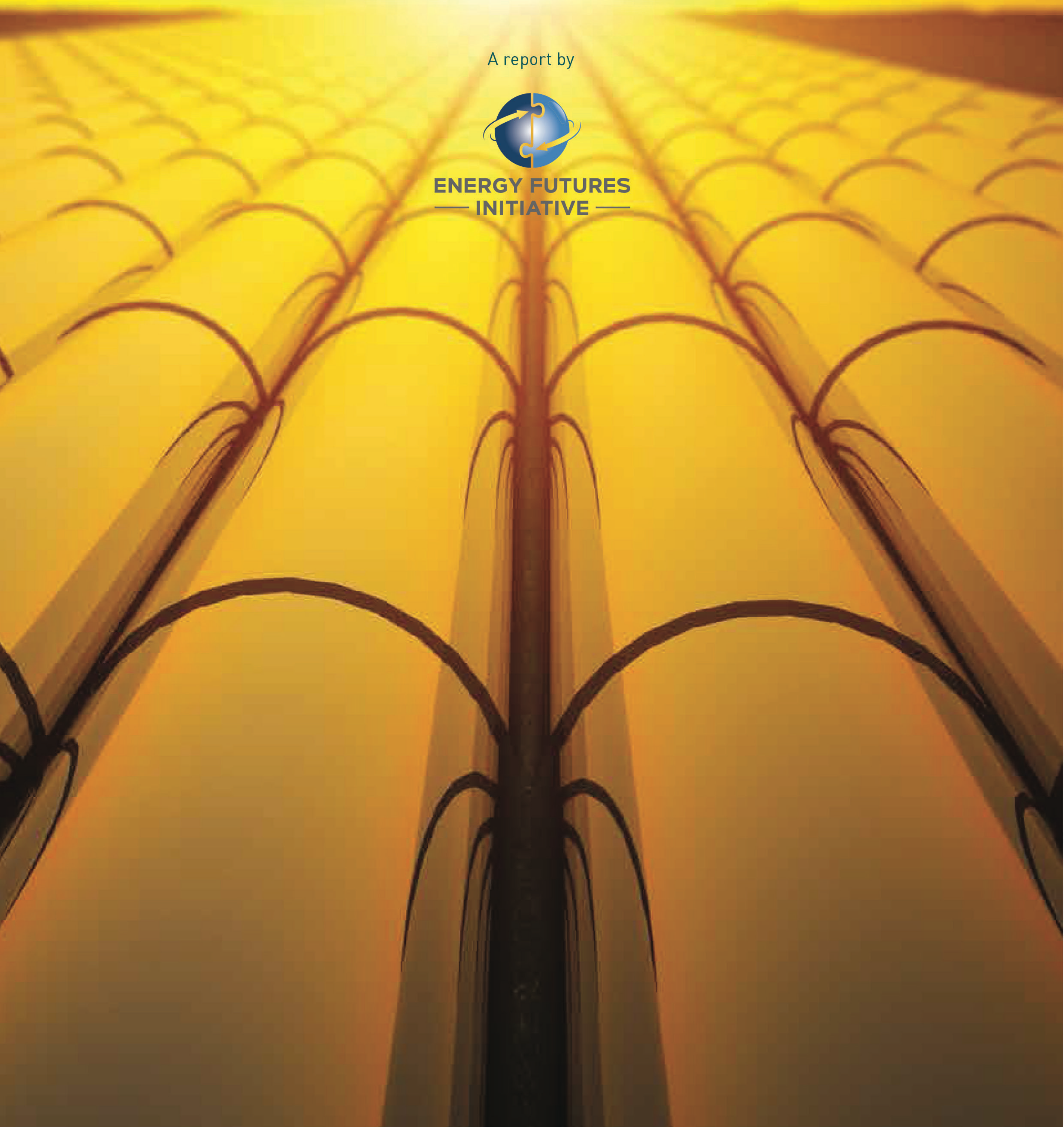
AFRICA50

Investing in Natural Gas for Africans: Doing Good and Doing Well

A report by

ENERGY FUTURES INITIATIVE



Foreword

This report by Energy Futures Initiative (EFI) was supported by Africa50, the pan-African infrastructure investment platform I have been honored to lead since August 2016. As at 30 August 2018, our shareholders include 27 African countries, the African Development Bank and two African central banks. We prioritize investments in power, transportation, information and communication technology, and midstream gas, with a particular emphasis on increasing the pipeline of investment-ready projects. To date we are developing and financing solar plants in Nigeria and Egypt, and a thermal plant in Senegal. We have a solid pipeline of projects under review and we will commit funding to several of these projects in the near term.

Recognizing the disconnect between Africa's vast natural gas reserves and the continent's low levels of gas infrastructure and the resulting low penetration of gas in African economies, we asked EFI to conduct an analysis of the opportunities and benefits of natural gas development in Africa. This report explores the scale of potential domestic demand by mid-century, and the technologies that can help increase this demand and the concomitant supply and infrastructure.

I am grateful for the solid analysis of EFI's team of experts in gas trends, technologies, and supply chains, presented in this report. We at Africa50 are ready to take a leadership role in helping Africa develop its gas resources for the power generation industry and other sectors of African economies, to help the continent reach its full economic potential. The report Investing in Natural Gas for Africans: Doing Good and Doing Well is expected to provide the background and analysis to move forward expeditiously.

Alain Ebobissé
Chief Executive Officer
Africa50

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SUMMARY FOR POLICYMAKERS

Africa is at an inflection point: its population is burgeoning, energy resources and demand are growing, its economic outlook is improving, and its national, regional and continental governance entities are focused on a range of policies and structures to support economic growth. Given the right set of policies and incentives, natural gas could provide a sound foundation to support and accelerate this growth, at the same time it helps African nations meet their key electrification, health, and environmental goals.

