

GE Power



GAS POWER SYSTEMS OFFERINGS | **2019**

# POWERING FORWARD

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# CONTENTS

Industry Overview .....	4
GE's Gas Power Systems .....	16
Solutions for Every Application .....	18
Power Plants.....	26
GE's Plant Approach .....	28
9HA Power Plants .....	36
7HA Power Plants .....	40
9F Power Plants .....	44
7F Power Plants .....	48
9E & GT13E2 Power Plants.....	52
7E Power Plants .....	56
LMS100 Power Plants.....	60
LM9000 Power Plants .....	64
6F Power Plants .....	66
LM6000 Power Plants .....	70
6B Power Plants .....	74
LM2500 Power Plants.....	78
TM2500 Power Plants.....	82
Topping Cycle .....	86
Gas Turbine Portfolio .....	90
Fuel Flexibility .....	98
Bottoming Cycle .....	104
HRSG Offerings .....	108
Steam Turbine Offerings .....	112
Heat Exchanger Offerings.....	116
Electrical Conversion.....	118
Generator Portfolio.....	122
Electrical Balance of Plant.....	124
Plant Controls.....	126
Power Generation Validation .....	132
Appendix .....	140

# INDUSTRY OVERVIEW

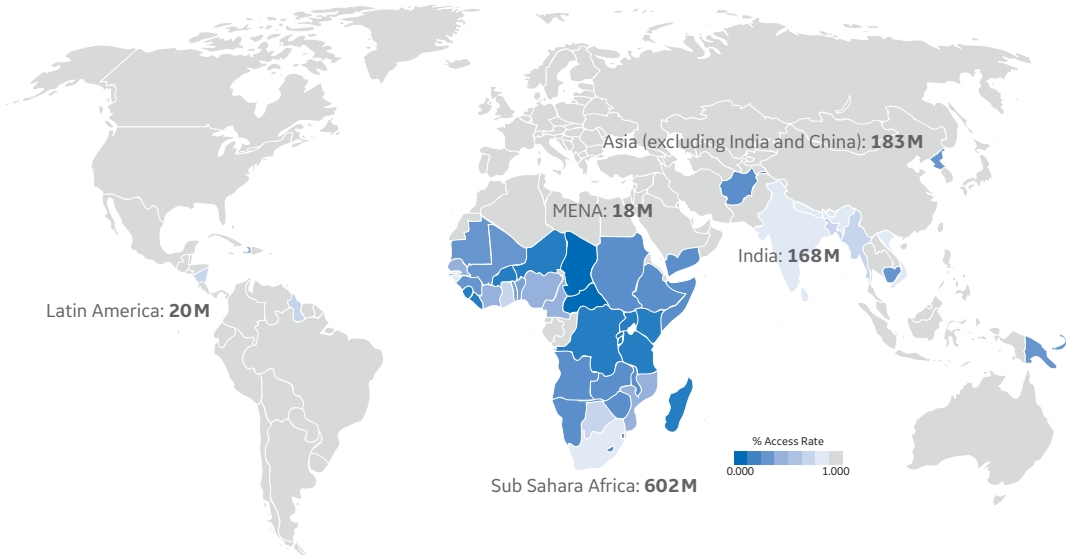
## GLOBAL DEMAND

Access to affordable, reliable energy is critical to sustaining and growing economies and is fundamental to quality of life in the modern world. According to the International Energy Agency (IEA), by 2025, the global economy's gross domestic product (GDP) is expected to grow by approximately 3.5 percent annually and the population will increase by more than 600 million. In line with these economic and demographic forecasts, the IEA projects that total electricity demand will rise by nearly 60 percent through 2040.

Power producers are under a lot of pressure to not only meet growing demand, but to provide access in remote areas, meet advancing regulations, and keep up with evolving technologies. Between new installed capacity and retired plants, IHS forecasts an additional 8,700 gigawatts (GW) of power is expected to be added to the global power grid in the next 25 years.

### Worldwide Access

One out of every six people is without access to electricity.



Nearly **1 billion** people **lack access** to reliable power  
**19%** of power added in the next decade will be **gas power**  
**More electricity** was generated in the U.S. **using gas** than from **any other fuel source** in 2018

### ENERGY DRIVERS

- Economic growth (GDP)
- Population growth
- Industrial vs. service sector growth
- Demand-side efficiency

### CAPACITY DRIVERS

- Environmental policy
- Economic displacement
- Peak demand growth
- Fuel availability and price

Source for worldwide access: IEA World Energy Outlook 2018; <https://www.iea.org/sdg/electricity/>

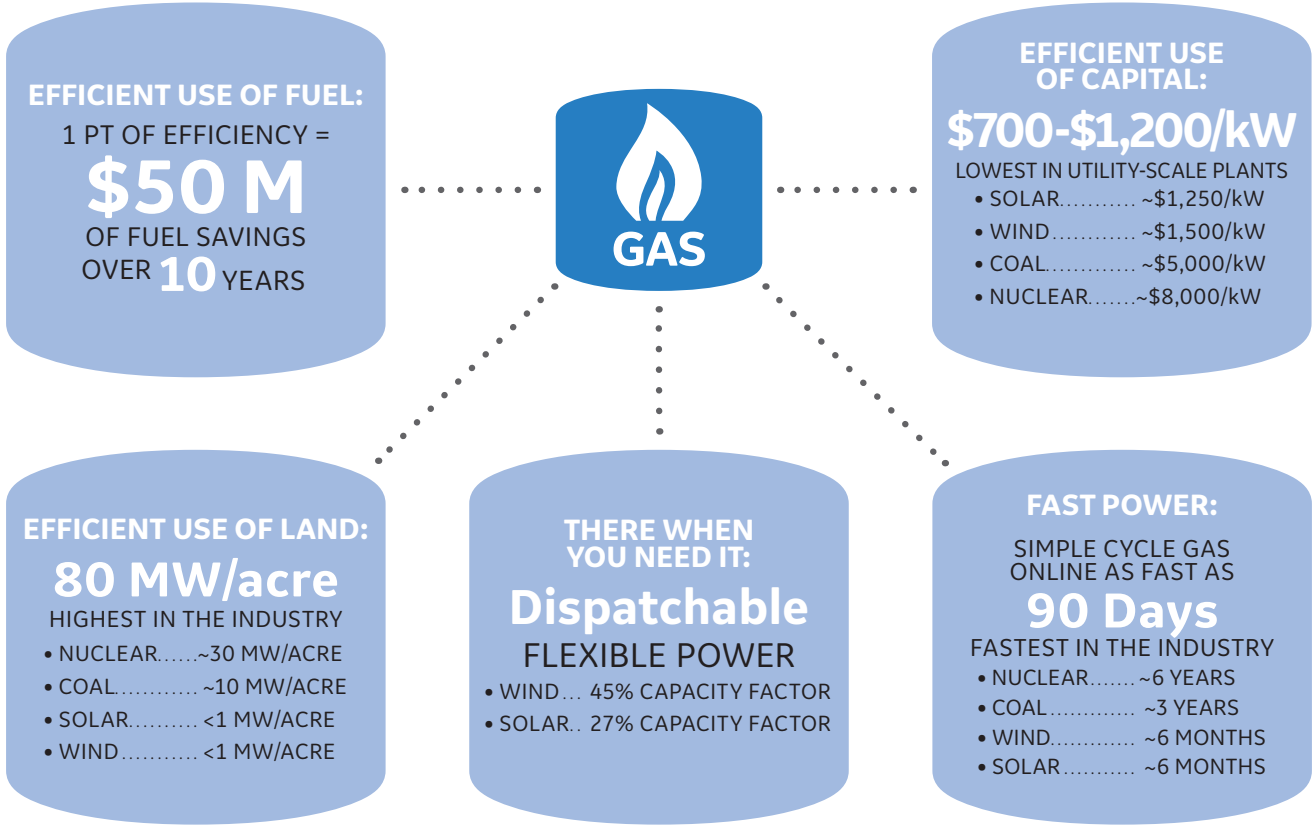
## GAS: A NATURAL CHOICE FOR POWER GENERATION

**Physical** – #1 in constrained environments; produces the most megawatts per square mile

**Financial** – Availability and advancements putting the levelized cost of electricity (LCOE) on par with best-in-class solar and coal

**Environmental** – Fewer emissions than coal or oil

**Sustainability** – Quickest to sync and quickest to reach full load for both renewable daily and seasonal intermittence



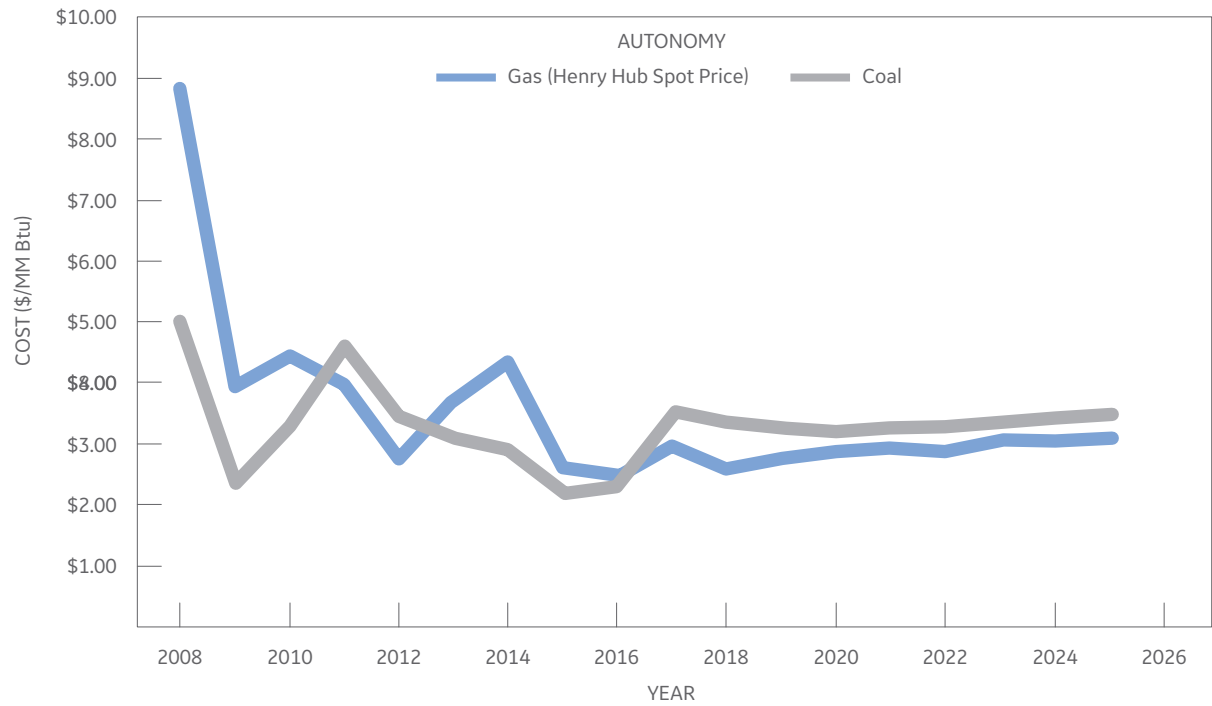
Source: IEA, IHS, EIA, EPRI, DoE EE&RE, GE Marketing

Global policy is evolving, and technology is invoking more environmentally-sustainable outcomes. For power producers, staying the course means embracing a total-plant approach that starts with a practical decision regarding fuel. With its stable price and simple combustion, coal long served as the number one fuel for power plant operators. That ship has sailed, however, and natural gas is taking the helm. By 2040, the IEA expects gas to emerge as the leading fossil fuel generation power player in the global energy mix due to its relatively low emissions and flexibility to be paired with the growing renewables base.

Abundant and Accessible

A combustible, gaseous mixture of simple hydrocarbon compounds, natural gas is the product of thousands of years of decay of prehistoric plant and animal life. Buried deep underground, natural gas consists mostly of methane but also includes small amounts of other gases<sup>1</sup>.

According to the International Gas Union (IGU), natural gas reserves are geographically diverse and so substantial that the fuel could meet the world’s energy needs for the next 250 years. With such high supply, the price has decreased in several regional markets, including North America.



CHALLENGE: TRANSPORTATION

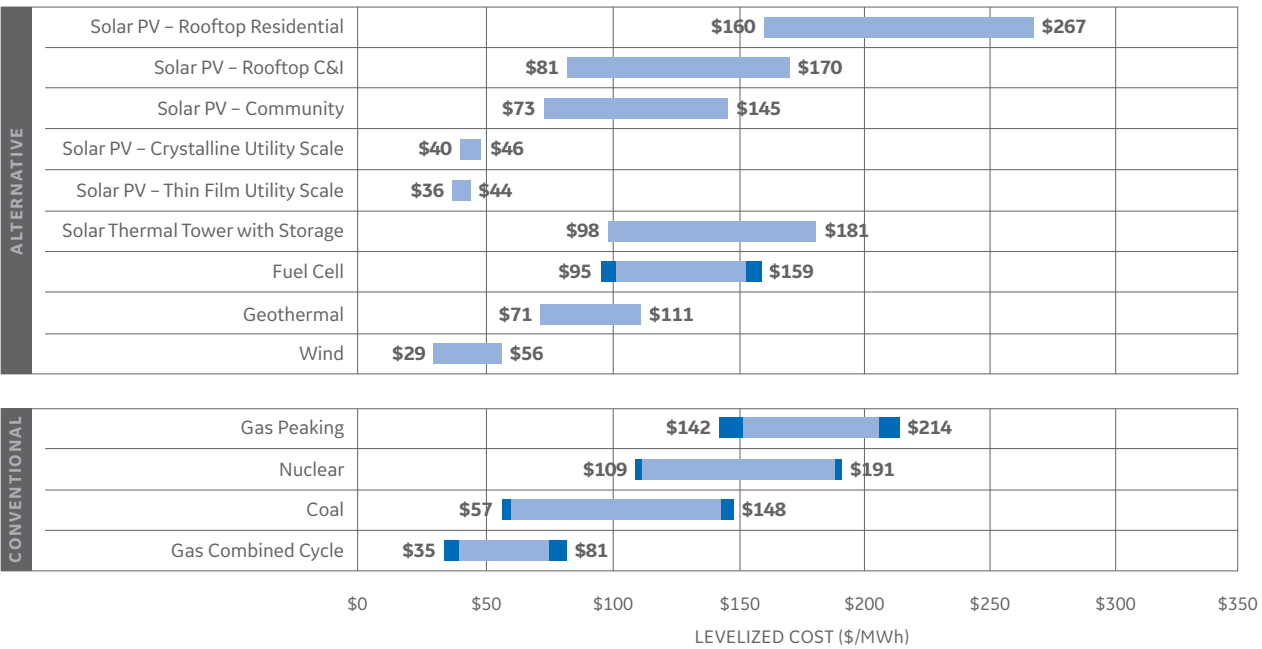
Natural gas is typically transported to end users via pipeline, but logistically this is impossible in some areas. To avoid pipelines, more and more plants are choosing liquefied natural gas (LNG) as a cost-effective alternative. A liquefaction facility cools the gas to -260°F, transforming it to its liquid state. The liquid is then transported—via ship or tanker truck—to an import terminal near the plant where it is warmed, returned to its gaseous state, and piped to the gas turbine.

In the past, power generators needed geographic proximity to gas reserves as well as an infrastructure developed enough to provide pipeline capacity from the fuel source to the plant site. Today, access to natural gas is growing worldwide, fueled by new methods of transportation, including shipping, trucking, and possibly even railway in the future.

Reliable and Efficient

Evolving emissions standards and technological advancements are prompting more and more utilities to incorporate renewable energy. The LCOE for wind and solar has dropped dramatically, with research and development efforts—led by companies like GE—aiming to continue that trend.

Renewable energy has its obvious advantages, and power producers who choose to utilize the shining sun and/or the blowing wind must have a plan for intermittency. With its high supply, low price, resilient supply chain, and stellar performance, natural gas is a great complement to any renewables collection.



NOTE: Darkened areas in horizontal bars represent low end and high end levelized cost of energy corresponding with +/-25% fuel price fluctuations.  
Source: Lazard Levelized Cost of Energy Analysis 12.0

CHALLENGE: BUILDING A POWER PLANT

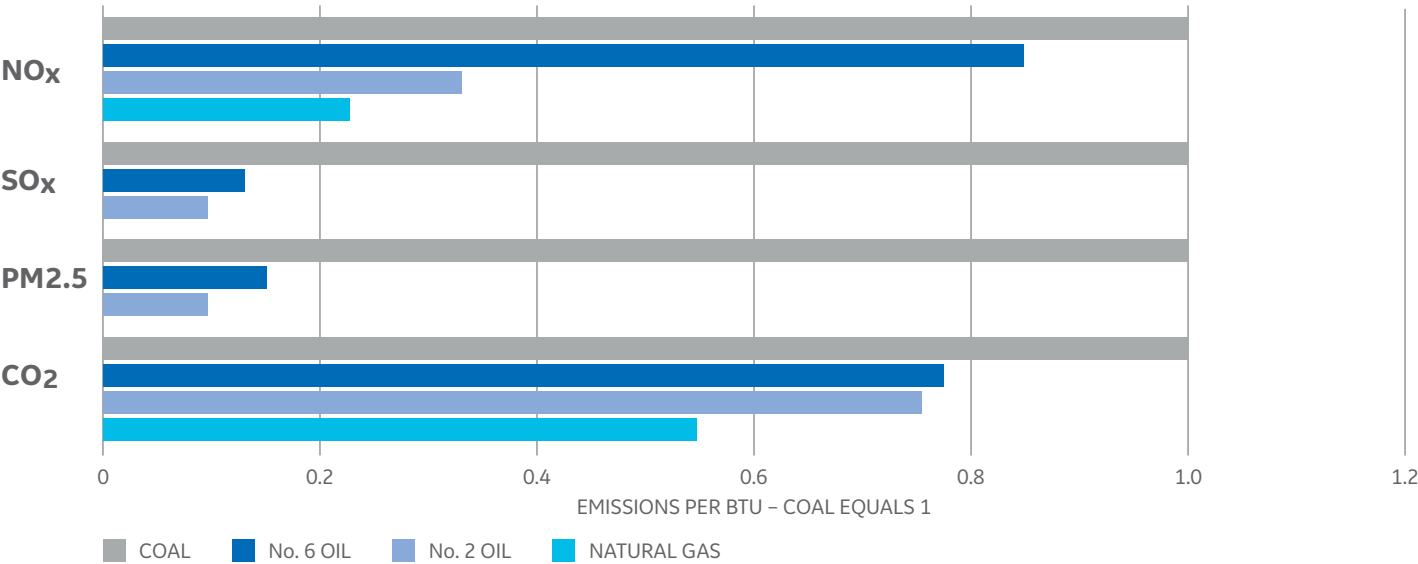
Natural gas or not, using fossil fuel to back up renewable energy requires building a power plant. While this may sound counterproductive, the alternative—battery storage—is not yet a cost-effective option at the scale needed for modern power grids or to shift supply seasonally. Advancing battery storage technology is a key priority at GE, and the operational and environmental benefits that this technology will usher in will be plentiful. Until then—and even beyond—gas-fired plants provide valuable features such as rapid start, output flexibility, and turndown capability, to enable around-the-clock stability.

Natural gas-fired power plants are cheaper and faster to build than plants that utilize other fossil fuels. Logistically, natural gas is land efficient; at around 80 MW/acre, a combined cycle natural gas-fired power plant requires less land than a power plant that fires coal, nuclear, or biomass. This dramatically reduces construction costs and speeds up the construction process. In fact, a 35 MW simple cycle power plant fueled by natural gas can be online in as little as three months, and a 1,650 MW combined cycle power plant can be online in as little as 27 months.

<sup>1</sup> American Gas Association

Cleaner Burning

Perhaps the biggest environmental benefit of natural gas is that it provides a cleaner alternative to coal and other fossil fuels. Burning natural gas produces 50 percent fewer carbon dioxide (CO<sub>2</sub>) emissions than coal and significantly less nitrogen oxide (NO<sub>x</sub>), sulfur oxide (SO<sub>x</sub>), and fine particulate matter (PM<sub>2.5</sub>). Fewer greenhouse gas emissions improves air quality, decreases costs, and helps facilities meet increasingly stringent environmental regulations.



- The IGU has studied the benefits of burning natural gas, noting the following accomplishments from cities across the globe<sup>2</sup>:
- Within four years of converting 30% of its heavy fuel-burning buildings to natural gas, New York City achieved a 69% reduction in SO<sub>x</sub> concentration.
  - Dublin, Ireland, tackled its pollution problems of the 1980s with natural gas. Now, 75% of the city’s residential demand is met by natural gas and the city has seen an 80% to 90% reduction in particulate matter emissions.
  - Over the course of 22 years (1990-2012), natural gas grew from 17% of the energy portfolio in Berlin, Germany, to 41%. This resulted in a 95% reduction in SO<sub>x</sub>, a 76% reduction in NO<sub>x</sub>, and an 83% reduction in particulate matter emissions.

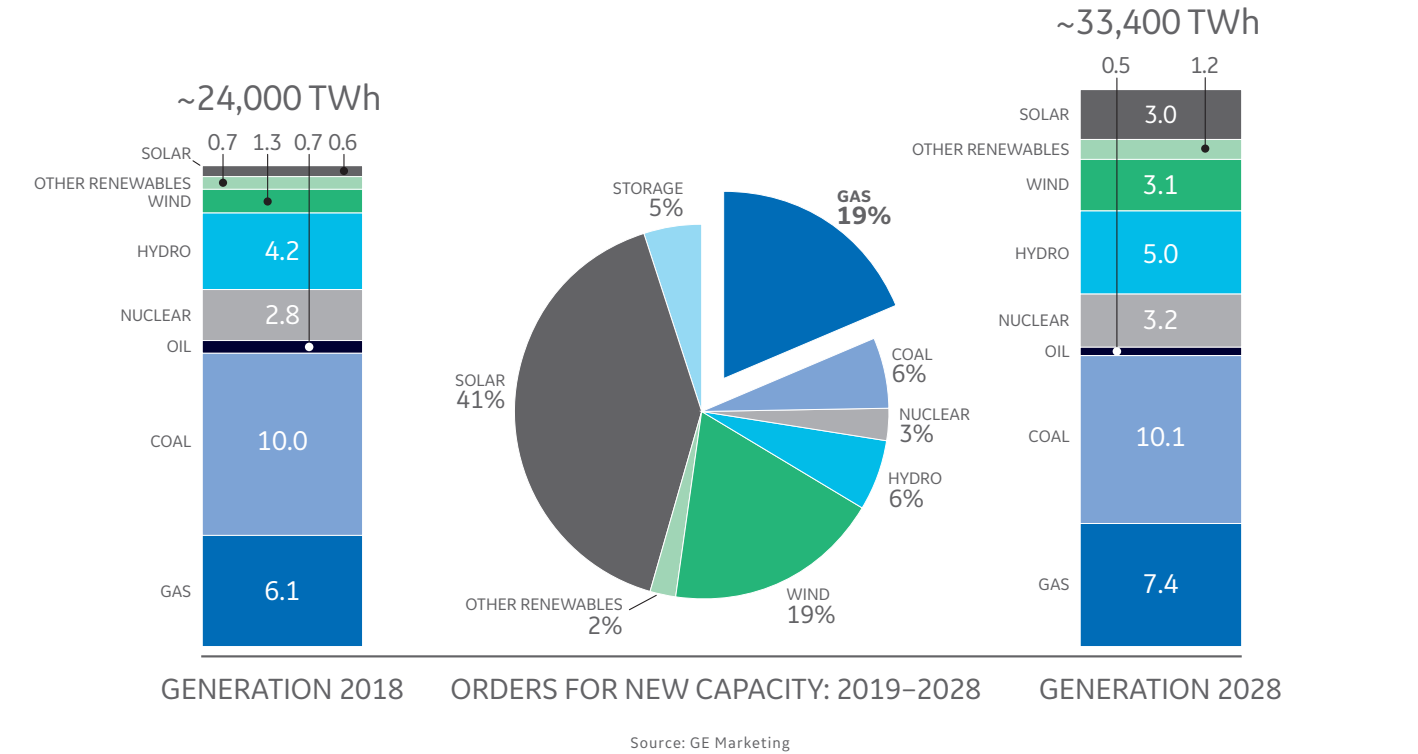
**~24% of global electricity generation in 2025 will be from natural gas**

**A gas-fired power plant produces ~50% less CO<sub>2</sub> emissions per TWh of generation compared to a coal plant**

<sup>2</sup> IGU, Global Natural Gas Insights 2017, page 10

THE FUTURE OF GAS

Gas is the fastest growing of the fossil fuels. Renewable power capacity additions are expected to be twice that of gas additions in the next decade, however larger load factors will cause gas and other fossil fuels to continue to be the primary source of power generation globally.



Regional Outlook

Population growth and economic convergence are shifting the center of energy growth towards emerging markets; China and India are becoming the largest consumers of energy, though with different dynamics.

China is the largest consumer of energy and the second largest consumer of oil (#1 is the United States). However, as its economy rebalances toward domestic consumption and services, China will become less energy intensive, and the pace of Chinese energy demand growth will slow. In India on the other hand, the process of industrialization is about to accelerate, which will drive up demand and increase oil consumption nearly threefold by 2040. Africa, the Middle East, and Latin America are also poised to see significant increases in demand.

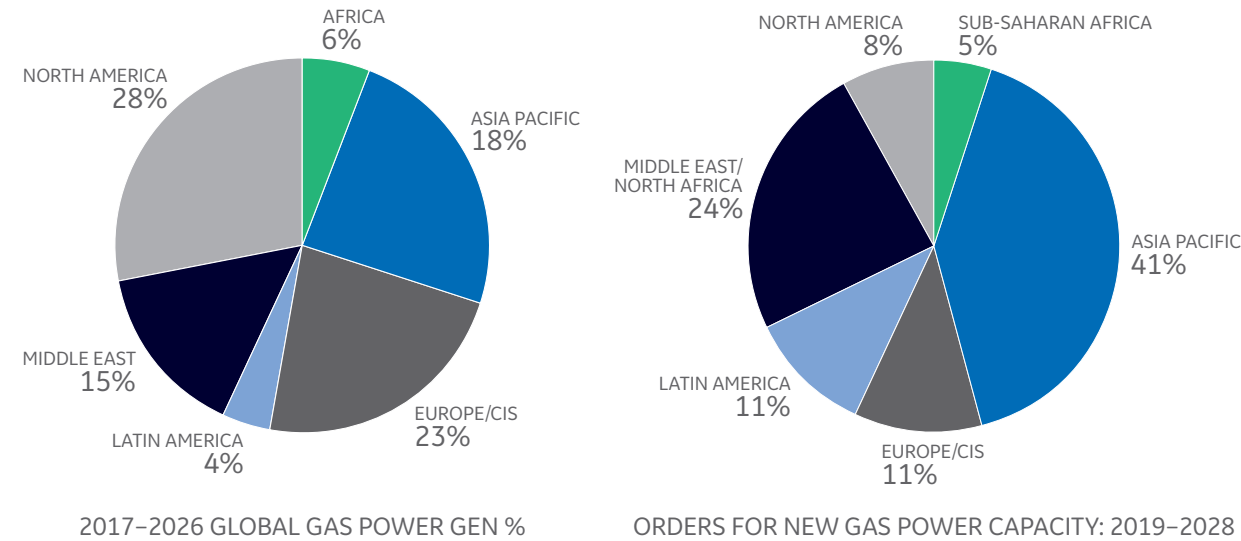
European electricity demand is projected to have the lowest rate of growth at <0.5 percent per year, influenced by slower economic growth, demographic changes, populations shifts, and faster improvements in energy efficiency. Electricity demand in the United States is expected to stabilize close to current levels.

*The first natural gas pipelines—fashioned from bamboo—were constructed in China around 500 B.C.*

Source: American Public Gas Association <http://www.apga.org/apgamainsite/aboutus/facts/history-of-natural-gas>

*For the first time in history, more natural gas-fired power generation capacity is forecast to be added over the next decade than from any other fossil fuel source.*

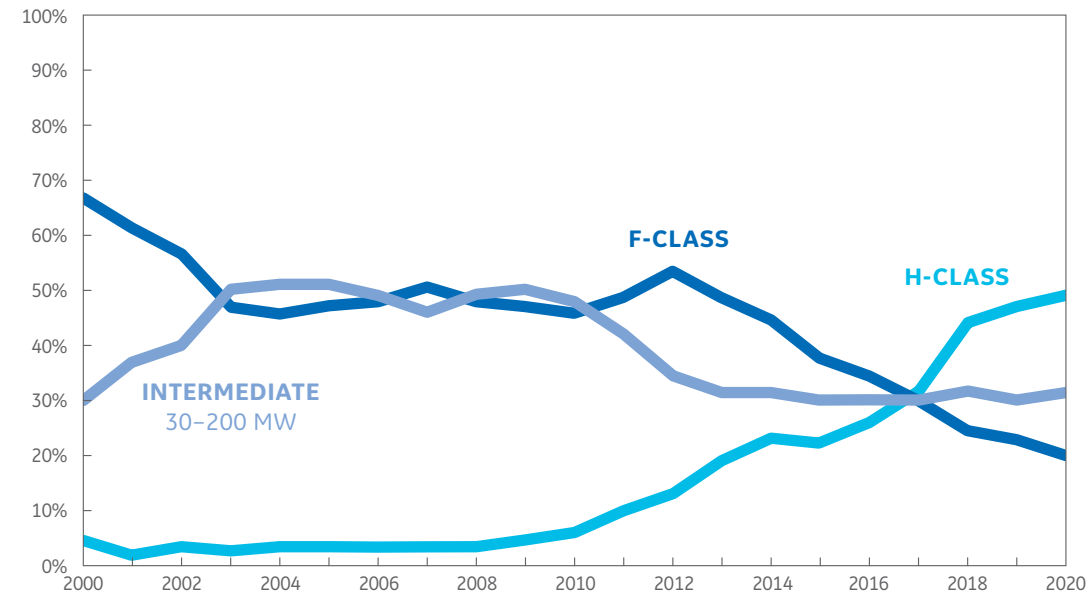
Forecast Demand for Gas Power Over the Next Decade



Source: IEA, IHS, EIA, EPRI, GE Marketing

As countries move forward with large heavy duty gas turbine projects, they are calling for greater efficiency in their gas power systems; H-class technology is answering that call, and the presence of these machines continues to increase, surpassing the volume by capacity of both Intermediate and F-class gas turbines.

Heavy Duty Gas Turbine Market Share (3-yr average by total GW)



Source: IEA, McCoy Power Reports, IHS, EIA, EPRI, GE Marketing

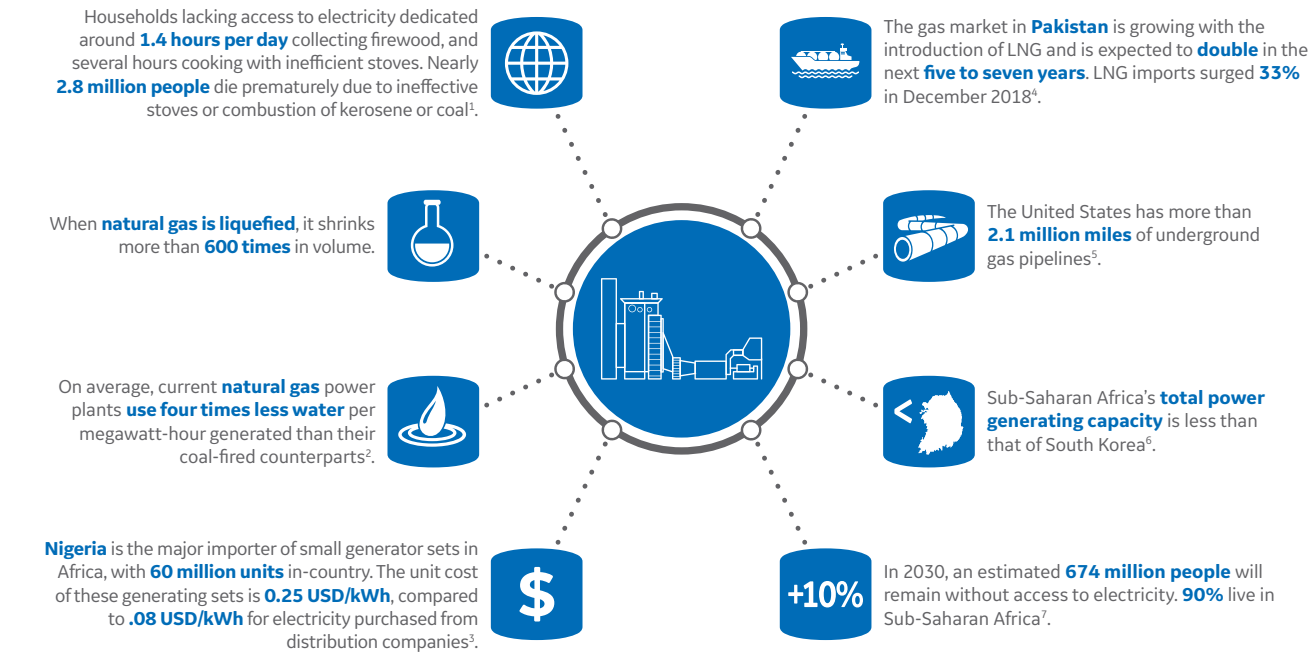
MARKET CONSIDERATIONS

Energy Access

While substantial achievements in science and technology have increased energy access for hundreds of millions of people, many areas of the world face nature-related challenges and infrastructure constraints that limit access to reliable electricity.

NATURE-RELATED CHALLENGES	INFRASTRUCTURE CONSTRAINTS
<ul style="list-style-type: none"><li>• Water availability</li><li>• Temperature, humidity, and seismic constraints</li><li>• Urban and dense populations</li><li>• Rural isolation</li><li>• Effects of climate change on global supply chain</li></ul>	<ul style="list-style-type: none"><li>• Fuel and gas access</li><li>• Grid systems and distribution</li><li>• Phased construction</li></ul>

Natural gas-fired power plants offer a reliable power generating source at an affordable cost. With growing LNG supplies, gas power has quickly become more accessible around the world. Gas-fired power plants can provide efficient, cost-effective power without the need for grid improvements. GE's power generation offerings are designed to perform reliably in austere, life essential, and demanding applications.



