Oil Change International

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BURNING THE GAS 'BRIDGE FUEL' MYTH:

WHY GAS IS NOT CLEAN, CHEAP, OR NECESSARY

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Oil Change International is a research, communications, and advocacy organization focused on exposing the true costs of fossil fuels and facilitating the coming transition towards clean energy.

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CONTENTS

LIST OF ABBREVIATIONS

°C	Degrees Celsius
BECCS	Bioenergy with carbon capture and storage
CCGT	Combined Cycle Gas Turbine
CCS	Carbon capture and storage
CO_2	Carbon dioxide
GHG	Greenhouse gas
GRE	Gas reciprocating engine
Gt	Billion metric tons / Gigatons
GW	Gigawatt
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LCOE	Levelized Cost of Energy
LNG	Liquefied Natural Gas
Mt	Million metric tons
MW	Megawatt
MWh	Megawatt hour
OCGT	Open Cycle Gas Turbine

INTRODUCTION – THE BRIDGE FUEL MYTH

As the global climate crisis intensifies while the production and consumption of gas[a] soars, it is clearer than ever that gas is not a solution to the climate crisis. This report unpacks and debunks the enduring myth that gas can form a bridge to a decarbonized future.

The mythology around gas being a "cleaner" fossil fuel that can support the transition to clean energy goes back at least three decades. Oil and gas corporations have championed and invested in this myth as a way to delay the transition away from fossil fuels. Alarmingly, despite the evidence that overreliance on gas is a recipe for climate breakdown, a number of politicians and decision-makers continue to repeat the myth of gas as a climate solution.[b]

In this report, we unpack the core arguments of the bridge fuel myth and the data that prove them to be false. First, we discuss how the issue of leaking methane, a highly potent greenhouse gas, makes clear that gas is not clean. But methane leakage does not define the climate impact of gas. This report details five additional reasons why gas cannot form a bridge to a clean energy future, even if methane leakage is addressed. These five points make clear that **gas is not clean, gas is not cheap, and gas is not necessary.**

Flaring on well pad, Lower Saxony, Germany. *©Andreas, Fractracker.*

FIVE REASONS GAS IS NOT A BRIDGE TO A SAFE CLIMATE

1. **Gas Breaks the Carbon Budget:** The economically recoverable oil, gas, and coal in the world's currently producing and under-construction extraction projects would take the world far beyond safe climate limits. Further development of untapped gas reserves is inconsistent with the climate goals in the Paris Agreement.

2. **Coal-to-Gas Switching Doesn't Cut It:** Climate goals require the energy sector to be decarbonized by mid-century. This means that both coal and gas must be phased out. Replacing coal plants with new gas plants will not cut emissions by nearly enough, even if methane leakage is kept to a minimum.

3. **Low-Cost Renewables Can Displace Coal and Gas:** The dramatic and ongoing cost declines for wind and solar disrupt the business model for gas in the power sector. Wind and solar will play an increasing role in replacing retiring fossil fuel capacity.

4. **Gas Is Not Essential for Grid Reliability:** Wind and solar require balancing, but gas is not the only, nor the best, resource available for doing so. Battery storage is fast becoming competitive with gas plants designed for this purpose (known as "peakers"). Wind and solar plants that are coupled with battery storage are also becoming a competitive "dispatchable" source of energy. Managing high levels of wind and solar on the grid requires optimizing a wide range of technologies and solutions, including battery storage, demand response, and transmission. There is no reason to favor gas as the primary solution.

5. **New Gas Infrastructure Locks In Emissions**: Multibillion-dollar gas infrastructure built today is designed to operate for decades to come. Given the barriers to closing down infrastructure ahead of its expected economic lifespan, it is critical to stop building new infrastructure, the full lifetime emissions of which will not fit within Paris-aligned carbon budgets.

a We use the term *gas* to mean all types of gas composed primarily of methane. *Fossil gas* is a term used in place of what the oil and gas industry calls *natural gas*. We use the term *fossil gas* where we are specifically referring to gas from fossil fuel sources. See Box 3 for details of why so-called *renewable gas* is not generally a solution to the impacts of *fossil gas*.

b For example, Secretary John Kerry used the term during the House Oversight and Reform Committee Hearing on Leadership to Combat Climate Change on April 9, 2019, and Virginia Governor Ralph Northam said, "gas has significant potential as a bridge fuel to help us reduce carbon pollution that drives climate change while we transition to solar, wind, and other clean energy sources" in a September 2018 press release on Virginia's climate action plan. https://www.governor.virginia.gov/newsroom/all-releases/2018/september/headline-829610-en.html

Gas fields and pipeline in the Netherlands. *©Ted Auch.*

The oil and gas industry has used the bridge fuel myth as cover for expanding gas supply and consumption as much as possible. Global gas production has grown 51 percent since 2000.[1] This has been greatly facilitated by the development of horizontal drilling and hydraulic fracturing (fracking) in North America, which has enabled access to vast quantities of hitherto inaccessible fossil gas. Aside from the climate implications, the growth in fracked gas has burdened many communities with pollution, health and safety hazards, and environmental injustice (see Box 1).

The growth in gas production has led to high levels of gas consumption in some regions such that for some, decarbonization now requires the transition from gas to clean energy rather than from coal and oil. This task is made more difficult by the lock-in effect of billions of dollars spent on recently built gas infrastructure.

During this period of rapid growth in gas production, global coal production also grew 68 percent.[2] Global fossil fuel emissions grew 2.7 percent in 2018, the largest increase in seven years.[3] Business-as-usual projections suggest gas production could grow a further 20 to 40 percent by the 2040s.[c]

This report does not attempt to map a detailed path towards an energy system with zero gas. There are many studies that show specific pathways to achieving zero emissions by 2050.[4] Instead, we detail why the transition to a zero-carbon energy system is being undermined by overreliance on gas and, in fact, requires a managed decline of gas production and consumption along with that of coal and oil.

While the power sector is the main sector discussed in this report, as it has been central to the bridge fuel myth, achieving climate goals will require that all sectors follow the power sector to decarbonization. Efficiency and electrification are key to reducing fossil fuel use in all energy sectors – not increasing reliance on a fuel that only makes the transition more challenging. The false hope of “renewable gas” likewise does not provide an adequate solution to the decarbonization of these other sectors (see Box 2).

By addressing these issues, this report makes clear that ongoing growth in gas production, consumption, export, and import cannot be justified on climate grounds. The urgent business of full decarbonization requires managing the phase-out of gas alongside other fossil fuels.

c Rystad Energy AS UCube Database projects a 20 percent growth in global gas production from 2018 to 2043, after which a modest decline leads to 2050 production some 17 percent above 2018 levels. The International Energy Agency projects a 43 percent growth in gas production from 2017 to 2040 in the “New Policies Scenario” in the *World Energy Outlook 2018*.

NOT CLEAN, NOT CHEAP, NOT NECESSARY

All methane-based gas emits carbon dioxide (CO_2) when it is combusted. In addition, methane leakage throughout the entire gas supply chain creates additional climate impacts. While some oil and gas producers have set targets for reducing methane leakage, in many cases there is insufficient transparency to verify how much methane is actually emitted.[5]

First, we briefly outline the methane issue. We then go on to demonstrate that methane is not what determines whether gas is positive for the transition to clean energy. With or without methane leakage, gas is not clean. Nor is gas the answer to the challenges of transitioning to a genuinely clean energy future.

METHANE LEAKAGE

Methane is the primary constituent of fossil gas. Gas produced at the wellhead may contain as little as 65 percent methane, with the rest a combination of gas liquids, mostly ethane, butane, and propane.[6] Liquids are separated at processing plants, and "dry" gas delivered in pipelines is generally more than 90 percent methane.[7]

Methane leaks from every part of the gas supply chain. Methane is highly potent when released to the atmosphere, i.e., without combustion. It is routine in the production, processing, transportation, and storage of gas for some gas to escape. Some is leaked through faulty equipment and human error, and some is vented as part of routine procedures, such as when pipelines must be emptied to perform routine maintenance or repairs.[8]

According to the Intergovernmental Panel on Climate Change (IPCC), the warming effect of methane is 87 times greater than CO_2 over a 20-year period and 36 times greater over a 100-year period.[9] However, the study of the radiative forcing, or warming effect, of different greenhouse gases is ongoing, and there is increasing evidence that these figures may underestimate the impact of methane.[10, 11]

If elevated levels of methane are leaked in the process of producing and delivering gas to consumers, then any emissions advantage gas may have over coal for power generation or other uses is reduced or negated.

Many studies have been conducted to ascertain how much methane leakage is occurring and what levels of leakage constitute a greater or lesser climate impact attributable to gas compared to the other fossil fuels.[d] Several studies have found that in the United States, especially, where gas production has been growing the fastest for most of the past decade, government estimates of methane leakage rates from oil and gas infrastructure underestimate the problem.[12]

While any broad consensus on how much methane is leaking remains elusive, there is hard data showing that oil and gas infrastructure is the prime source of the rising levels of methane in the global atmosphere over the past decade.[13] This rise in atmospheric methane corresponds very closely to the growth in fracked gas production in the United States.

