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Natural Gas and the Energy Transition:
Security, Equity, and Achieving Net Zero

Phillip Cornell

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Cover: Gas pipes are seen at Gas Connect Austria in Baumgarten, Austria, September 28, 2022. REUTERS/Lisa Leutner

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Executive Summary

The energy trilemma of energy security, affordability, and sustainability has gained newfound relevance in the presence of inflation and geopolitical conflict, and has complicated the global pathway to net-zero emissions. Navigating this trilemma underscores the challenge of sufficient investment in cleanest-possible fossil fuel resources, and particularly natural gas.

Power infrastructure must ensure stability across an increasingly complex and intermittent grid marked by high penetration of renewable electricity, while also coping with significant growth in energy demand (particularly in the developing world). And in some industrial applications where direct electrification is not feasible, alternative energy sources are still cost prohibitive or simply unavailable at scale. Stringent regulatory and public policy requirements to restrict fossil fuel production raise the risk of choking off supply before cleaner alternatives are sufficiently scaled, with significant effects on prices and reliability.

However, political events have caused many Western governments to rebalance their priorities. As Daniel Yergin wrote for the International Monetary Fund (IMF) in December 2022, “The energy shock, the economic hardship that ensued, skyrocketing energy prices that could not have been imagined 18 months ago, and geopolitical conflicts—all these combined to force many governments to reassess strategies…[and] recognize that the energy transition needs to be grounded in energy security—that is, adequate and reasonably priced supplies.”[1]

The protracted supply crisis in 2022 was exacerbated by the Russian invasion of Ukraine, and prompted developed countries to revise their energy transition messaging. Many highlighted the need to access and invest in fossil fuels during moments of economic and political crisis, softening their rhetoric around emissions. That shift complicated an ongoing debate about whether to phase out (or simply end) public financing for fossil fuels. At the same time, developing countries are increasingly unwilling to allow their economic development or security goals to be marginalized as the world builds a pathway to reach the goals of the Paris Agreement.

The persistent need for energy resources to meet growing demand while advancing the energy transition highlights a continued need for natural gas. Abundant and energy dense, natural gas is a valuable source of firm power and industrial fuel for both developing and developed economies. It is much less emissions intensive than fossil substitutes like coal or fuel oil, and it competes at cost to displace those fuels where they are used to generate power or heat. The emissions that remain are increasingly manageable, thanks to methane-abatement technologies and carbon capture, utilization, and storage (CCUS). Some of the infrastructure for delivering and burning natural gas can also be converted for hydrogen use once it is available on a large and sustainable scale. Put simply, even as policymakers move to aggressively deploy renewable and zero-carbon energy resources, natural gas remains a valuable tool in limited volumes to manage the context dependencies of a transitioning energy system in the short, medium, and long terms.

Effectively managing natural gas investment will require some nuance from policymakers, industry leaders, and those advocating for the rights of vulnerable populations. Regulatory and policy efforts to curtail supply in the name of carbon reduction raise the risk of stranded natural gas assets, and also of choking off supply before cleaner alternatives are sufficiently scaled. Both underscore the importance of policy stability. For natural gas in particular, technologies and business models to decarbonize processes and manage emissions are prerequisites to avoid locking in decades of additional emissions, and depend on clear policy signals. The January 2024 pause on US liquefied natural gas (LNG) export projects imposed by the Joe Biden administration highlights the impact of oscillating public policy, with ramifications for investment in cleanest-possible gas solutions.

When it comes to financing the natural gas investments necessary to stabilize net-zero power systems and enable industrial growth, issues abound across private investment, financing structures, and the construction of gas assets. Sovereign and multilateral support for energy-related financing in emerging markets and less-developed countries (LDCs) is especially sensitive given its outsized impact on the livelihoods of so many. Those concerned with equity and the welfare of vulnerable populations should consider the impacts of absolutist climate advocacy, and empower those populations to decide for themselves.

These issues were at the forefront of COP28 in Dubai, where the results of the United Nations Framework

1 Daniel Yergin, “Bumps in the Energy Transition,” International Monetary Fund, December 2022, https://www.imf.org/en/Publications/fandd/issues/2022/12/bumps-in-the-energy-transition-yergin.

Convention on Climate Change (UNFCCC)-mandated global stocktake of progress toward the Paris Agreement was underwhelming. At the same time, a multitude of crises within the energy system gives voice to those at the sharp end of the energy trilemma—whether Europeans facing deindustrialization, or those in developing countries experiencing acute deprivation and being blocked from key sectors. Navigating the balance between enabling equitable development while transitioning away from fossil fuels will require thoughtfulness with regard to the opportunities—and limitations—natural gas presents in a decarbonizing energy system.

1. Introduction: The Energy Trilemma and Gas in a Net-Zero World

Within the short span of three years, the global economy has needed to contend with the COVID-19 pandemic, subsequent inflation, the Russian invasion of Ukraine, and the impact of that conflict on commodity shortages, rising energy costs, and declining energy security. Russia's invasion precipitated a reinvigoration of supply security concerns, while higher inflation and interest rates have underscored the importance of affordability and complicated the investment landscape. As a result, short-term reliance on fossil fuels has increased, fewer resources are available for the energy transition, and coordination among regional and global partners has become more complicated.

In the longer term, the crisis underscored the dangers of reliance on fossil fuel imports and exposure to price volatility. That is the case both in Organisation for Economic Co-operation and Development (OECD) countries like Germany whose former complacency over gas imports was exposed, and also in developing economies like Bangladesh from which LNG cargoes were redirected to richer customers amid skyrocketing prices.

All of this augers broadly for accelerating the energy transition. Yet the whiplash nature of shifting public discourse around energy reinforces the notion that one size does not fit all, and that the path to decarbonizing the energy sector is not always linear. Faced with a protracted supply crisis in 2022, rich countries shifted their energy transition messaging for both energy producers and developing economies, suddenly highlighting the need to access and invest in fossil fuels during moments of economic and political crisis. While appropriate, the pivot came with important caveats about ensuring that investments are short term, flexible, and as clean as possible to avoid locking in decades of emissions.[2] However, the renewed lifeline for fossil fuel investments, even if only for the near term, underscores the status-quo bias and egocentrism in the original messaging, as well as the implication that tradeoffs are suddenly relevant when their impacts are felt by rich countries.

Indeed, purist or ideological approaches to energy transition inevitably cause more harm than good. They might prioritize rapid decarbonization without adequately considering the socioeconomic realities of different regions, resulting in uneven employment impacts and detrimental effects on livelihoods and local economies. In economies experiencing rapid industrialization, a sudden shift away from fossil fuels could exacerbate poverty and inequality. A singular focus on certain renewable technologies might overlook the immediate energy needs of poorer communities or those that lack access to reliable electricity. In the developing world, growth is still carbon intensive, and tying limited development-assistance resources to strict decarbonization targets can force countries to make hard choices about the poor, breeding resentment. As the *Economist* wrote in June 2023, "As well as facing stingier health-care and education budgets, [developing economies] might find scant funding for expanding a gas-powered electricity grid, even though nobody stands ready to pay for a new one. African governments rightly resent being told to cut emissions rather than help people in desperate need—especially given that Westerners continue to belch carbon."[3]

Narrow approaches to the transition run the risk of curtailing existing energy sources before viable alternatives are sufficiently scaled and integrated. Yergin wrote that underinvestment has constrained sufficient supplies of oil and gas, thanks to "government policies and regulations; environmental, social, and governance (ESG) considerations by investors; poor returns caused by two price collapses in seven years; and uncertainty about future demand." He describes the underinvestment as "preemptive" because it was rooted in the idea that low-carbon energy sources were already replacing fossil fuels at scale—they weren't.[4]

In their crudest form, policies to incentivize investment into decarbonization are based on categorizing energy sources as either "clean" or "dirty"—despite a wide range of emissions implications depending on the particular energy source. Legal efforts to taxonomize energy sources underpin future emissions-based trade and industrial policy regimes, particularly in Europe.

Yet those efforts also cause headaches when technical complexities contend with blunt policy measures. In 2022,

2 The 2022 and 2023 G7 communiqués were both the result of debates over public investment in natural gas. Germany and others insisted that both include language on the need for it.

3 "How Misfiring Environmentalism Risks Harming the World's Poor," *Economist,* June 29, 2023, https://www.economist.com/leaders/2023/06/29/how-misfiring-environmentalism-risks-harming-the-worlds-poor.

