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Natural Gas Improves Economic Feasibility of Hybrid Distributed Energy Systems

Peter Lilienthal

Facing concerns over climate change, energy security, and local air pollution, state governments have moved increasingly over the past few decades to "decarbonize, decentralize, and diversify" the electricity-generation sector.

The varying ways in which these goals are being incorporated across the country have important consequences for the natural gas industry, providing opportunities and challenges for the future. Fossil-fuel use in electricity generation is the primary target of efforts to reduce carbon emissions. However, natural gas is an excellent complement to renewable energy in decentralized systems for both technical and economic reasons and may actually help promote greater penetration of renewables.

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NATURAL GAS IN DISTRIBUTED ENERGY SYSTEMS

As of 2017, according to the US Energy Information Administration, about 63 percent of our electricity was

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generated from fossil fuels, and for over a century, we have relied on large, centralized fossil-fuel plants to produce it. But in the absence of federal leadership on energy policy, states have recently been promoting policies that will change that paradigm, including renewable energy standards, net metering laws, clean energy subsidies, interconnection standards, and efficiency mandates. Such policies, along with rising utility rates and concerns about climate-related resilience, are creating new economic incentives for distributed energy investments.

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Natural gas has long been a mainstay of distributed energy systems, regardless of whether they incorporate renewable energy. Most important, natural gas supplies cost-effective combined heat and power (CHP) plants, which provide highly efficient electricity, heating, and cooling in industrial and institutional settings. Natural gas with CHP also improves resiliency and reliability by providing backup power wherever there is access to gas pipelines, which is in most urban areas. After Hurricane Sandy, it was gas-fired cogeneration plants that kept the lights on and the elevators moving.

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Integrated with renewable resources in a distributed energy system such as a microgrid, natural gas generators have a different role, adding crucial flexibility to the system. For example, when a cloud passes over a photovoltaic (PV) array, that change can cause a 70-percent drop in renewable electricity production within seconds. Natural gas engines can adjust power output quickly to meet electricity demand; with superior load-following characteristics, natural gas engines are more flexible than other types of generators.

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Natural gas technology also lowers costs for distributed renewable energy systems by filling an important gap, producing power when renewables are unable to. Despite recent calls for 100 percent renewable energy by many state and local governments and businesses, meeting the last 20–30 percent of the load strictly with renewables is an expensive proposition. Until storage prices drop substantially, and until storage is a common feature of distributed energy systems, this will continue to be the case.

At HOMER Energy, we've spent more than a decade modeling hybrid renewable energy systems for remote, off-grid locations in developing countries, grid-tied systems in locations where the grid is unstable or inadequate, and grid-tied systems in industrialized countries (HOMER stands for hybrid optimization of multiple energy resources). Most remote, developing-country systems require some diesel backup power where there's no access to gas pipelines, even when these systems are coupled with renewable energy resources. It is clear that the lowest cost of energy in most hybrid systems occurs at around 70-percent renewable penetration. The presence of a reliable natural gas engine—or supplemental grid power—is still vital to meet the rest of the load demand. Given current storage costs, that resource is what makes this type of energy system economically feasible.

Unless and until stringent regulations on carbon emissions are in place, it is likely that natural gas or diesel generation will continue to provide cost-effective supplemental power and backup in distributed systems with high renewable penetration.

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WHICH NATURAL GAS GENERATION TECHNOLOGIES WORK BEST IN DISTRIBUTED ENERGY?

Depending on the type, scale, and goals of the distributed energy system, circumstances can favor gas generator sets, microturbines, or fuel cells. Different technologies provide different advantages.

Natural gas engines with CHP are a reliable, primary power source for many large microgrids. The University of California at San Diego microgrid has two 13-megawatt natural gas generators with CHP that supply baseload power and waste heat that chills water to cool campus buildings. Along with solar PV, fuel cells, and batteries, UCSD generates 85 percent of its own electricity at half the cost of grid power. The natural gas plant is a big part of that savings. In 2007, during a San Diego fire emergency, the UCSD microgrid was also able to provide 10 megawatts of emergency power to its utility, San Diego Gas & Electric, to prevent a shutdown of the main grid.

