NOVEMBER 2023
IB: 23-11-C

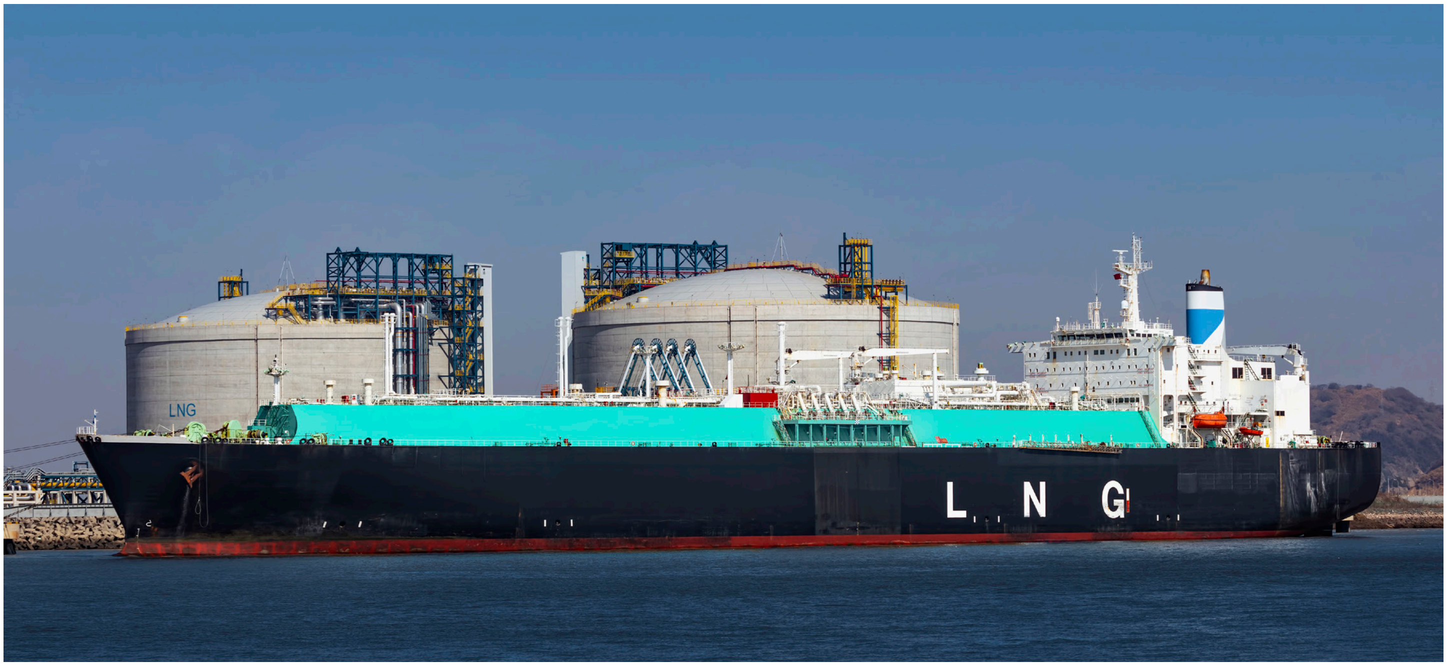
ISSUE BRIEF

# POWER SHIFT:
## RENEWABLES BEAT LNG for Climate and Competitiveness

Current climate actions and commitments are clearly not enough to keep global warming below 1.5 degrees Celsius and avoid accelerating climate impacts.[1] The latest Intergovernmental Panel on Climate Change (IPCC) report concludes, with very high confidence, that the window of opportunity to secure a livable and sustainable future for all is rapidly closing.[2]

All countries must urgently ramp up their efforts to reduce emissions. The upcoming United Nations (UN) climate summit in Dubai (COP28) offers an important opportunity to realign pledges with what climate science demands and accelerate global climate action. Under the ongoing *Global Stocktake (GST)* process of the UN climate talks; countries are required to assess the global response to the climate crisis every 5 years. The first ever GST is scheduled to conclude at COP28 in Dubai. It will assess the world's progress on slashing greenhouse gas (GHG) emissions, building resilience to climate impacts, and securing finance to address climate change. And importantly it will set the tone of ambition for countries' next round of national climate targets due in 2025.



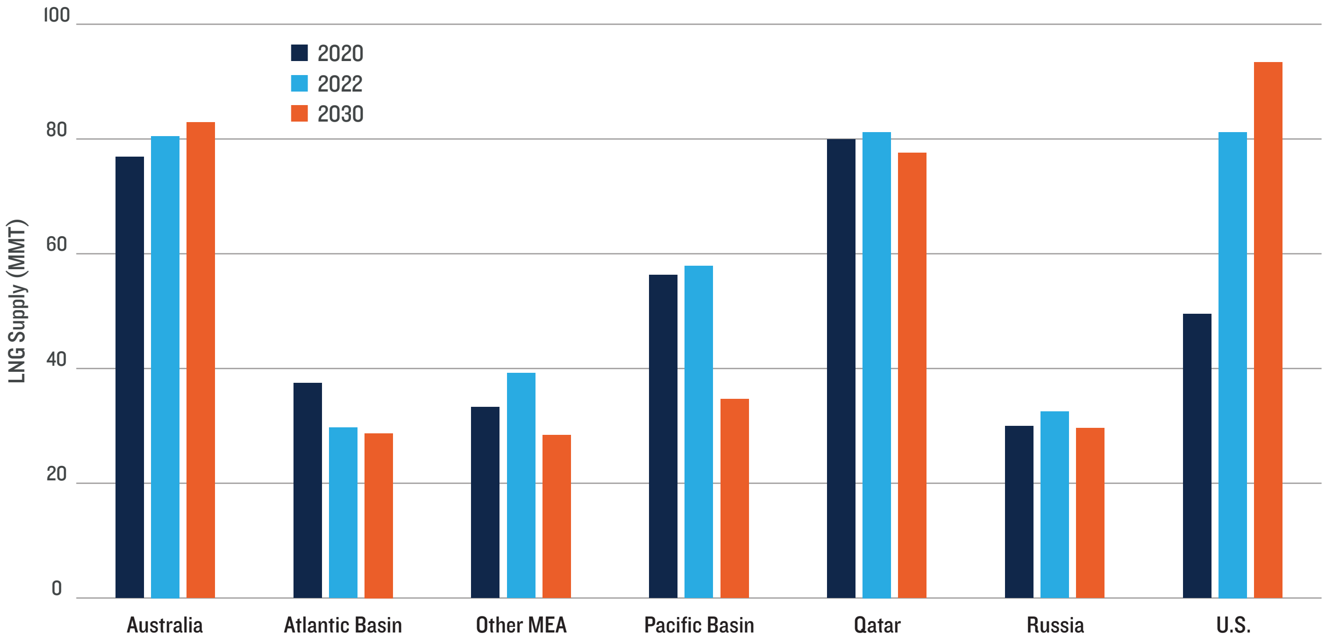



A large LNG tanker ship unloading its cargo at an LNG terminal.

For more information, please contact:
Ade Samuel, asamuel@nrdc.org
Shruti Shukla, sshukla@nrdc.org

www.nrdc.org
www.facebook.com/nrdc.org
www.twitter.com/NRDC

**FIGURE 1: LNG SUPPLY FORECAST BY REGION**




*Source:* BNEF "Qatar, US Race to Sign LNG Deals Before Supply Glut" (supplemental data) https://www.bnef.com/insights/32359 (subscription needed).

Within this context, a handful of countries—notably the United States and Qatar—continue to expand global liquefied natural gas (LNG) supply and trade (see Figure 1). LNG is a planet-warming fossil fuel with a notably large carbon footprint attributed to its carbon-intensive production. This LNG push must be assessed against a simple Latin phrase: *Cui bono?* Who benefits? It is certainly not the climate, our planet, or our communities. Instead, LNG largely benefits the fossil gas industry, energy traders, and producer economies.

By 2030, total LNG liquefaction capacity is expected to grow by 250 billion cubic meters (bcm) over today's global capacity of around 650 bcm, with more than half of this expansion coming from the United States and Qatar.[3] Globally more than 80 percent of the growth in demand for LNG between 2021 and 2030 will come from the power and industry sectors.[4]

Despite this projected growth in the short term, the International Energy Agency's (IEA) most recent World Energy Outlook estimates that the overall transition away from fossil fuels (including LNG) will continue to gain pace, with demand for all fossil fuels (coal, oil, and fossil gas) peaking by 2030.[5] However, we cannot wait for the market to catch up; the push for LNG expansion now could lock countries into polluting infrastructure (or the costs of decommissioning these terminals) for decades to come. The climate crisis demands that we reassess the true costs of building new LNG dependencies across the world by, among other things, conducting place-based alternatives analysis, especially for the power sector.

Countries that are investing in LNG often do so because it seems like the cheaper alternative in the near term. But when we account for the externalities associated with LNG build-out, that's not accurate. This issue brief examines the cost of building and maintaining LNG infrastructure in light of new research into place-based clean energy alternatives for the power sector (which sees high forecasts for new LNG demand) to enable a decarbonized energy system worldwide. In the final analysis, clean energy is cost effective compared with LNG-based options, for countries looking to transition their energy sector in line with their climate commitments.

## LNG IS A CLIMATE POLLUTANT AND MUST BE CURBED NOW

LNG is a major climate pollutant. It is typically between 85 and 95 percent methane ($CH_4$), which is more than 80 times more potent a greenhouse gas than carbon dioxide ($CO_2$) across a 20-year period (See Box 1).[6] The LNG supply chain is leaky, which causes significant life-cycle emissions of climate pollutants from extraction to end use.[7] Recent research shows that global fossil gas systems leak more than 4.7 percent of their methane (over a 20-year timeframe).[8] There is also significant variability across gas-producing regions: Studies have reported leakage rates from 0.65 to 11 percent in numerous onshore oil and gas basins and up to 66 percent for offshore oil and gas basins in the United States alone.[9]

Some countries use LNG for power generation under the misguided notion that it is a transition fuel or a near-term solution. This is a risky assumption with significant long-term repercussions (see Tables 1 and 2).[10] These projects represent a stranded-asset risk of hundreds of billions of dollars, and they will also potentially lock in tens of billions of tonnes of GHG emissions. At the same time, the IEA recently updated its Net Zero Emissions scenarios, and the message is clear: Cutting methane emissions from the energy sector by 75 percent by 2030 is one of the most cost-effective ways to limit global warming in the near term.[11]