4 Yergin, "Bumps in the Energy Transition."

debate raged in the European Union (EU) over whether gas and nuclear could qualify as "green" under the taxonomy. That argument was fraught with questions about perceptions and public messages, and ultimately exposed the necessary tradeoffs between some of the EU's sustainability criteria (particularly in the case of nuclear, where zero emissions also come with nuclear waste). In the United States, the Biden administration's pause on gas export projects is set to spark a similar public debate about whether gas is "dirty" ahead of the 2024 election, with technical differentiations and gradations likely to be drowned out in a simplistic political fight. Such debates further stoke ideological division, as complex topics are reduced to a duopoly of opposing talking points.

In the case of natural gas, the reality is that there are gradations of "clean." Technologies, business models, and use cases exist to mitigate emissions at points of production, processing, and use. The carbon intensity of natural gas depends on many different parts of the value chain, from extraction to burning, and rates of leakage or flaring.[5] Calculating carbon intensity and encouraging its reduction, in turn, require transparency within the value chain, which is often lacking, particularly for Russian gas (with high fugitive emissions rates) and LNG (with liquefaction and transport emissions). Transparency allows customers to prioritize lower-emissions natural gas, and for public policy to differentiate it. Emerging technologies such as "digital natural gas" can provide a digital record for a specific unit of natural gas production at the wellhead and at the point of consumption.

Alternatives also matter. Gas replacing coal or upgrading older gas-fired turbines to highly efficient modern ones are major wins. But greenfield unabated gas-fired generation will not be sustainable and will often be more costly than the renewable alternative.

Even under a credible net-zero scenario, gas demand will likely persist, both for technical reasons and to create low-carbon fuels like blue hydrogen. In the medium term, natural gas can be part of a solution in which sustainable economic development is a corollary (or prerequisite) to climate action. In developing countries where industrial activities are a source of growth and are particularly effective at addressing poverty, such development can equip societies with the resources and space to address climate concerns.

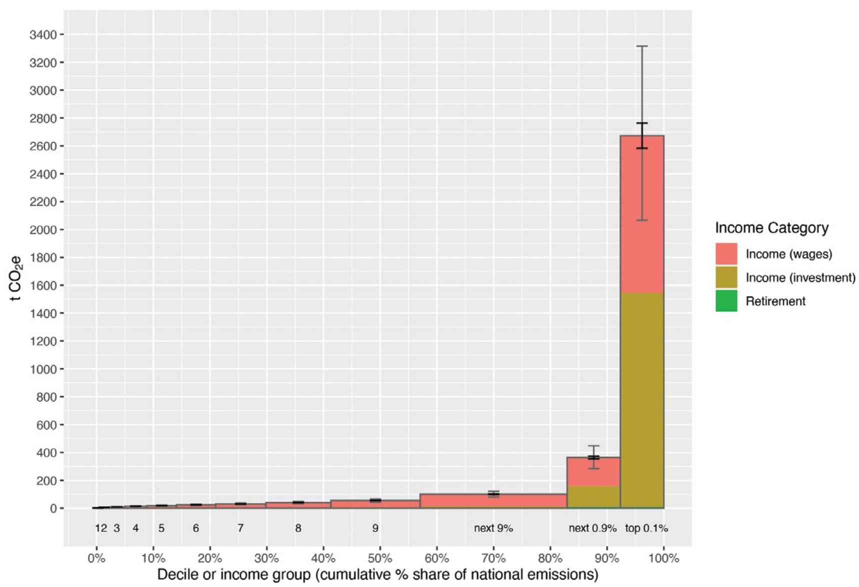
5 For example, analysis by the North Sea Transition Authority shows that gas extracted domestically from the UK continental shelf has an average production emissions intensity of 21 kilograms of carbon dioxide per barrel of oil equivalent (kgCO2/boe), whereas imported LNG has a significantly higher average intensity of 79 kgCO2/boe by the time it reaches the UK point of consumption—almost four times higher. "Natural Gas Carbon Footprint Analysis," North Sea Transition Authority, July 2023, https://www.nstauthority.co.uk/the-move-to-net-zero/net-zero-benchmarking-and-analysis/natural-gas-carbon-footprint-analysis/.

Uncomfortable Truths about Equity and Energy Policy

Energy demand is rising fast as the global middle class expands, demanding cleaner energy and much more of it. However, the massive resources needed to drive an accelerated uptake of renewable energy alternatives and curtail relatively cleaner fossil fuels are not forthcoming from those who can most afford it and who emit the most carbon. The top 10 percent of carbon emitters worldwide—most of whom live in wealthy countries—accounted for nearly half of energy-related carbon-dioxide (CO_2) emissions in 2021. The bottom 10 percent of emitters were responsible for only 0.2 percent of emissions.[1]

Even within wealthy countries, the burden of climate responsibility should be narrowly targeted. Young and marginalized people who struggle economically and are responsible for low amounts of carbon emissions will bear the worst impacts of climate change, and their tolerance for shouldering the costs of mitigation (for example through higher prices) will be limited.

Figure: Mean US Household CO_2e Emissions (2019) per Income Group



The top 0.1 percent of US households, numbering 131,000, hold $18.7 trillion, almost twice as much wealth as the 65 million households in the bottom 50 percent. The top 10 percent of US households are also responsible for 40 percent of the country's human-caused planet-heating pollution.
Source: Jared Starr, et al., "Income-Based U.S. Household Carbon Footprints (1990–2019) Offer New Insights on Emissions Inequality and Climate Finance," PLOS Climate, August 17, 2023, https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000190.

The Grantham Institute estimates that rich countries and development banks will need to provide at least $1 trillion each year to help close a $3.4-trillion annual shortfall between current figures and where combined spending on climate and human development should be.[2] Yet they have been failing to meet the much lower $100-billion annual target they set in 2019.

New policies and financing commitments must make up for this massive shortfall. In the best-case scenario, the energy transition will require simultaneous scaling across value chains at breakneck speed. The chances of economic mismatches, localized volatility, and discrete deprivations are high, however, and their impact will fall disproportionately on less developed countries and the poor. While the transition to net zero is ultimately deflationary and improves resilience, the near-term reality of "green-flation" risks undermining public support for the transition and raises larger questions about inequality and the burden of paying for it.[3] Losers from the energy transition, even in the short term, will require compensation and support for the world to progress in the broad enterprise of decarbonization. All of this suggests the need for shifting the financing risk burden, with its near-term costs and long-term pay-offs, onto the richest people in the richest countries.

1 Laura Cozzi, Olivia Chen, and Hyeji Kim, "The World's Top 1% of Emitters Produce over 1000 Times More CO_2 than the Bottom 1%," International Energy Agency, February 22, 2023, https://www.iea.org/commentaries/the-world-s-top-1-of-emitters-produce-over-1000-times-more-co2-than-the-bottom-1.

2 Vera Songwe, et al., "Finance for Climate Action: Scaling Up Investment for Climate and Development," London School of Economics and Political Science, November 8, 2022, https://www.lse.ac.uk/granthaminstitute/publication/finance-for-climate-action-scaling-up-investment-for-climate-and-development/.

3 This has also been referred to as a "green premium" by Bill Gates and others. "The Green Premium," Breakthrough Energy, last visited February 13, 2024, https://breakthroughenergy.org/our-approach/the-green-premium/.

2. The Role of Natural Gas in a Global Net-Zero Energy System

Gas is important for today's energy system, representing about a quarter of total energy demand in Europe and a third in the United States, while delivering a flexible and reliable supply of electricity and heat. It is also largely responsible for emissions reductions over the past twenty years—specifically by replacing coal, underscoring its role to date as a transition fuel.[6]

Yet as energy systems move toward deep decarbonization, legitimate questions remain about the role of gas within viable pathways to meet the targets of the Paris Agreement. Indeed, it is important to differentiate between the role of gas during the bridge or transition period and its function in the long term. When it comes to the former, the shorter the transition period, the more important gas is to achieving net zero. The evidence shows that accelerating decarbonization to reach net zero in 2035 entails greater contributions from natural gas than delaying that goal to 2050.[7]

Natural Gas in a Decarbonized Power System

Natural gas (combined with CCUS) underpins the timely achievement of a net-zero power system, which is key to economy-wide decarbonization.[8] The target dates set by some major countries to reach net-zero emissions in the power system are little more than a decade off—in the United States, Canada, the EU, and the United Kingdom (UK) by 2035. Gas capacity and generation can play key roles in decarbonizing these electricity systems both during the transition and in the decarbonized system. The extent to which gas will contribute to decarbonization depends on policy design, availability of carbon removal, ability to mitigate upstream methane emissions, and transition risks related to technological change.[9] But fundamentally, decarbonization and degasification are not the same thing.