There is no doubt about the importance of reducing methane leakage from existing oil and gas operations and distribution networks. But reducing methane leakage does not mean that gas production and consumption can continue to grow.

The limits of our climate system mean that we need to reduce all fossil fuel production and use, and gas is no exception. With this in mind, the five discussion points detailed below make clear that even in the hypothetical case of zero-methane leakage, gas cannot be a bridge fuel. To meet climate goals, gas production and consumption must, as with other fossil fuels, be phased out, and efforts to reduce methane leakage do not alter that conclusion.

d This is a substantial and ongoing area of study. We have avoided stating specific figures here on purpose as these parameters tend to change as new studies are published. Many of these studies are listed in a database maintained by PSE Healthy Energy under "climate/methane" found here: https://www.zotero.org/groups/248773/pse_study_citation_database/items

BOX 1: Gas Production Burdens Communities

Oil and gas production worldwide often brings pollution, habitat destruction, and health and safety risks for host communities, as well as issues of economic and environmental justice.[14] The process of fracking, which has become the main source of gas in the United States, is accompanied by particularly intense impacts for communities.

These impacts include groundwater contamination and excessive water consumption, air pollution, toxic chemical exposure, land erosion and habitat destruction, increased seismic activity, and health and safety risks associated with heavy truck traffic, man-camps, and the toxic and explosive nature of gas and associated hydrocarbons.[15, 16, 17]

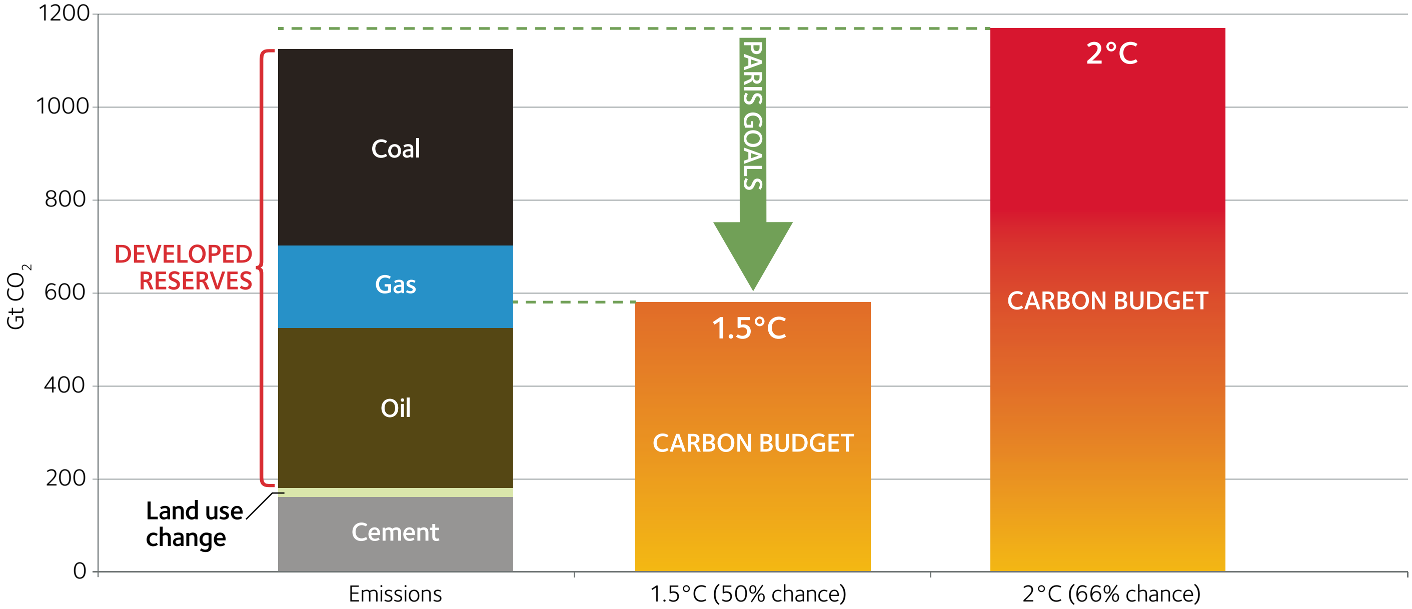
As gas production has grown in regions with previously little or no production, storage tanks, pipelines, and compressor stations have proliferated, bringing the risks into an increasing number of communities. Many gas pipeline projects have met with resistance from communities and landowners. Landowners have found themselves powerless to stop pipelines crossing their property due to the power of eminent domain granted to pipeline companies by state and federal regulators.[18] Gas infrastructure has been sited amidst poor rural, often minority, communities, in clear cases of environmental racism and injustice.[19]

The proliferation of gas drilling also produces associated hydrocarbons called natural gas liquids. Some of these liquids are used for plastic production and are triggering a disturbing rise in the number of petrochemical processing plants and plastics facilities constructed in already heavily burdened communities on the U.S. Gulf Coast and in Appalachia.[20]

These impacts add to the urgency with which the burgeoning growth in gas production must be addressed. Constraining gas production in line with climate limits will ease the tremendous burden that has been placed on the communities in the path of the ongoing fracked gas boom.

Drilling towers near a home in Colorado, U.S. *©Les Stone/Greenpeace.*

Figure 1: CO_2 Emissions from Global Developed Fossil Fuel Reserves, Compared to Carbon Budgets within Range of the Paris Goals



Source: Rystad Energy, IEA, World Energy Council, IPCC, OCI analysis[23]

1. GAS BREAKS THE CARBON BUDGET

The Paris Agreement, ratified by more than 170 nations, requires governments to pursue efforts to limit global temperature rise to 1.5 degrees Celsius (°C) above pre-industrial levels, and in any case, to hold it well below 2°C.[21] In 2018, the IPCC released a powerful report showing the critical importance of the 1.5°C threshold. Limiting warming to this level – the more ambitious end of the Paris goals – would significantly reduce the risks of unstoppable runaway climate change.[22]

Climate science shows us that cumulative CO_2 emissions over time are the primary determinant of how much global warming will occur. Based on the evolving study of this relationship, scientists are able to estimate the level of total cumulative CO_2 emissions that can occur for a given temperature limit. These cumulative totals – called a "carbon budget" – indicate a set limit to how much fossil fuel can be extracted and burned to meet global climate goals.

Using data sources from the energy industry and the IPCC, research by Oil Change International has found that CO_2 emissions from the oil, gas, and coal *in already-operating or under-construction fields and mines* globally would push the world far beyond 1.5°C of warming and would exhaust a 2°C carbon budget, as shown in Figure 1.[e] These "developed reserves" represent the oil, gas, and coal that fossil fuel companies have already invested in extracting over the coming decades: The necessary wells have been (or are being) drilled, the pits dug, and the related infrastructure built.

The licenses, permits, sunk capital, and related infrastructure that go into developing extraction projects create a "carbon lock-in" effect, meaning the oil, gas, and coal shown in Figure 1 will be more politically, legally, and economically difficult to leave in the ground, compared to reserves that have not yet been developed.

The implication of this analysis is clear: **There is no room for new fossil fuel development – gas included – within the Paris Agreement goals.** Even if global coal use were phased out overnight, developed reserves of oil and gas would push the world above 1.5°C of warming.

In practice, this means that achieving the Paris goals will require governments to proactively manage the decline of *all* fossil fuels together. The first step would be to stop digging a deeper hole by ceasing to issue licenses and permits for new oil, gas, and coal extraction projects (i.e., to stop pushing the developed reserves bar in Figure 1 even higher).

But stopping new projects alone will not be enough to keep warming well below 2°C. Governments must also phase out a significant number of existing projects ahead of schedule. These findings show that *managing the phase-out of gas* from our energy system – in tandem with other fossil fuels – is key to meeting the Paris goals.

e These conclusions account for optimistic estimates of future land use and cement manufacture emissions, which are the largest sources of non-energy emissions and more difficult to reduce than energy-sector emissions. The methodology and assumptions behind these estimates are detailed in: Greg Muttitt, *The Sky's Limit: Why the Paris Climate Goals Require A Managed Decline of Fossil Fuel Production,* Oil Change International, September 22, 2016, http://priceofoil.org/2016/09/22/the-skys-limitreport/, Appendix 2, p. 47.