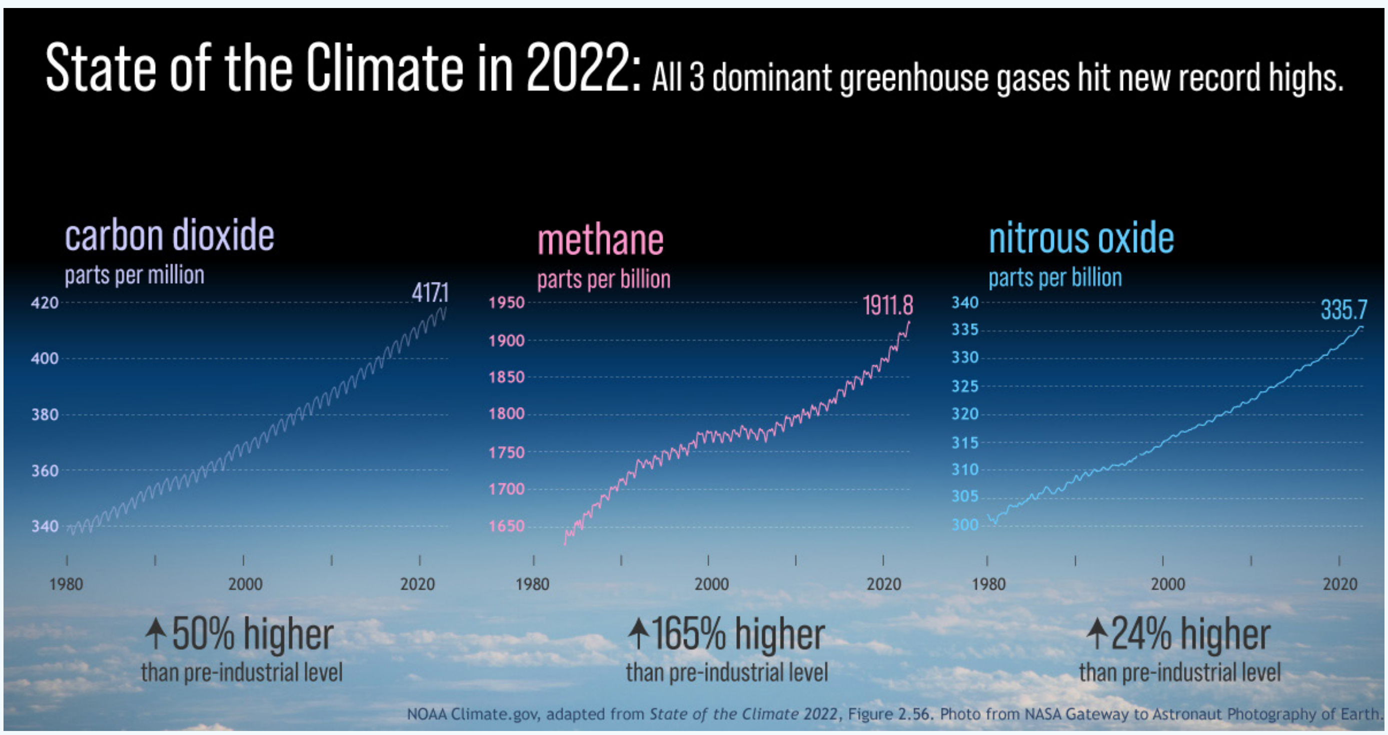
## BOX 1: GLOBAL RECOGNITION OF THE NEED TO REDUCE METHANE

Global average temperatures are reaching unprecedented levels. Increases in atmospheric greenhouse gas (GHG) loads, especially the long-lived GHGs like carbon dioxide, methane, and nitrous oxide, are largely responsible for increasing global temperatures. Methane emissions are especially rising at a record rate. According to the National Oceanic and Atmospheric Administration, in 2022 the atmospheric concentration of methane increased by 14 parts per billion following record growth in 2020 and 2021.[12]

A unique initiative led by the United States and the European Union called the Global Methane Pledge was launched at COP26 in November 2021 to catalyze action to reduce emissions.[13] By joining the Pledge, 150 countries have committed to collectively reducing methane emissions by at least 30 percent below 2020 levels by 2030. Sharp cuts in methane emissions such as those outlined by the pledge can significantly slow warming trends within a relatively short period. Almost 50 of these countries have developed Methane Action Plans.

Additionally, the Methane Alert and Response System (MARS) is a more recent initiative run by the U.N. Environment Programme to scale up global efforts to detect and act on major emissions sources in a transparent manner and accelerate implementation of the Global Methane Pledge.[14]

However, pursuing alternative actions under the pledge must be done in tandem with efforts to limit expansion of fossil gas and LNG supply. Reducing global GHG emissions to safe levels ultimately means curtailing, reducing, and phasing down the LNG supply here in the United States and elsewhere.



| TABLE 1: ESTIMATED CAPITAL COSTS FOR GAS-BASED POWER GENERATION PLANTS IN DEVELOPMENT (BY REGION)* | | | | |
|---|---|---|---|---|
| Region | Announced Capital Cost (USD billion) | Preconstruction Capital Cost (USD billion) | In-Construction Capital Cost (USD billion) | Total Regional Capital Cost (USD billion) |
| Africa | $24.8 | $19 | $10.2 | $54 |
| Americas | $43.2 | $41.9 | $27.7 | $112.8 |
| Asia | $145.2 | $132 | $107.3 | $384.5 |
| Europe | $9.9 | $37.4 | $11.1 | $58.3 |
| Oceania | $0.2 | $0.6 | $0.8 | $1.5 |
| **Total** | **$223.3** | **$230.8** | **$157** | **$611.1** |

*Gas/oil plant costs are estimated using the August 2023 Global Oil and Gas Plant Tracker database. The estimates for OECD member countries are based on Combined Cycle Gas Turbine (CCGT) capital costs ($1,000/kW) for the United States and Europe from IEA World Energy Model inputs. The estimates for non-OECD countries (except China) are based on CCGT capital costs that average India ($700/kW) and E.U. ($1,000/kW) CCGT capital costs from IEA World Energy Model inputs. China uses CCGT capital costs of $560/kW from IEA World Energy Model inputs. CCGT technology is assumed for gas plants with technology type that is not known. Open-cycle Gas Turbine (OCGT) capital costs are estimated to be 74.4 percent of CCGT costs, based on a comparison of costs for "Combustion Turbine H Class, 1100-MW Combined Cycle" to "Combustion Turbine F Class, 240-MW Simple Cycle," as detailed in the 2020 Energy Information Administration report.

*Source:* Gas Glut 2023, Global Energy Monitor

| TABLE 2: GAS-BASED POWER IN DEVELOPMENT—LIFETIME $CO_2$ EQUIVALENT EMISSIONS (MILLION TONNES) | | | | |
|---|---|---|---|---|
| Region | Announced | Preconstruction | Construction | Total in Development |
| Africa | 1,713 | 1,178 | 631 | 3,522 |
| Americas | 2,982 | 2,757 | 1,759 | 7,497 |
| Asia | 9,490 | 9,197 | 7,717 | 26,404 |
| Europe | 640 | 2,321 | 757 | 3,717 |
| Oceania | 12 | 37 | 51 | 100 |
| **TOTAL** | **14,836** | **15,488** | **10,915** | **41,239** |

*Source:* Gas Glut 2023, Global Energy Monitor

The following are some key reasons why LNG must be phased out rapidly:

1. **Emissions:** According to the IEA, the energy sector is responsible for nearly 40 percent of total global methane emissions.[15] In 2022, climate change–causing methane emissions from the global energy sector rose to nearly 135 million tonnes.[16] The bulk of these emissions occurs during the extraction, production, transportation, and end use of LNG. Main emission pathways include:

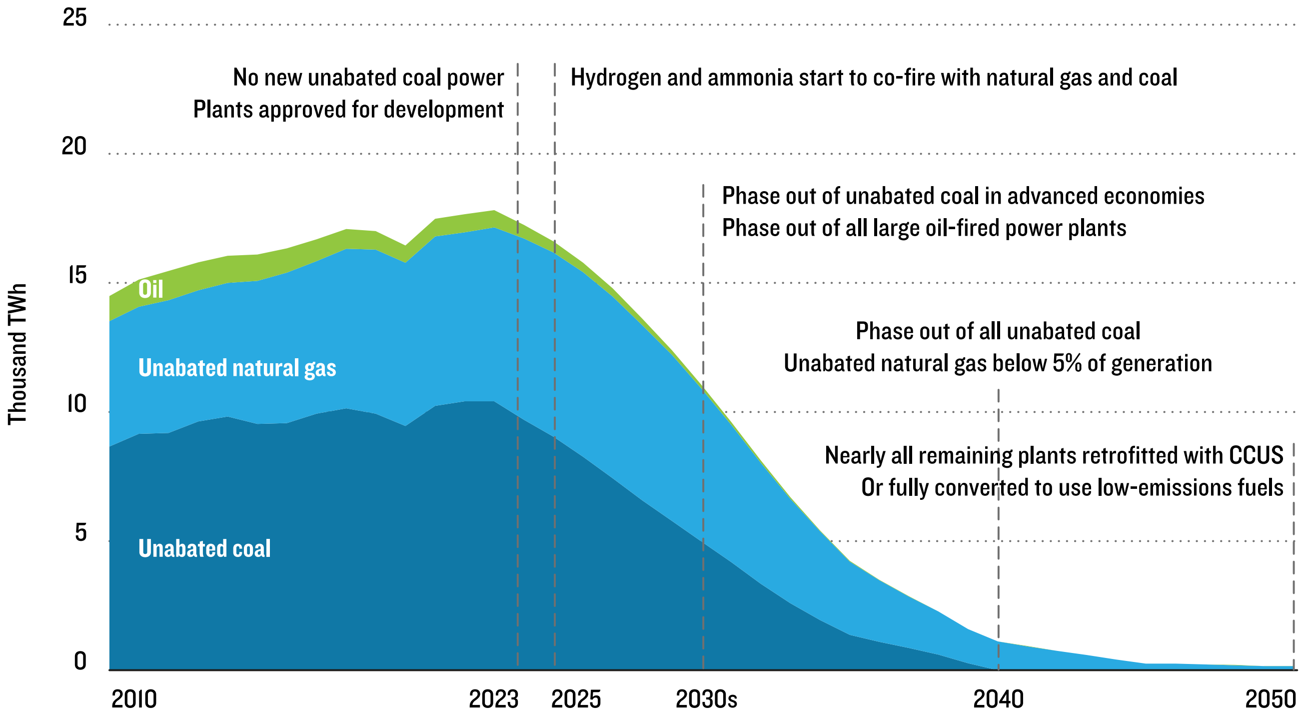
    a. **Direct and fugitive emissions:** Planned (venting or flaring) or accidental releases and leaks of methane can occur during the extraction, processing, and transportation stages of fossil gas and LNG.

    b. **Indirect emissions:** The overall emissions associated with LNG are not limited to production alone. Transportation, re-gasification, and combustion all require energy, which often comes from a fossil fuel–dependent grid. The emissions associated with these processes contribute to the overall carbon footprint of LNG.