Gas will continue to provide key flexibility for balancing a decarbonized grid. Gas-fired power units can provide firm and flexible capacity to ensure system dependability with additional renewable energy and meet rising electricity demand as end-use electrification spreads across the economy. As the share of variable renewable energy (VRE) increases, intermittency becomes a more serious issue across the grid, and firm capacity is needed to step in when lack of sun or wind means production drops below demand. Maintaining power quality by regulating rapid swings in voltage and frequency is also key. Synchronous condensing equipment—a standard option on certain types of gas turbines—can resolve power-quality issues by keeping alternating current and voltage waves properly synced on the grid.[10] Upgrades to existing gas-powered infrastructure would reduce emissions and help cope with the variation and fluctuation brought by renewables.

If it is to succeed, the energy transition needs to maintain the reliability and affordability of power delivery, and so the role of gas-fired power must be considered and compared within the context of alternative tools for flexibility, such as large-scale energy storage.[11] In that context, the costs of achieving net zero without gas rise very quickly, especially as the timeline is shortened, or in regions with lower-quality renewable resources. In their 2022 study for the Electric Power Research Institute (EPRI), John Bistline and David Young compared investment and cost outcomes for net-zero decarbonization in the United States against a carbon-free scenario in which generation from natural gas and CCS are prohibited, and found that the latter scenario requires more than 1300 gigawatts (GW) of cumulative investments in solar, wind, new nuclear, hydrogen, and battery storage by 2035, along with $300 billion of additional annual generation expenditures ($1.6 trillion total) and an extra $100 billion in bulk transmission investment per year.[12]

6 As of 2022, gas has replaced coal as the primary resource for electric generation, supplying nearly 40 percent of US power. The IEA estimated that coal-to-gas switching globally avoided more than 500 million tons of CO_2 emissions between 2010 and 2018, which is roughly equivalent to the total energy-related emissions of all Central American countries over the same period. "The Role of Gas in Today's Energy Transitions," International Energy Agency, July 2019, https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions

7 John E. T. Bistline and David T. Young, "The Role of Natural Gas in Reaching Net-Zero Emissions in the Electric Sector," *Nature*, August 12, 2022, https://www.nature.com/articles/s41467-022-32468-w.

8 John E. T. Bistline, "Roadmaps to Net-Zero Emissions Systems: Emerging Insights and Modeling Challenges," *Joule* 5, 10, 2551–2563 (2021), https://www.sciencedirect.com/science/article/pii/S2542435121004402.

9 Bistline and Young, "The Role of Natural Gas in Reaching Net-Zero Emissions in the Electric Sector."

10 Daniel Bush, "The Future of Gas Generation in an Increasingly Decarbonized World," Burns McDonnell, November 21, 2022, https://blog.burnsmcd.com/the-future-of-gas-generation-in-an-increasingly-decarbonized-world.

11 Maintaining reliable electricity delivery within a specific price threshold is also a legal mandate in many markets.

12 Bistline and Young, "The Role of Natural Gas in Reaching Net-Zero Emissions in the Electric Sector." Note: The International Energy Agency calculates this figure at 55 percent.

As the transition progresses, the value of natural gas shifts from providing energy itself to providing capacity for grid flexibility, thus requiring less gas overall. Natural gas capacity factors decline by roughly 50 percent from current levels under Bistline and Young's deep-decarbonization scenario, as natural gas plants are deployed as peakers rather than as baseload suppliers.[13] This will require new business models to make operating peaker plants viable. Their function is to quickly add power to the grid when needed to make sure that electricity is readily available. In a grid marked by high shares of VRE, peaker plants will be critical, if only occasionally needed, making it necessary to maintain low-utilization gas-generation capacity as insurance. Who will pay for that value to an increasingly disaggregated system is an ongoing issue.

Natural Gas for Industrial Uses

While the power sector is crucial for keeping open the path to a net-zero economy, it represents only about a quarter of global emissions. Industrial emissions—and those from agriculture, transportation, and heating—also need to be addressed. Natural gas plays a role in all of them, and is an important feedstock for the production of chemicals and fertilizers.

Three heavy industries—cement, chemicals, and steelmaking—are particularly tricky to clean up. They require very high temperatures for chemical processes, which today are generated almost exclusively by burning fossil fuels. For example, producing certain high-value chemicals requires temperatures close to 1,000 degrees Celsius and blast furnaces producing steel operate at temperatures even above 1,500 degrees Celsius.

In a net-zero economy, energy efficiency and technologies like CCUS can be applied to reduce industrial emissions from natural gas. But ideally, switching to zero-emissions alternative fuels or sources like hydrogen or bioenergy would provide a clean alternative.

Yet when it comes to fuel switching in these sectors, moving away from coal and oil is relatively easy, while switching away from gas in the immediate term (while attractive on its face) would be difficult. The use of bioenergy solids, liquids, or gases, such as biomethane, is promising in some applications, and making them with sewage sludge, food waste, or decaying matter is a positive example of circularity. But their production process emits carbon and their supply at scale faces significant challenges, including the availability of land for bioenergy crops, water needs, the necessity to adapt crops to a changing climate, and the ability to transport and store large quantities of such crops.[14]

Additionally, one must not lose sight of the scale of potentially electrifying heavy industry. Direct electrification may play a part if nascent technologies can improve and scale, but for now electrifying the hardest industrial processes means making molecules from electricity.[15] BASF, a German chemical and plastics firm, uses about 6 terawatt hours (TWh) at its Ludwigshafen production site, which includes three onsite gas plants—about 1 percent of Germany's energy consumption. If it and its domestic competitors were totally electrified, they would need three times their current energy-generation capacity, and the sector's energy consumption would reach 600 TWh, or as much as all of Germany uses today. To electrify Germany's chemical industry, the entire country's power consumption would need to double.[16]

Domestic renewable energy will be part of the solution, as will complex international physical networks of power interconnectors, pipelines, and ships to bring in clean energy produced abroad, such as in the form of hydrogen. Those are huge investments to make, build, and scale in decades, much less years. Their similar physical state means that much of the gas midstream infrastructure system can be shared or possibly repurposed for hydrogen in the future, but an international clean hydrogen economy simply does not currently exist.

And yet the most promising zero-emissions alternative for such "hard-to-abate" sectors is indeed hydrogen, which can be produced from various sources including natural gas with CCS (called blue hydrogen) and renewable energy via electrolysis (green hydrogen). While green hydrogen is ultimately the optimal solution, its enormous renewable energy generation capacity needs and production costs mean that, over the next ten years, blue hydrogen will present an attractive cost of abatement.

In the coming years, the utilization of blue hydrogen has the potential to boost hydrogen demand and expand markets, expediting the process of decarbonization. Looking ahead to 2050, there will be a gradual phase-out of natural

