ENERGY ACCESS AND ENERGY EQUITY FOCUS AREA REPORT

Project Title: **Energy Access and Energy Equity Focus Area (SPO278729)**
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Report: 2023

PROJECT DESCRIPTION

Lower-income and lower-middle-income countries with natural gas resources have historically hewn to one of two broad trajectories for developing those resources. Either the gas is developed entirely or almost entirely for domestic use (e.g. Pakistan and Bangladesh), or it is developed entirely or almost entirely for export (e.g. Nigeria, Bolivia, and Mozambique). The trajectory is influenced by the nature of the resources themselves. Low fixed-cost, onshore resources are relatively easier to develop for domestic use, whereas high fixed-cost, offshore resources have much higher risks and larger capital requirements, and as a result they tend to be developed by multinational oil and gas companies seeking the higher returns that exports are likely to bring. Developing gas for exports and developing gas for domestic use do not have to be incompatible objectives. "Win-win" opportunities are possible, for example if export revenues support gas field development that in turn results in more gas being available for domestic use. However, the lack of sufficient gas handling and transportation infrastructure within a country is often a major obstacle—arguably *the* major obstacle—to the development and expansion of domestic gas markets alongside export markets. Even where gas is available locally at low marginal cost—for example, when associated gas from oil production is being flared—it will not be used if the infrastructure is not there to absorb it. The infrastructure gaps for gas are a major reason why coal or diesel have sometimes served as the "default fuels" for new power supply, particularly in the developing world where the demand for energy is rapidly growing.

Financing expensive gas transmission and distribution networks for domestic markets—not to mention storage and perhaps import facilities for when domestic gas is insufficient—can be quite challenging, especially when domestic end uses do not offer the same returns as exports. There is also a fundamental coordination problem in making sure upstream, midstream, and downstream infrastructure are built out in concert. Nascent gas markets will tend to be out-of-balance at any particular moment, with either 1) too little gas available to support gas-using applications, 2) too much gas relative to current demand, incurring seemingly unnecessary costs, or 3) or a mismatch of locations where gas is available to those where it is needed. Once sufficient infrastructure is in place, the coordination problem eases and subsequent upstream and downstream developments become much easier.

This project examines development pathways for natural gas in lower-income and lower-middle- income countries, with the goal of identifying viable models through which natural gas may be developed to provide economic, environmental, and health benefits. One major research activity explores obstacles to development of natural gas infrastructure and how they can be overcome. This work involves compilation and analysis of historical data on gas infrastructure development and its role in reducing investment risk for both gas producers and gas consumers. Another research area uses case studies to explore gas development strategies in emerging economies. We consider different models for utilization of natural gas—for example, reliance on industrial anchor customers to finance gas infrastructure—and seek insights into the potential of different such models to expand natural gas utilization in developing countries in an environmentally and economically beneficial way.

Given that many emerging markets are relying heavily on intermittent renewables for growth in the electricity supply, this research platform assesses the potential role of gas in backing up wind and solar in an emerging market setting. Gas-fired generators are the mainstay for renewable energy backup in higher-income countries, but donor agencies and multilateral development banks have generally been unsupportive of new fossil fuel developments in lower-income countries. We compare gas-fired generation to other means of renewable backup, and in particular energy storage, which has been touted as a way to "leapfrog" fossil fuels in this role.

MAJOR FINDINGS TO DATE:

- Expanded gas generation can provide backup for growing shares of variable renewables in fast- growing African economies like Senegal and Ghana. Gas is more easily scalable than hydro and far cleaner than

coal. However, limited gas transportation, storage, and import infrastructure in these countries pose an obstacle to the vision of using gas to integrate high shares of wind and solar.

