THE IMPORTANCE OF

Gas-fired Generation in a Transformed Energy Landscape

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The world's electricity system is rapidly changing.

Amid the shifts, gas-fired generation will be an important part of the overall energy mix. In fact, according to the International Energy Agency's (IEA) most recent World Energy Outlook (WEO), published in November 2018, the contribution of gas to powering the world through 2040 is vital by almost any measure, across markets and sectors. Considering this demand, GE stands behind the significant role of gas because of its sustainability, generation flexibility, low capital costs, natural resource efficiency and "right-sized" and rapid deployment capabilities. All of these factors will help gas power meet the world's demand for electricity over the coming decades.

The Grand Transformation

The overall structure of the power industry is transitioning from one based primarily on a hub-and-spoke central generation model with one-way energy flows, to a hybrid system comprised of both distributed and centralized resources with two-way flows. At the same time, new digital innovations are pushing us towards a more efficient and autonomous grid, in which generation and transmission and distribution (T&D) are optimized in real time. Finally, as the world races to confront climate change caused by CO_2 and other emissions, the system is adapting to incorporate zero- and low-carbon power sources and innovations that make traditional thermal sources more efficient and sustainable.

With these profound changes, the emerging and future electric grid will be one powered by a mix of generation sources—from gas, wind and solar tohydropower and nuclear—that will work in tandem, across many different energy markets in the developed and developing worlds. This world is not binary, with stark choices required between fossil fuel sources of power generation and renewable ones. Instead, it is a tapestry of generation combinations reflecting market realities and the marriage of old and new technologies. Only with a hybrid system made possible by gas can we build the power grid of the future while at the same time diligently working toward decarbonization.

Demand for Gas-fired Generation

Given the size, complexity, and lifetime of electricity systems, the grand transformation of the energy landscape will not happen overnight. In fact, according to the International Energy Agency (IEA), traditional thermal sources—including fossil fuels and nuclear power—still account for 75% of total electricity generation; and even aggressive scenarios don't envision the global generation share of thermal sources falling below 50% until 2030.[1]

It is worth digging into the IEA's most recent forecasts—part of the organization's annual World Energy Outlook (WEO) published in November 2018—to highlight the essential role gas power will play. The IEA's base case scenario, the New Policies Scenario (NPS), looks to the future. It considers the effects of all existing climate policies and policy intentions of countries around the world, including those widely agreed on in the 2015 Paris Agreement.

Under the NPS scenario, the IEA explores different markets and sectors. For electricity generation, it predicts that natural gas, wind and solar photovoltaic (PV) will supply 70 percent of the additional electricity generated between now and 2040 in nearly equal shares.[2] By 2040, a total of 1,510 gigawatts (GW) of new capacity for gas-fired power plants will be needed, when factoring in the retirements of many existing plants.