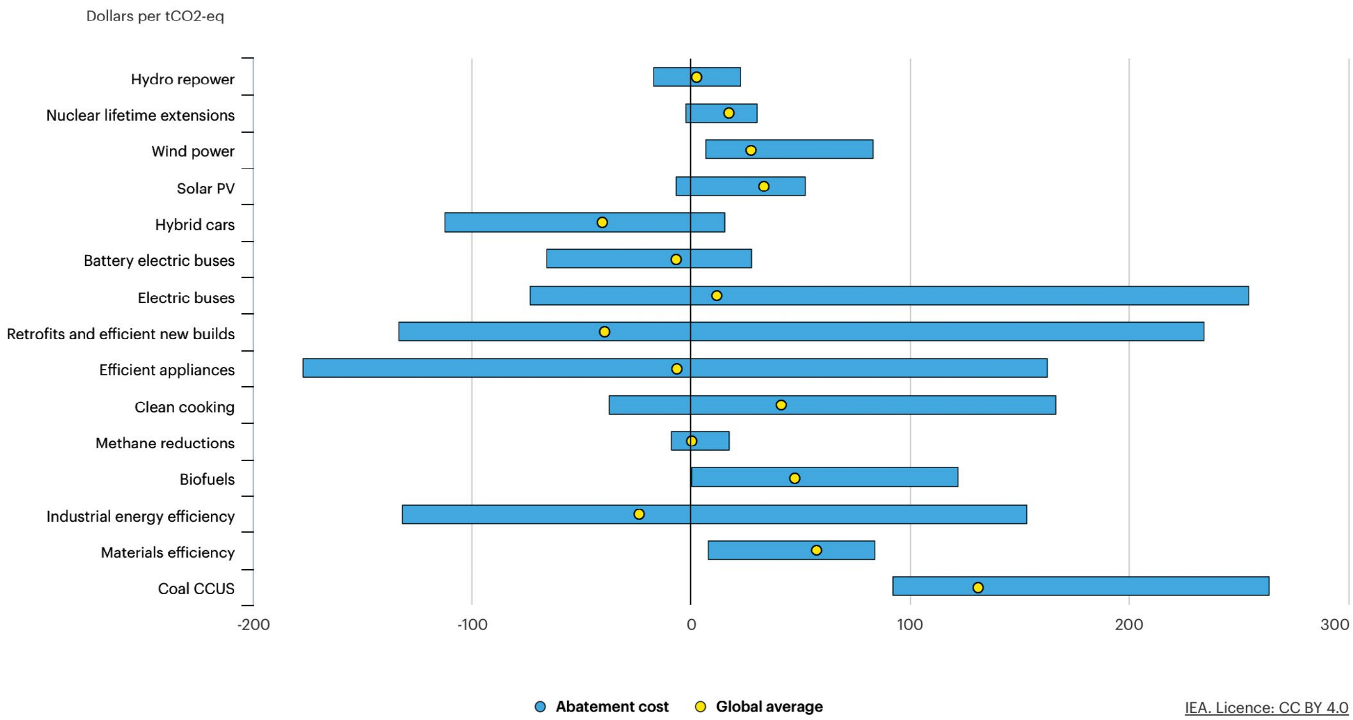
13 Ibid.

14 Elena Verdolini, et al., "Industrial Deep Decarbonization: Modeling Approaches and Data Challenges," Resources for the Future, August 16, 2023, https://www.rff.org/publications/reports/industrial-deep-decarbonization-modeling-approaches-and-data-challenges/.

15 "First electric cars. Next, electric factories?" *Economist,* February 15, 2024. https://www.economist.com/briefing/2024/02/15/first-electric-cars-next-electric-factories.

16 DW Documentary, "Power Failure in Germany: Horror Scenario or Genuine Possibility?" YouTube video, September 1, 2023, https://www.youtube.com/watch?v=52tzT09z81E.

Figure 1. GHG abatement costs for selected measures of the Sustainable Recovery Plan



Source: "GHG Abatement Costs for Selected Measures of the Sustainable Recovery Plan," International Energy Agency, last updated June 18, 2020, https://www.iea.org/data-and-statistics/charts/ghg-abatement-costs-for-selected-measures-of-the-sustainable-recovery-plan.

gas, with blue hydrogen increasingly making way for green hydrogen and renewable methane.[17] The rate at which green hydrogen can supplant blue depends partly on how fast all direct electricity demand can be met by renewable sources (as each marginal kilowatt will do more good on the grid), and the rate of the subsequent build-out of renewables. Any substantial increase in green hydrogen production prior to achieving full renewable coverage for direct electricity leads to an indirect rise in fossil-fired generation. Of course, the calculus would shift if policymakers were to limit the use of blue hydrogen by law.

Low-Hanging Fruit: Abatement Costs by Decarbonization Measure

In a fully decarbonized net-zero economy, there will still be an important role for natural gas, even if the demand will be smaller than today's. Overall, the IEA's Net-Zero Scenario (NZE) sees gas demand peaking before 2030, and by 2050 falling to 55 percent below current levels.[18] While the IEA insists, as it does with oil, that a net-zero trajectory should not require new gas-field development, that concept is often misunderstood to mean that new development should be curtailed. The point is that, under such a scenario, alternatives are scaled and in place (currently, they are not).[19]

In the crucial transitional period, sequencing matters. While some in civil society might simply advocate for doing all things immediately no matter the cost, or cutting off supply of entire fuel categories, those approaches would have demonstrably negative impacts on poorer, marginalized, and less-developed communities. In the real world of limited resources and trade-offs between communities, the impulse should be to focus first on the lowest-hanging fruit while

17 "Gas for Climate: The Optimal Role for Gas in a Net-Zero Energy System," Navigant, March 2019, iv, https://www.europeanbiogas.eu/wp-content/uploads/2019/11/GfC-study-The-optimal-role-for-gas-in-a-net-zero-emissions-energy-system.pdf.

18 "Net Zero Emissions by 2050 Scenario (NZE)," International Energy Agency, last visited February 13, 2024, https://www.iea.org/reports/global-energy-and-climate-model/net-zero-emissions-by-2050-scenario-nze.

19 In its 2022 update, the IEA clarified that decarbonizing the energy system begins with changes in demand, which lead to significant reductions in fossil-fuel use by 2030 in the Net-Zero Scenario. This "demand-led" shift is not about reducing supply preemptively. "An Updated Roadmap to Net Zero Emissions by 2050," International Energy Agency, last visited February 13, 2024, https://www.iea.org/reports/world-energy-outlook-2022/an-updated-roadmap-to-net-zero-emissions-by-2050.

asking tough questions about how to equitably expand the available resources (so that those who have the means should pay and assume the financing risk).[20]

Abatement costs can provide a simple, if rather crude, metric to identify these low-hanging fruit.[21] In many cases, applying CCS to existing facilities (such as power generation or industrial plants) presents the cheapest (or only) abatement option on the basis of a dollar per metric ton of CO_2, while alternatives are much more expensive—especially where flexible gas power plants are performing valuable functions like managing seasonal variations in renewable generation.[22]

In the wider scheme, focusing on electrified public transport, building retrofits, and improving industrial energy efficiency have a much greater impact on the marginal emissions reduction per dollar than efforts to eliminate all natural gas. That is particularly pertinent in places where resources and financing are constrained.

20 This is generally true, with myriad caveats about sequencing; there are cases in which abatement potential and cost of abatement capital also play a role beyond the marginal cost of abatement. For further analysis, see: Adrien Vogt-Schilb, Guy Meunier, and Stephane Hallegatte, "When Starting with the Most Expensive Option Makes Sense: Optimal Timing, Cost and Sectoral Allocation of Abatement Investment," *Journal of Environmental Economics and Management* 88 (2018), 210–233, https://www.sciencedirect.com/science/article/pii/S0095069617308392.

21 Stephane Hallegatte, "What You Need to Know about Abatement Costs and Decarbonization," World Bank, April 20, 2023, https://www.worldbank.org/en/news/feature/2023/04/20/what-you-need-to-know-about-abatement-costs-and-decarbonisation. "It is essential to understand that this approach is fundamentally 'marginal'. It was designed to reduce marginal emissions…But the climate objective is to reduce emissions to almost zero in order to achieve carbon neutrality. In this case, this approach no longer meets the requirements and the abatement cost can lead us to select very inefficient options, especially marginal improvements that prevent us from radically changing our modes of production." Assessing the levelized cost of carbon abatement is a slightly better alternative. For further analysis, see: Julio Friedman, et al., "Levelized Cost of Carbon Abatement: An Improved Cost-Assessment Methodology for a Net-Zero Emissions World," Center on Global Energy Policy, October 19, 2020, https://www.energypolicy.columbia.edu/publications/levelized-cost-carbon-abatement-improved-cost-assessment-methodology-net-zero-emissions-world/.

22 Adam Baylin-Stern and Niels Berghout, "Is Carbon Capture too Expensive?" International Energy Agency, February 17, 2021, https://www.iea.org/commentaries/is-carbon-capture-too-expensive.

3. Market and Regional Variations—One Size Won't Fit All

Due to varying geographies, power market models, and development trajectories, it is necessary to approach decarbonization pathways in a tailored manner. That is especially the case when it comes to natural gas, which presents very different cost implications and trade-offs depending on where and for which applications it is being used.