2. COAL-TO-GAS SWITCHING DOESN'T CUT IT

Power Sector Climate Goals Cannot Be Met with More Gas

Over 40 percent of the world's gas is consumed in the power sector today, producing around 23 percent of the world's electricity.[24] No other sector burns as much gas. In the United States, the power sector accounts for about 39 percent of gas consumption.[25]

The power sector represents the low-hanging fruit for decarbonization and plays an additional role in decarbonizing other sectors via electrification of currently non-electrified sectors, i.e., transport, heating and cooling systems for buildings, and industrial heat. The IPCC's report on pathways to 1.5°C states that, *"[s]ince the electricity sector is completely decarbonized by mid-century in 1.5°C pathways, electrification is the primary means to decarbonize energy end-use sectors."*[26] In other words, a genuine decarbonization strategy will entail eliminating fossil fuels from the power sector while electrifying these other sectors so that eventually, the maximum possible proportion of energy is supplied by a combination of clean energy resources generating electricity.[27, 28]

Yet the myth persists: Gas is widely promoted as a means to reduce emissions in the power sector by replacing coal-fired power plants with those running on gas. The extent of emissions reductions achieved by such fuel switching depends on many variables, including methane leakage, the technologies the plants use, and the remaining economic lifetime of the plants being replaced. In all scenarios, however, it is clear that coal-to-gas switching will not deliver the scale or pace of emissions reductions required to achieve climate goals, even if methane leakage is kept to a minimum.

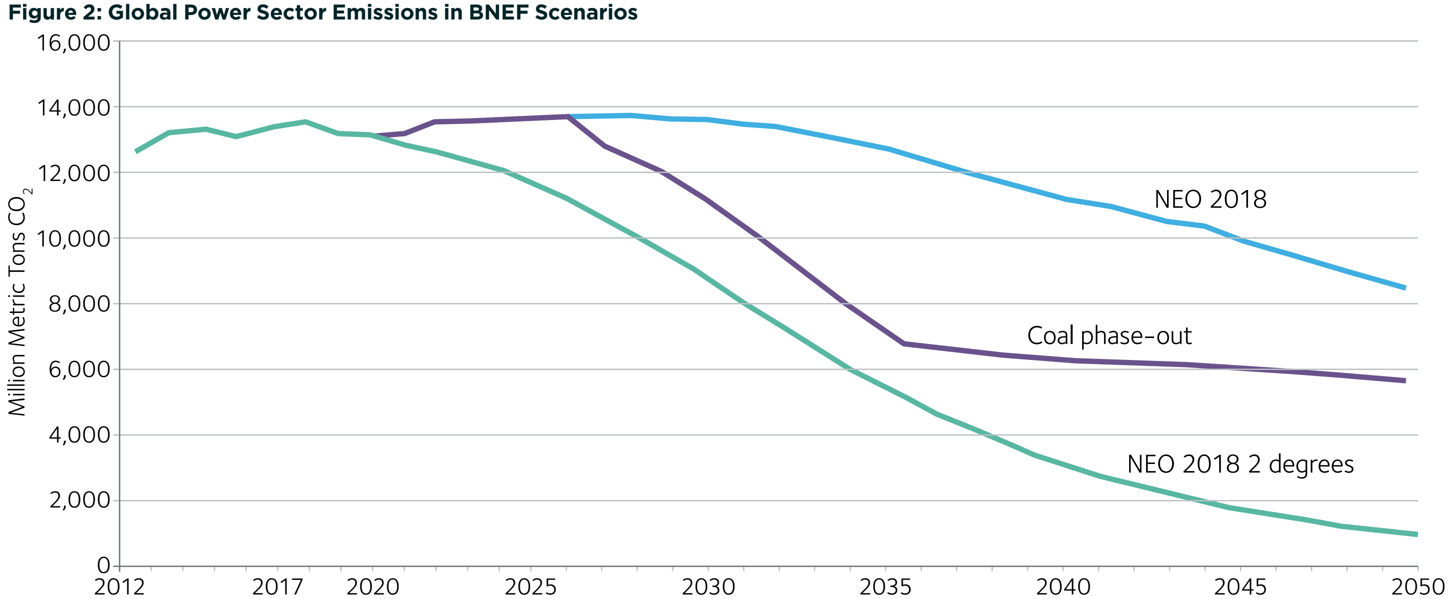
Current projections of how the global electricity sector is transitioning to cleaner energy sources show progress, but the sector remains a long way from aligning with climate goals. For example, the Bloomberg New Energy Finance (BNEF) New Energy Outlook 2018 (NEO 2018) projects that renewable energy is currently on course to provide nearly 50 percent of power generation globally by 2050.[29] This leads to a 36 percent decline in power sector emissions from 2017 levels by 2050 (see the blue line in Figure 2). However, this is well short of the emissions reductions needed.

But what if the phase-out of coal is accelerated with the help of more gas-fired generation? BNEF analysts also ran a scenario in which a phase-out of coal in the power sector by 2035 is implemented.[30] They measured how this would affect power generation from gas and renewables assuming current market dynamics and no other policy changes.

The results suggest that gas would fill around 70 percent of the void left by coal, while solar and wind would replace the rest. This would achieve significant carbon emissions reductions compared to business as usual.[f] But the projected level of gas generation locks in emissions such that by 2050, emissions remain substantially above thresholds consistent with the Paris goals (see the purple line in Figure 2). Note that BNEF measured this outcome against limiting warming to 2°C (see the green line in Figure 2), a threshold that carries extreme risks, rather than the Paris Agreement's goals of keeping warming *well below* 2°C and pursuing a 1.5°C limit.

If climate goals are to be met, any effort to phase out coal must be accompanied by policies to constrain gas and support zero-carbon generation. As Matthias Kimmel of BNEF stated, "[e]ven if we decommissioned all the world's coal plants by 2035, the power sector would still be tracking above a climate-safe trajectory, burning too much unabated gas. Getting to two degrees requires a zero-carbon solution."[32]

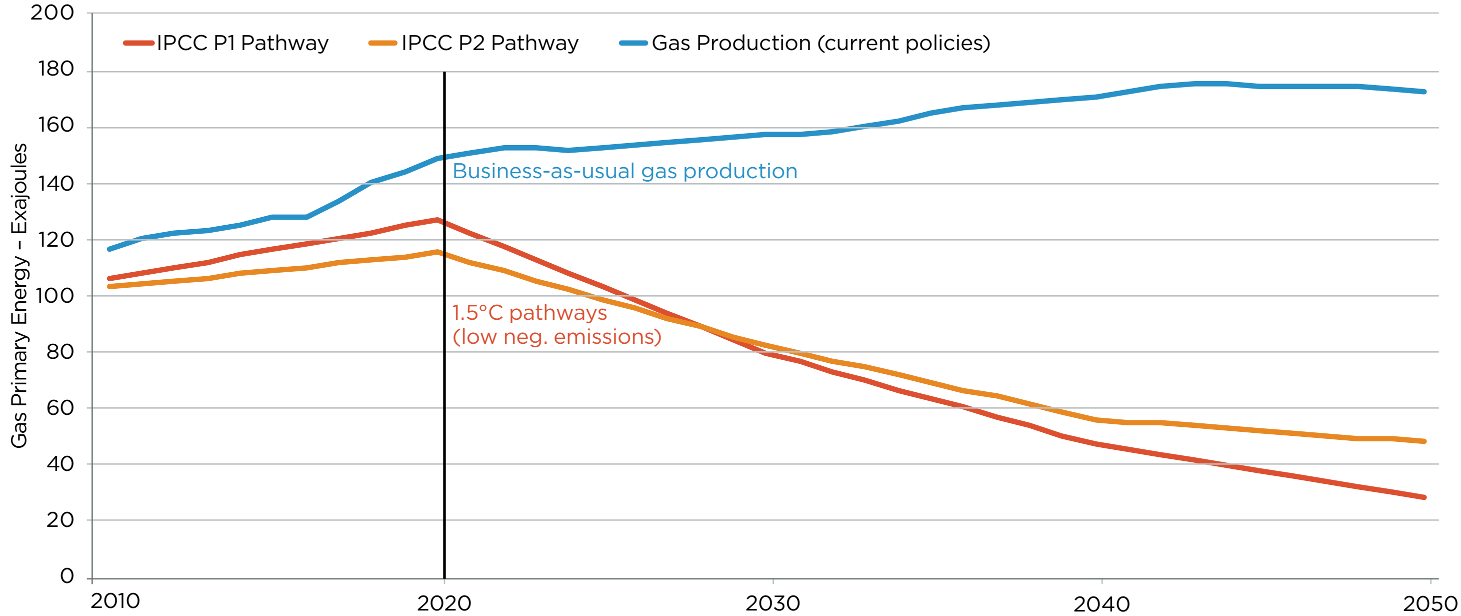
Figure 2: Global Power Sector Emissions in BNEF Scenarios



Source: Bloomberg New Energy Finance, 2018[31]

f Note that BNEF is only measuring emissions at the chimney stack. Methane leakage associated with gas production, processing, storage, and transport will mean that the actual reductions achieved in this scenario are less than stated.