2. **Dependency on fossil fuels:** The extensive costly infrastructure investments required for LNG, such as liquefaction plants and LNG tankers, lock countries into a long-term dependency on fossil fuels. This dependency hampers the transition to renewable energy sources and makes it more challenging to achieve steep emissions reductions, as discussed in the 2023 IEA Net Zero update (see Figure 2).[17] The 2023 Net Zero update reiterates the IEA's earlier finding that there is no room for new oil, gas, or coal beyond currently operating production sites if we are to limit global warming to 1.5 °C .[18] The three leading LNG exporters (Australia, Qatar, and the United States) have plans for significant expansion of LNG export capacity in this decade. They must take urgent steps to stem the national and global climate harms of this industry.[19]

3. **Ecosystem and habitat destruction:** The exploration and extraction of fossil gas, including the development of LNG infrastructure, can lead to habitat destruction and deforestation. These activities have adverse impacts on biodiversity and ecosystems, exacerbating the biodiversity crisis.

**FIGURE 2: IEA'S PROPOSED SCENARIO FOR PHASING OUT UNABATED FOSSIL FUELS IN ELECTRICITY GENERATION**




*Source:* IEA (2023), *Unabated fossil fuel-based electricity*, IEA, Paris https://www.iea.org/reports/unabated-fossil-fuel-based-electricity, License: CC BY 4.0.

Transitioning to cleaner energy alternatives is crucial for mitigating the climate burden associated with LNG. This includes investing in renewable energy sources, energy storage, and demand flexibility; minimizing methane leakage; implementing robust methane leakage monitoring and reporting systems; and supporting policies that prioritize a rapid and just energy transition worldwide.

## CLEAN LNG ALTERNATIVES IN THE POWER SECTOR ARE COST EFFECTIVE

Given the exigent need to move away from reliance on LNG, and fossil fuels more broadly, it is incumbent on governments to explore viable low-emissions energy alternatives—especially in the power sector, where demand for fossil gas is high, accounting for 39 percent of global demand.[20] There are several well-established and cost-effective alternatives in the power sector. Renewables, such as wind and solar, have seen drastic reductions in cost and are often among the cheapest power-generation technologies on a levelized cost of energy (LCOE) basis.[21]

A recent analysis conducted by Energy + Environmental Economics (E3) on behalf of NRDC highlights these trends in several countries currently at a crossroads with respect to investment in LNG infrastructure: Germany, Pakistan, and Vietnam.[22] E3's findings show that all three countries have sufficient renewables potential to meet their respective projected energy demand out to 2050 (see Table 3). Moreover, the analysis shows that renewables paired with battery storage are cheaper than LNG-fired power plants equipped with carbon capture and storage (CCS). These findings are particularly significant because they highlight that LNG investments are likely uneconomic when compared with investments in comparable renewable energy technologies for low-carbon baseload power generation.

Delivery of reliable clean power in instances of long-duration intermittency (i.e., over multiday periods of low solar or wind) will likely require further technological innovation and commercialization, according to E3's findings. E3 assessed the cost of pairing hydrogen-fired combustion turbines (CT) (using green hydrogen produced from renewable energy sources locally) with offshore wind turbines in both Germany and Pakistan as a potential means to maintain reliable power supply even during long-duration intermittency events. These hydrogen CT and offshore wind hybrids were found to be exceedingly expensive on an LCOE basis (see Figures A2, A4, and A6 in Appendix). While there may be a role for truly low-carbon hydrogen combustion for power generation as a form of peaking capacity in specific cases, E3's study found renewables and storage hybrids to be a consistently cheaper resource combination for providing baseload power.

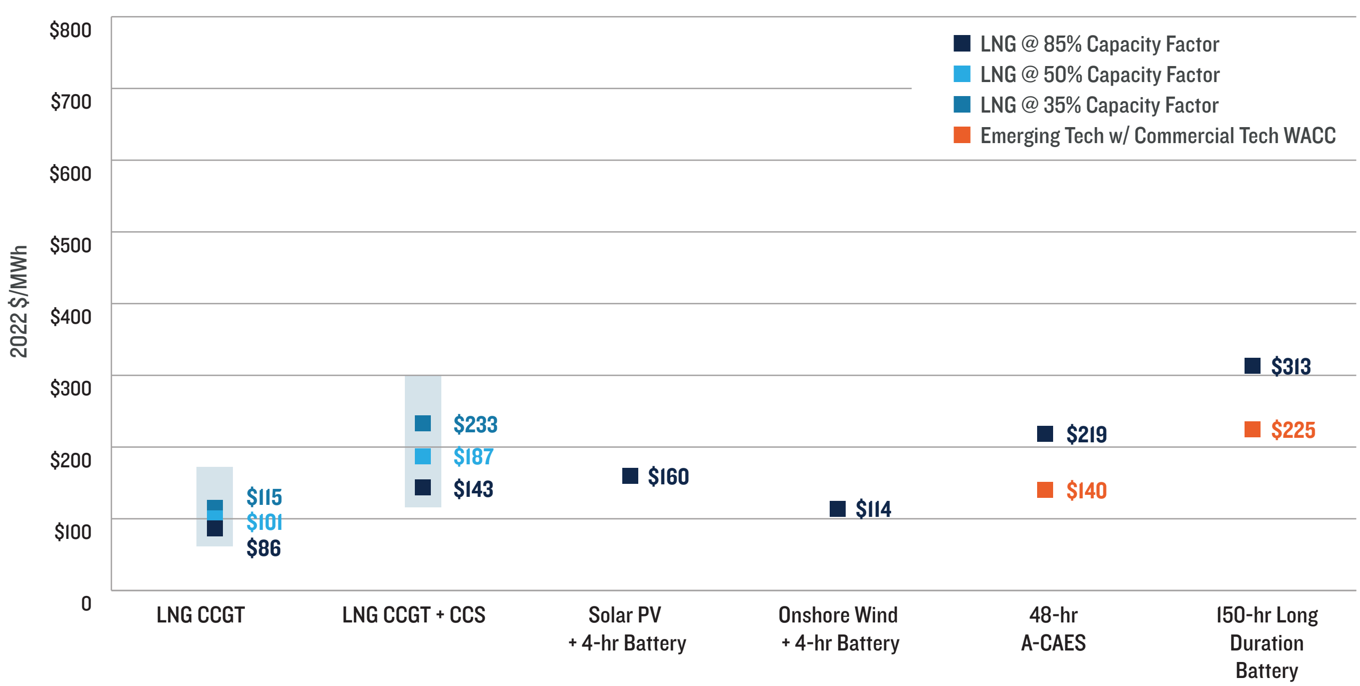
| TABLE 3: RENEWABLE ENERGY POTENTIAL BY COUNTRY VERSUS FORECAST ELECTRICITY DEMAND IN 2050 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Germany | | | Pakistan | | | Vietnam | | |
| | Potential GW | Capacity Factor % | Output TWh/yr | Potential GW | Capacity Factor % | Output TWh/yr | Potential GW | Capacity Factor % | Output TWh/yr |
| **Solar** | 481 | 12% | 506 | 2,420 | 20% | 4,240 | 2,465 | 15% | 3,239 |
| **Wind** | 184 | 45% | 727 | 264 | 37% | 857 | 113 | 36% | 357 |
| **Offshore Wind** | 61 | 60% | 322 | 18 | 46% | 72 | 404 | 54% | 1,910 |
| **Total Renewable Energy Potential (TWh/yr)** | | | 1,560 | | | 5,168 | | | 5,505 |
| **Forecast 2050 Energy Use (TWh/yr)** | | | 772 | | | 414 | | | 1,103 |
| **Ratio of Total Renewable Energy Potential to 2050 Energy Use** | | | 2.0 | | | 12.5 | | | 5.0 |

*Source:* John Stevens et al., *Liquified Natural Gas (LNG) Alternatives for Clean Electricity Production*, Energy + Environmental Economics (E3) and NRDC, May 2023, https://www.ethree.com/new-report-from-e3-and-nrdc-on-low-carbon-alternatives-to-lng/.

In the context of Vietnam specifically, the government's proposed expansion of LNG infrastructure is framed as necessary to keep pace with domestic energy demand growth, which is projected to increase by 77 percent between 2022 and 2030 and by almost 300 percent by 2050.[23] E3's analysis, however, adds to the growing literature questioning whether an LNG-dependent path forward is the best path, in terms of both climate and economics, for Vietnam (or any country) to meet its rising energy needs. E3 found that both wind and solar, when paired with four-hour Li-ion battery storage, were cost-competitive sources of firm generation compared with LNG-fired plants equipped with CCS in almost all modeled scenarios (see Figure 3).[24] The analysis found onshore wind/battery storage hybrids, in particular, to be cheaper than LNG paired with CCS across all analyzed geographies. This demonstrates that renewables can serve as a cost- and climate-effective way to provide firm power to the grid, a function traditionally assumed to be exclusive to fossil fuel generation technologies.

The volatility of LNG prices is also an increasing concern for countries planning to rely on it as a fuel source moving forward. In the short term, both elevated prices and pricing volatility are expected to persist across global LNG markets until significant new supply volumes come online around 2026–2027.[25] Greater volatility in global gas markets is expected to continue in the medium and long term as well, as markets adjust to gas being traded more like a global commodity.[26] E3's analysis substantiates these assessments when comparing LNG with cleaner alternatives, finding that "LNG generation appears to be more expensive with higher price volatility."[27] See Appendix A for detail on E3's LNG cost methodology for LCOE calculations.

**FIGURE 3: 2030 LCOE OF LNG VERSUS LOW-CARBON FIRM GENERATION IN VIETNAM**




*Note:* WACC: weighted average cost of capital; CCGT: combined cycle power plant; A-CAES: adiabatic compressed air energy storage.

For countries like Vietnam and the Philippines, this commodity risk is compounded by other unfavorable market dynamics. Developing countries often pay a premium to secure their cargoes because of perceived low creditworthiness, and they can be priced out of LNG markets altogether during supply shortages.[28] Events since early 2022 highlight the tangible impacts these dynamics can have on less wealthy countries looking to rely on LNG as a fuel. Both Pakistan and Bangladesh have experienced cascading energy and economic crises in large part due to concerns around the availability and affordability of LNG on the market in the fallout of Russia's invasion of Ukraine.[29] Given these market concerns, development of robust domestic capacity and generation resources, like renewables paired with battery storage, also carries an energy security benefit for Vietnam and other countries with emerging economies.