Source: <sup>1</sup> "Energy Access Outlook 2017: From Poverty to Prosperity." International Energy Agency. 2017. [http://iea.org/publications/freepublications/publication/WE02017SpecialReport\\_EnergyAccessOutlook.pdf](http://iea.org/publications/freepublications/publication/WE02017SpecialReport_EnergyAccessOutlook.pdf)  
<sup>2</sup> "Water Use Declining as Natural Gas Grows." Climate Central. June 30, 2015. <http://www.climatecentral.org/news/water-use-declines-as-natural-gas-grows-19162>  
<sup>3</sup> "The democratization of electricity in Nigeria." The Electricity Journal. 2018. Elo Adhekpukoli.  
<sup>4</sup> "Proposal to develop LNG storage facilities under consideration" <https://fp.brecorder.com/2019/01/20190123441634>  
<sup>5</sup> <http://www.pipeline101.com/Why-Do-We-Need-Pipelines/Natural-Gas-Pipelines>  
<sup>6</sup> Weak Power Grids in Africa Stunt Economies and Fire Up Tempers." The New York Times. July 2, 2015. [https://www.nytimes.com/2015/07/03/world/africa/weak-powergrids-in-africa-stunt-economies-and-fire-up-tempers.html?\\_r=0](https://www.nytimes.com/2015/07/03/world/africa/weak-powergrids-in-africa-stunt-economies-and-fire-up-tempers.html?_r=0)  
<sup>7</sup> "Energy Access Outlook 2017: From Poverty to Prosperity." International Energy Agency. 2017. [http://iea.org/publications/freepublications/publication/WE02017SpecialReport\\_EnergyAccessOutlook.pdf](http://iea.org/publications/freepublications/publication/WE02017SpecialReport_EnergyAccessOutlook.pdf)

“Energy is the golden thread that connects economic growth, social equity, and environmental sustainability.” — UN Secretary-General Ban Ki-moon

Energy Efficiency

As countries develop, populations swell, new technologies emerge, and demand for energy increases. For governments and individuals, embracing improved total grid efficiency means better economies, better health, a cost-effective way to fight climate change, and reduced energy costs. Industries, utilities, and cogeneration plants, however, bear the burden of selecting and implementing the equipment to make that possible.

For utilities that rely on capacity tariffs for revenue, declining energy intensity can be an issue. In most cases, the cost of installing and servicing equipment is not declining, so this cost must be covered by a decreasing amount of electricity sales. The logical answer, especially in developing countries, is to implement solutions that are energy and fuel efficient.

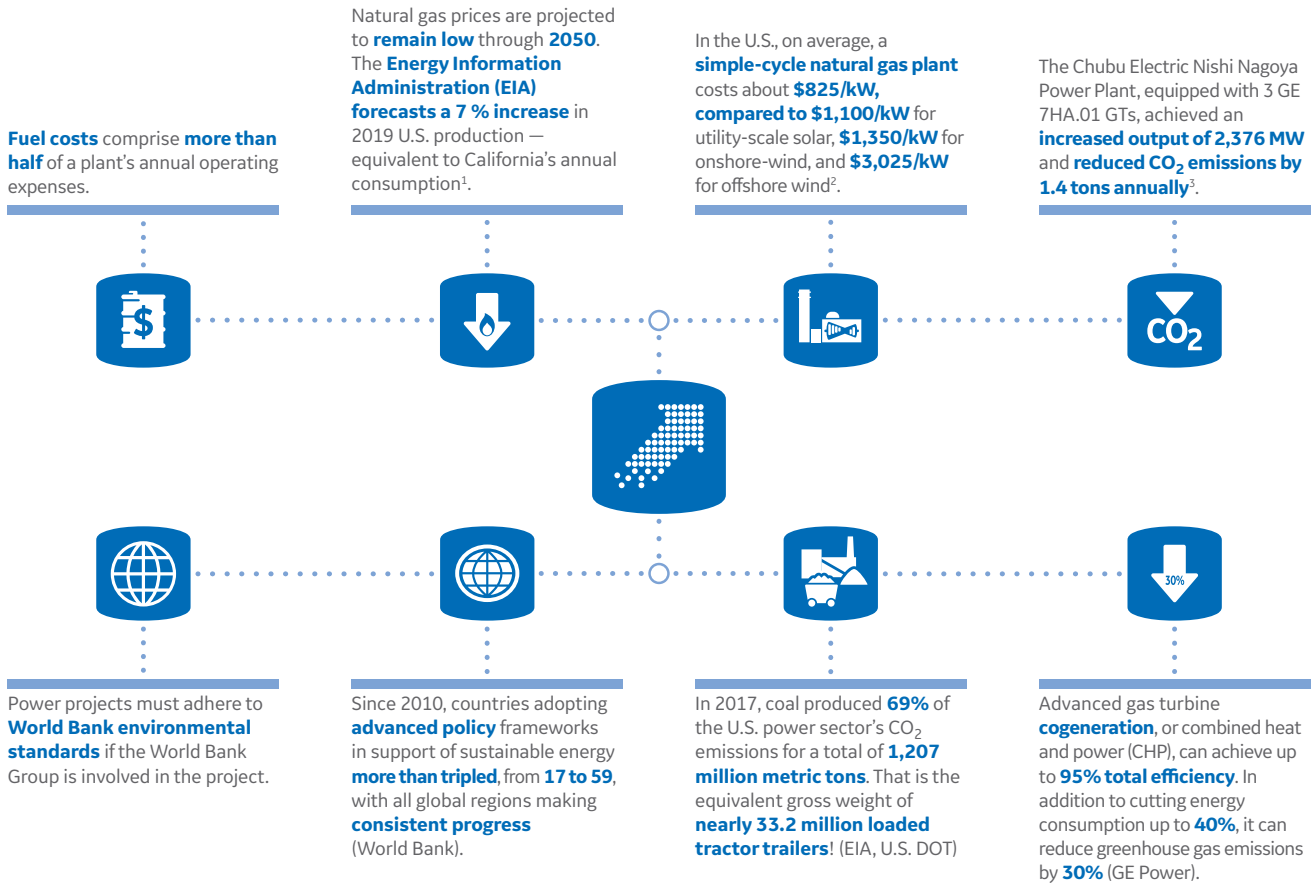
ECONOMIC CONSIDERATIONS

- Plant design efficiency
- Fuel efficiency
- Cycle efficiency

POLICY AND REGULATION CONSIDERATIONS

- Energy conservation and supply-side efficiency
- Decarbonization and reduced fossil fuel usage
- World Bank standards and targets

Thermal power generation technology offers better power density than solar, wind, and biofuels, and higher efficiency plants are dispatched more and can earn significantly more revenue.



Source: <sup>1</sup> "U.S. Shale Oil and Natural Gas, Underestimated Its Whole Life." January 13, 2019. <https://www.forbes.com/sites/judeclemente/2019/01/13/u-s-shale-oil-and-natural-gas-underestimated-its-whole-life/#6dc06c884b59>  
<sup>2</sup> Lazard's Levelized Cost of Energy Analysis – Version 12.0  
<sup>3</sup> "Another World Record for Combined Cycle Efficiency." October 1, 2018. <https://www.powermag.com/another-world-record-for-combined-cycle-efficiency>

Gas and Renewables

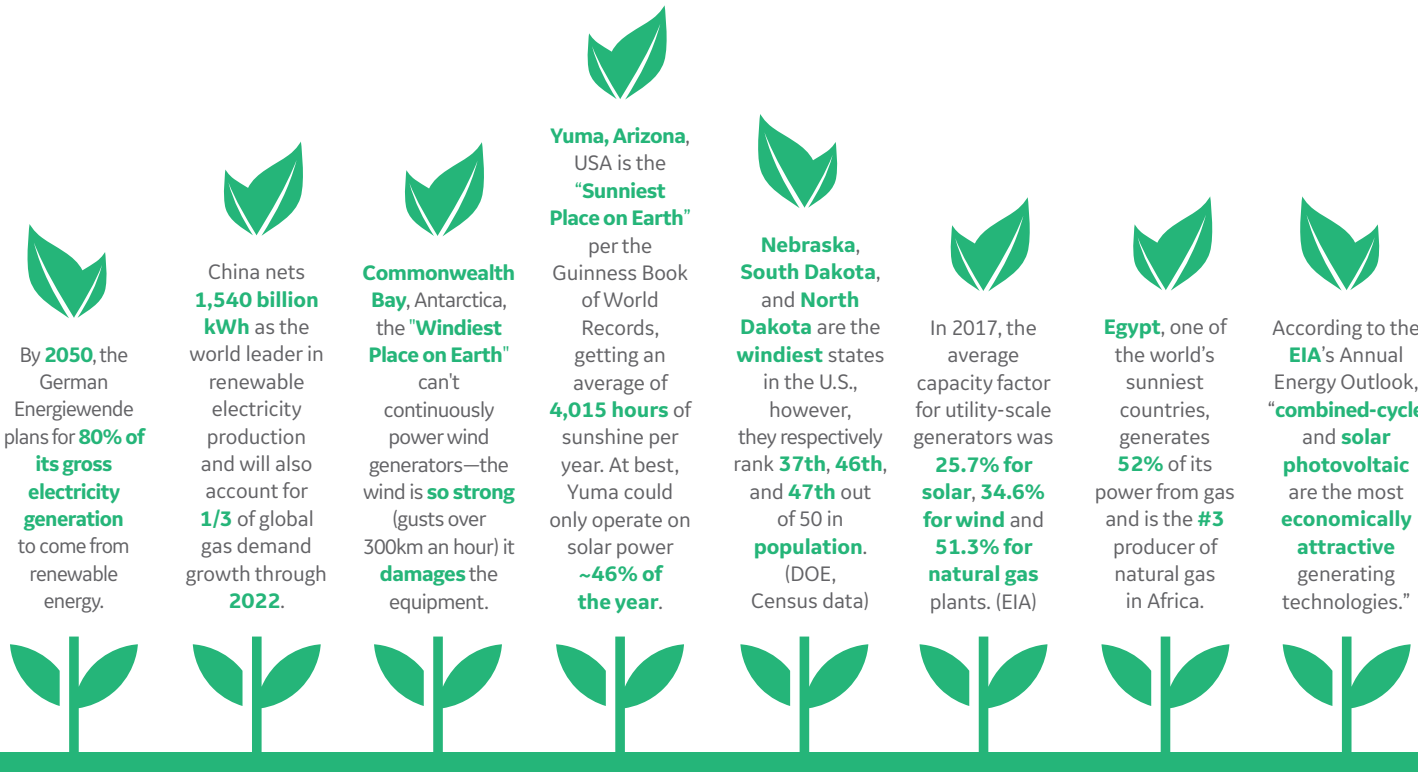
Renewable energy and natural gas are the big winners in the race to meet the demand for power over the next 25 years. The rapid growth in renewables—notably wind and solar power—is changing the electricity supply landscape and how gas turbines are being called on to generate to the grid. The modern power grid needs resources that can ramp up and down swiftly, efficiently, and repeatedly. The operational flexibility is critical for gas turbines that complement renewable energy, as it balances electric system loads and helps to maintain grid reliability.

MULTI-TECHNOLOGY CONSIDERATIONS

- Country-specific regulations
- Integrated solar components
- Energy storage
- Digital solutions

GAS RESOLVING INTERMITTENCY CONSIDERATIONS

- Shift inflexible sources (coal, nuclear, hydro) to flexible technologies
- Fast renewable fluctuations and uncertainty
- Daily and seasonal supply and demand fluctuations with heavy renewables

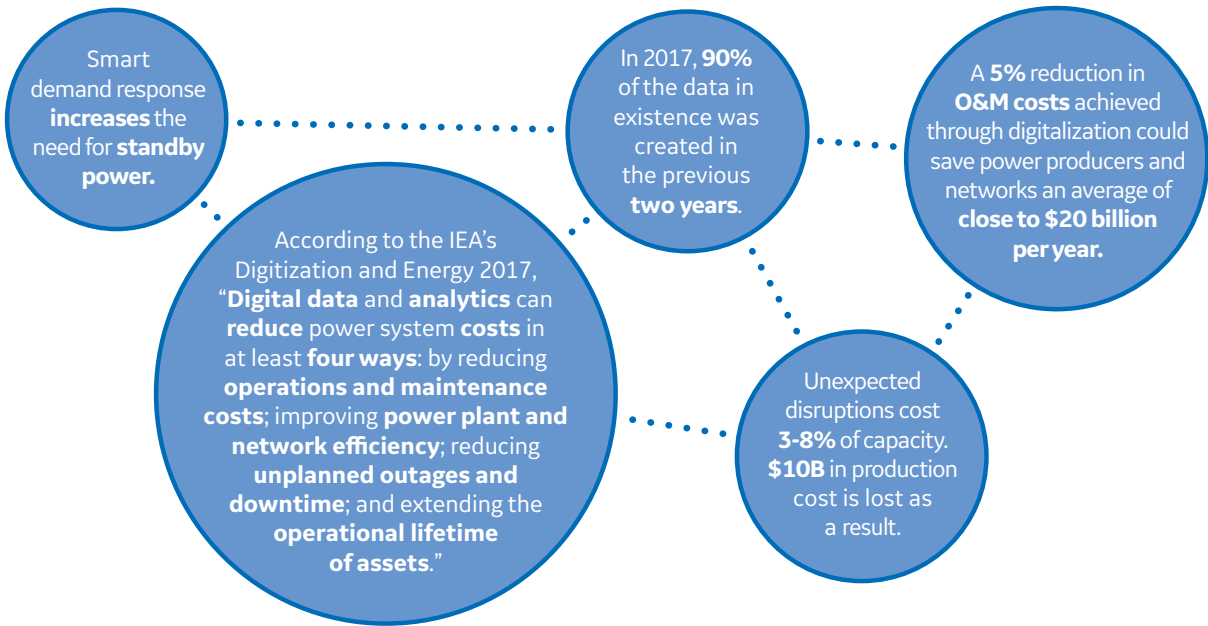


Source: Guinness Book of World Records, S&P Global, EIA, GE Marketing, U.S. DOE, Census Data, IEA



DIGITIZATION

The Information Age has impacted every industry, from retail to healthcare. Power generation has been no exception. While technologies have advanced, the same customer needs remain relevant today: low cost of production, flexible dispatch capability, and a premium on efficiency, reliability, and asset availability. Power producers that choose to invest in digital assets and operations will be better positioned to navigate the industry’s carbon-conscious shift across a more dynamic energy landscape.



Source: IEA, GE Power

Digital technologies enable owners to maximize the flexibility of plant operation on an individual basis. Spanning from software add-ons to fully digital networks and controls, fossil fuel-fired power plants can benefit immensely from GE’s vast digital portfolio of offerings.

OPERATE	ANALYZE	OPTIMIZE
<ul style="list-style-type: none"><li>• <b>A brilliant interface:</b> making the user experience easier</li><li>• <b>A tailored approach:</b> using modular applications to fit customer needs</li><li>• <b>Improved integration:</b> allow different systems to talk to one another, reducing cost</li></ul>	<ul style="list-style-type: none"><li>• <b>Increased availability:</b> identify equipment issues before they become potential failures, minimizing unplanned downtime</li><li>• <b>Data-driven insights:</b> transition from scheduled and reactive maintenance to predictive, reducing waste, lessening downtime, and increasing profitability</li><li>• <b>Improved plant efficiency:</b> with time, machines can learn to detect their own anomalies, meaning fewer repairs and more production</li></ul>	<ul style="list-style-type: none"><li>• <b>Flexibility:</b> balance renewables’ intermittency</li><li>• <b>Security:</b> technology, services, and policies that protect the grid</li><li>• <b>Maintenance:</b> develop policies that meet strategic goals and lessen risk</li><li>• <b>Fuel:</b> based on real-time market and operating information, maximize value by dispatching across all fuel types</li></ul>

Overall savings from digitally-enabled measures could be in the order of \$80 billion per year, a savings of approximately 5% of total annual power generation costs. (IEA)

# GE's GAS POWER SYSTEMS

Tough challenges need to be met with smart solutions. For 125+ years, GE has been delivering innovative products and services that create significant value for power generation customers. Advancing an industry is no easy feat; it takes commitment, knowledge, and above all, an intimate understanding of what customers want and need. GE Gas Power Systems has it all, and we are excited to put our global team to work for you.

Our focus spans three keys areas. First, we give our customers the capability to meet, and possibly even exceed, their project goals with assets that employ the latest cooling, aerodynamics, combustion, and digital technologies. Our claims for performance are backed by rigorous testing and validation that are completed before our products even leave the manufacturing floor. Next, we provide versatility to give our customers the tools and know-how they need to adapt quickly to changing environments. This includes access to a diverse product portfolio that features operational flexibility for startup and turndown, fuel flexibility, and integration with advanced, total-plant controls. Lastly, our commitment to sustainability is unwavering as we seek to provide solutions that benefit not only our customers, but our future generations. That means products that meet or exceed environmental regulations and technical innovations that strive for a cleaner, more prosperous environment.



## FIRST CLASS IN H-CLASS: 7HA.01 | 7HA.02 | 9HA.01 | 9HA.02

When people want to know what's new in the world of gas turbines, they ask GE. Our power generation experience is filled with industry firsts and impressive milestones, culminating in the 2014 introduction of the highly efficient HA gas turbine. Other original equipment manufacturers (OEMs) have followed suit, but none can offer the comprehensive outstanding performance, reliability, efficiency, and expertise that GE does.

Our engineers were the first to hit 63.08 percent efficiency (at Chubu Nishi Nagoya in 2018 with a 7HA.01) and 65 percent efficiency is on our horizon. Advanced materials and evolving combustor technology will put our H-class turbines ahead of the curve with the industry's lowest gas turbine LCOE, building on our heritage of continuous improvement and innovation.

All around the globe, our H-class turbines are delivering flexible and reliable power to millions of people. Our 36 installed units have achieved over 300,000+ operating hours, a number that will continue to grow as GE deploys four dozen additional HA gas turbines to customers in every corner of the earth.

# SOLUTIONS FOR EVERY APPLICATION

From simple cycle and combined cycle power generation to cogeneration, mechanical drive and waste-to-power, GE has the experience, and gas turbines, to serve your needs. Individual operating schemes are vast and varied, and GE is committed to providing a flexible portfolio of products to support a full spectrum of operating needs. GE’s portfolio of power generation products provides a sense of certainty in an uncertain world, delivering the operational flexibility and performance needed to adapt to the rapidly evolving energy environment.

## HEAVY DUTY HIGH EFFICIENCY

The largest and most efficient combined cycle gas turbines are GE gas turbines. As plants shift to more cyclic operation, owners and operators must choose equipment that generates electricity more cost effectively. At GE, flexibility and efficiency co-exist in our HA product line, a suite of highly advanced gas turbines. These turbines are built to last, and their durable architecture welcomes off-nominal operation. A strong case of economics—competitive CAPEX + fuel savings + unprecedented validation—has driven rapid acceptance of our HA offerings from customers, insurers, and lenders alike.

Heavy duty high efficiency turbines increase available energy and generate the highest possible level of revenue by reducing fuel burn and associated costs.



## CASE IN POINT: BANGLADESH

GE Power was selected by Unique Group to develop a 600 megawatt natural gas-based combined cycle power plant at Meghnaghat, near Dhaka, Bangladesh, that will produce power equivalent to the electricity needed to supply about 700,000 homes in the region. GE is developing the project on a turnkey basis which includes one 9HA.01 gas turbine, one heat recovery steam generator, one steam turbine generator, condenser and associated systems. Bangladesh is also making significant investments to enhance its LNG-based electricity generation and projects like the Meghnaghat power plant mark a significant milestone for GE to position its HA technology for high capacity

gas-based power plants in Bangladesh. “The Meghnaghat power project marks Unique Group’s foray into the power sector of Bangladesh. We are excited to partner with GE, whose technological expertise and global experience in managing large scale power projects helped our teams to understand the stringent project proposal parameters and configuration selection. The power plant will be built close to the growth centers in Bangladesh, supplying reliable power to the grid and contributing towards the development of infrastructure in Bangladesh.” said Mohd. Noor Ali, Managing Director, Unique Group.

COGENERATION

Also known as combined heat and power (CHP), cogeneration is a highly efficient process that generates electricity and heat simultaneously. A gas turbine generates electricity while exhaust heat is captured and recycled to generate hot water, steam, or cold water for other uses like heating or cooling. Cogeneration plants can reach up to 95 percent efficiency; their dual use can decrease energy usage by up to 40 percent.

Independent power producers (IPPs) and utilities choose cogeneration for its flexibility and potential money savings. Smaller industrial and commercial entities choose cogeneration—powered by aeroderivative gas turbines—for its predictability and resilience. Cogeneration plants have the innate ability to operate in island mode, meaning they can run independent from the grid in times of emergency, outage, or natural disaster.

GE offers a broad portfolio of gas turbines and aeroderivative gas turbines that support cogeneration in a range of outputs. With more than 10,000 machines already operating in cogeneration applications, GE has the experience and expertise to build an integrated power generation package that fits your needs.

CASE IN POINT: A RANGE OF OUTPUTS

TGK-16

Chasing energy independence and supporting growth in Russia's Republic of Tatarstan, TGK-16, an independent heat and electricity producer owned by TAIF, modernized its Kazan CHP-3 plant in 2017. Conventional gas-fired boilers, producing 420 MW of power, could no longer support the region's increasing demand, so the boilers were replaced with a GE 9HA.01 gas turbine. The upgrade boosted the operating rate by more than half, improved fuel efficiency by 30 percent, and doubled installed capacity to 790 MW. The new unit is bringing a vast improvement in power supply reliability to Kazan City.



BIO-PAPPEL

In 2017, Bio-PAPPEL's San Juan del Rio paper mill in Querétaro, Mexico commissioned a new natural gas-fired cogeneration power plant featuring a GE LM2500+ aeroderivative gas turbine. The 30 MW plant generates electricity and heat for the factory, which primarily makes uncoated wood-free paper in large rolls and cut size paper for printing and copying as well as notebooks for customers in Mexico. In addition to meeting the company's current production goals, the plant is helping Bio-PAPPEL maintain its leadership in Mexico's paper industry while supporting their commitment to sustainability.

FUEL FLEXIBLE

A growing global population, constrained fuel sources, and increasing environmental focus is the trifecta that's driving the quest for high efficiency/low emissions power generation and gas compression. Gas turbines have increasingly become the equipment of choice not only because of their performance, but because their fuel flexibility enables increased energy stability and security. These continuous flow machines feature robust designs and universal combustion systems that demonstrate distinctive capabilities to utilize a wide range of traditional and non-traditional fuels.

Fuel flexible gas turbines give plant owners the versatility to navigate the changing energy landscape by accommodating fuels that either increase energy conversion efficiency and/or are more carbon-neutral.

CASE IN POINT: WUHAN IRON AND STEEL

Wuhan Iron and Steel partnered with GE to grow its operations responsibly, in a way that demonstrated mindfulness of environmental impact. The Chinese company built the world's largest blast furnace gas power plant, reusing the mill's own blast furnace and coke oven waste gases to fuel two GE 9E gas turbines. The Wuhan plant produces 260 tons of steam per hour for steel production and generates 2.4 billion kWh of electricity. Annual output totals 1 TWh with an electrical efficiency greater than 42 percent.




Utilizing waste gas provides a number of benefits for Wuhan Iron and Steel. CO<sub>2</sub> emissions created during the steel production process have been reduced by 2 million tons. The mill also saves a great deal of money by generating 164 MW of its own electricity, and even makes money by selling a portion of that electricity to the local grid.

With steel production levels expected to double between 2010 and 2050, this method of boosting production while reducing emissions and generating on-site power will prove to be a real game changer.

HIGH EFFICIENCY SOLUTIONS (HES)

In a world where 1 percent can equal \$1+ million, efficiency is probably the most critical of all the power plant performance metrics. In fact, at GE we are so obsessed with efficiency that we have teams of scientists and engineers around the world working to advance efficiency-enabling technologies, including combustion and fuel delivery system components.

HES pairs our LM2500 and TM2500 aeroderivative gas turbines with an industry-leading bottoming cycle to create a fast-deploying and highly efficient simple cycle or combined cycle power plant with an output of up to 101 MW.

-  **Speed:** With pre-engineered main modules, 95 percent of the plant design is already complete. This means our simple cycle HES can go from order to power in six months or less. It also means our combined cycle HES deploy two times faster than standard combined cycle power plants.
-  **Performance:** The aeroderivative gas turbines that power our HES are offered with your choice of combustor (single annular or dry low emission (DLE)), dependent upon water availability and performance needs. Both combustors are dual fuel capable, increasing operational flexibility and enabling combined cycle efficiency of up to 53 percent.
-  **Modularity:** Having designed hundreds of custom power plants, GE has optimized the standardization/customization balance. It's not unlike buying a new car where most parts are standard while some options can be selected. Pre-fabrication and modular packaging of the plant's main modules ensure quick and easy installation and relocation.

GAS-TO-POWER

An expanding global natural gas network is creating new opportunities that are driving up demand across industries. Natural gas consumption in 2040 will be close to 45% higher than 2018, growing at just below 2% a year. Low cost, flexible operating characteristics, and environmental advantages position gas as the fuel of choice for power generation. Gas power is fast and affordable, and it’s enabling growth in developing countries. Nearly 90% of global electricity demand growth by 2040 will be in developing economies, where demand is expected to almost double from today’s levels<sup>1</sup>.

Gas-to-power applications support basic human needs and promote investment and economic growth in developing countries. They also act as a dispatchable resource for renewables and can displace high-cost, oil-fired peaking technology.

CASE IN POINT: PANAMA




When a power company in Panama needed a dual-fuel solution that could accommodate imported LNG, they turned to GE’s gas turbine technology. Panama’s power grid is small, and a 3x1 6F.03 combined cycle plant offered best-in-class efficiency and the lowest LCOE among those technologies that cleared in Panama’s auction to prove economic sustainability.

The 350 MW combined cycle power plant achieved commercial operation on natural gas in September 2018, becoming the country’s first natural gas-fired power generation plant. It draws its fuel from a nearby LNG import facility that is currently under construction.

<sup>1</sup> International Energy Agency World Energy Outlook 2018

FLOATING POWER

Floating power is an option in regions with land constraints, offering fast and flexible mobile power that’s easily permitted and financed. As semi-permanent or completely mobile structures, floating power is an ideal solution for the densely populated islands or coastal areas of Asia and Africa that have little to no grid access. With 70 in-service units operating in floating power plant applications and more than 1,400 in-service marine propulsion engines, GE has extensive experience deploying water-based power. Several of our product offerings are optimized for the unique requirements of floating power applications.

-  **Compact:** Small footprints and lean packaging streamline constructability, promote stability on the water, and ensure high power density at a low overall cost. This compact approach applies across the range of net plant outputs without compromising efficiency.
-  **Performance:** Our floating power solutions are available in simple or combined cycle, feature our aeroderivative or heavy duty gas turbine technology, and support dual fuel operation to increase operational flexibility. Solutions that feature heavy duty combined cycle technology boast efficiencies greater than 55 percent in block sizes of up to 250 MW.
-  **Flexibility:** Customer needs drive solution development. We work with our customers to select a plant configuration that best serves their project’s fuel composition, cyclic and baseload operation profiles, emissions and environmental restrictions, and ambient condition variations.

SMALL AND INTERMEDIATE SCALE POWER

Everyone wants reliable, efficient, and sustainable power, but not everyone needs the sheer output of a multi-shaft combined cycle or simple cycle power plant. Small scale power is attractive to those who need to generate on-site power, peaking power for industrial power generation, grid building and stabilization, or emergency supply. Sufficient output for these types of applications is provided by two types of machines: small block gas turbines, and aeroderivative gas turbines. Light weight, high efficiency, fast installation, and simplified maintenance are four distinctive characteristics that drive the small scale power market.

Small and intermediate scale power gives businesses, industry, and rural and remote areas the ability to generate affordable and easy to maintain power quickly and efficiently.

CASE IN POINT: CHUGACH ELECTRIC ASSOCIATION AND ANCHORAGE MUNICIPAL LIGHT & POWER (ML&P)

Chugach Electric Association and ML&P jointly own the 182.5 MW Southcentral Power Project (SPP) in Anchorage, Alaska, which features three 47.6 MW LM6000-PF aeroderivative gas turbines, a steam turbine, and can operate in simple or combined cycle. One of the most fuel efficient plants in Alaska, Southcentral boasts 41.7 percent simple cycle efficiency and ~52 percent combined cycle efficiency.

Known as The Last Frontier, Alaska’s rugged and choppy geography is supported by a small grid running from Fairbanks to the tip of the Kenai Peninsula. Utilities must coordinate closely to take care of customers during outages and emergencies. Generation cannot be installed on a large scale to avoid having a single unit cause a significant power outage. This makes aeroderivative gas turbines an ideal choice for power generation.




For Chugach the turbines at SPP replaced the operation of older, base loaded Frame units in a project that came in several months ahead of schedule and under budget. With the new equipment, Chugach Electric has decreased NOx emissions from about 75 ppm to below 5 ppm and has recorded significant fuel savings for Chugach: \$20 million in 2013, \$17 million in 2014, and \$19 million in 2015. Since commercial operation in February 2013, the plant has achieved 115,000 operating hours on four turbines, 300 starts, and 380 hours per start.



HYBRIDS

Each method of power generation has its pros and cons. For example, wind and solar consume no fuel and emit no greenhouse gases but they are intermittent; natural gas-fired technology is dispatchable but emits greenhouse gases. Uniquely positioned with extensive experience in the full gamut of power generation technologies, GE has created a more affordable, reliable, and sustainable way to deliver power—hybrid power solutions.

Hybrid power plants combine multiple power generation sources, energy storage, and a single controls system, blending the positive features of each to squeeze more value out of your assets.

-  **Generation Sources:** Includes simple or combined cycle gas turbine plants, gas engines, wind, solar photovoltaic, or hydroelectric.
- +
-  **Energy Storage:** Batteries are the most common form; other forms include hydro pumped-storage, flywheels, and compressed gas.
- +
-  **Controls:** Integrated plant controls are built on the Industrial Internet Control System (IICS) and include digital features that optimize performance.

Why Hybrids?

In 2015, the total global installed renewables capacity surpassed the total global installed coal capacity. This trend is an important step towards meeting global emissions goals, but incorporating renewables is not without its challenges. GE’s hybrid solutions are scalable, customizable, and flexible, designed to alleviate these burdens and seamlessly usher in an influx of renewables, providing industrial leading plant integrated solutions to our customers to maximize their assets’ profitability through the lifecycles.

Pick a Challenge, Any Challenge – Hybrids are the Solution

- Integration of variable and distributed generation
- Flat load growth, but faster ramps with higher peaks
- Multiple starts per day
- Thermal fleets dispatched to minimum loads
- Increased need for operating spinning reserve
- Weak grid infrastructure
- Reduced emissions
- And much more...



CASE IN POINT: SOUTHERN CALIFORNIA EDISON (SCE)

SCE installed the world’s first battery storage and gas turbine hybrid system. The LM6000 Hybrid EGT was installed at two sites in California in response to the state’s changing regulations and grid requirements and will ultimately support increasing renewable energy capacity on the grid. The system has been operational since early 2017.

# POWER PLANTS

# GE's PLANT APPROACH

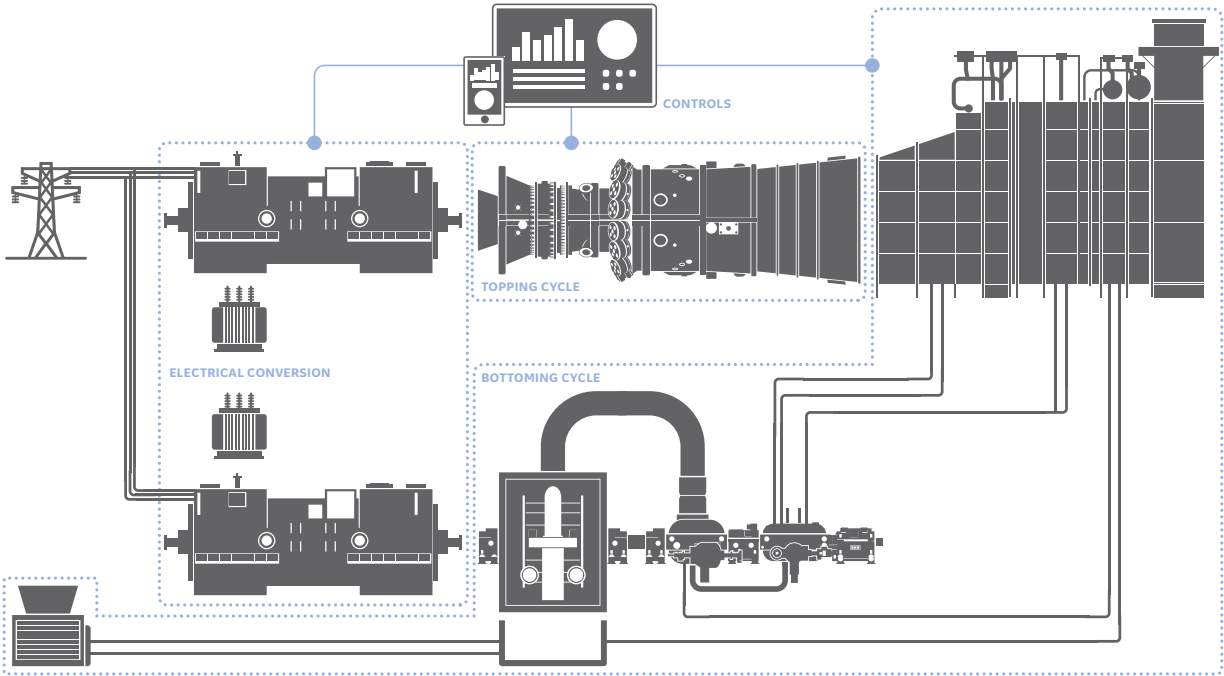
Technology, experience, and people—this combination is what allows GE to deliver the highest value simple cycle and combined cycle power plants anywhere in the world. Our technology provides the lowest life-cycle cost of converting fuel to electricity; our experience spans 125+ years and includes countless impactful innovations and technology improvements; and our people, they work every day to create and deliver ground breaking solutions for customers, partners, and communities around the world.

Our simple and combined cycle power plants are flexible in their operation and include features such as fast start and load ramping, low turndown, and high full- and part-load efficiencies. This flexibility delivers improved plant economics, including:

- Reduced capital costs
- Reduced operation and maintenance costs
- Shorter installation times, reduced installation costs, and fast revenue production
- Improved reliability and availability

GE's integrated approach to plant development means that, from planning through commissioning, we consider individual components as well as balance of plant systems in each decision we make with our customers. This holistic view keeps us focused on your wants and needs and in tune with each selection's impact on the overall product. Each system, and our associated power generation offerings, are discussed in the subsequent sections of this catalog.

