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RESEARCH BACKGROUNDER

Natural Gas for Development?

Understanding the opportunities and challenges for gas in a context of climate change

Kendra Kintzi

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CONTENTS

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Author information and acknowledgments

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ACRONYMS AND ABBREVIATIONS

CNG	compressed natural gas
EPC	engineering, procurement and construction
ESIA	environmental and social impact analysis
FS	feasibility study
FEED	front-end engineering and design
FID	final investment decision
FLNG	floating liquefied natural gas
FPIC	free, prior, and informed consent
FSRU	floating storage and regasification unit
GSA	gas supply agreement
IEA	International Energy Agency
LPG	liquefied petroleum gas
LNG	liquefied natural gas
MBtu	million British thermal units
MTPA	metric tons per annum
NDC	nationally determined contribution
OM	operation and maintenance
SPA	supply purchase agreement
Tg	teragram
USEIA	US Energy Information Administration

EXECUTIVE SUMMARY

The potential for natural gas development to deliver low-emissions, cost-competitive, reliable fuel for economic growth has garnered attention from governments, private developers, financial institutions, and others around the globe. Faced with mounting climate concerns and pressing development needs, countries in the Global South with domestic natural gas resources stand to benefit significantly from the exploitation of these resources. At the same time, however, gas development poses serious social, environmental, and economic risks that threaten inclusive development[1] and climate goals. Moreover, natural gas is but one alternative among a changing array of options for global energy development and a low-carbon transition.

Although it is often produced alongside oil, natural gas operates through distinct physical, market, and institutional infrastructures. Until recently, natural gas trade took place predominantly within regional markets using long-term contracts negotiated between suppliers and buyers. Since 2010, however, growing supplies, plummeting prices, and the growth of long-distance trade has transformed global gas markets. In response to these shifting dynamics, this report outlines key risks and recommendations for governments, civil society organizations, donors, and industry partners to better understand the challenges and opportunities for mobilizing natural gas as a tool for sustainable, equitable, and inclusive development. At the national level, a key task for legislators, administrators, and communities involved in energy planning is to carefully consider the trade-offs that accompany gas development. For some countries, the risks of natural gas development may outweigh the potential benefits.

KEY RISKS

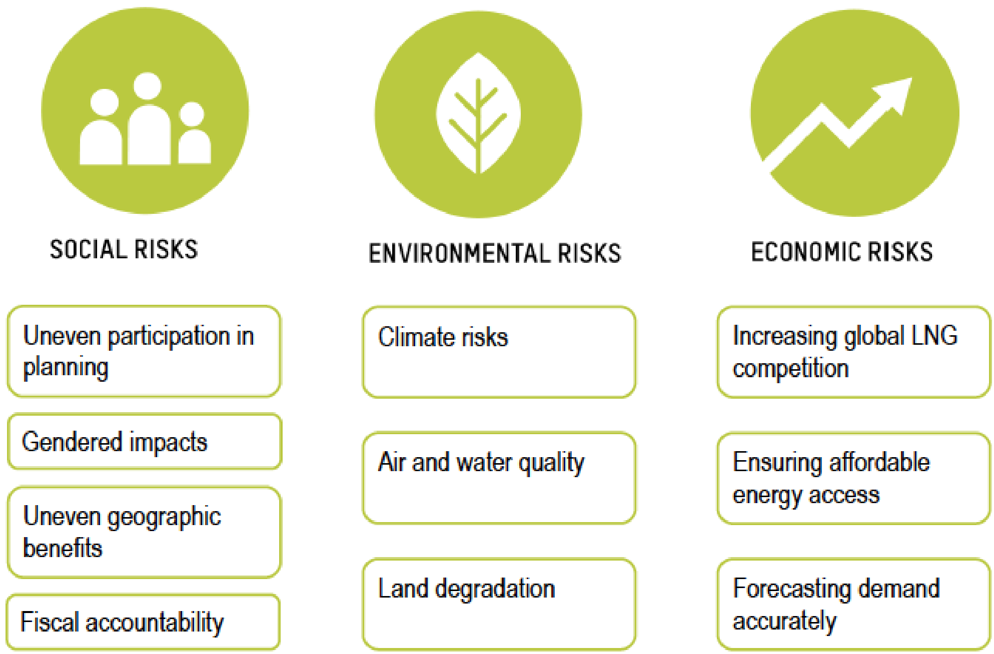
Social Risks

Natural gas development carries the potential to exacerbate social inequalities because the primary benefits of gas development are likely to accrue to particular groups, particularly urban, coastal communities and privileged socioeconomic groups. From the initial planning through the implementation stages of gas development, participation in decision-making and access to employment opportunities, revenue, and services may be unevenly distributed by gender, socioeconomic status, and geographic location. Natural gas development may

[1] The term "inclusive development" is used throughout the report to refer to development efforts that seek to maximize the equitable distribution of benefits to all members of society, with particular attention to development practices that prioritize the meaningful participation of socially and economically vulnerable communities.

also create a significant source of new government revenue, with attendant risks regarding fiscal transparency and accountability.

Figure 1: Social, environmental, and economic risks linked to natural gas development



Source: author

Environmental Risks

Significant concerns around greenhouse gas emissions across the natural gas supply chain call into question the climate benefits of natural gas for power generation, transportation, and household heating and cooking. In addition, the significant time required to develop gas infrastructure poses particular risks for carbon lock-in. Natural gas planning and development efforts must take account of how natural gas fits into countries' climate commitments to the nationally determined contributions (NDCs) under the Paris Agreement. For countries seeking to bring new gas resources online before 2030, the timeline for recuperating investment in new gas infrastructure may extend longer than the timeline for reducing hydrocarbon consumption. Finally, the extensive infrastructure required for natural gas development may negatively affect air and water quality and contribute to land degradation.

Economic Risks

Recent shifts in global gas markets mean that new producers will have to compete with major market players and that developers will have to navigate increasingly complex financial and contractual arrangements. For domestically oriented gas projects, balancing investor priorities with the need for affordable energy access poses a critical challenge as well. Finally, understanding domestic demand is pivotal to the success of developing gas for domestic use. Inaccurate demand projections threaten the economic sustainability of new gas investments, and imprecise understandings of local demand can lead to uneven outcomes for local communities.

KEY RECOMMENDATIONS

Host-country governments, advocacy networks, donors, investors, and the private sector all have important roles to play to ensure that natural gas development does not adversely affect local communities or compromise critical climate and development goals.

Social Policy Recommendations

Failure to deliver the promised benefits of gas development can foment social unrest, apathy, and mistrust. To ensure the equitable and democratic distribution of benefits from these revenues, authorities must give careful attention to questions of fiscal transparency, accountability, and oversight. Host-country governments, civil society organizations, advocacy partners, and donors should consider mechanisms to help ensure equitable access to the benefits of gas development for different local communities, such as rural inland communities and historically underrepresented groups. In regions where gas development is likely to generate gendered impacts, supporting women's meaningful participation in gas development decision-making can help promote gender-balanced outcomes and impacts.

Environmental Policy Recommendations

A portion of fugitive greenhouse gas emissions can be brought under control through cost-effective monitoring and leak detection and repair technologies and practices. Clear regulation and effective monitoring and oversight capacity are critical to ensuring that leak detection and repair technologies successfully mitigate emissions and to minimizing the risks to land, air, and water quality.

Economic Policy Recommendations

For export-oriented gas development projects, building legal, financial, regulatory, and technical expertise at the state level is critical for emerging producers to successfully negotiate complex contract structures and financing arrangements. For domestically oriented gas projects, detailed demand forecasting and analysis across the electricity, transport, and industrial sectors are key to ensuring the economic sustainability of new investments. Furthermore, careful analysis and dialogue at the state level are essential to shed light on domestic consumers' ability and willingness to pay cost-reflective rates for natural gas and related services. Advocacy organizations, donors, and governments may need to consider a variety of mechanisms to support affordable energy access for local communities.

AREAS FOR FURTHER RESEARCH

Risks and Challenges for Gas in the Global South

A large proportion of academic and policy-oriented research on natural gas tends to focus on European and North American markets, and to a lesser extent East Asian markets, highlighting a clear need for critical research that focuses on the specific risks and challenges for new producers in developing-country contexts. Recognizing that gas development takes place within an uneven global landscape, further research on the specific budgetary, governance, and climate challenges surrounding gas development in the Global South is critical.

Demand Forecasting and Analysis

More detailed demand forecasting and analysis are needed across the developing world, with particular attention to the social dimensions of changing demand and to the specific barriers to access and distribution in different global contexts. In addition to conventional, quantitative modeling techniques, in-depth qualitative analysis is essential to help explain the different ways that different communities use and understand energy.

Evolving Energy Planning Scenarios

The continuing evolution of smart-grid technologies, electric vehicles, and cost-effective electricity storage options may provide a broader suite of energy options for developing countries in the near future, warranting close attention and further analysis over the next 5 to 10 years.

OVERVIEW

GAS DEVELOPMENT IN THE GLOBAL SOUTH

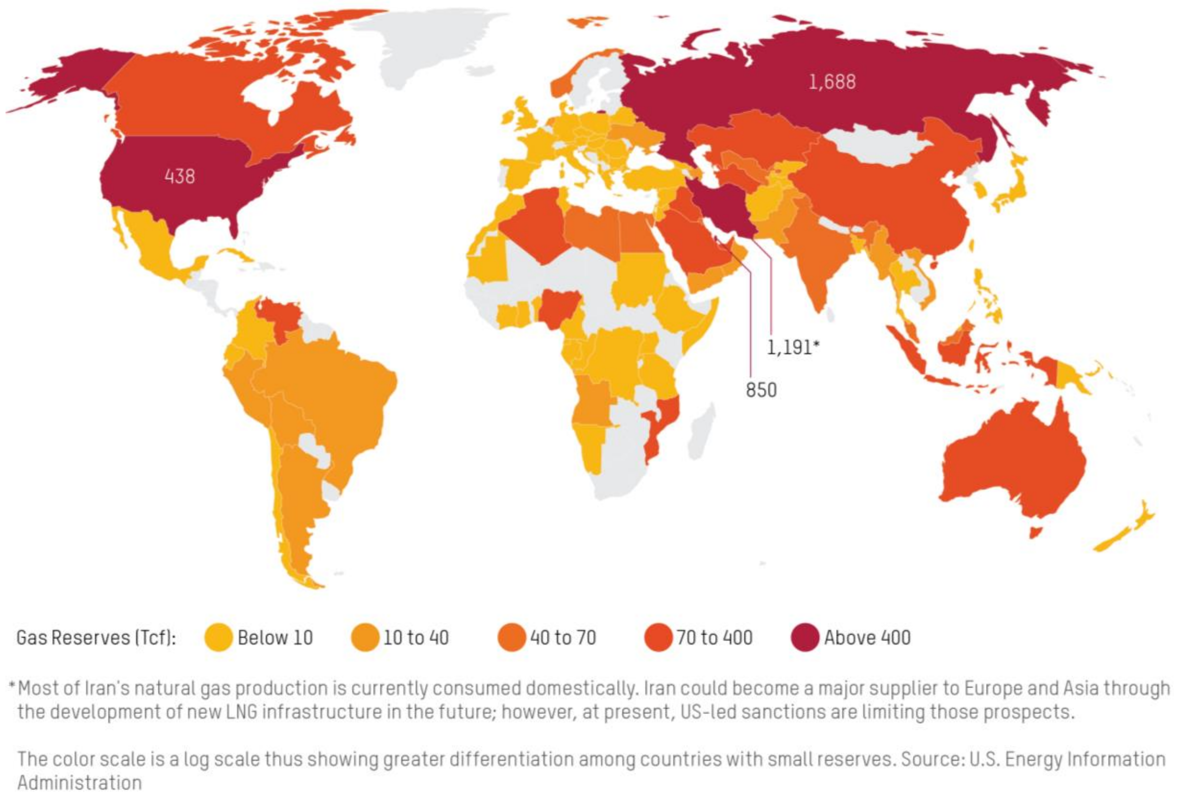
The potential for natural gas development to deliver lower-carbon, competitive, reliable fuel for economic growth has garnered attention from governments, private developers, and financial institutions around the globe. For countries in the Global South, developing domestic gas resources for export can provide a valuable source of revenue to support a variety of development goals, including alleviating poverty, creating new employment opportunities, and reducing the burden of public debt. Developing gas for domestic use can support a range of additional benefits, including reducing household energy poverty, lowering emissions from electricity and transportation systems, and stimulating economic growth and diversification. However, gas development poses serious social, environmental, and economic risks that threaten inclusive development and climate goals if not properly addressed. Furthermore, natural gas is but one option among an increasingly diverse array of energy choices for growth and development; for some countries, the risks of natural gas development may outweigh the potential benefits.

A key motivation for this report is to highlight the different considerations that attend natural gas production in developing countries. A large proportion of academic and policy-oriented research on natural gas tends to focus on European and North American markets, and to a lesser extent East Asian markets, highlighting a clear need for research that focuses on the specific risks and challenges for new producers in developing-country contexts. Recognizing the different risks and challenges in these contexts, this report outlines key infrastructural, institutional, and financing arrangements involved in natural gas development and examines how these arrangements intersect with development and climate priorities in the Global South.

Natural gas development efforts take place within an uneven global context, in which low-income countries face particular challenges to enjoying the full range of benefits from gas production. The combined impacts of public debt, constrained national budgets, and policies that limit institutional investment can make it difficult for countries to administer and oversee gas development projects. In addition, because technology and engineering firms are concentrated in high-income countries, the financial returns from gas investments in the Global South may flow primarily to external stakeholders. At the local and state levels, natural gas development efforts intersect with existing social dynamics, carrying the potential to deliver risks and benefits to different groups in different ways. In addition, resource deposits that cross national boundaries can become a source of cross-border conflict, particularly in regions where national borders are contested or not mutually agreed upon.

Within this uneven global landscape, natural gas markets are also rapidly changing. New gas-producing states in the Global South will have to compete with large, well-established transnational oil companies amid heightened global competition for gas supply contracts.

Figure 2: Estimated natural gas reserves by country



Source: Backspace 2019; source data drawn from USEIA 2019

FRAMEWORK AND RESEARCH QUESTIONS

Since 2010, falling global gas prices and increasing supplies have ushered in a so-called Golden Age of Gas (IEA 2012). This era is marked by significant changes in global gas market dynamics, with increasing cross-regional trade, the delinking of gas pricing from oil pricing, the growth of short-term gas contracts, and a shift toward modular solutions like floating liquefaction and regasification units for gas development.[2]

For developing countries with domestic gas resources, these changes have unlocked unique opportunities to foster local development, accompanied by unique risks. In addition to seeing natural gas production as a source of revenue, many developing countries see more favorable conditions for domestic gas distribution and gas-fired power generation. The benefits of domestic gas usage are well articulated. Reliable power is increasingly seen as a precondition for economic growth and industrialization. Many development actors have made gas a central part of their lower-carbon energy development strategies because gas combustion produces lower levels of greenhouse gas emissions, as well as lower levels of air pollutants like SO_2, NO_X, and particulate matter, than coal combustion does.[3] In addition, improving domestic gas distribution to displace biomass and diesel for heating, cooking, and transportation can reduce air pollution and improve human and environmental health, with potential ramifications for household energy poverty and gender equality.

Although the potential benefits of natural gas development are well known, the specific risks for developing countries tend to be articulated from the perspective of project investors and financiers. Accordingly, this research examines key risks associated with gas development, with particular attention to social, environmental, and economic risks for developing countries. In addition, although natural gas is frequently produced alongside oil, it operates through distinct physical, market, and institutional infrastructures, and this report provides an overview of these distinctive features. It focuses on the physical production, processing, transport, and utilization infrastructures as well as the institutional arrangements and financing structures that enable the development of natural gas for commercial use. The report examines what arrangements can best facilitate the development of natural gas as a tool to deliver equitable benefits to communities in the Global South.

The ultimate goal of this research is to provide a foundation for informed advocacy and future research to support natural gas production and use practices that do not threaten development and climate priorities. The report focuses on key risks and mitigation strategies, geared toward countries that have already invested in natural gas development. For countries considering future investment in domestic natural gas exploitation, this report is designed to highlight key social, environmental, and economic considerations to help governments, communities, and civil society organizations engage in dialogue

[2] Floating liquefaction, storage, and regasification units are modular systems that are constructed on ships, enabling them to float above offshore natural gas fields.

[3] For example, in June 2018 the multilateral electricity development program Power Africa announced a roadmap for developing 16,000 megawatts (MW) of gas-fired power in sub-Saharan Africa (USAID 2018).

and debate around whether natural gas development makes sense in their specific context.

NATURAL GAS IN TRANSITION

Types of Natural Gas

Like other fossil fuels, natural gas can be formed through the decomposition of organic matter under high pressure beneath the earth's surface over long periods of time. This type of gas, known as thermogenic gas, can typically be accessed only by drilling through the layers of rock that encapsulate the resource.[4] Natural gas can also be formed through biogenic processes closer to the earth's surface, where microorganisms break down organic matter, such as agricultural products or municipal waste, to produce biogas. This report focuses primarily on conventional, thermogenic forms of gas as the most likely resource types to be developed commercially in developing countries in the near future.[5]

Thermogenic gas can be found together with oil deposits (associated gas) or in its own deposits (nonassociated gas). The structure of the geological formations that encapsulate the gas determine whether it is considered “conventional” or “unconventional.” Conventional sources can be accessed using a variety of drilling techniques, whereas unconventional sources are typically accessed through hydraulic fracturing, which uses pressurized fluid to fracture rock formations and release natural gas. In its natural state, gas formations usually contain mixtures of methane and other hydrocarbons, which range from “dry” (containing mostly methane) to “wet” (containing other hydrocarbons such as ethane, butane, and propane).

The environmental and social concerns surrounding unconventional gas production are considerably more pronounced than for conventional gas, in large part because unconventional production requires large quantities of water. Problems surrounding the improper disposal of contaminated water produced as a byproduct of hydraulic fracturing (known as produced water), as well as groundwater contamination from faulty unconventional production and processing infrastructure, have raised serious environmental concerns.

[4] A “resource” refers to estimates of existing gas deposits, whereas “reserve” refers to the portion of those deposits that can be extracted using currently available technologies.

[5] Biogenic gas produced from landfills can provide a cost-effective source of energy for electricity production; in many developing countries, however, maintaining a consistent feedstock stream can pose a significant challenge. In addition, power generated from landfill gas has a higher levelized cost of energy (upward of US$0.15/kWh) than other renewable and conventional sources, making it a less likely source of power production in developing countries in the near future (IRENA 2018).

Associated

Associated gas is dissolved in oil deposits and recovered as a by-product of the oil extraction process. Historically, associated gas was often flared at oil production sites owing to a lack of developed markets and corresponding infrastructure for gas usage.

Nonassociated

Nonassociated gas reserves are sealed in porous, sedimentary rock layers underneath an impermeable rock layer. Nonassociated gas is typically 70–90% methane and may contain additional gases such as ethane, propane, butane, and carbon dioxide.

Conventional

Conventional gas is typically defined as geologic formations that permit gas to flow readily to the wellbore through drilling alone, without the need for additional mechanical stimulation.

Unconventional

Unconventional resources are trapped in geologic formations with low permeability that require mechanical stimulation, typically hydraulic fracturing, to create the flow of gas. Common types include shale gas, coalbed/coalmine methane, and tight gas. Unconventional gas production is currently concentrated in the United States, where shale gas comprises 70% of production.

Source: author

Natural Gas Uses

Natural gas has been used for lighting and heating for well over a century; however, the use of natural gas for electricity production, transportation, and industrial processes began to grow only with the build-out of extensive gas production, processing, and transportation networks in Europe and the United States beginning in the 1940s. For much of the 20th century, associated gas was less lucrative than oil and was consequently often flared[6] or reinjected into oil wells to stimulate further oil production. However, the expansion of commercial uses for natural gas and concern about climate change have increasingly led producers to invest in processing and transport infrastructure for marketing associated and nonassociated gas.

[6] Gas flaring is the practice of burning gas at production sites in order to relieve pressure.

Gas Trade in Historical Context

Until recently, natural gas trade took place predominantly within regional markets using long-term contracts negotiated between suppliers and buyers, who are also referred to as off-takers. These contracts traditionally included destination clauses, which restrict the delivery location, and take-or-pay clauses, which require buyers to pay for the amounts of gas specified in the contract even if actual demand levels vary (ICF International 2017). Designed primarily to protect producers, these clauses ensure stable financial returns to justify the high upfront capital costs associated with exploration and development. Historically, gas pricing was linked to oil pricing, but a growing number of gas markets are shifting to gas pricing delinked from oil (known as gas-on-gas pricing) with the rising consensus among investors that oil and gas should be treated as separate commodities. Countries with liberalized gas markets, where gas prices are not set by the government, often use regional hubs as a centralized pricing point.[7]

Under these historic conditions in which gas infrastructure was expensive, and limited supply meant little demand existed for interregional trade, gas exploration was limited to geographies with large supplies and significant demand, with highly restrictive contracts. Recently, however, major shifts have begun to unfold in global natural gas markets. Increasing global gas supplies, plummeting prices, and growing trade in liquefied natural gas (LNG) led to significant changes in pricing, contract structures, and trade routes, discussed below. LNG is produced by cooling and compressing gas into a liquid state so that it can be transported by ship to distant sites where it is regasified and fed into terrestrial distribution networks. LNG technology has been used commercially for more than half a century but requires additional capital-intensive production and transport infrastructure relative to traditional, land-based pipeline networks. Global LNG trade has grown substantially since 2010, as the emergence of new gas production techniques, surging global gas supplies, and falling prices have made LNG an increasingly attractive option for power generation and industrial production.

These changes come with new potential opportunities to effectively exploit smaller, fragmented, and previously uneconomical markets. While these changes have opened up new possibilities for gas producers and users, careful consideration must be given to the specific challenges that these changes present for developing countries. Notably, 50 percent of estimated global natural gas reserves are located in Iran, Qatar, and Russia (Holz, Richter, and Egging 2015). Global price convergence means that small developers will increasingly have to compete with established major market players, who benefit from economies of scale and extensive market knowledge and experience.