Emerging and developing countries represent a very diverse group. They typically consume low amounts of energy per capita (sometimes as low as 3 percent of that of North Americans), but economic growth and rising incomes hold significant potential for future growth. As a result, absent strong action to transform their energy systems, these countries will account for the bulk of emissions growth in the coming decades. The challenge is to embark on a more sustainable growth trajectory, with development models that adequately address the aspirations of their citizens while avoiding the emissions-intensive activities of historical economic growth. The falling cost of key clean energy technologies offers a tremendous opportunity to chart a new, lower-emissions pathway for growth and prosperity.[23]

Rapid advancements in renewable energy, efficiency, and widespread electrification play a pivotal role in climate-driven scenarios. However, these measures alone cannot ensure achieving the necessary emissions reductions. Complementary transitions in fuels and emissions-intensive sectors are crucial, but also particularly difficult in emerging and developing economies undergoing rapid industrialization and urbanization. Plus, some of those sectors are referred to as "hard to abate" precisely because options for emissions reduction are less mature and still expensive.[24]

Gas-Producing Developing Countries

Emerging and developing countries include some of the largest hydrocarbon producers. Gas producers in developing countries are typically low greenhouse-gas emitters, have comparatively low levels of electricity access, use significant proportions of gasoline and heavy fuel oil for off-grid electricity generation, and have relatively low access to clean fuels and technologies for cooking. They also rely on the revenue from fossil fuels—without it, at least a dozen poor countries would face unmanageable debt burdens.[25] The comparatively modest levels of emissions from some low-income and lower middle-income economies (with high reserve-to-production ratios and pressing developmental needs, such as poverty eradication or closing the energy access gap) can justify policy approaches that allow for continued gas development alongside sustainable measures for curbing carbon emissions.[26]

In some gas-rich countries, such as Iraq and Libya, wars have devastated national infrastructures, creating an urgent need for baseload power and grid improvements, especially to meet their summer peak demand. In the case of Iraq, the rate of electrification is relatively high, but is powered mostly by off-grid fossil fuels. The country has one of the highest per-capita usage levels of diesel generators. Repairing existing infrastructure to deliver natural gas over oil-fired generators would expand access and raise service quality, while significantly lowering emissions and benefiting a key domestic industry and employer.

However, in developing countries, gas producers and investors in those sectors must also recognize the risks. Depending both on gas economics dictated by the speed of the global transition and on policies that could impact access to markets and finance, long-term gas projects risk becoming stranded assets. Where gas exports represent a particularly high share of export and government revenues, the potential for demand and revenue shocks expose the country to vulnerabilities at the hands of global markets. Indeed, demand shocks represent the exporter's corollary to the volatility exposure felt by importers after the recent invasion of Ukraine. Finally, countries that depend on gas production could face emissions-related challenges, like missing their own targets or pledged nationally determined

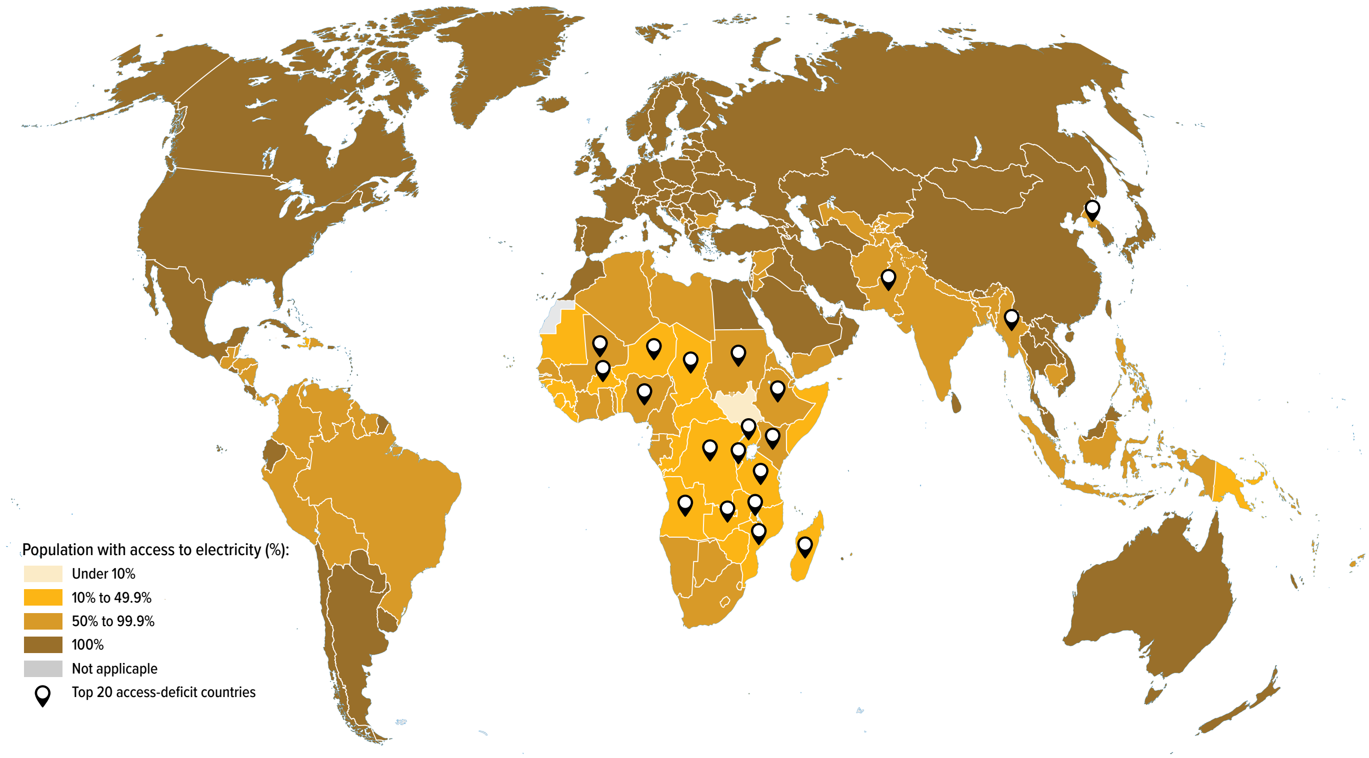
23 "Financing Clean Energy Transitions in Emerging and Developing Economies," International Energy Agency, June 2021, https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies.

24 Ibid.

25 "The Choice between a Poorer Today and a Hotter Tomorrow," *Economist*, June 27, 2023, https://www.economist.com/finance-and-economics/2023/06/27/the-choice-between-a-poorer-today-and-a-hotter-tomorrow.

26 "Natural Gas Development in Low-Carbon Energy Transition," Commonwealth Secretariat, 2023, https://production-new-commonwealth-files.s3.eu-west-2.amazonaws.com/s3fs-public/2023-05/D19233-CW-Natural-Gas-Development-in-Low-Carbon-Energy-Transition.pdf.

Figure 2. Share of Population with Access to Electricity in 2021



Source: "Tracking SDG7: The Energy Progress Report 2023," World Bank, 2023, 13, https://cdn.who.int/media/docs/default-source/air-pollution-documents/air-quality-and-health/sdg7-report2023-full-report_web.pdf.

contributions (NDCs). That reinforces the need to couple any gas production with a mitigation strategy that might include using domestic gas to replace high-polluting coal or heavy fuel oil, increasing energy efficiency, and improving energy access.

Energy-Importing Developing Countries

Among developing country consumers and importers, the value of using natural gas (and thus its relative alternative abatement cost) depends on factors like the power market model and the role of industrialization in the country's specific development phase.