There are significant natural gas resources across the African continent. Natural gas can be an essential source of liquid fuels like propane, and is an important building block for industrial products – fertilizers, plastics and pharmaceuticals. It is a heat source for the manufacturing of glass, cement, ceramics and more. This flexibility coupled with abundant natural gas resources in sub-Saharan Africa, Africa's energy demand growth, and its commitments to universal electricity access and cleaner energy, are intensifying the focus on the development of African gas.

While the flexibility of gas is attracting well-deserved attention, the inflexibility of the infrastructures for its transportation and distribution can diminish its uses in developing regions like sub-Saharan Africa. This inflexibility limits the value of natural gas to certain locations – urban areas with ports, large power generators, or locations with infrastructures already in place.

Creating demand for gas is an essential strategy for optimizing the development and value of Africa's indigenous gas resources. A suite of technologies can be used to address a range of demand-limiting infrastructure issues, creating new natural gas options for both urban and rural consumers. In particular, innovation in distributed technologies can positively impact the delivery of new energy services in rural settings. Key investments in technologies and infrastructures will increase sub-Saharan gas demand and grow national economies.

The following are highlights of natural gas technologies and infrastructure options that merit significant attention of policy-makers and investors in Africa. This is not intended to be an exhaustive list but it does represent technologies that are key to addressing population, energy, environmental and economic trends. These technologies also address time-scales, e.g. floating storage and regasification units (FSRUs) to meet and create gas demand in the near- to mid-term, as both urban and rural options.

Natural Gas Power Generation

Implications of Investment in **Large-Scale Gas Turbines** for African countries

- Historically, the desirability of natural gas generation has been tempered by widely fluctuating natural gas prices; however, with conventional and unconventional long-term gas supply, this concern is greatly diminished.
- For large, sustained daily demand, natural gas combined cycle technology offers a low cost, reliable option.
- For meeting variable demand, natural gas peaking technology offers an economical, flexible option.
- Large-scale gas generation can replace more carbon-intensive fuels like coal and oil, while complementing zero-carbon fuels by providing more stability of supply.
- Large scale gas turbines are most appropriate for high density areas with access to supplies supported by pipeline and other infrastructure.

Implications of Investment in **Small-Scale Gas Generation and Microgrids** for African countries

- These small-scale natural gas generation technologies offer flexibility within their class as well as through the technology range, enabling the matching of a variety of needs to specific technology capabilities based on size, operational flexibility and cost.
- Small-scale generation can be coupled with microgrids to provide power to rural areas that would be impractical to connect to the main electric grid.

Overland Transportation

Implications of Investment in **Virtual Pipelines** for African countries

- Modified small-scale shipping containers for LNG or compressed natural gas (CNG) for intermodal transportation offer affordable, technologically feasible alternatives to traditional natural gas pipeline infrastructure.
- LNG virtual pipelines would feature small-scale regasification (vaporizer) facilities.
- CNG or LNG carried by virtual pipeline would be primarily used for small-scale power generation, but could serve other end uses such as transportation, heating, and cooking.
- New airborne technologies, tailored to Africa's needs, are being developed that could provide an alternative to overland transport of natural gas products associated with Africa's flared/stranded gas.
- Given the multiple technologies associated with the virtual pipeline, from source to use, the economics of each project will vary significantly.

Liquefied Natural Gas Imports

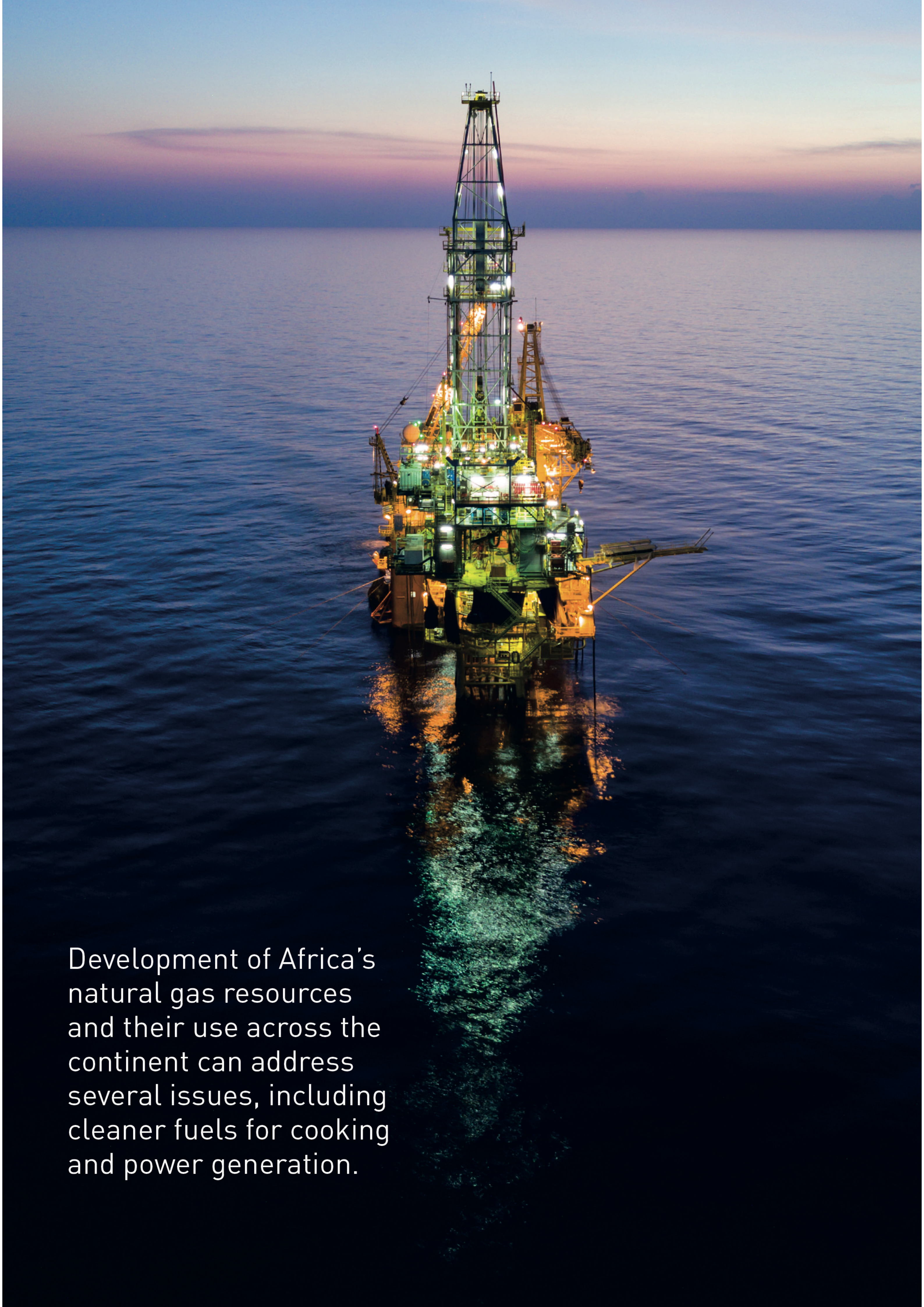
Implications of Investment in **Floating Regasification Storage Units** for African countries