UCSD generates 85 percent of its own electricity at half the cost of grid power.

Meanwhile, Cleveland, Ohio, has recently announced a $100-million microgrid for the city center that will be based around a natural gas–powered CHP system that also integrates renewables and storage. City officials were originally planning to build offshore wind-generation on Lake Erie but decided the CHP system would leverage the city's district heating and cooling system better and provide superior economics. The microgrid will lower emissions and improve electric reliability but won't be cheaper than current electricity. The city of Pittsburgh is also studying the potential for new microgrids in which traditional CHP systems will play an important role.

EMERGING NATURAL GAS TECHNOLOGIES IN MICROGRIDS

Microturbines

Microturbines have so far occupied a niche market in the distributed energy ecosystem. "The high upfront cost of microturbines currently makes it difficult for them to compete with reciprocating engines," says Adam Forni, an energy researcher with Navigant who specializes in natural gas. But that could change as microgrids with more diverse requirements emerge. Microturbines can be very cost-effective when there are constant thermal demands, producing more heat at higher temperatures than reciprocating engines. Combined with CHP systems, microturbines can be highly efficient.

Compact and lightweight, natural gas microturbines are ideal for locations with space constraints, and they run quietly with little vibration. They are easy to maintain and "fuel flexible," handling a wide variety of liquids and gas, including natural gas, propane, and biogas. Microturbines can potentially bridge the transition to renewable fuels with their ability to run on waste from landfills, farms, wastewater treatment plants, and other methane-producing facilities.

Fuel cells

Fuel cells have only recently become cost-competitive with other technologies. But with the capability of fuel cells to run on a variety of fuels, including natural gas, plus fuel cells' high efficiency and low emissions, they are likely to play an increasingly important role in distributed energy systems. The state of Connecticut just recently announced a $1-billion investment in a 20-megawatt microgrid powered by natural gas fuel cells that will support a data center.

WHY INVEST IN DISTRIBUTED ENERGY AT ALL?

Two important dynamics are driving investments in distributed energy systems across the United States, particularly those that incorporate renewable generation.

The first is rising electricity rates and the realignment of utility tariffs. The slowdown in the growth of utility electricity consumption, coupled with rapid growth of renewable energy resources, is causing substantial utility revenue losses, especially for volumetric energy sales. That's putting pressure on utilities to replace slumping revenues with demand charges and new fixed fees. In several states, utilities are revising their tariff structures to implement time-varying rates as part of an effort to respond to new demand patterns caused by renewable energy.

The second dynamic is plummeting prices for solar PV and energy storage. Solar prices have been dropping steadily for decades. They have decreased by 60 percent since 2010, outpacing everyone's expectations and are expected to continue to decline. In many states, solar generation has already reached grid parity, falling below utility prices for electricity generated from coal and gas. Meanwhile, energy storage has been growing over 200 percent per year; from 2015 to 2016, US battery prices fell by as much as 32 percent. The US market for energy storage is expected to reach $4.6 billion by 2023. Low-cost energy storage is a crucial prerequisite to high penetrations of renewable energy.

When commercial and industrial customers, institutions, and local governments are determining whether to make distributed energy investments, the most important consideration is simply whether it's possible to self-generate electricity more cheaply than buying utility power.

One reason natural gas resources are playing an increasingly important role in distributed energy systems is that prices have declined dramatically over the past five years, and abundant supplies are likely to maintain the downward price pressure. Second, natural gas–generating technologies are mature and declining in cost. According to Forni, vendors are also improving ways to package natural gas generation resources with renewables, which is promoting better market integration. Most important, natural gas costs on the whole are generally cheaper than utility electricity.

In addition to the impacts of gas pricing, we have an uneven national patchwork of regulatory incentives, a wide range of electricity rates, and varying geographical and climate factors, all of which can influence local investment decisions. As a result, the business case for investment varies highly from state to state and from region to region. The following factors need to be taken into account.

