DECARBONIZING OUR ENERGY ECOSYSTEM WITH GAS TURBINES

November 2020

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Gas turbines are integral to our power system today will continue to provide a significant percentage of global electricity for decades.

Gas turbines offer multiple technical pathways to lower and zero carbon emissions.

GE is the most experienced OEM in hydrogen and similar low BTU fuel operations.
The world today

Global CO₂ emissions
(33.7 gigatons)

- Buildings: 9%
- Industry: 26%
- Transportation: 25%
- Power Generation: 41%

Global electricity generation

- 27k TWh of electricity
- 770 M people w/out power
- 13.7 gigatons CO₂

2019

Significant opportunity to reduce CO₂ with power generation technologies

Source: IEA WEO 2020
DO WE NEED FOSSIL FUELS?

YES. NOT ENOUGH ZERO CARBON ENERGY TO MEET FUTURE DEMAND

Even with aggressive renewable growth such as Wind and Solar growing 2X current rate!
The role of gas turbines
Accelerating the transition to a lower carbon future

- **US POWER SECTOR CO₂ ↓ 33%**
  - Gas enabled ~40% of net reduction since ’07

- **FLEXIBLE TO COMPLEMENT RENEWABLES**
  - Fast start times and ramp rates, low minimum turndown

- **RELIABLE, DEPENDABLE CAPACITY**
  - Whenever needed, day or night, regardless of weather

- **ABUNDANT & AFFORDABLE NATURAL GAS**
  - Traded LNG to 80% increase by 2040, leading to increased availability

- **LESS SPACE REQUIRED IN URBAN AREAS**
  - 50-100X more MW/Acre than renewables + Storage

- **MULTIPLE PATHWAYS TO DECARBONIZE GTs**
  - H₂ Fuel, Carbon Capture, Biofuel
    - Avoid CO₂ lock-in or stranded assets

**SOCIETY IS DEMANDING AGGRESSIVE ACTION TO ADDRESS CLIMATE CHANGE ... NATURAL GAS WILL PLAY A CRITICAL ROLE**
Decarbonizing gas power ... a range of options

Use a 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)
- Carbon capture (solid sorbents)
- Oxy-fuel cycles
Technical Pathways: Hydrogen
# A tale of three molecules: HYDROGEN, AMMONIA, & METHANE

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Methane</th>
<th>Hydrogen</th>
<th>Ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>CH₄</td>
<td>H₂</td>
<td>NH₃</td>
</tr>
<tr>
<td>Molecular weight (grams/mol)</td>
<td>16</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Boiling temperature (°F (°C))</td>
<td>-258.7 (-161.5)</td>
<td>-423.2 (-252.9)</td>
<td>-28 (-33.3)</td>
</tr>
<tr>
<td>Lower / Upper flammability limits (%)</td>
<td>4.4 / 17</td>
<td>4 / 75</td>
<td>15 / 28</td>
</tr>
<tr>
<td>Flame speed (cm/sec)</td>
<td>~30-40</td>
<td>~200-300</td>
<td>~6-7</td>
</tr>
<tr>
<td>Adiabatic flame temperature (°F (°C))</td>
<td>~3,565</td>
<td>~4,000</td>
<td>~3,270</td>
</tr>
<tr>
<td>Lower Heating value (MJ/Nm³ (BTU/scf))</td>
<td>35.8 (911.6)</td>
<td>10.8 (274.7)</td>
<td>14.1 (360)</td>
</tr>
<tr>
<td>NOx impact (relative to methane)</td>
<td>~2x</td>
<td>~150x</td>
<td></td>
</tr>
</tbody>
</table>
Decades of experience with hydrogen and similar low BTU fuels

Over 75 gas turbines with more than 6 million operating hours
Commercial projects using hydrogen

High H₂ Fuel Operation

- A 6B gas turbine (~44 MW) been operating for over 20 years on a high-hydrogen fuel
- The hydrogen composition of the fuel varies between 70% and 95% (by volume)

Blending H₂ and Natural Gas

- Four GE 7F gas turbines (~187 MW each) located in the US operated on a blend of hydrogen with natural gas
- Post blending, the fuel contained ~5% (by volume) hydrogen

Targeting 100% H₂

- Long Ridge Energy intends to begin blending hydrogen in their new 7HA.02 gas turbine
- The owner’s plan is to transition the plant to be capable of burning 100% green hydrogen over the next decade
Technical Pathways: Carbon Capture
Pathway to decarbonization: post-combustion carbon capture

Experience with many post combustion capture methods ... CCUS is a viable option
Potential locations for CO$_2$ storage in the US

Estimated total US CO$_2$ storage capability: 2,600 to ~22,000 Billion metric tons

Source: https://edx.netl.doe.gov/geocube/#natcarbviewer
The Decarbonization Journey
GE … a key player in decarbonization

Rising to the challenges of the energy transition

Published on October 15, 2020

Larry Culp
Chairman & CEO at GE

Setting a New Goal of Carbon Neutrality

Today, GE is setting a goal of achieving carbon neutrality for our own operations by 2030. With over 1,000 facilities across the globe including factories, test sites, warehouses and offices, the scale of GE’s industrial manufacturing footprint means that achieving our

Uniper partners with GE to decarbonise gas plants in Europe

They have signed an agreement to explore, assess and develop technology options and produce a detailed decarbonisation roadmap by early 2021


Long Ridge Energy Terminal Partners with New Fortress Energy and GE to Transition Power Plant to Zero-Carbon Hydrogen

October 13, 2020

HANIBAL, Ohio, Oct. 13, 2020 (GLOBE NEWSWIRE) — Long Ridge Energy Terminal (“Long Ridge”), located in Hanibal, Ohio, announced plans to transition its 465 MW combined-cycle power plant to run on carbon-free hydrogen. In collaboration with New Fortress Energy (“NFE”) and GE, Long Ridge intends to begin providing carbon-free power to customers as early as next year by blending hydrogen in the gas stream and transition the plant to be capable of burning 100% green hydrogen over the next decade.

With commercial operations planned for November 2021, Long Ridge will be the first purpose-built hydrogen-burning power plant in the United States and the first worldwide to blend hydrogen in a GE H-class gas turbine. The plant utilizes a GE 7HA.02 combustion turbine, which can burn between 15-20% hydrogen by volume in the gas stream initially, with the capability to transition to 100% hydrogen over time. Long Ridge has engaged Black & Veatch to

GE is excited about the future and the role that gas turbines will play in decarbonizing our society

www.gepower.com/hydrogen

- Hydrogen white paper (2020 revision)
- Decarbonization webinar series
  - Hydrogen & Gas Turbines: Unleashing Decarbonized Power
  - Are we prepared for a hydrogen future?
  - Carbon Capture: What it Takes
- Decarbonization Podcast

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