Figure 3: Global Gas Pathways: Business-as-usual extraction vs. demand aligned with 1.5°C



Source: IPCC/IAMC 1.5°C Scenario Explorer and Data hosted by IIASA (Release 1.1)[34] *and Rystad Energy AS UCube* (April 2019)

Not Just Power: Business-as-Usual Gas Production Drastically Overshoots Climate Models

Decarbonizing the power sector – by shifting from coal and gas to renewables by mid-century – is key to rapidly reducing climate pollution. But gas use must begin winding down in other sectors as well to avoid climate breakdown.

The recent IPCC Special Report features four illustrative pathways to achieving the 1.5°C target, with varying degrees of reliance on "negative emissions" technologies and alignment with development goals.[33]

In Figure 3, we show the trajectory for global gas consumption in the two illustrative pathways with the lowest reliance on negative emissions and closest alignment with sustainable development and reduced inequality. These are called the P1 and P2 pathways in the IPCC report, shown in the red and orange lines in Figure 3. The P1 pathway excludes reliance on unproven negative emissions technologies to suck CO_2 out of the atmosphere.[g] The P2 pathway includes limited amounts of unproven negative emissions technologies. By contrast, the blue line shows a projection of business-as-usual global gas extraction – if the industry continues to build new infrastructure and open up new fields.[h]

Clearly, industry plans to continue building out new gas infrastructure are far out of line with the necessary decline of global gas use, starting in 2020, shown in pathways to limit warming to 1.5°C. In the P1 pathway, which takes the most precautionary approach to unproven technologies, gas consumption falls by 74 percent below 2010 levels by 2050. In both 1.5°C-consistent pathways, gas consumption falls by 3 to 5 percent per year on average between 2020 and 2050.

Carbon Capture and Storage (CCS): A Dangerous Bet

Representatives of the oil and gas industry frequently argue that increasing gas use well into the future, or at least maintaining a much slower decline, is still consistent with climate goals.[35] They generally make their case by including large-scale deployment of commercially unproven technologies in their models. These are typically both carbon capture and storage (CCS) and bioenergy with CCS (BECCS), a technology conceived of by energy models to sequester CO_2 in trees, burn them for energy, and capture the emissions.

Scientists Kevin Anderson and Glen Peters conclude that bioenergy production and CCS "both face major and perhaps insurmountable obstacles."[36] Given most of the few CCS pilot projects to date have proved more costly and less effective

g While not relying on carbon capture and storage (CCS) or BECCS, the P1 pathway does rely on sequestration of 246 billion tons of CO_2 through planting forests. Without reliance on significant afforestation, the gas declines shown in Figure 3 would need to occur even faster.

h To compare with demand trajectories given by the IPCC, we exported data from the Rystad Energy Ucube database in energy-equivalent units. The variation in historical gas use between the lines in Figure 3 is likely due to differences in energy accounting between Rystad's production-based data and the demand-based primary energy data in integrated assessment models. Note that the IEA's New Policies Scenario projects almost double the growth in gas production compared to the Rystad projection (WEO 2018).

than hoped,[i] many analysts now consider that wind and solar power, which are proven technologies, are likely to remain cheaper than CCS, even if CCS technology improves. Large-scale reliance on BECCS, which exists to date primarily in theoretical models, would require converting land to grow bioenergy instead of food, risking large-scale food shortages, unsustainable freshwater use, and massive habitat conversion: For example, offsetting a third of today's fossil fuel emissions would require land equivalent to up to half of the world's total crop-growing area.[j]

By promoting increasing reliance on gas, the oil and gas industry is asking the world to make an incredibly dangerous bet on uncertain technologies that pose significant risks to society and ecosystems. If negative emissions technologies do not work out, climate change will be locked in. In fact, the recent IPCC report warns that, "[Carbon dioxide removal] deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5°C."[37] It is far safer to reduce emissions in the first place – and that means planning for the phase-out of gas.

i For example, the world's first industrial-scale CCS project, the Sleipner project in Norway, started in 1996 and was assumed to be safe until it was discovered to have fractures in its caprock in 2013. The Boundary Dam project in Canada, the first to install CCS at a power station, was exceptionally expensive to build and has struggled to operate as planned, suffered considerable cost overruns, and been forced to pay out for missing contractual obligations.

j Twelve billion metric tons of carbon dioxide extracted per year is estimated to require a land area devoted to bioenergy of 380 to 700 million hectares, equivalent to 25 to 46 percent of total world crop-growing area. Pete Smith et al., "Biophysical and economic limits to negative CO_2 emissions," *Nature Climate Change* 6, 2015, p. 5, https://doi.org/10.1038/NCLIMATE2870.

BOX 2: Renewable Gas: No Excuse for Expansion

The gas industry is finding new ways to push its agenda. In Europe especially, the gas industry claims that the pipelines and other gas infrastructure it wants to build will one day be used to process and transport so-called *renewable gas*.[38]

While non-fossil forms of gas could play a limited, intermediate role in decarbonizing hard-to-electrify sectors like heavy industry, this transition would still require reducing overall gas use to serve climate goals. Analysis by the International Council on Clean Transportation found that renewable methane could play "a small role" in decarbonizing the European Union's economy by 2050 but "cannot represent the primary strategy for decarbonizing an entire sector."[39]

The energy think tank E3G notes, "None of the Paris-compliant scenarios with renewable or decarbonised gas show increasing gas demand, and most of them show a sharp decline in gas volumes compared to today. **This suggests there is no justification for the expansion of the gas networks** [emphasis added]."[40]

Furthermore, the term "renewable gas" can be misleading. The industry uses it as a catch-all to refer to a variety of production processes and end products – including some still derived from fossil gas – all with differing implications for future pollution, cost, and infrastructure. These include the following[41]:

- **Biogas/biomethane:** Both terms refer to gas produced through anaerobic digestion of organic matter such as manure, sewer sludge, landfill waste, or biomass grown for the purpose. Biomethane is the "upgraded" form of biogas. This process involves removing some of the CO_2 so that its composition is similar to fossil gas, enabling its transport via existing gas infrastructure. Biomethane is still methane. **It emits CO_2 when burned and can leak from pipelines and other infrastructure like fossil gas.** To produce on a large scale, it would also compete with agriculture and forestry over land use, reducing its sustainability.
- **Hydrogen:** Hydrogen is emissions-free when burned, but it has to be manufactured. Its pollution footprint depends on how it is produced. Today, most hydrogen is made via the combustion of fossil fuels. Hydrogen can be produced from renewable electricity. But this "power-to-gas" technology is expensive and exists so far only in pilot project form. **Because hydrogen is a smaller molecule than methane, existing gas pipelines, storage facilities, and appliances would need to be overhauled to use it.** Hydrogen can technically be converted to synthetic methane to adapt to existing infrastructure, but that process requires adding CO_2, increasing costs and pollution while decreasing efficiency.
- **Gas with carbon capture and storage (CCS):** Using CCS to strip CO_2 from fossil gas cannot be considered "renewable," but some industry proponents lump it into this category. CCS could reduce CO_2 pollution emitted when converting gas to hydrogen. CCS could also be used to reduce emissions from biogas or biomethane. **CCS itself remains an uncertain, risky, and still-costly technology (See above).**

The high costs, technical limits, and climate and environmental risks of these technologies suggest they have a highly limited, specialized role to play in genuine decarbonization – if they have a role at all. According to E3G analysis of the European context, estimates of the total potential of renewable gases (excluding fossil gas-derived forms) "represent a fraction of the current gas consumption, even in 2050."[42] The principle solutions for decarbonization beyond the power sector lie in electrifying transport, heating, and industry and increasing energy efficiency to reduce demand.

Wind turbines in Power County, Idaho, U.S. *©U.S. Department of Energy.*

3. LOW-COST RENEWABLES CAN DISPLACE COAL AND GAS

The bridge fuel idea is erroneously based on the assertion that only gas can affordably replace coal on a large scale in the short to medium term. While cost has been a constraint in the past, today, wind and solar are the cheapest forms of *bulk*[k] energy supply in most major markets.[43] As these technologies continue to gain from increasing economies of scale and implementation experience, the cost and performance of wind and solar power is only set to improve.[44] This means that renewable energy can and does replace coal as bulk generation while saving consumers money.

Even in regions of the United States where solar and wind are *not yet* lower cost than gas, we have reached the point where an energy system based on renewables will lower costs everywhere. As studies have shown, portfolios of clean energy resources will be needed to replace dispatchable fossil fuels.[45] Such portfolios will include variable renewables, flexible load, storage, transmission, and the gradual electrification of buildings and transportation. Modeling has shown that clean energy portfolios will produce a lower-cost energy system than the status quo gas-dependent system.[46]

While many energy markets are not currently designed to identify and support such clean energy portfolios, policymakers can step in. They can develop resource deployment pathways that grow these portfolios over time, developing balanced, reliable, and low-cost combinations of renewables, energy storage, flexible load, and other complementary resources while also electrifying buildings and transportation. Consumers will benefit from lower energy costs. This cost advantage will only grow over time.

k See Box 3 for definition of bulk generation.