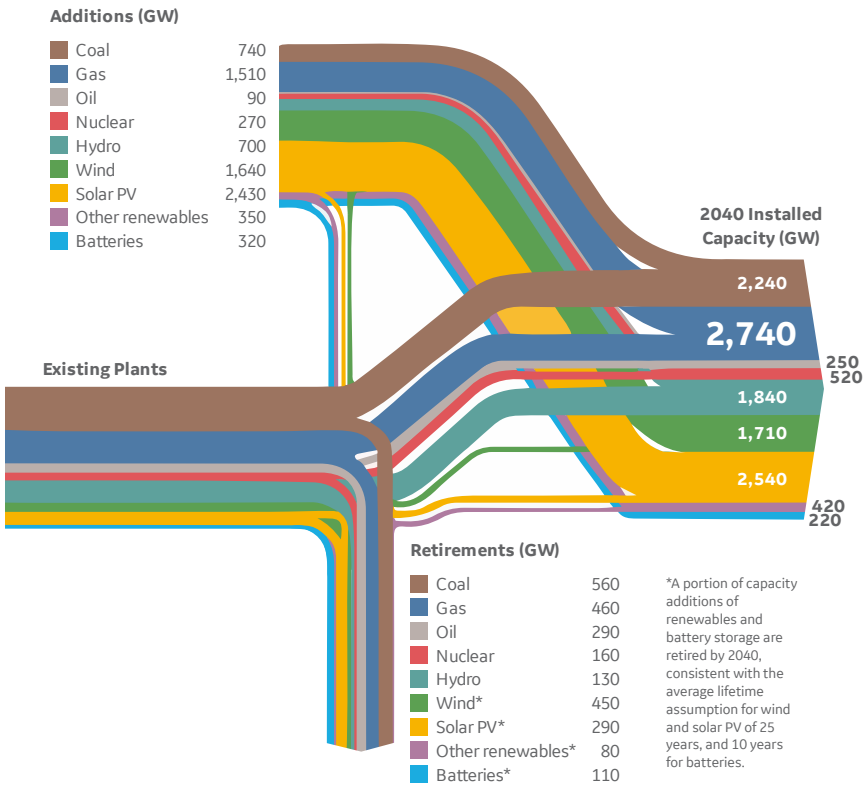
According to the IEA: "gas-fired power plants are the only fossil fuel technology set to grow in almost all regions, thanks to the low upfront investment cost for new plants, the increasing availability of gas, and the role of gas in [power] system flexibility."

[1-2] IEA WEO 2018.

The NPS also envisions natural gas overtaking coal in providing the most capacity by the mid-2020s, with renewables rising rapidly as well. Specifically, in 2040, the IEA projects that gas-powered capacity will be roughly 2,750 GW, edging out solar PV at around 2,500 GW. Coal hangs on at 2,250 GW, followed by hydro power at 1,800 GW. Finally, wind comes in at 1,750 GW, and battery storage kicks in at 250 GW.[3]

Probing deeper into the IEA's regional forecasts reveals an important shift underway in investment in gas-fired power plants: while advanced economies—led by the U.S. and EU—accounted for about 60 percent of cumulative investment in gas from 2000 to 2017, developing economies—led by China, India, and Southeast Asia—make up 60 percent of future investment. To take China as an example, while growing electricity demand will "primarily be met by renewables and nuclear," there is "scope for gas to contribute." The numbers belie this cautious language. Under the NPS, natural gas demand for the power sector quadruples between now and 2040, increasing from 50.3 bcm to 194.4 bcm.[4]

The IEA has also considered the outcomes if electricity demand grows even faster than in the NPS. This "Future is Electric" (FIE) scenario reflects the trends of electrification in transport and heating, an increasingly digital economy that requires more electric power, and expanded electricity access for the nearly one billion people still without it today. Here, renewables will meet a projected 45% of the additional demand for electricity that is imagined, but if supply is to keep up, gas will still have a key role to play, making up 30 percent of the extra demand.[5]



Gas overtakes coal by ~2025 as the #1 technology in terms of installed capacity globally in the IEA's New Policies Scenario (their reference case), and holds the #1 position through at least 2040, the end of the IEA's forecast period. Source: IEA WEO 2018

Key Features

Amidst the grand transformation, existing and new gas-fired plants will play an increasingly important role in maintaining reliable, low cost, and sustainable electric power around the globe. The fact is that natural gas-fired plants have key features and capabilities that make both centralized and distributed gas power the centerpiece of transformed electric power networks around the world.

There are several key features of gas-powered generation that make it uniquely positioned to usher in our short- and intermediate-term energy future.