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[7] The most prominent hubs are the Henry Hub in the United States, the National Balancing Point in Britain, and the Dutch Title Transfer Facility (TTF).

Sub-Saharan Africa holds an estimated 7.1 percent of the world's natural gas reserves, while Asia and the Pacific holds an estimated 10 percent and South and Central America hold an estimated 4.2 percent (BP 2018). Currently, unconventional gas is concentrated in the United States, which holds 97.6 percent of the global market share of shale gas (IEA 2014). There are currently no major unconventional gas producers in the Global South; however, Algeria, Argentina, China, and Mexico have identified substantial, technically recoverable shale gas reserves (USEIA 2015).

RECENT DEVELOPMENTS IN GLOBAL GAS MARKETS

A Golden Age of Gas?

In 2011 the International Energy Agency (IEA) observed that growing gas supplies coupled with rising global energy demand and decreasing appetites for nuclear power could lead to a "golden age" for natural gas (IEA 2011). Natural gas was presented at the time as an important bridge fuel that could help reduce greenhouse gas emissions by displacing coal-fired power plants and enabling greater integration of renewable sources. Since then, demand growth has been slower than projected, and the surge in supply has dramatically reduced gas prices, slowing new natural gas infrastructure investments.

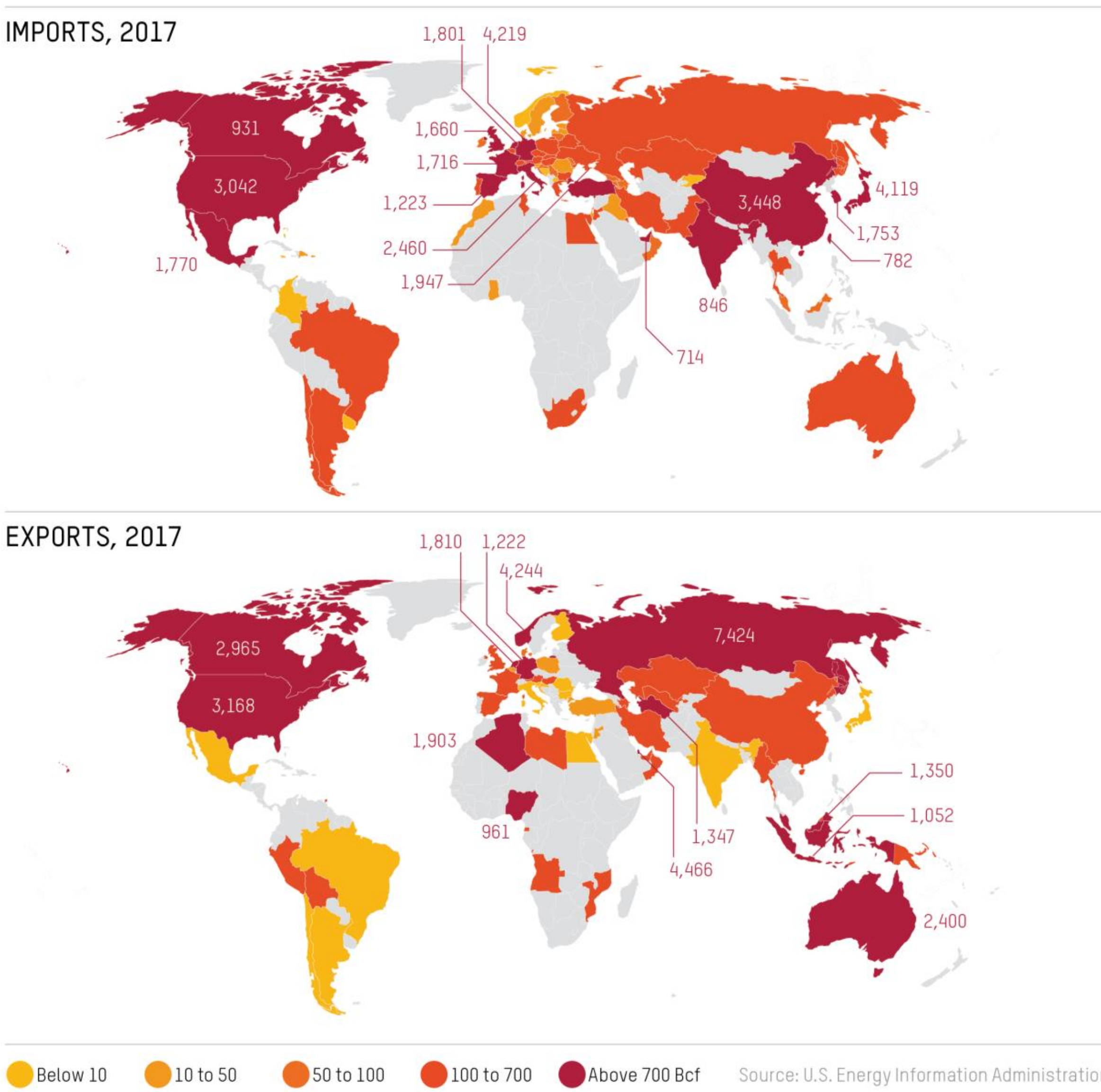
These shifts have led to significant changes in global gas markets. One prominent contributing factor is the transformation of the United States from a major importer to a rising exporter. The improvement and commercialization of unconventional drilling techniques led to a surge in unconventional gas production in the US beginning in 2010. In 2016 the US became a global exporter, and a growing number of US LNG facilities originally designed for import are being converted into export terminals.

Rising supplies from both Australia and the United States, coupled with slowing demand, caused a precipitous decline in gas prices, which fell to a record low of $3.35 per MBtu in 2016 (IEA 2017). This situation generated a rise in the construction of LNG import terminals in countries without domestic gas resources, as well as an increase in the number of market players seeking to take advantage of arbitrage opportunities in the global gas trade.[8] Globally, 33 countries now have LNG import facilities, and the number of LNG-receiving terminals has tripled since the early 2000s (IGU 2017). In 2015 alone, Egypt, Jordan, Pakistan, and Poland constructed new LNG import facilities, and

[8] Arbitrage is the practice of buying and selling commodities, in this case natural gas, in order to take advantage of price differences.

Bangladesh, Benin, Colombia, Ghana, and Uruguay appeared likely to enter the LNG import market in the following year (Grigas 2018). On the opposite end of the LNG spectrum, low prices dramatically slowed investment in new liquefaction terminals, as low prices made it difficult to recuperate the high capital cost of natural gas development (IEA 2017). At the end of 2018, global gas prices began to rebound, although price fluctuations are likely to continue (Wigglesworth and Meyer 2018).

Figure 3: Natural gas imports and exports in 2017



Source: Backspace 2019; source data drawn from USEIA 2019

Cross-Regional Trade and Pricing Changes

The global gas market is experiencing increasing liquidity[9] owing to the influx of US unconventional gas alongside Qatari gas that had been earmarked for the United States, then rerouted to Europe and Asia (IEA 2018). This gas glut has created a buyers' market, providing leverage particularly to growing Asian markets, which account for 57 percent of global LNG demand (Grigas 2018). Notably, Tokyo Gas Co. declared that it would no longer accept destination clauses in new LNG contracts in 2017, following Japan's Fair Trade Commission decision that these clauses were anti-competitive (Reuters 2017a). Consequently, purchasers like Tokyo Gas Co. could resell gas that they are contracted to purchase under a supply purchase agreement (SPA) and deliver it to a new location. US gas contracts have more flexibility because they are typically shorter term and do not have destination clauses or take-or-pay clauses. They thus provide the off-taker with the ability to resell unused gas (Grigas 2018; IEA 2017).

As contract structures change, efforts are also underway to establish new regional hubs in China, Japan, and Singapore (ICF International 2017). A hub serves as both a physical nexus and a financial platform that enables real-time gas trade and pricing based on gas supply and demand, delinked from oil prices. In 2016, 70 percent of gas sales in Asia still used oil indexation (gas prices were linked to oil prices); overall, however, the global trend is toward gas-on-gas pricing (delinked from oil), which has nearly doubled since 2012 (IEA 2017). The US Henry Hub is becoming an increasingly important reference point for global prices because US suppliers currently offer the most competitive prices globally (IEA 2017).

Some consultants argue that falling gas prices and increasing market competition create new opportunities for meeting fragmented demand pockets and mobilizing "stranded assets"—that is, reserves that have been identified but deemed too small or remote to exploit (Alverà, Carroll, and Marten 2018; Pereira and Wood 2017). Specifically, the growth of smaller-volume, shorter-term contracts and modular, floating production systems could make it easier for buyers in small or isolated demand pockets to access gas resources and for producers to commercialize previously stranded reserves. While falling prices and increasing contract flexibility create a favorable market for countries looking to import LNG, these shifts may also create potential challenges for new producers looking to secure long-term supply purchase agreements, a topic discussed further below.

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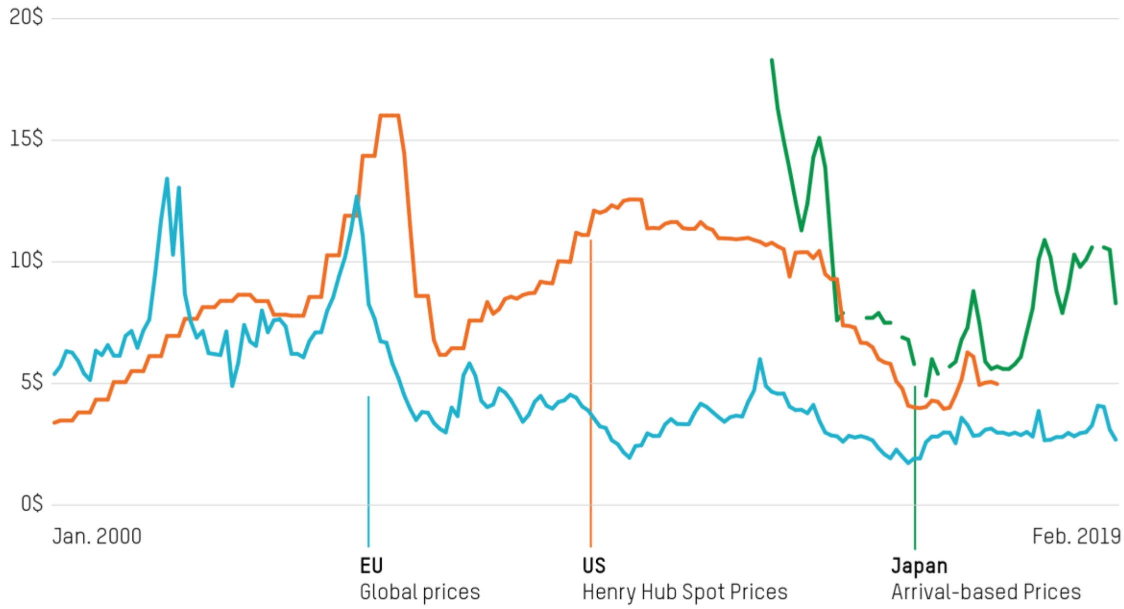
[9] Generally, this means that natural gas can be bought and sold quickly without dramatically affecting its price.

Figure 4: Global gas prices 2000-2019 (USD per MBtu)



Source: Backspace 2019; source data drawn from the US Federal Reserve Bank of St. Louis and Japan Ministry of Economy, Trade and Industry

Climate Context

Growing research on the life-cycle emissions of gas supply chains, particularly from unconventional sources, has called into question the potential for natural gas to serve as a bridge fuel (Boersma and Jordaan 2017; Howarth 2014; Howarth, Santoro, and Ingraffea 2011; Alvarez et al. 2012; Brandt, Heath, and Cooley 2016). A portion of this research focuses on calculating the greenhouse gas emissions from initial exploration and production to distribution and use, to determine whether natural gas in fact produces fewer greenhouse gas emissions than other hydrocarbon resources. A related portion of this research focuses on larger, systems-level questions about the potential for natural gas to serve as a bridge fuel to lower-emissions energy systems. While arguments mobilized in support of natural gas production often frame it as an attractive alternative to coal, for many countries gas development may not actually displace coal, but rather add to it. These systems-level questions warrant further dialogue and debate among governments, communities, civil society organizations, and industry at multiple levels, from that of global energy systems to the more situational context of individual countries and their major infrastructure decisions.

Methane is a highly potent greenhouse gases; because natural gas is composed mainly of methane, intended and unintended leaks along the gas supply chain constitute a significant climate risk associated with natural gas development. Delivering on the Paris Agreement means that individual countries will have to begin reducing hydrocarbon consumption in line with their nationally determined contributions (NDCs) by 2045 (Bradley, Lahn, and Pye 2018). This calls into question whether countries seeking to bring new resources online within the next decade will have sufficient time to recoup their new investments before the ramp-down period. Investors in natural gas development should consider the potential impact of countries' commitments in line with their NDCs under the Paris Agreement. For example, Ghana, Kenya, Tanzania, and Uganda have made initial commitments to increasing renewable energy use, reducing fossil fuel subsidies, strengthening air quality regulations, diversifying national energy mix, and promoting clean household lighting and cooking fuels (Bradley, Lahn, and Pye 2018). In a parallel vein, national-level climate planning efforts should account for gas development efforts that are currently underway. The Oxford Institute for Energy Studies notes that current NDCs do not clearly show whether and how natural gas fits into countries' greenhouse gas reduction and air quality improvement efforts (Stern 2017), including whether natural gas is used to balance the integration of renewable sources or offset the intermittent nature of renewable generation.

In addition to formal commitments through the NDCs, a number of voluntary efforts are underway, such as the Oil and Gas Climate Initiative, to curb emissions from the oil and gas industry. Notably, the Climate and Clean Air Coalition works in partnership with industry, multilateral, and governmental entities to reduce short-lived climate pollutants including methane. Within the Climate and Clean Air Coalition, the Oil and Gas Methane Partnership focuses specifically on reducing methane emissions from the oil and gas industry.

To ensure that new gas investments do not conflict with climate priorities, gas development efforts will need to be aligned with these mandatory and voluntary commitments. It must be emphasized, however, that gas is still a nonrenewable, hydrocarbon resource that contributes to anthropogenic climate change. Even in the best-case scenarios, where new gas infrastructure is brought in line with NDC commitments and held to high standards of accountability on emissions monitoring and reduction, this infrastructure will contribute unequivocally to greenhouse gas emissions.

At the national level, legislators, administrators, and communities involved in energy planning must carefully consider the trade-offs that gas development brings. On the one hand, natural gas development can contribute to national energy security and affordable energy access, facilitate greater renewable power integration, attract foreign investment, and potentially support national development goals. On the other hand, natural gas development will contribute to climate change and to new climate-linked social and environmental vulnerabilities that may counteract many of these goals. In addition, many of the gas fields currently under development in the Global South will be fully exploited within 20 to 30 years and will thus not provide a long-term solution to these challenges.

For some new gas producers in the Global South, offshore gas infrastructure may also damage coastal mangrove habitats, which are extremely important, carbon-rich ecosystems. Mangrove forests naturally sequester carbon dioxide, meaning that new gas developments in these ecosystems not only add greenhouse gas emissions but also damage a critical source of organic carbon capture and storage (Hutchison et al. 2014).

This trade-off presents particular challenges for many countries in the Global South that face serious risks related to climate change even though they have historically contributed little to its anthropogenic sources. The increase in severe weather events linked to climate change, such as storms, floods, and droughts, is likely to disproportionately affect socially and economically vulnerable communities in the Global South (Roy et al. 2018). These events are anticipated to have wide-ranging, deleterious impacts on human communities, food systems, and ecosystem health and may also put infrastructure (including new gas infrastructure) at greater risk of unintended malfunction and breakdown.

PROJECT STRUCTURE AND LIFECYCLE

Natural gas development is a complex process involving a large number of stakeholders, and development trajectories differ from country to country, depending on the institutional and regulatory environment and individual project decisions. The following sections describe broad considerations for common project structures and lifecycles.

From Exploration to Use: A Quick Primer

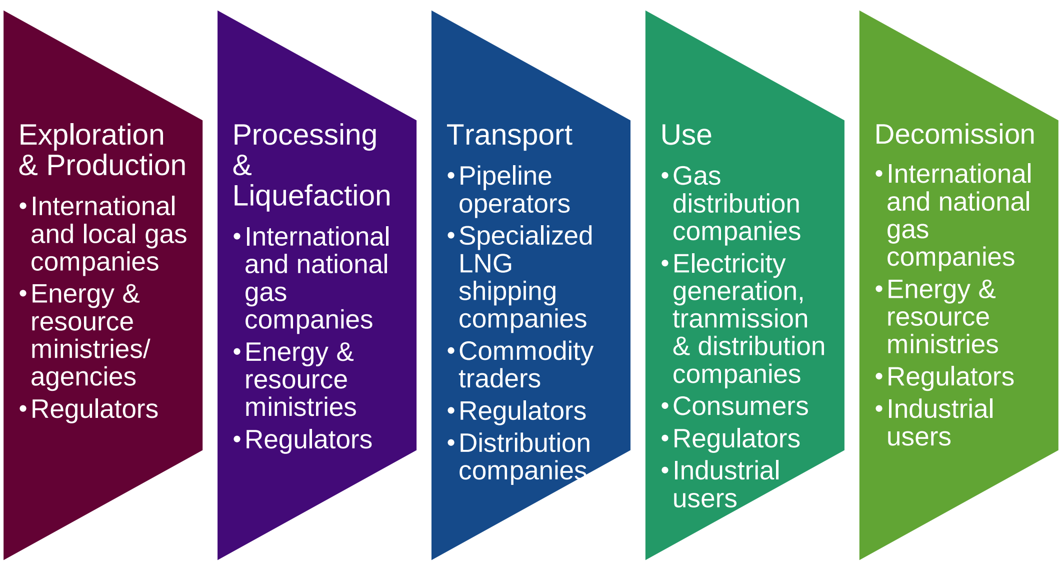
In broad terms, natural gas development begins with exploration and production (Figure 5). Because of the highly technical, capital-intensive nature of these activities, they are typically led by international oil and gas companies in partnership with local gas companies and national energy governance bodies. Once production begins, the raw natural gas must be processed and prepared for transport or converted to LNG. Processing and liquefaction plants may be owned by the producers or by separate international or national gas companies. The gas can then be transported regionally or delivered to domestic markets through pipeline networks, which are typically owned and operated by separate gas distribution companies. If the natural gas is liquefied, it can be transported on specialized LNG carriers, which are typically owned and operated by separate

LNG shipping companies and chartered or leased to LNG producers for transport.[10]

The primary options for gas use include utility-scale power production, household heating and cooking, transportation, and the creation of industrial products, particularly fertilizers. For many developing countries, domestic use requires the build-out of new gas transportation and distribution networks and coordination with a large number of additional stakeholders, including independent power producers, electricity grid operators, and industrial processors.

Financing plays a critical role in the opportunities and risks posed by gas development. Given the high capital costs of natural gas production, off-take agreements are key to determining the financing arrangements and the corresponding infrastructure to be developed. Although there are clear parallels, developing gas for export and developing gas for domestic consumption follow different infrastructural, institutional, and financing trajectories. The trade-offs between developing gas for export or for domestic consumption are complex and will be discussed further in the section on risk analysis and policy recommendations. Many countries pursue a combination of export- and domestic-oriented strategies; the following sections differentiate between these two trajectories in order to articulate their differential requirements and benefits and help host-country governments consider their options.

Figure 5: Key steps and actors in the gas supply chain



Source: author

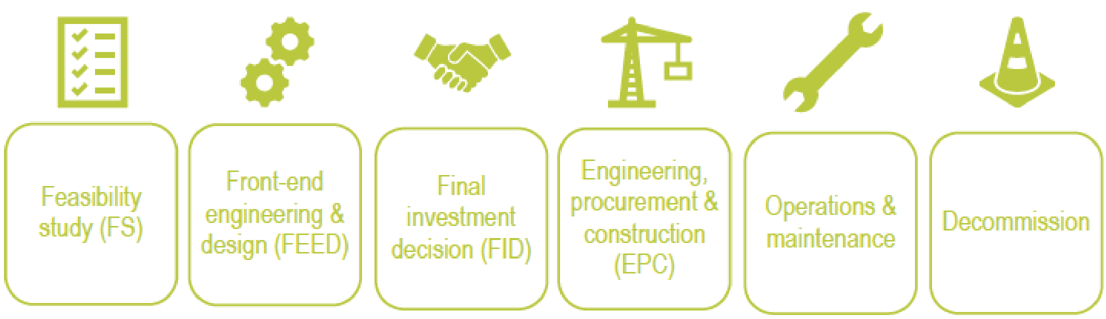
[10] Currently, there are 460 active ships with an average size of 160,000 cubic meters. The largest vessels available are the Qatari-made Q-Flex and Q-Max (210,000–266,000 cubic meters). In addition, Panamax is a special class of carriers designed to pass through the Panama Canal (Grigas, 2018).

Infrastructure Project Lifecycle

Most major infrastructure projects, including public and private gas infrastructure, are developed through the steps outlined in Figure 6. The length, cost, and complexity of each step vary with the nature of the project, which will be discussed further throughout the report. Most infrastructure projects follow this planning process to complete key requirements to obtain permits, approvals, and financing. From a regional or national perspective, planning often involves coordination among multiple simultaneous projects at various stages of this process. One of the key leverage points for many communities affected by natural gas development is at the front-end engineering and design (FEED) stage, which typically includes a full environmental and social impact analysis (ESIA).

In general terms, the feasibility study outlines the contours of the project and includes the following elements: technical analysis, preliminary cost and revenue generation estimates, financing and investment plan, and preliminary ESIA. The FEED contractor then conducts detailed design and technical analysis, often determining the specific architectural and engineering features of the project. The engineering, procurement, and construction (EPC) contractor then implements the design outlined in the FEED and manages the procurement and construction process. The project owner, or in some cases the EPC contractor, then assumes ongoing operations and maintenance.

