Gas Turbine Generators: Clean Now, Cleaner Tomorrow

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1. Introduction

Electric generators with gas turbine prime movers have a strong recent reputation as being flexible and relatively "clean" when fueled by natural gas, LNG, LPG or other fuels where natural gas service is not available.[1] Their flexibility comes from their capability to be rapidly deployed, and then provide a reasonable growth path via:

- A large number of small to medium-sized peakers that can be quickly deployed close to load-centers and/ or intermittent renewable generators.
- The above peakers can be selected with the ability to evolve to extremely efficient (>50%) cogeneration generators by adding steam-generators to convert residual heat in the combustion turbines' exhaust to medium-pressure steam and pass that through a steam-turbine generator.
- In situations where strong water-conservation is needed the low-pressure steam output can be condensed and recycled via a water loop that is passed through cooling towers (rather than venting the steam to the atmosphere).

The three technologies described above (gas-turbine, steam-turbine and combined-cycle electric generators) were described in detail in the earlier post (2018) summarized and linked below:

Old and New Cycles: *In past papers I have tried to focus on subjects that will be of interest to both electric utility and facility energy management readers. For a while I have wanted to write a paper on combined cycle power plants (a.k.a. combined cycle gas turbines or CCGTs). However, these are not particularly applicable to facilities, except the largest ones. Recently it occurred to me that if the paper were broadened to include the two prime movers in CCGTs, which are combustion turbines and steam turbines, as separate electric generators that these are frequently used in facilities, and are still applicable going forward.*

https://energycentral.com/c/pip/old-and-new-cycles

Also, there is a fourth related-technology that I have mentioned in an earlier paper, described and linked below, fueling the gas-turbine generator with partial- to 100%-hydrogen fuel. In the latter case, the gas turbine generator only emits steam in its exhaust, and effectively becomes renewable IF the hydrogen is renewably generated (mostly via electrolysis powered by intermittent renewables).

Zero-Emissions Combined Cycle and Beyond: *This paper has a proposal that will keep combined cycle power plants running by converting them to (nearly) zero greenhouse gas (GHG) emission operation. Ultimately these can be converted to negative emissions technology to offset other GHG sources.*

https://energycentral.com/c/cp/zero-emissions-combined-cycle-and-beyond

[1] (GE Vernova, "Flexible gas turbine fuel offerings, GE Vernova's variety of fuels," ©2025, https://www.gevernova.com/gas-power/applications/flexible-fuel-offerings

In section 4.3 of a 2021 post, summarized and linked below, I did a deep dive into converting existing natural gas fueled cogeneration plant to operate from hydrogen.

Future Long-Term Storage: *The hot technology now is Short-Term Storage (read: lithium-ion battery energy storage systems or BESS), and I write about these frequently.*

However, there are really two or three types of energy storage systems from a duration (discharge time) standpoint. Li-ion BESS typically have a one to four-hour discharge period at full-output. Although it really hasn't found a strong market, a BESS based on flow-battery technology can economically provide a duration of up to eight hours.

And finally, we have the subject of this post. Long-Term storage potentially provides a duration longer than could be economically provided by a Flow-BESS. In this post I will cover pumped storage, also I will cover a technology for long-term storage based on green-hydrogen, and finally a couple of emerging technologies that might provide long-term storage in the future.

https://energycentral.com/c/cp/future-long-term-storage

2. Hydrogen-Fueled Gas Turbines Recent Progress

All of the developments described and referenced in the Intro happened before the recent emergence of monster data centers hosting crypto and artificial intelligence applications. However, since the subject technology is very flexible, quickly-deployed, inexpensive and relatively clean, it was inevitable that these would be paired. The one problem is that natural-gas-fueled turbines emit greenhouse gas, and thus contribute to climate change. Also, most large IT firms that would use or fund the turbine installations tend to be very aware of their climate-change footprint, and would prefer to minimize it.

The good news I found an upcoming project that uses state-of-the-art gas turbines that will be very clean when installed next year, and easily evolve to use hydrogen fuel. The better news is that the maker of these turbines is my former employer (General Electric).

2.1. The Project

The energy services company founded by the current Energy Secretary Chris Wright is a partner in a "strategic alliance" to provide dedicated power generation to data centers and other large-load customers at a roughly 875-acre industrial park under development near Pittsburgh, it said on Tuesday, April 8.[2]

Liberty Energy will provide modular, 25-MW gas-fired power blocks collocated with customers in Imperial Land Corporation's Fort Cherry Development District and could eventually scale total onsite generation capacity to 1 GW or more, Liberty Energy Senior Vice President of Power Generation Execution Mike Brady told Utility Dive in an email.