- **Topping Cycle:** The gas turbine and its dedicated systems
- **Bottoming Cycle:** The steam turbine, heat recovery steam generator (HRSG), and systems that reject heat to the environment
- **Electrical Conversion:** The systems that produce and export power to the grid or supply power to plant equipment
- **Digital & Controls:** The systems and software that protect, control, monitor, and improve performance of the entire plant



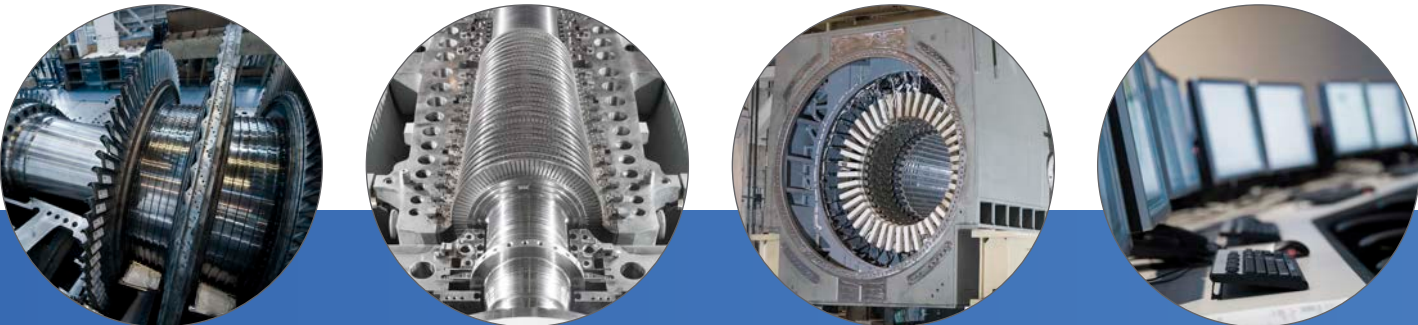
## SOLUTIONS TAILORED TO YOUR NEEDS

It is uncommon to find two plants perfectly alike, which is why you'll find GE working hand-in-hand with customers to develop and build custom-engineered solutions to match unique business and operational needs. Whether the project requires a single gas turbine generator set or a multi-unit turnkey solution, GE has readily available product designs to meet critical power needs quickly.

GE also has a global team of experienced application engineers around the world to support economic analysis and off-design performance of our products to satisfy

any special application, operational, or environmental need. We are committed to defining the best solution with our customers from the foundation of our product performance to other levels of support, whether through customized long-term service agreements, financing solutions, or additional product solutions and services.

Customization starts with product configuration and understanding the right scope of supply that customers and partners need from GE.



*When it comes to financing your project, GE's Energy Financial Services business offers a range of solutions to make your business model and well-defined strategy a reality. A full portfolio of equity investments includes projects with individual companies, partnerships, and both private and public energy companies. For those who require something a little different, GE also offers debt solutions, including options like leasing and limited partnerships.*

CONFIGURATIONS THAT PERFORM

The choice of simple cycle or combined cycle, and single-shaft or multi-shaft depends on numerous customer-specific requirements such as land availability, grid access constraints, funds availability, and expected operating profile. In all cases, GE's high-performance gas turbine-based power plants can meet your unique wants and needs.

EQUIPMENT ONLY TO FULL TURNKEY

With decades of experience and component know-how, GE extracts maximum value out of every piece of equipment we deploy. Whether we work directly with you or through an engineering, procurement, and

construction (EPC) contractor, our scopes of supply are designed to meet individual procurement strategies and risk profiles.

GE supplies as little or as much as you need—from equipment only to full turnkey. Moving beyond equipment enables more comprehensive performance and operability guarantees and reduces the risk of gaps in scope between suppliers and contractors. With the latter, customers may be able to obtain more favorable financing and insurance terms.

EXTENDED SCOPE OF SUPPLY

EQUIPMENT ONLY (EO)

**GE Supplies:** Any combination of gas turbines, steam turbines, generators, HRSGs + accessories + controls

**GE Guarantees:** Equipment performance and equipment delivery

ENGINEERED EQUIPMENT PACKAGE (EEP)

**GE Supplies:** Gas turbine + steam turbine + generator + HRSG + controls + emissions monitoring + critical control valves + condenser

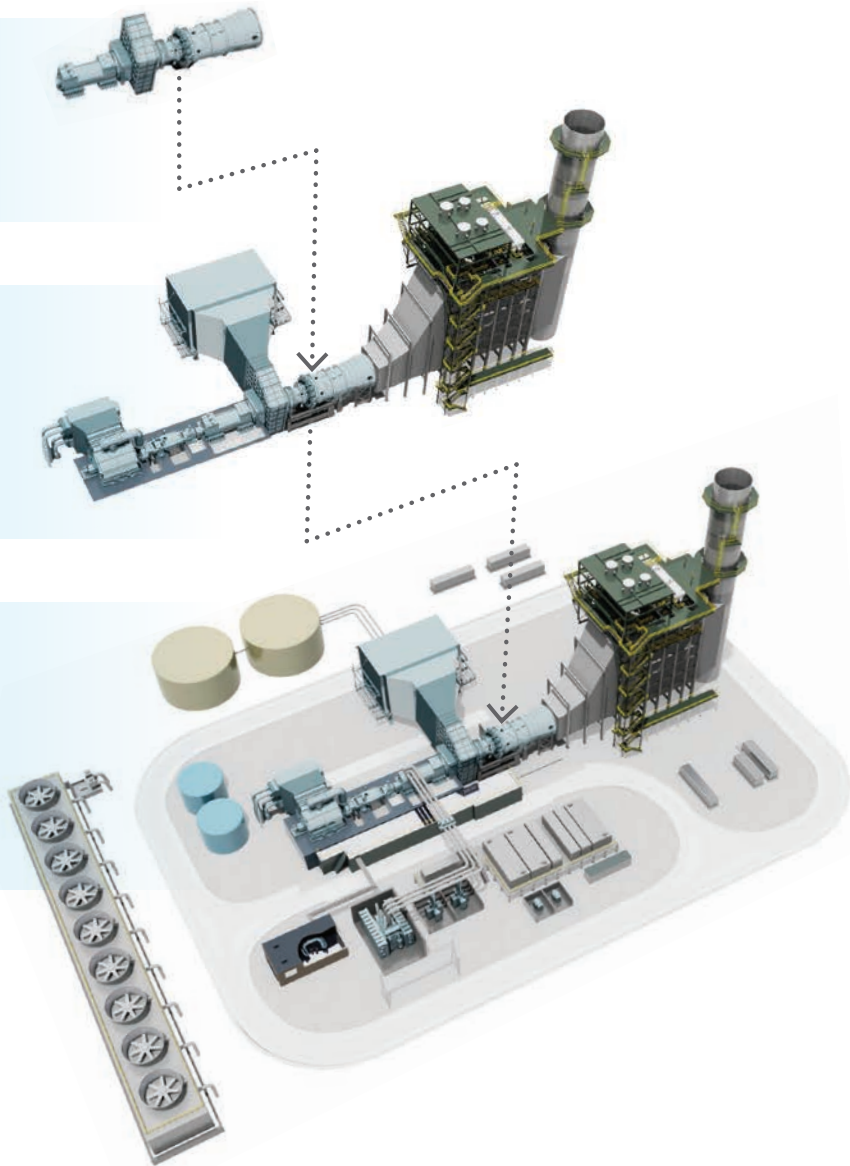
**GE Guarantees:** Combined cycle performance, operability, power island emissions, near-field acoustics, equipment delivery

TURNKEY PLANT (TK)

With partner or self-implement

**GE Supplies:** Various scope from EEP to total plant solution

**GE Guarantees (depending on partner scope split):** Combined cycle performance, operability, plant emissions, far-field acoustics, commercial operation date

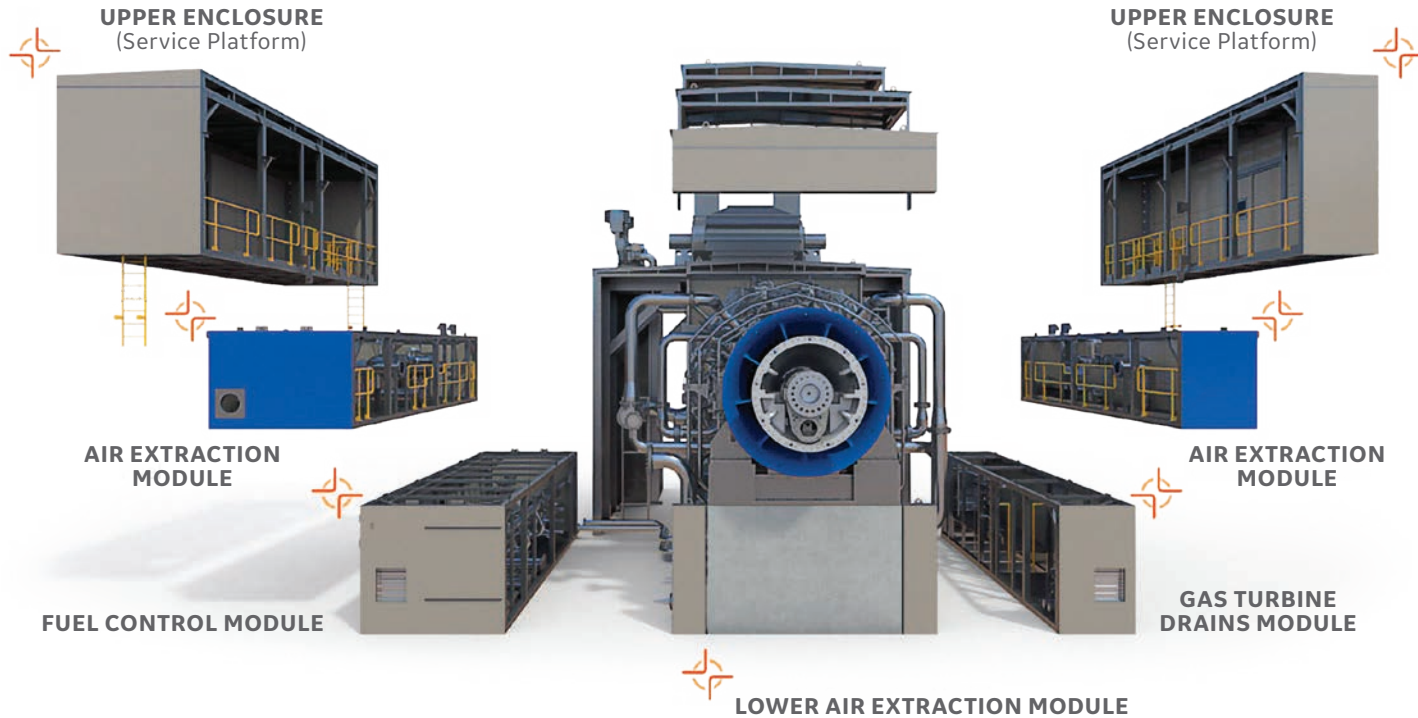


LESS SITE TIME, LESS RISK

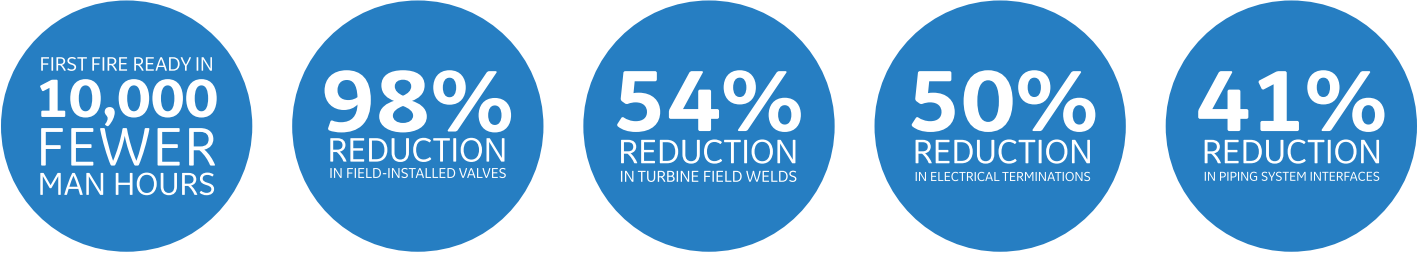
Time is precious, so meeting plant construction milestones is critical to project success. To help promote ease of constructability in all our projects, we have infused our offerings with features that support less on-site work, driving process efficiency and alleviating associated risk.

The main focus is on how we assemble the gas turbine and accessories onsite. GE's HA, 9F.05 and 6F.01 gas turbine enclosures feature a modular architecture with valves,

piping, and electrical systems packaged into stackable modules with segregated work zones. These zones allow for simultaneous installation of electrical, piping, and mechanical systems and reduce safety concerns and delays due to interfering tasks. With significantly more room for maintenance than the F-class, this enclosure—called our prime package—reduces installation time and cost while offering simpler and faster serviceability.



THE GE ADVANTAGE: PRIME PACKAGE



Versus traditional F-class packaging

SERVICE

It is rare to find a gas-fired power plant that operates the same way it did the day it was commissioned. Fluctuations in demand, fuel, and operating envelope require different load factors and characteristics. This ability to rapidly adapt to changing dynamics is often key to long-term sustainability. GE’s Power Services team stands ready to collaborate with you in delivering solutions that drive your competitiveness, profitability, and productive outcomes.

For every customer outcome needs, GE is ready to help with the right service solution and product offerings.

SERVICE PRODUCT OFFERING†

	Aeroderivatives	HDGT – F Class	HDGT – B/E Class	Generator	Steam	Digital	
Outcome	Output	<ul style="list-style-type: none"><li>• LM25/LM6 RePower</li><li>• OpFlex* Peak Performance</li><li>• Steam Injection</li><li>• Compressor Fouling Mitigation (HFWW/ Super Polish Blades)</li><li>• LMS100 PA+ Upgrade</li></ul>	<ul style="list-style-type: none"><li>• 7F AGP Portfolio</li><li>• 9F AGP Portfolio</li><li>• 7F Enhanced Compressor</li><li>• 6F AGP</li><li>• GT24/26 Compressor Upgrade</li></ul>	<ul style="list-style-type: none"><li>• 9E AGP</li><li>• 9EMax</li><li>• 13E MXL2</li></ul>	<ul style="list-style-type: none"><li>• Stator Rewind</li><li>• Rotor Rewind</li><li>• Replacement Generator</li></ul>	<ul style="list-style-type: none"><li>• ASP upgrades for large fossil LP</li><li>• ASP upgrades for D11 HP/IP</li><li>• SEC/DEC 600MW ASP solutions</li><li>• ASP upgrades for Industrial ST OEM</li></ul>	<ul style="list-style-type: none"><li>• Operations Optimization</li></ul>
	Efficiency	<ul style="list-style-type: none"><li>• LM25/LM6 RePower</li><li>• OpFlex* Peak Performance</li><li>• OpFlex VIGV Schedule Optimization</li><li>• Steam Injection</li><li>• Compressor Fouling Mitigation (HFWW/ Super Polish Blades)</li></ul>	<ul style="list-style-type: none"><li>• 7F AGP Portfolio</li><li>• 9F AGP Portfolio</li><li>• 6F AGP</li><li>• GT26 HE</li></ul>	<ul style="list-style-type: none"><li>• 9E AGP</li><li>• 9EMax</li><li>• 13E MXL2</li><li>• 6B AGP</li></ul>		<ul style="list-style-type: none"><li>• Dense Pack Advanced Steam Path upgrade</li><li>• Full Shaft line package for Chinese OEM</li><li>• Fossil Plant Solution for Regulatory Compliance</li><li>• Hitachi/Toshiba Steam Turbine ASP</li></ul>	<ul style="list-style-type: none"><li>• Operations Optimization</li></ul>
	Availability	<ul style="list-style-type: none"><li>• Xtend*</li><li>• Rad-Rad Combustor</li><li>• Core Software and Controls Upgrades</li><li>• Compressor Fouling Mitigation (HFWW/ Super Polish Blades)</li><li>• Asset Performance Management</li></ul>	<ul style="list-style-type: none"><li>• 7F AGP Portfolio</li><li>• 9F AGP Portfolio</li><li>• Rotor Life Management (RLM)</li><li>• Enhanced Compressor</li></ul>	<ul style="list-style-type: none"><li>• 9E AGP</li><li>• 9EMax</li><li>• 13E MXL2</li><li>• Rotor Life Extension</li><li>• 32K Extendor</li></ul>	<ul style="list-style-type: none"><li>• Stator Rewind</li><li>• Rotor Rewind</li><li>• Replacement Generator</li></ul>	<ul style="list-style-type: none"><li>• Valve Upgrades for extended maintenance interval</li><li>• Control System Upgrades</li><li>• ASP Upgrades for AEG KANIS and Wesel</li><li>• Lifetime Assessment and life extension</li></ul>	<ul style="list-style-type: none"><li>• Asset Performance Management (APM)</li></ul>
	Emissions	<ul style="list-style-type: none"><li>• DLE Conversion</li><li>• OpFlex* Automapping</li><li>• Hybrid EGT*</li><li>• OpFlex Auto NOx Biasing</li><li>• Water or Steam Injection for NO</li></ul>	<ul style="list-style-type: none"><li>• DLN2.6+</li><li>• DLN2.6</li></ul>	<ul style="list-style-type: none"><li>• DLN1+</li><li>• AEV</li><li>• EV Alpha</li></ul>			<ul style="list-style-type: none"><li>• Operations Optimization</li></ul>
	Flexibility	<ul style="list-style-type: none"><li>• Hybrid EGT*</li><li>• OpFlex Fast Start</li><li>• Alternative/Dual Fuel Systems Conversion</li><li>• Synchronous Condensing Upgrade</li><li>• LM25/LM6 RePower</li></ul>	<ul style="list-style-type: none"><li>• DLN2.6+</li><li>• 7F AGP Turndown</li><li>• GT24/26 LPL30</li><li>• GT26 EV LPL20</li></ul>	<ul style="list-style-type: none"><li>• DLN1+ LPL30</li><li>• EV Alpha with LPL50</li><li>• AEV with LPL10</li><li>• Fuel Flexibility</li></ul>		<ul style="list-style-type: none"><li>• OpFlex* package</li><li>• Shell Warming System</li><li>• Low Load District Heating</li><li>• Steam Turbines Subject to Flexible Operation</li><li>• Digital ASP</li></ul>	<ul style="list-style-type: none"><li>• Operations Optimization</li></ul>

Regardless of plant type, composition, or asset mix, GE delivers total plant and fleet-level solutions. While delivering tailored solutions for all major power plant components, our broadened understanding of system-wide operation is applied to unleash better performance, lower risk, and to realize greater value across your power generation operations and assets. Our digital solutions blend advanced hardware and software technologies to help achieve productive outcomes for both your operational and business goals.

† For further details on offerings, refer to the Power Service catalog 2019

DIGITAL SOLUTIONS

With growing renewables generation, new regulatory requirements, and numerous other fluctuating conditions, operational needs and business models are continually evolving. Much like operational flexibility, digital is a crucial consideration that affects power plant design and component selection. The convergence of hardware, digital software, and advanced analytics is disrupting the status quo and ushering in a new era where reactive becomes predictive, and limits get pushed to new heights.

GE’s Industrial Internet capabilities are positioning plant and fleet operators to harness and monetize in ways like never before. One example is the Digital Power Plant, a suite of hardware and software solutions that enable our customers to optimize all the critical components to adapt to changing market conditions. Our platform of apps and analytics adds the power you need to break through new barriers in performance, predictability, and profitability.

OUR SOLUTIONS INCLUDE:

Asset Performance Management:

Transform machine sensor data into actionable intelligence by combining robust analytics and domain expertise to provide predictive maintenance towards no unplanned downtime. Create optimal maintenance schedules for increased asset life and use by moving to a condition-based program for machine repairs.

Operations Optimization:

Gain enterprise visibility across power plant and fleet-wide footprints, providing a holistic understanding of the operational decisions that can improve efficiencies, reduce emissions, expand capabilities, and lower production costs.

Business Optimization:

With GE’s intelligent forecasting, portfolio optimization and trading, operations teams can make smart business decisions that reduce financial risk and enhance the profitability of your fleet.

**Predix\*:** GE combined cutting-edge technology with decades of industry experience to create a Platform-as-a-Service (PaaS) that securely ingests machine-grade data at scale and analyzes it to deliver outcomes for industrial customers.

**Cyber Security:** GE’s advanced defense system is designed to assess system gaps, detect vulnerabilities, and protect your critical infrastructure and controls in compliance with cyber security regulations.

# THE HEART OF A COMBINED CYCLE POWER PLANT IS THE GAS TURBINE

# 9HA

## POWER PLANTS

Marrying sheer power with record-breaking efficiency, the 9HA gas turbine delivers a validated, all-around solution for demanding customer economics. It offers the most cost-effective conversion of fuel to electricity as well as industry-leading operational flexibility for increased dispatch and ancillary revenue. Streamlined maintenance completes the offering, creating an ideal solution to meet increasingly dynamic power demands across a range of applications.

		9HA.01	9HA.02
SC Plant Performance	SC Net Output (MW)	446	571
	SC Net Heat Rate (Btu/kWh, LHV)	7,910	7,773
	SC Net Heat Rate (kJ/kWh, LHV)	8,346	8,201
	SC Net Efficiency (% LHV)	43.1%	43.9%
1x CC Plant Performance	CC Net Output (MW)	661	838
	CC Net Heat Rate (Btu/kWh, LHV)	5,378	5,320
	CC Net Heat Rate (kJ/kWh, LHV)	5,674	5,613
	CC Net Efficiency (% LHV)	63.5%	64.1%
	Plant Turndown – Minimum Load (%)	33.0%	33.0%
	Ramp Rate (MW/min)	65	88
	Startup Time (RR Hot, Minutes)	<30	<30
2x CC Plant Performance	CC Net Output (MW)	1,324	1,680
	CC Net Heat Rate (Btu/kWh, LHV)	5,369	5,306
	CC Net Heat Rate (kJ/kWh, LHV)	5,664	5,598
	CC Net Efficiency (% LHV)	63.6%	64.3%
	Plant Turndown – Minimum Load (%)	15.0%	15.0%
	Ramp Rate (MW/min)	130	176
	Startup Time (RR Hot, Minutes)	<30	<30

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



By the end of 2019, 9HA gas turbines will have accumulated over 130,000 fired hours since commercial operation began in July 2016.

446-571 MW  
SIMPLE CYCLE OUTPUT

>64%  
COMBINED CYCLE EFFICIENCY



**CAPABILITY**  
Outstanding grid capability with fast plant response suitable for interconnected grid or captive power plant applications



**VERSATILITY**  
Wide gas variability, including high ethane (shale) gas and LNG



**SUSTAINABILITY**  
Lowest air emissions (NOx, CO<sub>2</sub>) across all forms of fossil fuel-based power generation

# 9HA POWER PLANTS

## CUSTOMER HIGHLIGHTS

### PLTGU JAWA 1

**LOCATION:** Karawang, West Java, Indonesia

**OUTPUT:** 1,760 MW

**HARDWARE:** 2 9HA.02 gas turbines  
2 D650 steam turbines  
2 HRSGs

**COMMISSION DATE:** Mid-2021 (expected)



#### CHALLENGE

As an island nation and the fourth most populated country in the world, Indonesia faces unique challenges when it comes to power generation. With space a concern and reliability a necessity, state-owned electricity firm Perusahaan Listrik Negara (PLN) has set out to achieve a 99 percent electrification rate by 2020. Contributing to this initiative is a new high-output, combined cycle plant in Karawang by a consortium comprising state-owned oil and gas company Pertamina, Japan-based Marubeni, and Sojitz Corporation.

#### SOLUTION

Jawa Satu Power selected a suite of GE’s power generation equipment—including two 9HA.02 gas turbines—for its new 1,760 MW Jawa 1 power plant. GE’s Predix-based Asset Performance Management (APM) software will provide around-the-clock data monitoring and analysis from thousands of sensors throughout the power plant to ensure optimum turbine performance. Jawa 1, which will run on locally sourced LNG, is set to become the largest gas and steam power plant in Indonesia.



**Given Indonesia’s challenging geography, the Jawa 1 combined cycle power plant includes a 170,000 m<sup>3</sup> floating storage and regasification unit (FSRU) for its LNG fuel.**

### TAMBAK LOROK COMBINED CYCLE POWER PLANT BLOCK 3

**LOCATION:** Semarang, Central Java, Indonesia

**OUTPUT:** 780 MW

**HARDWARE:** 9HA.02 gas turbine  
D650 steam turbine  
HRSG

**COMMISSION DATE:** Mid-2020 (expected)



#### CHALLENGE

Indonesia is the fourth most populated country in the world, and the densely-occupied Island of Java is home to more than 140 million people. An ever-increasing population has pushed Indonesia’s power demands to new heights, forcing the islands to redefine the way power is generated, delivered, and maintained. Because of Java’s land restrictions, power plants must have a small footprint and generate the most output per land surface. Energy efficiency is also key, as gas prices tend to be high in South Asia.

#### SOLUTION

Indonesia Power (IP), a wholly owned subsidiary of PT Perusahaan Listrik Negara (PLN), is constructing Block 3 of the Tambak Lorok Combined Cycle Power Plant in Java’s north coast City of Semarang. GE’s record-setting 9HA gas turbine technology will be at the heart of the new 780 MW facility, providing the flexibility and efficiency needed to complement Java’s growing population. The full turnkey solution will pack a lot of punch in a small footprint and offer IP unmatched performance to drive the best economics over the plant’s lifetime.



**The Tambak Lorok Combined Cycle Power Plant Block 3 will generate enough electricity to power the equivalent of more than five million Indonesian homes.**

# 7HA POWER PLANTS

Whether your plant operates at baseload or peaking profiles, you can count on GE's 7HA gas turbine to deliver impressive performance. Its industry-leading operational flexibility enables increased dispatch and ancillary revenue while fuel flexibility accommodates a wide range of gas and liquid fuels, including high ethane (shale) gas and LNG. The 7HA combined cycle plant ramps up to full load in less than 30 minutes and features a novel configuration that supports simplified installation and maintenance.

		7HA.01	7HA.02
SC Plant Performance	SC Net Output (MW)	290	384
	SC Net Heat Rate (Btu/kWh, LHV)	8,120	8,009
	SC Net Heat Rate (kJ/kWh, LHV)	8,567	8,450
	SC Net Efficiency (% , LHV)	42.0%	42.6%
1x CC Plant Performance	CC Net Output (MW)	438	573
	CC Net Heat Rate (Btu/kWh, LHV)	5,481	5,381
	CC Net Heat Rate (kJ/kWh, LHV)	5,783	5,677
	CC Net Efficiency (% , LHV)	62.3%	63.4%
	Plant Turndown – Minimum Load (%)	33.0%	33.0%
	Ramp Rate (MW/min)	55	60
	Startup Time (RR Hot, Minutes)	<30	<30
2x CC Plant Performance	CC Net Output (MW)	880	1,148
	CC Net Heat Rate (Btu/kWh, LHV)	5,453	5,365
	CC Net Heat Rate (kJ/kWh, LHV)	5,753	5,660
	CC Net Efficiency (% , LHV)	62.6%	63.6%
	Plant Turndown – Minimum Load (%)	15.0%	15.0%
	Ramp Rate (MW/min)	110	120
	Startup Time (RR Hot, Minutes)	<30	<30

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



The 7HA gas turbine’s modular packaging configuration shortens the critical path installation cycle by eight weeks.

290-384 MW  
SIMPLE CYCLE OUTPUT

>63%  
COMBINED CYCLE EFFICIENCY



CAPABILITY  
55 MW/minute ramping capability within emissions compliance



VERSATILITY  
Turndown 2x1 plant load to about 15% of baseload while maintaining emissions compliance



SUSTAINABILITY  
Simplified dual-fuel system uses less water and eliminates recirculation

# 7HA POWER PLANTS

## CUSTOMER HIGHLIGHTS

### SEWAREN 7 COMBINED CYCLE POWER PLANT

**LOCATION:** Woodbridge, New Jersey, United States

**OUTPUT:** 538 MW

**HARDWARE:** 1 7HA.02 gas turbine  
1 A650 steam turbine

**COMMISSION DATE:** June 2018



#### CHALLENGE

Committed to providing reliable and environmentally-responsible energy, PSEG Fossil, a subsidiary of PSEG Power, was seeking to retire the four existing units at its 70-year-old Sewaren Generating Station in northern New Jersey. The plant's aging steam generators were no longer capable of meeting PSEG Fossil's ambitious goals for efficiency and emissions. The utility set out to commission a solution that would capitalize on lower gas prices as well as reduce power plant emissions.

#### SOLUTION

PSEG Fossil has replaced units 1, 2, 3, and 4 of the old Sewaren plant with a new 538-MW combined-cycle power plant—Sewaren 7—featuring GE's 7HA.02 gas turbine. In the event of a shortfall in natural gas supply, the turbine is dual-fuel capable and can operate on ultra-low sulfur distillate (ULSD) fuel oil. Compared to the old steam generators, Sewaren 7 produces the same amount of power from half the quantity of fuel and reduces emissions by about 50 percent.



**The 7HA turbine installed at PSEG Fossil's Sewaren 7 combined cycle power plant was the first H-class turbine in the world capable of dual-fuel operation.**

### ANYANG COMBINED HEAT & POWER PLANT – BLOCK 1, UNIT 1

**LOCATION:** Anyang, Gyeonggi Province, Korea

**OUTPUT:** 935 MW

**HARDWARE:** 1 7HA.02 gas turbine  
1 D652 steam turbine  
1 HRSG

**COMMISSION DATE:** May 2018



#### CHALLENGE

The South Korean government is investing in cogeneration—also known as combined heat and power (CHP)—as a way to meet decarbonization and energy efficiency targets. By 2029, cogeneration, which produces heat and electricity simultaneously from a single source of fuel, will account for 12.5 percent of Korea's energy mix. Originally commissioned in 1992, GS Power's Anyang Combined Heat & Power Plant was reaching the end of its operational life. A decline in efficiency and increase in operational difficulties had the company seeking a new solution for the plant.

#### SOLUTION

GS Power selected GE's 7HA.02 gas turbine as the heartbeat for its new 935 MW Anyang CHP plant. Producing the equivalent output needed to power 900,000 Korean homes, the new plant increases electricity generation efficiency by more than 13 percentage points. In district heating mode, the new plant achieves more than 91 percent efficiency and 100 percent of the steam generated is usable for district heating during Korea's brutal winter months.



**“This is a meaningful project that will increase the efficiency at Anyang CHP through the adoption of GE's superior 7HA technology. We will continue to partner with GE for the success of the unit 2-2 renewal project to ensure a stable supply of heat in the Anyang region.”**

**Kim Eung-hwan**  
Vice President, GS Power

# 9F POWER PLANTS

With over 450 units deployed to more than 40 countries, GE has the largest operating and most experienced OEM F-class fleet in the world. Our 9F gas turbine delivers consistent performance and accommodates a diverse range of fuels, making it ideal for a variety of combined cycle and CHP applications. The simple and robust air-cooled architecture is designed for longer parts durability and extended service inspection intervals, making the 9F an ideal choice for life-cycle value.

		9F.04	9F.05
SC Plant Performance	SC Net Output (MW)	288	314
	SC Net Heat Rate (Btu/kWh, LHV)	8,810	8,846
	SC Net Heat Rate (kJ/kWh, LHV)	9,295	9,333
	SC Net Efficiency (% , LHV)	38.7%	38.6%
1x CC Plant Performance	CC Net Output (MW)	443	493
	CC Net Heat Rate (Btu/kWh, LHV)	5,666	5,619
	CC Net Heat Rate (kJ/kWh, LHV)	5,978	5,928
	CC Net Efficiency (% , LHV)	60.2%	60.7%
	Plant Turndown – Minimum Load (%)	48.0%	43.0%
	Ramp Rate (MW/min)	22	24
	Startup Time (RR Hot, Minutes)	30	30
2x CC Plant Performance	CC Net Output (MW)	889	989
	CC Net Heat Rate (Btu/kWh, LHV)	5,649	5,603
	CC Net Heat Rate (kJ/kWh, LHV)	5,960	5,911
	CC Net Efficiency (% , LHV)	60.4%	60.9%
	Plant Turndown – Minimum Load (%)	22.0%	20.0%
	Ramp Rate (MW/min)	44	48
	Startup Time (RR Hot, Minutes)	39	39

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



*The 9F.05 heavy duty gas turbine provides combined cycle efficiency of more than 60% with low 15 ppm NOx emissions. It is an all-around workhorse that provides great hot day performance to maximize customer economics under a wide range of ambient conditions.*

**288-314 MW**  
SIMPLE CYCLE OUTPUT

**>60%**  
COMBINED CYCLE EFFICIENCY



**CAPABILITY**  
Proven reliability/availability with 450+ units sold, more than 22 million fired hours, and 270,000 fired starts



**VERSATILITY**  
Operating in more than 40 countries across the Middle East, China, Europe, India, Asia, and South America



**SUSTAINABILITY**  
Delivers high steam-topower ratio for high fuel utilization on any CHP application (industrial cogeneration, district heating, desalination)

# 9F POWER PLANTS

## CUSTOMER HIGHLIGHTS

### HUADIAN KUNSHAN THERMAL POWER PLANT

**LOCATION:** Kunshan, Jiangsu Province, China

**OUTPUT:** 450 MW

**HARDWARE:** 2 9F.05 gas turbines (flange-to-flange)

**COMMISSION DATE:** October 2017

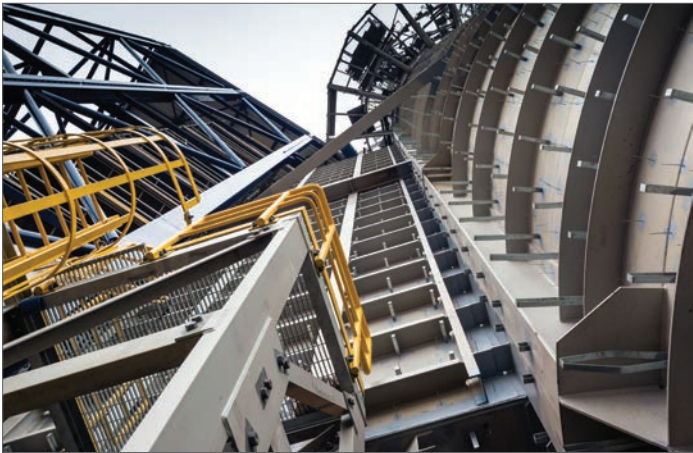


#### CHALLENGE

China Huadian Corporation is one of the largest state-owned power generation enterprises in China, administrated by SASAC for the State Council of the People’s Republic of China. With air pollution a serious concern in China, the government has pledged to offset the decommissioning of coal-fired plants with the addition of gas-fired technology. In line with this goal, China Huadian Corporation set out to build a cogeneration plant that could provide 900 MW of output.

#### SOLUTION

Through Harbin Electric Company Limited, GE provided two 9F.05 gas turbines as a flange-to-flange solution for China Huadian Corporation’s Kunshan Thermal Power Plant. Selected for its high technical scores and commercial evaluation, the 9F.05 came with extended technical support from GE. A dedicated site team ensured plant commissioning—including first fire, synchronization, baseload, and a 168-hour reliability test run—without any unplanned trips by GE. The first unit achieved commercial operation 32 days from first fire, and just 17 days later, the second unit achieved commercial operation.



To ensure all of the customer’s expectations were met, GE hosted a technical seminar with the customer and their installation and commissioning contractors on 9F.05 requirements, including control points, installation sequencing, and necessary tools.