Figure 6: Key steps in the infrastructure development lifecycle



Source: author

One of the most important steps to consider in infrastructure project planning is the final phase of decommissioning. While the productive period for extracting natural gas may last only a few decades, the infrastructure built to support gas extraction often lives on for many decades after developers have moved on to new fields. If not properly decommissioned and dismantled, natural gas infrastructure can pose serious health and environmental risks long after the extraction boom. The importance of this step is too often overlooked and deserves careful consideration during initial planning stages to ensure that proper regulation, oversight, and accountability mechanisms are put in place.

DEVELOPING GAS FOR EXPORT

Many governments and multilateral development institutions frame the development of natural gas for export as a way to encourage foreign direct investment and create a public revenue stream from royalties and taxes to support broader economic growth and development. This section examines the infrastructural, financing, and institutional arrangements involved in developing gas for export as outlined in Figure 7 below, with the general proviso that questions of transparency, accountability, and citizen empowerment should be addressed at each stage of the development process. For governments, civil society organizations, advocacy groups, and community-based organizations working in partnership with industry and investors to advance development and goals, the following list outlines key pressure points along the gas supply chain:

1. *LNG versus pipeline export*: For developing countries with potential to export natural gas, LNG provides greater flexibility to export to a variety of different markets, while pipelines tend to be more cost-effective. Capital costs and energy inputs tend to be higher for LNG export, but the flexibility that it provides has made it more attractive than regional pipelines for many developers and investors.

2. *Project structure*: During the planning and design of LNG export projects, developers and investors must work collaboratively with host-country governments to determine an appropriate structure (integrated commercial, merchant, or tolling). Details on the format and allocation of risk within each of these project structures are provided in the section below.

3. *Environmental and social impact analysis (ESIA)*: For many infrastructure projects, the ESIA completed during the front-end engineering and design phase represents an early opportunity to voice concerns and work collaboratively to address potential social and environmental risks that attend the gas development project. ESIAs conducted by an independent entity are typically required by financiers before financial closing; thus they can be a mechanism for ensuring that social and environmental concerns are brought to the attention of project stakeholders.

4. *Final investment decision (FID)*: The FID also represents a potential pressure point for communicating concerns directly to investors and financiers. Investments involving public finance entities and international financial institutions sometimes provide direct avenues for civil society input; in other cases, civil society and advocacy organizations can sometimes use alternative avenues, such as targeted media campaigns, to raise investor awareness.

5. *Climate concerns during production*: Recent research on fugitive emissions during production shows that methane leakage is likely much higher than estimates from the US Environmental Protection Agency (EPA) suggest, owing to unintended leaks and equipment malfunctions. About 40 percent of these emissions can be managed using cost-effective leak detection and repair equipment if proper regulation, enforcement, and oversight mechanisms are in place. Voluntary corporate methane reduction commitments, such as through programs like the Climate and Clean Air Coalition, may provide an additional lever for reducing emissions. Nevertheless, even with proper monitoring and regulation, gas production will contribute to climate change through both intended and unintended greenhouse gas emissions.

6. *Gathering and processing*: For both onshore and offshore gas production facilities, limitations in the infrastructure for gathering and processing gas can create bottlenecks in the supply chain, with problematic environmental and economic ramifications.

7. *Modular, floating solutions*: Lower-cost floating liquefaction, storage, and regasification units are gaining attention as a promising option for developing countries with limited financial resources. However, the particular geography and geology of the resource may have consequences for the cost of production.

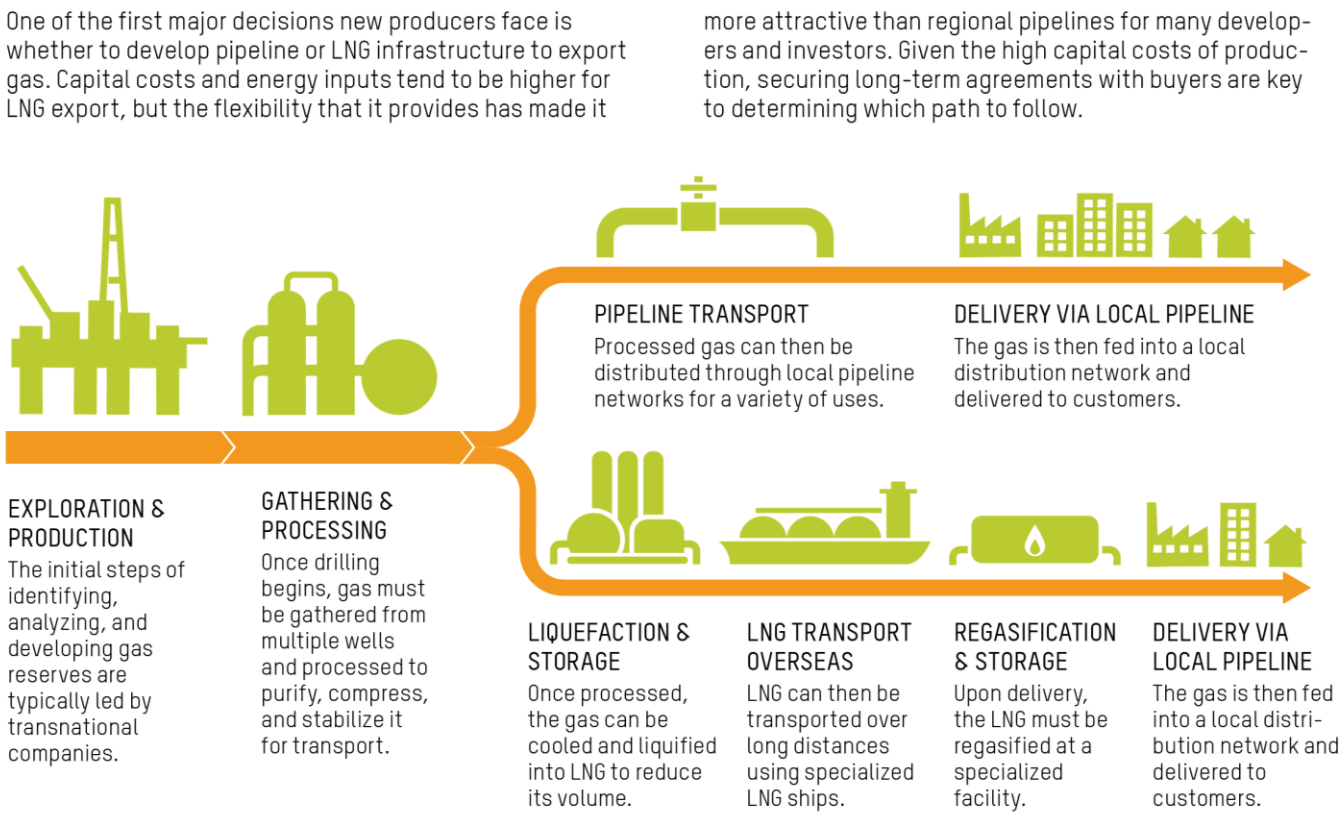
Once host-country stakeholders and commercial partners agree to move forward with developing gas for export through LNG, they must determine an appropriate project structure. Currently, there are three prevailing structures for such projects: integrated commercial, merchant, and tolling. Tolling structures are most commonly used in the United States, whereas integrated commercial structures are often used in developing gas markets.[11] The legal and regulatory frameworks that accompany each of these structures depend on the specific host-country context.

1. *Integrated commercial structure:* In this arrangement, exploration and production activities are integrated with the LNG liquefaction and export facilities under the same owner (USEA 2018). Before beginning production, the owner negotiates off-take agreements with prospective LNG buyers; credit from these off-takers then provides the foundation for financing upstream and midstream gas development activities. The majority of the financial risk is assumed by the integrated project owner (typically a special purpose vehicle), and this risk is typically ameliorated through long-term gas sales agreements that ensure a steady revenue stream over a 20- to 25-year period.

[11] Additional information on the agreements associated with each of these structures can be found in the Power Africa/US Department of Energy report *Global LNG Fundamentals* (USEA 2018).

2. *Merchant structure:* In a merchant structure, LNG liquefaction facilities are owned and operated by an entity separate from upstream producers, and the LNG facility typically purchases gas from upstream producers under long-term supply purchase agreements (USEA 2018). The LNG facility then resells this gas (in liquefied form) to international buyers under long-term off-take agreements. The projected revenue from these agreements provides the basis for securing financing for the capital costs of developing the LNG facility. The financial risk is divided between the upstream producers and the LNG facility developer.
3. *Tolling structure:* In a tolling structure, the LNG facility is also owned and operated by a separate entity from the upstream producers; however, the LNG facility does not purchase gas directly from producers. Instead, the gas is purchased by a separate buyer or aggregator who then pays the LNG liquefaction company a tolling fee for the use of their facilities (USEA 2018). The tolling fee typically has a two-part structure consisting of a fixed monthly payment and a variable payment linked to actual cargo loads. In this scenario, the buyer's credit provides the foundation for securing financing. This structure reduces risk for LNG facility owners; instead, the LNG producers and buyers assume a greater portion of the financial risk associated with fluctuations in gas prices and supply or demand.

Figure 7: Developing gas for export: pipeline vs. LNG



Source: Backspace 2019

INFRASTRUCTURE

Upstream: Exploration, Production, and Processing

Process and Components

Exploration, the first stage in the development process, begins with initial geological assessments and seismic surveys that are typically undertaken by international oil and gas companies in partnership with local gas companies and national bodies. After obtaining appropriate leases and permits, the developer begins pre-production activities. These activities include preparing the site (clearing and preparing well sites, constructing access roads, preparing gathering facilities), drilling exploratory wells, and conducting more sophisticated geological surveys, production tests, and 3D seismic imaging of the resource in order to develop accurate estimates of reserves and field flow rates (USEA 2018). Pre-production activities are undertaken simultaneously with the development of financing and contractual arrangements with the gas off-taker; typically, a final investment decision is made before the developer proceeds with production (USEA 2018). Before finalizing investment, most financiers also require reserves to be certified by an independent engineering firm specializing in petroleum certification.

Production may include both vertical drilling and horizontal drilling (also known as directional drilling), which enables the surface well to branch out in multiple directions underground. For unconventional resources, exploration and production are ongoing, intertwined processes because new imaging and drilling are needed continually throughout production. For both conventional and unconventional resources, the well completion process includes the installation of tubing systems, pressure control valves, and casings to strengthen the well and prevent gas and fluid leakage. The developer must also construct a gathering system, or small pipeline network, linking the production wells to the processing facility.

Offshore resource development requires significant additional infrastructure, including an artificial platform, a marine rise that houses the drill bit, and a drilling template, which is secured to the seafloor and ensures accurate drilling while allowing for the natural movement of the platform in the water. Artificial platforms can be either permanent or movable, depending on the size, depth, and anticipated value of the reserve. Movable platforms are the most common and include submersible and semisubmersible rigs (including floating production systems) and drillships. Permanent platforms are much larger and more expensive, so only sizable reserves justify the investment.[12]

Processing is required in order to prepare raw natural gas for pipeline transport or liquefaction by removing all non-methane components, which can include water; natural gas liquids like ethane, propane, and butane; carbon dioxide; sulfur; hydrogen sulfide; and mercury (USEA 2018). Processing typically takes place close to production at both onshore and offshore sites. The raw gas is heated to prevent the formation of hydrates (which can block the flow of gas), then cooled. Any liquids are separated out in a process known as liquids unloading. The gas may go through additional treatments, known as sweetening, particularly if it contains hydrogen sulfide (sour gas). The hydrogen sulfide can be further reduced through catalytic reactions to elemental sulfur, which can be sold as a by-product. In addition, processing and distilling natural gas liquids can provide a valuable additional revenue stream. Finally, the gas is stabilized and compressed to prepare it for transport via pipeline or liquefaction.

[12] Common types of permanent platforms include compliant tower platforms with flexible legs, seastar platforms with tension leg systems, and spar platforms with a large cylinder secured with cables (NGSA 2013). More detailed cost information appears in the section on financing.

Timeframe and Project Cycle

Preparation for exploration and production can take three years or more. Once preparation activities are complete, production can continue for several years to several decades, depending on the size of the reserve (USEA 2018). As noted, the technical exploration process typically occurs alongside financing and contractual negotiations. To ensure a viable return on investment, investors typically look for 15–20 years of plateau production, particularly for capital-intensive LNG projects (USEA 2018).

Emissions Profile and Mitigation Strategies

Recent efforts led by multiple research teams estimate that fugitive emissions during the production process are substantially higher than official projections, owing in large part to the skewed distribution of abnormally operating facilities known as super emitters (Alvarez et al. 2018; Brandt, Heath, and Cooley 2016). This means that a small number of facilities emit a disproportionately high level of emissions, often because of equipment malfunctions, which have an outsized impact on overall emissions and are not captured using traditional measurement approaches. Recent research published in *Science* suggests that methane emissions are approximately 60 percent higher than previous EPA estimates (Alvarez et al. 2018). About 40 percent of these fugitive emissions can be managed through cost-effective monitoring and leak detection and repair technologies and practices. However, clear regulation, effective monitoring and oversight capacity, and robust measurement methods that account for abnormal distributions are critical to ensure the effective deployment of these strategies.

Midstream: LNG Liquefaction, Shipping, Regasification, and Storage

Process and Components

In its most basic form, LNG production involves three steps: first, the gas is treated to remove any residual impurities such as mercury, particulate matter, and hydrogen sulfide; next, it is dehydrated; finally, it is fed through multiple parallel chilling trains, or linked chilling units, where it is cooled to −162ºC (−260ºF) and reduced to 1/600th of its original volume. Individual liquefaction trains currently have an average size of 5 million metric tons per annum (MTPA), with the largest trains (7.8 MPTA) located in Qatar. According to a recent report, all liquefaction facilities around the globe use one of two technologies developed in the United States: the Cascade process developed by ConocoPhillips or the C3MR process developed by Air Products (USEA 2018).

Once LNG reaches its destination, it must be offloaded and returned to a gaseous state through an LNG import terminal, which typically contains docking facilities for the LNG carrier, cryogenic storage tanks, and regasification facilities.

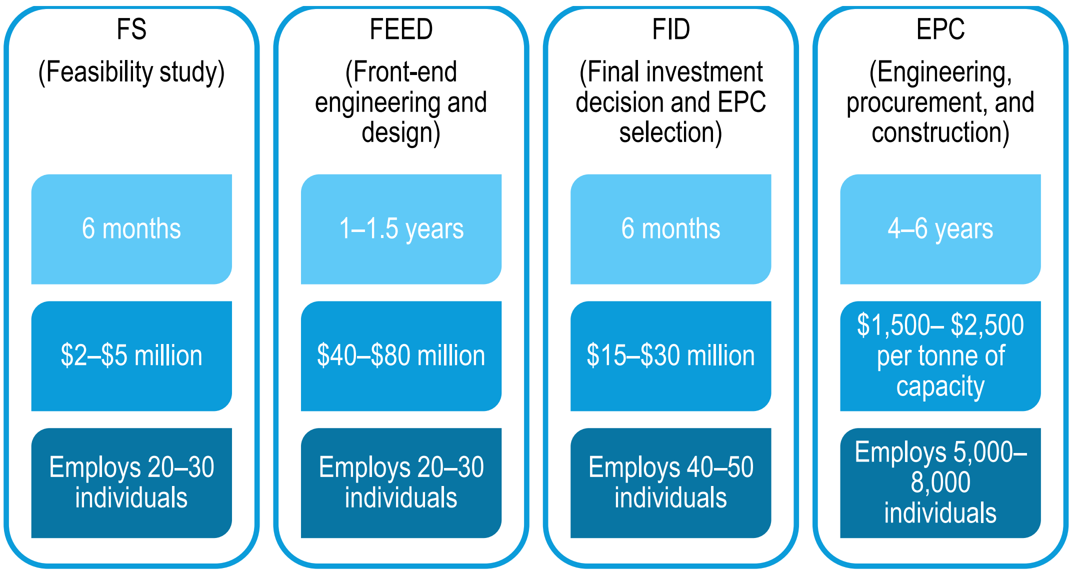
Regasification typically takes place by means of seawater heat exchangers, which gradually reheat the gas under high pressure (Grigas 2018).

Underground gas storage can be used to supplement cryogenic storage facilities at LNG import terminals. Underground storage can be used for either LNG or piped gas and is typically developed by converting depleted oil and gas reservoirs, aquifers, or salt caverns. Developing existing oil and gas reservoirs for storage is relatively inexpensive and straightforward; in contrast, developing salt caverns to serve as storage facilities entails high up-front capital costs but lower lifetime extraction costs.

The primary function of gas storage is undergoing a shift. Whereas underground natural gas storage facilities were historically owned and operated by local gas distribution companies to ensure a consistent supply, they are now increasingly held by merchant operators as a way to take advantage of rapid pricing changes or arbitrage opportunities (DOE 2015).

Timeframe: Even in the best-case scenarios, LNG projects take approximately 6–10 years to execute, depending on the type of reserve (conventional or unconventional, associated or nonassociated, onshore or offshore), the size of the reserve, and its proximity to existing infrastructure (USEA 2018). Figure 8 shows the key steps required to develop conventional reserves (USEA 2018). Each stage depicted in this figure typically involves some form of regulatory or government oversight, depending on the country context and the nature of the project. These regulatory requirements can include permits from energy or mineral resource ministries, legal and regulatory approvals from energy and utility regulators, land leasing agreements or concessions from land agencies or ministries, and finance ministry approvals.

Figure 8: Timeframe and cost estimates for LNG development phases



Source: author

Emissions profile and mitigation strategies: LNG liquefaction and transport are more energy intensive than pipeline transport. For comparison, about 7 percent of gas transported via pipeline from Russia to Europe is used to power compression stations to maintain pressure and flow; transportation via LNG requires about 13 percent of the gas to be used to power the liquefaction, transport, and regasification processes (IEA 2017). In addition, temperature fluctuations during LNG transport can cause a portion of the liquefied gas to evaporate (producing what is known as boil-off gas), adding to the total emissions profile. Key mitigation strategies include continuous monitoring and leak detection and repair throughout the liquefaction and regasification process. In addition, maintaining stable temperatures during transport can help minimize boil-off emissions.

Recent shifts in contract structures may also increase LNG emissions, as a growing number of buyers push for the removal of destination clauses in LNG supply agreements. This change means that LNG can be resold by the off-taker and potentially travel to a new destination, adding to total boil-off emissions. For example, unused shipments from Australia to Japan could hypothetically be resold to China, adding to total transport emissions.

Modular LNG Solutions

Floating storage and regasification units (FSRUs) are receiving growing attention as a cost-effective, flexible alternative for countries looking to import LNG, particularly for developing countries with limited financial resources. FSRUs can be built at an average cost of $240–$300 million and a construction timeline of

27–36 months for new facilities or 12–18 months for LNG carrier conversions—half the time and half the cost of traditional regasification facilities (Songhurst 2017). Over the past decade, 23 FSRU terminals have been constructed, with capacities ranging from 2.9 to 5.8 MTPA. The majority of these facilities are converted LNG carriers with an added high-pressure gas export arm and a heat exchanger to vaporize the gas. Heat exchangers are designed with either an open-loop system using seawater or a closed-loop system using fresh water/glycol. These systems consume 1.5 and 2.5 percent of the gas, respectively; these rates are comparable to onshore systems (Songhurst 2017).

The FSRU industry is dominated by three main companies: Excelerate Energy (United States), Golar LNG (Norway), and Hoegh LNG (Norway); however, there have been a number of new entrants in recent years, including MOL (Japan), BW Gas (Norway), and Maran Gas (Greece) (Songhurst 2017). In contrast to onshore LNG regasification terminals, which are typically structured using the merchant, tolling, or integrated commercial structures outlined in the Overview section, FSRUs are typically leased from one of these companies on a day-rate basis ranging from $130,000 to $205,000 a day. Because FSRUs are constructed on a modular basis, there is limited opportunity for local job creation during construction.

Floating LNG (FLNG) is also receiving growing attention as an option for small or remote deposits that might not justify the high cost of onshore liquefaction facilities. The report *World Energy Outlook 2017* describes FLNG as a "nascent" technology, given that only one FLNG is currently operational (IEA 2017). While the technology appears promising, there are lingering concerns over higher insurance costs and how FLNG plants may fare in different ocean environments (Lo 2014). In addition to Mozambique LNG, three FLNG facilities are currently under development: the Prelude off the coast of Australia, the Kribi gas field off the coast of Cameroon, and the Fortuna FLNG off the coast of Equatorial Guinea. For new FLNG facilities, critical attention should be given to the requisite gathering and processing infrastructures. FLNG developments like the Prelude, for example, are designed to produce and gather gas from multiple small fields for processing and liquefaction aboard the facility; a lack of adequately planned and monitored gathering infrastructure could potentially lead to bottlenecks in production, resulting in venting or flaring.

In recent years a small number of floating storage units—converted from LNG tankers—have also been deployed in Jamaica, Malaysia, and Malta. These units provide a cost-effective storage option, particularly in regions where onshore storage is expensive or technically challenging (Songhurst 2017).

Investors and developers herald modular, floating options as market game-changers in that they have the potential to commercialize previously "stranded" reserves and to open up markets previously considered too small or remote

(Stern 2017). However, the lower capital expenditures and shorter timelines associated with modular construction can be outweighed by higher delivery costs and specialized equipment needs. A report from the Oxford Institute for Energy Studies notes that for some islands in the Caribbean, low demand volumes and the high cost of specialized equipment have nearly doubled unit gas delivery costs (Stern 2017). Such concerns are relevant not only to FSRUs, but also to FLNG projects.

Midstream: Pipeline Transport

Process and Components

Pipeline transmission networks are composed of coated steel transmission pipes, valves, compressor stations, and metering stations. Compressor stations are placed at regular intervals along the pipeline to maintain pressure and are typically powered with gas from the pipeline itself. The network is monitored through a supervisory control and data acquisition system, which typically draws data through the metering stations.