- Low costs (compared to land-based regasification facilities) reduce barriers for new market entrants, especially those without established infrastructure and which have lower volumes of gas demand.
- Reduced construction schedules increase ability to respond to emerging market conditions and/or energy needs.
- The ability of FSRUs to be moved to new, more favorable locations reduces risks to investors and promotes regional development.
- FSRUs can accelerate the LNG-to-Power Sector when integrated with natural gas turbines.
- FSRUs can be a bridge or temporary approach while a conventional land-based terminal is explored.
- The complexity of the transactions and individual attributes of each marine location require major due diligence at the front end.
- Floating Storage Units (FSUs) without regasification are cheaper and can facilitate the creation of an LNG virtual pipeline, allowing for small scale regasification at point of use.
- A range of factors must be considered when deciding between FSRUs and an onshore terminal including port space, water depth, and vessel size, among others.

Natural Gas Products

Implications of Investment in **Small-Scale Gas Processing** for African countries

- The processing of wet natural gas, which consists of methane along with natural gas liquids, creates commodity byproducts such as liquefied petroleum gas (LPG) that can be used for cooking and heating; as well as ethane, that can be used as a feedstock for petrochemical production.
- A significant amount of associated and non-associated natural gas in Africa is flared because of lack of access to gas processing facilities or because the resource is of sub-optimal size, making it uneconomic to transport.
- Small scale, skid mounted gas processing units have been developed to produce LPG units can condition dry gas for power generation and can also process gas to produce CNG.



Development of Africa's natural gas resources and their use across the continent can address several issues, including cleaner fuels for cooking and power generation.

WHY FOCUS ON NATURAL GAS DEVELOPMENT IN AFRICA?

Natural gas is a highly flexible, versatile fuel. Development of Africa's natural gas resources and their use across the continent can address several issues, including cleaner fuels for cooking and power generation. It can promote economic growth in key areas such as plastics and pharmaceuticals; manufacturing of glass, steel, bricks, and cement; and chemical production of hydrogen, ammonia/fertilizer, and alternative fuels for transportation (Figure 1).

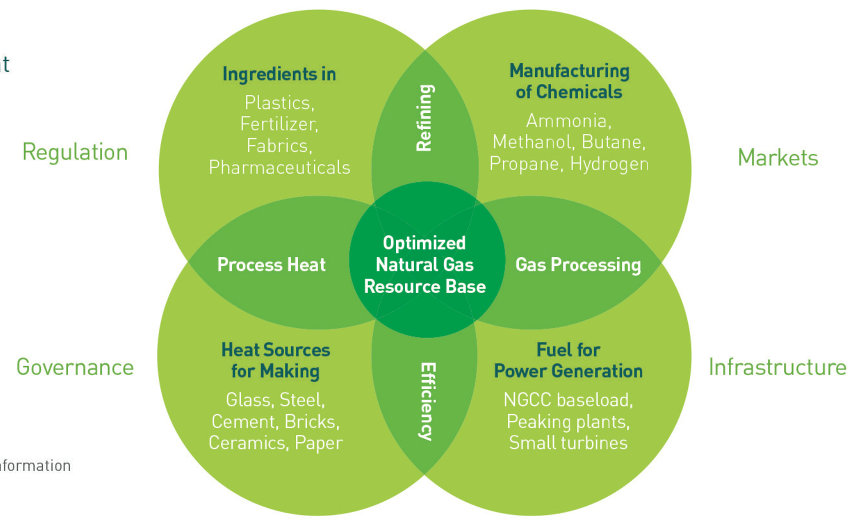
Africa is gas resource-rich relative to its consumption but faces several critical issues for increasing the use of its gas resources. One major challenge historically has been the large distance between resource bases for production and major demand centers, which poses the need for adequate infrastructure.[1] A related issue is that Africa lacks robust gas transmission and distribution infrastructures that could help optimize the value of natural gas. The flexibility of natural gas uses is, however, matched by the relative lack of flexibility in how it gets delivered to markets where it can be fully utilized. Without a suite of technologies to address these infrastructure issues, this inflexibility will limit the uses and value of African gas to certain locations – large urban areas with ports, locations with infrastructures in place, and large demand centers.