BOX 3: Three Broad Types of Power Generation

We describe three categories of power generation technologies, based on BNEF[47], as follows:

- **Bulk Generation:** Technologies that can supply large amounts of cheap energy, including wind and solar, as well as Combined Cycle Gas Turbine[I] (CCGT) plants, coal, nuclear, and large hydro.
- **Dispatchable Generation:** Technologies that offer bulk generation but can be dispatched when needed, including coal, CCGT, nuclear, and large hydro. Wind and solar plants that are paired with storage capacity can be partially dispatchable.
- **Peaking and Flexibility:** Technologies that provide quick response and can be dispatched when needed, including open cycle gas turbines (OCGT) and gas reciprocating engines (GRE), as well as utility-scale batteries, demand response, and pumped-storage hydro. Wind and solar combined with battery storage can also be used as flexible generation.

Falling Costs

The burgeoning competitiveness of utility-scale wind and solar generation has been documented by at least two energy analyst teams that have each tracked the remarkable decline in the cost of these technologies over the past decade. They do this by calculating the Levelized Cost of Energy (or Electricity) (LCOE) for different power generation technologies. This is the unsubsidized cost per unit of energy produced of financing, building, and operating power plants.

Financial advisor firm Lazard has published an annual LCOE report for more than a decade. The 2018 report found that the average global unsubsidized LCOE for utility-scale solar and wind has dropped 88 percent and 69 percent, respectively, since 2009.[48] Despite the LCOE for gas-fired CCGT declining by 30 percent in the same period, wind and solar are now cheaper on average (see Figure 4). The clear implication is that wind and solar are not only cleaner but also more cost-effective choices for replacing coal-fired power, and they can also replace gas.

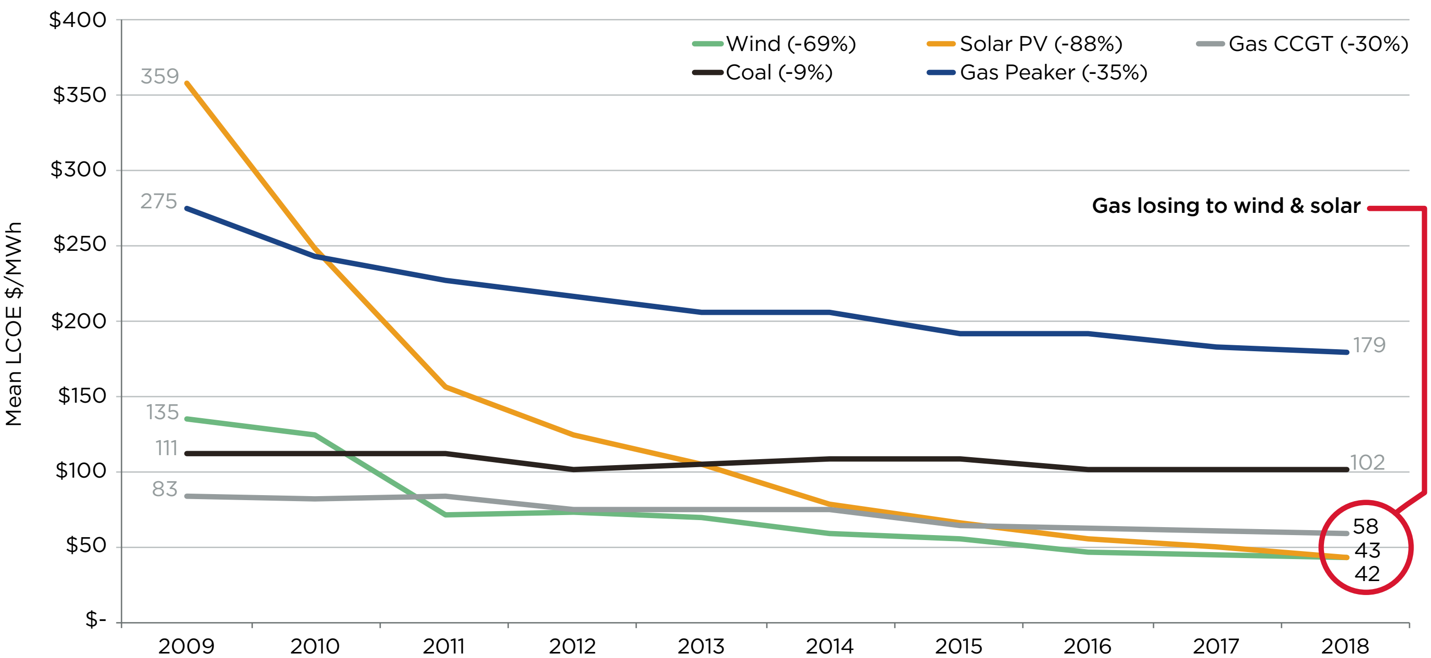
In March 2019, BNEF's LCOE report stated, "*The relentless decline of solar and wind costs has made these technologies the cheapest sources of new bulk electricity in all major economies, except Japan. This includes China and India, where not long ago coal dominated capacity additions, as well as the U.S. where the shale gas revolution has made gas cheap and abundant.*"[50]

Disruption

These steep and ongoing cost declines upend a key aspect of the bridge fuel myth. Wind and solar are now able to challenge the dominance of coal in many major markets. The high cost of imported gas in Asia and Europe, coupled with the effect of zero fuel-cost renewable energy on fossil fuel plant utilization rates, disrupts the economic case for new gas plant build.

As renewable energy capacity increases and its distribution improves, fossil fuel plants are switched on for less time because the energy produced by wind and solar is free at the point of generation. This means fossil fuel plants designed to operate for extended periods are increasingly used below their optimal utilization rates, known as the capacity factor.

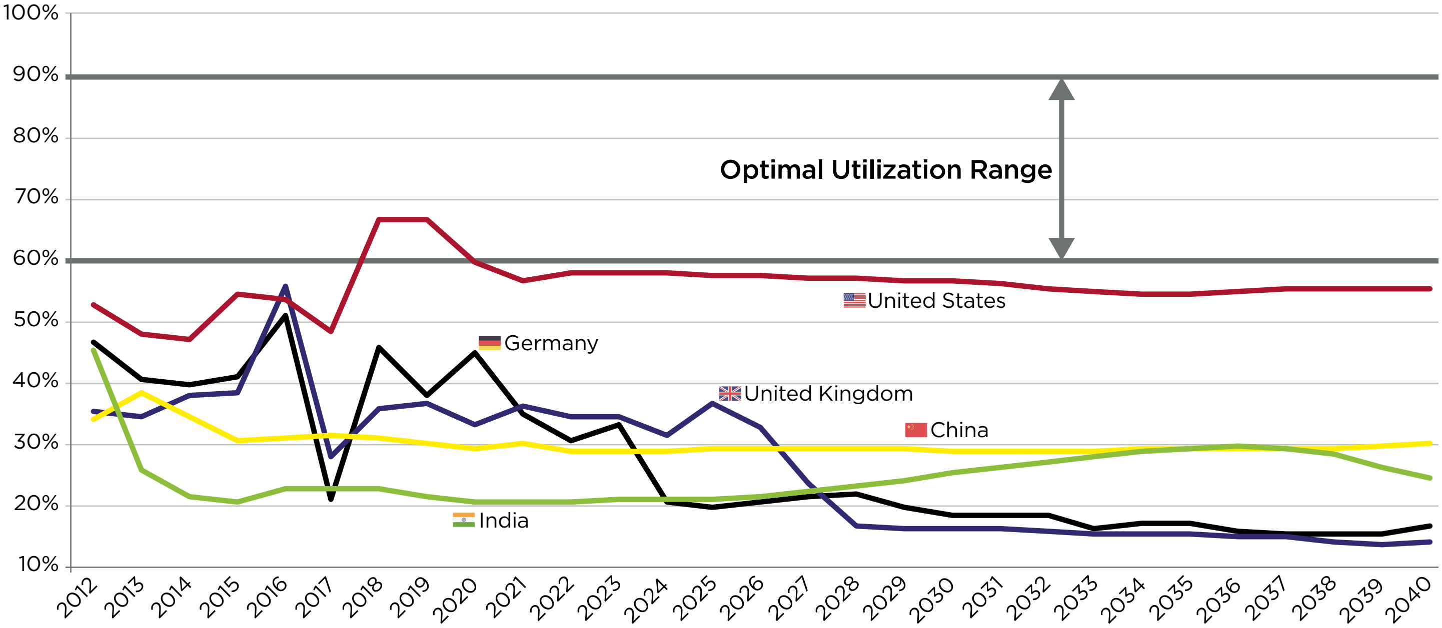
Figure 4: Wind and Solar Are Cheaper than Coal and Gas: Mean Global Levelized Cost of Energy for Select Technologies



Source: Lazard 2018[49]

I Also known as Natural Gas Combined Cycle (NGCC).