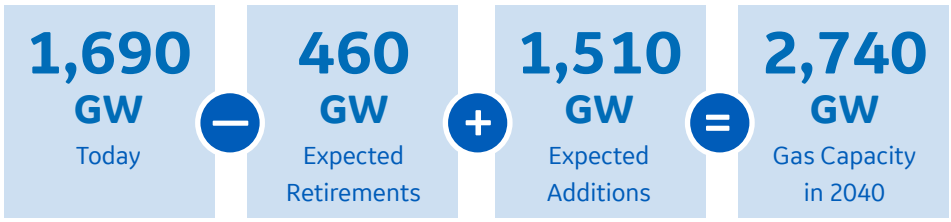
Sustainability

The carbon-led economic growth that powered the 20th century is unsustainable in the 21st. GE agrees with the global scientific consensus, stated in reports by the Intergovernmental Panel on Climate Change (IPCC), that ever-greater emissions of greenhouses gases like CO_2 will continue to lead to global climate change. To confront this challenge, the power system must decarbonize. Natural gas-fired generators have the lowest CO_2 emissions of all fossil power generation fuels—a natural gas-fired combined cycle plant has roughly 50% of the CO_2 emissions of

[3-5] IEA WEO 2018.

a similarly sized coal plant, and lower emissions levels for other pollutants such as mercury, NO_x, SO_x and particulate matter.[6] Meanwhile, coal-to-gas switching was responsible for two thirds of the 27% reduction in CO_2 in the U.S. across all sectors (power, transportation, industry, agriculture) since 2005.[7]

Gas Takes the Capacity Lead in IEA's New Policies Scenario



Source: IEA WEO 2018

Generation Flexibility

The global system is evolving toward an integrated and hybridized network containing elements of old and new technologies working synergistically to provide reliable, affordable, and sustainable electric power to factories, businesses, and communities around the world. Increasing levels of variable renewable energy like wind and solar will challenge power markets and operators, requiring them to more rapidly respond to changes in supply and demand. Natural gas-fired generators are ideally suited to provide increasing power market flexibility over time. For starters, gas-fired generators are an ideal complement to variable renewable resources because they can change power levels quickly, turn down to low levels when demand is less, and start up very rapidly. All of these attributes enable gas turbines to work in concert with renewables to maintain reliability in a power system. As an example, a 570 megawatt (MW) 7HA.02 combined cycle power plant, which is capable of powering more than half a million U.S. homes, can start in less than 30 minutes, can ramp up or down at 60 MW per minute, and can turn down to less than 200 MW while maintaining emissions limits.[8]

[6] "Coal vs. Natural Gas Energy Production," Daniel Frazier, Renee Gomez and Nathan Westbrook, Chemistry Department, Texas A&M University (see link).

[7] GE Power Strategic Marketing Analysis.

[8] GPS Product Catalog, 2018.

Case Study: The World's First Hybrid Battery-Gas Turbine Power Plant

In 2017, Southern California Edison (SCE)—which provides 15 million residents with energy in the greater Los Angeles area—launched the world's first hybrid battery-gas turbine power plant. The technology pairs GE's 10 MW/4.3 MWh battery system with its LM6000 "peaker" gas turbine, which can ramp up to 50 MW in under five minutes. This flexible solution allows the battery to supply the grid with electricity for up to 30 minutes when solar and wind energy from the two sources ebbs. With the additional help of sophisticated software that matches demand and supply, the hybrid plant not only enables more use of renewables but also obviates the previous need to keep the gas turbine operating in spinning reserve mode, burning fuel and producing CO_2 and other emissions.

Case Study: Reducing Carbon Emissions Through Installed Base Upgrades

With lifespans extending in many cases beyond 30 years, existing gas turbine fleets are experiencing greater value and efficiency through upgrades that incorporate advanced technology. First commissioned in 2017, GE's 9EMax gas turbine upgrade solution helps customers reduce annual fuel costs and uncover new revenue opportunities. After installing the first-ever 9EMax, TEPCO anticipates a 4.2% efficiency improvement at its plant, resulting in $7 million in annual fuel savings—which is equivalent to eliminating 40 tons of CO_2 per year. "I would give it an A++ score—that's how well it performed," said Mr. Sasaki, TEPCO General Manager at their Futtsu Power Plant. Producers using the 9EMax can see increased turbine output up to 145 MW in simple-cycle operation and up to 210 MW in a combined cycle configuration. The 9EMax helps customers achieve up to 37 percent efficiency in simple cycle and up to 53.5 percent efficiency in combined-cycle plants. In addition, the 9EMax can operate at partial loads, making it ideal for power producers looking to add renewables to their energy mix. An array of digital solutions is boosting operational reliability, improving combustion operations, and helping to manage emissions.