Sub-Saharan Africa also lacks many of the industrial building blocks needed (e.g. gas processing and refining) to increase gas demand sufficient to attract necessary investment. In addition, tariff structures and other policies designed to subsidize power and fuel costs tend to discourage investments in needed production, generation and distribution infrastructures.

One of the solutions to these infrastructure problems will be to have centralized facilities that use gas to produce a final product that can be distributed with existing infrastructure. Such final products could include electricity (where grids are well-developed), canisters of gas byproducts for cooking fuel, or fertilizer. The other solution is the use of innovative technologies to build infrastructure that is smaller, cheaper, and more flexible than the vast gas distribution infrastructure that exists in the U.S. and Europe. This includes solutions for gas imports, distribution, and end use. Several of these technologies, however, will still require improvements to complementary infrastructure, such as roads.

Developing the infrastructure to increase natural gas consumption in Africa – both through the bootstrapping enabled by imports of LNG and increased indigenous production – will create viable pathways to help meet increasing demand for energy, promote economic development, and help countries in Africa to meet their air quality and other environmental goals and objectives.

Figure 1.
Economic Development in Africa: Natural Gas Can be Used for...



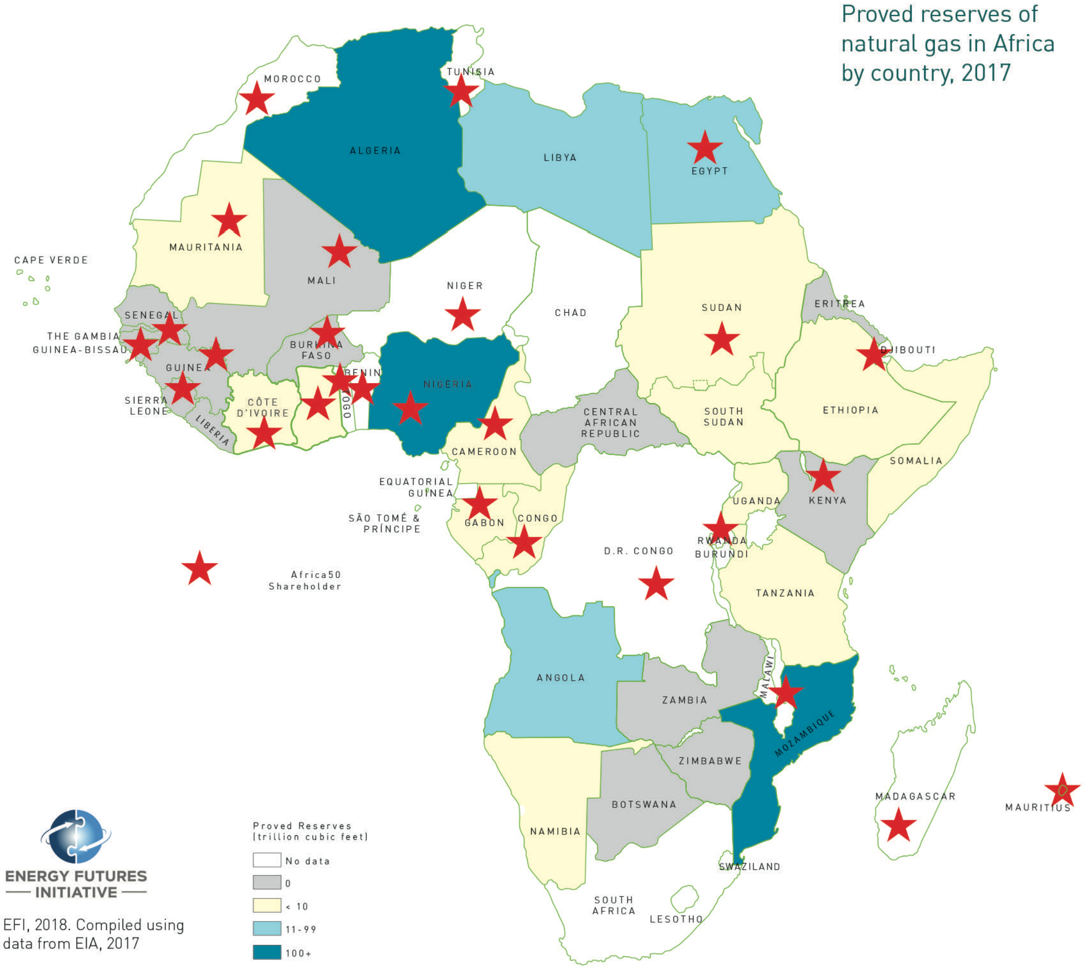
Source: EFI 2018, compiled with information from Geology.com

1. https://openknowledge.worldbank.org/bitstream/handle/10986/20685/896220WP0P1318040Box0385289B000UO0900ACS.pdf?sequence=1&isAllowed=y

Africa's Natural Gas Resources

The abundance of natural gas reserves in Africa – in Nigeria, Angola, Algeria, Mozambique, Tanzania, and approximately 25 trillion cubic feet (Tcf) of newly discovered offshore resources in the Greater Tortue field that spans Senegal and Mauritania – means that it could remain a low-cost fuel option for the foreseeable future (Figure 2). Estimates from the U.S. Energy Information Administration suggest that there are more than 600 Tcf of proved natural gas reserves in Africa as of 2017,[2] and the continent contains approximately 7.5% of the world's proved natural gas reserves.[3,4] The 160 Tcf of newly-discovered recoverable gas in Mozambique's Rovuma Offshore Basin rivals the reserves found in Nigeria and Algeria, while 57 Tcf of gas has been found in Tanzania's Mafia Deep Basin.[5] Gas production in Africa is expected to increase by 22 billion cubic feet (Bcf) per day (about 7 Tcf/year) from 2016 to 2040. By 2040, natural gas will almost match oil's share of total energy production in Africa, with gas at 33% and oil at 34%.