Theoretically, pipeline export networks are technically simpler, more efficient, and often cheaper to construct than LNG infrastructure. However, pipelines are geographically fixed, making them increasingly unattractive in an era marked by uncertain demand fluctuations, price volatility, and changing market norms. As a result, few transnational pipeline projects are currently under consideration, with the exceptions of the Turkish Stream (Russia to Turkey), TANAP/TAP (Azerbaijan to Turkey), the Power of Siberia (Russia to China), and the Nord Stream II (Russia to Germany) (Stern 2017). Since 2010 the global gas glut, low gas prices, and the growth of global LNG trade has put competitive pressure on landlocked, isolated gas-producing states like Kazakhstan, Turkmenistan, and Uzbekistan, as potential buyers look to more affordable sources. Consequently, the prospects for pipeline growth to increase export capacity in the Caspian and Central Asian regions is likely limited for the foreseeable future (Grigas 2018).

Overall, for developing countries with the potential to export gas via pipeline or LNG transport, pipelines tend to be more cost-effective while LNG provides greater flexibility. However, the specific geographic location of the resource, the existing infrastructure, and demand levels in surrounding countries all heavily influence whether regional pipelines are good investments. LNG export tends to demand higher capital costs and energy inputs, but the flexibility it provides has made it more attractive than regional pipelines for many developers and investors.

Timeframe

Pipeline developments follow the same trajectory as LNG developments: an initial feasibility study and pre-FEED evaluations; the FEED stage, including a full environmental and social impact analysis (ESIA); and then the EPC stage. Each of these steps can take six months to a year or more. Moreover, the timeline for developing transnational pipelines is often protracted by negotiations between producing and receiving countries and may also be affected by disputes over land rights.

Emissions Profile and Mitigation Strategies

Within natural gas pipeline networks, compressors are significant sources of emissions. The report *World Energy Outlook 2017* notes that methane emissions along gas pipeline networks are challenging to monitor, given the long distances covered by these networks. Moreover, the report finds that even with modern equipment, it is impossible to eliminate emissions from compressors on long-distance pipelines; with the technologies currently available, it is possible to reduce downstream vented methane emissions only by 25 percent (IEA 2017).

INSTITUTIONS

Traditionally, gas development was led by international oil and gas companies in partnership with local and national bodies, and regional markets were developed in relative isolation. Accordingly, the primary institutions involved in developing gas for export were national energy and mineral resource ministries or agencies, private companies, and regulatory agencies. With the expansion of LNG and growing cross-regional trade, institutional configurations are becoming increasingly complex, involving a growing number of commodity traders, investors, and off-takers. Regulatory environments are growing more complex as well, with the increasing production of unconventional sources, changing technologies (particularly for modular solutions), and more complex financial transactions.

Key Trends

Two key institutional trends in the natural gas sector warrant further analysis. First, within the global LNG trade, aggregators are playing a growing role. Aggregators, or “portfolio players,” like Shell, Total, and BP have begun contracting large volumes of LNG from other producers (beyond their own production) to resell globally (IEA 2017). Wood Mackenzie further identifies Trafigura, Vitol, Gunvor, and Glencore as portfolio players that have shaken up the industry as they have quintupled their LNG traded volumes since 2012 (Wood Mackenzie 2018). While this arrangement may mitigate risk for producers and consumers, it has made contracting gas an increasingly complex financial process that is no longer dominated by direct, long-term contractual relationships between suppliers and buyers. This reality raises important questions about the regulation and oversight of these transactions, as gas trade increasingly involves a greater number of actors and complex transactions across longer geographical distances and supply chains.

Second, South-South cooperation is growing as both China and India increase their investment and technical engagement in upstream and midstream activities, particularly in sub-Saharan Africa. For example, Oil India, ONGC, Bharat PetroResources, and CNPC are prominent partners in the Mozambique LNG project, providing investment, technology, and engineering services. While China's investments in natural resource development in Africa have come under heavy scrutiny in recent years in policy circles, growing South-South cooperation is a key driver of energy transitions and a distinctive arena of shifting global energy politics (Power et al. 2016). New producers can potentially choose from more sources of investment that provide different financing terms and conditions. They may, however, face challenges in evaluating the risks and benefits of these different investment sources.

Key Actors

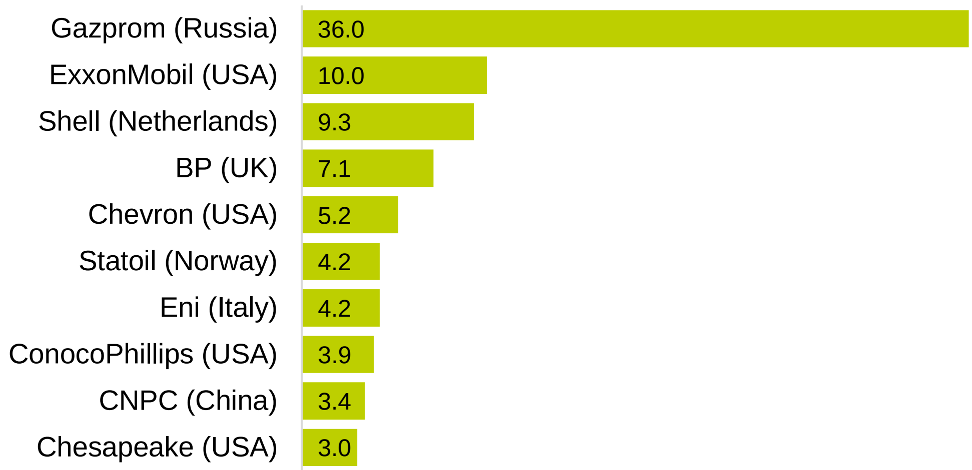
National and International Gas Companies

Private and state-owned companies continue to play a central role in natural gas exploration and production. The 10 largest international gas companies produce about 30 percent of the global gas supply, with estimated production exceeding 80 billion cubic feet per day (Figure 9) (Carpenter 2018; Rapier 2016).

The LNG shipping market is highly concentrated, with the top 11 companies owning nearly half of the entire global fleet and shipping capacity. Key players include Teekay (Bahamas), Qatar Gas (Qatar), MOL (Japan), NYK Line (Japan), Maran Gas (Greece), Gaslog (Monaco), Dynagas (Monaco), K Line (Japan), BP (UK), and BW Gas (Bermuda) (Thomas 2017).

The market for LNG EPC services is also highly concentrated; it is dominated by a small number of transnational engineering firms, including Bechtel (US), CB&I (US), Technip (France), KBR (US), Foster Wheeler (UK), JGC (Japan), and Chiyoda (Japan) (Songhurst 2014).

Figure 9: Leading global gas producers (billion cubic feet produced per day)



Source: Carpenter, 2018.

Investors and Financiers

Active investors and financiers in the natural gas market include international commercial banks, domestic banks, export credit agencies, and multilateral development banks. The export credit agencies of multiple countries, including the Export-Import Bank of the United States (US Ex-Im), the Japanese Bank for International Cooperation, the Export-Import Bank of China, and the Export-Import Bank of Korea, provide low interest rates and are increasingly active in the natural gas sector.

Export credit agencies are often designed to support domestic economic growth through the exports of goods and services, and thus play a strategic geopolitical role in maintaining the global competitiveness of their suppliers. US Ex-Im played a large role in financing natural gas projects around the globe, providing an estimated $10 billion for LNG liquefaction projects between 2003 and 2015; since 2015, however, US Ex-Im has not had the necessary quorum of board members to authorize large transactions. If the bank's operations remain constrained for an extended period, this vacuum could create more opportunities for greater South-South financial flows. It may also have long-term implications for the supply chains of major equipment and technology providers, who are increasingly looking to other export credit agencies to finance their transactions.

International financial institutions and donors also play a large role in many countries in the Global South and can be directly involved in natural gas development through financial support for specific projects or indirectly through legal, technical, and institutional support for energy sector planning and development.

Government Entities

Public entities have an increasingly prominent role to play in the natural gas development process in light of climate commitments. One of the most prominent public sector institutional roles is to set the national policy goals and regulatory framework for gas development, both of which are instrumental in minimizing environmental and social risks and maximizing the potential for gas to contribute to development and climate goals. In addition, governments play a crucial role in negotiating key agreements with industry, investors, and international buyers; the quality of these negotiations can generate or reduce revenue risks for decades to come. At a minimum, planning and regulating the development of natural gas for export involves the host-country energy and/or natural resource ministries, land management bureaus, environmental protection agencies, regulators, finance ministries, and legislative bodies.

FINANCING

Gas production is highly capital intensive, particularly when it is developed for LNG. Consequently, special financing mechanisms are required to enable production to proceed. Investors and financiers typically require strong evidence that a project has secured commitments from reliable, financially viable off-takers before proceeding with investment. Historically, this evidence came in the form of long-term gas supply purchase agreements (SPAs). This may be changing, however, with the growth of spot and short-term markets, which accounted for 28 percent of global LNG trade as of 2016 (USEA 2018). As gas consumers, particularly East Asian buyers, push for greater contract flexibility, it is unclear what impact this might have on financing terms for new producers. Japan has played a key role in the growth of this spot trade, as its demand for natural gas increased substantially following the Fukushima nuclear disaster in 2011. Japan’s Ministry of Economy, Trade, and Industry published a Strategy for LNG Market Development in 2016, signaling a move toward shorter-term contracts and pricing flexibility in order to create a more liquid LNG market and trading hub (Stern 2016).

Project Finance

Most major infrastructure projects, including both LNG import and export projects, are structured using project finance rather than corporate finance. Project finance is structured around the revenue generated by the project in order to limit the liability of the project sponsors and investors in the case of project failure. Project debt is paid back through the anticipated revenue of the project rather than through the balance sheets of the project sponsors. For projects that include public-private partnerships with governments that have low credit ratings, project finance also provides a ring-fenced structure, which limits the project's liability in the case of government default and allows the project to access more favorable financing terms. Executing project finance arrangements is a lengthy process, often taking two years or more and requiring sophisticated financial advisory services (USEA 2018).

Structurally, this type of financing often requires the establishment of a special purpose vehicle, which assumes the project debt (USEA 2018). The special purpose vehicle acquires equity (typically 30 percent) from project shareholders and debt (typically 70 percent) from commercial lenders, export credit agencies, and multilateral development banks. The revenue generated from the project off-take agreements is then used to pay for project mobilization, EPC costs, and ongoing operations and maintenance. In this type of arrangement, the lenders assume the greatest share of risk, with smaller portions of the project risk assumed by the project shareholders (particularly during mobilization) and by the EPC contractor (during construction).

The project can also be "de-risked" through loan guarantees and other types of insurance, particularly political risk insurance, which insures against political unrest and leads to better financing terms. Loan guarantees and insurance are provided by private insurers, such as AIG and Zurich, as well as multilateral development banks, such as the Multilateral Investment Guarantee Agency, and public entities, such as the Overseas Private Investment Corporation and export credit agencies. The loan tenor or payback period typically ranges from 7 to 15 years, which is a key reason why investors often prioritize projects with secure SPAs over a 20- to 25-year timeframe (USEA 2018).

Considering climate concerns from a financing perspective, projects under development now could potentially be ramped down by 2035 to contribute to climate mitigation strategies, but retiring these plants early may dramatically impact profit margins and return on investment. This means that additional financial incentives or regulatory measures may be needed in contexts where country-level climate mitigation strategies may be at odds with new gas investments.

Typical Capital Costs and Operating Expenses

The major cost components are broken down as follows:

Upstream Costs

Exploration and production costs vary widely depending on the geology and geography of the reserve, whether it is onshore or offshore, the quality of the gas, and the complexity of pre-production activities (site preparation and the cost of the land and/or leases and permits). A recent study found that capital expenditures for onshore exploration and development in the United States range from $4.9 million to $8.3 million per well, with an additional $1.0 million to $3.3 million in operating expenses over a 20-year period (EIA 2016). The average breakdown of this cost is around 31 percent for drilling, 63 percent for well completion activities, and 6 percent for facilities. It is important to note that most onshore production in the United States is unconventional, so although this cost per well may seem low, it primarily applies to unconventional production sites with a high number of wells. Offshore production, in contrast, typically uses a much smaller number of wells and is associated with higher capital expenditures per well, with the majority of the cost (more than 60 percent) associated with drilling. Well depth, water depth, and distance to land are additional features of offshore production that dramatically affect cost; production in Miocene plays, which were formed more recently and are therefore at a relatively shallow depth and typically have higher productivity, cost an average $120 million per well. In contrast, Lower Tertiary and Jurassic plays are much older and typically deeper, with costs exceeding $200 million per well (EIA 2016).

Midstream LNG Liquefaction Costs

Onshore LNG liquefaction facilities can be as large as 50 Olympic-sized swimming pools and can cost more than $1 billion per 1 billion cubic feet of capacity (Grigas 2018). The first facility in the United States, Cheniere's Sabine Pass, cost an estimated $18 billion at a capacity of 27 metric tonnes per annum (MPTA), while Mozambique LNG is anticipated to cost $7.7 billion at a capacity of 12.8 MPTA. Major cost components for LNG facilities include owner's costs such as land, permits, and preliminary studies (10 percent), engineering and management services (8 percent), equipment and bulk materials (50 percent), and construction (32 percent) (Songhurst 2014). Modular, floating liquefaction units can provide a lower-cost option.

Midstream LNG Transport Costs

On the transport side, new LNG carriers can cost $200–$250 million, and recovering this cost requires daily charter rates of $80,000–$100,000 (USEA 2018). In line with broader changes across the shipping industry, average LNG ship sizes have increased over the past three decades from 125,000 cubic meters to 160,000–180,000 cubic meters (USEA 2018). Low LNG prices exerted downward pressure on LNG charter rates in 2016–2017, making it difficult for shipping companies to recoup their investments in new ships; consequently, a number of LNG ships were converted into FSRUs and FLNGs (USEA 2018). However, LNG shipping rates skyrocketed in the final months of 2018 as a result of growing LNG exports and the corresponding rise in demand for shipping (Terazono 2018; Zawadzki and Jaganathan 2018). Consequently, charter rates at the end of 2018 were quadruple the rates in 2016, and these rates may continue to climb. These changes to charter rates may affect the competitiveness or profitability of projects currently under development.

Midstream Pipeline Costs

Capital expenditures and operating expenses for pipeline networks vary widely, depending on the geography of the network and the location of pipe fabrication facilities. For landlocked countries with limited domestic pipe fabrication facilities, the cost of transporting pipes can be prohibitively expensive. Another major challenge to transnational pipeline development is securing 20- to 25-year contract commitments from creditworthy buyers, necessary to secure financing for pipeline construction (Stern 2017).

Local Employment Opportunities

While the construction phase provides opportunities for local job creation, the bulk of the cost associated with LNG facility development is dedicated to equipment, materials, and EPC services, with little opportunity for local job creation. The Oxford Energy Institute reports that EPC services for LNG are dominated by a small number of transnational engineering companies in Europe, Japan, and the United States (Songhurst 2014). In addition, major equipment primarily sourced mainly as follows: refrigeration compressors from GE; cryogenic heat exchangers from Chart, Air Products, and Linde; and storage tanks from CB&I, Bechtel, Samsung, Tractebel, and Techint (Songhurst 2014).

CASE STUDY: MOZAMBIQUE

The discovery of sizable new natural gas reserves in Mozambique's Rovuma Basin in 2011 generated a wave of excitement across the gas industry and the development community alike. With per capita GDP at US$486 and nearly half of its population living on less than $1.25 a day, Mozambique could benefit significantly from gas development revenues, which could be a transformative resource for poverty reduction, growth, and development. However, efforts to move forward with gas development stalled shortly after the new discovery, largely because of falling gas prices and growing competition in the global gas market. Still, in 2018, new signals suggested that development is moving forward.

Revenues from private gas production could potentially reach into the billions for Mozambique within the next decade, but the realization of these benefits hinges on significant unknowns, including the changing global LNG context, accountability and oversight over projected revenues, and the equitable distribution of anticipated benefits. In particular, convergence in global pricing could mean that Mozambique will have to compete with market leaders like the United States for supply agreements, even if Mozambican gas is exported to Asian markets. In this context, shifting toward short-term supply agreements may pose new risks to revenue and the recovery of public investments.

Key Players and Projects

The Government of Mozambique's (GoM) interests are represented through the Empresa Nacional de Hidrocarbonetos (ENH), the key state-owned company for gas development. ENH is the key commercial arm of the GoM; it takes an equity stake in hydrocarbon production operations and participates in the development of processing, transport, and distribution infrastructure. Mozambique's petroleum regulator, the National Petroleum Institute, is responsible for awarding contracts and handling licensing rounds.

Exploration rights were granted by the GoM through a series of concessions to major international oil and gas companies and regional players like South Africa's Sasol. Exploration led by the US company Anadarko identified an estimated 75 trillion cubic feet of natural gas in the Rovuma basin (Offshore Area 1), located off the coast of the Cabo Delgado Province. The Italian conglomerate Eni identified additional reserves in the adjacent offshore Coral gas field (Area 4) (Gqada 2013). These are the largest discoveries in Mozambique to date; however, exploration continues, as a new round of concessions awarded exclusive exploration and production rights for Block 5 in August 2018 (Husseini 2018; INP 2014).

Mozambique LNG

The Mozambique LNG project, led by Anadarko, may reach a final investment decision in 2019. The project will include offshore, deepwater drilling wells that will link to an underwater gathering system and pipeline network to channel the raw gas to an onshore processing and liquefaction facility. This will be the country's first onshore liquefaction facility. The project is anticipated to cost $7.7 billion, and its sponsors include ENH, Mitsui and Co. (Japan), Oil and Natural Gas Corporation (India), Bharat PetroResources (India), Oil India Ltd. (India), and PT TEP (Thailand).

Anadarko is prioritizing export contracts in order to recover its capital investment costs; so far, it has secured a 15-year SPA with EDF of France, as well as 20-year SPAs with Tokyo Gas of Japan and Centrica of the UK (Crooks, 2018). Together, these mid- and long-term SPAs are likely to provide the requisite confidence to secure financing from export credit agencies and commercial lenders.

Although a portion of production from Mozambique LNG was originally slated for domestic use, those plans have recently been rescinded. Anadarko has delayed supplies for domestic projects, including a natural gas liquids plant under development by Royal Dutch Shell, a gas fertilizer plant under development by Yara, and a 250 MW gas-fired power plant, until the second phase of the project in 2031 (Pilling 2018). Domestic gas usage in Mozambique poses challenges that merit greater critical attention. Reserving a portion of the gas finds for domestic use is seen by many as important to fuel balanced economic growth and diversification and to counterbalance the potential for unintended economic consequences from currency inflows, including Dutch disease.[13] From an investor perspective, however, the creditworthiness of domestic off-takers poses a serious challenge, as evidenced by this latest deferment of the natural gas liquid, fertilizer, and power plants for Mozambique LNG (Pilling 2018).

Delaying domestic gas distribution until 2031 or beyond significantly narrows the window for Mozambique to take advantage of natural gas as a bridge fuel and means that future developments will likely have to compete with more cost-competitive renewable energy storage options. This situation could provide justification for forgoing natural gas development altogether as a strategy for domestic energy security, access, and growth, and for shifting to alternative fuel sources instead (Boersma and Jordaan 2017).

The onshore liquefaction facility will be located on a site roughly the size of Manhattan (Nhamire and Hill 2018). The development will displace an estimated 500 families, particularly in the northeastern Quitupo village. While Anadarko asserts that it has followed international resettlement best practices and Mozambican law, working in consultation with local communities, Bloomberg reports that the resettlement still raises concerns for some community members. The *Wall Street Journal* similarly reports growing concerns at local and national levels due to a recent rise in violent attacks by a militant group in northern Mozambique (Bariyo 2018). These attacks call attention to certain local perceptions of gas development as delivering unequal benefits and causing unjust hardship. For example, one local perception is that the increasing violence is the result of external interference and destabilization linked to the global security industry; in particular, there is growing local criticism of recent investments and partnerships made by Erik Prince, the founder of the private security firm Blackwater, in Mozambique's energy and security sectors (Mozambique Resources Post 2018; Reuters 2017b). These different perceptions and responses highlight the need for sensitivity to the ways that gas development projects intersect with local social dynamics, generating benefits for certain groups that may exacerbate existing tensions or create new ones.

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[13] Dutch disease refers to an economic situation in which exploitation of a new resource (most commonly oil or gas) for export leads to an influx of foreign currency, which in turn leads to currency appreciation that hampers the price competitiveness of the country's other exports in the global market. In other words, the revenues from exporting one resource can be inadvertently harmful to the development and competitiveness of other sectors in that economy.

Coral South

The Italian developer Eni reached its FID in 2017 and recently began construction on the floating LNG project Coral South. The development is anticipated to cost $4.7 billion, and the project development consortium includes ENH (Mozambique), ExxonMobil (US), China National Petroleum Corporation (China), Galp Energia (Portugal), and Kogas (Korea). The FEED plans, designed by KBR and Daewoo, include six subsea drilling wells that will connect to a 3.4 MPTA floating LNG facility. The EPC contract was awarded to a consortium led by TechnipFMC, which is now constructing the platform with Samsung Heavy Industries in South Korea. TechnipFMC has also contracted with GE Oil and Gas and its subsidiary Baker Hughes for equipment and technology licenses. Eni secured a 20-year SPA with BP for the entirety of its Coral South production and secured financing through a combination of East Asian export credit agencies and commercial lenders (Eni 2017).

In 2018 Eni sold a portion of its Area 4 assets to ExxonMobil, which is now exploring options for an onshore LNG liquefaction facility, Rovuma LNG. These plans are still in the early development phases but will likely face many of the same challenges as Mozambique LNG.

Changing Global LNG Competition

Growing global demand for LNG is changing the options for countries like Mozambique that possess limited domestic demand and limited regional pipeline trade networks. Currently, Sasol Ltd. produces gas from its concessions in the Pande and Temane fields in Mozambique for export to South Africa, with a small portion of this gas distributed domestically in the Inhambane Province (Ledesma 2013). Sasol plays a significant role in setting prices, limiting the potential for the GoM to maximize revenues. Consequently, this project has delivered limited benefits to average Mozambican citizens (CIP 2013b). LNG has the potential to provide attractive options for Mozambique to export beyond South Africa and find more lucrative contract options; however, increasing global price competition may threaten that potential and make it challenging for the GoM to maximize revenue and deliver on development promises.