Figure 5: Historical and Projected Average Utilization Rates for CCGT Plants in Select Countries in BAU Scenario



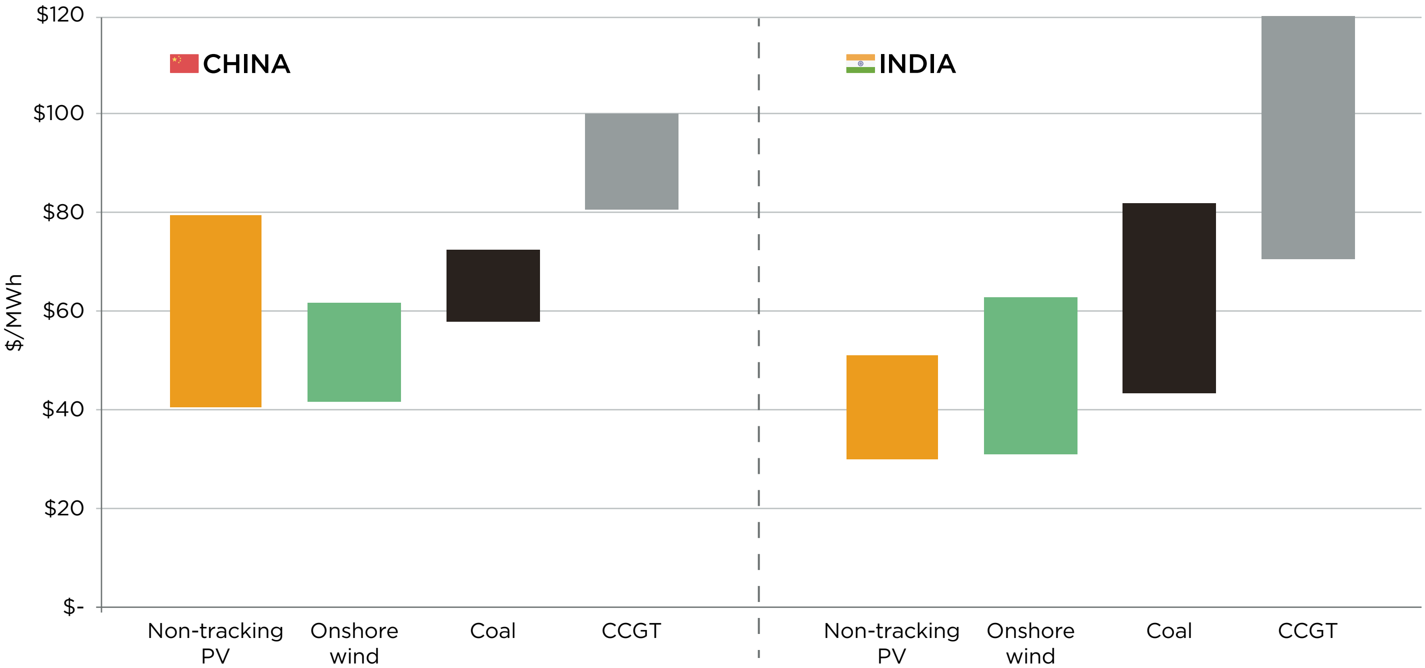
Source: Bloomberg New Energy Finance, New Energy Outlook 2018

Figure 5 shows historical and projected annual capacity factors for CCGT plants in five major markets. In the United Kingdom, Germany, India, and China, capacity factors have been well below the optimal level since at least 2012, and are projected to stay there through 2040. In the United States, capacity factors have been close to the lower end of the range and are projected to remain just below the optimal range through the same period, despite U.S. wholesale gas prices being among the lowest in the world. Note that these projections are from the business-as-usual case shown in Figure 2 (blue line), in which global emissions remain far above a weak interpretation of the Paris climate goals.

Low capacity factors raise the LCOE for new CCGT plants, and can be a factor in them losing out to wind and solar on a cost basis. Figure 6 compares the current LCOE for new generation in China and India. It is clear that utility-scale wind and solar have emerged as winners in the competition to provide the cheapest bulk power in these major emerging markets that are currently dominated by coal. Cost is clearly not a prohibitive factor to adding renewable generation capacity, whether to replace fossil fuel capacity or meet rising demand. This additionally raises challenges to both the economic and climate justifications for the massive Liquefied Natural Gas (LNG) capacity being built and planned in the United States and elsewhere, much of which targets the Asian market (See Box 4).

Workers install solar panels in the U.S. *©U.S. Department of Energy/Schroeder.*

Figure 6: Current LCOE of New Bulk Generation in China and India



Source: Bloomberg New Energy Finance, 1H-2019 LCOE Update

BOX 4: LNG: Making the Problem Worse

Liquefied Natural Gas (LNG) is fossil gas that is cooled to –162°C (–260 degrees Fahrenheit) to reduce volume and facilitate shipping across oceans. On arrival, the liquefied gas is generally regasified to be further transported by pipeline to its final destination.

As might be expected, this intense process requires a lot of energy. Electricity and gas are generally used to power the plants that chill the gas into LNG. Where gas is used, it is estimated that six to 10 percent of the gas processed is required for powering the plant.[51] Additional energy is required for shipping and regasification.

So, the LNG process adds a significant amount to the full lifecycle emissions of producing and using gas. If methane leakage is not kept at very low levels – well below two percent, depending on shipping distance and other factors – replacing coal with LNG will result in increased greenhouse gas emissions.[52]

But it is also dangerous to assume that LNG exports automatically lead to the displacement of coal in destination markets. A paper published in November 2017 in the international journal *Energy* studied this issue in detail, examining scenarios in which U.S. LNG is exported to Asia.[53] The study found that the displacement of coal by LNG exports is far from a given, and that, as a result of U.S. exports of LNG, "greenhouse gas emissions are not likely to decrease and may significantly increase due to greater global energy consumption, higher emissions in the United States, and methane leakage."[54]

4. GAS IS NOT ESSENTIAL FOR GRID RELIABILITY

As renewable energy costs have declined, eroding the economic case for new gas development, gas industry advocates have increasingly emphasized the variability of wind and solar as the reason to build more gas capacity. The sun does not always shine, and the wind does not always blow, and therefore – they argue – gas-fired generation is needed to balance supply and demand. But gas advocates are misleading the public on the role of gas in an electricity system dominated by renewable energy. The reality is that there are many choices for balancing wind and solar on the grid, and gas is losing ground to cheaper, cleaner, and more flexible alternatives. In summary:

- Most of the gas generation capacity being built today uses Combined Cycle Gas Turbine (CCGT) technology. CCGT technology is challenged by increasing renewable energy, rather than enabling it.
- Other types of gas generators, known as peakers, are already being challenged on cost by battery storage.
- With multiple technologies already available, managing grids with high renewable energy penetration is about policy and power market design, not adding or maintaining fossil fuel capacity.
- Policymakers can drive the adoption of complementary resources that enable the integration of high levels of renewables while maintaining reliable electric service at low costs.

CCGT – The Wrong Technology for the Energy Transition

The vast majority of gas-fired generation capacity being built today uses CCGT technology. In the United States alone, around 24 gigawatts (GW) of CCGT capacity was commissioned in 2017 and 2018, and more than 14 GW was under construction at the beginning of 2019.[55] There is more than 425 GW of CCGT capacity in operation globally.[56]

With its two-cycle system of directing heat from a gas turbine to a steam turbine, CCGT is the most efficient and cost-effective gas-fired generation technology for producing large amounts of energy.[57] But because most CCGTs take a relatively long time to ramp up to full power – at least 25 minutes – they are not as well suited or as economical for providing the flexibility needed to balance large amounts of variable renewable generation (see Figure 7).