Liberty's announcement comes a week after Homer City Redevelopment (HCR) and Kiewit Power Constructors announced plans to build up to 4.5 GW of gas-fired generation on the site of the retired, 1,884-MW coal-fired Homer City power plant about 60 miles from the Fort Cherry project.

[2] Brian Martucci, Utility Dive, "Liberty Energy to deploy modular gas-fired 'power blocks' at Pennsylvania industrial site," April 9, 2025, https://www.utilitydive.com/news/liberty-energy-modular-gas-fired-pennsylvania-industrial-marcellus-shale/744854/

Data centers are increasingly turning to onsite power generation as interconnection timelines and grid congestion grows, experts say. Power availability and time-to-power have emerged as crucial considerations for data center developers and operators…

Earlier this year, GE Vernova CEO Scott Strazik said his company's order backlog for gas turbines and other power-system equipment would soon stretch into 2028 amid escalating demand for gas-fired power generation. GE Vernova plans to nearly double its gas turbine production capacity by 2027 and maintain it at that level for the foreseeable future, Strazik said in January.

Liberty uses "high-efficiency flexible natural gas generation" equipment that can scale quickly, allowing it to deliver power to the project's first phase in as little as 12 months, Brady said.[3]

"We utilize gensets from a range of manufacturers with proprietary Liberty controls systems that seamlessly integrate into our centralized, grid-integrated network operating center," Brady said. "[We have] already purchased items with long lead times, so we could deliver quickly."

2.2. GE Vernova Hydrogen Fueled Gas Turbines

First of all, I need to provide some information about the GE reorganization that resulted in GE Vernova:

General Electric completed its transition of splitting into three separate companies Tuesday, with GE Vernova, GE Aerospace, and GE Healthcare all trading under separate stock tickers.[4]

GE's energy division, GE Vernova, started trading under the "GEV" ticker Tuesday (April 2, 2024), while the longtime "GE" ticker is now attached to GE Aerospace.

GE Healthcare was spun off last year (2023) and trades under the "GEHC" ticker.

There was a division that was spun out of GE earlier: *GE Nuclear Energy Division was spun out of GE and became part of a joint venture called GE Hitachi Nuclear Energy (GEH) in 2007.*[5]

I found a GE Vernova site that discussed their hydrogen-fueled gas turbines. This site is huge and has many additional linked resources.

While the effort to reduce carbon emissions from traditional power generation assets is driving an increase in renewable power production from renewables, hydrogen-ready gas turbines could also play a role. See how we're leading the charge.[6]

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[3] Liberty Energy Senior Vice President of Power Generation Execution, Mike Brady
[4] Aaron McDade, Investopedia, "GE Completes Split Into 3 Public Companies as GE Vernova Makes Trading Debut," April 02, 2024, https://www.investopedia.com/ge-completes-its-split-into-3-public-companies-as-ge-vernova-makes-its-trading-debut-8623533
[5] https://en.wikipedia.org/wiki/GE_Hitachi_Nuclear_Energy
[6] GE Vernova, "Hydrogen fueled gas turbines," 2025, https://www.gevernova.com/gas-power/future-of-energy/hydrogen-fueled-gas-turbines

2.2.1. Experience

GE Vernova has the following experience in hydrogen-fueled gas turbines:

GE Vernova gas turbines have experience operating on fuels with hydrogen content ranging from 5% (by volume) up to 100%. This includes:

- *120+ units running on hydrogen fuels*
- *50 years of hydrogen experience*
- *8.5M+ operating hours industry-leading experience*

2.3. Case Studies:

2.3.1. South Australia, World's Largest Hydrogen Plant

The South Australian government has established Hydrogen Power SA to offer grid firming services via several new hydrogen electrolyzers, including at the massive Whyalla Hydrogen power facility. This plant will house one of the world's largest green hydrogen production and storage plants, using surplus wind and solar energy to produce renewable hydrogen through water electrolysis.