Figure 2.
Proved reserves of natural gas in Africa by country, 2017



EFI, 2018. Compiled using data from EIA, 2017

2. https://www.eia.gov/beta/international/data/browser/#/?pa=00000000000000000004&c=ruvvvvvfvtvnvv1urvvvvfvvvvvfvvvou20evvvvvvvvvnvvuvo&ct=0&tl_id=3002-A&vs=INTL.3-6-AFG-TCF.A&cy=2017&vo=0&v=H
3. https://www.icafrica.org/fileadmin/documents/Publications/Africa_Energy_Atlas.pdf
4. http://www.powermag.com/power-in-africa-prospects-for-an-economic-foothold/
5. https://ngi.stanford.edu/sites/default/files/NGI_EAfrica_LitReview%284-17%29.pdf

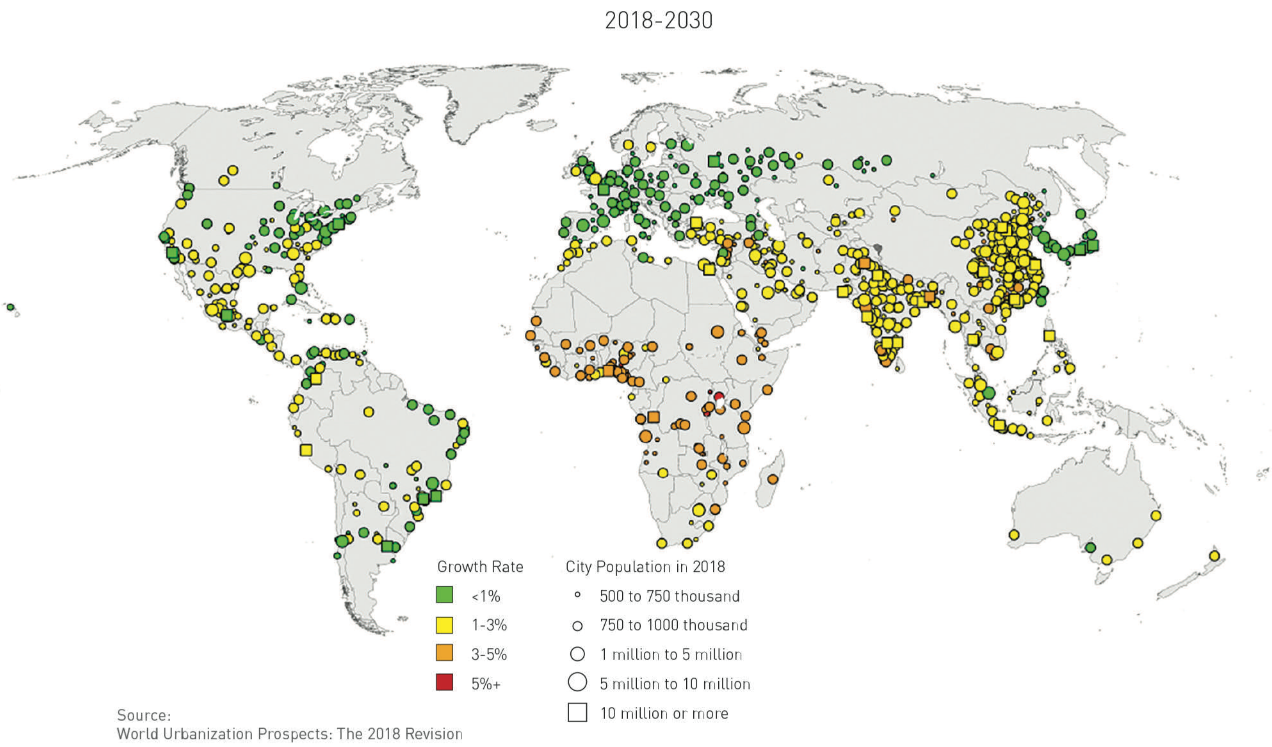
Growing Populations and Energy Demand

Development of Africa's natural gas resources will be needed to meet the energy demand of growing populations. Rapid population growth, urbanization (Figure 3), expanding economies, increasing levels of energy access and electrification, and rising living standards and human development are all contributing to an increase in overall energy demand.

By 2050, Nigeria will be third most populous country in the world. While they are already in the top 20 most populous countries, the Democratic Republic of the Congo, Ethiopia and Egypt can expect their populations to more than double by mid-century. Currently, three cities in Africa – Cairo, Lagos and Kinshasa – have 10 million or more people, qualifying as "megacities". This number will expand to include Nairobi, Dar-es-Salaam, Khartoum and Casablanca over the next couple of decades. Between 2010 and 2050, Africa's urban population will rise from 400 million to 1.26 billion.[6]

Natural gas consumption in Africa has seen a steady rise since 1980 and has more than doubled since 2000.[7] In 2015, Africa consumed 22.7 quadrillion Btu (quads) of primary energy, nearly 23% of which was from natural gas. This proportion was second only to liquid fuels, which comprised 37% of total primary energy consumption in 2015.[8] The amount of natural gas consumed is expected to continue to rise, though it is not expected to increase as a proportion of total primary consumption. This could change, however, with targeted investment.