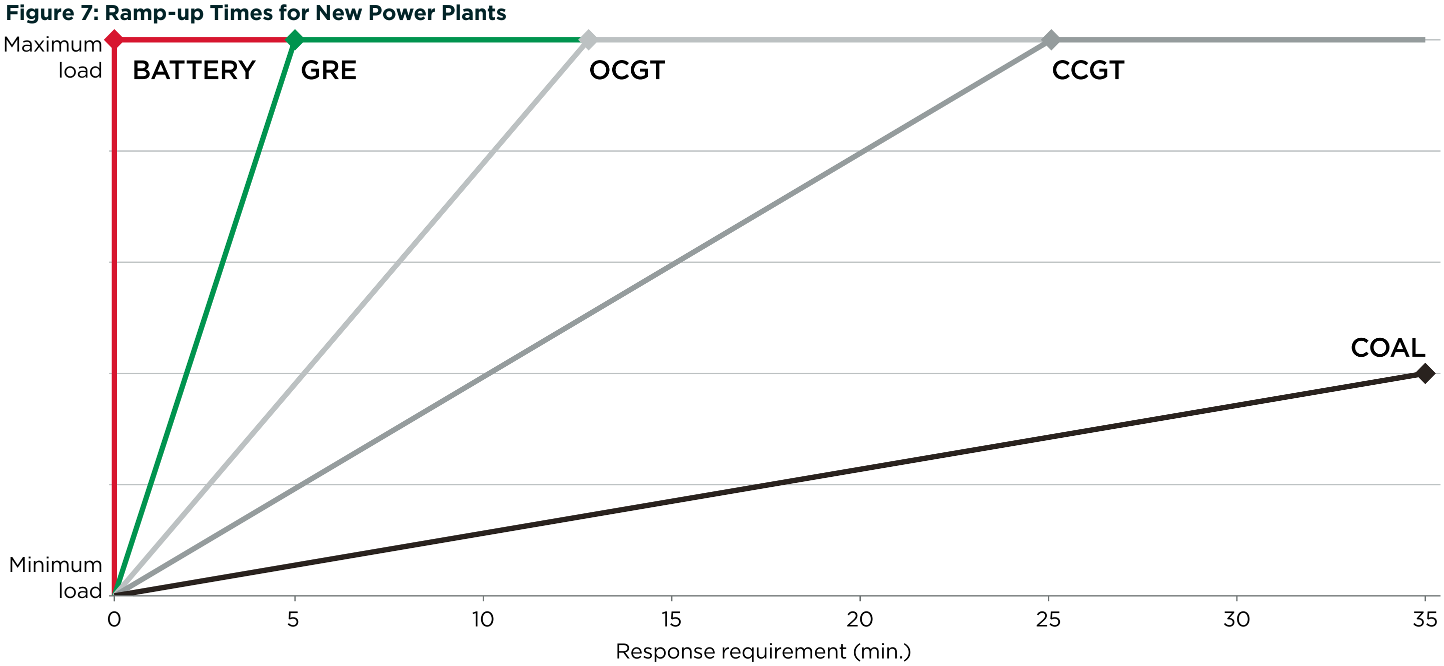
Further, CCGT plants are generally operationally and economically optimal at high utilization rates between 60 and 90 percent (see Figure 5 above). These factors mean that as increasing amounts of wind and solar are placed onto the grid, the economics of CCGT plants are challenged. In other words, rather than enabling higher penetration of wind and solar, CCGT plants are threatened by it. As new, more flexible, cost effective, and clean technologies come on stream, the addition of new CCGT capacity is unlikely to be the best solution for the flexibility requirements of a clean energy grid.

Batteries Challenge Gas 'Peakers'

The gas-fired technologies that are more suited to providing flexible generation capacity – gas reciprocating engines (GRE) and Open Cycle Gas Turbines (OCGT) – are often referred to as peakers, as they are designed to operate during periods of peak demand. They have faster response times compared to CCGT, but are slower than batteries (see Figure 7).

The immediate response capability of batteries is just one advantage the technology has over gas peakers. They are also cheaper over the lifetime of their operation. Utility-scale batteries are already competitive with gas peakers

Figure 7: Ramp-up Times for New Power Plants



Source: Bloomberg New Energy Finance, 2H 2018 LCOE Update[m]

m Ramp-up times assume a hot start.

in some major global markets, such as Australia, Japan, and the United Kingdom.[58] As the combination of accelerating demand for both electric vehicle and stationary uses triggers increasing economies of scale, costs are set to decline rapidly in the coming decade and beyond.

In the United States, the LCOE of stand-alone utility-scale batteries is currently above gas peakers, primarily due to the low cost of gas. But while gas peaker costs are set to rise over the next decade, battery costs are set to decline more than 55 percent by 2030. By 2023, four-hour stand-alone batteries are projected to be cheaper to build and operate than both OCGT and GRE gas peaker technologies in the United States (see Figure 8).

The emergence of batteries as an increasingly affordable and capable technology for storing energy has implications for the clean energy transition beyond their stand-alone flexible generation capacity. Batteries can be co-located with utility-scale wind and solar plants, storing excess power when sunshine and wind are abundant, and effectively allowing a proportion of a wind and solar plant's capacity to be dispatchable. This technology also allows the plant to provide load-shifting services, giving these plants access to high-value hours when they might otherwise be offline.[59] Combining wind or solar with battery storage enhances both the profitability and utility of these clean energy power plants.

BNEF reports that wind and solar plants with onsite battery storage are already able to compete with new coal or gas plants on an LCOE basis in Germany, the United Kingdom, China, Australia, and the United States.[60] They note, "these projects cannot displace fossil fuel plants entirely, but they are able to eat into their run-hours and negatively affect their economics."[61]

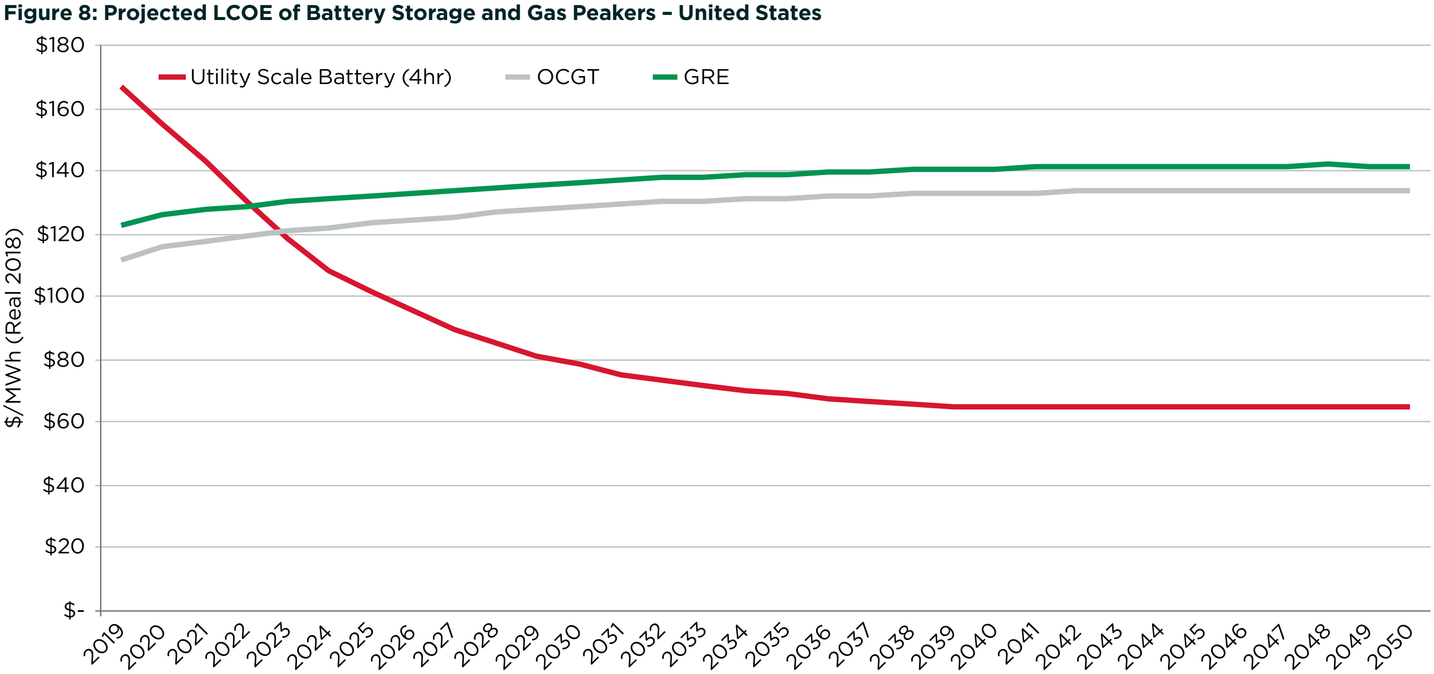
The key issue for batteries today is the duration for which they can discharge. The most common systems being installed today have durations of between one and four hours. The forecast in Figure 8 is based on four-storage-hour systems.[n] Gas peakers can, of course, operate for as long as needed given uninterrupted fuel supply. But a study by Wood Mackenzie in 2018 found that six- and eight-hour battery storage systems, which are beginning to enter commercial operation today, can address 74 percent and 90 percent of peaking demand, respectively.[62]

As battery technology evolves and installed capacity grows, additional gas-fired generation is not needed. As BNEF recently stated, "[t]he economic case for building new coal and gas capacity is crumbling, as batteries start to encroach on the flexibility and peaking revenues enjoyed by fossil fuel plants."[63]

With clean energy technologies beating gas on costs, flexibility, and emissions, it is imperative that policymakers avoid picking gas as the winner in the race to support variable renewable energy as the transition to clean energy gathers pace. In order to accelerate the clean energy transition, they must proactively design power systems and power markets that optimize a suite of truly clean technologies and resources that can meet reliability requirements with the lowest emissions and costs.