On the one hand, changing LNG prices and rising competition on the global gas market may create risks for Mozambique’s ambitions for future gas exports; on the other hand, there are some positive signs that Mozambique may be competitive globally. Mozambique will have to compete with major suppliers such as Australia and the United States for lucrative SPAs with buyers in East Asian markets (Ledesma 2013). Australia holds a geographical advantage over Mozambique because LNG shipping distances to East Asia are shorter and thus less expensive. The United States faces higher shipping costs, but these costs could be offset by lower production costs. Still, both Mozambique LNG and Coral South have successfully secured long-term SPAs with Asian buyers, and these developments appear promising for Mozambique's competitiveness on the global gas market.

Transparency and Accountability

Like other extractive industries, developing natural gas for export creates risks related to the transparent and accountable use of public finances. In addition, optimistic or overambitious initial revenue projections can create false perceptions of the benefits these projects can deliver. For example, research from the Center for Public Integrity in Mozambique suggests that only a fraction ($1.2 billion) of the initial projections ($4–$5 billion) of government revenue from the Rovuma Basin are likely to materialize.[14]

In Mozambique, concerns about the recent misuse of funds and opaque financial dealings[15] call attention to the need for heightened oversight and transparency. Mozambique is ranked 158 out of 180 on Transparency International's 2018 Transparency Index, a substantial decline from its rank of 119 in 2014. Revelations regarding a recent scandal involving $2 billion in government loans earmarked for the state-owned tuna industry led the GoM to default on its debt in 2017. Through subsequent debt-restructuring negotiations, the GoM agreed to use 5 percent of its future natural gas revenues to repay multimillion dollar bonds to international investors (Cotterill 2018). Thus, the lack of transparency and accountability have already diminished the size of the potential benefits gas development could provide to local communities. In this context, critical attention must be given to government fiscal accountability.[16]

Climate Concerns

Climate change poses considerable challenges for Mozambique, with particular risks for communities dependent on subsidence agriculture as well as for large, urban coastal populations. Mozambique is ranked third within Africa in terms of exposure to climate-related risks, which include severe floods, droughts, storms, and related risks to human and ecosystem health (GFDRR 2018). Mozambique's coastline is also home to significant mangrove forests (Suliman 2018), which are critical to global carbon storage and which may be damaged through natural gas development.

[14] For more detail, see the report *Implications of the 2006 Contracts for Government Income* (CIP 2013a).

[15] See recent reporting from Joseph Coterill (2018) and David Pilling (2017) in the *Financial Times.*

[16] For additional information, please refer to the Mozambique Extractive Industries Transparency Initiative, https://eiti.org/mozambique.

DEVELOPING GAS FOR DOMESTIC USE

In comparison with developing gas for export, developing gas for domestic use holds the potential to deliver even greater social and economic benefits by providing a reliable, cost-effective source of domestic power and an input for a variety of household, transportation, and industrial uses. However, the main barrier to implementing domestic gas projects in developing countries, from an investor perspective, is the limited ability of local populations to generate sufficient revenues to justify the high capital expenditures. In addition, developing gas for domestic use requires the involvement of a large number of private and public entities and the harmonization of multiple planning, development, and management processes. In many countries in the Global South, the combined impacts of public debt, constrained national budgets, limited regulatory and oversight capacity, and policies that limit institutional investment create serious challenges for the administration and oversight of gas development projects. For governments, civil society organizations, advocacy groups, and community-based organizations working in partnership with industry and investors to advance development goals, the following list outlines key pressure points along the gas supply chain:

1. *Gas master planning and development policies*: The initial stages of country-level energy planning and the development of national natural gas development strategies and policies provide an important arena for civil society engagement.

2. *Environmental and social impact analysis (ESIA) and final investment decision (FID)*: Here again, ESIA and FID are key points at which a variety of actors can call attention to development and climate goals and advocate for strategies to mitigate the risks of gas development. Domestically oriented gas projects will have multiple ESIAs and FIDs for each phase of the project, including production, processing, transport, gas distribution, power production, electricity distribution, and industrial use.

3. *Gas sales agreements (GSA)*: For domestic gas distribution projects, GSAs form the basis for revenue projection and are critical to unlocking project financing. Any prospective project sponsors looking to finance gas exploration and production for domestic consumption will thus need to begin by conducting detailed demand modeling, which will serve as the foundation for pricing and GSA negotiation. Distribution projects that do

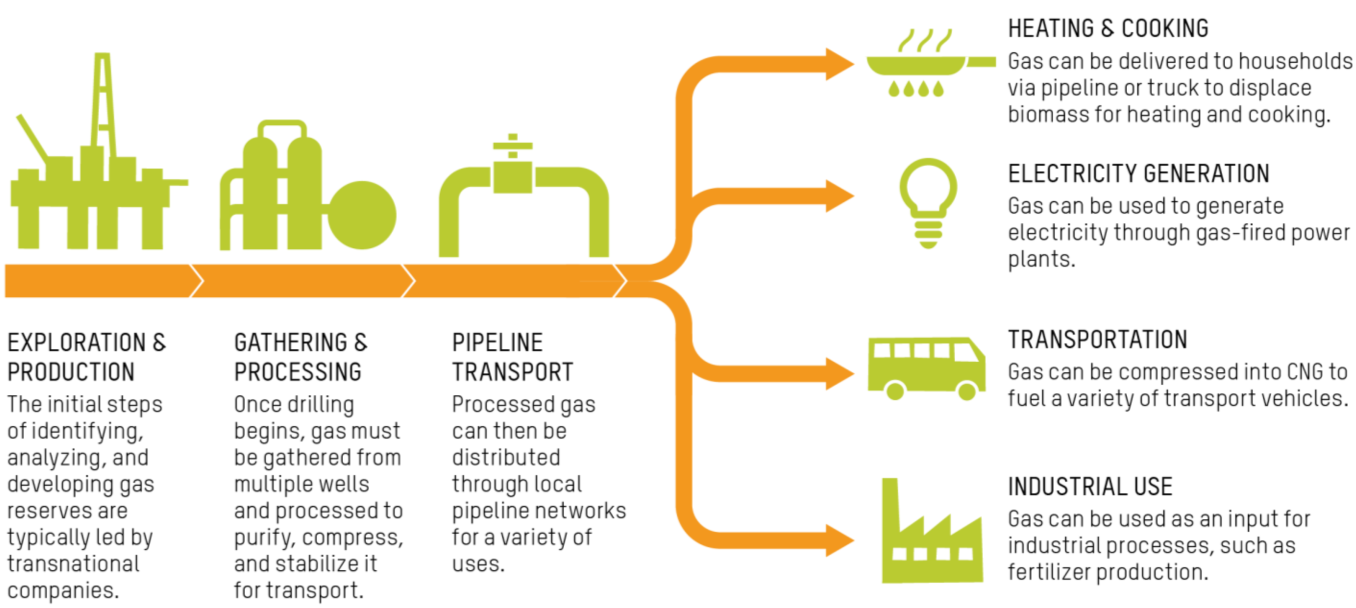
not have reliable, anchor industrial users are extremely challenging to finance.

4. *Power purchase agreement:* For gas-to-power projects, the financial health and viability of the power off-taker (the transmission operator or distribution utility) are often the primary factor in gaining financing new power generation. Negotiating the power purchase agreement, a binding commitment between the power producer and the utility, thus represents a key pressure point in gas-to-power projects.

5. *Climate concerns and electricity generation planning*: Arguments for natural gas as a climate-smart bridge fuel are often based on the assumption that new gas-fired power generation will displace coal; some countries, however, may pursue both coal and gas as an all-of-the-above energy diversification strategy. If new gas-fired power does not displace coal, but rather complements it, these scenarios may call into question the emissions reduction argument for natural gas development.

Figure 10: Developing gas for domestic use

Developing gas for domestic use can contribute to affordable power access, reduced household energy poverty, and diversified economic growth. For many developing countries, domestic utilization requires the buildout of new gas transportation and distribution networks and coordination with a large number of additional stakeholders, including independent power producers, electricity grid operators, and industrial processors. Understanding domestic demand is pivotal to the success of developing gas for domestic use.



Source: Backspace 2019

INFRASTRUCTURE

Domestic Gas Distribution Networks

Process and Components

Gas distribution networks are critical to the success of domestically oriented natural gas development projects. In contrast to export-oriented projects, whose financial viability rests on SPAs with international buyers, domestic projects must carefully consider the infrastructure requirements for gas delivery, the level of domestic demand, and consumers' ability and willingness to pay. Infrastructure requirements include both transmission and distribution networks, which vary depending on the geographic distribution of demand relative to the location of the gas reserves.

The traditional approach to gas distribution involves a hub-and-spoke network, where local distribution companies own and operate fixed pipeline networks and act as intermediaries between gas wholesalers and end users. Local distribution companies are typically regulated utilities, subject to safety and environmental regulations depending on the country context. Local distribution company networks encompass the same basic types of infrastructure as midstream pipeline transmission networks, including coated steel pipes, compressor stations, metering infrastructure, and supervisory control systems, but on a smaller scale.

The cost of building new pipeline distribution networks can be prohibitive for many regions, especially rural and remote communities and regions with seasonally variable demand or limited commercial and industrial users. In these regions, gas delivery via truck or rail is sometimes feasible. LNG is currently delivered by rail in Alaska and Japan, while trucks and road tankers are more common across the globe; truck deliveries of liquefied petroleum gas (LPG) are another option (USEA 2018).

Compressed natural gas (CNG) is another lower-cost alternative that can be used to fuel local vehicles that have been converted for CNG use. CNG requires the development of a network of mother stations, or central refueling stations, where piped gas is loaded into mobile CNG trailers and then transported via road to daughter stations, where it can be unloaded directly into local vehicles or into small storage units using small compressors. CNG networks were recently launched in India, Mozambique, and Nigeria (USEA 2018). Per-unit costs of CNG vary depending on the volumes and geographical extent of the distribution network. One recent analysis estimates that CNG produced from domestic natural gas in East Africa could be cost competitive with gasoline as a transport fuel (Demierre et al. 2015). The per-unit cost of CNG, however, is estimated to increase by about 25 percent from mother stations to daughter stations, thereby reducing access for communities located inland or outside of major metropolitan areas. In addition, lower demand is likely to increase prices as well. Demierre et al. estimate that demand levels 50 percent lower than expected would correspond with price increases averaging around 35 percent, with variation depending on location. Even with this price increase, CNG would provide a viable alternative transport fuel for coastal metropolitan areas; however, further analysis is warranted. Finally, closer attention to the climate effects of CNG is also needed, as discussed in the emissions section below.

Among the most lucrative drivers of gas distribution development are industrial use and downstream petrochemical production. The primary technology used in natural gas petrochemical production is an ethane cracker, which can produce ammonia and methanol from natural gas feedstock and ethylene and propylene from natural gas liquids. Ammonia and methanol are used in the production of fertilizer, latex, acrylics, insulation, building materials, and electronics, while ethylene and propylene are used in plastics, food insulation, bottles, carpets, and tires (USEA 2018). Consequently, petrochemicals from natural gas can provide an important input for industrial growth and economic diversification. Given the significant capital expenditures required, petrochemical plants are typically private developments. They are often factored into gas distribution planning as anchor customers that can drive the financing for new networks.

Timeframe

The design and planning stages (including feasibility studies, pre-FEED, and FEED) for domestic gas distribution networks can take at least year, and potentially much longer if broader regulatory changes or market reforms are required (USEA 2018). In regions currently unserved by any gas distribution networks (whether piped, trucked, or otherwise), it may be necessary to establish new local distribution companies to serve as intermediaries with end users. EPC stages then vary widely, depending on whether the network involves pipeline construction or distribution by truck, rail, or CNG vehicles.

Emissions Profile and Mitigation Strategies

The domestic use of natural gas for household cooking and heating has the potential to greatly reduce air pollution compared with biomass; however, achieving these emissions reductions presents logistical and economic challenges. In regions where diesel or biomass is used for household heating and cooking, use of natural gas can reduce carbon dioxide, carbon monoxide, and particulate matter. Indoor air pollution can cause serious respiratory infections and is estimated to lead to more deaths than malaria (IEA 2006). In addition, indoor pollution from biomass use has gendered implications in regions where women do the majority of indoor cooking (IEA 2006).

To effectively displace biomass with natural gas, close attention must be given to both the cost and the geographic distribution of gas, particularly for rural and remote areas. For many of these regions, developing pipeline infrastructure may be prohibitively expensive, and liquefied petroleum gas (LPG) delivery via trucks may be more logistically and economically feasible. LPG can be derived from wet natural gas or from petroleum through refining. Considering that the offshore finds in East Africa are primarily dry gas, the potential for producing LPG in that region is limited. In the 1990s and early 2000s, Brazil developed an extensive LPG delivery network and provided LPG subsidies, which led to a successful decline in household biomass use and indoor pollution (IEA 2006). However, because many developing countries have committed to reducing fossil fuel subsidies as part of their NDCs under the Paris Agreement, replicating the success of this model in the future may prove challenging. While the IEA Outlook optimistically projected emissions reductions from natural gas for household heating and cooking in the mid-2000s, the outlook from 2017 was more muted: "Developing new networks is expensive even in areas with high population density, so the potential for pipeline gas to provide a cleaner alternative looks very limited" (IEA 2017, p. 443).

On the transportation side, replacing diesel vehicles with CNG has been shown to have environmental benefits. Considerable declines in ambient air pollution were documented as a result of the conversion of auto rickshaws in Mumbai to CNG in the mid-2000s, including a 53 percent reduction in SO_2, a 64 percent reduction in NO_x, and a 30 percent reduction in respirable suspended particulate matter (Bandela and Tare 2008). In addition, the US Department of Energy reports that CNG vehicles can reduce greenhouse gas emissions by 15 percent (DOE 2018). These claims should be further investigated, however; other sources argue that CNG vehicles are not a viable strategy for climate change mitigation because of methane leaks from natural gas production and the lack of data on CNG vehicle leakage (Alvarez et al. 2012). The future market potential for CNG vehicles is also increasingly uncertain given the rise of electric vehicles. Depending on the source of electricity used, electric vehicles may have lower emissions profiles than CNG vehicles. Nevertheless, if fugitive emissions in the gas supply chain are appropriately addressed, CNG vehicles could be an attractive option, because converting vehicles to CNG is less capital intensive than investing in new electric vehicle fleets.

Gas to Power

One of the arguments frequently mobilized in support of natural gas exploration and production is the potential to contribute to lower-carbon power production by displacing coal and enabling greater integration of renewable sources, particularly in the developing world. Although gas-to-power projects generate high levels of donor interest (USAID 2018), these projects are technically and economically complex and difficult to execute. The infrastructure requirements for gas to power include gas production facilities, gas transport systems, gas-fired power plants, and electricity transmission and distribution infrastructure. Even in integrated gas-to-power projects, each of these components is typically owned and operated by a separate entity, as seen in the example of Ghana's Offshore Cape Three Points (OCTP) project, discussed further below. Consequently, the development of each component requires harmonization between the contractual and financial requirements of each entity.

Process and Components

Gas-fired power plants are typically developed by independent power producers (IPPs) in markets where the power sector is unbundled.[17] They are normally constructed with a generating capacity of several hundred megawatts (MW), using simple-cycle, combined-cycle, or cogeneration technologies. Simple-cycle plants use either heavy frame or aeroderivative turbines, which pressurize and combust gas to spin rotating aerofoil-section blades to generate electricity (Brayton cycle). Combined-cycle plants add considerable efficiency to the process by capturing the waste heat generated by the gas turbine and channeling it through a steam turbine (Rankine cycle) to generate additional electricity (MacKinnon, Brouwer, and Samuelsen 2018). Cogeneration (also known as combined heat and power, or CHP) plants also provide significant efficiency gains by capturing waste heat and using it to directly meet commercial, industrial, or residential heating and cooling needs (MacKinnon, Brouwer, and Samuelsen 2018).

Transmission and distribution infrastructure typically includes power lines, substations, distribution automation equipment, and metering infrastructure. Similar to pipeline transport networks, supervisory control and data acquisition systems form the foundation for monitoring and operating electricity transmission and distribution networks. The efficiency of these networks has increased dramatically in recent years through the use of two-way communications-enabled technologies (also known as smart-grid technologies) that enable the collection of real-time data on electricity usage in order to harmonize the supply and demand. Most new on-grid generation will interface with transmission and distribution networks through these digital infrastructures.

In addition to on-grid power, a growing number of off-grid gas-fired power technologies have emerged in recent years. Off-grid, or distributed energy systems, are self-contained units that balance generation and distribution. Currently, most distributed energy systems in operation around the globe are designed to support critical infrastructures like hospitals and military bases. Many of these systems are used only as back-up or emergency power, as the high cost

[17] Unbundling is a term for electricity markets that are not vertically integrated, where generation, transmission, and distribution activities are conducted by separate (often private) entities.

of decentralized generation typically cannot compete with on-grid, utility-scale generation. Continued low gas prices, however, could make distributed power a more appealing option, particularly for remote locations. GE's TM2500 system, for example, is a mobile, modular gas-fired power plant that can be commissioned in 11 days. These units produce 34–37 MW of power through an aeroderivative gas turbine generator set, which can be ramped up to full power in 10 minutes.

Sequencing and Planning Considerations

For greenfield gas-fired IPPs to be successful, corresponding electricity transmission and distribution infrastructure must be built simultaneously in order to evacuate power as soon as the new generation comes online. In unbundled power markets, distribution companies are often privately owned and operated; however, ownership and operation of the transmission system are often retained at the state level. Consequently, depending on the geographic location of the IPP relative to demand centers, the power-generating company may need to coordinate infrastructure planning with the transmission operator and one or more distribution companies. Power generation is likely to be more cost-effective in coastal, metropolitan areas that are situated closer to offshore gas production sites. Electricity production for rural or inland areas, in contrast, is likely to cost more and may ultimately be economically unsustainable.

Timeframe

Gas-to-power projects follow roughly the same process as LNG export projects, beginning with an initial feasibility study and progressing through the FEED, EPC, and operations and maintenance stages. This process must be completed for each component, including the gas transport system, the power plant, and the transmission and distribution infrastructure. The timeline for each of these components varies depending on size and complexity, presenting a major challenge in planning and executing large-scale projects. For gas-to-power projects linked with LNG facilities, a minimum of five to seven years from initial planning to power delivery is likely.

Emissions Profile and Mitigation Strategies

When compared with coal, power produced from natural gas generates fewer carbon dioxide emissions as well as fewer non-greenhouse gas air pollutants, including SO_2, NO_x, and particulate matter. However, recent improvements in the efficiency of coal-fired power technologies are closing these gaps, particularly advanced ultra supercritical (A-USC) turbines, coal-fired integrated gasification combined cycles (IGCC), and integrated gasification fuel cells (IGFCs) (MacKinnon, Brouwer, and Samuelsen 2018) (see Figure 11).

Figure 11: Greenhouse gas emissions from gas and coal-fired power (gCO2e/kWh)

Source: MacKinnon, Brouwer, and Samuelsen 2018

These falling greenhouse gas emission rates for coal-fired power plants, coupled with their price competitiveness compared with gas-fired power plants, means that countries with abundant domestic coal may continue to prioritize coal over gas for power generation. Alternatively, some countries may pursue both coal and gas as an all-of-the-above energy diversification strategy.