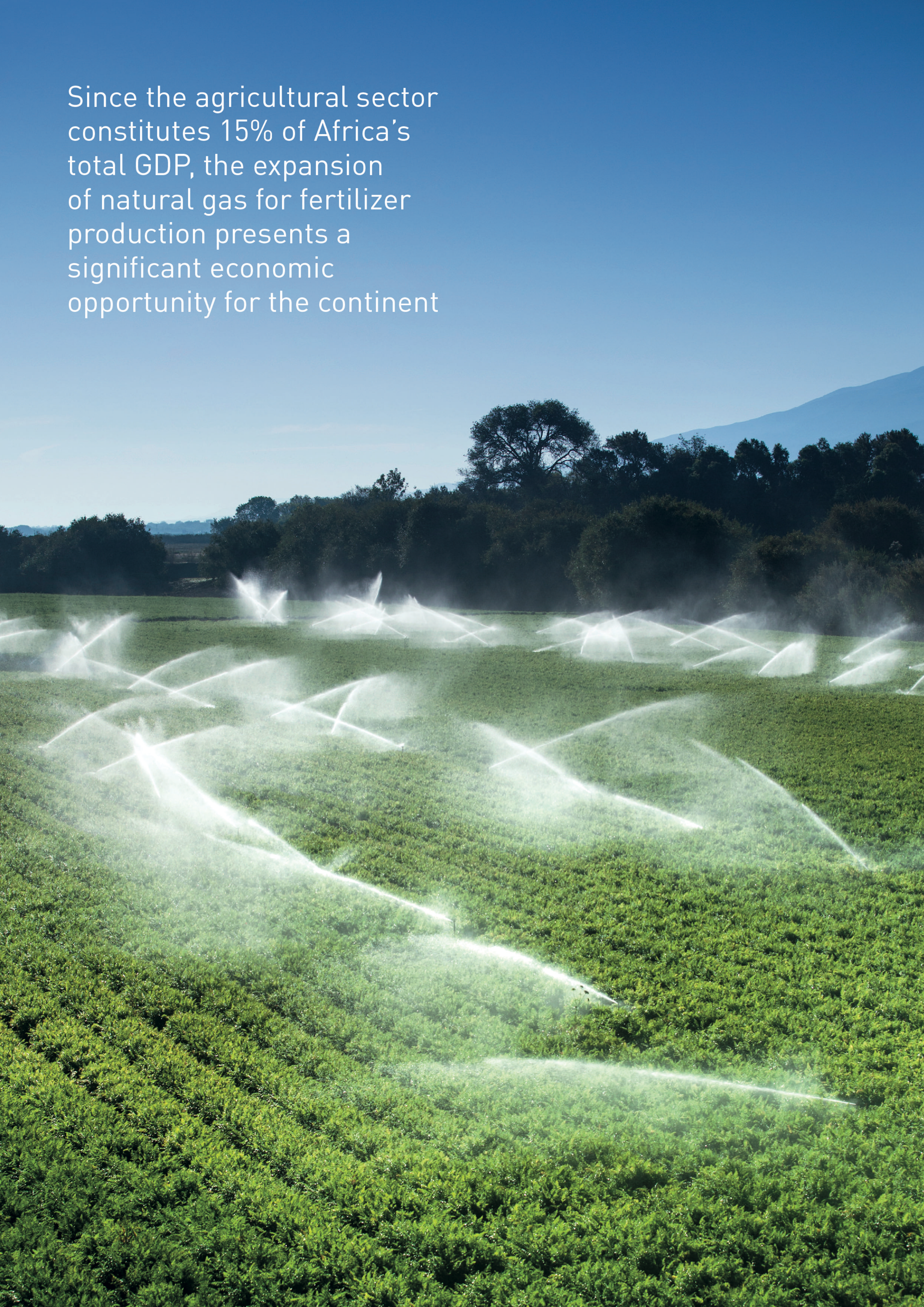
Figure 3.
Growth Rates of Urban Agglomerations by Size Class



Source:
World Urbanization Prospects: The 2018 Revision

6. Sow, Mariama, Foresight Africa 2016: Urbanization in the African Context, Brookings Institution, 2015
7. https://www.eia.gov/outlooks/ieo/
8. https://www.eia.gov/outlooks/ieo/

Since the agricultural sector constitutes 15% of Africa's total GDP, the expansion of natural gas for fertilizer production presents a significant economic opportunity for the continent



USES OF NATURAL GAS

Sub-Saharan Africa has significant natural gas resources. Natural gas is also an extremely flexible fuel. It can be used in all sectors of modern economies – industry, buildings, transportation, and power generation. It is an essential building block for liquid fuels like propane, and for industrial products -- fertilizer, plastics and pharmaceuticals. It is a heat source for glass, cement, ceramics production and more. This flexibility, coupled with abundant natural gas resources in sub-Saharan Africa, Africa's energy demand growth, and its commitments to universal electricity access and cleaner energy, are intensifying the focus on the development of African gas.

Natural Gas for Power Generation

Natural gas power generation is perhaps the most impactful option for Africa in the near to mid-term. The UN's Human Development Index (HDI) suggests a strong correlation between electricity consumption and a country's ranking on the index. Also, infrastructure needs for power generation are generally less complicated and costly than for other use.