1. *Utility tariffs.* Beyond high electricity prices, specific tariff structures, such as high demand charges, high peak rates, or time-of-use rates, can make self-generation a viable economic alternative to utility power. California and many Northeastern and Atlantic states have high electricity prices, tariff types, and demand charges that make distributed energy investments in these regions attractive.
2. *The price of natural gas.* Low natural gas prices, while they may also be reflected in lower utility rates, are generally conducive to distributed energy investments with natural gas generation resources.
3. *The cost of carbon emissions.* While there are no US states that currently have a carbon tax, this is a future possibility and potential financial risk. Also, nearly half the Fortune 500 companies, in addition to over a dozen states and 50 cities, have set their own emissions-reduction goals. Depending on the investor or system owner, a low-carbon profile can be financially justified for a variety of reasons.
4. *Regulatory incentives/mandates.* What incentives are available for renewables, microgrids, CHP, distributed energy, or storage, such as tax breaks, grant programs, and subsidies? For example, California has incentives for solar, self-generation, storage, and microgrids. New York has new storage incentives, and other states are considering similar policies. How do these policies affect financial outcomes and future prospects for a given project?
5. *Reduction of barriers*. Interconnection standards, mandates that utilities purchase renewable power, "solar rights" legislation, and efforts that standardize permitting policies and procedures can smooth pathways to distributed energy investment. These policies will affect development and operations costs.

WHAT ARE THE DISTRIBUTED ENERGY PROJECT GOALS?

The financial justification for distributed energy developments also varies depending on the intended outcomes.

1. *Cost savings*. Can distributed energy investors beat utility rates through self-generation? Are they seeking to reduce demand or volumetric

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charges or both? Distributed energy investments can provide stable and predictable long-term electricity costs, as well as savings to commercial customers through peak shaving and demand-charge reductions.
2. *Resiliency*. Although resiliency is hard to monetize, many local governments are investing in microgrids to ensure power supply to critical assets such as hospitals and public safety facilities in the event of climate-related extreme weather events.
3. *Carbon emissions*. Public-relations goals and government mandates are driving corporations, cities, and other entities to invest in distributed energy systems.
4. *Profitability.* New digital technologies are introducing opportunities for energy arbitrage or trading in wholesale markets, among utilities and their customers, and between peers.
5. *Power quality*. Microgrids, with their ability to manage loads and power flows, can help stabilize the electric grid by providing ancillary services such as frequency and voltage regulation. Eventually, that service might be profitable.
6. *Deferred transmission costs*. Utilities are already investing in distributed energy and storage projects as cheaper alternatives to transmission upgrades.

Finally, the customer's own load profile affects whether distributed energy can be a good investment. Businesses with "peaky" loads are likely to benefit most from the load-flattening capabilities of hybrid renewable energy systems.

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REGULATORY UNCERTAINTIES ARE ON THE HORIZON

Recent climate-change reports give new urgency to CO_2 emissions reductions.

In addition to all the other factors, there is a new wild card that is likely to have a profound impact on energy policy and the evolution of our new electricity system: a recent report by the UN International Panel on Climate Change (IPPC) predicts devastating damage to the Earth's natural ecosystems if we don't keep our global warming increases below 1.5ºC forever.

Laying out pathways to stay below the 1.5ºC threshold, the IPCC concludes that we must reduce our carbon emissions by 45 percent by 2030, and reach net zero emissions by 2050. To meet that goal, according to the UN panel, efforts must intensify immediately. This will require a dramatic reconfiguration of our electricity-generation sector to eventually phase out fossil fuels, especially coal-fired generation. The recent IPCC report is likely to prompt new policies to reduce carbon emissions, although existing policies will also have important impacts on the evolution of distributed energy systems in the near future.

For example, the University of California System has multiple campuses where natural gas cogeneration plants provide baseload electricity and drive thermal loops that heat and cool their buildings. But by 2025, the university system is committed to carbon neutrality. That is already prompting an urgent search for biogas resources that can work in the current natural gas infrastructure. Meanwhile, the state of California, in recent legislation, is committed to "100 percent carbon-free" electricity by 2045. Other states are likely to follow suit and propose new carbon regulations. What impact will that have on the design of distributed energy systems?