High levels of clean energy generation are possible and affordable today, and are only going to become cheaper and more reliable over time. Managing the challenges raised by transitioning to clean energy will require state and wholesale market policies that incentivize the right combination of solutions. The key problem to solve is climate change, which can only lead to substantial reductions in gas use.

Figure 8: Projected LCOE of Battery Storage and Gas Peakers – United States



Source: Bloomberg New Energy Finance, 1H-2019 LCOE Update

n I.e. systems designed to supply power at maximum capacity for 4 hours.

Solar photovoltaic array in Montezuma County, Colorado, U.S. *©U.S. Department of Energy/Schroeder.*

Power Market Design Is Key to the Clean Energy Transition

High levels of renewables are disrupting current energy markets. Two-thirds of the U.S. electric load is served by Regional Transmission Organizations (RTOs) that provide competitive markets for electricity.[64] In the United States and around the world, a myriad of competitive markets exist, each with rules that govern markets for energy services, ancillary services, and capacity. These markets were designed for centralized generation that is dispatched to meet predictable demand. It is increasingly clear that power market design will need to evolve to take advantage of low-cost variable renewable energy.

In many regions, current power market rules are an obstacle to the growth of renewable resources and complementary resources such as demand response and storage. Energy experts at Energy Innovation point to a number of near-term changes that would provide greater flexibility in wholesale markets. "Simple changes to market rules could unlock a significant amount of flexibility for RTOs. In some instances, existing market rules, even when well intentioned, preclude certain resources from offering services even though they could provide value. In other instances, market rules designed to accommodate certain technologies or contract structures limit the ability of grid operators to tap those resources."[65]

Renewables have also lowered energy prices for all generators. Most competitive power markets are based on power generators bidding their electricity into a market. At times of high demand, bids from more expensive sources of power are accepted and all generators are paid the highest accepted bid price. During periods of low demand, only the cheapest sources are compensated for supplying the grid.

Renewable energy is disrupting this model.[66] As wind and sunshine are free, renewable energy has low marginal running costs. In competitive power markets, wind and solar are pushing wholesale power prices down and reducing revenues for all generators. Indeed, far from being expensive for consumers, the rise of wind and solar has led to lower consumer costs by lowering the floor for wholesale energy prices.[67]

Policymakers in many regions, including U.S. states, have significant authority to influence the generation mix serving their state or regional electric grid. These policymakers can develop resource deployment pathways that grow clean energy portfolios over time, developing balanced, reliable, and low-cost combinations of renewables, energy storage, flexible load, and other complementary resources, while also electrifying buildings and transportation.

The International Renewable Energy Agency (IRENA) states that in order to maximize renewable energy capacity and foster the solutions to wind and solar variability, policymakers must support investment in a suite of technologies, none of which include gas. To do this, policymakers and regulators need to "*(p)romote innovative business models that enhance the system's flexibility and incentivise deployment of renewable technologies. Examples include virtual power plants, innovative forms of power purchase agreements, platform business models such as peer-to-peer trading, and business models that enhance demand side response.*"[68]

These are just a few examples of innovations in energy market development and management that are making headway today, and must be adopted more widely to truly enable the transition to clean energy.

5. NEW GAS INFRASTRUCTURE LOCKS IN EMISSIONS

Gas-fired power plants and related infrastructure such as pipelines and LNG terminals require large, up-front multibillion-dollar investments. Such investments are economically predicated on producing revenue for several decades.[69] Building more gas infrastructure today risks locking in emissions from gas for many decades to come. Every new gas-fired power plant we build, along with the pipelines and associated infrastructure to serve it, is making it more difficult to decarbonize by 2050, as the IPCC states we must.[70]

According to a database of global power-generating units, there are more than 1,100 gas-fired generators rated over 5MW, built in or before 1970 that are still in operation today; over 400 of these are in the United States.[71] In 2014, the Interstate Natural Gas Association of America reported that 60 percent of the country's interstate gas transmission pipeline network was installed prior to 1970.[72] Once it is built, gas infrastructure can last a very long time.

The Center for Sustainable Energy found that for potential gas power plants applying for permits in California between 2016 and 2020, most would be operating beyond 2050 based on average permitting and operating periods in that state.[73] The report points out that this would be a threat to California's plans for decarbonization.

The problem of carbon lock-in describes a feature of fossil fuel infrastructure that tends to persist over long timeframes and lock out alternatives due not only to economics, but also technical and institutional factors.[74]

Regulated utilities in the United States are incentivized to build infrastructure by a system that guarantees high returns by passing the cost and risk of new infrastructure onto ratepayers.[75] While this system can be utilized to support clean energy, in recent years it has been extensively used by utilities to build large interstate gas transmission pipelines that have only served to lock in gas supply during a period in which the transition to clean energy must proceed apace.[76]

However, economics is the prime factor at work when capital-intensive infrastructure has been built. Once capital has been sunk, operators can keep running a plant as long as it can sell power for more than the marginal cost of producing it – even if it incurs a loss on the invested capital. For this reason, the lower cost of new wind and solar capacity does not guarantee the early retirement of dirtier fossil fuel capacity.

For the clean energy transition to accelerate, it is crucial to cease investment in polluting energy sources and do everything feasible to encourage zero-carbon sources to grow to meet emissions targets. At this late stage in the depletion of carbon budgets, it is necessary to move straight to zero-carbon energy and avoid locking in further emissions before it is too late.

Fracking for fossil gas in the Marcellus Shale formations in Pennsylvania, U.S. *©Les Stone/Greenpeace.*

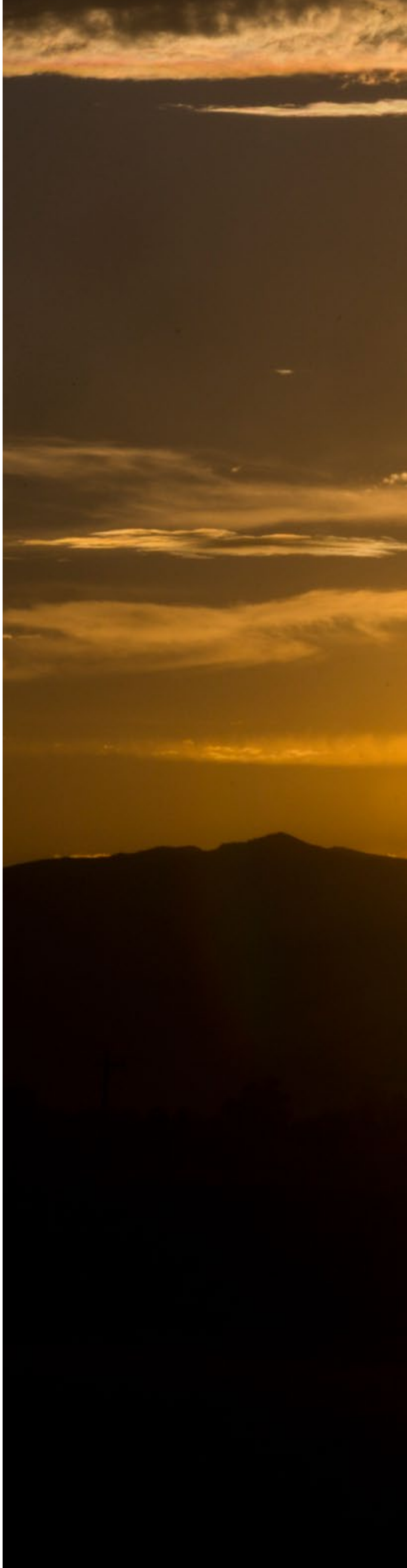
CONCLUSION

The myth of gas as a “bridge” to a stable climate does not stand up to scrutiny. While much of the debate to date has focused on methane leakage, the data show that the greenhouse gas emissions just from burning the gas itself are enough to overshoot climate goals. We must reduce gas combustion rather than increase it, and the fact that methane leakage will never be reduced to zero only makes this task more urgent.

Expanding renewable energy capacity does not require expanding gas use. Existing gas plants will not be shut down immediately, but power markets must be designed to enable the suite of technologies and resources that will support renewable energy as fossil fuels are phased out.

There is an urgent need for policymakers and investors to use climate goals as a starting point for energy decisions, particularly when it comes to gas. Rather than searching for ways to justify using the abundant supply that new drilling methods have unleashed, policymakers and investors should consider how much gas is compatible with achieving the goals of the Paris Agreement. The answer is the same for gas as it is for coal and oil: We need less, not more.

In the next ten years, global greenhouse gas emissions must be substantially in decline. It is clearer than ever, despite decades of industry propaganda, that gas is not clean, cheap, or necessary. Like all fossil fuels, we must urgently embark upon a managed decline of gas production and consumption.



The sun sets over the mountains beyond a fracking rig in Colorado, U.S.
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