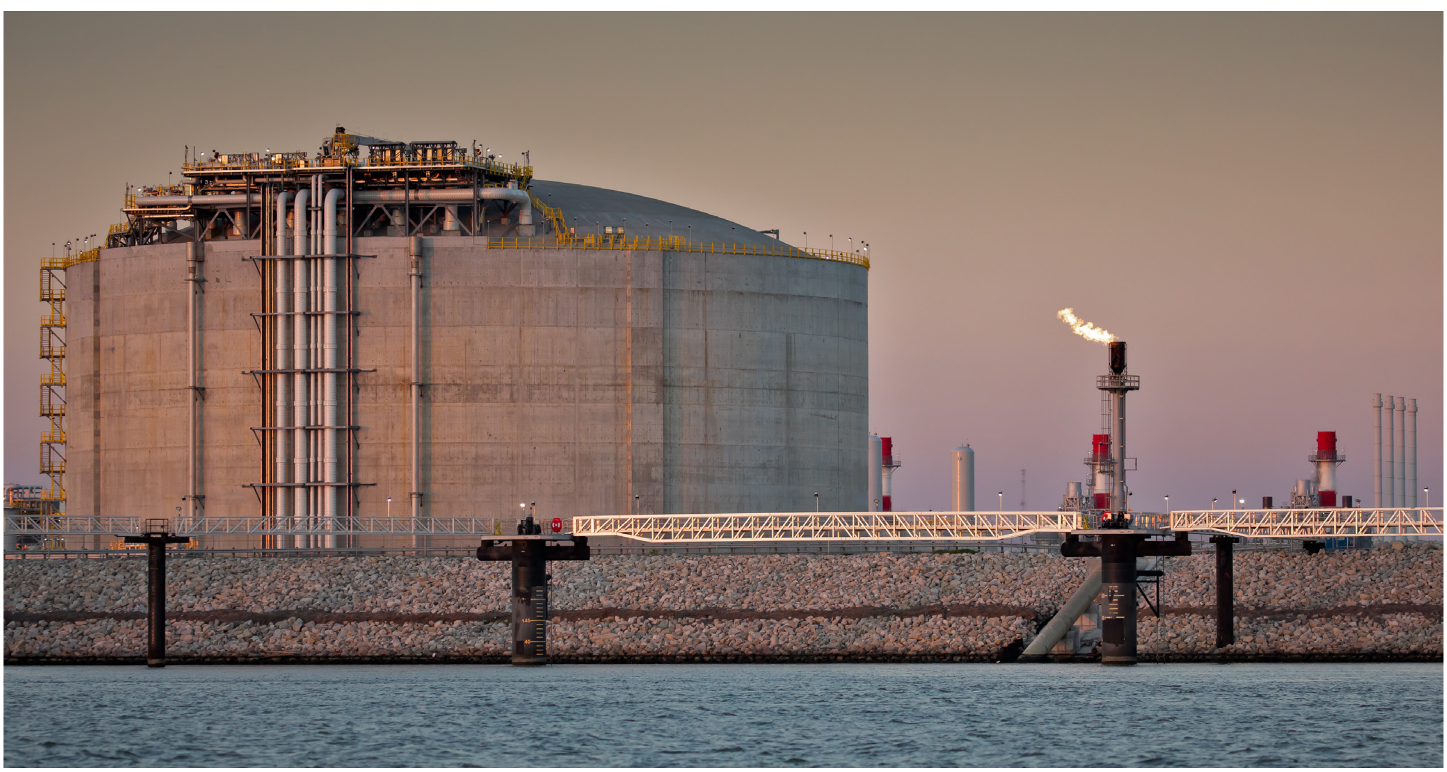
Vietnam's Power Development Plan VIII (PDP 8), released in May 2023, is somewhat of a mixed bag in light of the findings above.[30] LNG-fired power and onshore wind have the largest shares of planned capacity additions under PDP 8 in Vietnam between 2023 and 2030, at 27 percent and 22 percent, respectively.[31] The projected expansion of gas/LNG-to-power capacity is reflective of trends within the Asia Pacific region, as a recent Global Energy Monitor report points out.[32]

Given the well-established climate and public health advantages of renewable power over LNG-fired power generation, as well as the demonstrated competitive cost of renewables paired with battery storage in LNG-importing countries, governments and financiers should be developing measures to further ramp up renewable energy deployment within the power sector.

## BOX 2: LNG ALTERNATIVES BEYOND THE POWER SECTOR

Beyond just the power sector, alternatives to gas use in buildings and industry are becoming more prevalent as well. In 2022 record numbers of heat pumps were installed in various countries that historically have been reliant on gas and other fossil fuels for heating needs.[33] The development of these electric alternatives is key, as many countries currently importing LNG (or planning to) have significant gas demand for heating needs.[34] Germany, despite having limited LNG import capacity at the time of writing, is planning a rapid expansion of LNG imports in coming years in order to replace Russian piped gas. It is expected that significant volumes of this imported LNG will be used to meet heating demand in residential, commercial, and industrial sectors.

A recent study published in *Nature* highlights the opportunity that the deployment of heat pumps at scale presents to rapidly reduce gas consumption in Germany.[35] This study modeled several scenarios around the pace of heat pump deployment in Germany and its impact on gas consumption in the residential, commercial, industrial, and power sectors. It found that, with targeted measures to support heat pump deployment, up to 60 percent of the gas imported by Germany from Russia in 2020 could be substituted by 2025. This and other studies have found that uptake of heat pumps can be facilitated by initiatives to promote increased consumer engagement, energy efficiency, demand reduction, and grid expansion.[36] Many of these enabling measures are applicable across the sectors where LNG is commonly used today.





A burning gas flare at Venture Global's Calcasieu Pass LNG export facility in Cameron Parish, Louisiana.

## EXPANSION OF LNG INDUSTRY REMAINS A RISKY BUSINESS

The Institute for Energy Economics and Financial Analysis (IEEFA) anticipates that roughly 17 million tons per annum (mtpa) of LNG liquefaction projects will come online globally in 2025, followed by an additional 64 mtpa in 2026 and 37 mtpa in 2027 (see Figure 4).[37] These numbers largely represent projects that are already under construction, but many other projects are on the drawing board and in various stages of preconstruction globally. If those projects are approved over the coming year, they will create a situation in which new LNG supply far outstrips demand after the mid 2020s. This is not in line with country commitments under the Paris Agreement and net zero pathways.

Even as the industry continues to expand, it has not addressed many of its inherent risks—risks that make renewables an even better option by comparison. LNG is bad for the environment, but it's also bad business for investors. The following are some key risks that need to be considered by decision-makers and energy planners when looking at LNG-related investments:

1. **Impact of turbulent market conditions:** Since early 2022, global LNG prices have seen significant fluctuations due to various factors such as supply and demand dynamics, geopolitical tensions, and changes in energy policies.[38] According to the IEA, the average monthly fossil gas price increased tenfold and the price of hard coal quintupled between January 2021 and August 2022.[39] Exposure to global markets will add uncertainties to LNG-based energy needs and pose financial risks for buyers and companies involved in the LNG sector. This is especially true for those based in poorer economies with structural exposure to LNG imports, as discussed previously.

   Developing any LNG infrastructure requires substantial up-front investments, including the construction of liquefaction plants, storage facilities, and transportation infrastructure. The downstream power projects utilizing supply from these LNG import facilities would involve significant fuel-price risks. Gas-based megaprojects are very costly and are likely to face cost overruns from project execution delays as well as regulatory barriers due to tightening climate restrictions in the coming years.[40] The gas crisis in Europe has made it clear that greater investment in renewables-based power generation in the past decade saved countries billions.[41] For example, since Russia's invasion of Ukraine an estimated 230 terawatt-hours (TWh) of expensive fossil fuel generation was replaced with low-cost wind and solar PV installations. resulting in a reduction in wholesale electricity prices across all European markets.[42]

2. **Long-term contracts:** Many new LNG projects rely on long-term contracts with fixed pricing structures. However, these contracts can expose companies to future environmental, social, governance and financial risks if regulatory and market conditions change significantly during the contract's duration. For example, if the climate regulations of a country become stricter, companies will have to curb the use of LNG and struggle to recover their investments and meet contractual obligations.

3. **Environmental justice and public health risks:** Liquefaction and export facilities pose serious health risks to the communities living nearby.[43] The communities where projects are sited tend to be overwhelmingly populated by low-income households. Health risks are posed by exposure to harmful toxic gases that can be released from accidents or spills during transportation, storage, or re-gasification processes. One study estimated that air pollution from U.S. oil and gas production activities, including LNG production, resulted in 410,000 asthma exacerbations, 2,200 new cases of childhood asthma, and 7,500 excess deaths in 2016, costing $77 billion in total health impacts in this country alone.[44] The health impacts of oil and gas production worldwide would be many times worse.[45]

4. **Energy transition uncertainties:** As the world's energy sector moves toward decarbonization through renewable energy sources, the medium- to long-term demand for LNG becomes tenuous at best.[46] Recently released projections in the IEA's World Energy Outlook highlight the demand trend, with its "Announced Pledges Scenario" finding that LNG demand will peak before 2030 and its "Net Zero Scenario" projecting an LNG oversupply by the mid 2020s, rendering projects currently in construction unnecessary.[47] If countries and industries transition more rapidly than anticipated to cleaner energy alternatives, the demand for LNG could further decrease, leading to stranded assets and financial losses for LNG producers and investors. This would create an extraordinary financial burden, especially on low- and middle-income economies.

Given these inherent dangers, companies involved across the entire LNG industry value chain need to conduct comprehensive risk assessments of the impacts of expanding their operations, including public health impacts. LNG buyers and investors will need to diversify away from fossil fuels in their portfolios to include carbon-neutral solutions that reflect the long-term environmental and social impacts of their investments as climate initiatives ramp up worldwide.

A single row of wind turbines stretching along the shoreline off Bangui Bay in Ilocos Norte, Philippines.

## KEY ENABLERS CAN ACCELERATE THE TRANSITION AWAY FROM LNG IN THE POWER SECTOR

LNG cannot be part of our zero-emissions energy future. It's a risky investment for companies and governments, especially when renewable alternatives exist and are cost effective. Ideally a decarbonized electricity sector should provide gas utilities and power generators an opportunity to rethink their traditional business models—considering ways to repurpose assets or invest in new ones—while at the same time working with policymakers, customers, investors, and other stakeholders on system-wide decarbonization. Converting a gas-based energy system to decarbonized energy could provide significant benefits for existing utilities and the environment.

Globally, a set of common enablers like the following can be used in various combinations to help bring about this energy transition:

1. **Enhance policy and regulatory support:** Establishing clear and supportive policies and regulations is crucial for encouraging the transition to renewable energy. Governments can provide incentives, subsidies, and tax breaks for renewable energy projects, as well as set renewable energy targets and mandates. They can similarly implement measures to curb emissions from fossil fuel operations (e.g., imposing emission rate or mass-based caps, mandating fossil phaseout or electrification dates). Moreover, regulatory frameworks can be designed to facilitate grid integration, streamline permitting processes, and promote renewable energy development. Finally, governments must allow for independent assessment of flexibility needs in the power system.