In countries with low levels of energy access outside of major cities and far from grid connections, distributed and off-grid renewable energy (DRE) can provide a cost-effective solution to accelerate clean energy access. Over the last ten years, 20 percent of all new electric connections in sub-Saharan Africa have been through DRE systems, and that is expected to rise to 50 percent over the next decade.[27]

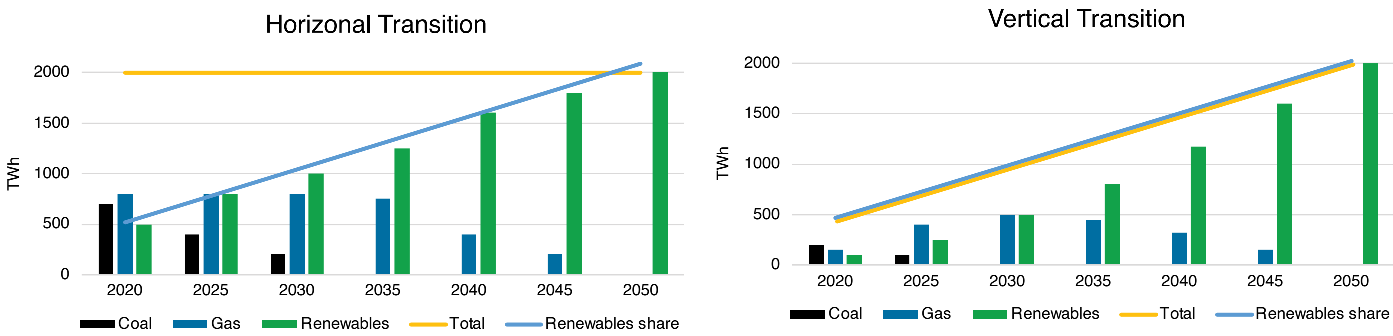
However in most cases, energy poverty will still be alleviated by expanding grid access, especially in the contexts of population growth and rapid urbanization. Due to the extraordinary decline in renewable costs, and with rising demand in places like sub-Saharan Africa, renewables (at grid scale) are often cheaper in these cases as well. While accompanying grid flexibility is needed to enable such renewable growth, so is generation capacity itself. In advanced economies, the question might be whether and how to run gas peakers. But in many African countries, where there is often a lack of access to reliable energy, building a gas plant that will run only 20 percent of the time would be difficult to justify.[28]

In a 2021 paper by the CDC Group, the authors explain why decarbonization in many African countries is different

27 "Off-Grid Solar Market Trends Report 2022: Outlook," World Bank, 2020, https://www.lightingglobal.org/resource/off-grid-solar-market-trends-report-2022-outlook-part-2/.

28 As a result, most gas-plant additions in Africa are combined-cycle gas turbines, that cost more to build and cannot be ramped up so quickly, but use fuel more efficiently and run at higher capacity.

Figure 3. Stylized depiction of a horizontal (left) versus a vertical (right) grid energy transition



Source: Kitetu, et al., "Decarbonizing Africa's Grid Electricity Generation," 4.

from the energy transition in other emerging markets, citing the very low base from which many of them start and the need to rapidly expand generation capacity to meet urgent development objectives. Advanced economies, by contrast, face relatively flat demand and already have sophisticated power systems. Over time, these countries can decommission fossil generation while adding VREs. Many African countries do not have this opportunity—rather, they need to multiply their output several times in just a couple of decades.[29]

Among the models for system transition in Africa that aim for net zero by 2050 while rapidly expanding generation capacity for economic development, all include a combination of power-generation technologies—including cleaner fossil fuels. Under one model that takes a stringent approach to controlling emissions, between 2030 and 2050 Africa would need to add 24 GW of solar, 20 GW of wind, and 18 GW of gas.[30] Other models come to similar conclusions.[31] All scenarios require rapid and sustained investment in wind, solar, batteries, national and international transmission infrastructure, and network-management technologies. But some investments in firm and dispatchable capacity (on which rich countries all currently rely) will also be key. Countries lacking large hydropower or geothermal resources that could otherwise provide that capacity will require some investments in natural gas-fired generation.[32] As the president of the African Development Bank (AfDB) wrote in a recent IEA report, "As we accelerate the development of our massive renewable energy sources, Africa must also be given time to transition and allowed to use its natural gas as a transition fuel."[33]

In the context of rapidly rising electricity demand (known as a vertical transition), additional gas resources will be needed to enable large-scale renewable energy outlays before being phased out in the future. However, in economies where overall demand stays flat (a horizontal transition, as in most OECD countries), gas phaseout should begin now.[34]

High rates of population growth, urbanization, and development all contribute to very high rates of energy demand growth in sub-Saharan Africa. Consumption patterns will also vary within Africa according to geography, and depending on the local types of economic activity, governance capacity, and development trajectory. As countries develop, electricity demand will rise fastest on the grid where productive activity and incomes are relatively higher, and also based on the probability of electricity uptake by small and medium enterprises (SMEs) in the region. Meeting that demand will require 30 GW of natural gas power generation capacity additions by 2030 under the IEA's Sustainable Africa Scenario, alongside major renewable energy expansion.

It is worth noting that in developing countries like India—where the government has avoided rapidly expanding natural gas to displace coal, and instead focuses on

29 Martin Kitetu, et al., "Decarbonizing Africa's Grid Electricity Generation," CDC Group, May 2021, https://assets.cdcgroup.com/wp-content/uploads/2021/05/25111607/Decarbonising-Africas-grid-electricity.pdf.

30 Bob van der Zwaan, et al., "An Integrated Assessment of Pathways for Low-Carbon Development in Africa," *Energy Policy* 117 (2018), 387–395, https://www.sciencedirect.com/science/article/pii/S0301421518301484.

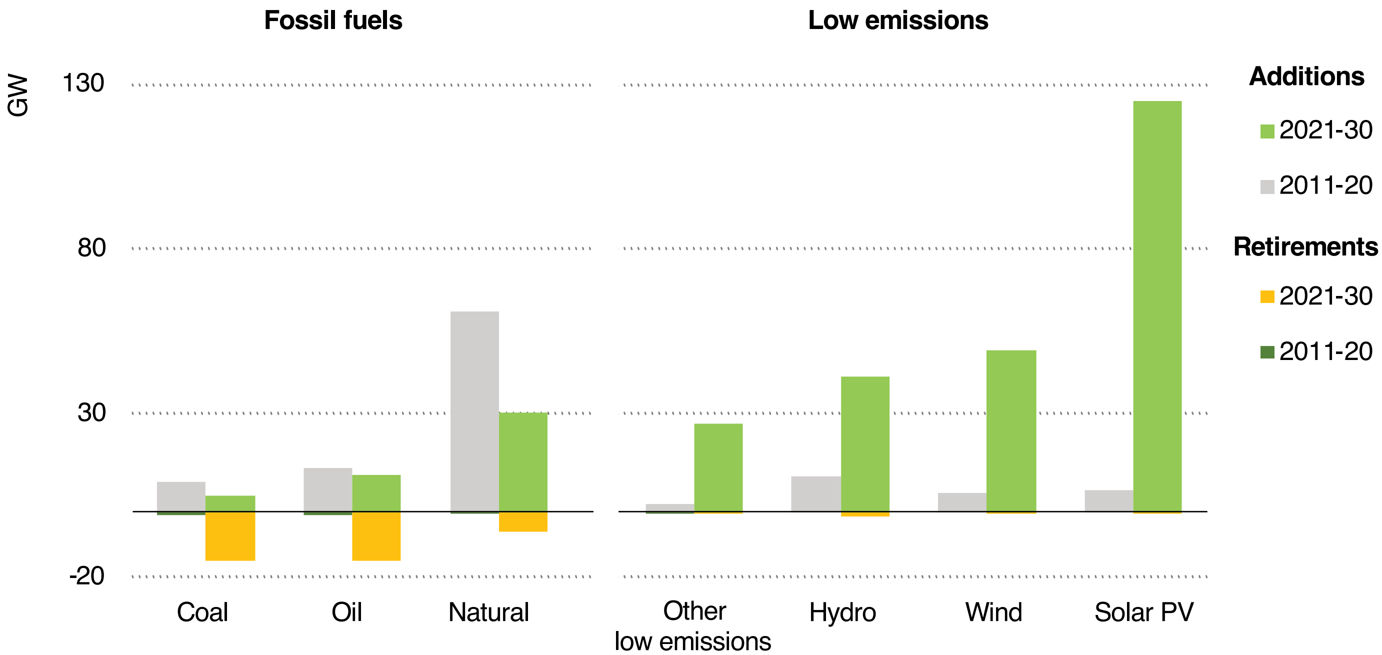
31 Gregor Schwerhoff and Mouhamadou Sy, "Developing Africa's Energy Mix," *Climate Policy* 19, 1, (2019), 108–124, https://ideas.repec.org/a/taf/tcpoxx/v19y2019i1p108-124.html.

32 van der Zwaan, et al., "An Integrated Assessment of Pathways for Low-Carbon Development in Africa."

33 "Financing Clean Energy in Africa," International Energy Agency, September 2023, https://iea.blob.core.windows.net/assets/5afce034-9bd7-451a-ac36-1b35c63aaf5e/FinancingCleanEnergyinAfrica.pdf.