Natural gas already plays an important role in the African power sector, constituting nearly one quarter of all power plants by fuel type[9] (Figure 4) and the single largest source of installed capacity on the continent (86 GW).[10] Many of Africa's natural gas-fired power plants are located along coastal areas in countries with large proved reserves of gas, such Algeria, Libya, Egypt, and Nigeria.[11]

Expanding gas-fired power generation in other parts of Africa can be critical for increasing electrification rates across the continent, especially in the sub-Saharan region where these rates are particularly low.[12] Gas-fired generation could also be used to enable further deployment of zero marginal cost renewables, including variable solar and wind resources. In addition, gas-fired generation could supplement hydropower, a key source of electricity in sub-Saharan Africa (and the main source of power in certain countries). While there is substantial hydro-power generation in Africa, it has limitations such as those stemming from hydrological uncertainties.[13] For example, A 2015 World Bank study assessed the impacts of future climate uncertainty on hydropower and irrigation expansion planning in Africa and found that, under the driest climate scenario, revenue losses from overbuilding hydropower infrastructure could range from five to sixty percent across Africa's seven main river basins.[14]

Natural gas will also be key for decarbonizing the power sector. Coal and (to a lesser extent) petroleum make up a significant part of the African generation mix; combined, they make of 45% of the energy used for power generation continent-wide. Coal generation is also projected to grow in Africa at a much faster rate than the world as a whole. Substituting gas for oil and coal in both existing and new generation could go a long way to helping African countries meet their decarbonization goals.

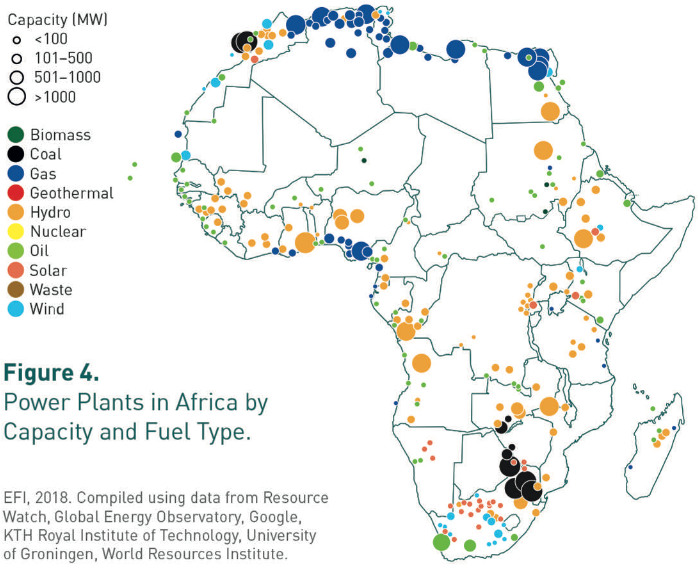


Figure 4.
Power Plants in Africa by Capacity and Fuel Type.

EFI, 2018. Compiled using data from Resource Watch, Global Energy Observatory, Google, KTH Royal Institute of Technology, University of Groningen, World Resources Institute.

9. https://resourcewatch.org/data/explore/a86d906d-9862-4783-9e30-cdb68cd808b8
10. https://www.eia.gov/outlooks/ieo/pdf/apph.pdf
11. https://resourcewatch.org/data/explore/a86d906d
12. https://resourcewatch.org/data/explore/d446a52e-c4c1-4e74-ae30-3204620a0365
13. https://sustainabledevelopment.un.org/content/documents/3209nepadkalitsi_ppt.pdf
14. http://www.worldbank.org/en/region/afr/publication/planning-africas-infrastructure-uncertain-climate-future

Natural Gas Byproducts

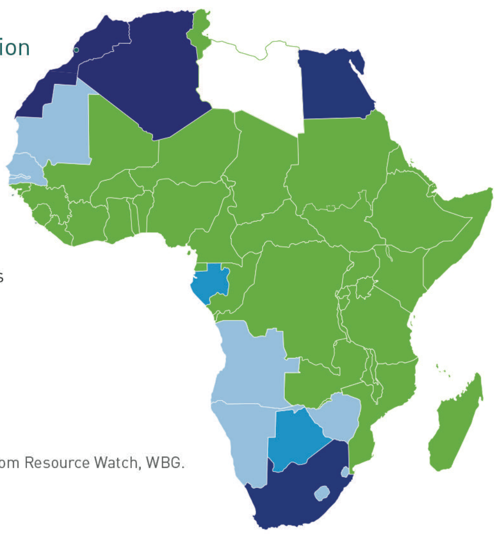
In addition to power generation, natural gas can provide value to end-use markets in Africa. The processing of wet natural gas, which consists of methane along with a group of hydrocarbons known as natural gas liquids (NGLs),[15, 16] creates commodity byproducts such as liquified petroleum gas (LPG) and ethane that can be used for various purposes such as cooking and heating in the residential sector, power generation, and as an industrial feedstock.

LPG, which consists of several gases including propane, butane, and isobutane, is a fossil fuel that is found in combination with other hydrocarbons such as natural gas. The production of LPG may occur during the processing of natural gas where it is separated from the gas mixture and pressurized into liquid form for storage in steel cylinders or tanks of various sizes.[17] Estimates suggest that nearly 60 percent of global LPG is produced through natural gas processing.[18] However, LPG can also be found with crude oil and recovered through oil refining.[19] Previously, LPG was burned off through flaring which negated its ability to provide value for end-use markets[20] such as household cooking fuel and a feedstock for numerous industries including petrochemical, food processing, metal processing, and ceramics.[21]

A major market opportunity for LPG in Africa involves fuel-switching from biomass to LPG to increase access to clean cooking fuels (Figure 5)[22] and assist climate mitigation efforts through lower black carbon emissions and less deforestation. The increased use of LPG—along with more efficient cook stove technologies—would help reduce air pollution and support decarbonization efforts in sub-Saharan Africa. Some countries have already started to encourage LPG adoption through subsidies or other government programs, with mixed success.[23] Infrastructure issues are, however, problematic and the costs for a gas distribution system in an urban area are not inconsequential.