### TUCUMÁN FAST POWER PROJECT

**LOCATION:** YPF’s Generación Tucumán Complex, Tucumán Province, Argentina

**OUTPUT:** 261 MW simple cycle plus an additional 200 MW in combined cycle

**HARDWARE:** 1 9F.04 gas turbine

**COMMISSION DATE:** Simple cycle: February 2018, Combined cycle: June 2020 (expected)



#### CHALLENGE

The Renewable Energy Auction Programme of Argentina (RenovAr) has been a three-part initiative aimed at boosting renewables electricity generation. Under the program the Argentine government tendered 59 projects to generate 2.4 GW of power<sup>1</sup>. Complementing these additions is new gas-fired plants and Argentina’s Fast Power tender aimed to displacing expensive and inefficient generating capacity. Among those projects: a simple cycle (to be converted to a combined cycle) plant to join two others at YPF Luz’s Generación Tucumán Complex.

#### SOLUTION

In just 16 months, GE designed, delivered, built, and commissioned a 261 MW simple cycle gas-fired power plant for YPF Luz. Featuring GE’s 9F.04 gas turbine, the plant provides enough electricity to power more than 280,000 homes. With the project’s time, quality, and performance goals met, work has now begun on the plant’s combined cycle conversion. This will add 200 MW of generation, pushing total output at the Generación Tucumán Complex to 1,300 MW.



As part of the Government of Argentina’s “Fast Power” tender in 2016, GE provided equipment to seven projects totaling 896 megawatts comprising 9F, LMS100, and TM2500 gas turbines.

<sup>1</sup> The World Bank. <https://www.worldbank.org/en/results/2018/02/15/argentina-taps-its-renewable-energy-potential>

# 7F POWER PLANTS

The demands of today’s power generation industry are many: low cost of electricity, dispatch volatility, along with high efficiency, reliability, and asset availability. With approximately 900 installed units producing ~150 GW of power in 12 countries, GE’s 7F gas turbine is a proven performer in all these areas. Among its features, the 7F.05 provides 99.7% reliability, which enables more than eight additional days of operation per year than the industry average.

		7F.04	7F.05
SC Plant Performance	SC Net Output (MW)	198	243
	SC Net Heat Rate (Btu/kWh, LHV)	8,840	8,570
	SC Net Heat Rate (kJ/kWh, LHV)	9,327	9,042
	SC Net Efficiency (% , LHV)	38.6%	39.8%
1x CC Plant Performance	CC Net Output (MW)	305	376
	CC Net Heat Rate (Btu/kWh, LHV)	5,715	5,649
	CC Net Heat Rate (kJ/kWh, LHV)	6,030	5,960
	CC Net Efficiency (% , LHV)	59.7%	60.4%
	Plant Turndown – Minimum Load (%)	58.0%	46.0%
	Ramp Rate (MW/min)	30	40
	Startup Time (RR Hot, Minutes)	28	25
2x CC Plant Performance	CC Net Output (MW)	615	756
	CC Net Heat Rate (Btu/kWh, LHV)	5,676	5,649
	CC Net Heat Rate (kJ/kWh, LHV)	5,989	5,960
	CC Net Efficiency (% , LHV)	60.1%	60.4%
	Plant Turndown – Minimum Load (%)	27.0%	22.0%
	Ramp Rate (MW/min)	60	80
	Startup Time (RR Hot, Minutes)	28	25

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



*The 7F.05 achieves a field-validated and customer-accepted 10-minute cold start to 200 MW on natural gas and liquid fuel.*

**198-243 MW**  
SIMPLE CYCLE OUTPUT

**>60%**  
COMBINED CYCLE EFFICIENCY



**CAPABILITY**  
Field replaceable compressor blades reduce downtime and outage costs



**VERSATILITY**  
Only F-class that burns Arabian Super Light; also offers 15% CO<sub>2</sub>, +20%/-10% Modified Wobbe Index, and 5% hydrogen



**SUSTAINABILITY**  
Continually leading the way since being the first F-class to achieve 5 ppm NOx emissions

# 7F POWER PLANTS

## CUSTOMER HIGHLIGHTS

### ALAMITOS ENERGY CENTER

**LOCATION:** Long Beach, California, United States

**OUTPUT:** 640 MW

**HARDWARE:** 2 7F.05 gas turbines

**COMMISSION DATE:** Mid-2020 (expected)

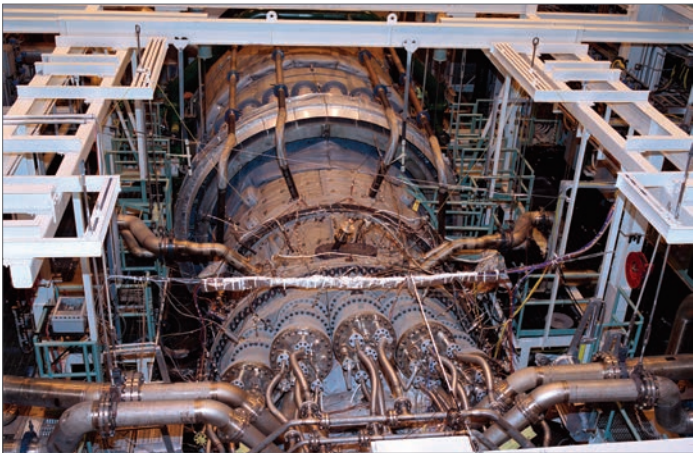


#### CHALLENGE

In an effort to usher in cleaner, more environmentally-friendly power generation technology, the California state government has enacted legislation that significantly reduces the amount of ocean water power plants can use to cool steam generators. AES Corporation's Alamos Generating Station, a natural gas-fired plant operating in Long Beach since the 1950s, is not equipped to meet the new mandates. AES set forth a plan to develop a new, more modern and efficient plant with a smaller footprint.

#### SOLUTION

AES Alamos, a subsidiary of AES, is constructing the 640 MW Alamos Energy Center, a natural gas-fired, combined cycle, air-cooled power plant with two GE 7F.05 gas turbines at the helm. In addition to being half the size of the existing plant, the new plant will eliminate the use of ocean water for cooling and reduce fresh water use by 70 percent. A modern solution, Alamos will also feature a 100 MW battery energy storage system for seamless integration of renewable energy.



**“Not only will the plant be more efficient and use about half as much fuel to generate the same amount of power, it will be highly flexible, meaning it can start and stop quickly and ramp up and down to more closely match energy demands.”**

**Dalia Gomez**  
AES spokesperson


### CRICKET VALLEY ENERGY CENTER

**LOCATION:** Dover, New York, United States

**OUTPUT:** 1,100 MW

**HARDWARE:** 3 7F.05 gas turbines  
3 A450 steam turbines  
3 HRSGs

**COMMISSION DATE:** First Quarter 2020 (expected)



#### CHALLENGE

In 2017, the Indian Point Energy Center in New York's Hudson Valley scheduled its early and orderly shutdown for 2020-2021. The two-unit nuclear power plant generates approximately 2,000 MW of electricity, which accounts for approximately 25 percent of the electric power used in the region. To help lessen the energy gap that the plant's closure will cause, the New York State Public Service Commission has been seeking new, high-efficiency, low-emissions power generation options.

#### SOLUTION

One of the commission's approved projects, the natural gas-fired 1,100 MW Cricket Valley Energy Center, will use three GE 7F.05 gas turbines in combined cycle to generate enough power for nearly one million homes. The facility is being constructed by Bechtel for a consortium of owners, including Advanced Power. In addition to its highly-efficient, low-emissions turbines, the plant will include a rooftop rainfall capture system that will contribute to a 98 percent reduction in water use.



**GE Capital's Energy Financial Services served as a co-lead arranger and administrative agent to help secure approximately \$1 billion in senior-secured credit facilities for the project. This money is being used to support construction/operation of the plant.**

# 9E&GT13E2

## POWER PLANTS

Whether meeting peak loads, providing baseload heat and power, or driving industrial processes, GE’s 9E/GT13E2 heavy duty gas turbines deliver power and performance while maintaining the simplicity and operational strengths expected of the E-class fleet. GE’s 9E/13E2 power plants operate in the most rugged conditions, from arctic cold to extreme desert heat, and burn a wide range of fuels, from syngas to propane to crude oil. The 9E.04 delivers more power and performance with a new 4-stage turbine, while the GT13E2 offers a flexible extended maintenance concept that reduces operating costs while saving fuel.

		9E.03	9E.04	GT13E2
SC Plant Performance	SC Net Output (MW)	132	145	210
	SC Net Heat Rate (Btu/kWh, LHV)	9,860	9,210	8,980
	SC Net Heat Rate (kJ/kWh, LHV)	10,403	9,717	9,474
	SC Net Efficiency (% LHV)	34.6%	37.0%	38.0%
1x CC Plant Performance	CC Net Output (MW)	204	216	305
	CC Net Heat Rate (Btu/kWh, LHV)	6,399	6,220	6,189
	CC Net Heat Rate (kJ/kWh, LHV)	6,751	6,563	6,530
	CC Net Efficiency (% LHV)	53.3%	54.9%	55.1%
	Plant Turndown – Minimum Load (%)	45.0%	46.0%	39.0%
	Ramp Rate (MW/min)	50	16	14
	Startup Time (RR Hot, Minutes)	38	38	30
2x CC Plant Performance	CC Net Output (MW)	410	436	613
	CC Net Heat Rate (Btu/kWh, LHV)	6,353	6,180	6,153
	CC Net Heat Rate (kJ/kWh, LHV)	6,703	6,520	6,492
	CC Net Efficiency (% LHV)	53.7%	55.2%	55.5%
	Plant Turndown – Minimum Load (%)	22.0%	22.0%	19.0%
	Ramp Rate (MW/min)	100	25	28
	Startup Time (RR Hot, Minutes)	38	38	30

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



GE’s 9E.04 shares the same footprint as the 9E.03 but delivers 9.8% more power and 2.4% more efficiency.

132-210 MW  
SIMPLE CYCLE OUTPUT

>55%  
COMBINED CYCLE EFFICIENCY



**CAPABILITY**  
Burns more than 50 types of fuels; operates in ambient conditions ranging from -40°F to 120°F



**VERSATILITY**  
Capable of order to operation in less than six months



**SUSTAINABILITY**  
World Bank-compliant, including dual fuel heavy fuel oil plants

# 9E & GT13E2 POWER PLANTS

## CUSTOMER HIGHLIGHTS

### KELAR COMBINED CYCLE POWER PLANT

**LOCATION:** Mejillones, Chile

**OUTPUT:** 517 MW

**HARDWARE:** 2 GT13E2 gas turbines

**COMMISSION DATE:** December 2016

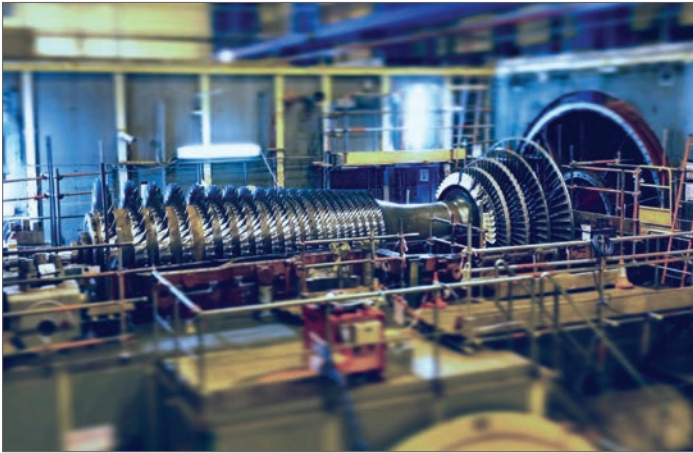


#### CHALLENGE

As the world’s largest copper supplier, Chile produces more than 5 million tons of the metal per year, accounting for more than 30 percent of the global supply<sup>2</sup>. BHP Billiton, a major player in the world of copper mining, commissioned a consortium, which contracted with an EPC, to execute its vision of responsible and sustainable growth via the construction of a new power plant. Flexibility and reliability were key. Because the plant would utilize LNG, which is expensive in the region, BHP Billiton also required a power generation solution that offers high efficiency and availability.

#### SOLUTION

The consortium and EPC selected two GT13E2 heavy duty gas turbines to power BHP Billiton’s 517 MW Kelar combined cycle power plant. LNG-fired gas plants are not a typical choice to power mining operations, but with LNG and the two GT13E2 turbines, Kelar should be able to achieve around 54 percent overall plant efficiency. In keeping with BHP Billiton’s commitment to sustainable growth, the Kelar plant is expected to replace coal-based power generation in Chile, offsetting up to 1.5 million tons of CO<sub>2</sub> emissions per year<sup>3</sup>.



**Copper’s antimicrobial properties make it a good choice for eliminating pathogens and reducing the spread of disease<sup>1</sup>.**

<sup>1</sup> Applied and Environmental Microbiology. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3067274/>  
<sup>2</sup> The Santiago Times. <http://santiagotimes.cl/2017/04/06/chiles-copper-sector-will-return-to-growth-by-2018/>  
<sup>3</sup> Samsung C&T. <http://news.samsungcnt.com/the-kelar-power-plant-marks-a-milestone-for-samsung-cts-chilean-business/>

### FUTTSU POWER STATION BLOCK 1 UPGRADE

**LOCATION:** Futtsu, Chiba, Japan

**OUTPUT:** 1,000 MW

**HARDWARE:** 6 9E.04 gas turbines

**COMMISSION DATE:** June 2017 – Mid-2019 (expected)



#### CHALLENGE

The power generation dynamics in Japan shifted after the disastrous earthquake and tsunami of March 2011. With nuclear power generation cut almost entirely, Japan has been experiencing difficulty in electricity shortages, especially during peak summer months. Tokyo Electric Power Company (TEPCO), one of the largest power producing utilities in the world, is seeking to upgrade Block 1 of their Futtsu Thermal Power Station. The goal is to boost output and enhance heat rate, all while continuing to use existing steam turbines and generators.

#### SOLUTION

In operation for three decades, the six older 9E gas turbines at Futtsu Block 1 are ideal for GE’s 9E.04 flange-to-flange solution. This consists of new gas turbine components and a step from three- to four-stage, which increases hot gas components from nine to 12. These upgrades will increase turbine output to up to 167 MW and improve combustion efficiency by 4.2 percent (from 47.2 percent to 51.4 percent). The 9E.04 will also provide TEPCO with an array of digital solutions to boost performance and optimize emissions management.



**With four combined cycle blocks and 5,160 MW of output, the Futtsu Power Station is one of the largest thermal power stations in the world.**

# 7E POWER PLANTS

When reliability and availability are critical, customers turn to GE’s 7E gas turbine. Whether providing raw horsepower to drive industrial and petrochemical processes, or steady, reliable output for CHP operation, the 7E delivers. Known for its world-leading fuel handling equipment and combustion system options, the 7E includes tri-fuel capability, which allows fuel switching while running or shutdown.

	7E.03
SC Plant Performance	SC Net Output (MW)
	91
	SC Net Heat Rate (Btu/kWh, LHV)
	10,060
1x CC Plant Performance	SC Net Heat Rate (kJ/kWh, LHV)
	10,614
	SC Net Efficiency (% , LHV)
	33.9%
2x CC Plant Performance	CC Net Output (MW)
	142
	CC Net Heat Rate (Btu/kWh, LHV)
	6,505
	CC Net Heat Rate (kJ/kWh, LHV)
	6,863
	CC Net Efficiency (% , LHV)
	52.5%
2x CC Plant Performance	Plant Turndown – Minimum Load (%)
	45.0%
	Ramp Rate (MW/min)
	40
	Startup Time (RR Hot, Minutes)
	35
	CC Net Output (MW)
2x CC Plant Performance	287
	CC Net Heat Rate (Btu/kWh, LHV)
	6,439
	CC Net Heat Rate (kJ/kWh, LHV)
	6,793
	CC Net Efficiency (% , LHV)
	53.0%
2x CC Plant Performance	Plant Turndown – Minimum Load (%)
	22.0%
	Ramp Rate (MW/min)
2x CC Plant Performance	80
	Startup Time (RR Hot, Minutes)
	35

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



40 U.S. states have one or more installed GE 7E gas turbines, providing a total capacity of more than 40 GW.

91 MW  
SIMPLE CYCLE OUTPUT

53%  
COMBINED CYCLE EFFICIENCY



**CAPABILITY**  
Full range of fuel alternatives while delivering better efficiency and lower emissions with NOx/CO-compliant turndown to 35% of baseload



**VERSATILITY**  
Robust architecture supports a wide variety of applications, including peaking, cyclic, and baseload power; compact footprint optimizes integration in industrial applications



**SUSTAINABILITY**  
Sub 3 ppm NOx emissions without selective catalytic reduction (SCR)

# 7E POWER PLANTS

## CUSTOMER HIGHLIGHTS

### PENAL POWER STATION UPGRADE

**LOCATION:** Penal, Trinidad

**OUTPUT:** 236 MW

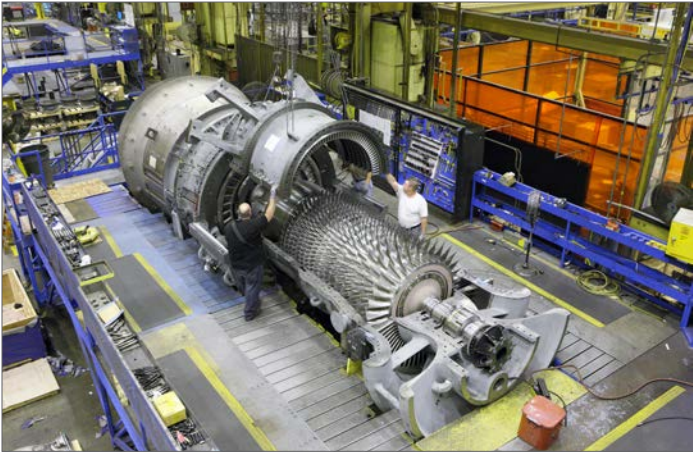
**HARDWARE:** 2 7E.03 gas turbines

**COMMISSION DATE:** February 2017



**CHALLENGE**  
In 1985, the Penal Power Station in Trinidad & Tobago commissioned its natural gas-fired combined cycle power plant featuring two GE 7E gas turbines. After 30+ years of operation, the gas turbines’ rotors and other components were nearing the end of their operational life. Faced with increasing maintenance costs, the Power Generation Company of Trinidad and Tobago Limited (PowerGen Ltd.) decided to replace the two turbines during a scheduled maintenance outage.

**SOLUTION**  
Satisfied with three decades of GE performance, PowerGen Ltd. chose to replace the turbines with two new GE 7E gas turbine units, run on natural gas. It was the first flange-to-flange gas turbine replacement in the Latin America/Caribbean region for GE. The new turbines improved plant efficiency, increased output by 26 MW, improved heat rate by 2.25 percent, and added 25 to 30 years of gas turbine life to the site.



**“Replacing the existing gas turbines will improve our power generation efficiency and provide added value in terms of greater availability by establishing longer intervals between scheduled maintenance outages.”**

**Surindranath Ramsingh**  
General Manager, PowerGen Ltd.

### BAYPORT INDUSTRIAL DISTRICT COGENERATION REDEVELOPMENT

**LOCATION:** La Porte, Texas, United States

**OUTPUT:** 300 MW/1,300 tons of steam per hour

**HARDWARE:** 4 7E.03 gas turbines

**COMMISSION DATE:** February 2016 (upgrade)



**CHALLENGE**  
Air Liquide’s gas production facility in La Porte, Texas, USA blends and packages pure industrial gases such as oxygen, nitrogen, hydrogen, and specialty gases. These gases serve customers in a range of industries, aiding in research, analysis, process control, and manufacturing. The facility is one of two located within the Bayport Industrial District, an 88-acre complex that’s central to Air Liquide’s extensive Gulf Coast Pipeline System. A long-term contract renewal with the Bayport Industrial District prompted Air Liquide to invest in facility upgrades.

**SOLUTION**  
Four GE 7E gas turbines at Air Liquide’s La Porte cogeneration facility were upgraded to increase production capacity and extended unit life. The facility now produces 300 MW of electricity and more than 1,300 tons of steam per hour with minimal waste heat. Prior to the upgrades, Air Liquide consumed some of the produced steam, but sold most of it to a neighboring chemical manufacturer and top customer. The redevelopment project positions Air Liquide to better serve the growing needs of its customers and provides additional steam capacity to sell to other customers in the region.



**“The redevelopment of our Bayport facility, which is Air Liquide’s largest industrial complex in North America, has positioned us to better serve the growing needs of our customers in this region in a safe, reliable, and efficient way.”**

**Sue Ellerbusch**  
CEO of Air Liquide USA

# LMS100

## POWER PLANTS

If it’s efficiency you’re looking for, search no more. Our LMS100 aeroderivative gas turbine is the highest simple cycle efficiency gas turbine in the world. Its intercooled gas turbine system provides rapid startup, with an 8-minute start to full load and emergency ramp speeds of up to 500 MW/minute. In high renewable penetration areas like California, our LMS100 gas turbines are providing 2.8 GW of generation with more than 1,400 MW/minute of ramping capability.

		LMS100 (50 Hz)	LMS100 (60 Hz)
SC Plant Performance	SC Net Output (MW)	117	117
	SC Net Heat Rate (Btu/kWh, LHV)	7,925	7,718
	SC Net Heat Rate (kJ/kWh, LHV)	8,362	8,143
	SC Net Efficiency (% , LHV)	43.1%	44.2%
1x CC Plant Performance	CC Net Output (MW)	142	140
	CC Net Heat Rate (Btu/kWh, LHV)	6,540	6,438
	CC Net Heat Rate (kJ/kWh, LHV)	6,900	6,793
	CC Net Efficiency (% , LHV)	52.2%	53.0%
	Plant Turndown – Minimum Load (%)	13.0%	13.0%
	Ramp Rate (MW/min)	50	50
	Startup Time (RR Hot, Minutes)	30	30
2x CC Plant Performance	CC Net Output (MW)	284	281
	CC Net Heat Rate (Btu/kWh, LHV)	6,511	6,411
	CC Net Heat Rate (kJ/kWh, LHV)	6,870	6,764
	CC Net Efficiency (% , LHV)	52.4%	53.2%
	Plant Turndown – Minimum Load (%)	6.0%	6.0%
	Ramp Rate (MW/min)	100	100
	Startup Time (RR Hot, Minutes)	30	30

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



**A spinning reserve can be generated by combining an LMS100 and a clutch. The synchronous condensing that it creates requires zero fuel use and enables an 8-minute return from reactive to 100% real power generation.**

**117 MW**  
SIMPLE CYCLE OUTPUT

**>44%**  
SIMPLE CYCLE EFFICIENCY



**CAPABILITY**  
Desalination capability from waste heat off intercooler can generate up to 3,000+ gallons per minute



**VERSATILITY**  
Available dual fuel capability with fuel switching at full power



**SUSTAINABILITY**  
Zero water option and lowest CO<sub>2</sub> emitting simple cycle gas turbine

# LMS100 POWER PLANTS

## CUSTOMER HIGHLIGHTS

### SENTINEL ENERGY PROJECT

**LOCATION:** Northeast of Palm Springs, California, United States

**OUTPUT:** 800 MW

**HARDWARE:** 8 LMS100 gas turbines

**COMMISSION DATE:** April 2013



#### CHALLENGE

Southern California has become a hotbed for renewable energy projects. To offset the intermittency of Coachella Valley’s 700+ MW of wind power capacity, Competitive Power Venture (CPV) set out to build a natural gas-fired power plant capable of providing efficient and reliable summer peaking and backup power. Unique operating requirements for the plant included: varying capacity, flat efficiency curve, rapid start, and load changes.

#### SOLUTION

At 800 MW, CPV constructed the world’s largest facility utilizing GE’s intercooled LMS100 aeroderivative gas turbine. The turbine was selected for its rapid start (10 minutes) and ramp rate (greater than 10 MW per minute) capabilities. Eight total turbines provide a wide range of dispatch loads—from 50 MW to 800 MW—and a variety of ancillary services, like spinning- and non-spinning reserve, to help stabilize the grid and support intermittent renewable power sources.



**Despite site location construction challenges—including wind, heat, and extreme dry conditions—the project execution team demonstrated all required operating and performance criteria 103 days ahead of schedule.**

### SHAHJIBAZAR GAS-FIRED POWER PLANT

**LOCATION:** Shahjibazar, Bangladesh

**OUTPUT:** 100 MW

**HARDWARE:** 1 LMS100 gas turbine

**COMMISSION DATE:** Third quarter 2019 (expected)

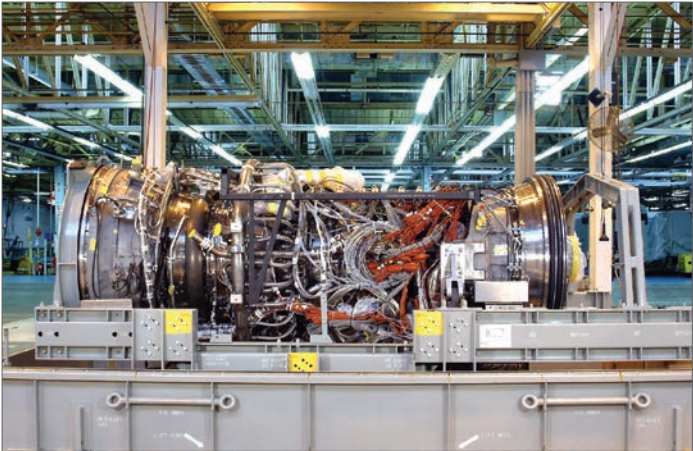


#### CHALLENGE

Bangladesh is undergoing a rapid transformation, and to support a growing economy, the government is fast tracking projects to add power generation capacity to the grid. Flexibility is key to these projects, as the Bangladesh Power Development Board (BPDB) is also focused on improving grid stability in an otherwise variable grid environment. Among their projects is a 100 MW simple cycle natural gas-fired power plant in Shahjibazar.

#### SOLUTION

Jiangsu Etern Co. Ltd., the company designated by BPDB to provide the turnkey solution, has selected GE’s highly efficient LMS100 aeroderivative gas turbine to power the Shahjibazar plant. Ideally suited to meet fluctuating grid conditions, the LMS100 will enable plant operation in three modes: base, peak, and swing. The added flexibility of dual fuel operation will allow the turbine to operate on both natural gas and LPG with zero fuel transition cost.



**The Shahjibazar project marks BPDB’s first EPC contract for an aeroderivative gas turbine in the Bangladesh power segment.**

# LM9000

## POWER PLANTS

Harnessing the engineering heritage of GE’s jet engines, the LM9000—launched in 2017—takes the world’s most powerful jet engine, the GE90-115B, and transforms it into a highly reliable, fast-start, simple cycle power generation offering. Ideal for peaking applications, the LM9000 can go from cold metal to full power in less than 10 minutes.

A power dense package with a DLE 1.5 combustor provides dual fuel capability while the combustor’s reengineered diffuser and resized premixer helps meet low emission requirements and generate the desired MW of power.

The LM9000 features a modular package design that enables shorter manufacturing cycles and faster installation, with lower installed and operational costs than field-erected units. This contributes to the LM9000’s compact footprint, which helps meet stringent space requirements, especially for retrofits or smaller new plants, and greatly simplifies balance of plant requirements.

Installation:~35days/Pre-commissioning:~20days/Commissioning:~15days


High operating efficiency and 50 percent longer maintenance intervals help reduce operating costs related to fuel and maintenance compared to non-GE DLE aeroderivative gas turbines. Maintenance intervals for the LM9000 are as follows:


- 67 MW†: 36,000 hours hot section interval / 72,000 hours overhaul
- 70 MW††: 25,000 hours hot section interval / 50,000 hours overhaul


† 67 MW (15 ppm NOx)      †† 70 MW (25 ppm NOx)

67-75 MW  
SIMPLE CYCLE OUTPUT

42%  
SIMPLE CYCLE EFFICIENCY

 **CAPABILITY**  
70 MW at 42% SC Net efficiency is the industry leader for medium sized aeroderivative gas turbines

 **VERSATILITY**  
Dual fuel and fast start capabilities make the LM9000 ideal for renewables intermittency

 **SUSTAINABILITY**  
DLE design produces 30% more power than competitor DLE design

# 6F POWER PLANTS

GE's 6F gas turbines offer the superior performance, reliability, and flexibility typically associated with larger power plants. The 6F packs a lot of power into a small package, offering durability and flexibility for harsh, remote, or floating power environments. Whether it be for 50 or 60 Hz, the 6F maintains best-in-class efficiency and exhaust energy for combined cycle and CHP performance. The 6F offers segment-leading 32,000-hour combustion and hot gas path inspection intervals.

		6F.01	6F.03
SC Plant Performance	SC Net Output (MW)	57	88
	SC Net Heat Rate (Btu/kWh, LHV)	8,880	9,277
	SC Net Heat Rate (kJ/kWh, LHV)	9,369	9,788
	SC Net Efficiency (% , LHV)	38.4%	36.8%
1x CC Plant Performance	CC Net Output (MW)	85	135
	CC Net Heat Rate (Btu/kWh, LHV)	5,896	5,998
	CC Net Heat Rate (kJ/kWh, LHV)	6,221	6,328
	CC Net Efficiency (% , LHV)	57.9%	56.9%
	Plant Turndown – Minimum Load (%)	39.0%	44.0%
	Ramp Rate (MW/min)	12	7
	Startup Time (RR Hot, Minutes)	30	45
2x CC Plant Performance	CC Net Output (MW)	171	272
	CC Net Heat Rate (Btu/kWh, LHV)	5,849	5,944
	CC Net Heat Rate (kJ/kWh, LHV)	6,171	6,271
	CC Net Efficiency (% , LHV)	58.3%	57.4%
	Plant Turndown – Minimum Load (%)	19.0%	21.0%
	Ramp Rate (MW/min)	24	13
	Startup Time (RR Hot, Minutes)	30	35

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



With their extended combustion and hot gas path inspection, GE's 6F gas turbines can run for more than four years without an outage.

57-88 MW  
SIMPLE CYCLE OUTPUT

>58%  
COMBINED CYCLE EFFICIENCY



**CAPABILITY**  
High exhaust energy provides capability for a wide range of CHP needs, including a variety of steam temperature levels



**VERSATILITY**  
Offers F-class efficiency and the superior fuel flexibility typically associated with E-class technology



**SUSTAINABILITY**  
Leading DLN emissions: 15 ppm NOx, 9 ppm CO, and best-in-class CO<sub>2</sub> per MWh for a carbon-conscious world

# 6F POWER PLANTS

## CUSTOMER HIGHLIGHTS

### JEJU LNG COMBINED CYCLE POWER PLANT

**LOCATION:** Jeju Island, Korea

**OUTPUT:** 250 MW

**HARDWARE:** 2 6F.03 gas turbines  
steam turbines  
HRSGs  
4 generators  
controls

**COMMISSION DATE:** June – August 2018



#### CHALLENGE

The Korea Midland Power Company (KOMIPO) was seeking a small block, high efficiency power solution to burn imported LNG on Korea’s Jeju Island. The island, a top tourist destination, is building its energy self-reliance with power projects that have relatively low environmental impact. The region’s small power grid cannot accommodate large H-class or F-class technology, even when burning LNG.

#### SOLUTION

Featuring two 6F.03 gas turbines, GE’s power island solution will deliver 250 MW of power at more than 55 percent efficiency. Minimal greenhouse gas emissions and a low LCOE serve KOMIPO’s long-term operational needs. Once complete, the Jeju LNG combined cycle power plant is expected to supply about 20 percent of the total power demand to the Jeju region.



**“GE’s state-of-art technology and full solution capabilities made them the right choice for our project needs. The 250 MW Jeju power plant will provide reliable and efficient electricity to address Jeju Island’s increasing power needs and contribute to its further growth.”**

**Mr. Changkil Chung**  
President and CEO, KOMIPO

### HUANENG GUILIN DISTRIBUTED ENERGY PROJECT

**LOCATION:** Guilin, Guangxi Zhuang Autonomous Region, China

**OUTPUT:** 9,210 MW

**HARDWARE:** 3 6F.01 gas turbines

**COMMISSION DATE:** November 2017



#### CHALLENGE

The City of Guilin is a popular tourist destination with a growing industrial district. The Huaneng Guilin Gas Distributed Energy Co. Ltd. was seeking a solution to provide heat and power to nearby industries as well as heat and cooling to surrounding public, commercial, and residential areas. As gas is increasingly being viewed as a reliable, more efficient, and cleaner alternative to coal and oil, China’s 13th Five-Year Plan, unveiled in March 2016, calls for adding 50 GW of gas-fired capacity to the grid. To jump start these projects, gas infrastructure and incentives have gradually been put into place.

#### SOLUTION

The Huaneng Guilin Distributed Energy Project employs three natural gas-fired 6F.01 gas turbines, features an innovative combined cooling, heating, and power (CCHP) configuration, and generates 210 MW of output. This is the first ever gas power project for the city of Guilin, and with 81.15 percent fuel efficiency, the project serves as a new model of high efficiency energy use for the city. The project is expected to replace 300,000 tons of standard coal; emissions benefits include an expected reduction of up to 527 tons of SO<sub>2</sub>, 1,560 tons of NO<sub>2</sub>, an 85 percent drop in dust, and a 70 percent drop in CO<sub>2</sub>.



**“The Huaneng Guilin Distributed Energy Project is cleaner, more stable, and safer with strong peak load dispatching operation. It provides a new model of high efficiency energy use for this city.”**

**Li Xiaodong**  
General Manager, Huaneng Guilin Gas Distributed Energy Co. Ltd.

# LM6000

## POWER PLANTS

40 million operating hours and more than 1,320 units shipped makes GE's LM6000 aeroderivative gas turbine a leader in the +40 MW space. The LM6000 offers greater than 99 percent start and operational reliability and greater than 98 percent availability. Its 5-minute fast start allows operators to differentiate their dispatch capability while a simple two-spool design results in lower overall maintenance costs. Universal and modular packaging gives the LM6000 a smaller footprint and allows for faster installation and commissioning.