2. **Scale up investment in renewable energy:** Significant investments in renewable energy infrastructure are needed to support the transition away from LNG dependency in the power sector and put countries on a pathway to net-zero emissions. According to the International Renewable Energy Agency (IRENA), by 2030 cumulative investments in energy systems should reach $44 trillion (USD), with energy transition technologies—led by efficiency, electrification, grid expansion, and flexibility—accounting for 80 percent of the total investment ($35 trillion).[48]

   Governments, private investors, and international organizations can provide funding and financial support for the construction of renewable energy generation facilities, transmission lines, and energy storage systems. Encouraging investment in renewable energy projects through green finance and policy mechanisms (e.g. feed-in tariffs), clean portfolio standards, and power purchase agreements can also accelerate the transition. Signatories of the Glasgow Declaration should take the lead on these initiatives by implementing their commitments to stop funding fossil fuel projects overseas and by financing clean energy instead.

E3's findings also highlight that supporting a lower cost of capital for clean energy projects through targeted programs is a vital potential enabler for transitioning away from LNG dependence in the power sector, particularly in developing countries.[49] According to the IEA, scaling up clean energy investment in developing countries is critical as it leads to a reduction in overall demand for fossil fuels like LNG.[50] Investment needs to almost triple from 2022 levels of $1.6 trillion annually to $4.5 trillion by the early 2030s to meet the IEA's updated Net Zero scenario in line with a 1.5 °C pathway.[51] Concessional climate finance through below market rate financial products plays a key role in catalyzing energy transitions. E3's sensitivity analysis shows that when the cost of capital in Vietnam and Pakistan is lowered to a level comparable to that of the German market, renewables and storage hybrids are significantly cheaper than abated LNG-fired power infrastructure and cost competitive with even unabated LNG-fired infrastructure.

3. **Expand and modernize the grid:** Across much of the world, the power grid needs to be expanded, modernized, and made more flexible to accommodate larger shares of renewable energy sources. Advanced grid management systems, smart grid technologies, and demand-response programs can serve as the first step to help balance the intermittent nature of renewable energy and ensure grid stability. Over the medium to long term, upgrading and expanding transmission and distribution infrastructure is essential to facilitate the uptake and integration of renewable energy into national power systems.

4. **Accelerate innovation and technological progress:** Governments, research institutions, and private companies must proactively invest in research and development to drive technological innovation in the renewable energy and climate technologies sector. To achieve their net-zero targets, countries around the globe are building support for climate-friendly technologies into their economic plans, aiming to reduce emissions, generate economic benefits for local industry, and improve energy security. For example, the United States' cutting-edge RD&D efforts, often backed by government money, have allowed hundreds of enterprising firms to work on rapidly delivering decarbonization goals.[52] In addition to domestic investments, countries around the world can partner and collaborate to scale up joint clean energy RD&D efforts and solutions with the help of export credit agencies, international financial institutions, and ethical investors.

5. **Enhance rollout of energy storage:** Energy storage technologies will be an important and growing part of the transition to a clean, renewable energy system. Efficient and increasingly cost-effective energy storage solutions, such as long-duration batteries and pumped hydro storage, can help overcome the intermittent nature of renewable energy–based power generation. Governments, project developers, and private investors should support piloting energy storage technologies at a scale to enhance their capabilities and rapidly reduce costs. E3's analysis shows that renewables paired with battery storage are already competitive with LNG-fired power on an LCOE basis in multiple LNG-importing countries, but further cost reductions could accelerate the uptake of storage technologies, especially in lower-income countries.[53]

6. **Improve public awareness and engagement:** Educating the public about the benefits of renewable energy and raising awareness about the environmental and health impacts of fossil fuels can foster support for the clean energy transition. Governments, nonprofit organizations, and the media should actively promote renewable energy and engage communities in the transition process. Public participation in decision-making and community-based renewable energy projects can also enhance acceptance and engagement.

7. **Foster international cooperation and collaboration:** Transitioning away from LNG requires international cooperation and collaboration. Sharing best practices, knowledge, and experiences among countries can accelerate the adoption of renewable energy technologies. International organizations, such as the United Nations and IRENA, can facilitate collaboration and provide technical assistance to countries seeking to transition their power systems away from LNG. Additionally, global development finance can provide vital support for renewable power infrastructure projects. The multi-country Just Energy Transition Partnership, formed to help Vietnam avoid building out LNG-based power generation and to further support its climate goals, is one suitable model for other countries to follow.[54]

By leveraging these enablers, countries can overcome barriers and successfully transition from LNG-based power generation to renewable energy, leading to a sustainable and clean energy future.

## COP28 MUST DELIVER COMMITMENTS TO END LNG EXPANSION

The LNG industry's unrestrained growth has and will continue to worsen the climate crisis. Energy sector $CO_2$ emissions reached a new record of 37 gigatonnes in 2022.[55] As the IEA recently stated, transforming the global energy system in line with the 1.5 °C goal needs immediate action to reduce methane—which means decreasing production and use of LNG.[56] This transition is economically feasible given the cost-effective nature of renewable alternatives in most LNG-producing and -importing nations. The first-ever Global Stocktake (GST) assessing the global response to the climate crisis is scheduled to conclude at COP28 in Dubai. By the end of COP28, countries must agree on how they will leverage the GST findings to keep alive the global goal of limiting temperature rise to 1.5 °C and to address the impacts of climate change. Leaders must make concrete and accountable commitments to curtail fossil fuel expansion including new LNG supply, rapidly reduce global fossil gas dependencies, and clean up the current energy supply by accelerating the build-out of renewables and prioritizing energy efficiency. Leaders should focus on:

- Achieving a deep, rapid, and equitable phaseout of all fossil fuels (led by the power sector), including LNG, with interim benchmarks for major emitters aligned with cutting global GHG emissions in half by 2030 relative to 2019.
- Cutting methane emissions by at least 75 percent from 2022 levels by 2030. For the power sector in particular, the IEA's Net Zero trajectory requires sectoral emissions to decline 45 percent below 2022 levels by 2030 and to reach net zero by 2045.
- Committing to fully end public finance of carbon-intensive energy infrastructure, including new LNG related infrastructure.

Vulnerable communities across the world have no protection against the rising volume and intensity of climate impacts. Delaying tactics by the fossil fuel industry that claim LNG is a "transition fuel" are not in line with net zero pathways. Cost effective alternatives are available to deploy. A global energy transition must be built through investing in clean, sustainable, and affordable energy systems, starting today.



Wind turbines and solar panels in Jhampir, in Thatta District, Sindh, Pakistan.

# APPENDIX: EXCERPTS FROM E3'S LIQUEFIED NATURAL GAS ALTERNATIVES FOR CLEAN ELECTRICITY PRODUCTION

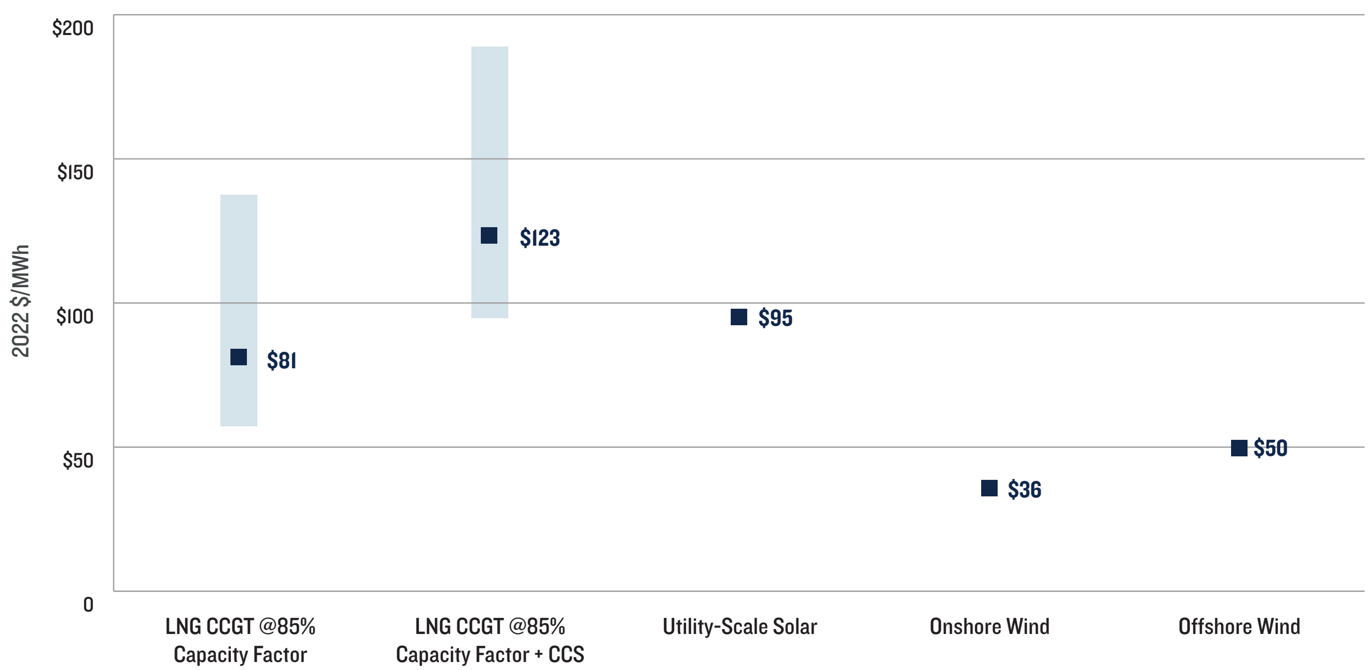
## LNG PRICING METHODOLOGY

E3 estimates the LCOE of future LNG-fired generation for a range of potential LNG prices based on the historical average annual U.S. LNG export prices observed from 2000 to 2022, adjusted for inflation to 2022 dollars. This yields a range of LNG prices (in real 2022 dollars) of $5.09 to $17.60 per MMBTU, with a mid-range price of $8.87/MMBTU based on the 2000-2022 historical average. These historical LNG export prices are presented by the U.S. EIA as "Free on Board (FOB)," meaning that the prices include all costs up to the point of export (including commodity costs and liquefaction fees), but these prices do not include the costs to receive the ships, re-gasify the LNG at a floating or onshore terminal, and transport the gas to a power plant via pipeline or other delivery mechanism. These 'excluded' costs vary widely depending on the specific locations and infrastructure used—for this analysis, E3 uses a conservative assumption of $1 per MMBTU to cover all costs of LNG receipt, regasification, and delivery to a power plant. This assumption results in a range of LNG prices delivered to a power plant of $6.09 to $18.60 per MMBTU and an expected price of $9.87 per MMBTU (in real 2022 dollars).