Low Capital Costs[9]

In a capital constrained world, a key feature of gas-fired generators is their relatively low up-front capital costs as well as the ability to upgrade older assets. Simple cycle and combined cycle natural gas-fired power plants have the lowest upfront capital costs on a $/kW installed basis. As an example, in the U.S., a combined cycle plant costs approximately $1,000/kW, while simple cycle is $825/kW. Onshore wind is approximately $1,350/kW and utility scale solar is $1,100/kW. New nuclear is $9,500/kW and offshore wind is $3,025/kW. When factoring in the capacity factor of a combined cycle plant (~70%) and a utility scale solar field (~19%), roughly seven times the upfront capital is needed to provide the equivalent power capacity from the solar field.

Natural Resource Efficiency

Gas-fired generators are resource efficient, conserving fuel, water and land relative to alternatives. Gas is the most land efficient power generation source. It requires 50–100 times less space per MWh generated compared to a renewables and battery storage system. As urbanization and electrification accelerate around the world, it will become more difficult to satisfy electricity demand with dispersed renewables that are often located far from the demand. As an example, to meet NYC's goal of electrifying its bus fleet by 2040 would require covering 15% of Manhattan with solar panels.[10] Fuel can account for up to 50% of the total lifecycle cost of a natural gas power plant.[11] The most efficient combined cycle power plants are capable of achieving 64% efficiency.[12]

In combined heat and power applications, greater than 80% fuel efficiency can be achieved.[13] This fuel efficiency results in real cost savings and lower emissions per MWh generated. Additionally, according to Climate Central, current natural gas power plants use four times less water per MWh generated than their coal-fired counterparts.[14]

[9] Lazard's Levelized Cost of Energy (LCOE) Analysis, Version 12.0, November 2018.

[10] GE Power Strategic Marketing Analysis.

[11] Lazard's LCOE Analysis, November 2018.

[12] GE Gas Power Systems Product Catalog, 2018.

[13] https://www.epa.gov/chp/chp-benefits

[14] http://www.climatecentral.org/news/water-use-declines-as-natural-gas-grows-19162

Case Study: Two World-Records for Efficiency

GE's HA gas turbines helped achieve world records for combined-cycle efficiency in both the 50Hz and 60Hz segments. EDF's Bouchain plant in France reached a net combined-cycle efficiency of 62.22% in 2016 using the 50Hz 9HA gas turbine; and Chubu's Nishi-Nagoya plant, which features the 60Hz 7HA, reached a gross combined-cycle efficiency of 63.08% in Japan in 2018. GE's HA is the world's largest, most efficient, and most flexible gas turbine available today. Each point of efficiency can generate up to $50 million in fuel savings over 10 years for a 1 GW plant. The high power density of the HA can help bring power online for millions of households in just a few years, making it a cost-effective and efficient solution for utilities and power producers around the world.

Right-Sized and Rapid Deployment

In a power plant landscape with a large degree of uncertainty around future supply and demand, gas-fired technologies provide developers with the flexibility to install both small and large increments of power very quickly. Gas-fired generation options range in size from hundreds of kilowatts to hundreds of megawatts. A 30 MW simple cycle power plant can be transported by land, sea or air to remote locations and can be generating power in a matter of weeks. A large combined cycle power plant can be commissioned in 2-3 years, 1-2 years faster than a comparably sized coal power plant and 3-4 years faster than a comparably sized nuclear plant.[15]