DESIGN CHOICES IN DISTRIBUTED ENERGY SYSTEMS

Given powerful policy and price signals for moving rapidly to low-carbon energy alternatives, it's no surprise that electricity customers are investing. But are we seeing a logical alignment between social goals and economic incentives? Given the regulatory uncertainties, which policies and technologies will help electricity customers reach their goals? Is there a risk of committing to choices that result in "technology lock-in"? What is the role for natural gas in this transition and how might it evolve?

As our electricity-generation system changes rapidly, adding more distributed resources, on-site generation is already taking

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many different forms. How should energy developers choose?

One of the fastest-growing types of distributed energy systems is the microgrid, defined as a discrete energy distribution network that can be islanded from the main grid, if necessary. A microgrid can work either behind or in front of the meter and be scaled to apply to anything from a building to a city. But, grid-tied solar storage systems are also growing fast, and individual generation resources are proliferating in an infinite variety of configurations ranging from utility-scale solar to single rooftop installations.

Now rooftops can be re-aggregated using digital technology to form virtual power plants. People can trade energy using blockchain. The variety seems endless. Finally, thanks to the evolution of the electric car industry, there is a new kind of disaggregated energy resource coming on line, traveling the nation's roads in the form of car batteries that can potentially feed power back to the grid.

Paradoxically, distributed generation systems are smaller but also much more complex than traditional generation.

Should a distributed energy system be built at all, and should it include diesel and natural gas generators, solar, wind, hydro, fuel cells, flywheels, batteries, and thermal storage, and if so, in which combinations and configurations? It turns out that, paradoxically, distributed generation systems are smaller but also much more complex than traditional generation. They require special approaches in design and evaluation.

THE ADVANTAGES OF A DECISION SUPPORT FRAMEWORK

To help business and institutional utility customers understand their energy options, HOMER Energy has created the HOMER Grid energy modeling software.

Descended from an earlier version developed at the National Renewable Energy Laboratory, HOMER software has been helping stakeholders weigh the complexities and tradeoffs of designing cost-effective, reliable microgrids and hybrid energy systems for over two decades. HOMER Grid eases the design process by modeling grid-tied, behind-the-meter, distributed energy systems that can function as islanded microgrids in case of power outages on the main grid.

Combining engineering and financial feasibility analysis, the software helps users determine the right combination of assets for any given microgrid projects and their relative sizes. The value of energy modeling is not to come up with a single "answer" that defines a project configuration but to explore a complex problem from a variety of perspectives and, ultimately, make better decisions.

HOMER Grid manages the complexity that goes into distributed energy resource design by including equipment specifications for generators, CHP, solar, wind, inverters, and options to create custom microgrid control algorithms. Incorporating the continuously updated utility tariff databases, HOMER Grid helps predict the financial impact of utility tariff changes on a given system. Its inputs include weather and insolation data building load profiles, equipment costs, and performance data. Its utility-rate database covers the United States, Canada, and Mexico, or users can create custom utility tariffs.

After users have chosen inputs, HOMER Grid runs simulations for different system configurations for an entire year and ranks the results by financial performance. Then HOMER Grid calculates costs and savings in demand charges and electricity consumption for each system, as well as emissions, fuel consumption, and other parameters that can be selected by the user. HOMER Grid also helps users compare the performance of different equipment brands for PV, batteries, inverters, and other components.

Finally, HOMER Grid produces full financial reports explaining capital and operating costs, internal rate of return, payback periods, and potential demand-charge savings. HOMER's detailed charts and graphs provide powerful documentation and are an important communication tool that links clients, investors, engineers, and other stakeholders. Although it's not a crystal ball, HOMER Grid helps developers approach distributed energy with a good grasp of the possibilities.

A fully featured version of HOMER Grid is available for download with a 21-day trial at http://homerenergy.com/trygrid.

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