		LM6000 PG	LM6000 PF+
SC Plant Performance	SC Net Output (MW)	55/57 <sup>1</sup>	53/58 <sup>1</sup>
	SC Net Heat Rate (Btu/kWh, LHV)	8,692	8,271
	SC Net Heat Rate (kJ/kWh, LHV)	9,170	8,726
	SC Net Efficiency (% , LHV)	39.3%	41.3%
1x CC Plant Performance	CC Net Output (MW)	73/76 <sup>1</sup>	70/77 <sup>1</sup>
	CC Net Heat Rate (Btu/kWh, LHV)	6,535	6,105
	CC Net Heat Rate (kJ/kWh, LHV)	6,895	6,441
	CC Net Efficiency (% , LHV)	52.2%	55.9%
	Plant Turndown – Minimum Load (%)	19.0%	37.0%
	Ramp Rate (MW/min)	50	50
	Startup Time (RR Hot, Minutes)	30	30
2x CC Plant Performance	CC Net Output (MW)	146/153 <sup>1</sup>	142/155 <sup>1</sup>
	CC Net Heat Rate (Btu/kWh, LHV)	6,516	6,085
	CC Net Heat Rate (kJ/kWh, LHV)	6,874	6,420
	CC Net Efficiency (% , LHV)	52.4%	56.1%
	Plant Turndown – Minimum Load (%)	19.0%	18.0%
	Ramp Rate (MW/min)	100	100
	Startup Time (RR Hot, Minutes)	30	30

1.) MW output with SPRINT and Evaporation Inlet Cooling.  
NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



*The LM6000 was selected as GE's first gas turbine model to feature a battery energy storage system. Two units are already in operation, and the technology is expanding to create a new "hybrid" product line.*

45-58 MW  
SIMPLE CYCLE OUTPUT

>41%  
SIMPLE CYCLE EFFICIENCY



**CAPABILITY**  
Achieves various dispatch profiles with 3-minute synchronization to the grid



**VERSATILITY**  
Operates from peaking to baseload with applications in combined cycle, simple cycle, industrial cogeneration, and district heating



**SUSTAINABILITY**  
Reduces greenhouse gas emissions as part of the LM6000 battery Hybrid EGT\* offering

# LM6000 POWER PLANTS

## CUSTOMER HIGHLIGHTS

### GLENARM REPOWERING PROJECT

**LOCATION:** Pasadena, California, United States

**OUTPUT:** 71 MW

**HARDWARE:** 1 LM6000 aeroderivative gas turbine

**COMMISSION DATE:** December 2016



#### CHALLENGE

In 2009, the City of Pasadena, California, adopted a long-term plan to upgrade its aging power and water infrastructure. A key feature of the plan was to replace inefficient local power generation units, including the city’s 51-year-old steam generating unit known as B-3. The solution selected to replace B-3 would need to accommodate Pasadena’s increasing renewable energy portfolio and provide reliable and environmentally responsible power to Pasadena’s end users.

#### SOLUTION

The city selected GE’s LM6000 natural gas-fired aeroderivative gas turbine to bring new life to the Glenarm Power Plant. The turbine provides 71 MW of power and can go from cold metal to full power in minutes, a dramatic improvement compared to B-3’s startup time of 72 hours. The plant also features a GE-specified HRSG, which allows for the flexibility to operate in combined or simple cycle.



**In 2016, Pasadena Water and Power ranked 10th on the Smart Electric Power Alliance’s Utility Solar Top 10 list, with 454 solar watts per customer installed during the year.**


### UBUNGO POWER PLANT UPGRADE

**LOCATION:** Dar es Salaam, Tanzania

**OUTPUT:** Up to 180 MW

**HARDWARE:** 4 LM6000 aeroderivative gas turbines

**COMMISSION DATE:** July 2008



#### CHALLENGE

Tanzania has a traditionally hydro-dependent power system, but severe drought in the early 2000s left the country scrambling for a more stable energy portfolio. The government allocated funds to the Tanzania Electric Supply Company (TANESCO) for the development of emergency power generation projects, including upgrades at the Ubungu Power Plant. Operating since 1995, the plant’s turbines ran exclusively on heavy fuel oil, which was expensive to import. TANESCO was seeking a cleaner, more flexible alternative to enable the delivery of reliable, efficient power.

#### SOLUTION

Upgrades at the Ubungu Power Plant included the addition of four natural gas-fired LM6000PA aeroderivative gas turbines. Songas was given the contract to run the plant, plus to source, process, and deliver locally available natural gas from the Songo Songo gas fields in southern Tanzania. The partnership and combined operational expertise of TANESCO, GE, Songas, and Songas’ majority owner Globeloq, has transformed Ubungu into a critical piece of infrastructure, providing 13 percent of Tanzania’s installed power capacity.



**The natural gas used to power the Ubungu Power Plant is transported through 225 kilometers of pipeline from the Songo Songo gas field to Dar es Salaam<sup>1</sup>.**

<sup>1</sup> Songas. <http://www.songas.com/>

# 6B POWER PLANTS

Rugged, versatile, and reliable is the best way to describe plants utilizing GE’s 6B.03 gas turbine. The turbine can ramp to 20 MW in less than five seconds and accommodate non-standard fuels in cogeneration and industrial power generation operations. Capable of black starts on volatile grid environments, the 6B.03 remains a preferred solution for remote installations and extreme operating conditions. Pre-installed gas turbine packaging means easier transport and faster site installation—as quick as six months from order to operation.

	6B.03
SC Plant Performance	SC Net Output (MW)
	44
	SC Net Heat Rate (Btu/kWh, LHV)
	10,180
1x CC Plant Performance	SC Net Heat Rate (kJ/kWh, LHV)
	10,741
	SC Net Efficiency (% , LHV)
	33.5%
2x CC Plant Performance	CC Net Output (MW)
	68
	CC Net Heat Rate (Btu/kWh, LHV)
	6,614
	CC Net Heat Rate (kJ/kWh, LHV)
	6,978
	CC Net Efficiency (% , LHV)
	51.6%
1x CC Plant Performance	Plant Turndown – Minimum Load (%)
	41.0%
	Ramp Rate (MW/min)
	20
2x CC Plant Performance	Startup Time (RR Hot, Minutes)
	30
	CC Net Output (MW)
	137
1x CC Plant Performance	CC Net Heat Rate (Btu/kWh, LHV)
	6,551
	CC Net Heat Rate (kJ/kWh, LHV)
	6,912
2x CC Plant Performance	CC Net Efficiency (% , LHV)
	52.1%
	Plant Turndown – Minimum Load (%)
	20.0%
1x CC Plant Performance	Ramp Rate (MW/min)
	40
	Startup Time (RR Hot, Minutes)
	30


NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.





GE has more than 1,100 6B units in operation today, and the platform has exceeded 60 million running hours.

44 MW  
SIMPLE CYCLE OUTPUT

>51%  
COMBINED CYCLE EFFICIENCY

 **CAPABILITY**  
High quantity of steam with pressure of up to 110 bar for industrial steam without supplementary firing

 **VERSATILITY**  
Operates on a broad range of fuels: process/low-calorie gases; 95% hydrogen; heavy fuel oil up to 200 ppm vanadium

 **SUSTAINABILITY**  
Ultra low NOx technology allows operation on a blend of gases and 4 ppm NOx on natural gas with an allowable +/-30% MWI variation

# 6B POWER PLANTS

## CUSTOMER HIGHLIGHTS

### OLD HARBOUR COMBINED CYCLE POWER PLANT

**LOCATION:** Old Harbour Bay, St. Catherine, Jamaica

**OUTPUT:** 190 MW

**HARDWARE:** 3 6B.03 gas turbines

**COMMISSION DATE:** September 2019 (expected)



#### CHALLENGE

Jamaica Public Service Company Ltd. (JPS), Jamaica’s sole distributor of electricity, is working to update power infrastructure, including replacement of obsolete power stations that run on heavy fuel oil. With low natural gas prices, JPS was seeking to build a new dual fuel combined cycle power plant that could provide between 180 MW and 200 MW of reliable and efficient output.

#### SOLUTION

JPS has selected GE’s 6B gas turbine as the workhorse of the Old Harbour combined cycle power plant because it meets all the requirements for reliability and efficiency. The turbines will run primarily on imported LNG and feature DLN1 combustion, which will save more than 300 kJ/kWh versus traditional STD combustion. With an already existing fleet of 6Bs, JPS is familiar with the turbine’s robust operation and GE’s commitment to technical excellence.



**This will be the first combined cycle power plant in Jamaica to run on LNG; once commissioned, the Old Harbour plant will add ~15% capacity to the country’s grid.**

### JABABEKA INDUSTRIAL ESTATE GAS-FIRED POWER PLANT

**LOCATION:** Cikarang, Bekasi, West Java, Indonesia

**OUTPUT:** 864 MW

**HARDWARE:** 6 6B gas turbines  
3 9E gas turbines

**COMMISSION DATE:** 6B turbines: 1993, 1996;  
9E turbines: 2006 – 2012, 2015

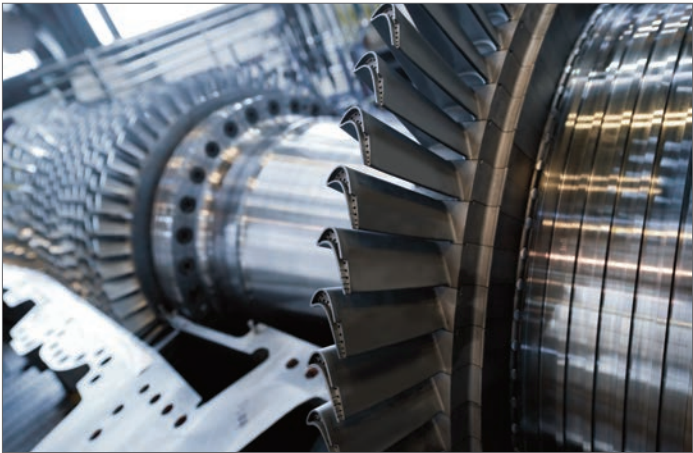


#### CHALLENGE

The Jababeka Industrial Estate was established in 1989 as the “first modern Indonesian eco-industrial estate.” Early growth was limited due to a restricted supply of reliable power. The estate turned to independent power producer PT Cikarang Listrindo to provide a new reliable supply of electricity. With interest in the estate increasing, the plant had to guarantee a certain level of reliable output at each phase of expansion.

#### SOLUTION

The original Jababeka Industrial Estate gas-fired power plant was constructed in 1993, designed to provide 60 MW of output with two GE 6B gas turbines. In 1996, PT Cikarang Listrindo added four 6B units to increase output to 180 MW. Growth of the estate continued, so a bottoming cycle and three 9E gas turbines were added to increase output to 864 MW. Fast forward to 2017, and PT Cikarang Listrindo is pulling additional power from its coal-fired power plant Babelan, West Java to meet the demand of the estate’s more than 1,650 tenants.



**The Jababeka Industrial Estate spans 5,600 hectares (almost 14,000 acres) and is home to more than 1,650 multinational companies.**

# LM2500

## POWER PLANTS

With more than 2,500 units sold and more than 97 million operating hours, GE's LM2500 is the top-selling gas turbine globally. Ideal for CHP applications between 20 to 40 MW, the LM2500's greater than 85 percent efficiency helps reduce operating costs, plant emissions, and reliance on the local grid. A lightweight and compact modular design complements the universal packaging, which improves accessibility for maintenance. The LM2500 delivers power with reliability greater than 99 percent and availability greater than 98 percent.

		LM2500 DLE	LM2500+ DLE	LM2500+G4 DLE
SC Plant Performance	SC Net Output (MW)	22.7	30.6	33.6
	SC Net Heat Rate (Btu/kWh, LHV)	9,501	8,988	8,897
	SC Net Heat Rate (kJ/kWh, LHV)	10,024	9,482	9,387
	SC Net Efficiency (% LHV)	35.9%	38.0%	38.4%
1x CC Plant Performance	CC Net Output (MW)	33.2	43.9	47.7
	CC Net Heat Rate (Btu/kWh, LHV)	6,456	6,299	6,239
	CC Net Heat Rate (kJ/kWh, LHV)	6,811	6,645	6,583
	CC Net Efficiency (% LHV)	52.9%	54.2%	54.7%
	Plant Turndown – Minimum Load (%)	34.0%	35.0%	35.0%
	Ramp Rate (MW/min)	30	30	30
	Startup Time (RR Hot, Minutes)	30	30	30
2x CC Plant Performance	CC Net Output (MW)	66.6	88.2	95.7
	CC Net Heat Rate (Btu/kWh, LHV)	6,431	6,277	6,218
	CC Net Heat Rate (kJ/kWh, LHV)	6,785	6,622	6,560
	CC Net Efficiency (% LHV)	53.1%	54.4%	54.9%
	Plant Turndown – Minimum Load (%)	17.0%	17.0%	18.0%
	Ramp Rate (MW/min)	60	60	60
	Startup Time (RR Hot, Minutes)	30	30	30

NOTE: See Appendix for 50 Hz performance without gearbox. All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.


Additionally, the LM2500Xpress offering is available with a new faster install time, increased modularity, and fewer interconnects when speed of power is critical.





**Our LM2500 is the most reliable gas turbine in its class, and the latest package provides a complete generator set with a 10-15% lower total installed cost.**

**24 MW**  
SIMPLE CYCLE OUTPUT

**>38%**  
SIMPLE CYCLE EFFICIENCY

 **CAPABILITY**  
Ideal for combined cycle, onshore and offshore power generation, mechanical drive, and cogeneration

 **VERSATILITY**  
Accommodates a wide variety of fuels, including coke oven gas, naphtha, propane, diesel, ethanol, and LNG

 **SUSTAINABILITY**  
Multiple technology options available to lower NOx and other emissions concerns

# LM2500 POWER PLANTS

## CUSTOMER HIGHLIGHTS

### COVE POWER STATION EXPANSION

**LOCATION:** Lowlands, Tobago

**OUTPUT:** 20 MW

**HARDWARE:** 1 LM2500 aeroderivative gas turbine

**COMMISSION DATE:** December 2018

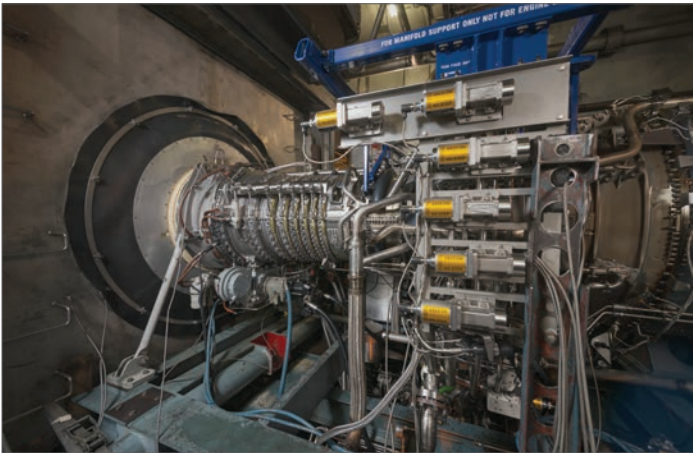


#### CHALLENGE

The 140-acre Cove Eco-Industrial and Business Park in the Cove Estate in Lowlands, Tobago, is attracting new and developing businesses to the island. The park draws its power from the Cove Power Station, a 64 MW, dual fuel capable facility run by the Trinidad and Tobago Electricity Commission (T&TEC). If one of the power station’s four 16 MW units is offline, the reliability of the system is grossly reduced. Tobago was put on notice that additional projects requiring power were on the horizon, these included a large hotel development, expansion of the airport and a desalination plant. To alleviate this issue and to accommodate future growth, funding was made available by the government for T&TEC to expand the facility.

#### SOLUTION

Reliable and available power is a must for Tobago, and, given its growth potential, the size of the additional units was increased to meet current and future demands. T&TEC selected GE’s LM2500 aeroderivative gas turbine to power its expansion due to the turbine’s Industry record of proven reliability, albeit at a slightly higher overall life-cycle cost compared to a similar size reciprocating engine. With 20 additional megawatts of clean and efficient energy, the Cove Power Station expansion project is a great step in the right direction for the island’s goal of energy independence.



**The Cove Eco-Industrial and Business Park includes a \$3.7-million solar street lighting systems that features 79 lighting units throughout the park<sup>1</sup>.**

<sup>1</sup> Government of the Republic of Trinidad and Tobago. <http://www.news.gov.tt/content/tobagos-eco-friendly-industrial-park#.WZEKjVWGPIU>

### POWER STATION IN SOUTH AFRICA

**LOCATION:** South Africa

**OUTPUT:** 70 MW

**HARDWARE:** 3 LM2500+G4 DLE aeroderivative gas turbines

**COMMISSION DATE:** September 2019 (expected)



#### CHALLENGE

One company generates roughly 95% of the electricity used in South Africa, a country of 53 million people. With limited supplies of natural gas, the company relies on coal and nuclear generation for baseload power, with diesel-fired combustion turbines and hydro pumped-storage for load following. When the need to upgrade a second, dedicated offsite power supply for an 1800 MW power station was identified, gas-fired turbines were selected as the best technology due to their flexibility, dual fuel capability, and operational efficiency.

#### SOLUTION

Three LM2500+G4 DLE turbines will produce 132 kV of backup supply for the project. Auto-start will supply power solely to essential safety loads and reactor cooling pumps for the shutdown and recovery of the power station’s units. A secondary function will be to supply peaking power for grid support. If the plant is operating in peaking mode when a fault occurs, the plant will detach from the grid, reduce power to house load, then provide power to the power station. The LM2500+G4s will meet safety load requirements within 10 minutes of receiving an auto-start signal.



**These are GE’s first dual fuel DLE turbines in the LM2X ‘universal’ package, designed to reduce cost and improve reliability by utilizing common system designs across engine models.**

# TM2500

## POWER PLANTS

The TM2500 is ideal for providing a baseload bridge to permanent power installations or for generating backup power in the wake of natural disasters, plant shutdowns, or grid instability. Our complete solutions—including trailer-mounted gas turbine generator set and containerized balance of plant—can put power on the grid within 30 days of the contract signature. This fast power provides the greatest power density among gas turbine trailer-mounted offerings.

		TM2500 (50 Hz)	TM2500 (60 Hz)
SC Plant Performance	SC Net Output (MW)	33.6	35.9
	SC Net Heat Rate (Btu/kWh, LHV)	9,794	9,330
	SC Net Heat Rate (kJ/kWh, LHV)	10,333	9,844
	SC Net Efficiency (% LHV)	34.8%	36.6%
1x CC Plant Performance	CC Net Output (MW)	48.4	50.5
	CC Net Heat Rate (Btu/kWh, LHV)	6,851	6,703
	CC Net Heat Rate (kJ/kWh, LHV)	7,229	7,072
	CC Net Efficiency (% LHV)	49.8%	50.9%
	Plant Turndown – Minimum Load (%)	35.0%	36.0%
	Ramp Rate (MW/min)	30	30
	Startup Time (RR Hot, Minutes)	30	30
2x CC Plant Performance	CC Net Output (MW)	97.2	101.3
	CC Net Heat Rate (Btu/kWh, LHV)	6,827	6,681
	CC Net Heat Rate (kJ/kWh, LHV)	7,203	7,049
	CC Net Efficiency (% LHV)	50.0%	51.1%
	Plant Turndown – Minimum Load (%)	35.0%	35.0%
	Ramp Rate (MW/min)	60	60
	Startup Time (RR Hot, Minutes)	30	30

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.



Switching from a diesel engine and electric generator (diesel genset) to a TM2500 burning liquefied petroleum gas (LPG) can save \$7 million per year in operating costs.

32 MW AT 30°C  
HOT-DAY PERFORMANCE



**CAPABILITY**  
8-minute start from cold metal to full power output



**VERSATILITY**  
All units are natural gas/liquid fuel capable across a wide range of fuels, including propane and naphtha



**SUSTAINABILITY**  
10X lower emissions than reciprocating technology; exceeds World Bank requirements

# TM2500 POWER PLANTS

## CUSTOMER HIGHLIGHTS

### AL-HISWA FAST POWER EXPANSION

**LOCATION:** Aden, Yemen

**OUTPUT:** 60 MW

**HARDWARE:** 2 TM2500 gas turbines

**COMMISSION DATE:** May 2017



**CHALLENGE**  
Yemen struggles to maintain reliable power generation, even in its densely-populated areas. Cities can lose electricity and water without notice, making day-to-day tasks nearly impossible. Yemen is in urgent need of power that is easy to transport, quick to install, and flexible in its operation.

**SOLUTION**  
GE supplied two TM2500 aeroderivative gas turbines to Çalik Enerji, the EPC on the Al-Hiswa fast power expansion project. The first GE aeroderivative gas turbines in Yemen, these units accommodate gaseous and liquid fuels without major hardware modifications, and can start in as little as 10 minutes. Pairing GE’s advanced technology with Çalik Enerji’s execution expertise got these turbines up and running quickly, providing 60 MW of additional power just in time for 40°C temperatures during the fasting month of Ramadan.



**“The expansion of the plant using GE’s advanced aeroderivative gas turbine generators will enable us to deliver power quickly and with great reliability. These turbines have [proven] their efficiency and offer fuel flexibility, which is crucial in driving towards uninterrupted power generation.”**

**Özgür Sarıkaya**  
Çalik Enerji (EPC)

### YANGON FAST POWER PROJECT

**LOCATION:** Yangon, Myanmar

**OUTPUT:** 25 MW

**HARDWARE:** 1 TM2500 gas turbine

**COMMISSION DATE:** July 2017



**CHALLENGE**  
The Asian Development Bank anticipates that Myanmar’s nationwide electricity peak load consumption will grow by 80 percent between 2017 and 2020. Yangon, Myanmar’s business capital, needs more electricity urgently because demand already outstrips supply in the peak season, leading to power outages throughout the city. In early 2017, the Union Parliament approved an investment of 30 billion Kyat (USD ~22 million) in the Yangon Region Government to boost the area’s power generation capacity.

**SOLUTION**  
As one of the first initiatives, the Yangon Region Government green-lighted a fast power project, a 25 MW mobile power plant that produces the equivalent electricity to power approximately 160,000 homes. The plant was installed and commissioned just 60 days from order placement, thanks to GE’s TM2500 trailer-mounted gas turbine generator and containerized balance of plant. The TM2500 can achieve full power within 10 minutes, making it ideal for providing a baseload bridge to permanent power installations or for generating backup power for factories and industries.



**Yangon served as the capital of Myanmar from 1948 to 2006. Today, the city remains the commercial and industrial center of the country.**

# TOPPING CYCLE

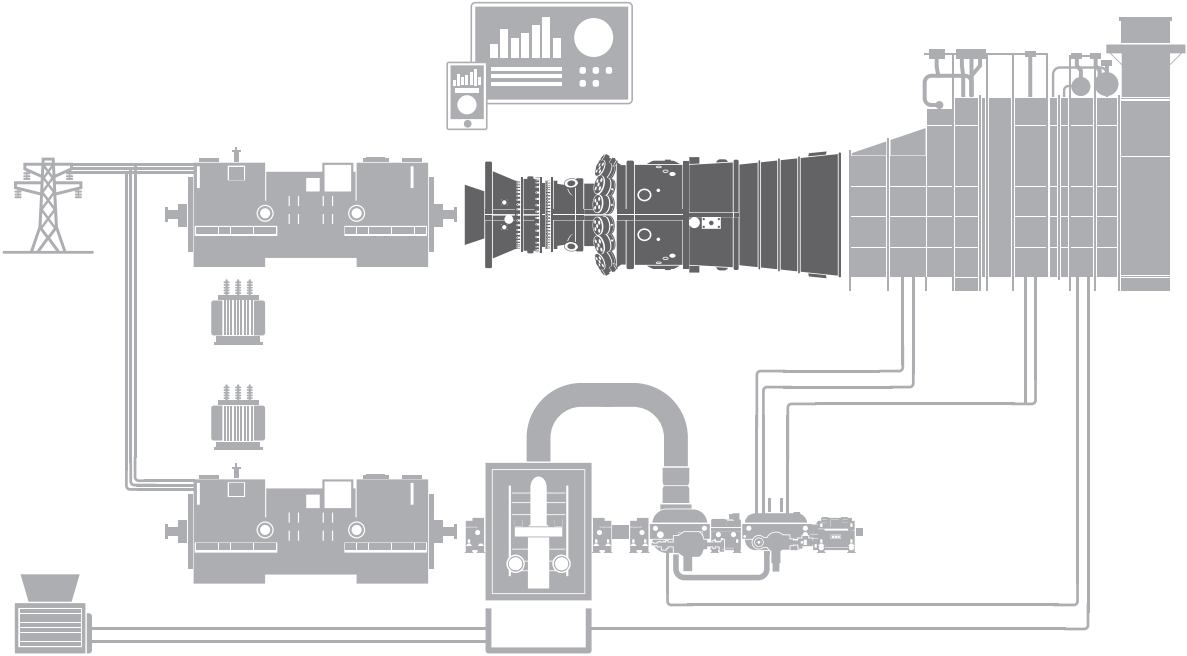
# OVERVIEW & SCOPE

Consisting of the gas turbine and supporting accessory systems, the topping cycle is the most significant and technologically challenging step in the conversion of fuel to electrical power. The topping cycle contributes to more than two-thirds of a power plant’s total output and defines combined cycle efficiency entitlement based on operating temperature capability.

GE maintains a plant-level view while focusing on the key considerations for topping cycle development: performance, emissions, reliability, and cost. Each of our topping cycle

configurations strike a balance between pressure ratio, firing temperature, and air flow to help you achieve optimum plant performance at world-class emissions levels.

Most importantly, we recognize that these factors vary greatly from customer to customer, so we engage our customers early on in the development process to gain an intimate understanding of their wants and needs. This ensures a topping cycle that provides value, no matter what the application.



# GAS TURBINE PORTFOLIO

At the heart of a combined cycle plant is the gas turbine, the machine that has the power to make a good solution great. GE's heavy duty and aeroderivative gas turbines are versatile and reliable, with individual output from 22 MW to 571 MW. They are proven performers in a range of applications, capable of achieving world-class efficiency with next-generation capabilities.

### HIGH EFFICIENCY H-CLASS

- Most cost-effective conversion of fuel to electricity in the industry.
- Includes the world's largest high efficiency turbine.
- Holds the world record for powering the most efficient combined cycle power plant at 63.08% efficiency.
- Over 300,000 operating hours across 36 gas turbines.



### INDUSTRY-LEADING F-CLASS

- Introduced F-class technology 30 years ago.
- World's largest fleet, with more than 1,300 installed units and 70 million operating hours.
- Highest reliability in its class, providing customers more days of operation per year.



### RELIABLE B- AND E-CLASS

- Rugged and available, even in harsh climates.
- Industry-leading fuel flexibility, burning more than 50 gases and liquids.
- Quick installation for fast-track projects.
- More than 3,700 installed units with more than 217 million combined operating hours.

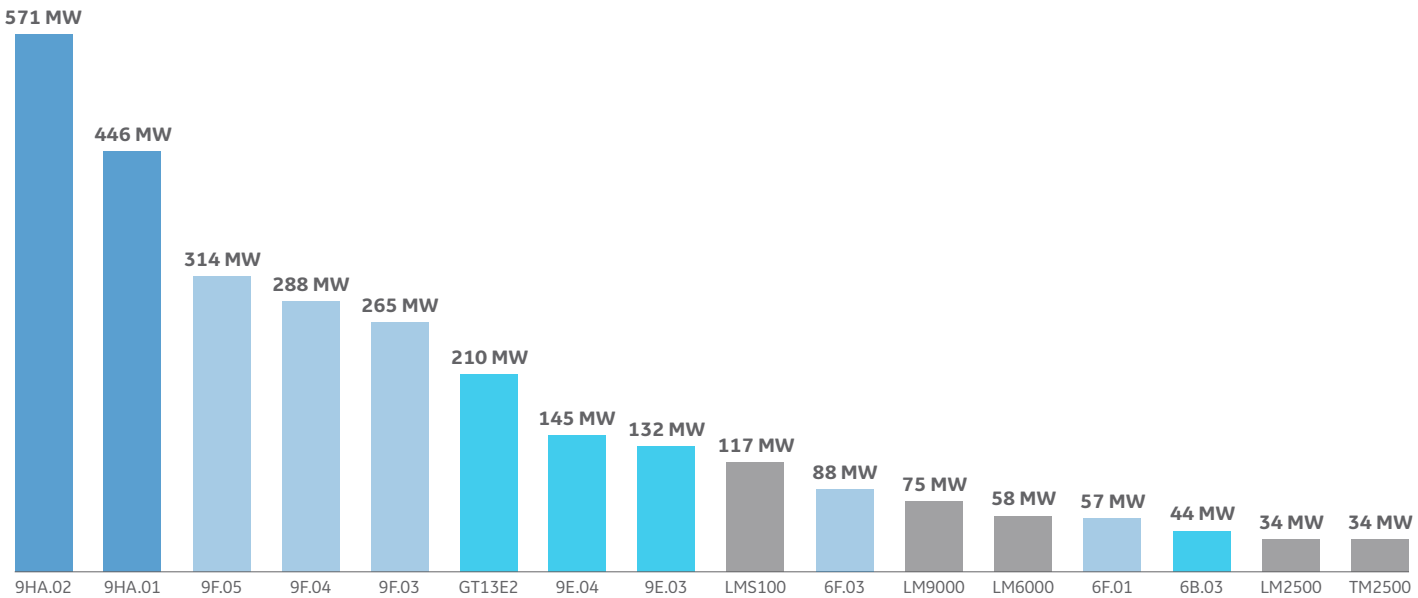


### COMPACT AND PROVEN AERODERIVATIVES

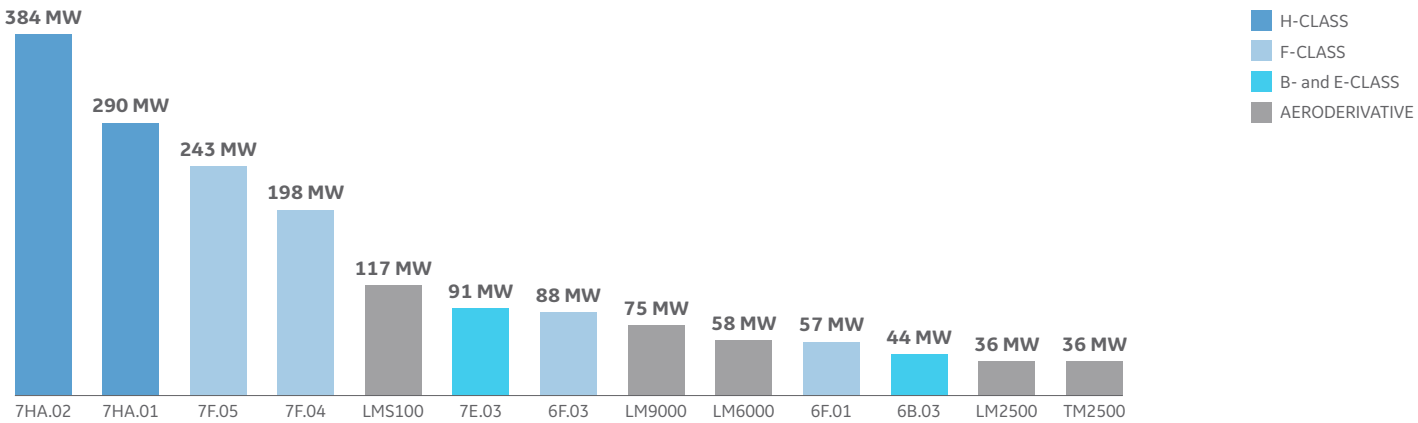
- Flexible and reliable power generation packages with aviation-derived engines.
- More than 100 million operating hours acquired over the last 45 years.
- Up to 44% simple cycle efficiency and 56% combined cycle efficiency with fast startup, high ramp rates, and outstanding cycling capability.



### 50 HZ PORTFOLIO BY RATING



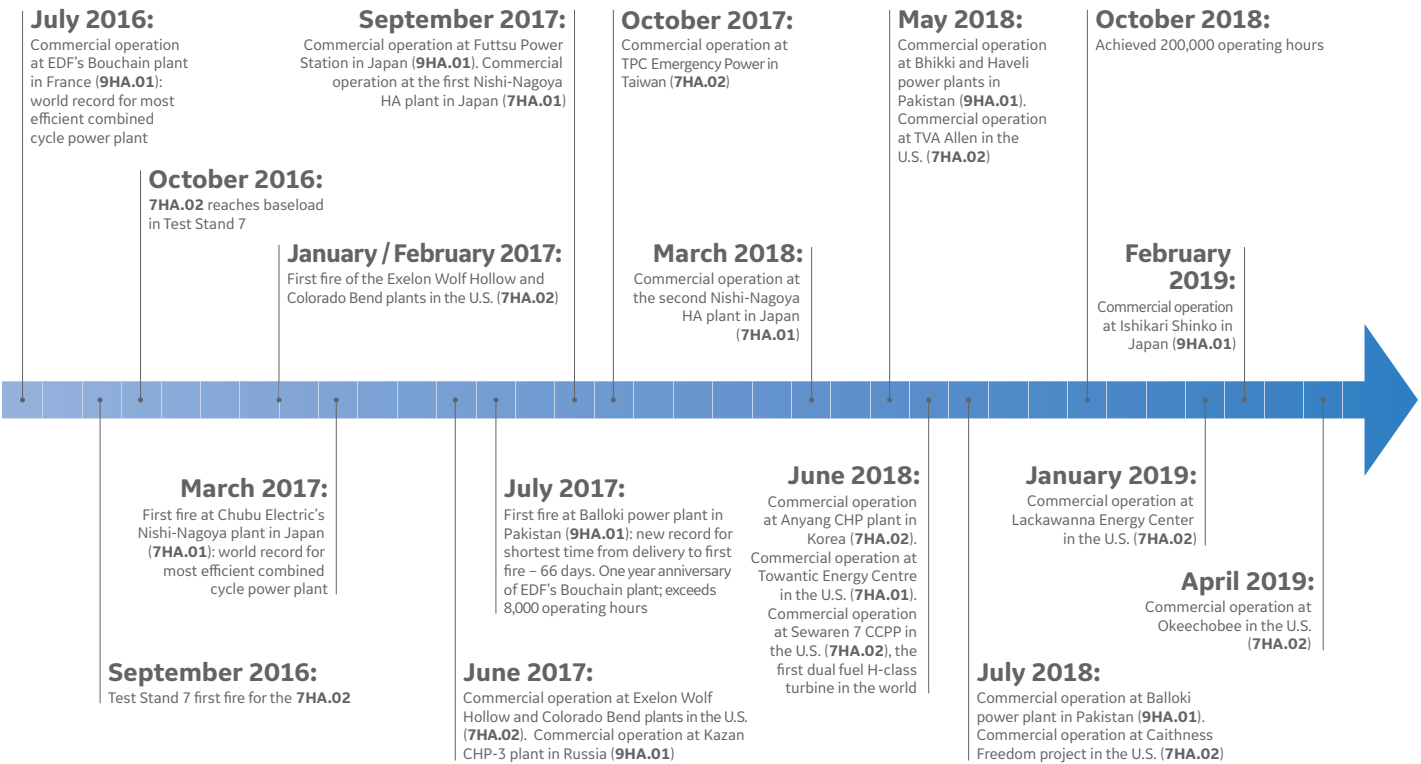
### 60 HZ PORTFOLIO BY RATING



■ H-CLASS  
■ F-CLASS  
■ B- and E-CLASS  
■ AERODERIVATIVE

H-CLASS MILESTONES

Long before our 9HA.01 and 7HA.01 set world records for most efficient combined cycle gas power plants, GE was pioneering gas turbine technology through advancements in materials, aerodynamics, and advanced manufacturing. GE is carving an impressive path as the power industry progresses into a new digital era where integrated software and analytics drive greater performance and efficiency.



F-CLASS MILESTONES

When GE debuted the industry's first F-class gas turbine in 1987, it ushered in a whole new era of blended flexibility and efficiency. Fast forward to today, and we've had more than 1,500 installed F-class machines exceed 54 million operating hours. These turbines have been proven time and again in a range of applications; they are a reliable, efficient, flexible, and validated flagship of our power generation offerings.