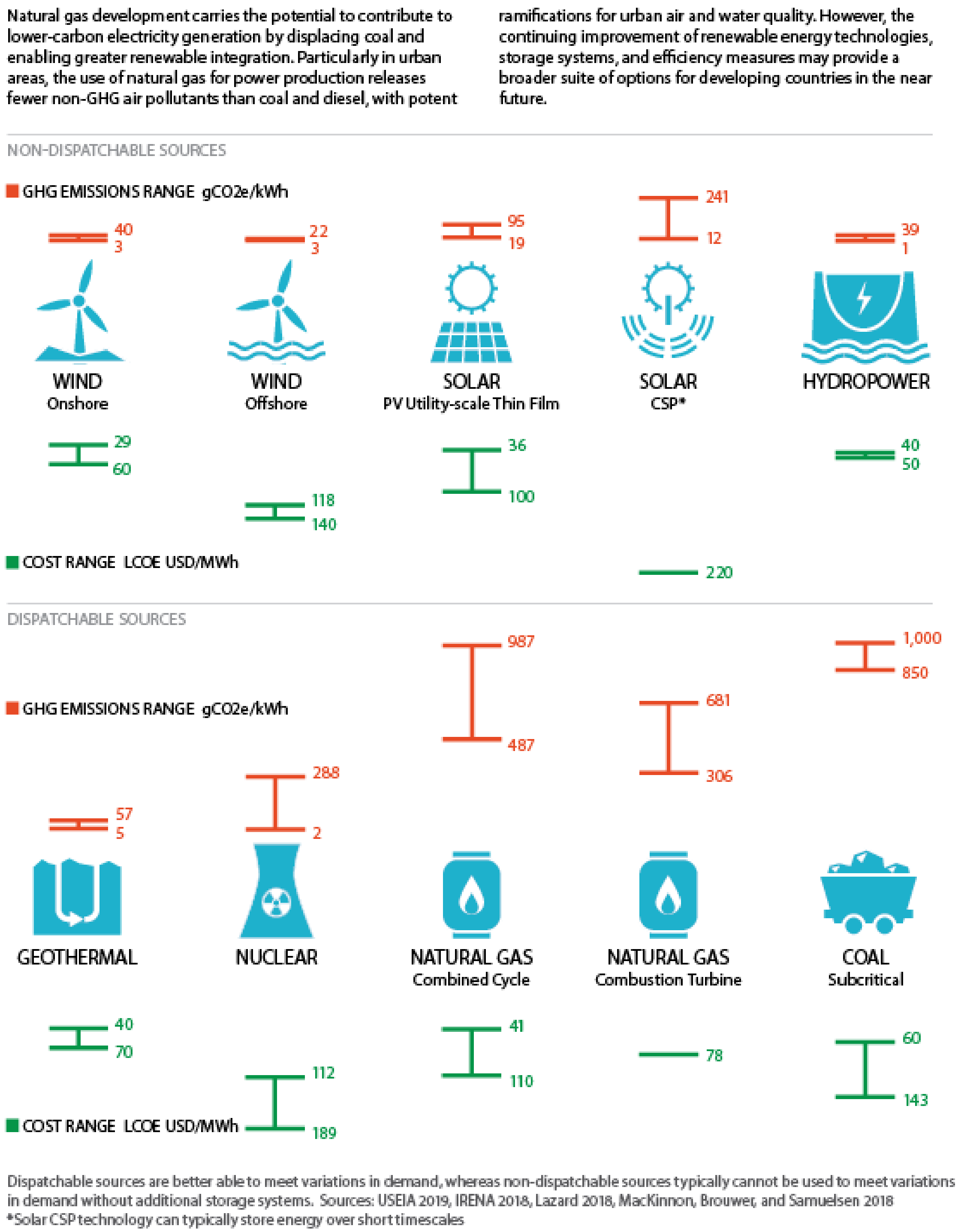
The rapid improvement of renewable energy storage technologies complicates the future prospects for gas-fired power generation to serve as a bridge fuel. Natural gas advocates have long argued that gas-fired power is critical for grid stability and can support the integration of intermittent renewable power generation. However, this argument may become less relevant as utility-scale storage systems, coupled with efficiency measures enabled by information and communication technologies that can help balance supply and demand, make renewable energy increasingly cost competitive and reliable. Utility-scale battery storage is still too expensive for renewable energy to be competitive with fossil fuels, particularly in contexts where fossil fuel power production is subsidized. Even without storage, however, some researchers argue that smart-grid improvements are obviating the need for much of the balancing capacity that natural gas was intended to fill (Boersma and Jordaan 2017). It is important to note here that most smart-grid technologies are currently designed for unbundled, highly developed electricity markets with large, predictable demand patterns, specific industrial and commercial use profiles, and financially healthy grid operators. Further research is needed to better understand the specific needs and demand profiles of developing electricity markets in order to realize the potential of these technologies in a variety of global contexts.

At 2016 gas prices, electricity production from integrated LNG-to-power projects was estimated to cost $0.10/kWh, while small-scale and distributed gas power projects were estimated to cost $0.15/kWh. Costs for recent non–fossil fuel power plants are increasingly competitive with these prices, with the Mumia biomass power plant in Kenya at $0.05/kWh, geothermal IPPs in Kenya at

$0.09/kWh, and small hydropower plants in Uganda at $0.09/kWh (USAID 2018). Geothermal and small hydropower resources are available only in certain geographic regions. Where they are available and do not present significant greenhouse gas emissions challenges, geothermal and small hydropower can provide an attractive alternative to LNG power, particularly in light of concerns about fugitive emissions across the gas supply chain.

Further complicating this picture are the differential ramp rates, or the time that it takes to increase or decrease output from different types of generation to respond to fluctuations in demand. Gas-fired power plants have exceptionally fast ramp times, with some models capable of ramping up or down in a matter of minutes. This makes gas uniquely attractive for both baseload (continuous demand) and peaking power (periods of high demand). Ultra supercritical coal plants offer ramp times comparable to gas, making them attractive in this regard as well. Until utility-scale storage solutions can be delivered in a cost-competitive manner, the potential for renewable generation to meet peaking demand is limited.

Figure 12: Comparison of lifecycle costs (USD/MWh) and emissions (gCO2e/kWh) for electricity generation



Source: Backspace 2019; source data drawn from USEIA 2019, IRENA 2018, Lazard 2018, and MacKinnon, Brouwer, and Samuelsen 2018

INSTITUTIONS

Shifting from export-oriented gas development to domestic utilization involves a substantial increase in the number of institutions involved. In addition to national and international gas companies, energy and resource ministries, international financial institutions, and regulatory agencies, domestic gas utilization typically involves local gas distribution companies, independent power producers, electricity transmission and distribution operators, and industrial processors. Coordinating all of these stakeholders is complex, requiring close consultation throughout the development process. Clear, enforceable legislation, strong regulatory capacity, and a national framework or development plan are critical to successfully balancing the competing demands of different institutions and stakeholders.

Key Trends

The unbundling of electricity markets across the developing world in the 2010s is a key institutional shift with important ramifications for domestic gas distribution and power production. International financial institutions, particularly the World Bank/International Finance Corporation and the International Monetary Fund (IMF), have played a driving role in designing power sector liberalization programs and providing the financial and technical assistance to implement them. These programs are designed to improve the macroeconomic stability of developing countries by rationalizing electricity tariffs, reducing the fiscal pressure on national transmission operators, and opening up generation and distribution markets to private investment. However, many of these programs have led to sharp increases in electricity prices for everyday citizens, leading to shifting patterns of demand. Further modeling and close analysis of changing demand is critical to the success of future gas-to-power programs in unbundled power markets. In this context, electricity regulators play a particularly important role in protecting the interests of local communities.

Key Actors

Government Entities

Governments in particular play a foundational role in setting national priorities; developing appropriate policies, legislation, and regulatory frameworks; and negotiating revenue and investment terms with international investors and developers. Both gas distribution and gas-to-power projects require significant involvement from national energy, mineral, and environmental ministries; regulators; legislative bodies; and gas and electricity transmission operators, if publicly owned. These entities should ideally set the terms of engagement with international investors and developers and provide mechanisms for local communities to inform national priorities.

Domestic Developers

Domestic gas usage can provide significant opportunities for local companies to expand and lead the development of gas and electricity distribution networks, IPPs, and industrial production. These actors carry the potential to contribute substantially to local economic growth, job creation, and economic diversification (USEA 2018). These kinds of developments also, however, carry the potential to exacerbate inequalities between different social groups, as historically privileged groups are often better positioned to take advantage of these opportunities. Consequently, government entities should give careful consideration to contracting mechanisms that can help address differential access to development opportunities.

International Technology and Service Providers

In addition to the upstream and midstream companies discussed in above, gas distribution and gas-to-power projects are dominated by the following providers:

- Engineering and design services: Black and Veatch, Bechtel, Fluor, Power Engineers, S&K Engineering, Jacobs Engineering, Foster Wheeler, CH2M Hill, Parsons Engineering, and Stone and Webster
- Gas turbine manufacturers: GE, Siemens, Ansaldo Energia, Kawasaki Heavy Industries, Mitsubishi Heavy Industries, Solar Turbines (Caterpillar), and Capstone Turbines
- Consulting and financial advisory services: Nexant, Taylor-DeJongh, Deloitte
- Electricity distribution and transmission equipment: Cooper Power Systems, Schneider Electric, Schweitzer Engineering Laboratories, ABB, Sumitomo Electric, Fuji Electric, Mitsubishi Electric, and Siemens

FINANCING

Financing gas development for domestic consumption faces particular challenges around questions of demand and consumer willingness and ability to pay. For gas distribution projects, gas sales agreements (GSAs) form the basis for revenue projection and are consequently critical to unlocking project financing.[18] Any prospective project sponsors looking to finance gas exploration and production for domestic consumption will thus need to begin by conducting

[18] Additional information related to gas sales agreements can be found in the handbook *Global LNG Fundamentals*, developed by the US Department of Energy and the US Energy Association (USEA 2018).

detailed demand modeling, which will form the foundation for pricing and GSA negotiation. Distribution projects that do not have reliable, anchor industrial users are extremely challenging to finance.

Financing Models

Gas distribution projects can be structured using a direct commercial structure, an exclusive structure, or a back-to-back arrangement. The direct commercial structure, where the gas supplier sells directly to an end user or a local distribution company, is the most straightforward. In an exclusive structure, a gas aggregator or national oil company acts as an intermediary between the producer and the end user and develops the transport and distribution infrastructure; in this structure, the intermediary assumes the bulk of the financial risk if revenues from end users fail to materialize. In a back-to-back arrangement, this risk is mitigated through payment securities from end users (USEA 2018).

Gas-to-power projects typically use project finance models that rely on projected revenue from the sale of power to the utility; the financial health of transmission and distribution companies is critical to authorize financing for domestic power transactions. The most important document, from a financing perspective, is the power purchase agreement, a binding commitment between the IPP and the utility that is typically set for a period of 20 years or more. The power sale price negotiated in the power purchase agreement then sets the financing terms. In addition to the power purchase agreement, financiers typically also require a gas supply agreement (GSA), a full ESIA, and clear land-use agreements.

For gas-to-power projects, the inadequate financial health and viability of the power off-taker (the transmission operator or distribution utility) are often the primary barrier to financing new power generation. Traditionally, financiers looked for utilities with flawless credit ratings and reliable anchor customers, including industrial and commercial users with high, predictable demand, to underpin new power investments (Stern 2017). Most developing-country utilities, however, do not match this profile. Consequently, over the past decade, multilateral development banks and donor institutions have advocated a suite of electricity sector reforms across the developing world to rationalize electricity tariffs, reduce energy subsidies, and improve utility financial health in order to unlock investment in the power sector. While these reforms have improved the creditworthiness of multiple utilities, the question of anchor demand remains. Ambitious projections of household, commercial, and industrial demand growth have been slow to materialize (Boersma and Jordaan 2017). In addition, a growing number of commercial and industrial users are turning to captive power and distributed energy systems, which may further challenge the financial health of distribution companies and reduce the economic viability of new investment in gas-fired power.

Typical Capital Costs and Operating Expenses

Gas Distribution Costs

Capital expenditures for pipeline distribution networks vary depending on the pipe material and the geography of the network. In the United States, distribution mains typically account for 65 percent of total capital expenditures, while service lines account for 27 percent and metering and measurement equipment account for about 7 percent (ICF 2017). In developing-country contexts, these proportions may vary. Local distribution companies increasingly use plastic pipes for distribution, which are considered superior in reducing leakages and may reduce capital and operating expenditures.

For CNG networks, capital expenditures range from $400,000 for small stations (100–200 gallons of gasoline equivalent per day) to $1.8 million for large stations (up to 2,000 gallons of gasoline equivalent per day). While small stations are sufficient for local vehicles, large stations are necessary for buses, commercial vehicles, freight trucks, and tractors. In addition to land costs and engineering costs, major equipment costs for both small and large stations include gas dryers, compressors, dispensers, storage tanks, and metering systems (Smith and Gonzales 2014). CNG network development must also consider the cost of converting vehicles to CNG, which can range from a few thousand dollars for small vehicles to more than $10,000 for large commercial vehicles. Successful CNG network development often requires either an anchor fleet or pricing strategies to incentivize CNG conversion.

Gas-to-Power Costs

Large-scale, grid-tied power plants tend to generate lower costs per kilowatt-hour, but capital costs for these plants are often hundreds of millions of dollars. For example, the 200 MW Amandi gas-to-power project in Ghana has an estimated capital expenditure of $542 million. A recent report produced by the financial advisory firm Lazard estimates the unsubsidized levelized cost of energy (LCOE)[19] for gas-fired power for a combined cycle plant to range from $41 to $74/MWh, compared with $152 to $206/MWh for gas-fired peaking power, $60 to $143/MWh for coal, and $29 to $56/MWh for wind (Lazard 2018).

Local Job Creation

Pipeline network development is a potentially promising area for local job creation, during both construction and ongoing maintenance. A recent ICF report prepared for the American Petroleum Institute estimates that gas distribution is the second-highest job creator in the gas supply chain, after production (ICF

[19] LCOE is the net present value of electricity over the lifetime of the generation asset.

2017). A key caveat, however, is that these jobs may not be equally accessible to men and women. In addition, some companies may choose to employ foreign workers, reducing the prospects for local job creation.

CASE STUDY: GHANA

Recent gas development efforts in Ghana illustrate the challenging realities of developing domestic power markets and executing more flexible supply arrangements. The uncertain financial viability of Ghana's national transmission off-taker, GridCo, has imperiled the future of at least one gas-to-power project, the ambitious Ghana 1000 development led by Endeavor Energy. However, Eni's development of the Sankofa gas field, guaranteed by the World Bank, recently began production entirely dedicated to domestic consumption. The $7.9 billion project is anticipated to create $2.3 billion in revenue for the Government of Ghana (GoG), deliver 1,000 MW of new power generation, and reduce carbon emissions by an estimated 8 million tons over five years by reducing oil imports (World Bank 2015). Nevertheless, achieving stable, affordable power delivery in Ghana faces substantial challenges. Gas-to-power projects hinge significantly on the financial viability of GridCo and the two electricity distribution companies.

Key Players and Projects

On the upstream side, Ghana's National Petroleum Corporation (GNPC) manages the planning and licensing of all hydrocarbon exploration and production activities and typically maintains a stake in production.[20] In the Offshore Cape Three Points (OCTP) project, which produces gas from the Sankofa field, GNPC maintains a 20 percent stake alongside Eni (44.44 percent) and Vitol (35.56 percent). Midstream activities are managed by Ghana's National Gas Company (Ghana Gas). In 2017 Ghana Gas initiated efforts to develop a 400 km gas pipeline from Takoradi to the industrial enclave in Tema. This pipeline is expected to evacuate up to 550 million standard cubic feet per day (mmscfd) of gas, at an estimated cost of $500 million.

National gas and power planning and policymaking are led by Ghana's Ministry of Energy and Petroleum. Electricity generation, transmission, and distribution were originally bundled under the Volta River Authority; however, the unbundling of the electricity sector through liberalization reforms in the mid-2000s restricted the Volta River Authority's purview to power generation and opened the sector to private developments. Transmission is managed by GridCo, and distribution is split geographically between the Electricity Company of Ghana and the Northern

[20] For more information on Ghana's petroleum sector, see the Petroleum Register, produced by Ghana's Petroleum Commission, at https://www.ghanapetroleumregister.com/.

Electricity Distribution Company, a subsidiary of the Volta River Authority. These private entities are regulated by the Public Utilities Regulatory Commission (PURC) and the Energy Commission (EC).

International donors and international financial institutions are extremely active in Ghana's energy and power sectors. The US Millennium Challenge Corporation (MCC) signed a $498 million compact with Ghana in 2014 that focused on power sector policy reform to encourage private investment. In 2018, the World Bank announced an additional $20 million for an Energy Sector Transformation Initiative Project designed to improve energy sector financial flows and natural gas development.

The Sankofa Gas Project, which received a $700 million loan guarantee from the World Bank,[21] was developed by the OCTP and began production from the offshore, deepwater Sankofa and Gye Nyame gas fields in 2018. The OCTP constructed five undersea drilling wells that connect to a floating production storage and offloading facility built from a converted crude carrier (Offshore Technology n.d.). From there, the gas is piped to an onshore facility for processing and connected to the national gas pipeline network to be delivered to private gas-fired IPPs. The IPPs transmit the power through GridCo for delivery through the Electricity Company of Ghana and the Northern Electricity Distribution Company.

Project financing of the OCTP follows an integrated commercial structure with a few special protections: Vitol, ENI, and GNPC developed the upstream and midstream infrastructure with financing from the IFC, UK Export Finance, and commercial lenders, backed by political risk insurance from the Multilateral Investment Guarantee Agency, a World Bank International Bank for Reconstruction and Development loan guarantee and International Development Association payment guarantee, and an indemnity agreement with the Government of Ghana (World Bank 2018). Under a gas sales agreement, OCTP delivers gas to GNPC, which then delivers it to gas-fired IPPs. Payments from IPPs are routed through a designated account, which prioritizes repayment to the project's private sponsors. The project is designed to generate $2.3 billion in revenue for GNPC and $1.2 billion in fuel cost savings (World Bank 2018).

The first IPP developed in Ghana is the Cenpower Kpone 350 MW thermal generation plant, which uses GE tri-fuel combined cycle turbines that can switch between natural gas, diesel, and crude oil. The plant was built in 2017 using project finance, with equity from the founding special purpose vehicle (Cenpower), the Africa Finance Corporation, and Sumitomo (Japan), and debt provided by South African commercial banks with export credit guarantees

[21] For additional details, please see the World Bank project records: http://projects.worldbank.org/P152670?lang=en.

(Cenpower 2016). Power generated from the plant is distributed through a power purchase agreement with the Electricity Company of Ghana.

Creditworthy Off-takers

As already noted, one of the primary challenges to gas production for domestic consumption in developing countries is inadequate off-taker financial viability. GridCo's ability to generate sufficient revenue to sustain major gas development and power generation investments has been the subject of much investor and donor scrutiny. Energy sector debt amassed by Ghana's state-owned power companies has surged to more than $2.4 billion, leading the Government of Ghana to announce plans in 2017 to issue bonds to alleviate fiscal pressure (Dzawu 2018). This measure was criticized, however, when 95 percent of the bonds were purchased by one investment fund, Franklin Templeton, with ties to the minister of finance (Laye 2018).

The future of Ghana's utilities is uncertain, as debt, high technical and non-technical losses, and management challenges continue to plague their ability to generate stable revenues for investors and stable electricity for local communities. Gas from Sankofa is intended to help address the frequent power outages, or *dumsor,* and to alleviate financial pressure on utilities by providing an affordable, reliable fuel source. The main question that remains, however, is whether demand will meet projections in order to generate sufficient revenues. Because the Sankofa Gas Project provides sophisticated financial guarantees to protect private investors from revenue shortfalls, the financial risks of default fall upon the gas-fired IPPs, the grid operators, and the Government of Ghana.

Rural Electrification and Gas Distribution

Another challenge with domestic gas utilization that deserves closer attention is the question of access, particularly for rural communities, inland communities, and economically precarious communities. Rural electrification is a notoriously difficult proposition from an investment perspective, and this holds true for power generated from domestic gas resources. Ghana's past efforts to promote rural electrification, particularly through the Self Help Electrification Program, were successful in raising electrification rates from roughly 15 percent in 1989 to more than 80 percent in 2016 (Kumi 2017, p. 30). However, rural and inland communities often do not generate sufficient revenues or demand volumes to cover the costs of transmitting power and maintaining grid infrastructure over long distances.

Much of the debate around power sector reform in Ghana centers on cost-reflective tariffs. Government subsidies for electricity tariffs contribute to energy sector debt and are seen as unsustainable by many investors (Kumi 2017). Yet raising energy tariffs to reflect the costs of energy production poses challenges for economically vulnerable communities. Developers, government ministries, regulatory bodies, and the utilities must give careful attention to the goal of inclusive energy access and seek to balance investor priorities with local development priorities over the long term.

Similar challenges face the domestic gas distribution network. A recent review found that Ghana's efforts to expand rural people's use of LPG[22] to displace biomass for household heating and cooking achieved limited results (Asante et al. 2018). Although the health benefits of replacing biomass for household energy use are well documented, this study found that households often continued to use both biomass and LPG, or were located close to other households that still used biomass, and consequently did not experience the anticipated health benefits. The many barriers to LPG adoption included seasonal income variation, lack of access to spare parts and accompanying hardware, and inadequate refilling stations (Asante et al. 2018).

Climate Concerns

Ghana stands to face critical challenges linked to climate change, particularly for populations living in coastal regions and near key lakes and rivers that may be prone to severe flooding and erosion (UNDP 2018). A report on Ghana's National Climate Change Adaptation Strategy also highlights the deleterious impact that climate change may have on agricultural production and food security, health and sanitation systems, and infrastructure (UNEP/UNDP 2012). In this context, the development of natural gas infrastructure may both be adversely affected by these risks and further contribute to them.

[22] In the 1990s and early 2000s, LPG consumption in Ghana included both domestic LPG produced from petroleum at the Tema Oil Refinery and imported LPG from Nigeria. However, the Atuabo Gas Processing Plant commissioned in 2011 is designed to produce LPG from Ghana's domestic gas fields.

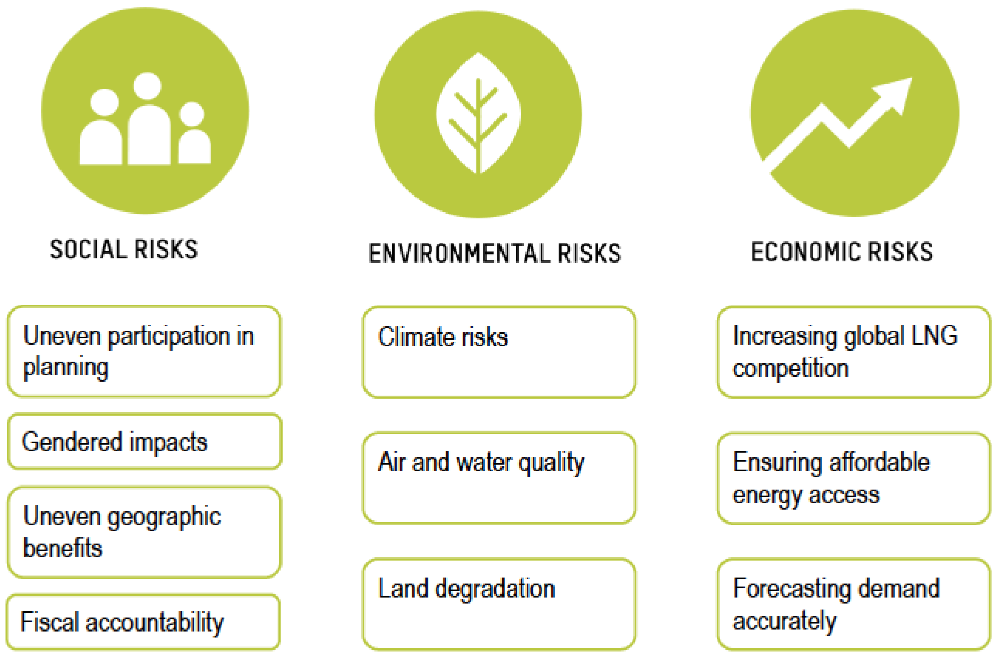
RISK ANALYSIS AND POLICY RECOMMENDATIONS

Natural gas development has the potential to contribute to broad-based growth and development in the Global South. Historically, gas markets were characterized by limited supply and rigid markets with specific regional characteristics. However, the recent surge in global supply, increasing LNG trade, and evolving cross-regional markets have dramatically changed the prospects for new producers. Reserves previously considered marginal may now be profitably developed, and gas producers with limited domestic or regional demand may now be better positioned to reap the benefits of global gas trade. Natural gas developed for export can provide a valuable source of national revenue to support domestic development, while gas developed for domestic use can additionally contribute to affordable power access, reduced household energy poverty, and diversified economic growth. Finally, natural gas can potentially provide opportunities for climate-smart, low-carbon power generation both by displacing coal-fired power and by enabling greater renewable energy integration.