The Whyalla facility will employ four GE Vernova LM6000VELOX aeroderivative gas turbines, marking the first commercial-scale deployment of GE Vernova's turbines capable of operating on 100% hydrogen. This groundbreaking technology is expected to provide zero CO_2 emissions at the exhaust when fueled entirely by renewable (green) hydrogen in 2026.[7]

2.3.2. First Hydrogen Burn at Long Ridge Marks Triumph for GE

Hydrogen combustion has begun at the 485-MW Long Ridge Energy Terminal combined cycle power plant—a flagship GE HA-class project that is purpose-built to transition from natural gas to hydrogen blends and ultimately be capable of burning 100% hydrogen.[8]

While the sprawling multimodal facility in Hannibal, Ohio—which sits on the Ohio and West Virginia border—achieved commercial operation in October 2021, efforts to kick off its GE 7HA.02 gas turbine's transition to hydrogen combustion began in earnest earlier this year (2022). A test to combust an initial blending of 5% hydrogen and 95% natural gas fuel successfully completed on March 30 demonstrated that capability.

The test is part of a project spearheaded by Long Ridge Energy Generation, Black & Veatch, GE, NAES, and Long Ridge's engineering, procurement, and construction (EPC) contractor Kiewit to integrate hydrogen fuel blending at the plant without disrupting its power production for PJM Interconnection. The project's key aim was to create an operational regime for hydrogen blending of 5% maximum hydrogen by volume in preparation for the next phase, which could involve blending of 20% hydrogen…

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[7] https://reneweconomy.com.au/south-australia-orders-worlds-first-100-pct-hydrogen-capable-turbines-for-whyalla/

[8] Sonal Patel, Power, "First Hydrogen Burn at Long Ridge HA-Class Gas Turbine Marks Triumph for GE," April 22, 2022, https://www.powermag.com/first-hydrogen-burn-at-long-ridge-ha-class-gas-turbine-marks-triumph-for-ge/

The blended fuel's injection into the gas turbine's combustion system marks a substantial triumph for gas power technology, Jeff Goldmeer, director of Emergent Technologies at GE Gas Power's Decarbonization division, told POWER. "It's definitely GE's first HA machine to start using hydrogen, and it may be the first H-class machine anywhere in the world to start using hydrogen," he said.

3. For Deep Divers

I like to provide additional resources for readers that would like to do a deep dive into the information that a post covers. I found an excellent paper from a really authoritative source (referenced below). I will paste some content and a chart from this below, and let my deep-diving readers do their thing via the link in the reference.[9]

Hydrogen does not contain carbon and therefore emits no carbon dioxide (CO_2) when combusted. There is increasing interest in hydrogen as a viable, potentially low-greenhouse gas (GHG) fuel source for stationary combustion turbines in the utility power sector. The direct benefit of combusting hydrogen to produce electricity is zero CO_2 emissions at the stack.

The use of hydrogen in the United States (U.S.) to date has been primarily limited to certain applications in industrial sectors. The nation produced approximately 10 million metric tons (MMT) of hydrogen in 2018 and 70 percent of that total was used by refineries to remove sulfur from petroleum products and 20 percent was used to produce ammonia in the manufacture of fertilizer. The remaining 10 percent was used for treating metals, processing foods, and other miscellaneous applications. Hydrogen is also used in the transportation sector, currently in light duty hydrogen fuel cell vehicles. The fact that hydrogen emits no CO_2 when combusted is the key to its potential for reducing GHG emissions in hard-to-decarbonize industries that require a high heat source, such as cement and steel manufacturing. For example, hydrogen can replace the metallurgical or coking coal and other fossil fuels used in a traditional blast furnace to reduce iron oxides to iron in the direct reduction of iron (DRI) process.

3.1. Hydrogen in Combustion Turbines Emissions Reductions

Industrial combustion turbines have been burning byproduct fuels containing hydrogen for decades, and combustion turbines have been developed to burn syngas from the gasification of coal in integrated gasification combined cycle units. There are several noteworthy physical characteristics of hydrogen that differ from natural gas (i.e., methane) when used as a fuel in utility combustion turbines.

One of the differences between hydrogen and natural gas is the energy density by volume of the gases. To achieve significant GHG reductions from burning hydrogen in a combustion turbine, the volume of hydrogen must be high relative to the volume of natural gas. Blending or combusting such high volumes of hydrogen presents challenges to fuel availability because of limited production and demand from other sectors, infrastructure (i.e., distribution and transportation pipelines, storage), turbine design capabilities, and safety…

[9] U.S. Environmental Protection Agency, Office of Air and Radiation, "Hydrogen in Combustion Turbine Electric Generating Units Technical Support Document" May 23, 2023, https://www.epa.gov/system/files/documents/2023-05/TSD%20-%20Hydrogen%20in%20Combustion%20Turbine%20EGUs.pdf

Hydrogen-enriched fuels have a lower GHG intensity than typical natural gas fuels. To visualize, estimates of the CO_2 emissions reductions as a function of percent hydrogen by volume for the working fuel is shown in Figure 1.