9F MILESTONES

- 1991: GE introduces first 9F unit
- 2019: 450 units sold in 40 countries, 22 million fired hours, and 270,000 fired starts

7F MILESTONES

- 2008: GE launches 7F.05 program
- 2014: Commercial delivery of first 7F.05 unit
- 2018: Over 475,000 operating hours on the 7F.05 alone

6F.03 MILESTONES

- 1994: GE receives first order for 6F.03
- 2001: Introduction of flared compressor for next generation 6F.03
- 2019: Over 230 orders booked with ~200 units in operation, running 9 million hours

6F.01 MILESTONES

- 2005: First commercial operation date with original 6C technology
- 2012: First 6C units accumulate 100k operating hours
- 2014: Relaunch of 6F.01, first order received for Guilin, China
- 2019: Commercial operation for 8th unit, over 145k operating hours on installed fleet

B- AND E-CLASS MILESTONES

From desert heat to arctic cold, GE's B- and E-class gas turbines operate in some of the world's harshest and most demanding locations. Since commissioning the fleet over 40 years ago, our more than 3,000 B- and E-class gas turbines have exceeded 140 million operating hours. These turbines burn the widest range of fuels, delivering operational flexibility and long-term value for the plants that harness their power.

GT13E2 MILESTONES

- 2002-2018: 38 MW increase in output (from 172 MW to 210 MW) and 1.6% increase in efficiency (from 36.4% to 38%)
- 2018: The 250th GT13 unit was ordered and is expected to be on line by 2020 in Israel, making it the unit's 38th country
- 2019: Exceeds 165 units in operation, 14 million operating hours, and 105,000 starts



Two GE 7E turbines were named 2016's ten hardest working gas turbines (U.S.) by Simpfony, a purveyor of U.S.-based power generation operating statistics. The list included turbines with the most operating hours for 2016.

9E MILESTONES

- 1978: GE introduces first 9E unit
- 2016: First 9E.04 online
- 2018: 820+ units ordered spanning over 45 countries
- 2019: Exceeds 660 units in service and 30 million operating hours, the largest worldwide installed base of any frame 50Hz gas turbine



7E MILESTONES

- 1970: GE ships first 7E unit
- 2019: Exceeds 1,000 units in operation, 35 million operating hours, and 600,000 starts



6B MILESTONES

- 1978: GE introduces first 6B unit
- 1978 to 2017: 40 years of orders in six of seven continents
- 2018: Exceeds 1,200 units in operation, 60 million operating hours, and 450,000 starts
- 2019: The Daesan refinery in South Korea has been operating a 6B.03 for 20 years, totaling over 100,000 hours using fuel >70% H2 by volume and max levels exceeding 90%



AERODERIVATIVE MILESTONES

GE's aeroderivative gas turbines draw on the engineering expertise of GE's aviation engine fleet, leveraging material science innovation to achieve impressive performance at high firing temperatures. Our LM and TM series of turbines feature advanced technology, performance, and operational flexibility that drive maximum value and profitability for our customers. With wide acceptance in the industry, our aeroderivative gas turbines have surpassed 100 million operating hours.



- 1969: First LM2500 achieves commercial operation (pipeline application)
- 1975: Commissioning of USS Spruance, the first ship commissioned with two LM2500s as main propulsion
- 1978: LM2500 exceeds 1 million operating hours
- 1988: GE receives first order for LM6000
- 1996: GE introduces the trailer-mounted TM2500 for fast power installations
- 2004: GE receives first order for LMS100
- 2017: Introduction of the LM9000

BORN FROM THE BEST

GE has a proven record of developing robust industrial gas turbines from world-class aircraft engines.

AIRCRAFT	AVIATION ENGINE	GAS TURBINE
Lockheed C-5/McDonnell Douglas DC-10	TF39/CF6-6	LM2500, LM2500+/G4
Airbus 300,310,330/Boeing 747, 767	CF6-80C2/E1	LMS100/LM6000
Boeing 777	GE90-115B	LM9000

AS A MATTER OF FACT

- Total turbine starts across the product line: **1.243 million**
- Total MWs currently in service: **117,916**
- Hours on the LM product line: **134 million**
- Total DLE hours: **30.8 million**; max hours on a DLE turbine: **165,000**; max starts on a DLE turbine: **8,500**
- Max hours on a SAC turbine: **303,000**; max starts on a SAC turbine: **19,300**

# MOBILE FAST POWER

Business doesn't always go as planned, and sometimes you need a little help... FAST. When natural disaster strikes or unanticipated demand exceeds domestic capacity, GE can rally the troops to provide mobile power generation—anytime and anywhere.

**Emergency/Mobile Power**

Our TM2500 trailer-mounted aeroderivative gas turbine generator sets can be swiftly transported by land, air, or sea, and can be commissioned in less than 11 days to provide up to 35 MW of reliable power. The mobility of the TM2500 allows customers the flexibility to reposition power at the point of use to respond to emergency situations, overhauls, and outages.

**Quick Shipment/Construction**

To meet the time-critical needs of our customers, we are committed to maintaining an inventory of finished TM2500 gas turbine generator sets, ready to ship at a moment's notice. Ten years of experience has allowed us to optimize our modular design to provide a unit that is easy to transport and quick to install and commission.

**Bridging Power**

You can't hurry love... or power generation. Developing, building, and commissioning a custom solution can take years, but in the meantime, your short-term power needs can be met with our mobile, ready-to-deploy TM2500 units.

**A CASE FOR FAST POWER: INDONESIA**

Indonesia faces serious logistical challenges regarding power generation infrastructure and distribution. More than half of the country's 260 million people live on the island of Java while the remaining population is spread amongst 922 permanently inhabited islands.

Energy access constraints are typically attributed to either remote or densely populated locations, but in Indonesia, barriers are caused by both. Land is the biggest challenge for densely populated areas while logistics serves as the biggest challenge for remote locations. Ideal for Indonesia's geography, GE's fast power solutions transcend typical logistical challenges and provide more localized power generation.



***GE's TM2500 aeroderivative mobile gas turbine can ramp up to full power in less than 10 minutes.***

Among GE's recent and ongoing projects is a deal with the Indonesian state utility, Perusahaan Listrik Negara (PLN), to provide 500 MW of fast power—via TM2500 units—to eight sites on six different islands. Another project with PLN Batam included the installation of two TM2500 gas turbines on the island of Lombok, where only 72 percent of the 3.2 million residents reported access to electricity. The 25 MW units arrived in 2016 and have been supplying approximately 400,000 Indonesian homes with consistent electricity.

# FUEL FLEXIBILITY

For more than 50 years, GE has developed close collaborative relationships with owners, operators, and fuel suppliers with the goal of understanding new fuel trends, expanding capabilities for existing fuels, qualifying new fuels, and actively investing in new fuel system technologies. This fuel flexibility legacy has spurred GE’s industry leadership as we reliably convert the full spectrum of fuels to mechanical, electrical, and thermal energy. This legacy is built upon a platform with three key elements: expertise, equipment, and experience.

### Expertise

We are committed to providing efficient and reliable power from a wide variety of fuels. GE Power draws on leading fuels and combustion experts from across the company, including our Aviation business, our Global Research Centers, and Baker Hughes, a GE company. Our experts actively enhance our combustion and fuels technologies to further expand the available range of fuel sources for gas turbine operation and to lower emissions. We can test nearly any fuel at our world-class facilities in Greenville, South Carolina, and Niskayuna, New York (United States), as well as at our other locations around the globe. Over the last decade, GE’s experts have performed more than 25,000 hours of combustion testing to validate our technology and to develop new technologies and expanded fuel capabilities. As a result, our gas turbines can efficiently use liquid and gaseous fuels to produce electricity.

### Equipment

GE offers combustion technologies, hardware, and controls to help you use a broad range of fuels. We continually evolve our proven gas turbine combustion technology, a process that started more than 40+ years ago, leading to the development of the first DLN combustion system. Since then, our range of diffusion and premixed combustion systems has accrued nearly 300 million fired hours. Today, modern systems continue to evolve to meet new fuel challenges, providing new capabilities. The technology required to operate on a variety of fuels includes not only the combustor, but the accessory and control systems needed to support reliable operation.

### Experience

With more than 9,000 GE gas turbines installed around the world operating on more than 50 different fuels and fuel blends, we know the challenges operators face—volatile fuel prices, variability in fuel sources, increasingly strict environmental regulations, and the need for more power generation flexibility. Our broad industry experience allows us to reliably convert the full spectrum of fuels to mechanical, electrical, and thermal energy, giving us the ability to deliver solutions that meet your specific fuel needs. Adding to this capability is our powerful Digital Twin models, which evolve throughout a plant’s life cycle to build “what if” scenarios to improve performance and optimize maintenance schedules. These models have enabled an increase in plant efficiency of up to 1 percent, representing millions of dollars in savings.

### Fuel Capability

GE’s vast experience operating on natural gas and alternative fuels sets us apart from other OEMs. Our gas turbines are versatile, and they operate on a variety of fuels, including gases with a wide range of heating values, like steel mill gases, syngas, lean methane fuels, natural gas, higher order hydrocarbons (such as ethane and propane from shale gas), and high hydrogen fuels. The combustion systems for these gas turbines are also capable of operating on a wide range of liquid fuels, including diesel, other light distillates (i.e. naphtha), and a range of ash bearing fuels (i.e. crude oils and heavy fuel oil).

FUELS	AERODERIVATIVE					HEAVY DUTY							
	LM/TM2500	LM6000	LMS100	6B.03	7E.03	9E	GT13E2	6F.01	6F.03	7F	9F	7HA	9HA
GASES	High C <sub>2</sub> + (Ethane, etc.)												
	Liquefied Petroleum Gas (LPG)												
	Flare Gas and Associated Gas												
	Natural Gas												
	Liquefied Natural Gas (LNG)												
	Coal Bed Methane (CBM)												
	H <sub>2</sub> Blends												
	Lean Methane (Weak NG)												
	High H <sub>2</sub>												
	Syngas (O <sub>2</sub> Blown)												
	Blast Furnace Gas (BFG)												
	Coke Oven Gas (COG)												
	Sour Gas												
	Refinery/Process Off Gas												
	Landfill/Digester Gas												
LIQUIDS	Distillate Oil (#2)												
	Marine Gas Oil (MGO)												
	Naphtha												
	Condensate (NGL)												
	Biodiesel (GE DO#2 Spec)												
	Alcohols (i.e. Ethanol, Methanol)												
	Kerosene/Jet Fuel												
	Butane												
	Gasoline												
	Dimethyl Ether (DME)												
	Super/Extra Light Crude Oil (ASL, AXL)												
	Light Crude Oil												
	Medium Crude Oil												
	Heavy Crude Oil												
	Heavy Fuel Oil (HFO)												

GE has the largest installed fleet of gas turbines for alternative fuel applications†.

†Per McCoy Power Reports, 1980-2017; Alternative fuels = all fuels except natural gas & diesel #2.

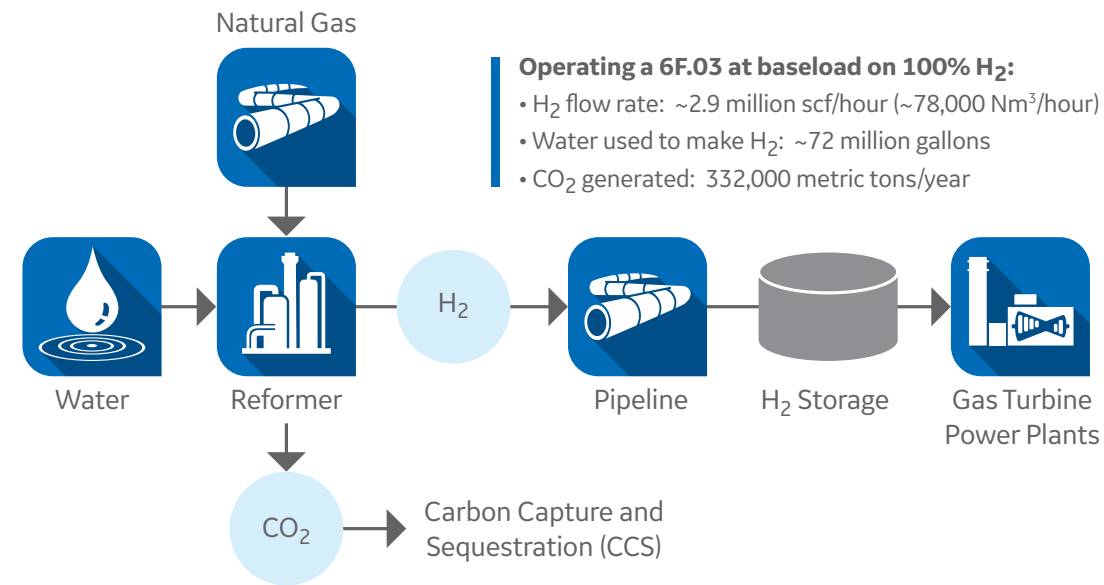


# DECARBONIZING POWER GENERATION

TRANSITION TO A REDUCED OR ZERO-CARBON ENERGY ECOSYSTEM WITH HYDROGEN

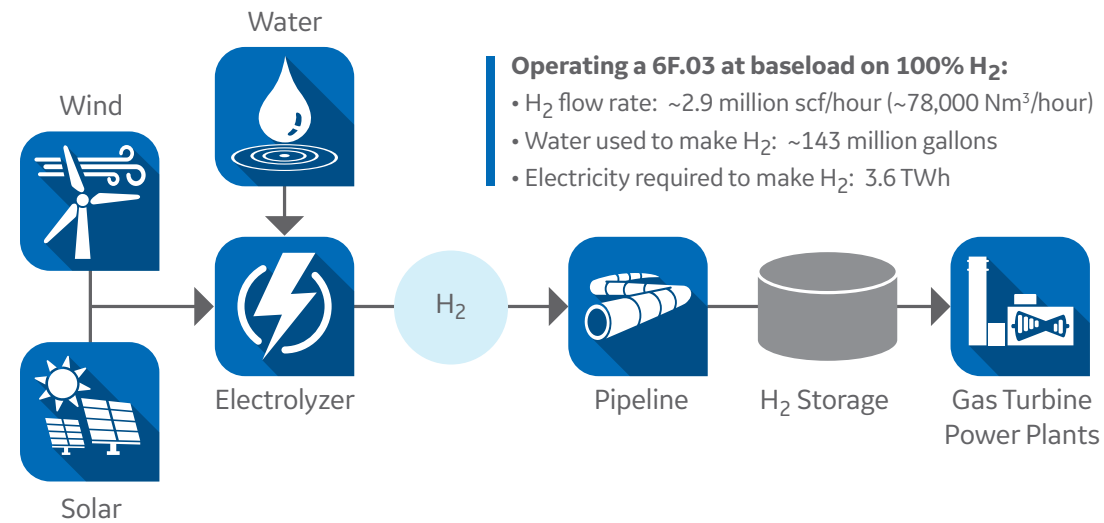
## PRODUCTION OF H<sub>2</sub> AND OTHER CARBON-NEUTRAL FUELS

### Steam Methane Reforming



**2kg of methane + 4.5kg of water → 1kg of H<sub>2</sub> + 5.5 kg of CO<sub>2</sub>**  
To be carbon neutral, CCS is required. This adds ~\$17/MMBTU to the fuel cost

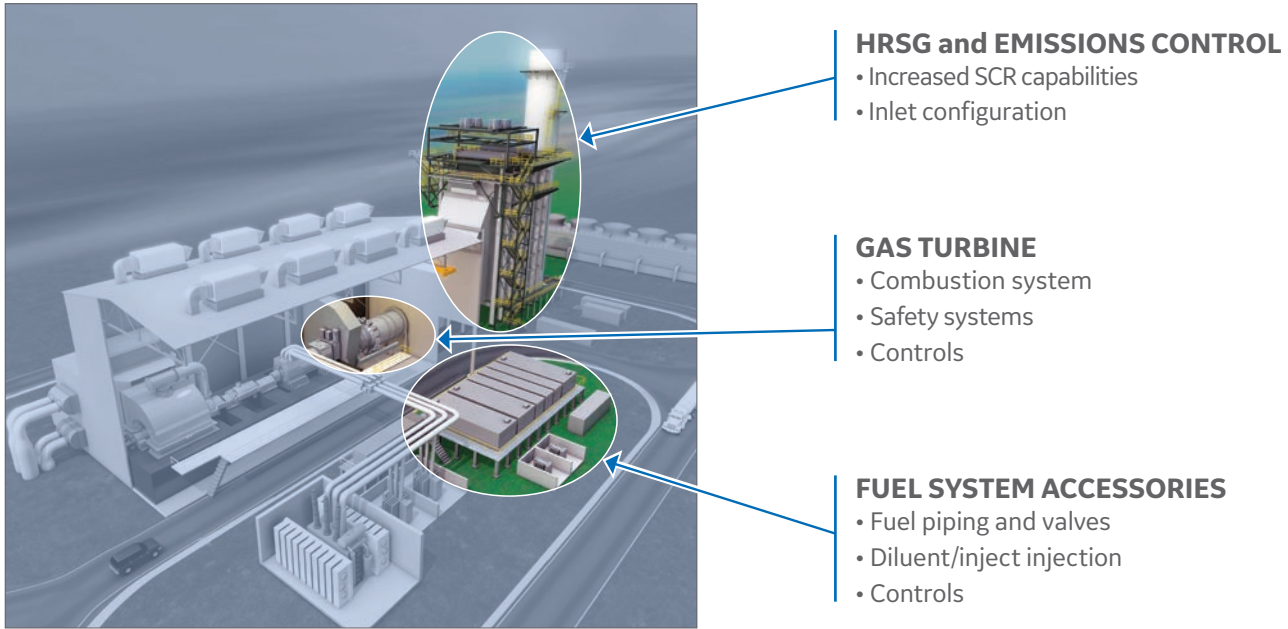
### Power to H<sub>2</sub>: Electrolysis of Water



**2kg of water + electricity → 1kg of H<sub>2</sub>**  
Electricity required can vary from 45-60 kWh per kg of H<sub>2</sub>  
H<sub>2</sub> from electrolysis costs 3-10X cost of natural gas

Other carbon neutral fuels may include some biofuels and synthetic methane.

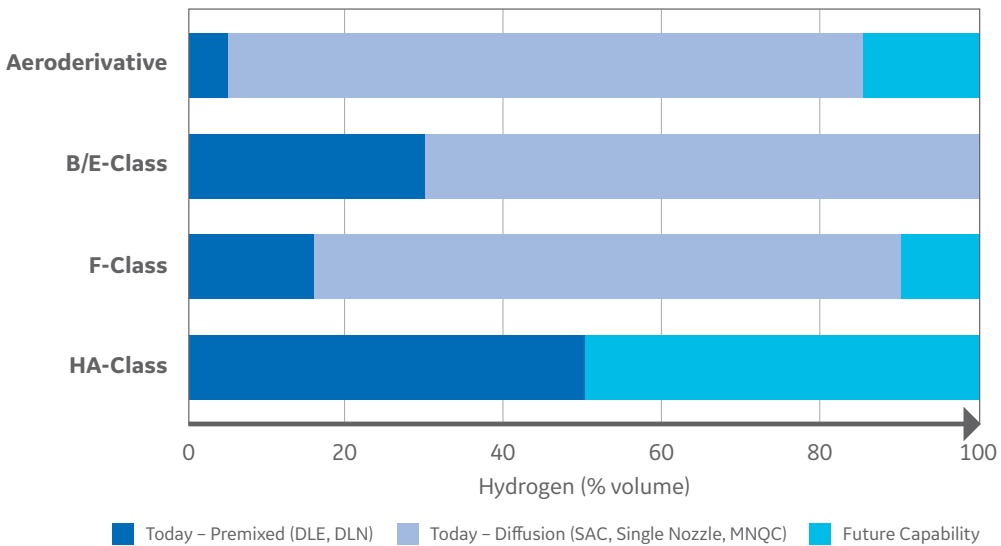
## H<sub>2</sub> IMPACT TO POWER PLANT SYSTEMS COULD INCLUDE:†



Other considerations may include the need for hydrogen storage and adherence to national and local safety regulations.

†The overall plant impact is defined by the amount % of hydrogen in the fuel. Lower concentrations may require little to no change, while higher concentrations may require more significant changes. Please consult with your local GE representative for more details.

## GE GAS TURBINE HYDROGEN CAPABILITY†

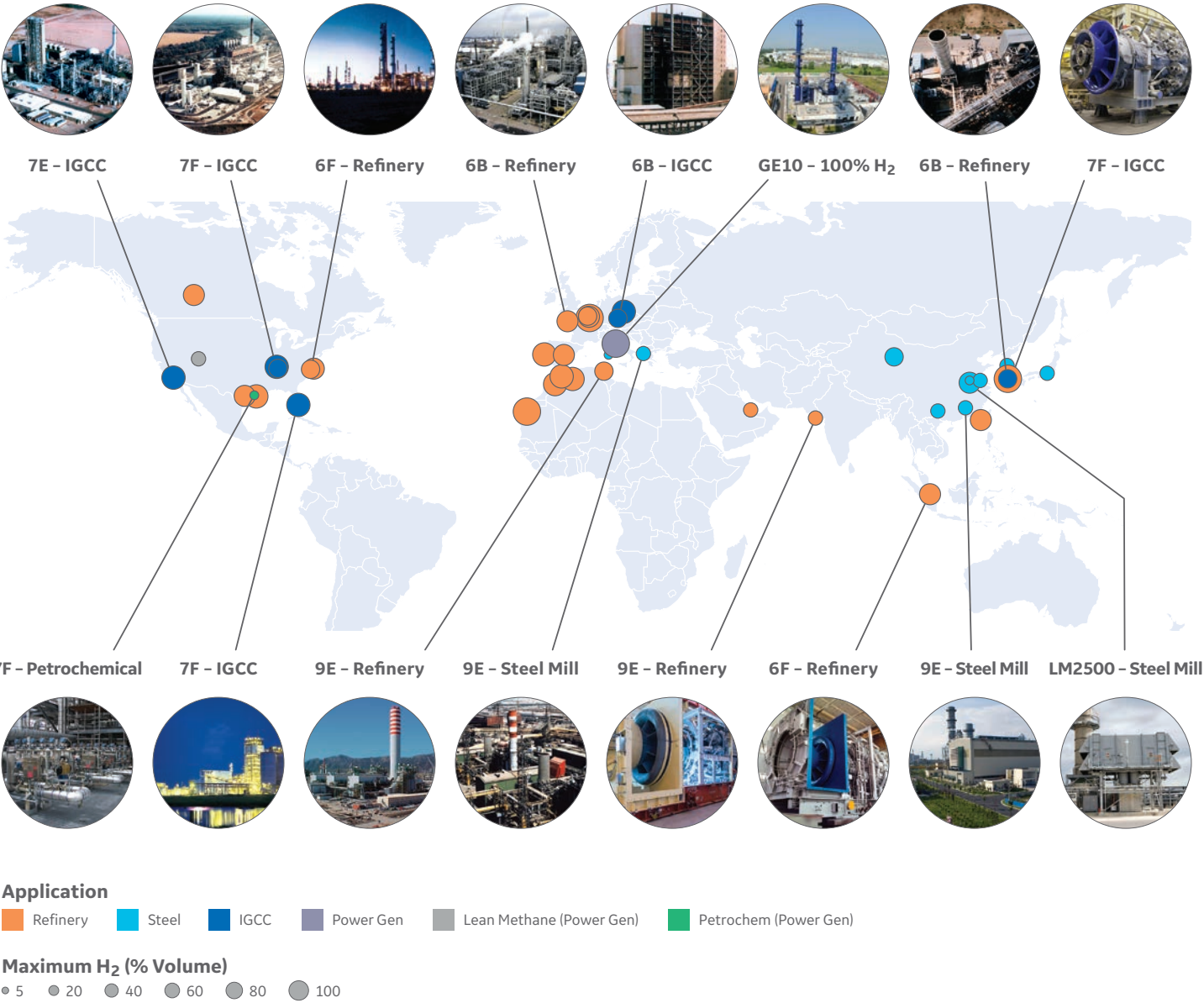


GE has combustion technologies that are capable of operating on a wide range of hydrogen concentrations up to ~100% (by volume)

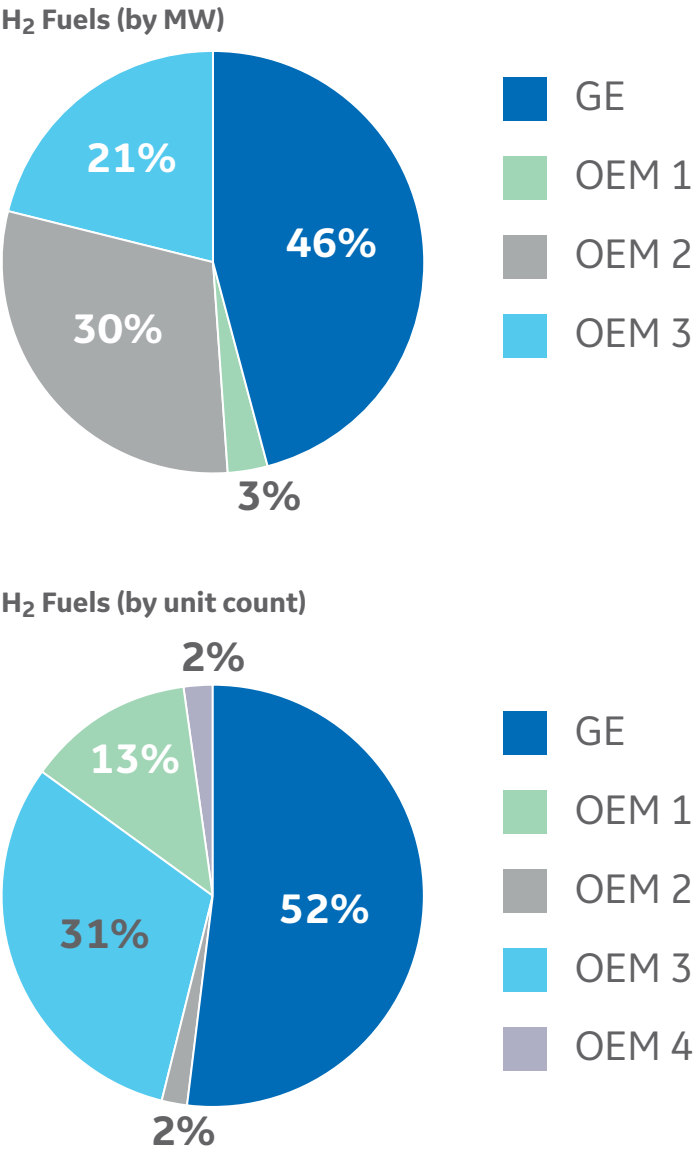
†To get details on H<sub>2</sub> capabilities for a specific gas turbine, please contact your local GE representative.

INDUSTRY LEADING EXPERIENCE ON FUELS WITH HYDROGEN

Over 70 gas turbines supporting power generation with H<sub>2</sub> and associated fuels with more than 4 million operating hours



More MW and more units have operated on fuels with H<sub>2</sub> than any other OEM<sup>†</sup>



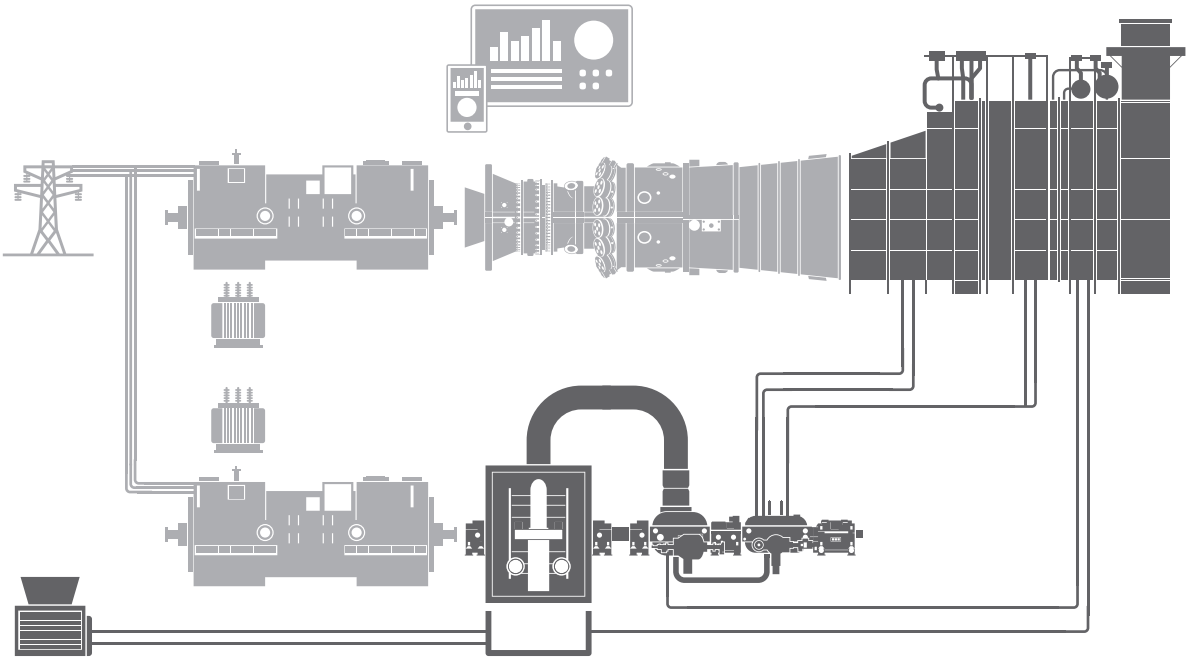
<sup>†</sup>Per McCoy Power Reports, 1980-2018; Hydrogen containing fuels include BFG, COG, COREX, H<sub>2</sub>, Refinery gas, and syngas.

# BOTTOMING CYCLE

# OVERVIEW & SCOPE

The bottoming cycle consists of an HRSG, steam turbine generator, and heat exchanger system. It converts gas turbine exhaust energy to electrical power and heat energy (in CHP applications), and it's the difference between a simple cycle power plant and a combined cycle power plant. The addition of a bottoming cycle increases plant output by about 50 percent and boosts efficiency from 40 percent to around 60 percent.

GE has expanded its bottoming cycle portfolio to utilize 100+ years of combined experience and the very best technologies of GE, Alstom, and Doosan HRSG. With a large installed base and significant technical expertise, GE offers solutions for gas turbines of any OEM. Maximizing the benefits of a bottoming cycle means fully exploiting site-specific thermal conditions. For GE, that means working with customers to understand a multitude of operating conditions so we can provide the highest value solution that optimizes return on investment.



# HRSG OFFERINGS

HRSG technology is critical to combined cycle efficiency. At GE, HRSG solutions are tailored to meet our customers’ requirements. With over 100 years of boiler experience and more than 1,250 HRSGs installed worldwide, we are a world leader in supplying HRSGs behind all major OEM gas turbines.

Our portfolio of products and services brings the engineering and manufacturing of all major components in a combined cycle power plant in-house. For our customers, this means seamless integration with other major components and, when combined with our Digital Power Plant solutions, delivers optimized performance and improved reliability for even the most demanding

project requirements. Our whole system approach provides high power output and efficiency as well as improved plant operability.

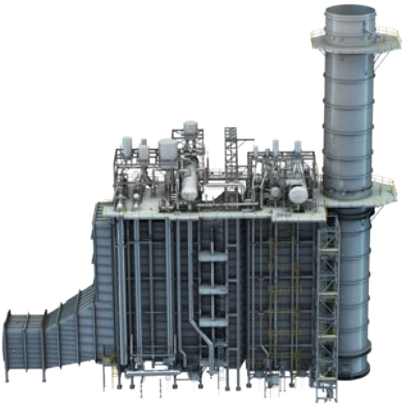
We are also continually working with our gas turbine and steam turbine specialists, utility boiler experts, and teams from GE Global Research to optimize our whole system offerings through advancements in materials, aerodynamics, and manufacturing.

Numerous integrated scope options are available, such as supplementary firing for peak power output, SCR, and CO catalysts for emissions control, and exhaust gas bypass systems for simple cycle operation in combined cycle configuration.

A choice of modular construction options lets you choose the degree of prefabrication that best fits your specific project site requirements:

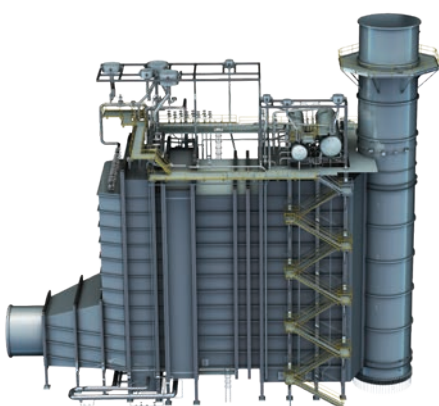
HARP BUNDLE	MODULES	C-FRAME	FULLY ASSEMBLED
<ul style="list-style-type: none"><li>• Limited infrastructure</li><li>• Limited large crane availability</li><li>• Low site labor costs</li></ul>	<ul style="list-style-type: none"><li>• Suitable for most sites</li><li>• Fewer transportation restrictions</li><li>• Large crane availability</li><li>• Medium site labor costs</li></ul>	<ul style="list-style-type: none"><li>• Sites with good water access</li><li>• Large crane availability</li><li>• High site labor costs</li></ul>	<ul style="list-style-type: none"><li>• Sites with excellent water access and specialized transport</li><li>• High site labor costs</li></ul>

## GE’S HRSGs



### HORIZONTAL DRUM

The flow of gas in this most popular HRSG type is horizontal while the water is heated in vertical tubes with natural circulation.



### HORIZONTAL ONCE-THROUGH

Employs the same basic arrangement as the horizontal drum type, but eliminates the high pressure drum and utilizes GE’s in-house once-through technology. This increases flexibility, efficiency, and daily cycling capabilities.

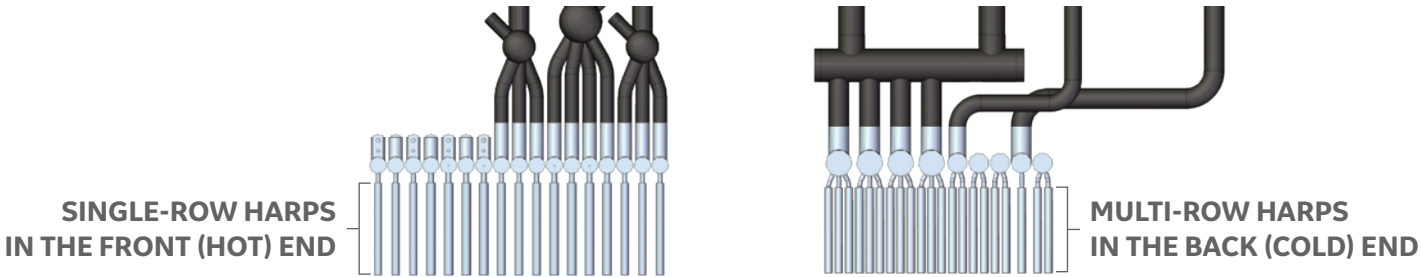


### VERTICAL DRUM

With vertical gas flowing across horizontal tubes, this HRSG type is ideal when site space is limited. It is particularly well suited for heavy fuel oil applications.

