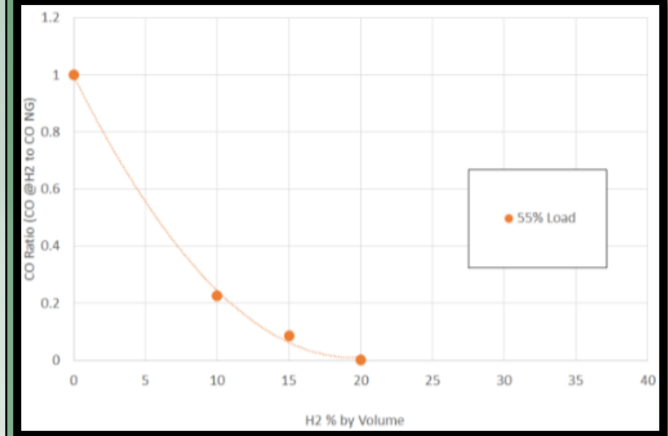
1 Introduction

Testing of a Siemens SGT-6000G gas turbine with up to 38.8% by volume hydrogen blending is discussed herein. This configuration is deemed important to the gas turbine and power generation community by the authors as this turbine, like many gas turbines in operation today, was not built with hydrogen fueling in mind. Similar configuration testing has been conducted [1–3], though the subject of current research [5–14]. NO_x emissions with increasing hydrogen blends have been shown to be able to be maintained at relative constant levels to natural gas in dry low NO_x (DLN) [3,15] combustion systems utilizing varying methods of control and with diffusion systems utilizing diluent for emissions control [16,17]. Test results here exhibit the ability to maintain emissions with this system utilizing combustion temperature reduction and fuel delivery

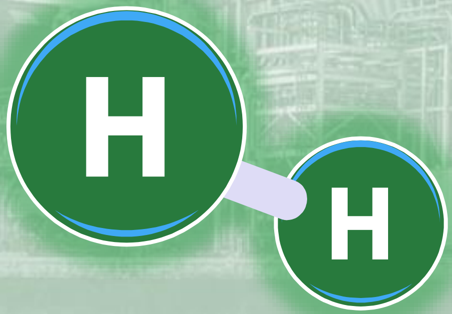
Hydrogen = More Flexible GTs?

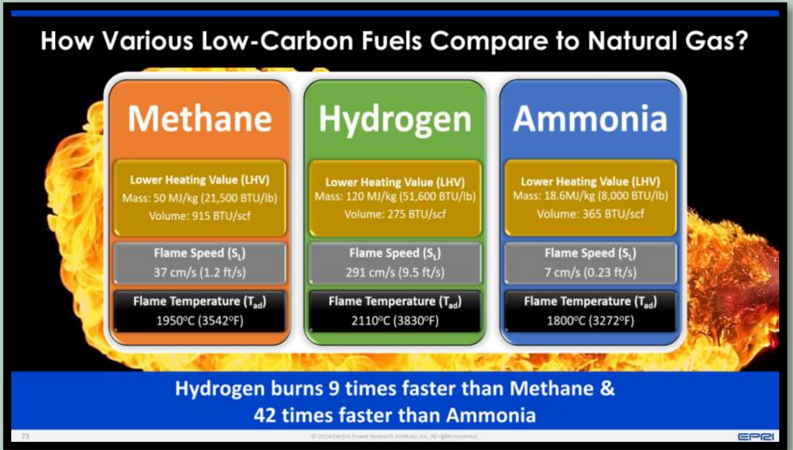
- Combined Cycle Gas Turbine demonstrations have shown 70+% reduction in CO at low-load
- McDonough M501G unit at 20.9% H_2 (vol)
  - Additional 10% turndown
  - *Possibly could have gone lower*

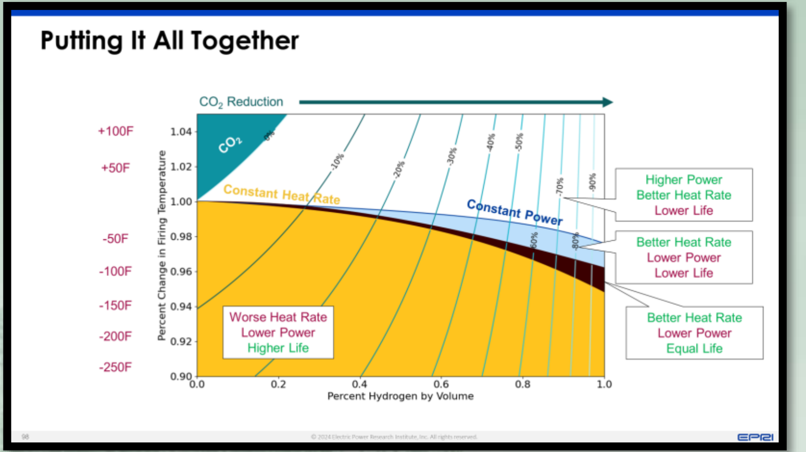
CO Emissions

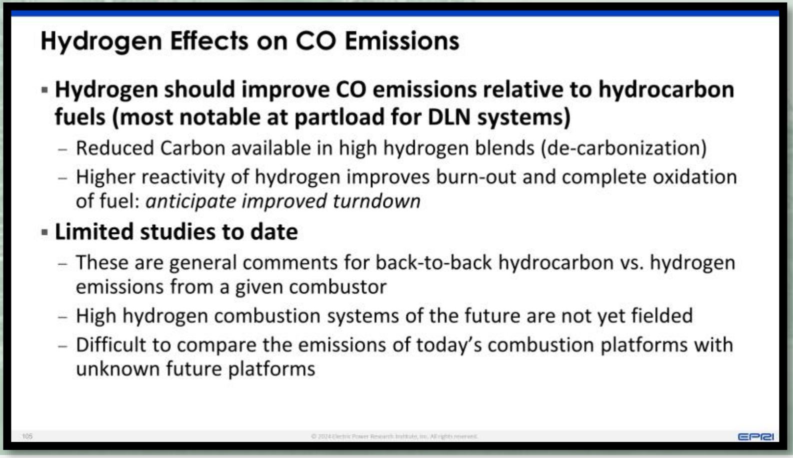


H_2 caused more complete combustion, reducing CO emissions









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Key Codes

ASME B31.12 (*ASME B31/B31.3*)

- Piping code applicable to hydrogen
- Includes guidance for:
  - Functional testing
  - Necessary inspections
  - Review of quality documents

CGA G5-4

- Material guidance for hydrogen piping
- Recommends austenitic stainless steels, specifically 316/316L
- Recommends using helium (He) when performing leak tests
- Harmonized with AIGA 087

Benefits of Demonstrations for the Industry

- Safety procedure framework development
- Pretest procedure development
- Instrumentation and monitoring experience
- Leak testing best practices
- H_2 blending operational experience

New resources to support member H_2 demonstrations and long-term planning