34 Kitetu, et al., "Decarbonizing Africa's Grid Electricity Generation."

Figure 4. Power generation capacity additions and retirements by source in the IEA Sustainable Africa Scenario



Source: "African Energy Outlook 2022," International Energy Agency, 2022, 92, Figure 2.21, https://iea.blob.core.windows.net/assets/220b2862-33a6-47bd-81e9-00e586f4d384/AfricaEnergyOutlook2022.pdf.

renewable energy outlays to meet growing demand and address energy access—addressing shortfalls and security means reverting to the worst possible option. As the country heads into elections during April and May, Prime Minister Narendra Modi is keen to avoid any risks of power shortages, and so the government has pledged to add 88 GW of thermal plants by 2032 while doubling coal output by 2030.[35]

35 Askshat Rathi, "India's Plans to Double Coal Production Ignore Climate Threat," Bloomberg, January 9, 2024, https://www.bnnbloomberg.ca/india-s-plans-to-double-coal-production-ignore-climate-threat-1.2019558.

4. Financing Sustainable and Equitable Development in Line with Energy Transitions

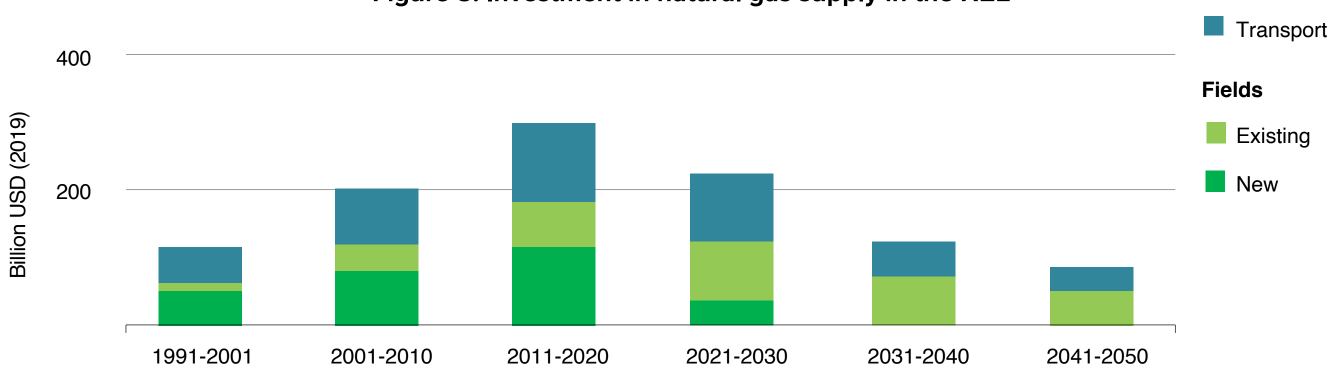
The financing needed to provide enough natural gas to meet demand while reducing emissions is enormous. Even under the IEA's NZE, which optimistically foresees no necessary investments in new oil and gas fields, more than $120 billion per year is still needed for upstream gas investment through 2030. An additional $100 billion is needed each year for the transport networks.

Broadly, natural gas projects in more mature markets are financed partly from gas companies' own balance sheets (particularly when they are flush, as they are today), and partly from equity or debt financing. In the United States, intense competition among developers along with escalating costs are complicating efforts to bring new LNG online, despite a huge appetite for US fuel exports.[36] Dramatic cost increases for large energy infrastructure projects and higher interest rates mean that financing needs are even greater, while struggles to secure the necessary commitment from offtakers force financiers to weigh long-term demand as the world commits to rapid decarbonization.

Hesitancy by off-takers is not because the gas isn't in high demand; rather, it is due to anxious European buyers who elect to secure near-term LNG supplies rather than lock in the multi-decade contracts that developers need in order to secure financing for their projects.[37] At the same time, the cash windfall to private oil and gas majors (IOCs) in 2022 has scarcely been reinvested in production, because of efforts to maintain profitability and capital discipline after years of poor returns for equity investors. Consequently, higher profits have been allocated to debt reduction, dividend payments, and repurchasing stocks. These choices highlight a firm commitment to capital discipline, and also reflect a degree of pessimism among some shareholders regarding the long-term value of oil and gas assets.[38]

State-owned energy companies (NOCs) in the Middle East and other emerging economies have been reinvesting more heavily in production, accounting for well over half of total investments in 2022. In richer parts of Asia and Europe, some public financing support for domestic gas projects might come from national or regional governments, or from home-based development banks.

Figure 5. Investment in natural gas supply in the NZE



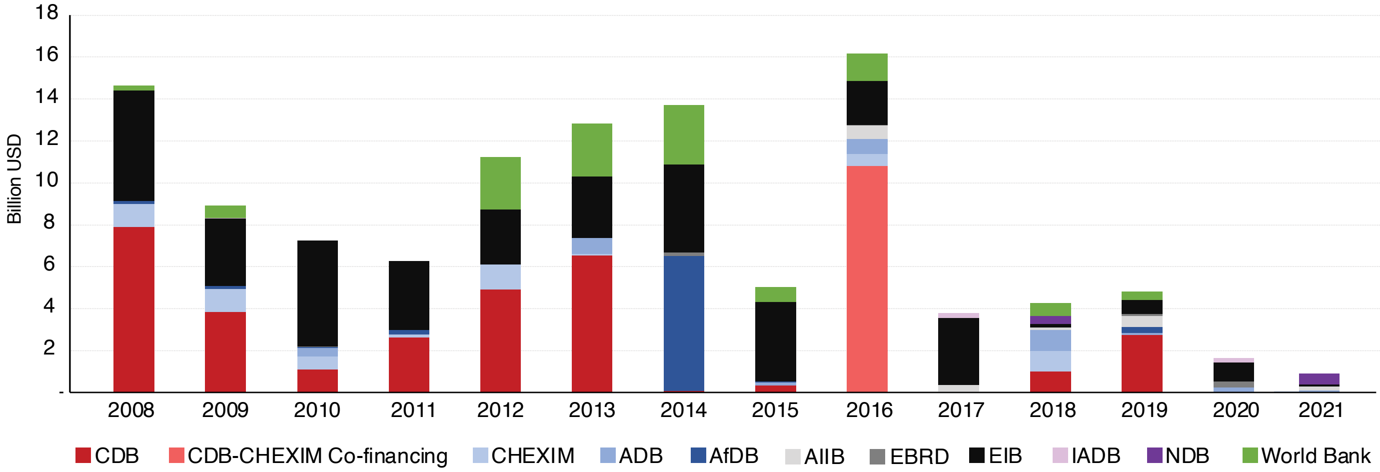
Source: "Net Zero by 2050," International Energy Agency, May 2021, 103, Figure 3.4, https://www.iea.org/reports/net-zero-by-2050.

36 Miles McCormick, "Rising Costs and Competition Threaten US Boom in LNG Projects," *Financial Times*, April 17, 2023, https://www.ft.com/content/e7f3681f-3f0a-40de-ab65-65f62c7d6acb.

37 Ibid.

38 Gautam Jain and Luisa Palacio, "Investing in Oil and Gas Transition Assets en Route to Net Zero," Center on Global Energy Policy, March 2023, https://www.energypolicy.columbia.edu/publications/investing-in-oil-and-gas-transition-assets-en-route-to-net-zero-2/.

Figure 6. Selected MDBs commitments to the gas sector, 2008-2021



Source: Cecilia Springer, "Who Funds Overseas Gas Projects? Comparing Development Finance from China and Major Multilateral Development Banks," Boston University Global Development Policy Center, June 2022, 8, Figure 1, https://www.bu.edu/gdp/files/2022/06/GEGI_PB_020_EN.pdf. Data is from the 2022 edition of the China's Global Energy Finance Database.

Gas projects in developing countries, such as those in Africa, are typically financed through a combination of sources, including private investment, international oil and gas companies, export credit agencies, and development banks. The role of multilateral or national development banks is significant in providing financial support and promoting sustainable development in these projects. Export credit agencies (ECAs) from the home countries of investors or buyers may provide financing or insurance to support the export of gas or related products. All this helps to de-risk projects and make them attractive to private finance, which is still difficult to attract for independent and local players across regions including Africa. Compared to the oil and gas majors, which were squarely driving activity on the continent in 2023 thanks to their balance sheets, smaller or project-specific companies must demonstrate excellent cost, management, and ESG credentials (inclusive of efforts to reduce emissions) in order to attract any lending as international banks continue their retreat.