At the same time, though, gas development poses serious environmental, social, and economic risks that may compromise inclusive development and climate goals if not properly addressed. From a social perspective, natural gas development carries the potential to exacerbate certain social inequalities, given that the primary benefits of gas development are likely to accrue to particular groups, particularly urban, coastal communities and privileged socioeconomic groups. From the initial planning through the implementation stages of gas development, participation in decision-making and access to employment opportunities, revenue, and services may be unevenly distributed by gender, socioeconomic status, and geographic location. On the environmental side, significant concerns about greenhouse gas emissions across the supply chain call into question the climate benefits of natural gas for power generation, transportation, and household heating and cooking. In addition, natural gas development may worsen air and water quality and contribute to land degradation. From an economic perspective, the recent shifts in global gas markets mean that new producers will have to compete with major market players and that developers will have to navigate increasingly complex financial and contractual arrangements. In addition, the difficulty of accurately forecasting demand and ensuring affordable energy access may pose serious challenges for efforts to develop gas for domestic use.

This section expands upon these risks, which should be considered carefully by host-country governments, developers, financiers, and civil society groups in order to maximize the potential for gas to deliver sustainable benefits in an equitable, inclusive manner to communities in the Global South.

Figure 13: Social, environmental, and economic risks linked to natural gas development



Source: author

SOCIAL RISKS

Major resource development projects are inherently political because they shape the role of the state and deliver benefits to specific groups (Ferguson 1990). Many development projects are framed as purely technical interventions without careful attention to the social dimensions of the worlds they seek to transform, and they thus routinely fail to deliver the benefits they promise. Thoughtful attention should be given to maximizing the distribution of natural gas development benefits to diverse groups, to proactively building transparency and accountability at all levels of public and private governance, and to facilitating the equitable participation of host-country governments in leading development efforts.

Planning and Stakeholder Engagement

Planning and coordination at the state level can facilitate gas development that better serves host-country communities. A clear regulatory environment, which includes well-defined legislation and enforcement mechanisms, and a national gas master plan and development framework are critical. Gas master plans and legislation should be developed in close consultation with local communities, and regular consultation should continue throughout the development process. Particularly for communities directly affected by development activities, critical recognition must be given to free, prior, and informed consent as a right of customary land holders (Oxfam America 2018a, 2018b). Any consultative process should carefully consider the existing social dynamics within communities and seek to maximize the meaningful participation of women and other groups who are often underrepresented in consultations with developers and government institutions.

Gender Dimensions

Natural gas development may create gendered impacts for local communities in developing countries. Developing gas for export has limited prospects for local job creation, and where they do exist, these jobs tend to be concentrated in male-dominated fields like construction (Eftimie, Heller, and Strongman 2009). In addition, family resettlement for onshore gas facility development often unevenly affects women family members in regions where women carry a larger share of household responsibilities. For natural gas developments that involve resettlement, critical attention should be given to how compensation is administered to households and whether women can equally access compensation and benefits.[23] The loss of access to land and water resources through resettlement or through gas-related environmental degradation may lead to gender-specific health outcomes as well, in regions where cooking, cleaning, and subsistence farming activities are led by women (Eftimie, Heller, and Strongman 2009).

Expanding regulatory and oversight roles to improve fiscal transparency and accountability at the government level could potentially provide employment and advancement opportunities; however, these fields also tend to be male-dominated. Consequently, host-country governments, investors, and civil society organizations should carefully consider the gendered implications of export-oriented gas development and proactively facilitate the meaningful participation of women and women's organizations in key decision-making processes.

[23] A more detailed analysis of the gendered dimensions of resettlement related to extractive industries can be found in the World Bank report *Gender Dimensions of the Extractive Industries* (Eftimie, Heller, and Strongman 2009) and the UN Women report *Gender Equality in the Extractive Industries in Africa* (Lawson 2014).

Developing gas for domestic use may provide more opportunities for gender-balanced benefits, depending on existing local social dynamics. Expanding gas distribution networks for household cooking and heating may reduce the harmful health risks of biomass use, with gendered implications for communities where women perform the majority of household work. However, expectations around these benefits should be managed, as the potential for gas distribution networks to penetrate remote, inland areas where biomass is primarily used is limited by several factors. Improving domestic power production may also provide promising employment and advancement prospects for women as, for instance, utility operators, engineers, architects, and business owners. Here again, careful attention should be given to facilitating women's meaningful participation in decision-making and to the access and participation of women's organizations.

It should be noted that gender representation alone does not necessarily ensure equitable gender outcomes (Keenan and Kemp 2014). Consequently, host-country governments, donors, and advocacy networks may want to consider additional mechanisms to incentivize or support women's meaningful participation in gas development to promote gender-balanced outcomes and impacts.

Differential Rural-Urban Access

As discussed above, one major concern about developing gas for domestic consumption is the differential benefits it creates for rural versus urban communities, as well as coastal versus inland communities. The benefits of gas distribution and gas-fired power are concentrated in large, coastal, metropolitan areas, and the prospects for these benefits to reach remote, rural areas are currently limited. This situation may promote urban migration and may negatively affect local social dynamics around access and privilege. In addition, domestic gas development may contribute to or even exacerbate local socioeconomic divisions, because historically privileged groups are better positioned to take advantage of employment opportunities, lucrative contracts, and partnerships with national and international developers and investors. These dynamics also often intersect with the gender dynamics already discussed, compounding challenges for women in rural, inland communities and historically underprivileged groups.

Host-country governments, civil society organizations, and donors should carefully consider mechanisms to support historically underrepresented groups and counterbalance the differential access and benefits that gas development may create. These solutions need to be tailored to specific local contexts and social dynamics and designed in participatory and inclusive ways with local communities; in addition, solutions should address differential access and power within these communities. Ensuring equitable access to information, as a key gateway for promoting equitable participation, is a critical part of this process.

Further research is needed to better understand the unique features of particular contexts and communities and to review the challenges and successes of existing programs to support historically underprivileged groups. For example, further research on the impacts of South Africa's Black Economic Empowerment mechanisms within the Renewable Energy Independent Power Producer Procurement Program could provide insights into the challenges and opportunities for addressing historical inequalities and promoting equitable access within power development programs.

Local Content Requirements

Local content requirements are gathering attention as a potential pathway to encourage greater domestic participation in major infrastructure development programs and to maximize the benefits of these projects in terms of local employment and revenue generation. Typically, local content requirements are stipulations that require a certain percentage of goods or services for major new investments to be sourced from local providers, in order to boost domestic economic growth. To be successful, however, local content requirements warrant careful consideration of existing domestic technical and labor capacity, alongside meticulous planning around the specific mechanisms to support local capacity development and mobilize these capabilities to meet project requirements. Without such planning, local content policies risk falling far short of their anticipated impacts (USEA 2018).

Fiscal Transparency and Accountability

Like many extractive industries, natural gas development carries the potential to generate substantial revenue for host-country governments through production-sharing agreements, taxation, and licensing arrangements. To ensure the democratic distribution of benefits from these revenues, careful attention must be given to questions of fiscal transparency, oversight, and accountability. While transparency refers specifically to the process of making data publicly available, accountability refers more broadly to the recognition of governments' rights and responsibilities toward their citizens. Developing appropriate legal and institutional frameworks to support transparency and accountability requires time and resources. The Extractive Industries Transparency Initiative, a multi-stakeholder coalition designed to promote accountable management of extractive resources, provides a model for reporting standards that countries can work toward to improve transparency and accountability.

ENVIRONMENTAL RISKS

Climate Risks

The climate risks associated with natural gas development are significant and warrant careful examination and discussion within specific country contexts. Natural gas contributes to greenhouse gas emissions through both intended and unintended emissions of greenhouse gases, particularly methane and carbon dioxide. Recent research published in *Science* suggests that across the natural gas supply chain, emissions of methane, a highly potent greenhouse gas, are approximately 60 percent higher than previous EPA estimates, and that exploration and production activities are the leading sources of methane emissions in the US gas supply chain (Alvarez et al. 2018). This research argues that conventional measurement methods undersample facilities with abnormal operating conditions, and therefore systematically underestimate total emissions. The research team deployed a bottom-up approach that captures facility-level emissions, including aerial infrared surveys of more than 8,000 production sites, yielding new total emissions estimates of 13 teragrams (Tg) of methane per year, compared with the EPA top-down estimate of 8.1 Tg/y (see Figure 14 for a breakdown of methane emissions estimates).

The *Science* article aligns with previous findings that identify a small number of disproportionately high emitters, known as “super emitters,” as a driving source of fugitive emissions (Brandt, Heath, and Cooley 2016; Balcombe et al. 2017). Super emitters are individual facilities that emit abnormally high levels of fugitive emissions, often due to equipment malfunctions. Super emitters exist across the gas supply chain, from production to gathering, processing, transmission, and distribution; multiple studies have pointed specifically to well completions, automated liquids unloading facilities, and compressor stations as key sites in the gas supply chain where super-emitting facilities are concentrated.

The *Science* article is limited to methane emissions in the US gas supply chain, which is dominated by unconventional production. Nevertheless, the finding that a small number of abnormally operating or malfunctioning producers (e.g., from malfunctioning controllers or equipment leaks) disproportionately affect total emissions is consistent with the findings of a 2018 study by Balcombe et al. in the UK, which examines both methane and carbon dioxide emissions patterns across the globe for both conventional and unconventional sources. Their study estimates that the top quintile of emitters population (the super emitters) contribute 40–60 percent of total emissions (Balcombe, Brandon, and Hawkes 2018). Like the *Science* article, Balcombe et al. recommend leak detection and repair strategies to address these emissions, because bringing these super emitters in line would address a major emissions source. Specifically, the researchers recommend optical gas imaging, passive sensors, and remote-sensing approaches to leak detection and repair. Balcombe et al. further emphasize the need for preemptive maintenance and faster responses to repair leaks and malfunctions, alongside the use of better technologies, including plastic distribution pipework, manual plunger lifts for liquid unloading, and reduced-emissions well completion techniques (also known as green completions). These findings are consistent with recent work conducted by researchers from Stanford University, the National Renewable Energy Laboratory, and Colorado University that emphasizes the need for strong regulatory oversight that mandates leak detection and repair and regular checkups to reduce the outsized impact of super emitters (Brandt, Heath, and Cooley 2016).

Besides endorsing these technical fixes, the *World Energy Outlook 2017* points to compressors and pneumatic devices as common emissions sources that can be reduced by replacing seals; conducting swift, routine maintenance; and installing degassing systems and electrical-driven controllers. Although abatement technologies are reasonably well known and cost-effective (in that captured methane often offsets the cost of investment), effective detection systems are a larger challenge. The IEA examined the technical and economic potential for a range of detection and abatement technologies and found that at 2015 prices, 40 percent of methane emissions in the gas supply chain can be avoided with measures that have positive net present values (in other words, technologies that pay for themselves). These models, however, are highly sensitive to the gas price used (IEA 2017).

Although processing, on its own, is not a large source of emissions, it can become a critical bottleneck in the gas supply chain, which is both environmentally and economically problematic. In the United States, for example, insufficient processing and pipeline capacity has stalled the completion of 1,500 production wells in the US Marcellus shale field and has led to significant gas flaring[24] in the Bakken (DOE 2015). By way of comparison, more natural gas was flared in the Bakken in 2014 (129.4 billion cubic feet) than the amount of gas that Gazprom sold to Finland the previous year (Grigas 2018).

While most exploration and production in developing countries is currently focused on conventional, offshore gas resources, these findings call attention to the critical importance of environmental oversight and enforcement mechanisms across the gas supply chain. Countries committed to exploiting either conventional or unconventional resources should carefully examine and plan for the processing and transmission infrastructure necessary to prevent bottlenecks that cause unnecessary flaring, alongside strong environmental regulations that specifically address abnormal operations through improved detection and

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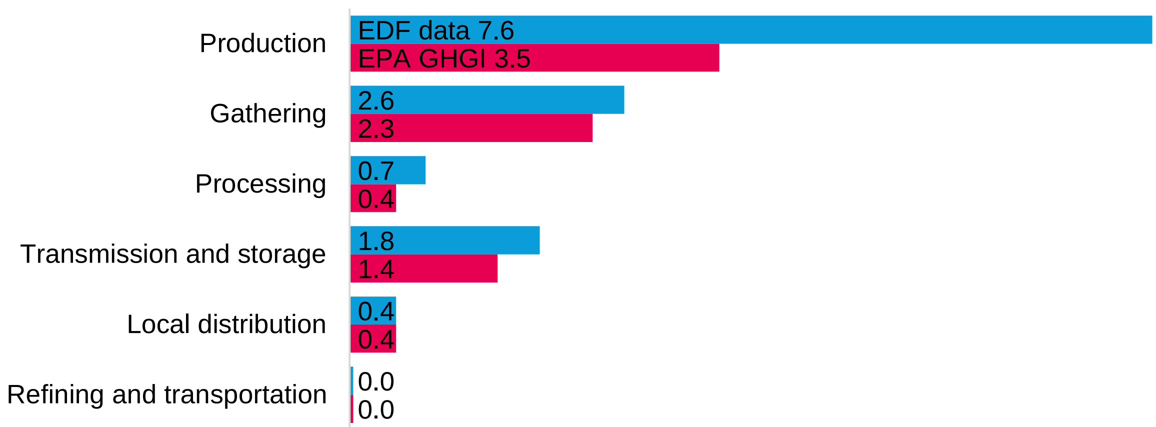
[24] Flaring is the practice of burning natural gas during production and processing, typically in order to reduce pressure, allow for testing, maintenance, or safety procedures, or to manage gas that cannot be otherwise captured. Venting is often used for similar reasons, but involves direct release of the gas without combustion.

abatement measures.[25] For countries considering potential future investments in natural gas extraction, these risks should be carefully examined through dialogue and debate that situates natural gas as one among a variety of options for the energy transition.

Figure 14: 2015 estimated methane emissions in US gas production (Tg/year)



Source: Data are from Alvarez et al. 2018.

Urban Air and Water Quality

The use of natural gas for power production, transportation, and household energy generally releases fewer non-greenhouse gas air pollutants, including SO_2, NO_X, and particulate matter, than do coal and diesel (Kinnon, Brouwer, and Samuelsen 2018). These pollutants can significantly affect human and environmental health, including air and water quality. However, as a non-renewable hydrocarbon resource, gas production typically generates a larger environmental footprint than renewable resources and efficiency measures in terms of air and water impacts. The continuing evolution of smart grid technologies, electric vehicles, and cost-effective storage options may provide a broader suite of options for developing countries in the near future, warranting close attention and further analysis over the next 5 to 10 years.

Land Degradation

Natural gas exploitation requires the development of extensive extraction, processing, and transport infrastructure, as detailed in the section on developing

[25] Additional information regarding best practices in the design, development, and oversight of gas infrastructure projects can be found in the report *Global LNG Fundamentals* produced by the US Department of Energy and the US Energy Association (USEA 2018).

gas for export. These infrastructures may disrupt delicate ecosystems and harm ecological health and biodiversity. As noted in the Overview, offshore gas infrastructure poses particular risks for countries with coastal mangrove habitats, which are extremely important, carbon-rich ecosystems that naturally sequester carbon dioxide.

ECONOMIC RISKS

Global LNG Competition

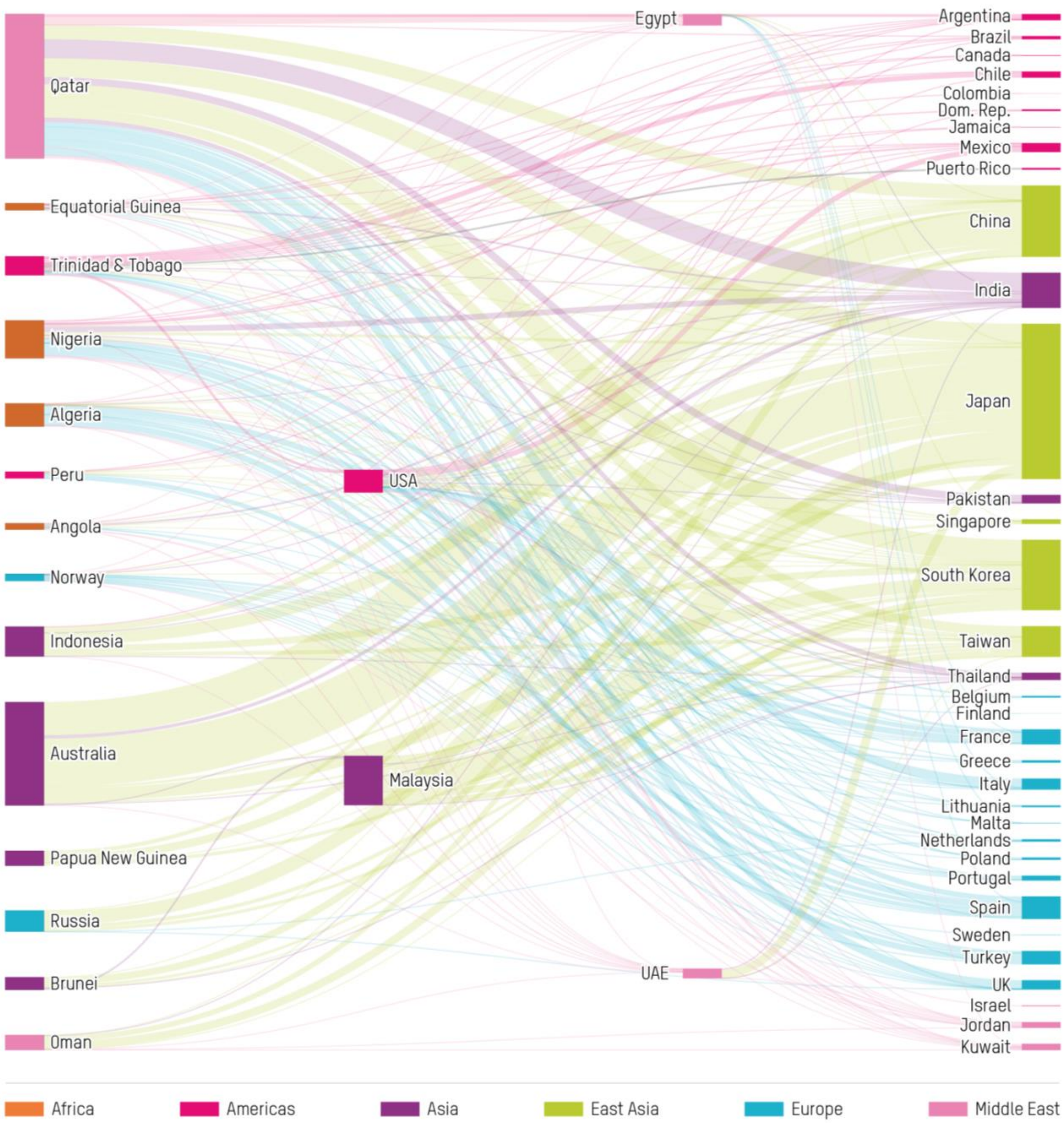
For export-oriented gas development projects, growing global LNG competition poses serious risks for new producers. New market entrants will have to compete with major market players and face stiff pricing competition from highly developed suppliers like Australia, Qatar, Russia, and the United States; a visualization of global LNG flows is provided in Figure 15 below. For many export-oriented gas projects, the potential to deliver on development promises and generate sufficient return on investment for investors rests on the negotiation of long-term SPAs with international buyers. Greater support for detailed technical planning and design services is needed to understand the geological and geographical features of specific reserves and develop accurate cost estimates and revenue projections. Furthermore, the growing use of complex contract structures and financing mechanisms in international gas trade warrants a renewed focus on technical assistance to help build legal, financial, regulatory, and technical expertise amongst emerging gas exporters.

For export-oriented gas projects, the primary domestic benefits will be accrued and distributed through government revenues. Consequently, delivering broad-based development benefits from those revenues depends on several factors, including the ability of state governments to successfully negotiate contracts, control costs, limit tax evasion, and manage price volatility. Government entities involved in energy planning, regulation, and gas production must also have the capacity to continually adjust their models to varying levels of production and to revise planning and oversight strategies accordingly. Failure to update optimistic revenue and production estimates as projects move forward may create serious economic and social risks. For some countries in the Global South, these risks surrounding project development and revenue management may make it exceedingly difficult to deliver on the promises of natural gas development. Failure to deliver anticipated benefits can, in turn, generate public discontent and social unrest.

In a world of converging global gas prices and increasing competition among suppliers, new gas producers will have to consider the competitiveness of their reserves against major market players. Modular, floating solutions may appear to be a cost-effective option for developing countries, but the particular geography and geology of the resource may have consequences for the cost of production, imperiling the prospects for securing SPAs or generating anticipated revenues. Many financiers and developers consider floating solutions flexible because they can be redeployed to a new location; at the same time, this feature reduces the potential bargaining power of national-level entities and local communities in negotiating terms with international developers.