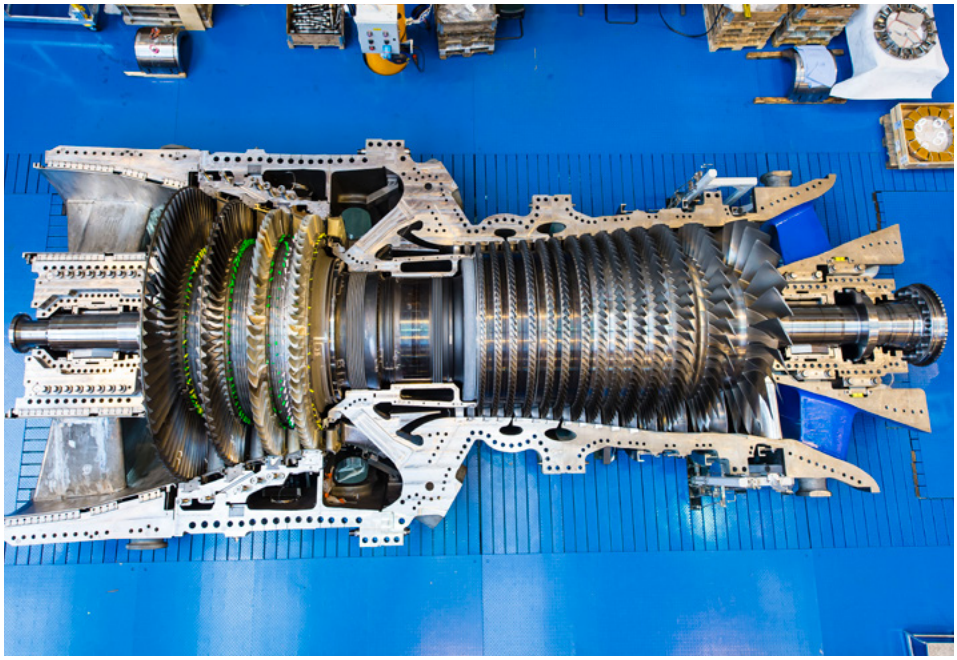
[15] These are the estimates GE Power uses in its forecast model, based on experience.

Case Study: Flexible, Fast & Mobile Power

In places where extending grid connections the "last mile" can be cost- and time-prohibitive, because of the infrastructure challenges faced or investment required, mobile power plants provide a fast, reliable and scalable solution. These flexible power systems also help generate power during natural disaster relief, plant shutdowns, or periods of grid instability.With installation and commissioning in as few as 11 days, more than 300 of GE's TM2500 gas-powered mobile power plants are helping power communities around the world. In Indonesia, the TM2500 is bringing 500 MW of power to eight different sites scattered across six different islands. In Algeria, 38 trailer-mounted TM2500 aeroderivative gas turbine generators are providing reliable and fast power to all regions, bringing much-needed supplemental power during the hot summer months.

Case Study: Gas Closes a Power Gap in Pakistan

High population growth, rapid urbanization and increased manufacturing placed a giant strain on Pakistan's electricity grid. In 2014, GE embarked on its largest infrastructure development project in a decade to help plug this gap, building three combined cycle gas power plants in record time that together are expected to add 3.6 GW to the national grid, the equivalent power needed to supply up to 7.3 million Pakistani homes. The plants are equipped with GE's HA technology, the world's most efficient heavy duty gas turbines. The rapid start-up times of HA turbines offer a flexible component to intermittent renewable sources, the share of which is growing in Pakistan's overall energy mix.



Conclusion

The importance of natural gas-fired generators in the transformed energy landscape emerging today and tomorrow cannot be overstated. As the world moves toward a combination of centralized and distributed resources, while increasing environmental sustainability and lowering the environmental footprint of the energy systems, natural gas generation technologies will serve both as a bridge to the past and the foundation of the future.

GE is continuing to lead the way for the industry and support our customers by operationalizing our business to support the entire gas lifecycle, investing in the best technology and servicing capability, and successfully executing, with our partners, complex projects all around the globe.

Visit GE's website here to learn more about how we're helping customers navigate the changing energy landscape with our equipment, software, and services to deliver quality, affordable, reliable, flexible, sustainable power to their consumers, all around the world.