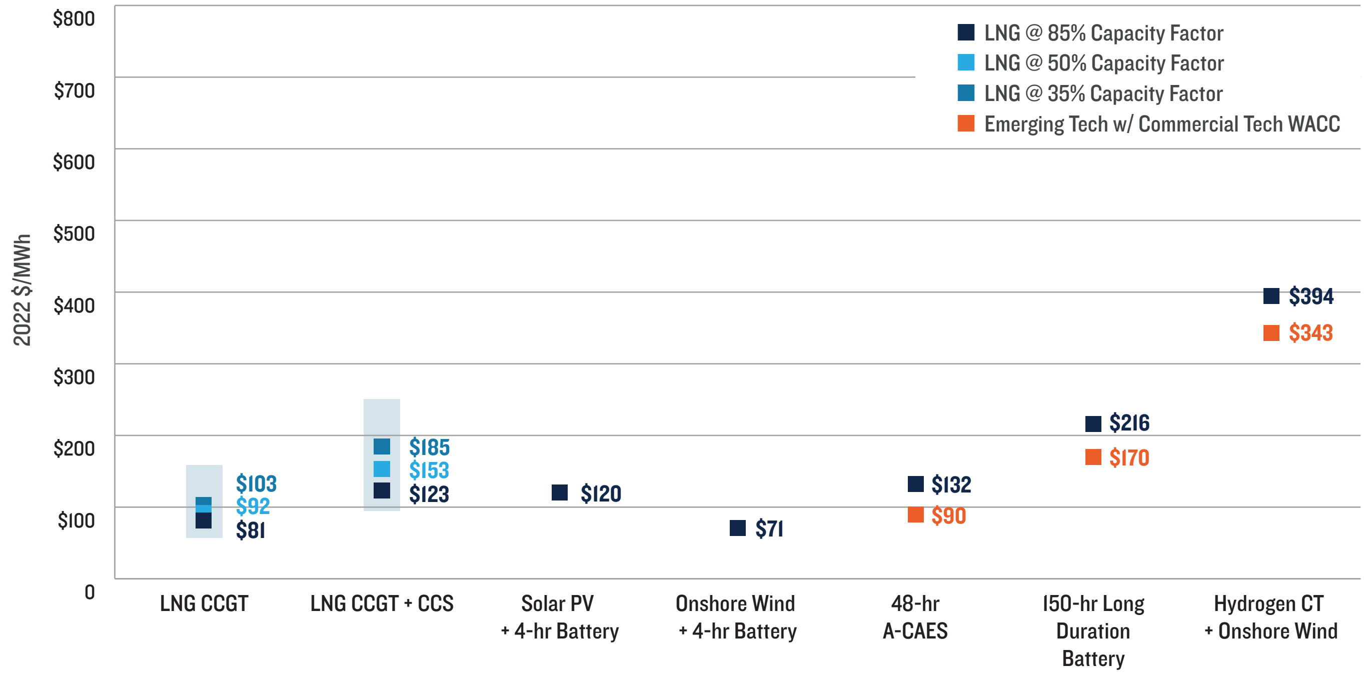
## GERMANY LCOE COMPARISONS:

The following charts show LCOE comparisons for various configurations of LNG-fired power generation with various configurations of clean power generation in Germany. The bounds of LCOE's provided in the analysis encompass technology capital cost uncertainty bounds, as well as variations in fuel price for LNG-powered generators.

**FIGURE A1: 2030 LCOE OF LNG VS. RENEWABLES IN GERMANY**



#### FIGURE A2: 2030 LCOE OF LNG VS. LOW CARBON FIRM GENERATION IN GERMANY




## PAKISTAN LCOE COMPARISONS

The following charts show LCOE comparisons for various configurations of LNG-fired power generation with various configurations of clean power generation in Pakistan. The bounds of LCOE's provided in the analysis encompass technology capital cost uncertainty bounds, as well as variations in fuel price for LNG-powered generators.

#### FIGURE A3: 2030 LCOE OF LNG VS. RENEWABLES IN PAKISTAN

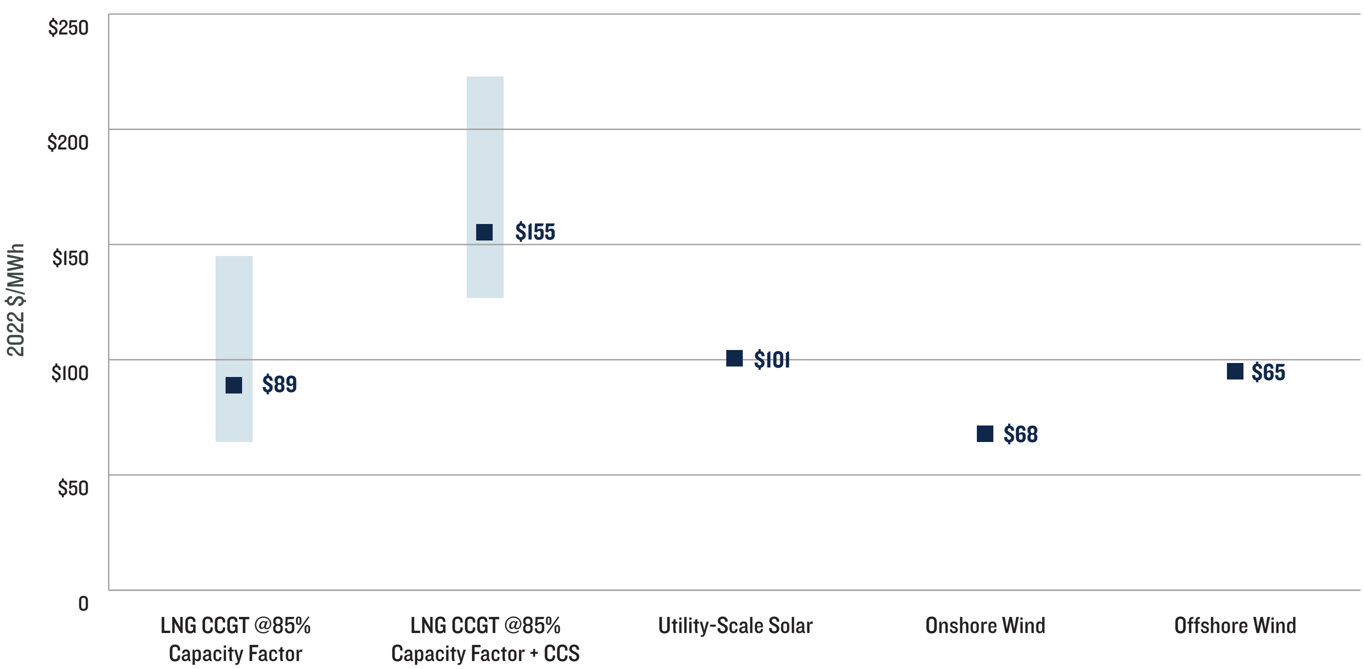
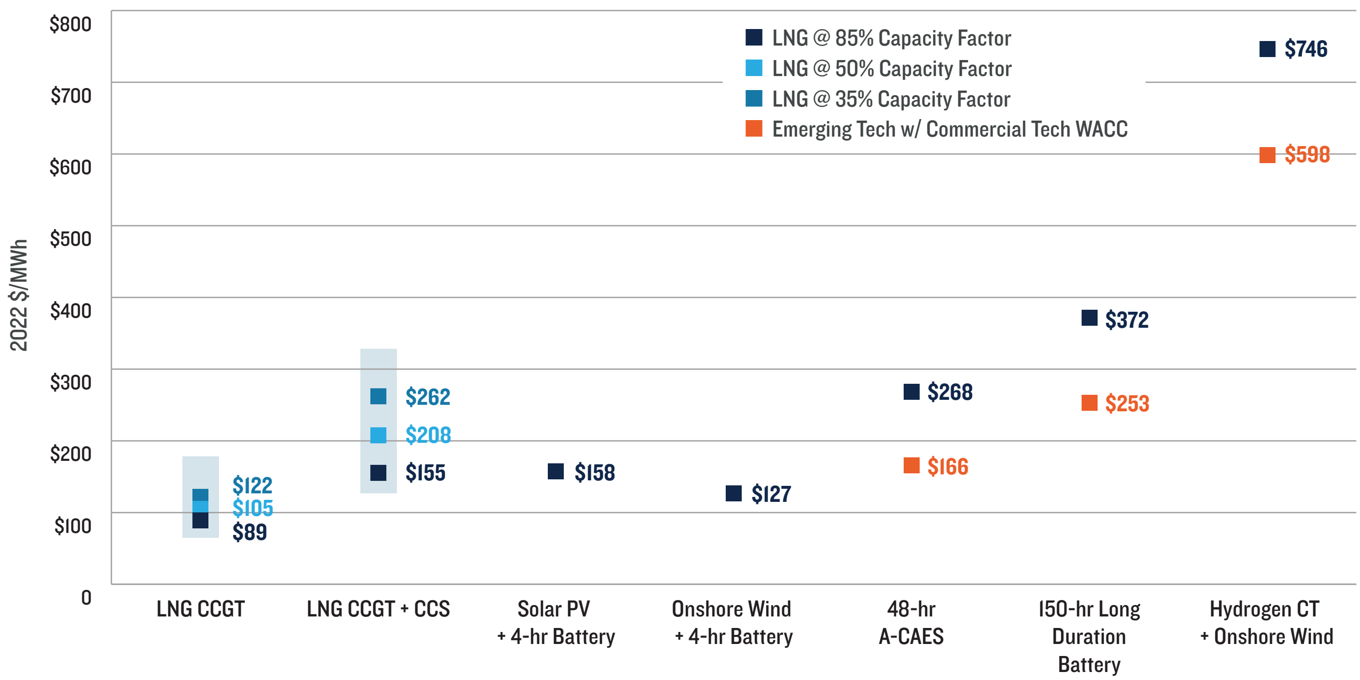


FIGURE A4: 2030 LCOE OF LNG VS. LOW CARBON FIRM GENERATION IN PAKISTAN




## PAKISTAN AND VIETNAM LOWER COST OF CAPITAL LCOE COMPARISONS:

The following charts show LCOE comparisons for various configurations of LNG-fired power generation with various configurations of clean power generation in Pakistan and Vietnam. However, as opposed to the results previously presented for these geographies, the following graphs show the cost of these various technologies if Pakistan and Vietnam had the same weighted average cost of capital (WACC) as Germany. This sensitivity analysis was applied to demonstrate the catalyzing effect that lower the cost of borrowing can have on clean energy transitions in various country contexts. The bounds of LCOE's provided in the analysis encompass technology capital cost uncertainty bounds, as well as variations in fuel price for LNG-powered generators.