Figure 15: Global LNG trade flows in 2017

Global trade in liquifies natural gas (LNG) has grown substantially over the past decade, as the emergence of new gas production techniques, surging global gas supplies, and falling prices have made LNG an increasingly attractive option for power generation and industrial production. LNG is produced by cooling and compressing gas into a liquid state so that it can be transported by ship to distant sites where it is regasified and fed into local distribution networks. Globally, thirty-three countries now have LNG import facilities, and the number of LNG receiving terminals has tripled in the past fifteen years. Currently, East Asia accounts for over half of the global demand for LNG. Some countries, like the US, Egypt, and Malaysia, both import and export LNG. For developing countries with potential to export natural gas, LNG provides greater flexibility to export to a variety of different markets compared to regional pipeline networks, but often involves higher capital costs and complex contractual and institutional arrangements. With the expansion of LNG and growing cross-regional trade, new gas producers in the Global South will face increasing competition from large, experienced suppliers in the US, Russia, Qatar, and Australia.



Source: Backspace 2019

Affordable Energy Access

For domestically oriented natural gas development projects, one of the biggest hurdles to implementation is the issue of affordable energy access. As noted previously, investors and financiers typically look to the financial health and creditworthiness of gas and power transmission and distribution companies as the primary foundation for securing financing. Their creditworthiness is defined by their ability to generate sufficient revenues, typically through cost-reflective energy tariffs, to sustain investment. In many developing countries, gas and power distribution networks not only lack a robust commercial and industrial user base to carry the cost of anchor energy loads, but also are home to significant populations living at or below the poverty line. In these contexts, many consumers may be unable or unwilling to pay for gas-fueled heating or electricity at cost-reflective tariff rates. Utilities may face the challenges of technical losses, including distribution system inefficiencies, and non-technical losses, such as gas or electricity theft, resulting in actual revenues that do not meet initial projections. This gap in revenue can result in substantial public debt in contexts where utilities are state owned.

The conventional guidance from international financial institutions is for governments to provide temporary cash transfers to economically vulnerable populations to offset the increases in the cost of electricity.[26] However, multiple host-country governments and communities have pushed back against this guidance as insufficient for addressing affordable energy access. In Jordan, for example, the IMF aggressively pushed for cost-reflective tariffs that dramatically increased energy costs for consumers, leading to a series of large social protests and strikes in 2018. Accordingly, any country looking to develop gas for domestic use must consider the ability and willingness of local communities to pay for energy cost increases. In addition to considering temporary cash transfers, countries would be wise to look at a variety of support mechanisms and to work in partnership with local stakeholders to design socially and economically viable strategies for affordable energy access. Utility regulators play a particularly important role in mediating the impact of new investments on consumers.

Forecasting Demand

Understanding domestic demand is pivotal to the success of developing gas for domestic use. Inaccurate demand projections threaten the economic sustainability of new gas investments, and imprecise understandings of local demand can lead to uneven impacts and serious social challenges. More detailed demand forecasting and analysis are needed across the developing world, with particular attention to the social dimensions of changing demand and

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[26] For example, the International Monetary Fund's program note for Jordan identifies cash transfers as the primary mechanism to shield low- and middle-income families from the negative impacts of electricity price increases caused by electricity sector reforms (IMF 2015).

to the specific barriers to access and distribution in different global contexts. A recent study on domestic gas utilization in East Africa provides an excellent example of a good starting point for the kinds demand forecasting and modeling that is needed (Demierre et al. 2015); while this study examines macro-level factors, additional detailed modeling will be needed to examine many of the assumptions at a finer scale.

In additional to conventional, quantitative modeling techniques, in-depth qualitative analysis is essential to better understand the different ways that energy is used and understood by different communities. As demonstrated by the challenges of the rural LPG promotion program in Ghana, detailed understanding of household and community heating, cooking, and transportation needs is vital to successfully extend gas access and use, whether via pipeline, LPG, CNG, or by other means. Similarly, more detailed understanding of household and community electricity needs is critical to utility planning and management, to effective regulatory oversight, and to the overall success of gas-fired power production.

CONCLUSION

Natural gas carries the potential to contribute positively to broad-based, pro-poor development in the Global South, but it comes with serious environmental, economic, and social risks (USAID 2018). Host-country governments, advocacy networks, donors, investors, and the private sector all have important roles to play to ensure that natural gas development does not adversely affect local communities or compromise critical climate and development goals. Governments in particular play a foundational role in setting national priorities; developing appropriate policies, legislation, and regulatory frameworks; and negotiating revenue and investment terms with international investors and developers. Civil society organizations play multiple crucial roles as well, by critically examining industry claims, by providing input into the development of policy and regulatory frameworks, and by working in partnership with local communities to call attention to specific needs and concerns. This report provides an overview of the infrastructural, institutional, and financing arrangements that attend natural gas development in order to support informed dialogue and debate among public, private, and civil society actors. Further research, conducted in close partnership with host-country governments and communities, is needed in the areas outlined above.

REFERENCES

Alvarez, Ramón A., Stephen W. Pacala, James J. Winebrake, William L. Chameides, and Steven P. Hamburg. 2012. “Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure.” *Proceedings of the National Academy of Sciences* 109 (17): 6435–6440. https://doi.org/10.1073/pnas.1202407109.

Alvarez, Ramón A., Daniel Zavala-Araiza, David R. Lyon, David T. Allen, Zachary R. Barkley, Adam R. Brandt, Kenneth J. Davis, et al. 2018. “Assessment of Methane Emissions from the U.S. Oil and Gas Supply Chain.” *Science* 361 (6398): 186–88. https://doi.org/10.1126/science.aar7204.

Alverà, Marco, David C. Carroll, and Ivan Marten. 2018. *Global Gas Report 2018*. Special Edition. 27th World Gas Conference, June 25–29, Washington, DC.

Asante, Kwaku Poku, Samuel Afari-Asiedu, Martha Ali Abdulai, Maxwell Ayindenaba Dalaba, Daniel Carrión, Katherine L. Dickinson, Ali Nuhu Abeka, Kwesi Sarpong, and Darby W. Jack. 2018. “Ghana’s Rural Liquefied Petroleum Gas Program Scale Up: A Case Study.” *Energy for Sustainable Development* 46 (October): 94–102. https://doi.org/10.1016/j.esd.2018.06.010.

Balcombe, P., N. P. Brandon, and A. D. Hawkes. 2018. “Characterising the Distribution of Methane and Carbon Dioxide Emissions from the Natural Gas Supply Chain.” *Journal of Cleaner Production* 172 (January 20): 2019–2032. https://doi.org/10.1016/j.jclepro.2017.11.223.

Balcombe, Paul, Kris Anderson, Jamie Speirs, Nigel Brandon, and Adam Hawkes. 2017. “The Natural Gas Supply Chain: The Importance of Methane and Carbon Dioxide Emissions.” *ACS Sustainable Chemistry and Engineering* 5 (1): 3–20. https://doi.org/10.1021/acssuschemeng.6b00144.

Bandela, N. N., and D. G. Tare. 2008. “Reducing Air Pollution by Using CNG as a Vehicle Fuel: A Study From Mumbai.” *Environmental Quality Management* 18 (2): 67–70. https://onlinelibrary.wiley.com/doi/abs/10.1002/tqem.20206.

Bariyo, Nicholas. 2018. “Emerging Militant Group Threatens Villages, Gas Projects in Mozambique.” *Wall Street Journal*, July 30. https://www.wsj.com/articles/emerging-militant-group-threatens-villages-gas-projects-in-mozambique-1532970924.

Boersma, Tim, and Sarah M. Jordaan. 2017. “Whatever Happened to the Golden Age of Natural Gas?” *Energy Transitions* 1 (2): 5. https://doi.org/10.1007/s41825-017-0005-4.

BP. 2018. *BP Statistical Review of World Energy 2018*. London.

Bradley, Siân, Glada Lahn, and Steve Pye. 2018. *Carbon Risk and Resilience: How Energy Transition Is Changing the Prospects for Developing Countries with Fossil Fuels*. Research Paper. London: Chatham House.

———. 2016. “Methane Leaks from Natural Gas Systems Follow Extreme Distributions.” *Environmental Science and Technology* 50 (22): 12512–12520. https://doi.org/10.1021/acs.est.6b04303.

Carpenter, J. W. 2018. “The World’s Top 10 Natural Gas Companies.” *Investopedia*, February 9.

Cenpower. 2016. *Powering Ghana’s Future: Fast Facts*. Accra, Ghana.

CIP (Centro de Integridade Pública Moçambique). 2013a. *Implications of the 2006 Contracts for Government Income*. Maputo. https://cipmoz.org/wp-content/uploads/2018/08/208_As_potenciais_Receitas_do_Rovuma_-_Ingles.pdf.

CIP. 2013b. *Pande Temane Gas Exports to South Africa: First Major Extractive Sector Projects Fails Mozambique*. Maputo.

Cotterill, Joseph. 2018. “Mozambique to Hand Over Gas Revenues to Fix ‘Tuna Bond’ Dispute.” *Financial Times*, November 6. https://www.ft.com/content/d239e548-e1a9-11e8-8e70-5e22a430c1ad.

Crooks, Ed. 2018. “Mozambique to Become a Gas Supplier to World.” *Financial Times*, June 27, 2018. https://www.ft.com/content/d34685b2-7995-11e8-bc55-50daf11b720d.

Demierre, Jonathan, Morgan Bazilian, Jonathan Carbajal, Shaky Sherpa, and Vijay Modi. 2015. “Potential for Regional Use of East Africa’s Natural Gas.” *Applied Energy* 143 (April): 414–436. https://doi.org/10.1016/j.apenergy.2015.01.012.

DOE (US Department of Energy). 2015. “Appendix B: Natural Gas.” In *Quadrennial Energy Review.* Washington, DC.

———. 2018. “Natural Gas Benefits and Considerations.” Washington, DC: US Department of Energy Alternative Fuels Data Center. https://www.afdc.energy.gov/fuels/natural_gas_benefits.html.

Dzawu, Moses. 2018. “Ghana to Sell Stakes in Thermal-Power Plants to Cut Debt.” Bloomberg, April 3. https://www.bloomberg.com/news/articles/2018-04-03/ghana-plans-to-sell-stakes-in-thermal-power-plants-to-cut-debt.

Eftimie, Adriana, Katherine Heller, and John Strongman. 2009. *Gender Dimensions of the Extractive Industries*. Extractive Industries and Development Series #8. Washington, DC: World Bank.

EIA (US Energy Information Administration). 2016. *Trends in US Oil and Natural Gas Upstream Costs*. Washington, DC: US Department of Energy.

Eni. 2017. “Eni Achieves Financial Close for Coral South FLNG.” Press release, December 6. https://www.eni.com:443/en_IT/media/2017/12/eni-achieves-financial-close-for-coral-south-flng.

Ferguson, James. 1990. *The Anti-Politics Machine: “Development”, Depoliticization, and Bureaucratic Power in Lesotho*. Cambridge, UK: Cambridge University Press.

GFDRR (Global Facility for Disaster Reduction and Recovery). 2018. “Mozambique.” https://www.gfdrr.org/en/mozambique.

GIIGNL (International Group of LNG Importers). 2018. Annual Report.

Gqada, Ichumile. 2013. “A Boom for Whom? Mozambique’s Natural Gas and the New Development Opportunity.” Africa Portal, August 1. https://www.africaportal.org/publications/a-boom-for-whom-mozambiques-natural-gas-and-the-new-development-opportunity/.

Grigas, Agnia. 2018. *The New Geopolitics of Natural Gas*. Cambridge, MA: Harvard University Press.

Holz, Franziska, Philipp M Richter, and Ruud Egging. 2015. “A Global Perspective on the Future of Natural Gas: Resources, Trade, and Climate

Constraints.” *Review of Environmental Economics and Policy* 9 (1): 85–106. https://doi.org/10.1093/reep/reu016.
Howarth, Robert W. 2014. “A Bridge to Nowhere: Methane Emissions and the Greenhouse Gas Footprint of Natural Gas.” *Energy Science and Engineering* 2 (2): 47–60. https://doi.org/10.1002/ese3.35.
Howarth, Robert W., Renee Santoro, and Anthony Ingraffea. 2011. “Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations.” *Climatic Change* 106 (4): 679. https://doi.org/10.1007/s10584-011-0061-5.
Husseini, Talal. 2018. “Oil Giants Granted Exclusive Rights for Block 5 Offshore Mozambique.” Offshore Technology, August 8. https://www.offshore-technology.com/news/oil-block-5-offshore-mozambique/.
Hutchison, James, Andrea Manica, Ruth Swetnam, Andrew Balmford, and Mark Spalding. 2014. “Predicting Global Patterns in Mangrove Forest Biomass.” *Conservation Letters* 7 (3): 233–40. https://doi.org/10.1111/conl.12060.
ICF. 2017. *Benefits and Opportunities of Natural Gas Use, Transportation, and Production Benefits and Opportunities*. Prepared for American Petroleum Institute. Fairfax, VA: ICF.
ICF International. 2017. *Perspectives on the Development of LNG Market Hubs in the Asia Pacific Region*. Washington, DC: US Department of Energy, Energy Information Administration.
IEA (International Energy Agency). 2006. “Energy for Cooking in Developing Countries.” In *World Energy Outlook 2006*, 419–445. Paris. https://doi.org/10.1787/weo-2006-16-en.
———. 2011. *Are We Entering a Golden Age of Gas?* Special report in the *World Energy Outlook 2011* series. Paris.
———. 2012. *Golden Rules for a Golden Age of Gas*. *World Energy Outlook* Special Report on Unconventional Gas. Paris.
———. 2014. “Unconventional Gas Production Database.” https://www.iea.org/ugforum/ugd/.
———. 2018. *World Energy Outlook 2017 Excerpt: Outlook for Natural Gas*. Paris. https://webstore.iea.org/world-energy-outlook-2017-excerpt-outlook-for-natural-gas.
IGU (International Gas Union). 2017. *2017 World LNG Report*. Barcelona.
IGU (International Gas Union). 2018. *2018 World LNG Report*. Barcelona.
IMF (International Monetary Fund). 2015. “Program Note: Jordan.” April 3. Washington, DC. https://www.imf.org/external/np/country/notes/jordan.htm.
INP (Instituto Nacional de Petroleo). 2014. “Instituto Nacional de Petroleo: Concursos (Competition Awards).” http://www.inp.gov.mz/index.php/pt/Concursos.
IRENA (International Renewable Energy Agency). 2018. *Renewable Power Generation Costs in 2017*. Abu Dhabi.
Keenan, J. C., and D. L. Kemp. 2014. *Mining and Local-Level Development: Examining the Gender Dimensions of Agreements between Companies and Communities*. Brisbane, Australia: Centre for Social Responsibility in Mining, University of Queensland. https://www.csrm.uq.edu.au/publications/mining-and-local-level-development-examining-the-gender-dimensions-of-agreements-between-companies-and-communities.

Kumi, Ebenezer Nyarko. 2017. *The Electricity Situation in Ghana: Challenges and Opportunities*. CGD Policy Paper 109. Washington, DC: Center for Global Development.

Lawson, Lynda Merilyn. 2014. *Gender Equality in the Extractive Industries in Africa*. UN Women Policy Brief. Nairobi: UN Women.

Laye, Sebastien. 2018. "Ghana's Energy Bond Saga: Debt Binge Continues." *ESI-Africa.com* (blog), March 12. https://www.esi-africa.com/ghanas-energy-bond-saga-debt-binge-continues/.

Lazard. 2018. "Levelized Cost of Energy and Levelized Cost of Storage 2018." November 8. https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/.

Ledesma, David. 2013. *East Africa Gas: Potential for Export.* Oxford, UK: Oxford Institute for Energy Studies.

Lo, Chris. 2014. "Offshore LNG: Does the Future Float?" Offshore Technology, October 28. https://www.offshore-technology.com/features/featureoffshore-lng-does-the-future-float-4419881/.

MacKinnon, Michael A. Mac, Jacob Brouwer, and Scott Samuelsen. 2018. "The Role of Natural Gas and Its Infrastructure in Mitigating Greenhouse Gas Emissions, Improving Regional Air Quality, and Renewable Resource Integration." *Progress in Energy and Combustion Science* 64 (January): 62–92. https://doi.org/10.1016/j.pecs.2017.10.002.

Mozambique Resources Post. 2018. "Mozambique Oil and Gas: Is Eric Prince Teamed up with ENH?" August 14. https://mozambiqueminingpost.com/2018/08/14/mozambique-oil-gas-is-eric-prince-teamed-up-with-enh/.

NGSA (Natural Gas Supply Association). 2013. "Natural Gas—From Wellhead to Burner Tip." Washington, DC. http://naturalgas.org/naturalgas/.

Nhamire, Borges, and Matthew Hill. 2018. "Mozambique's $49 Billion Gas Plan Stokes Anxiety in North." *Bloomberg News*, July 22.

Offshore Technology. n.d. "Sankofa Gas Project, Tano Basin." Offshore Technology. Accessed December 19, 2018. https://www.offshore-technology.com/projects/sankofa-gas-project-tano-basin/.

Oxfam America. 2018a. *Examining the Crude Details*. Boston. https://www.oxfamamerica.org/explore/research-publications/examining-the-crude-details/.

———. 2018b. *Free, Prior and Informed Consent in the Extractive Industries in Southern Africa*. Boston. https://www.oxfamamerica.org/explore/research-publications/free-prior-and-informed-consent-in-the-extractive-industries-in-southern-africa/.

Pereira, Ryan, and Mike Wood. 2017. "Value Creation: Gas to Power-via LNG Import or Domestic Development?" Presentation at Institution of Mechanical Engineers, May 18, London.

Pilling, David. 2018. "Shell and Anadarko in Dispute over Mozambique Gas." *Financial Times*, November 12. https://www.ft.com/content/a83be082-e642-11e8-8a85-04b8afea6ea3.

Power, Marcus, Peter Newell, Lucy Baker, Harriet Bulkeley, Joshua Kirshner, and Adrian Smith. 2016. "The Political Economy of Energy Transitions in Mozambique and South Africa: The Role of the Rising Powers." *Energy Research and Social Science* 17 (July): 10–19. https://doi.org/10.1016/j.erss.2016.03.007.

Rapier, R. 2016. “The Top 10 Natural Gas Producers.” *Forbes*, August 12.
Reuters. 2017a. “Tokyo Gas Will Not Accept Destination Clauses in New LNG Contracts.” October 5. https://www.reuters.com/article/japan-tokyo-gas-idUSL4N1MG0O1.
———. 2017b. “Blackwater Founder Prince to Invest in Mozambique’s Hidden-Loan Firm.” December 13. https://www.reuters.com/article/us-mozambique-investment-idUSKBN1E7282.
Roy, Joyashree, Petra Tschakert, Henri Waisman, Sharina Abdul Halim, Philip Antwi-Agyei, Purnamita Dasgupta, Patricia Fernanda Pinho, et al. 2018. “Sustainable Development, Poverty Eradication and Reducing Inequalities.” In *Global warming of 1.5°C.* IPCC Special Report Vol. SR15. Geneva: Intergovernmental Panel on Climate Change.
Smith, Margaret, and John Gonzales. 2014. *Costs Associated with Compressed Natural Gas Vehicle Fueling Infrastructure*. Washington, DC: US Department of Energy. https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf.
Songhurst, Brian. 2014. *LNG Plant Cost Escalation*. Oxford, UK: Oxford Institute for Energy Studies.
———. 2017. *The Outlook for Floating Storage and Regasification Units (FSRUs).* Oxford, UK: Oxford Institute for Energy Studies.
Stern, Jonathan. 2016. *The New Japanese LNG Strategy : A Major Step towards Hub-Based Gas Pricing in Asia*. Oxford, UK: Oxford Institute for Energy Studies.
———. 2017. *Challenges to the Future of Gas: Unburnable or Unaffordable?* Oxford, UK: Oxford Institute for Energy Studies. https://doi.org/10.26889/9781784670993.
Suliman, Adelia. 2018. “Mangroves and Mapping Help Mozambique Tackle Climate Change.” Reuters, April 27. https://www.reuters.com/article/us-mozambique-climatechange-cities-idUSKBN1HY2OC.
Terazono, Emiko. 2018. “Record LNG Shipping Rates Raise Capacity Concerns.” *Financial Times*, November 6. https://www.ft.com/content/733088aa-d613-11e8-a854-33d6f82e62f8.
Thomas, Karen. 2017. “LNG Shipping Rich List – The Top Owners of 2017.” LNG World Shipping, April 4. https://www.lngworldshipping.com/news/view,lng-shipping-rich-list-the-top-owners-of-2017_47026.htm.
UNDP (United Nations Development Programme). 2018. UNDP Climate Change Adaptation Program Overview: Ghana. https://www.adaptation-undp.org/explore/western-africa/ghana.
UNEP (United Nations Environment Programme)/UNDP (United Nations Development Programme). 2012. *Ghana National Climate Change Adaptation Strategy*. Nairobi and New York.
USAID (US Agency for International Development). 2018. *Power Africa: Gas Roadmap to 2030*. Washington, DC.
USEA (US Energy Association). 2018. *Global LNG Fundamentals*. Washington, DC.
USEIA (US Energy Information Administration). 2015. “World Shale Resource Assessments.” https://www.eia.gov/analysis/studies/worldshalegas/.
USEIA (US Energy Information Administration). 2019. International Energy Statistics Database. https://www.eia.gov/opendata/.

Wigglesworth, Robin, and Gregory Meyer. 2018. "Wild Gas Price Swings Spur CME 'Emergency Action.'" *Financial Times*, November 15. https://www.ft.com/content/589157d8-e8ea-11e8-885c-e64da4c0f981.

Wood Mackenzie. 2018. *Commodity Traders in LNG: How Four Trading Houses Are Shaking Up the Industry*. Edinburgh.

World Bank. 2018. "Ghana Sankofa Gas Project." World Bank Financial Solutions Brief. http://pubdocs.worldbank.org/en/969011518200591340/Briefs-Guarantees-GhanaSankofa.pdf.

Zawadzki, Sabina, and Jessica Jaganathan. 2018. "LNG Shipping Rates Spike with No Respite Seen through 2019." *Reuters*, September 21. https://www.reuters.com/article/us-lng-shipping-rates-idUSKCN1M11W4.

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