Finance Restrictions from North onto South

Policies of public financing institutions send clear signals to private markets, and so the policy-based financing constraints that risk curtailing even net-zero compliant gas investments get compounded.[39] European ECAs are broadly strict on the issue, but some make exceptions for gas-fired power generation "which improves a country's energy mix," "has documented and realistic transition plans," "intends to follow best practice," "includes CCS," "is viable at a shadow carbon price," "replaces production with higher emissions," and broadly which meets the EU's Taxonomy (hence the importance of the European Commission's 2022 decision).[40] Some ECA decisions are contingent on the presence of specific national regulations, such as a net-zero target to 2050, and risk becoming inflexible box-checking exercises that exclude entire countries while failing to account for a project's emissions contribution. Projects that meet some combination of these requirements might receive support, but in cases such as in the UK, the result is still an effective freeze on natural gas financing overseas.[41]

The largest multilateral development banks are even stricter, coming very close to outright bans while still providing avenues in theory. In November 2019, the European Investment Bank (EIB) announced its intention to stop financing fossil fuel projects, including natural gas, by the end of 2021. The World Bank ended upstream gas financing after 2019 and has been under extreme pressure to

39 Among global private-sector investors, major global banks have committed to aligning their lending and investment portfolios to meet net-zero emissions by 2050. A significant number have also committed to meeting intermediate targets as part of the Glasgow Financial Alliance for Net Zero (GFANZ), which aims to reduce their financed emissions in the oil and gas sector by 2030. Such targets imply increased scrutiny of fossil-fuel activities, but an Economist Impact study found that among the largest banks around the world, only a few were actively phasing out high-emitting projects. Even so, very little went to projects in developing countries, as the same banks and major asset managers reassess their risk profiles and follow policy signals.

40 BPI France; Swedish EKN; UK Export Finance (UKEF); Spanish CESCE; Swiss SERV; Finnvera Finland.

41 Sarah George, "UK Export Finance Marks First Fossil-Fuel-Free Allocation Year, Sets New Emissions Targets," edie, July 1, 2022, https://www.edie.net/uk-export-finance-marks-first-fossil-fuel-free-allocation-year-sets-new-emissions-targets/.

end all financing of fossil fuels—but is apparently reconsidering gas projects that meet strict criteria, including some in Mozambique, where 30.6 percent of people had access to electricity in 2020.

In practice, financing from these institutions has stopped—and even ones backed by China have essentially eliminated their commitments.

Yet there are some exceptions among development finance institutions. For instance, certain regional development banks, such as the Africa Finance Corporation and Afreximbank, are more lenient than their larger counterparts and continue to support financing of gas projects, including upstream field developments. Such regional banks, including the AfDB, seem more willing to take into account Africa's infrastructure deficit and challenging operating environment.

In some cases, restrictive development financing policies might represent a lack of understanding about country-specific realities. Some institutions, like the World Bank, contend that their aim is to maximize regional financing for energy transition and enhance the role of local and regional banks. On the other hand, it is also the result of an epic fight for resources within such institutions between those who believe development banks should focus on alleviating poverty and those who want to retool the institutions as wholehearted instruments of climate change mitigation.[42]

As the IEA states, "Natural gas occupies a difficult space in EMDE clean energy transitions. It is seen in many cases by these countries as an ally in the push for national development and lower-emissions growth, but projects will need to demonstrate a strong alignment with transition objectives; financing criteria for gas projects are tightening. Around 90% of project debt for large-scale natural gas infrastructure projects in EMDEs over the last decade has been raised internationally, and 70% of the total came from entities domiciled in countries that now have net zero targets."[43]

That is true, insofar as wealthy countries and institutions that are actively cutting off such financing are responsible for hindering lower-emissions development plans designed by countries themselves. Higher prices for electricity would dampen economic development, restrict access to essential services that require power (such as healthcare), and lower the standard of living across the continent more generally. Meanwhile energy-intensive industries, which are especially good at raising living standards, would be effectively shut out of national economic futures. That kind of shifting of risk, cost, and lost opportunity from rich countries onto poor ones appears callous, especially among those who consume 3–6 percent of the energy per capita that North Americans or rich Europeans do.

At the 2022 climate conference in Sharm-el-Sheikh, the recurring message during that "African COP" was that outsiders do not generally appreciate the needs and views of developing countries, whether they are idealistic young climate campaigners or Western governments with myriad colonial pasts. The main achievement at COP27 for addressing equity was a new "loss-and-damage" fund; while not large, it was a welcome gesture. More importantly, it was an overdue acknowledgment that Africans should have a voice in which energy they make and use, particularly if the technology burns cleaner than almost all power plants in OECD countries.

Within the environmental activist community, the energy transition has posed trade-offs that can pit internal constituents against each other—the need for massive construction projects that enrage NIMBYs, the pressing need for rapid expansion of mining with all its social and environmental risks, and the practical (if occasional) conflict between the equitable empowerment of underprivileged communities and an insistence on emissions reductions that might further repress them.[44] Taking a practical approach to comparing the value of abating a ton of CO_2 with otherwise noble goals must necessarily be more inclusive of those directly involved.

42 "How Misfiring Environmentalism Risks Harming the World's Poor."

43 "Financing Clean Energy Transitions in Emerging and Developing Economies."

44 NIMBYs are those with a "not-in-my-backyard" attitude. "The Case for an Environmentalism that Builds," *Economist*, April 5, 2023, https://www.economist.com/leaders/2023/04/05/the-case-for-an-environmentalism-that-builds.

5. Conclusions

The pace of the energy transition is not solely determined by policy and cost. Factors such as infrastructure, public perception, and availability of financing also play a role. In order to maintain affordability and energy security while also decarbonizing, renewable alternatives need to be ramped up quickly before gas supply is curtailed. Outside of the power sector, the alternatives can be too early stage, or require so much renewable generation that could otherwise be cleaning up the grid.

The situation calls for maintaining a channel for public investment and de-risking support for gas projects, including those upstream and especially in developing countries. Conditions must ensure that those projects are as clean as possible, while recognizing market and regional variances.

Phasing out cleaner and more value-producing natural gas too early can lead to dramatic price volatility, causing similar energy security and affordability crises to those felt in the wake of the invasion of Ukraine. Price instability can be an additional incentive to decouple the energy system from uncertain fuel markets, adopt renewable alternatives, and ultimately advance the energy transition—but, in the near term, volatility can reverse progress. Plus, the green transition became an easy target for misinformed voters looking for the cause of inflation and the energy crisis, when it was mostly unrelated. Where decarbonization policies really do cause volatility and deprivations, the public's sensitivity to those trade-offs will become very clear.

Natural gas has a limited, but important, role in maintaining both grid and price stability during the crucial transition phase to net zero; it even has a place in fully decarbonized economies. In poorer countries, the contribution of efficient natural gas use to development and industrialization has particular value. If limits on multinational financing are too strict, the impact on equitable access to prosperity will be immediate, and might be detrimental to the energy transition itself down the line.

About the Author

Phillip Cornell is a nonresident senior fellow at the Atlantic Council's Global Energy Center. He is a specialist on energy and foreign policy, global energy markets and regulatory issues, critical energy infrastructure protection, energy security strategy and policy, Saudi Arabian oil policy, Gulf energy economics, and sustainable energy transition policy.

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Prior to joining the Atlantic Council, Cornell was a senior corporate planning advisor to the chairman and chief executive officer of Saudi Aramco, where he provided market analysis and business development support to the executive management during the implementation of Saudi oil price strategy. In that capacity, he also provided advice to the Royal Court in the context of Saudi economic transition and foreign policy.

From 2011–2014, he was special adviser to the executive director of the International Energy Agency in Paris, responsible for strategic messaging and policy advice to the Executive Office of the IEA. Previously, he developed IEA simulations and wargaming among ministries in preparation for major oil and gas emergencies.

Before joining the IEA, Cornell served with NATO as the senior fellow and director of international programs at the NATO School (NSO) in Oberammergau, Germany, where his policy research focused on NATO and energy security. During that period, he also served on the secretary general's committee in Brussels to develop NATO policy in the area of energy infrastructure security.

Cornell has held research positions at the Naval Postgraduate School (Monterey), the Royal United Services Institute (London), and the Center for International Security and Cooperation (Stanford), and he is the author of a number of articles and volumes on energy security and security policy. He holds master's degrees with distinction in international economics (energy focus) and European studies (security focus) from the Johns Hopkins School of Advanced International Studies. He received his BA cum laude in international relations from Stanford University.

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