- Large domestic gas pipelines are most commonly developed and financed to serve large industrial uses. For example, India's Hazira-Vijaipur-Jagdishpur (HVJ) pipeline was commissioned in 1997 with the primary goal of carrying gas to fertilizer producers in the state of Uttar Pradesh. Power markets in lower-income countries can be too dysfunctional to support the required investment in gas infrastructure.
- Analysis of historical gas development trajectories suggests that LNG exports and domestic use of gas are not zero-sum. LNG export developments generally finance the development of new gasfields rather than cannibalizing existing gas supplies that were previously directed toward domestic uses.
- Following the start of LNG exports, domestic consumption of gas often (though not always) grows over time as surplus gas and infrastructure developed for LNG find use in domestic markets.
- Once gas transportation infrastructure is well-developed in a country, as it is in the United States, a diversity of applications for gas can flourish. China's gas consumption mix today remains more industry-heavy and power-light than that of the United States, but the mix of gas uses is far more diverse than in 1980, thanks in large part to the country's expanded gas transportation network.
- Improved gas infrastructure lets increased gas supply translate more directly into increased gas consumption. For example, a notable factor supporting the shale gas revolution in the US was the existing pipeline infrastructure to bring this new gas to customers.
- To the extent gas displaces coal in power generation, as it has, for example, in the US and UK, this can help reduce local pollution and greenhouse gas emissions. While it's generally less remarked upon, the expansion of gas as a residential and commercial fuel in developing countries could also have health and environmental advantages over incumbent fuels, especially in coal-producing regions where the incumbent fuel is coal or in agricultural regions where it is biomass.
- In emerging markets that do not already use significant quantities of coal, coal-fired power is unlikely to become a major part of the energy mix going forward. Capital costs of new coal-fired generation are too high, the disastrous rollout of new coal-fired power plants in South Africa has discouraged other new coal projects of ambitious scope, China seems to be phasing out its support of many coal-fired power projects abroad, and climate concern has created obstacles to international coal finance. In settings, diesel may turn out to be a more direct competitor to gas than coal when it comes to industrial and commercial power.
- Lower-income countries should generally choose open cycle gas turbines (combustion turbines) for power rather than the combined cycle facilities that have made up the bulk of gas-fired capacity additions in the United States and other countries over the past several decades. Combined cycle units are more efficient, which results in lower variable costs and lower emissions, but their higher capital costs of construction translate into higher total costs in emerging market settings characterized by high cost of capital (due to a higher risk premium), construction delays (due to a less settled project and regulatory environment), and lower capacity factors (due to the inability of transmission networks to consistently absorb power as well as periodic unavailability of gas). More broadly, high-renewables grids are most effectively backed up by combustion turbines, which are more operationally flexible and don't need to run as often to break even due to their low fixed costs.
- When emerging markets build out their natural gas value chain, there can be concern about "stranded assets" (if GHG constraints limit the useful life of new gas assets) or "carbon lock-in" (if these assets operate for their entire planned lifetimes.) Our analysis suggests that gas-fired generators—and especially open cycle gas turbines—are unlikely to present either problem due to their fast payback times, and they can in fact support decarbonization by facilitating renewable buildouts. Stranded asset or carbon lock-in concerns might be more applicable to transportation infrastructure, with its high capital costs, but there are ways that such infrastructure can be repurposed for very-low-carbon energy systems in the future.
- Energy storage is not at present a viable alternative to gas-fired generation for renewable energy backup in lower-income countries. It is too expensive, and its financial viability depends on ancillary services markets that do not yet exist in these countries.

STUDENT INVOLVED IN PROJECT:

- Trevor Davis (postdoctoral scholar at PESD): development of gas/renewables integration scenarios in PESD's Energy Market Game.

- Ryan Triolo (Ph.D. student in Civil and Environmental Engineering): support for gas scenario development for PESD's Energy Market Game.

PROJECT RESULTS:

Publications, Conferences, Presentations:

- Mark Thurber, "LNG exports and domestic gas use are not zero-sum," Energy for Growth Hub, May 22, 2023, https://energyforgrowth.org/article/lng-exports-and-domestic-gas-use-are-not-zero-sum/
- Mark Thurber, "Perspectives on energy storage for South Asia and Africa," presentation at Long- Duration Energy Storage Workshop, Stanford University, May 4, 2023.
- Mark Thurber, "The role of gas for global decarbonization," presentation at NGI Industrial Affiliates meeting, May 1, 2023.
- Jake Kincer, Katie Auth, and Mark Thurber, "Untangling 'stranded assets' and 'carbon lock-in,'" Energy for Growth Hub, August 17, 2022, https://energyforgrowth.org/article/untangling-stranded-assets-and-carbon-lock-in/
- Jake Kincer, Todd Moss, and Mark Thurber, "A coal renaissance is not coming to Africa," World Development Perspectives 25, March 2022, https://doi.org/10.1016/j.wdp.2021.100375
- Mark Thurber and Olu Verheijen, "Should lower-income countries build open cycle or combined cycle gas turbines?" Energy for Growth Hub, March 2, 2022, https://energyforgrowth.org/article/should-lower-income-countries-build-open-cycle-or-combined-cycle-gas-turbines/
- Murefu Barasa and Mark Thurber, "Energy-poor countries face a special challenge: vertical energy transitions," Energy for Growth Hub, February 7, 2022, https://energyforgrowth.org/article/energy-poor-countries-face-a-special-challenge-vertical-energy-transitions/
- Mark Thurber, Murefu Barasa, Rose M. Mutiso, and Beryl Ajwang, "Wind and solar in Africa need grids to match," The Electricity Journal 34(6), July 2021, https://doi.org/10.1016/j.tej.2021.106976
- Mark Thurber, "Gas markets usually start with industrial applications," Energy for Growth Hub, February 2, 2021, https://www.energyforgrowth.org/memo/gas-markets-usually-start-with-industrial- applications/
- Mark Thurber, "The rise and inevitable fall of the coal + renewables model," conference paper for the 2020 Energy Futures Forum, Center for Strategic and International Studies, October 27-29, 2020.
- Mark Thurber and Todd Moss, "12 reasons why gas should be part of Africa's clean energy future," World Economic Forum, July 23, 2020, https://www.weforum.org/agenda/2020/07/12-reasons-gas-africas-renewable-energy-future/
- Mark Thurber, "Could natural gas help India exit coal?" Energy for Growth Hub, January 16, 2020, https://www.energyforgrowth.org/memo/could-natural-gas-help-india-exit-coal/

Partnerships:

We have partnered with Energy for Growth Hub to disseminate our research results and develop research partnerships in sub-Saharan Africa.

Public education activities in conjunction with the project:

We have disseminated our work through the Energy for Growth Hub partnership described above. We have also presented results of this project at conferences and workshops, including:

- Stanford Energy Solutions Week, "Long Duration Energy Storage Workshop," May 4, 2023.
- Center for Strategic and International Studies, "Energy Futures Forum," October 27-29, 2020.
- Energy Futures Initiative and Rice University's Baker Institute for Public Policy, "The Global Future of Natural Gas in a Low Carbon World," December 17-18, 2020.