## GE’S HORIZONTAL GAS FLOW HRSG

GE’s horizontal gas flow HRSG is a cost-competitive and reliable product that is designed with single-row harps in the front (hot) end and multi-row harps in the back (cold) end.



*GE’s versatile HRSGs can be installed behind any gas turbine.*

# THE GE ADVANTAGE

## CAPABILITY

- A whole system approach ensures integrated engineering with other system components.
- HRSGs can be configured and optimized for any type of gas turbine and steam cycle.
- Predictive analytics around lifetime and failure modes overcome more severe operating conditions.

## VERSATILITY

- GE's HRSG design provides reliable high cycling duty due to innovative single-row harp configuration in the front (hot) end of the HRSG; produces three times less stress than conventional multi-row harps.
- Capable of fast starts, rapid response, and low turndown.

## RELIABILITY

- Increased quality assurance through in-house manufacturing of pressure parts and drums.
- Access to a worldwide dedicated service organization.



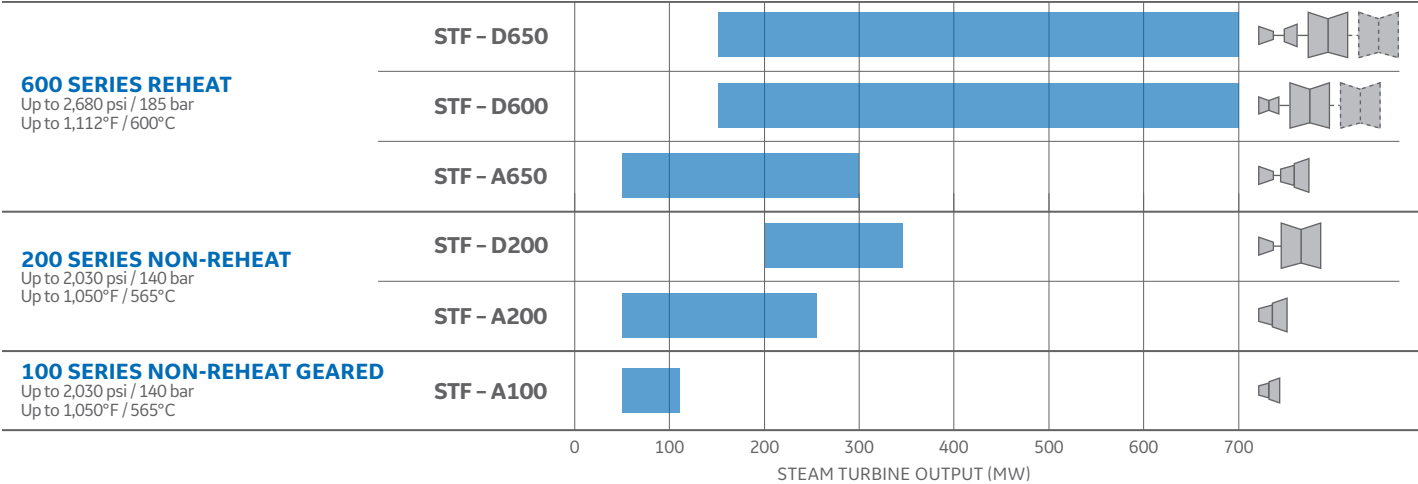
Photo courtesy of Nick Grancharoff at Zachry Group.

# STEAM TURBINE OFFERINGS

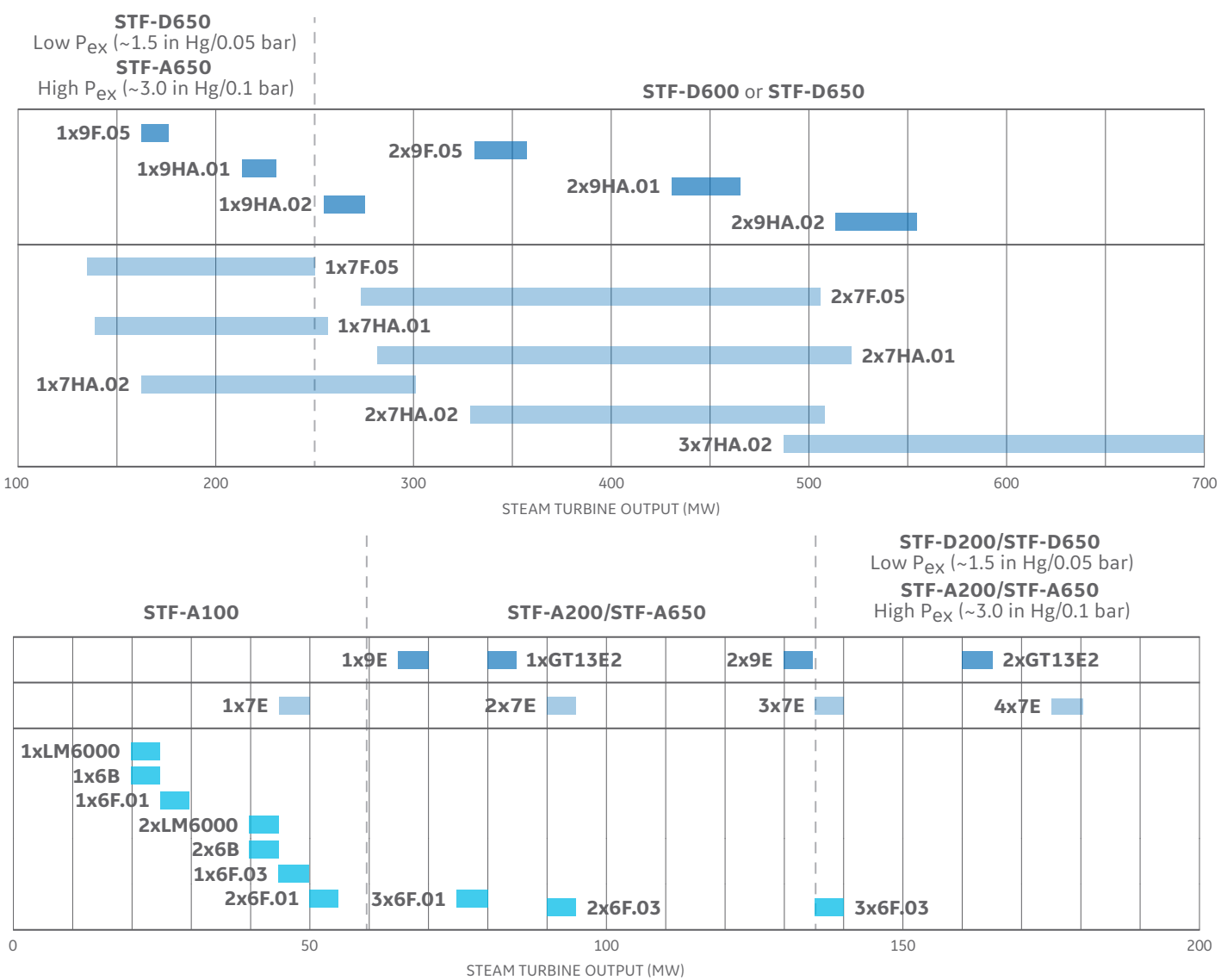
When the Alstom and GE portfolios merged in 2015 we created the industry’s most competitive and historically significant steam turbine portfolio. Alstom’s steam turbine business originated in 1901 when Brown-Boveri Company (BBC) built continental Europe’s first steam turbine in Frankfurt, Germany, operating with an output of 250 kW. Within a year, BBC had delivered 16 more steam turbines with a combined output of 15 MW. GE’s first commercial steam turbine shipped in 1903, making 5,000 kW for use in Newport, Rhode Island, USA.

Within the next 10 years, an estimated 1,000 steam turbines were sold by GE to companies in the United States.

Fast forward a few generations and countless technical advances, and today, GE’s steam turbines offer industry-leading efficiency while accommodating outputs of 15 MW to 1,770 MW. GE’s products account for more than 41 percent of the world’s installed steam turbine base, and in the last 100+ years, has produced more than 1.2 TW of power production capability.



Our steam turbine portfolio has the breadth and depth to meet any project-specific need, integrating seamlessly with our gas turbines, HRSGs, and balance of plant to ensure operational success, satisfaction, and profitability for our customers.



# THE GE ADVANTAGE

## CAPABILITY

A wide range of customizable features ensures maximum value for our customers:

- Meet any project-specific cold-end condition with a densely staggered family of last stage blades. Up to 50 inch (1,270 mm) for 60 Hz and up to 60 inch (1,524 mm) for 50 Hz.
- Industry-leading performance with high-reaction 3D blades and nozzles that are optimized for high pressure (HP), intermediate pressure (IP), and low pressure (LP) steam conditions.
- Improved leakage control, reduced radial clearances, and decreased long-term performance degradation with cost-effective advanced sealing.

## VERSATILITY

GE's steam turbines are designed for operational flexibility, ensuring the highest levels of availability and reliability, even when demand fluctuates:

- Welded rotors in the HP, IP, and LP sections enable longer component life during thermal transients to allow for faster and more frequent load cycling.
- The unique and proven HP inner casing shrink ring design reduces distortion and allows critical clearances to be maintained to ensure sustained performance.
- Axial, side, or down exhaust options facilitate integration into almost any plant configuration.

## RELIABILITY

Our leading efficiency means lower emissions, cleaner air, and better economics for our customers:

- Bottoming cycle contributes 33 percent of the total combined cycle electrical output with no additional fuel consumption.
- Achieves the highest efficiencies with our CHP applications, available in reheat or non-reheat with condensing or backpressure exhaust, and optional HP and LP steam extractions.



*Proven validation methods ensure our steam turbine products meet our customers' needs. We have a variety of validation rigs for our steam turbines, including sub-scale low pressure turbines with full steam conditions located in Schenectady, New York, USA. This rig tests LP blading designs, validating*

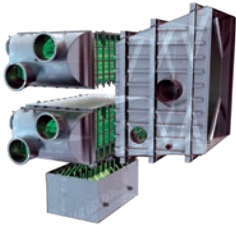
*mechanical robustness and aerodynamic efficiency. Another test rig integral to GE's continued improvement in steam turbine performance is the HP & IP blading test rig in Rugby, United Kingdom, used to validate advancements in more efficient airfoil designs.*

# HEAT EXCHANGER OFFERINGS

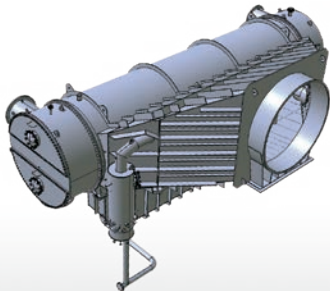
The method in which a power plant rejects process waste heat impacts critical engineering decisions and significantly affects overall plant efficiency. GE’s portfolio of heat rejection systems covers a range of heat exchanger types, providing options to optimize plant operations and performance.

## WATER-COOLED CONDENSERS

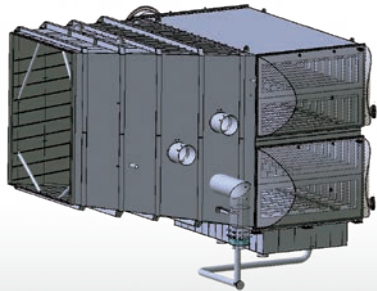
GE offers high-performing deaerating surface condensers for once-through and cooling tower heat rejection systems. These condensers support a full range of steam turbine power output, starting as low as 30 MW. As an experienced manufacturer of both steam turbines and condensers, we understand how asset intricacies must work together to achieve sustained high performance and enhanced reliability. Our condensers are customized for each individual project and feature simplified construction and pre-assembled modules for ease of installation at site.



In addition to rejecting heat and deaerating make-up water and the condensate, our surface condensers feature several critical safety functions. For example, in bypass mode when boiler live steam is led directly into the condenser, it is exposed to very high loads; our designs handle these loads both safely and efficiently.



Cylindrical Shell



Rectangular Shell

Application	Condensing steam turbines or steam dumping	Condensing steam turbines or steam dumping
Power Range	Up to approx. 100 MWe steam turbine output	From 50 MWe up to the largest steam turbine outputs
Arrangement	Down, side, or axial turbine exhaust	Down, side, or axial turbine exhaust
Surface Area	1,000 m² (10,0800 ft²) up to 6,000 m² (640,6000 ft²)	3,000 m² (32,3000 ft²) up to 35,000 m² (380,000 ft²) with single shell
Tube Length	Typical 5 to 14 m (16-46 ft)	Maximum 18 m (60 ft)

## KEY BENEFITS OF GE’S SURFACE CONDENSERS

- **Impressive performance, high reliability:** GE’s tube bundle has a 50-year track record of outstanding performance and unrivaled reliability in both original installations and retrofits.
- **Highly efficient:** The standardized tube bundles are scaled to meet the needs of any power plant, regardless of size. Each bundle contains between 870 and 7,300 tubes.
- **Reduced costs:** Floor-mounted axial or lateral condensers simplify construction of the turbine foundation and shorten civil work and erection durations. The condensers are delivered as fully tubed per-assembled and pre-tested modules to minimize on-site welding.
- **Robust:** Our condensers are built to handle turbine and steam generator overloads and variations in cooling water temperature. They are resistant to impingement erosion and tube vibration. GE engineers also carefully select tube and tubesheet material based on cooling water specifications.
- **Deaerating performance:** GE’s condensers reach extremely low oxygen content in the condensate by efficiently deaerating make-up water.

## FEEDWATER STORAGE TANKS AND DEAERATORS

Proper deaeration of HRSG feedwater/make-up water is crucial to protecting your asset from harmful corrosion. GE’s feedwater storage tanks and deaerating direct-contact feedwater heaters feature simple, yet robust designs that are based on decades of experience. These storage tanks and deaerators accommodate all combined cycle power plant applications and operate across all load ranges to provide high condensate returns and make-up water flows.



## DISTRICT HEATERS AND LOW PRESSURE FEEDWATER HEATERS

GE’s district heaters transfer up to 300 MW of thermal heat with highly efficient heat transfer coefficients and optimum heat transfer surfaces. This type of district heater is extremely reliable, even under transient conditions, and is a major contributing factor to maximizing fuel utilization. GE district heaters are of shell and tube type with tubes fixed in a tubesheet. They are designed either as a condensing heat exchanger or with an integral drain cooler zone.



Custom designed by GE, our low pressure feedwater heaters improve system thermodynamic efficiency by pre-heating water for the steam generating boiler. Once they are commissioned and tuned via the power plant’s control system, GE’s feedwater heaters are maintenance-free.

## OTHER HEAT EXCHANGER PRODUCTS

In addition to the above highlighted offerings, GE offers many other heat exchanger products, including water/water coolers—applied to closed cooling water systems or district heating applications—and atmospheric drain vessels for collecting all external drains, efficiently separating water and steam.

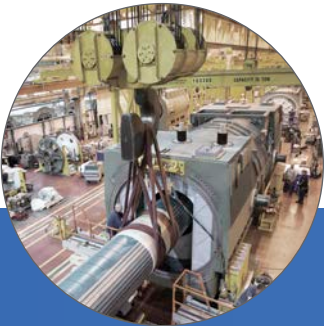
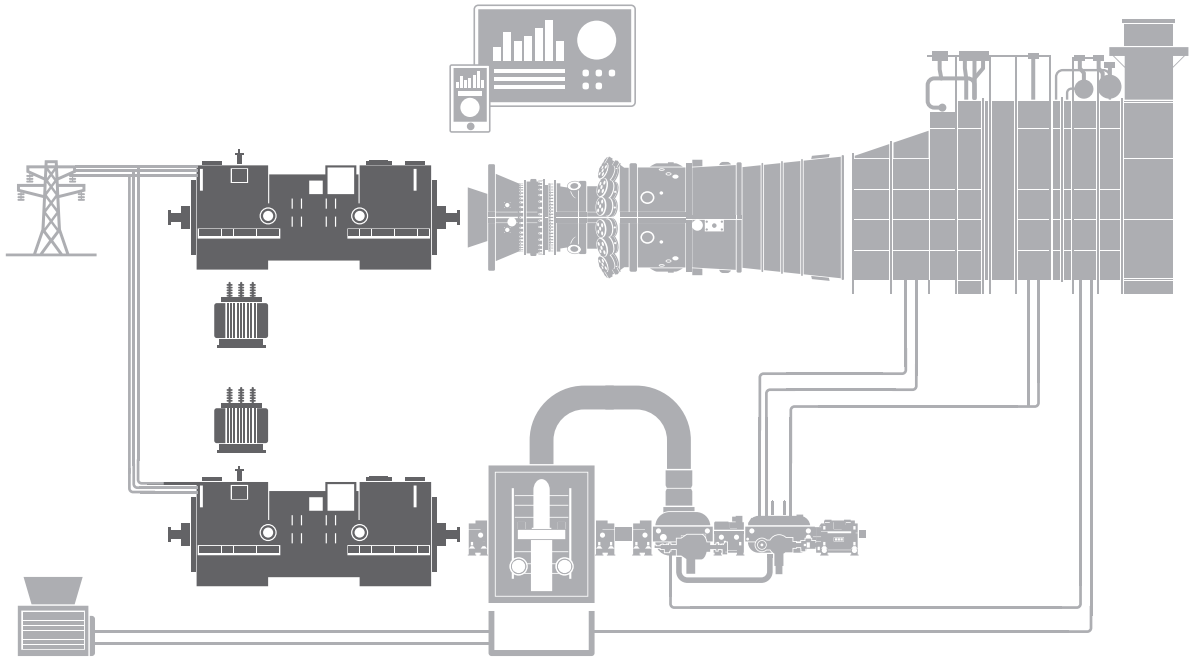
*GE’s condenser design goes beyond Heat Exchange Institute (HEI) guidelines for condenser heat exchanger area, resulting in less area at the same condenser pressure. This typically leads to a 10-20% reduction in surface area depending on thermodynamic design conditions.*

# ELECTRICAL CONVERSION

# OVERVIEW & SCOPE

The final step in the power plant schematic is electrical conversion—supplying power to the grid, which is facilitated by an industrial generator and the electrical balance of plant (EBoP). GE has an installed base of 12,000+ turbine generators, and more than a century of experience delivering innovative, high voltage solutions in generation, transmission, and distribution networks.

Our portfolio of generator and EBoP offerings is configured to serve your needs, no matter how specific or unique. When selecting a generator for your project, our engineers will consider a range of variables, including desired output, and gas and steam turbine selection. Connecting systems to one another as well as the plant to the electrical grid requires an intimate understanding of the power generation process. For EBoP, GE offers a versatile and robust suite of solutions for today’s increasingly complex power plants.

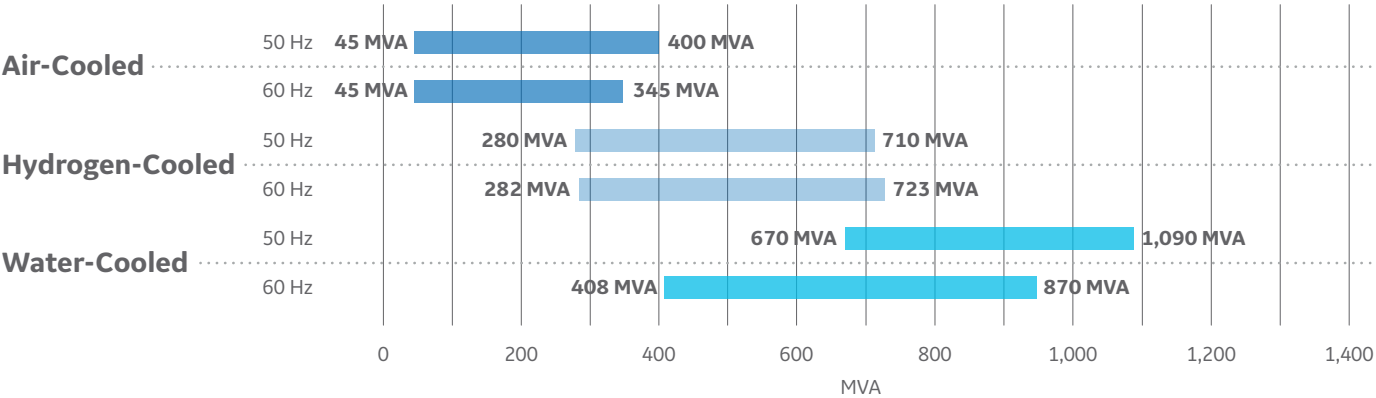


# GENERATOR PORTFOLIO

GE's generators can be configured for multi-shaft or single-shaft operation, with project-specific variables like gas and steam turbine, desired output, regional fuel costs, and local environmental conditions ultimately driving product selection.

GE's generator product line is divided into three categories based on cooling method:

- **GEN-A** air-cooled generators are ideal for systems that demand simple, flexible operation.
- **GEN-H** hydrogen-cooled generators feature low gas density, high specific heat, and high thermal conductivity, making them ideal for high efficiency applications.
- **GEN-W** water-cooled generators operate efficiently and reliably within a small footprint when high output requirements exceed the cooling capabilities of air-cooled or conventional hydrogen-cooled generators.



GE's generators integrate easily, operate reliably, and provide more power. They are flexible and efficient, yet powerful enough to accommodate aggressive outputs. Designed for easy maintenance, their modular architecture features constant cross-section core segments for higher product ratings and 85 percent common parts and tooling for greater spare parts efficiency, interchangeability, and maintenance familiarity. Comprehensive model engineering ensures integrity of electrical and mechanical system design.

Supply chain efficiencies and expanded logistics capabilities reduce manufacturing, delivery, and installation times. Pre-assembled equipment, a single-piece frame architecture, and fixator utilization combine to reduce on site installation by one to two weeks. A modular, pre-wired, and pre-tested eRoom eliminates approximately \$1 million in construction labor costs.

When building or upgrading a plant, our engineers will evaluate all parameters then determine which generator is the most appropriate. While the final product can differ, the outcome is always the same—a cost-effective, fully integrated, reliable solution that serves the needs of the total plant.

*Our generators operate at an availability rate that's .38% above the industry average, equating to more than \$1.6 million net present value for a 2x1 multi-shaft power plant.*

## PROVEN TECHNOLOGY POWERS RELIABLE OPERATION

### Stator

- GE's Tetraloc\* technology helps maintain end-winding mechanical integrity across specific models in all cooling technologies, driving lifelong reliability.
- Advanced insulation systems provide full life-cycle performance, durability, and maximum capability for today's high output machines.

### Rotor

- Computational fluid dynamics (CFD) ensures optimal overall thermal performance and a simplified, radially cooled field winding configuration.
- Continuous monitoring for electrical shorted turns in the rotor winding keeps output consistent and minimizes the potential for thermal rotor vibration.

### Armature Insulation System

- Micapal III\* and ADINS\* stator bar insulation technologies enable higher power density with advanced voltage stress and thermal conductivity capabilities for greater armature performance.
- Online partial discharge monitoring is one of a suite of condition-based monitoring tools that empowers

customers to manage their scheduled maintenance, increase availability, and reduce overall plant operating and maintenance costs.

### Other Components

- Leads-up or side exit iso-phase bus arrangements complement GE steam turbines with axial or side exhausts and capture the value of reduced centerline height foundations.
- Configuration flexibility drives lower plant centerlines, smaller turbine buildings, and more efficient use of plant maintenance equipment, resulting in approximately \$12 million in overall plant cost savings.
- Collector brush monitoring continuously assesses machine condition, providing data that helps maximize availability and optimize maintenance outage planning.
- Low-loss bearings, advanced aero fan blades, and optimized cooling architecture contributes up to \$1.8 million in net present value for a 2x1 multi-shaft combined cycle power plant.

A rigorous validation program complements our technology development, with reliability and performance acting as key drivers. Many aspects of GE's generators are thoroughly tested and validated prior to deployment, including the insulation system, non-metallic components, full-train rotor torsional models, and ventilation patterns.

GE also operates a no load generator test facility that enables full-scale rapid thermal cycling and endurance testing. This capability accelerates testing to simulate extended operation, cyclic loading, and multiple machine start-stops. Every new product is subject to this testing to ensure operability and performance prior to commercial operation.

Source: ORAP®; All rights to underlying data reserved. SPS®, Modified by GE



# ELECTRICAL BALANCE OF PLANT (EBOP)

Once a power plant is built, it needs to be efficiently connected to the electrical grid. The products and services that make that happen are commonly referred to as the EBoP. GE's EBoP solutions work seamlessly across an extensive range of application and power generation types to ensure optimal performance and unprecedented reliability.

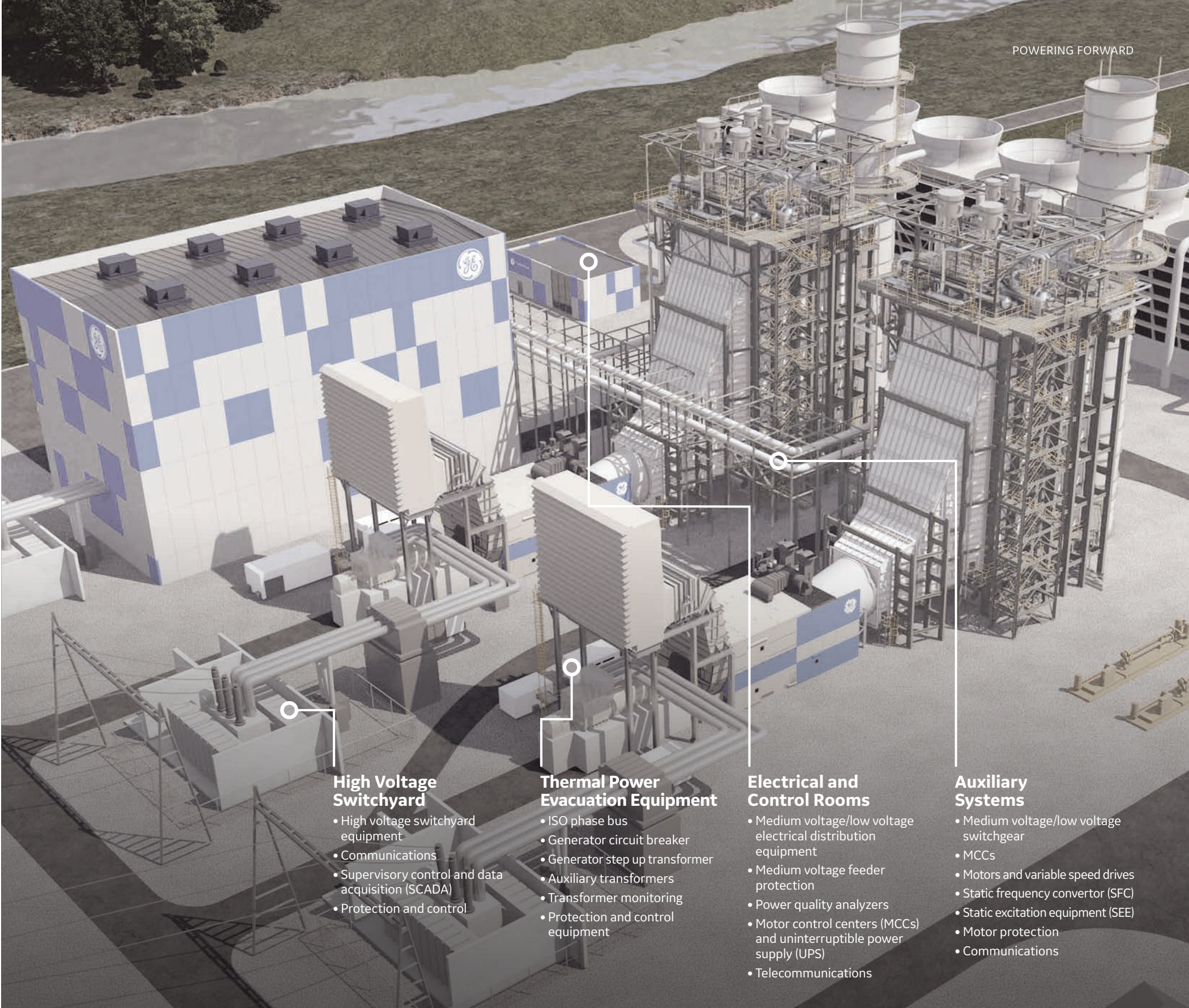
Our systems cater to all types of project requirements. We can supply equipment, engineered packages, and provide full EPC implementation. We provide an integrated system with complete monitoring and control of the power plant for thermal power generation. This includes all electrical aspects of a plant for power generation, power quality, evacuation, and switchyard control.

GE's solutions are engineered using reference designs, resulting in higher efficiency, flexibility, reliability, and quicker return on investment. Systems can be tailored to meet specific needs, compliance codes, and standards. Major components include:

- High voltage equipment
- Medium and low voltage electrical equipment, including motors, drives, protection, and control systems
- Monitoring and diagnostic systems for starters/exciters, drive systems transformers, and motors
- Generator protection
- Generator step up transformers
- Auxiliary transformers
- Power metering systems
- Communications systems
- Plant control system
- Power quality systems.

## THE GE ADVANTAGE

- Fast return on investment facilitated by on time commercial operation date.
- High reliability enhanced by proven design, which is compliant with international standards.
- Complete monitoring and control of power plant electrical systems, enabling better visibility and maintenance.
- Seamless installation and commissioning of integrated system and optimized interfaces.
- Increased visibility and maintenance due to complete monitoring and control of power plant electrical system.
- Smooth project execution due to single coordinating design and construction entity.



### High Voltage Switchyard

- High voltage switchyard equipment
- Communications
- Supervisory control and data acquisition (SCADA)
- Protection and control

### Thermal Power Evacuation Equipment

- ISO phase bus
- Generator circuit breaker
- Generator step up transformer
- Auxiliary transformers
- Transformer monitoring
- Protection and control equipment

### Electrical and Control Rooms

- Medium voltage/low voltage electrical distribution equipment
- Medium voltage feeder protection
- Power quality analyzers
- Motor control centers (MCCs) and uninterruptible power supply (UPS)
- Telecommunications

### Auxiliary Systems

- Medium voltage/low voltage switchgear
- MCCs
- Motors and variable speed drives
- Static frequency convertor (SFC)
- Static excitation equipment (SEE)
- Motor protection
- Communications

## EBOP FOR POWER GENERATION

GE's high voltage power equipment is designed and manufactured in accordance with the Grid Solutions Sourcing Quality guidelines. Our design systems and manufacturing facilities are certified under the requirements ISO 9001:2008, ISO14001:2004, and OHSAS18001:2007.

# PLANT CONTROLS



# PLANT CONTROLS

Protecting, controlling, and monitoring your plant is critical to optimizing performance and operability. By uniting turbine and plant controls with integrated, real-time strategies, GE accommodates load flexibility, combustion versatility, and startup agility while ensuring reliable operation even during weather, fuel, and grid variations.

Industrial digitization is pushing controls capabilities to new heights, driving outcomes that increase output and fuel efficiency while decreasing overall costs and unplanned downtime. GE has long served the power industry with plant-level controls, and now we’re leveraging our decades of experience to deploy a platform that accommodates this digital paradigm.

As an OEM, GE leverages strong domain expertise to differentiate turbine and plant performance and operability with controls. High-fidelity physics-based models of the plant are used to validate the controls software and operability. These models are embedded within the controls logic to run in real-time, and are the backbone of adaptive control strategies that protect assets and enhance operation. Features and benefits of this model-based control strategy include:

- Startup agility, providing fast, reliable, repeatable starts with low emissions
- Combustion versatility and improved turndown, providing robust operation during variations in weather, fuel, and grid
- Load flexibility, for load range expansion, and improved efficiency and responsiveness
- System reliability enhancements for reliable, cost-effective operations

Using the Industrial Internet Control System (IICS), the Mark\* Vle control system provides a flexible and scalable architecture for applications ranging from plant-level to turbine-level control.

## INDUSTRIAL INTERNET CONTROL SYSTEM

GE’s Predix-ready, modular controls platform was founded on the premise that a connected controller takes more intelligent actions. IICS connects and controls the entire plant, providing an integrated, real-time approach that’s driven by data and optimized through a robust set of features.

IICS consists of outcome optimizing controllers, mix-and-match I/O modules, flexible connectivity options, and advanced analytical software and the apps; the combination can be customized to meet specific application needs.

The Mark Vle-based control system unifies and simplifies protection, control, and monitoring of the entire plant to enhance performance and deliver predictable operation. The Mark Vle control system is flexible and scalable to cover a wide range of applications, modular in architecture for future technology upgrades, and SIL certifiable to meet compliance needs.

## CUSTOMER BENEFITS



Power plants with IICS can unlock new insights and hidden value through total-plant controls.

ASSET AND PROCESS PERFORMANCE	MAXIMIZE PRODUCTIVITY	GENERATE NEW REVENUE
<ul style="list-style-type: none"><li>• Securely connect and integrate data across the plant</li><li>• Analyze data on premise or in the cloud</li><li>• Use ready-made apps or develop new apps</li></ul>	<ul style="list-style-type: none"><li>• Create data-driven insights to optimize resource usage</li><li>• Reduce maintenance costs through monitoring and diagnostics</li></ul>	<ul style="list-style-type: none"><li>• Develop new data-driven service offerings</li><li>• Create new channels to market through the emerging Industrial App Economy</li><li>• Maintain competitive advantage through continuous software-based innovation</li></ul>

The biggest benefits of IICS are realized through the platform’s four distinct features, which are common across the power plant to provide a common look and feel. These features are:

**ActivePoint\*** Human Machine Interface (HMI): Contemporary user experience with enhanced visualization, alarm rationalization, and server-based thin client deployment. Alarms are directly represented and actionable within HMI screens and dedicated lists, reducing alarms by as much as 80 percent.

**Control Server:** A commercial grade server for high-capacity edge computing and supervisory control applications. The server features embedded Field Agent technology, a rugged and secure solution for collection and analysis of large quantities of data in the cloud or at the machine.

**Digital Bus and Smart Devices:** Sensors, actuators, and electrical equipment with digital bus technologies exchange information with the plant controller and remote platforms. This digital communication system decreases total installed cost by reducing the effort spent on interconnecting wires, simplifying and speeding up checkout and commissioning.

**Cyber Security:** GE’s in-depth defense approach starts at the hardware and device layer and carries throughout every interface and communication medium to maintain a chain of trust. Firewalls, authenticated communication, and encryption are also utilized throughout the platform and its leveraged software to ensure protection against malicious activity and attacks.