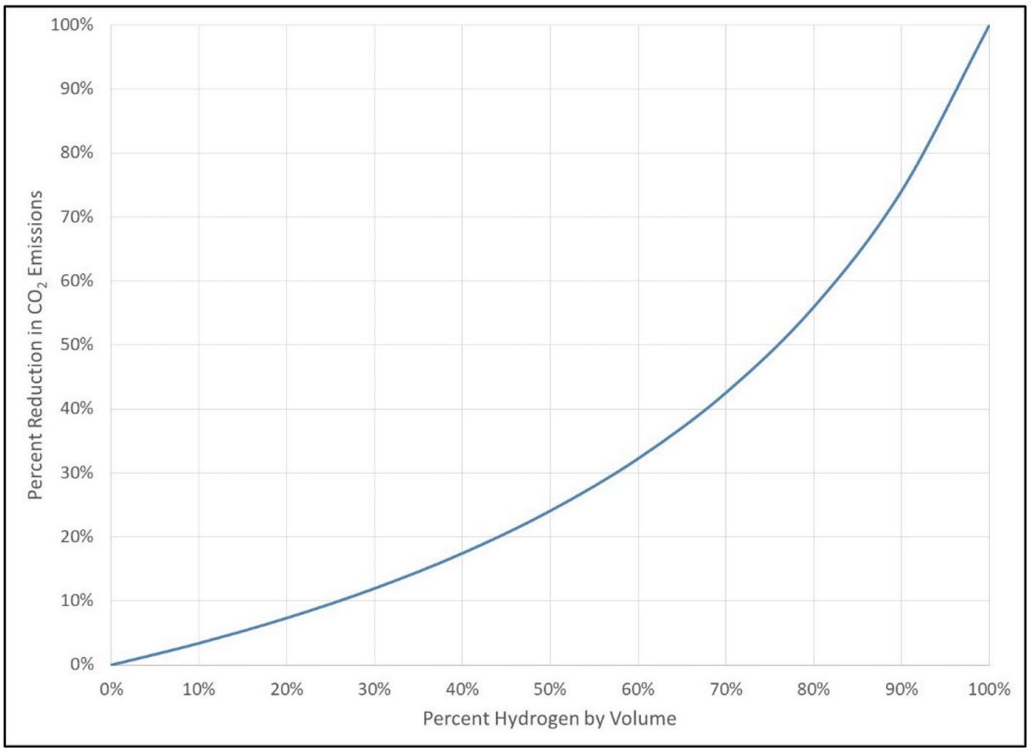

Figure 1: CO_2 Emission Reductions and Percent Hydrogen by Volume

4. Market Forces Slow Growth

In any free-market economy (like the US), When a particular capital product with a long production and delivery time experiences high demand, there is a natural pushback caused by the inability of the market to quickly respond with supply growth to meet that demand. This is currently happening with the gas turbine market.

The CEO of NextEra Energy said that gas turbines have a multi-year backlog, leading to soaring costs for new gas-fired power plants. Renewables "are cheaper and available right now."[10]

The explosive growth of data centers has raised expectations that the U.S. will see a surge in gas consumption. Some forecasts see electricity used for data centers tripling by 2028.

At the CERAWeek conference in Houston in mid-March, oil and gas executives talked excitedly about the growth prospects for gas provided by the AI boom. There was wide speculation that gas would account for much of the new electricity demand.

[10] Ges Outlook, "Costs to build gas plants triple, says CEO of NextEra Energy," March 25, 2025, https://gasoutlook.com/analysis/costs-to-build-gas-plants-triple-says-ceo-of-nextera-energy/

But not everyone saw it that way.

“There is a lot of demand for gas turbines right now. You have to get in a long line. It has pushed the prices up,” NextEra Energy CEO John Ketchum said at CERAWeek. NextEra built 16 gigawatts of gas-fired power over the past two decades, and operates a fleet of 26 GW of gas capacity. It also builds renewable energy.

“We built our last gas-fired facility in 2022, at $785/kW. If we wanted to build that same gas-fired combined cycle unit today…$2,400/kW,” he said. “The cost of gas-fired generation has gone up three-fold.”