FIGURE A5: 2030 LCOE OF LNG VS. RENEWABLES IN PAKISTAN WITH LOW COST OF CAPITAL

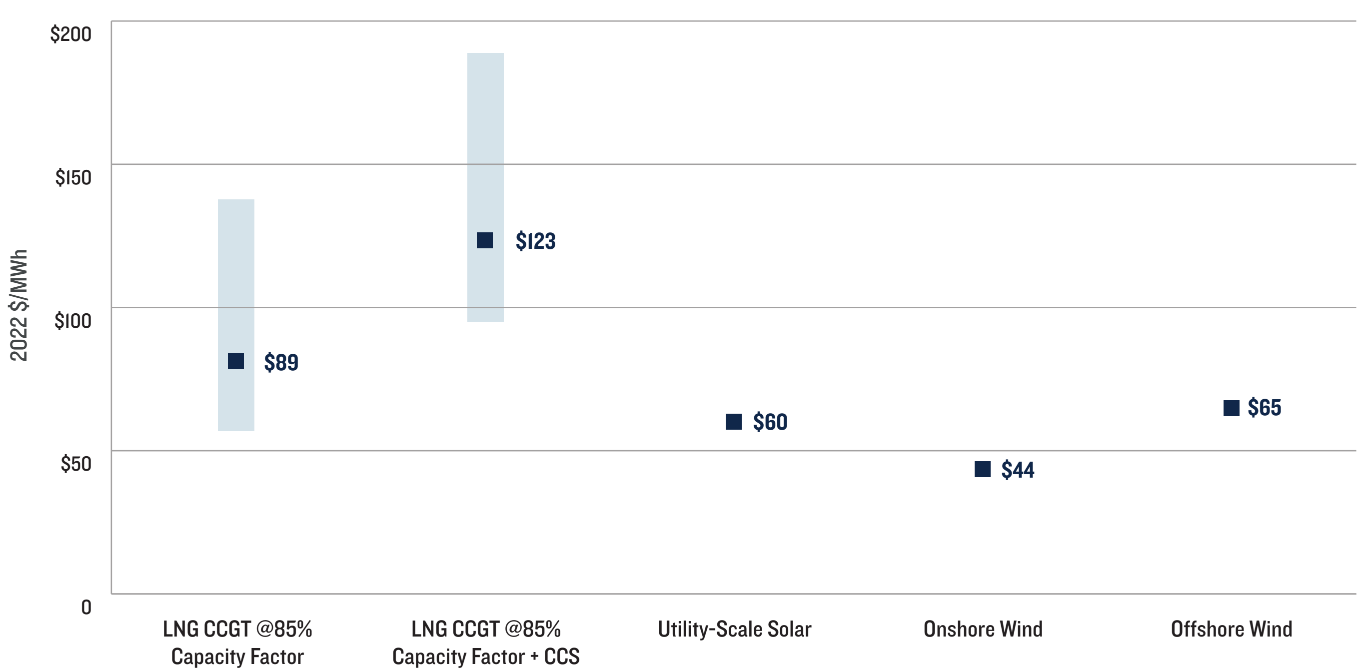


**FIGURE A6: 2030 LCOE OF LNG VS. LOW CARBON FIRM GENERATION IN PAKISTAN—LOW COST OF CAPITAL**

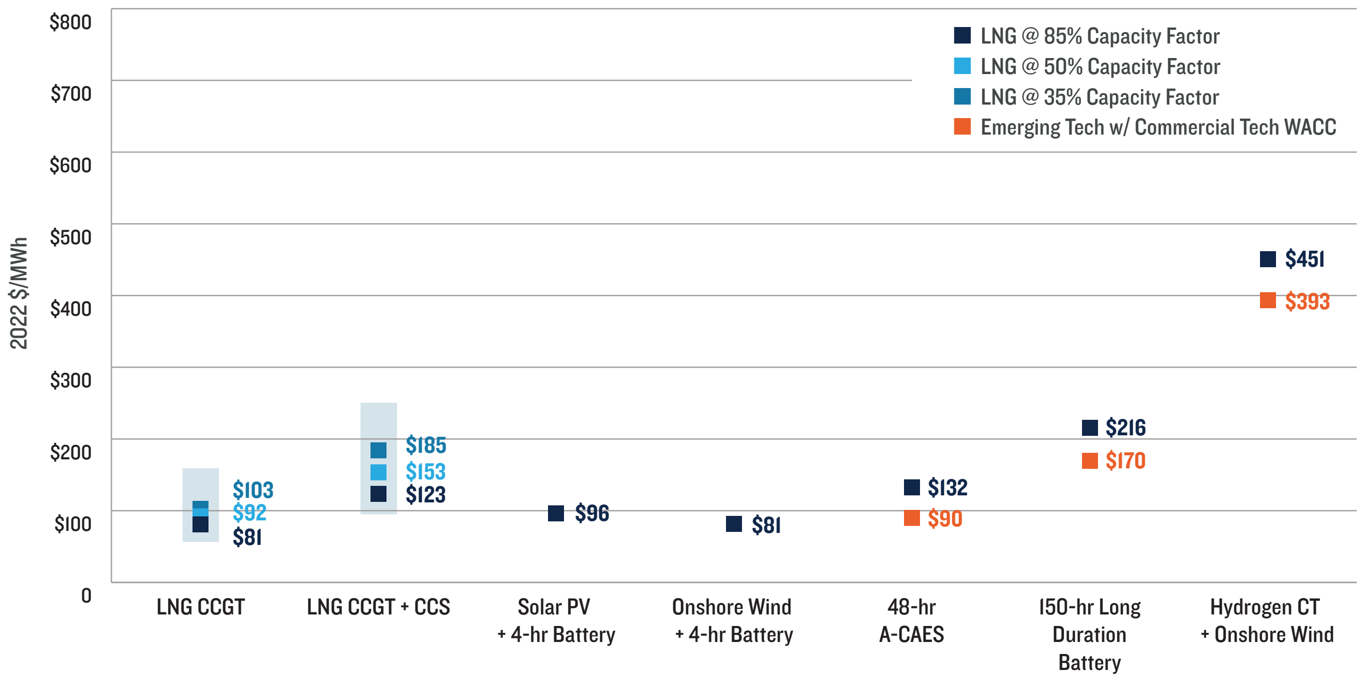



**FIGURE A7: 2030 LCOE OF LNG VS. RENEWABLES IN VIETNAM WITH LOW COST OF CAPITAL**

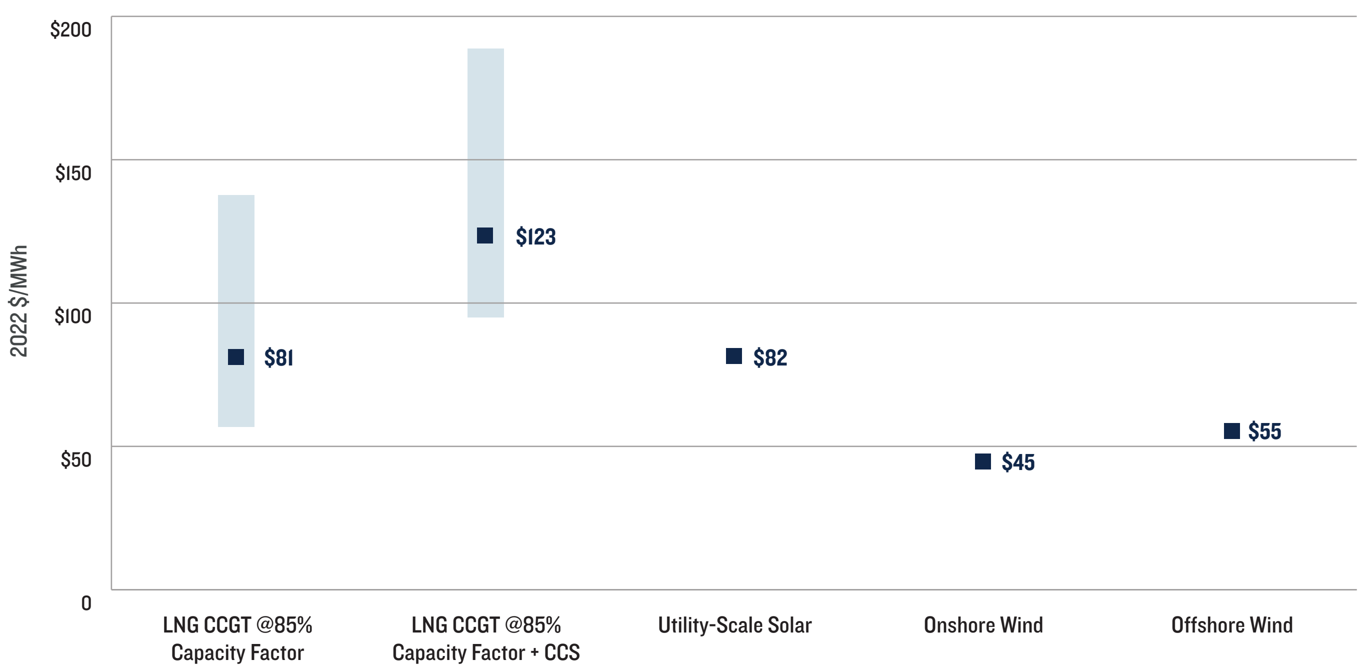
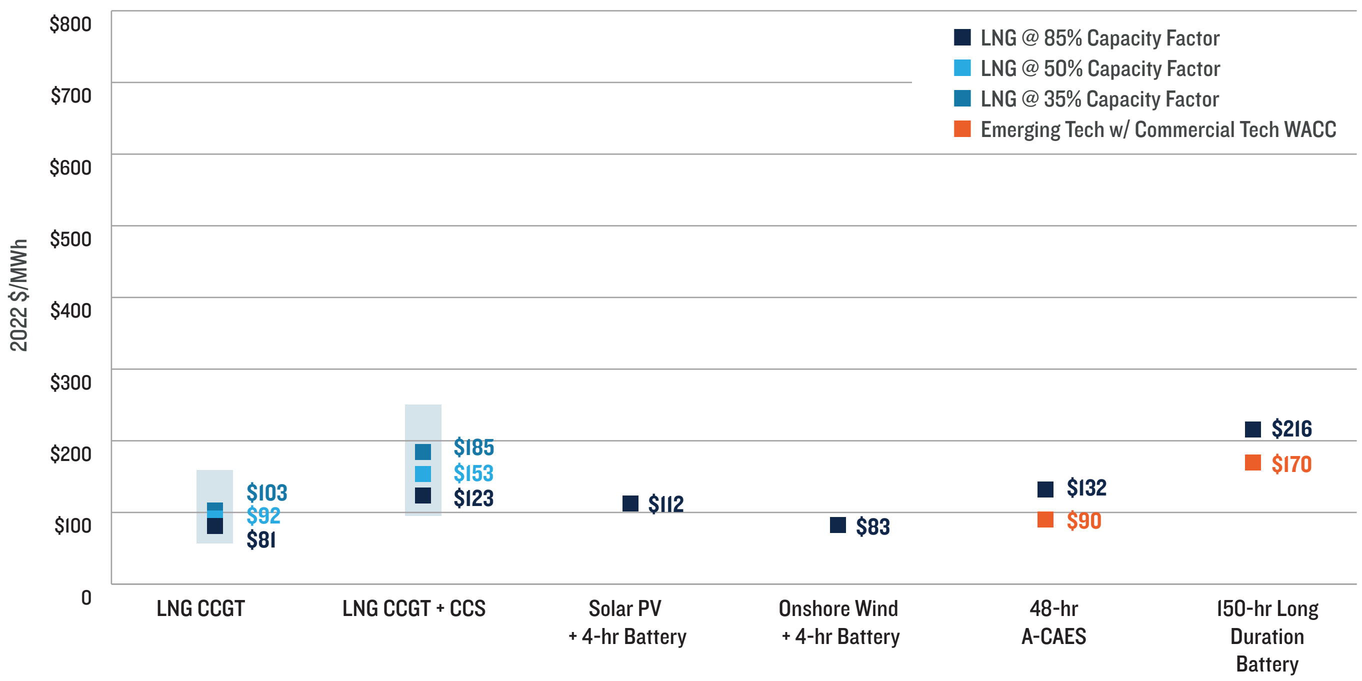


**FIGURE A8: 2030 LCOE OF LNG VS. LOW CARBON FIRM GENERATION IN VIETNAM—LOW COST OF CAPITAL**



ENDNOTES


1 World Meteorological Organization, "World Temperatures Set to Reach New Records in Next Five Years, May 17, 2023, https://public.wmo.int/en/media/press-release/global-temperatures-set-reach-new-records-next-five-years.