*A typical 9HA plant with digital bus technology will realize approximately \$1 million in installed cost savings. Digital bus also provides long-term benefits through improved fault detection and diagnosis.*

**DISTRIBUTED CONTROL SYSTEM**

GE's Mark VIe platform provides advanced operational capabilities to the entire fleet, including balance of plant equipment, machine controllers, and dedicated control for critical components. Flexible architecture enables optimal solutions, from the traditional unit controls to complete plant solutions for optimized performance, advanced operability, and high availability. Mark VIe is widely used in a diverse range of applications, including gas and steam turbines, safety systems, wind turbines, gasification, hydro, nuclear, and combined cycle power plants. Many of these applications require a compact controller that can deliver the high performance and flexibility needed to reliably run application-specific control.

**MARK VIe BENEFITS**

- Single user interface and tools across system for reduced training costs and improved operator productivity.
- Improved root cause analysis, diagnostics, and overall operational decisions.
- Reduced project risks and integration cost.

The addition of an outcome optimizing controller transforms the Mark VIe into an IICS with virtual Field Agent technology. This provides access to Predix applications and connectivity to the Predix cloud. Real-time control can then be augmented using external intelligence delivered through market analysis, fleet and enterprise data, and asset/process knowledge. With this transformation to a Digital Power Plant, operators can improve efficiency and optimize production while reducing risk and life-cycle costs.

Traditional control systems look down to control the power plant to make sure it's safe, operating reliably, and performing per specifications. IICS looks up to apply a broader context to day-to-day operation by factoring in external data such as power prices, supply cost, and maintenance schedules, allowing users to run the plant differently based on external data.



# POWER GENERATION VALIDATION

# POWER GENERATION VALIDATION

At GE, we are constantly investing in our products and enhancing our validation capabilities to ensure our assets, components, and subsystems are on point. Advancing our offerings to deliver added value is no easy feat; it requires the brightest people, the best ideas, and an across-the-board allegiance to a rigorous and methodical validation philosophy.

Our commitment to engineering excellence is brought to life at our development and validation facilities, which are scattered throughout the world. These laboratories and test stands serve all our major products across their entire life cycle—from materials selection and manufacturing methods to gas turbine system validation and field service optimization. It is these facilities that give GE the ability to accelerate the pace at which new technology and products are introduced.

The industry is demanding, and the competition is fierce. Our goal is to offer proven, validated products that give you the confidence you need to make GE your power generation solution provider.

## GAS TURBINES + COMBUSTION

### Greenville, South Carolina, USA

GE operates the world’s largest and most powerful variable speed, variable load, off-grid gas turbine test facility in Greenville. Capable of replicating a real-world grid environment at full capacity, this facility tests 50 and 60 Hz gas turbines well beyond normal power plant conditions seen in the field. Comprehensive testing provides GE with an unrivaled understanding of component-level functionality and operating temperatures, which are crucial in confirming the thermal strain on parts and accurately analyzing component life.

An advanced communication system connects Greenville’s control room, data center, and nerve center, and facilitates thorough data collection during each test. A digital control system operates the gas turbine throughout testing to validate and refine the control logic and advanced models.

### WHY OFF-GRID?

- **Flexible Testing Capability:** No frequency, speed, or load restrictions; prompt post-test teardown inspection and product enhancement implementation.
- **Unique Operability:** Combustion mapping beyond what’s possible in the field; complete compressor mapping; testing for product capability and durability during extreme grid events.
- **Unmatched Performance:** Ability to tune part-load performance and turndown; optimization of compressor variable vane position scheduling; enhanced load path with expanded knowledge of compressor/combustion boundaries.

## SPOTLIGHT ON GREENVILLE, SOUTH CAROLINA, USA

### Gas Turbine Validation Capabilities

- 8,000+ data streams captured during testing
- Runs both natural gas and liquid distillate fuels
- Capable of testing multiple gas turbine models
- Full-scale compressor mapping and validation

### Combustion Validation Capabilities

- Up to 1,000 data streams captured during each test
- Runs natural gas, propane, butane, ethane, nitrogen, hydrogen, CO, CO<sub>2</sub>, and multiple liquid fuels
- Capable of testing all fleet configurations up to full-scale conditions; can develop new combustion systems as needed
- Full-scale combustor development before gas turbine is on site.



Greenville is also home to the world’s largest and most flexible combustor module test facility, 575,000 square feet of space that includes five independent test cells that house 10 full-scale, single-can test stands. The facility includes a control room, data center, emissions measurement center, instrumentation shop, and fabrication shop.

Capable of running eight different fired tests per week and up to 342 fired tests per year, the combustion lab replicates real-world fuel compositions at full-scale flow conditions to determine combustor operability and fuel flexibility envelope. It also performs component-level flow testing, as well as ping testing and accelerated life testing to provide an overall system-level architecture for operability and durability requirements. This comprehensive approach prepares GE’s combustors for any condition they may experience once installed and operating in the field.

### Seals Rig – Rugby, United Kingdom

This rig evaluates new gas turbine seal designs and has capabilities for accelerated endurance testing, including radial excursion and seal pack tilt tests. It also monitors flowrate, absorbed power, and wear. The facility can supply air inlet temperatures as high as 450°C and pressures of 110 psig. Following recent improvements, the rig shaftline is capable of 18,000 revolutions per minute (RPM), providing a surface speed at the seal interface of 280 ms-1.

### Field Measurements

GE performs regular field measurements at customer power plants to support both research and development activities and customer support (fault diagnosis). A wide range of vibration, temperature, and pressure measurements are offered in fields such as:

- Rotor dynamics (shaft line diagnostics and in-situ balancing)
- Last stage blade airfoil vibration characteristics (tip timing)
- Aerodynamic performance (dynamic pressure measurements)
- Full-scale engine validation

STEAM TURBINES

Low Pressure Development Turbine – Schenectady, New York, USA

This rig provides aeromechanics and performance testing of last stage blades and steam paths. It simulates fossil or combined cycle operation and breaks down performance by section or stage. The rig is equipped with advanced data systems, including non-contact blade vibration detection and unique inner stage, exhaust, and hood measurement capabilities. Testing includes advanced turbine path component technologies, including 3D aerodynamics and seal architecture.

Variable Density Model Turbine (Vdmt) Test Facility – Rugby, United Kingdom

This world-class test facility provides high Reynolds Number aerodynamic testing using a variable mixture of R134a and air as the working fluid. A closed-circuit loop allows operation at elevated and sub-atmospheric pressures. Reynolds Numbers up to full scale can be achieved with the cost and lead-time benefits of scaled components.

Low Pressure Model Turbine (Sophia) – Rugby, United Kingdom

Utilizing the VDMT capabilities, Sophia provides a unique platform for rapid performance measurements of 1/9th scale testing of the last low pressure stage, diffuser, exhaust box, and furniture arrangement. The multi-axis instrumentation traverse system allows detailed volumetric flow field data from rotor trailing edge to condenser inlet.

High/Medium Pressure Model Turbine (Grace) – Rugby, United Kingdom

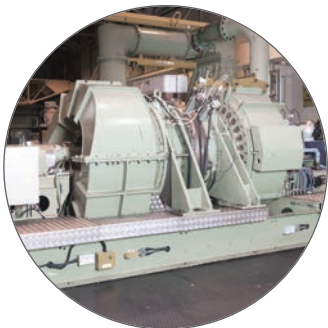
Also utilizing the VDMT, Grace offers a 2½ stage high pressure/intermediate pressure test vehicle on a split shaft arrangement giving high accuracy turbine and stage efficiency measurements. The high Reynolds Number allows the latest generation of reaction and impulse high pressure/intermediate pressure blades to be characterized and validated.

High Pressure Test Vehicle – Lynn, Massachusetts, USA

This multi-stage high pressure test rig has similar capabilities and data acquisition technologies as the low pressure development turbine. It provides best-in-class aero performance test capability of high pressure and intermediate pressure steam turbine blades and steam paths.

Wheel Box Test Facility – Schenectady, New York, USA

The wheel box test facility collects aeromechanical data on single- or multi-stage gas or steam turbine products. The rig simulates a variety of operating conditions by running at varying speeds in a deep vacuum and by varying excitation. Validating airfoil vibration characteristics are critical to ensuring parts life and product operational capabilities.



Sub-Sonic Air Turbine – Schenectady, New York, USA

Utilizing compressed air in lieu of steam, this rig provides section or stage-by-stage performance of up to two stages of steam or gas turbine airfoils. It provides key data needed to validate improvements obtained using 3D aerodynamics in the turbine airfoils by allowing for rapid DOEs critical to the development of advanced airfoil configuration tools.

Stationary Air Cells Test Facility – Schenectady, New York, USA

The stationary air cells provide flexibility to flow test a variety of components in both full- and part-scale configurations. The cells allow for varying flow, velocity, and back pressure to acquire data for use in gas and steam turbine inlets, exhausts, diffusers, seals, flow guides, and hoods.

Seals Rig – Rugby, United Kingdom

This rig evaluates new steam turbine seal designs and has capabilities for accelerated endurance testing, including radial excursion and seal pack tilt tests. It also monitors flowrate, absorbed power, and wear. The facility can supply air inlet temperatures as high as 450°C and pressures of 110 psig. Following recent improvements, the rig shaftline is capable of 18,000 RPM, providing a surface speed at the seal interface of 280 ms-1.

Blade Vibration Testing

Steam turbine airfoil vibration testing is conducted at any GE overspeed/vacuum chamber facility worldwide and can range from first stage high pressure blading through to last stage low pressure blading, for both new (first of its kind) and in-service components. The facilities use state-of-the art testing methods such as strain gauging, telemetry, and tip-timing, using both air jets and DC + AC electromagnets for simulated excitation.

Field Measurements

GE performs regular field measurements at customer power plants to support both research and development activities and customer support (fault diagnosis). A wide range of vibration, temperature, and pressure measurements are offered in fields such as:

- Rotor dynamics (shaft line diagnostics and in-situ balancing)
- Last stage blade airfoil vibration characteristics (tip timing)
- Aerodynamic performance (dynamic pressure measurements)
- Steam turbine valve vibration and noise surveys
- Full-scale engine validation



GENERATORS

Schenectady, New York, USA

The generator development and validation facility tests components, subsystems, systems, and complete generators.

- The non-metallic materials lab enables insulation systems development and non-metallic component testing.
- A balance bunker performs rotor torsional vibration tests on generator fields, producing data for each individual rotor. This data is used to validate full-train torsional models and to mitigate risk of torsional resonance.
- This stationary test rig validates new ventilation schemes for generator fields for potential uprates to both new and existing units with field rewinds. DC current is passed through copper field turns while ventilation gas cools the turns.
- At the armature end-winding lab, thermal and mechanical cycling of full-scale end-winding support systems allow for the evaluation of new materials, support systems, and configurations.
- The armature development lab tests new armature bar and slot support systems at current levels up to 17,000 amps or bar forces upwards of 200 lbf per inch of stator bar length.

A \$14 million upgrade to the existing generator thermal cycling and endurance test stand adds the capability for full-scale, rapid, thermal cyclic duty and endurance testing with capabilities that include open circuit, short circuit, and sudden short circuit. In addition to housing the drive train, the test facility includes control room and data centers, as well as an on-site remote nerve center area, all connected by an advanced communication system that facilitates thorough data collection during each test.

DIGITAL SOLUTIONS

Our partners at GE Digital in San Ramon, California, USA create software to design, build, operate, and manage the entire asset life cycle. The team blends innovation, domain expertise, and proven technologies to seamlessly integrate software, apps, and analytics into GE’s industrial business offerings. For GE Power this means access to an expanded network of engineers to help create more holistic offerings; for you it means access to high-value assets that leverage the latest in digital features and capabilities.

GE Digital created IICS, our Predix-ready, modular controls platform. As GE Power’s premier advanced software solution, IICS is being deployed to our power plant customers around the world. Each IICS application is closely monitored by GE Power’s Digital Solutions team and our co-creators at GE Digital to enhance and optimize the platform and its many ancillary applications.

PRODUCT ENGINEERING & DESIGN

At GE, we imagine a future without energy poverty, a future where every home, school, and business can tap into a cleaner and modern source of electricity. For more than a century, we have been investing in fundamental applied research and development, often with the support of the United States Department of Energy, to make this future today’s reality. GE also operates state-of-the-art Global Research facilities where the world’s brightest scientists, engineers, and researchers create a path for GE’s future.

GE’s technology heritage is unparalleled in the power generation industry. Technology innovation, coupled with vast fleet experience from our installed base, is expanding our domain expertise in core energy industry disciplines such as materials science, aerodynamics, combustion, and heat transfer. Additive technology is increasingly disrupting how we design, build, and service our products. These advancements translate to more power and more efficient power, which reduces life-cycle costs and maximizes profitability for our customers.

*GE’s long history and deep experience in the power industry includes over 700 power-related patents, 550,000+ Digital Twins deployed, 2,700+ gas and steam turbines installed, and more than 800 power plants worldwide running on GE equipment.*

ADVANCED MANUFACTURING IS REVOLUTIONIZING TECHNOLOGY GROWTH

GE’s 125,000-square-foot Advanced Manufacturing Works facility in Greenville, South Carolina, USA, is leading future growth in manufacturing technology by changing the way we make things, allowing us to launch new technologies and products faster.

CAPABILITIES: 3D PRINTING | COMPOSITE MATERIALS | ADVANCED ROBOTICS | INNOVATIVE MACHINING

# APPENDIX

TECHNICAL DATA

HEAVY DUTY GAS TURBINES

		50/60 Hz (Geared)			50 Hz	
		6B.03	6F.01	6F.03	9E.03	9E.04
SC Plant Performance	SC Net Output (MW)	44	57	88	132	145
	SC Net Heat Rate (Btu/kWh, LHV)	10,180	8,880	9,277	9,860	9,210
	SC Net Heat Rate (kJ/kWh, LHV)	10,741	9,369	9,788	10,403	9,717
	SC Net Efficiency (% , LHV)	33.5%	38.4%	36.8%	34.6%	37.0%
Gas Turbine Parameters	Compression Pressure Ratio (X:1)	12.7	21.4	16.4	13.1	13.3
	Exhaust Temperature (°F)	1,023	1,152	1,151	1,012	1,007
	Exhaust Temperature (°C)	551	622	622	544	542
	Exhaust Mass Flow (lb/s)	319.7	291.4	482.4	924.4	917.1
	Exhaust Mass Flow (kg/s)	145.0	132.2	218.8	419.3	416.0
	GT Turndown Minimum Load (%)	30%	40%	35%	35%	35%
	GT Ramp Rate (MW/min) <sup>1</sup>	20	12	14	50	16
	NOx (ppmvd) at Baseload (@15% O <sub>2</sub> )	4	25	15	5	15
	CO (ppm) at Min. Turndown w/o Abatement	25	9	9	25	25
1x1 CC Plant Performance	Startup Time, Conventional/Peaking (Min.) <sup>2</sup>	12/10	12/10	19/11	30/10	30/10
	CC Net Output (MW)	68	85	135	204	216
	CC Net Heat Rate (Btu/kWh, LHV)	6,614	5,896	5,998	6,399	6,220
	CC Net Heat Rate (kJ/kWh, LHV)	6,978	6,221	6,328	6,751	6,563
	CC Net Efficiency (% , LHV)	51.6%	57.9%	56.9%	53.3%	54.9%
	Plant Turndown – Minimum Load (%)	41%	39%	44%	45%	46%
	Ramp Rate (MW/Minute) <sup>1</sup>	20	12	7	50	16
	Startup Time (RR Hot, Minutes) <sup>3</sup>	30	30	45	38	38
1x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	3PNRH	3PNRH	2PNRH	2PNRH
	ST Configuration (Type)	STF-A100	STF-A100	STF-A200	STF-A200	STF-A200
2x1 CC Plant Performance	CC Net Output (MW)	137	171	272	410	436
	CC Net Heat Rate (Btu/kWh, LHV)	6,551	5,849	5,944	6,353	6,180
	CC Net Heat Rate (kJ/kWh, LHV)	6,912	6,171	6,271	6,703	6,520
	CC Net Efficiency (% , LHV)	52.1%	58.3%	57.4%	53.7%	55.2%
	Plant Turndown – Minimum Load (%)	20%	19%	21%	22%	22%
	Ramp Rate (MW/Minute) <sup>1</sup>	40	24	13	100	25
	Startup Time (RR Hot, Minutes) <sup>3</sup>	30	30	35	38	38
2x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	3PNRH	3PNRH	2PNRH	2PNRH
	ST Configuration (Type)	STF-A200	STF-A200	STF-A200	STF-D200	STF-D200

50 Hz					
GT13E2	9F.03	9F.04	9F.05	9HA.01	9HA.02
210	265	288	314	446	571
8,980	9,020	8,810	8,846	7,910	7,740
9,474	9,517	9,295	9,333	8,346	8,201
38.0%	37.8%	38.7%	38.6%	43.1%	44.0%
18.2	16.7	16.9	18.3	23.5	23.8
959	1,104	1,150	1,170	1,164	1,184
515	596	621	632	629	640
1,370.4	1,466.2	1,459.0	1,572.7	1,889.7	2,292.5
621.6	665.1	661.8	713.4	857.2	1,039.9
30%	35%	35%	35%	25%	25%
14/36/68	22	23	24	65	88
15	15	15	25	25	25
25	24	24	24	9	9
25/15/10	23/20	23/20	23/20	23/	23/
305	412	443	493	661	838
6,189	5,778	5,666	5,619	5,378	5,320
6,530	6,096	5,978	5,928	5,674	5,613
55.1%	59.1%	60.2%	60.7%	63.5%	64.1%
39%	46%	48%	43%	33%	33%
14	22	22	24	65	88
30	30	30	30	<30	<30
2PNRH	3PRH	3PRH	3PRH	3PRH	3PRH
STF-A200	STF-D650	STF-D650	STF-D650	STF-D650	STF-D650
613	825	889	989	1,324	1,680
6,153	5,764	5,649	5,603	5,369	5,306
6,492	6,081	5,960	5,911	5,664	5,598
55.5%	59.2%	60.4%	60.9%	63.6%	64.3%
19%	21%	22%	20%	15%	15%
28	44	44	48	130	176
30	39	39	39	<30	<30
2PNRH	3PRH	3PRH	3PRH	3PRH	3PRH
STF-D200	STF-D650	STF-D650	STF-D650	STF-D650	STF-D650

<sup>1</sup> Ramp rates are Fast Ramp via AGC.

<sup>2</sup> Start times recognize purge credit. Turning gear to full speed, full load and synchronized to grid. Peaking maintenance factors may apply depending on the operating profile.

<sup>3</sup> Start times are based on rapid response technologies in hot start conditions with purge credit recognized. Simultaneous start sequence of gas turbine may apply depending on exact project configurations.

NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.

All performance figures based on once-through condenser with 1.2" Hga condenser pressure. 2PNRH = Two pressure, non-reheat; 3PRH = Three pressure, reheat.

TECHNICAL DATA  
HEAVY DUTY GAS TURBINES (continued)

		60 Hz				
		7E.03	7F.04	7F.05	7HA.01	7HA.02
SC Plant Performance	SC Net Output (MW)	91	198	243	290	384
	SC Net Heat Rate (Btu/kWh, LHV)	10,060	8,840	8,570	8,120	8,009
	SC Net Heat Rate (kJ/kWh, LHV)	10,614	9,327	9,042	8,567	8,450
	SC Net Efficiency (% LHV)	33.9%	38.6%	39.8%	42.0%	42.6%
Gas Turbine Parameters	Compression Pressure Ratio (X:1)	13.0	16.7	18.6	21.6	23.1
	Exhaust Temperature (°F)	1,026	1,151	1,189	1,158	1,202
	Exhaust Temperature (°C)	552	622	643	626	650
	Exhaust Mass Flow (lb/s)	650.4	1,013.2	1,159.9	1,293.7	1,609.4
	Exhaust Mass Flow (kg/s)	295.0	459.6	526.1	586.8	730.0
	GT Turndown Minimum Load (%)	35%	49%	43%	25%	25%
	GT Ramp Rate (MW/min) <sup>1</sup>	40	30	40	55	60
	NOx (ppmvd) at Baseload (@15% O <sub>2</sub> )	4	9	12	25	25
	CO (ppm) at Min. Turndown w/o Abatement	25	9	9	9	9
	Startup Time, Conventional/Peaking (Min.) <sup>2</sup>	23/10	21/11	21/11	21/10	21/10
1x1 CC Plant Performance	CC Net Output (MW)	142	305	376	438	573
	CC Net Heat Rate (Btu/kWh, LHV)	6,505	5,715	5,649	5,481	5,381
	CC Net Heat Rate (kJ/kWh, LHV)	6,863	6,030	5,960	5,783	5,677
	CC Net Efficiency (% LHV)	52.5%	59.7%	60.4%	62.3%	63.4%
	Plant Turndown – Minimum Load (%)	45%	58%	46%	33%	33%
	Ramp Rate (MW/Minute) <sup>1</sup>	40	30	40	55	60
	Startup Time (RR Hot, Minutes) <sup>3</sup>	35	28	25	<30	<30
1x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	3PRH	3PRH	3PRH	3PRH
	ST Configuration (Type)	STF-A200	STF-D650	STF-D650	STF-D650	STF-D650
2x1 CC Plant Performance	CC Net Output (MW)	287	615	756	880	1,148
	CC Net Heat Rate (Btu/kWh, LHV)	6,439	5,676	5,649	5,453	5,365
	CC Net Heat Rate (kJ/kWh, LHV)	6,793	5,989	5,960	5,753	5,660
	CC Net Efficiency (% LHV)	53.0%	60.1%	60.4%	62.6%	63.6%
	Plant Turndown – Minimum Load (%)	22%	27%	22%	15%	15%
	Ramp Rate (MW/Minute) <sup>1</sup>	80	60	80	110	120
	Startup Time (RR Hot, Minutes) <sup>3</sup>	35	28	25	<30	<30
2x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	3PRH	3PRH	3PRH	3PRH
	ST Configuration (Type)	STF-D200	STF-D650	STF-D650	STF-D650	STF-D650

<sup>1</sup> Ramp rates are Fast Ramp via AGC.  
<sup>2</sup> Start times recognize purge credit. Turning gear to full speed, full load and synchronized to grid. Peaking maintenance factors may apply depending on the operating profile.  
<sup>3</sup> Start times are based on rapid response technologies in hot start conditions with purge credit recognized. Simultaneous start sequence of gas turbine may apply depending on exact project configurations.  
NOTE: All ratings are net plant, based on ISO conditions and natural gas fuel. Actual performance will vary with project-specific conditions and fuel.  
All performance figures based on once-through condenser with 1.2" Hga condenser pressure. 2PNRH = Two pressure, non-reheat; 3PRH = Three pressure, reheat.



TECHNICAL DATA

AERODERIVATIVE GAS TURBINES

		TM2500	
Gas Turbine Rating	Frequency	50	60
	ISO Base Rating (MW)	34.3	37.1
	Gross Heat Rate (Btu/kWh, LHV)	9,665	9,171
	Gross Heat Rate (kJ/kWh, LHV)	10,197	9,676
	Gross Efficiency (% , LHV)	35.3%	37.2%
	Exhaust Temperature (°F)	963	950
	Exhaust Temperature (°C)	517	510
	Exhaust Mass Flow (lb/s)	203.9	208.6
	Exhaust Mass Flow (kg/s)	92.5	94.6
Gas Turbine Parameters	Compression Pressure Ratio (X:1)	24.5	24.7
	GT Turndown Minimum Load (%)	50%	50%
	GT Ramp Rate (MW/min)	30	30
	NOx (ppmvd) at Baseload (@15% O <sub>2</sub> )	25	25
	CO (ppm) (@15% O <sub>2</sub> ) <sup>1</sup>	15/275	15/275
	Startup Time (Hot, Minutes)	8	8
SC Plant Performance	SC Net Output (MW)	33.6	35.9
	SC Net Heat Rate (Btu/kWh, LHV)	9,794	9,330
	SC Net Heat Rate (kJ/kWh, LHV)	10,333	9,844
	SC Net Efficiency (% , LHV)	34.8%	36.6%
1x1 CC Plant Performance	CC Net Output (MW)	48.4	50.5
	CC Net Heat Rate (Btu/kWh, LHV)	6,851	6,703
	CC Net Heat Rate (kJ/kWh, LHV)	7,229	7,072
	CC Net Efficiency (% , LHV)	49.8%	50.9%
	Plant Turndown – Minimum Load (%)	35%	36%
	Ramp Rate (MW/min)	30	30
	Startup Time (Hot, Minutes)	30	30
1x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	2PNRH
	ST Configuration (Type)	Condensing	Condensing
2x1 CC Plant Performance	CC Net Output (MW)	97.2	101.3
	CC Net Heat Rate (Btu/kWh, LHV)	6,827	6,681
	CC Net Heat Rate (kJ/kWh, LHV)	7,203	7,049
	CC Net Efficiency (% , LHV)	50.0%	51.1%
	Plant Turndown – Minimum Load (%)	35%	35%
	Ramp Rate (MW/min)	60	60
	Startup Time (Hot, Minutes)	30	30
2x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	2PNRH
	ST Configuration (Type)	Condensing	Condensing

<sup>1</sup> At baseload/minimum turndown without abatement

<sup>2</sup> Consult GE for project-specific data

NOTE: Gas turbine ratings are at the generator terminals; 15°C (59°F), 60% relative humidity; unity power factor, natural gas, inlet, and exhaust losses excluded. Plant ratings are on a net plant basis; 15°C (59°F), 60% relative humidity; 0.8 power factor, natural gas, inlet, and exhaust losses included. Actual performance will vary with project-specific conditions and fuel.

2PNRH = Two pressure, non-reheat.

LM2500+		LM2500+ DLE	
50	60	50	60
30.0	31.8	31.1	31.9
9,624	9,252	9,169	8,785
10,154	9,761	9,674	9,269
35.5%	36.9%	37.2%	38.8%
920	914	1,003	978
493	490	539	525
197.3	196.9	195.8	191.7
89.5	89.3	88.8	87.0
23.1	23.1	23.6	23.1
50%	50%	50%	50%
30	30	30	30
25	25	25	25
250/250	250/250	25/25	25/25
10	10	10	10
29.3	31.0	30.1	30.6
9,826	9,453	9,338	8,988
10,367	9,973	9,852	9,482
34.7%	36.1%	36.5%	38.0%
41.5	43.0	44.0	43.9
6,931	6,809	6,384	6,299
7,312	7,184	6,736	6,645
49.2%	50.1%	53.4%	54.2%
35%	36%	34%	35%
30	30	30	30
30	30	30	30
2PNRH	2PNRH	2PNRH	2PNRH
Condensing	Condensing	Condensing	Condensing
83.2	86.3	88.2	88.2
6,907	6,787	6,361	6,277
7,287	7,161	6,711	6,622
49.4%	50.3%	53.6%	54.4%
18%	18%	17%	17%
60	60	60	60
30	30	30	30
2PNRH	2PNRH	2PNRH	2PNRH
Condensing	Condensing	Condensing	Condensing

LM2500+ G4		LM2500+ G4 DLE	
50	60	50	60
34.5	37.1	33.4	34.5
9,676	9,171	9,166	8,709
10,209	9,676	9,671	9,188
35.3%	37.2%	37.2%	39.2%
966	950	1,026	995
519	510	552	535
212.9	212.8	205.1	201.7
96.6	96.5	93.0	91.5
24.6	24.7	24.0	23.6
50%	50%	50%	50%
30	30	30	30
25	25	25	25
250/275	250/275	25/25	25/25
10	10	10	10
33.6	36.2	32.5	33.6
9,870	9,348	9,352	8,897
10,413	9,862	9,867	9,387
34.6%	36.5%	36.5%	38.4%
48.2	50.3	47.7	47.7
6,884	6,729	6,343	6,239
7,263	7,099	6,693	6,583
49.6%	50.7%	53.8%	54.7%
35%	36%	34%	35%
30	30	30	30
30	30	30	30
2PNRH	2PNRH	2PNRH	2PNRH
Condensing	Condensing	Condensing	Condensing
96.8	100.9	95.7	95.7
6,860	6,707	6,320	6,218
7,238	7,076	6,668	6,560
49.7%	50.9%	54.0%	54.9%
17%	18%	17%	18%
60	60	60	60
30	30	30	30
2PNRH	2PNRH	2PNRH	2PNRH
Condensing	Condensing	Condensing	Condensing

TECHNICAL DATA

AERODERIVATIVE GAS TURBINES (continued)

		LM6000 PC	LM6000 PG	LM6000 PF	LM6000 PF+
Gas Turbine Rating	Frequency	50/60	50/60	50/60	50/60
	ISO Base Rating (MW)	46/52 <sup>2</sup>	56/59 <sup>2</sup>	45/50 <sup>2</sup>	54/59 <sup>3</sup>
	Gross Heat Rate (Btu/kWh, LHV)	8,458	8,524	8,097	8,162
	Gross Heat Rate (kJ/kWh, LHV)	8,924	8,993	8,543	8,612
	Gross Efficiency (% , LHV)	40.3%	40.0%	42.1%	41.8%
	Exhaust Temperature (°F)	824	879	861	927
	Exhaust Temperature (°C)	440	470	461	497
	Exhaust Mass Flow (lb/s)	284.4	315.9	277.0	307.3
	Exhaust Mass Flow (kg/s)	129.0	143.3	125.6	139.4
Gas Turbine Parameters	Compression Pressure Ratio (X:1)	29.6	33.5	29.8	33.5
	GT Turndown Minimum Load (%)	25%	25%	50%	50%
	GT Ramp Rate (MW/min)	50	50	50	50
	NOx (ppmvd) at Baseload (@15% O <sub>2</sub> )	25	25	15	25
	CO (ppm) (@15% O <sub>2</sub> ) <sup>1</sup>	89/150	94/150	25/70	25/25
	Startup Time (Hot, Minutes)	5	5	5	5
SC Plant Performance	SC Net Output (MW)	45/50 <sup>2</sup>	55/57 <sup>2</sup>	44/49 <sup>2</sup>	53/58 <sup>3</sup>
	SC Net Heat Rate (Btu/kWh, LHV)	8,651	8,692	8,281	8,271
	SC Net Heat Rate (kJ/kWh, LHV)	9,127	9,170	8,737	8,726
	SC Net Efficiency (% , LHV)	39.4%	39.3%	41.2%	41.3%
1x1 CC Plant Performance	CC Net Output (MW)	59/66 <sup>2</sup>	73/76 <sup>2</sup>	58/64 <sup>2</sup>	70/77 <sup>3</sup>
	CC Net Heat Rate (Btu/kWh, LHV)	6,573	6,535	6,179	6,105
	CC Net Heat Rate (kJ/kWh, LHV)	6,935	6,895	6,520	6,441
	CC Net Efficiency (% , LHV)	51.9%	52.2%	55.2%	55.9%
	Plant Turndown – Minimum Load (%)	19%	19%	37%	37%
	Ramp Rate (MW/min)	50	50	50	50
	Startup Time (Hot, Minutes)	30	30	30	30
1x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	2PNRH	2PNRH	2PNRH
	ST Configuration (Type)	Condensing	Condensing	Condensing	Condensing
2x1 CC Plant Performance	CC Net Output (MW)	118/133 <sup>2</sup>	146/153 <sup>2</sup>	117/129 <sup>2</sup>	142/155 <sup>3</sup>
	CC Net Heat Rate (Btu/kWh, LHV)	6,555	6,516	6,161	6,085
	CC Net Heat Rate (kJ/kWh, LHV)	6,916	6,874	6,500	6,420
	CC Net Efficiency (% , LHV)	52.1%	52.4%	55.4%	56.1%
	Plant Turndown – Minimum Load (%)	19%	19%	19%	18%
	Ramp Rate (MW/min)	100	100	100	100
	Startup Time (Hot, Minutes)	30	30	30	30
2x1 CC Power Plant Features	Bottoming Cycle Type	2PNRH	2PNRH	2PNRH	2PNRH
	ST Configuration (Type)	Condensing	Condensing	Condensing	Condensing

<sup>1</sup> At baseload/minimum turndown without abatement  
<sup>2</sup> Output with SPRINT  
<sup>3</sup> Sprint flow at 37 gpm  
NOTE: Gas turbine ratings are at the generator terminals; 15°C (59°F), 60% relative humidity; unity power factor, natural gas, inlet, and exhaust losses excluded. Plant ratings are on a net plant basis; 15°C (59°F), 60% relative humidity; 0.8 power factor, natural gas, inlet, and exhaust losses included. Actual performance will vary with project-specific conditions and fuel.  
2PNRH = Two pressure, non-reheat.

LMS100	
50	60
118	118
7,833	7,628
8,265	8,048
43.6%	44.7%
824	810
440	432
516.9	516.9
234.5	234.5
42.5	42.5
15%	15%
50	50
25	25
95/250	95/250
8	8
117	117
7,925	7,718
8,362	8,143
43.1%	44.2%
142	140
6,540	6,438
6,900	6,793
52.2%	53.0%
13%	13%
50	50
30	30
2PNRH	2PNRH
Condensing	Condensing
284	281
6,511	6,411
6,870	6,764
52.4%	53.2%
6%	6%
100	100
30	30
2PNRH	2PNRH
Condensing	Condensing

<sup>3</sup> Sprint flow at 37 gpm

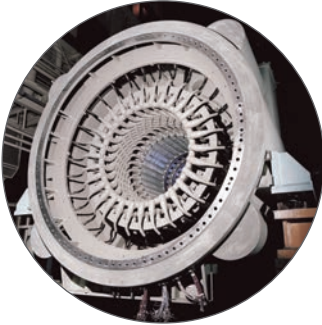
LM9000 (Low NOx)	LM9000 (Sprint)
50/60	50/60
68	76
8,107	8,053
8,553	8,496
42.1%	42.4%
880	880
471	471
410.5	446.3
186.2	202.4
33.5	34.0
50%	50%
50	50
15	25
25/60	25/60
10	10
67	75
8,155	8,096
8,604	8,541
41.8%	42.1%
88	95
6,109	6,220
6,445	6,562
55.9%	54.9%
37%	37%
50	50
30	30
2PNRH	2PNRH
Condensing	Condensing
176	191
6,089	6,200
6,424	6,541
56.0%	55.0%
19%	19%
100	100
30	30
2PNRH	2PNRH
Condensing	Condensing

# TECHNICAL DATA

## GENERATORS

MW	30–320			240–615			530–920		
Gas Turbine	LM/TM 2500 / LM6000 / LMS100 / B/E/F-Class			F-Class / H-Class			H-Class SS		
Steam Turbine	O&G / IST / A200 / D200			A200 / D200 / A650 / D650 / D600			A650 / D650		
	Model	MVA	Frequency	Model	MVA	Frequency	Model	MVA	Frequency
	A04	45	50/60	H35	282	60	W84	710/790	50/60
	A30	61/72	50/60	H53	360/408	50/60	W86	915/870	50/60
	A32	85	50	H65	460/512	50/60	W88	1,090	50
	A35	115/144	50/60	H78	710	50			
	A37	157	60	H84	622/723	50/60			
	A39	185/200	50/60						
	A70	250	60						
	A72	236	50						
	A63	337	60						
	A74	280	50						
	A78	400	60						

Alternate configurations are available upon customer request.





# POWERING FORWARD

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