2 Intergovernmental Panel on Climate Change, "AR6 Synthesis Report: Headline Statements," accessed November 20th, 2023, https://www.ipcc.ch/report/ar6/syr/resources/spm-headline-statements/.

3 International Energy Agency (hereinafter IEA), *World Energy Outlook 2023*, October 2023, https://iea.blob.core.windows.net/assets/26ca51d0-4a42-4649-a7c0-552d75ddf9b2/WorldEnergyOutlook2023.pdf.

4 Mike Fulwood, "A New Global Gas Order? (Part 1): The Outlook to 2030 After the Energy Crisis," Oxford Institute for Energy Studies, July 2023, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2023/07/NG-184-A-New-Global-Gas-Order-Part-1.pdf.

5 IEA, *World Energy Outlook 2023*.

6 U.S. Department of Energy (DOE), "Liquified Natural Gas: Understanding the Basic Facts," August 2005, https://www.energy.gov/fecm/articles/liquefied-natural-gas-understanding-basic-facts; and United Nations Environment Programme, "What's the Deal with Methane?" October 18, 2022, https://www.unep.org/news-and-stories/video/whats-deal-methane.

7 Christina Swanson and Amanda Levin, *Sailing to Nowhere: Liquified Natural Gas Is Not an Effective Climate Strategy*, NRDC, December 8, 2020, https://www.nrdc.org/resources/sailing-nowhere-liquefied-natural-gas-not-effective-climate-strategy.

8 Deborah Gordon et al., "Evaluating Net Life-Cycle Greenhouse Gas Emissions Intensities from Gas and Coal at Varying Methane Leakage Rates," *Environmental Research Letters* 18, no. 8 (August 2023), https://doi.org/10.1088/1748-9326/ace3db.

9 Ibid.

10 Jenny Martos et al., "Gas Glut: Global Gas Power Expansion Continues to Thwart Energy Transition," Global Energy Monitor, September 2023, https://globalenergymonitor.org/report/gas-glut-2023-global-gas-power-expansion-continues-to-thwart-energy-transition/.

11 Araceli Fernández and Thomas Spencer, *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach*, IEA, September 2023, https://iea.blob.core.windows.net/assets/13dab083-08c3-4dfd-a887-42a3ebe533bc/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf.

12 National Oceanic and Atmospheric Administration (hereinafter NOAA), "Highlights from State of the Climate 2022," September 5, 2023, https://www.climate.gov/news-features/understanding-climate/highlights-state-climate-2022.

13 Global Methane Pledge, "Fast Action on Methane to Keep a 1.5°C Future Within Reach," accessed November 20th, 2023, https://www.globalmethanepledge.org/#pledges.

14 United Nations Environmental Programme, "UN Announces High-Tech, Satellite-Based Global Methane Detection System," November 11, 2022, https://www.unep.org/news-and-stories/press-release/un-announces-high-tech-satellite-based-global-methane-detection.

15 IEA, "Global Methane Tracker 2023: Overview," accessed November 20th, 2023, https://www.iea.org/reports/global-methane-tracker-2023/overview.

16 IEA, "Global Methane Tracker 2023: Overview."

17 Fernández and Spencer, *Net Zero Roadmap*.

18 Ibid.

19 Victoria Zaretskaya and Max Ober, "Global Liquefied Natural Gas Trade Volumes Set a New Record in 2022," Today in Energy, July 5, 2023, https://www.eia.gov/todayinenergy/detail.php?id=57000.

20 IEA, *World Energy Outlook 2023*.

21 International Renewable Energy Agency (hereinafter IRENA), *Renewable Power Generation Costs in 2022*, August 2023, https://www.irena.org/Publications/2023/Aug/Renewable-Power-Generation-Costs-in-2022#:~:text=For%20newly%20commissioned%20onshore%20wind,2022%20to%20USD%200.049%2FkWh.

22 John Stevens et al., *Liquified Natural Gas (LNG) Alternatives for Clean Electricity Production*, Energy + Environmental Economics (E3) and NRDC, May 2023, https://www.ethree.com/new-report-from-e3-and-nrdc-on-low-carbon-alternatives-to-lng/.

23 Ibid.

24 Ibid.

25 Corey Paul and Dylan Chase, "Global LNG Tightness Means 'Extreme Market Volatility' in 2023: S&P Global," December 8, 2022, https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/120822-global-lng-tightness-means-extreme-market-volatility-in-2023-s-p-global#:~:text=Extreme%20volatility%20in%20the%20global,Insights'%20latest%202023%20energy%20outlook.

26 Ana Maria Jaller-Makarewicz, "Seesawing Gas Market Dominated by Fear and Volatility," Institute for Energy Economics and Financial Analysis, September 6, 2023, https://ieefa.org/resources/seesawing-gas-market-dominated-fear-and-volatility.

27 Stevens et al., *Liquified Natural Gas (LNG) Alternatives*.

28 Robert Tuttle and Faseeh Mangi, "Pakistan's Demand for LNG to Nearly Triple in Five Years," Bloomberg New Energy Finance (hereinafter BNEF), September 21, 2023, https://www.bnef.com/news/s1bl5lt0afb401.

29 Sudarshan Varadhan, Mubasher Bukhari, and Ruma Paul, "Analysis: Gas Shortage Exposes Fragile South Asian Economies to More Pain," Reuters, February 20, 2023, https://www.reuters.com/markets/asia/gas-shortage-exposes-fragile-south-asian-economies-more-pain-2023-02-20/.

30 BNEF, "Vietnam Bets on LNG and Wind to Power Its Economy," May 17, 2023, https://www.bnef.com/insights/31397/view.

31 Allen Tom Abraham, Caroline Chua, and Vicky Adijanto, "1H 2023 Southeast Asia Power Market Outlook," BNEF, June 28, 2023, https://www.bnef.com/insights/31699/view.

32 Martos et al., "Gas Glut."

33 IEA, "Global Heat Pump Sales Continue Double-Digit Growth," last updated July 11, 2023, https://www.iea.org/energy-system/buildings/heat-pumps.

34 Shafiqul Alam et al., *Global LNG Outlook 2023–27*, Institute for Energy Economics and Financial Analysis, February 2023, https://ieefa.org/resources/global-lng-outlook-2023-27.

35 Pietro P. Altermatt et al., "Replacing Gas Boilers with Heat Pumps Is the Fastest Way to Cut German Gas Consumption," *Communications Earth & Environment* 4, art. 56, March 3, 2023, https://www.nature.com/articles/s43247-023-00715-7.

36 Pooya Hoseinpoori et al., "Comparing Alternative Pathways for the Future Role of the Gas Grid in a Low-Carbon Heating System," *Energy Strategy Reviews* 49 (September 2023), https://www.sciencedirect.com/science/article/pii/S2211467X23000925.

37 Alam et al., *Global LNG Outlook 2023-27*.

38 IEA, *Gas Market Report, Q2–2023*, May 2023, https://www.iea.org/reports/gas-market-report-q2-2023.

39 IEA, "How Much Money Are European Consumers Saving Thanks to Renewables?" June 2023, https://www.iea.org/reports/renewable-energy-market-update-june-2023/how-much-money-are-european-consumers-saving-thanks-to-renewables.

40 Munmun Basak, Robert K. Perrons, and Vaughan Coffey, "Schedule Overruns as a Barrier for Liquefied Natural Gas Projects: A Review of the Literature and Research Agenda," *Energy Reports* 5 (November 2019): 210–20, https://www.sciencedirect.com/science/article/pii/S2352484718302890.

41 Dolf Gielen, Michael Taylor, and Barbara Jinks, "Renewables and Green Gas: The Only Viable Antidote to High Fossil Fuel Prices," IRENA, February 24, 2022, https://www.irena.org/News/expertinsights/2022/Feb/Renewables-and-green-gas.

42 IEA, "How Much Money Are European Consumers Saving."

43 Brian Palmer, "Liquefied Natural Gas 101," NRDC, January 4, 2022, https://www.nrdc.org/stories/liquefied-natural-gas-101#whatis.

44 Jonathan J. Buonocore et al., "Air Pollution and Health Impacts of Oil & Gas Production in the United States," *Environmental Research: Health* 1, no. 2 (June 2023), https://iopscience.iop.org/article/10.1088/2752-5309/acc886.

45 Ibid.

46 BP, *Energy Outlook 2023*, July 5, 2023, https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html.

47 IEA, *World Energy Outlook 2023*.

48 IRENA, "Investment Needs of USD 35 Trillion by 2030 for Successful Energy Transition," March 28, 2023, https://www.irena.org/News/pressreleases/2023/Mar/Investment-Needs-of-USD-35-trillion-by-2030-for-Successful-Energy-Transition.

49 Stevens et al., *Liquified Natural Gas (LNG) Alternatives*.

50 Fernández and Spencer, *Net Zero Roadmap*.

51 Ibid.

52 Susanna Twidale, "Reuters Impact: New US Administration Would Not Derail Climate Tech Progress, Executives Say," Reuters, September 11, 2023, https://www.reuters.com/sustainability/reuters-impact-new-us-administration-would-not-derail-climate-tech-progress-2023-09-07/.

53 Fernández and Spencer, *Net Zero Roadmap*.

54 U.S. Mission Vietnam, "International Agreement to Support Vietnam's Ambitious Climate and Energy Goals," U.S. Embassy & Consulate in Vietnam, December 15, 2022, https://vn.usembassy.gov/international-agreement-to-support-vietnams-ambitious-climate-and-energy-goals/.

55 Fernández and Spencer, *Net Zero Roadmap*.

56 Ibid.