Other commodity byproducts of natural gas processing that could be used for end-use markets in Africa include ethane and subsequently, ethylene. Ethane is a hydrocarbon that is produced through the processing of wet natural gas and can be used for a variety of purposes such as a feedstock for petrochemical production and for power generation. In some cases, ethane could even be a more affordable option than LNG for power generation due to cost advantages for liquefaction, transportation, and regasification.[24, 25] Ethylene is produced from the ethane in natural gas streams and serves as an important precursor for commercial products such as plastics and chemicals.[26] These gases could further support industrial growth in Africa, especially for the petrochemical industry.

Figure 5.
Percentage of Population with Access to Clean Cooking Fuels, 2014



Access to clean cooking fuels
- No data
- ≤25%
- 26-50%
- 51-75%
- 76-100%

EFI, 2018. Compiled using data from Resource Watch, WBG.

15. https://www.eia.gov/tools/glossary/index.php?id=Wet%20natural%20gas
16. https://www.eia.gov/tools/glossary/index.php?id=N
17. https://www.elgas.com.au/blog/1682-where-does-lpg-come-from-lpg-production-process
18. https://www.wlpga.org/about-lpg/production-distribution/
19. https://www.elgas.com.au/blog/1682-where-does-lpg-come-from-lpg-production-process
20. https://www.wlpga.org/about-lpg/production-distribution/
21. https://www.businesswire.com/news/home/20180109005856/en/Global-LPG-Market-Competition-Forecast-Opportunities-2012-2026
22. https://resourcewatch.org/data/explore/ene028-Access-to-Clean-Cooking-Fuels
23. https://ngi.stanford.edu/sites/default/files/NGI_EAfrica_LitReview%284-17%29.pdf
24. https://www.americanethane.com/what-is-ethane/
25. https://www.ge.com/content/dam/gepower-pgdp/global/en_US/documents/outcomes%20and%20key%20projects/GEA32198%20Final%20PGI%20paper_R6.pdf
26. https://www1.eere.energy.gov/manufacturing/resources/chemicals/pdfs/ng_ethylene.pdf

Natural Gas for Fertilizer Production

Fertilizer is key to increasing agricultural productivity. Agriculture is the largest economic driver on the continent,[27] especially in sub-Saharan Africa. Since the agricultural sector constitutes 15% of Africa's total GDP, the expansion of natural gas for fertilizer production presents a significant economic opportunity for the continent and its individual nations.[28] Increased fertilizer use, and therefore increased crop yields,[29] would have significant positive impacts on the national economy -- a 2017 study found that a "half ton increase in staple yields generates a 14 to 19 percent higher GDP per capita."[30]

Natural gas is the base of many fertilizers (ammonia) and yet very few countries in sub-Saharan Africa produce it domestically. There are several blending facilities, but few locally produced products. Also, because of the lack of good roads and inland waterways, transportation of fertilizer and other bulk items in Africa is expensive; moving fertilizer from an African port to a farm 62 miles inland can sometimes cost as much as the shipping from the United States. As such, fertilizer use in sub-Saharan Africa is around one-twelfth of that in North America and 75% lower than in East Asia. National governments in Mozambique and Tanzania have programs in place to encourage fertilizer adoption and keep fertilizer prices low.[31]

Low-cost gas produced in Africa could reduce fertilizer costs, helping to bridge the gap in fertilizer application rates, which are currently 138 kg/hectare globally compared to 16 kg/hectare in sub-Saharan Africa.[32] Also, in many places, especially inland, natural gas is considered a worthless byproduct of oil production and is generally flared into the atmosphere. Rather than flaring the natural gas at oil production sites, it could be turned into fertilizer. However, the technology exists to build small fertilizer production plants adjacent to oil refineries and use natural gas as the main source. It is already being done in Nigeria and there is interest in other regions. Companies like Notore, a Scandinavian business, have developed technology for these types of facilities. There is a worldwide surplus production capacity of fertilizers, but their price quadruples when they arrive inland. Local, small fertilizer plants close to the oil fields eliminate the transportation component and utilize a wasted resource as input, and could be profitable. Not only is it better for the environment, but it's an incentive for the oil producers to make more profit from their extraction. This should eventually become a "must-have" rather than a "nice-to-have" at oil fields across Africa.

Production for both fertilizer and gas byproducts is best situated close to the production site for natural gas, since they can be produced at a large scale and then easily shipped overland as finished products. Byproducts also must be produced early in the natural gas supply chain because they are removed from the gas during the processing that occurs before gas can be liquefied or transferred in pipelines. The idea in the African context would be to have gas-rich countries serve as regional hubs for fertilizer, LPG, etc., with facilities situated near where gas is coming onshore to minimize the necessary distribution infrastructure. Tanzania, for example, has already begun construction on a fertilizer plant located near its offshore oil fields.[33] Other gas-rich sub-Saharan nations – such as Nigeria and Mozambique – have similar plans. Ideally, having plentiful fertilizer, LPG, or other gas-based products produced domestically or by regional neighbors will drive down prices and increase use.

27. https://www.mckinsey.com/featured-insights/middle-east-and-africa/africas-path-to-growth-sector-by-sector
28. https://www.mckinsey.com/featured-insights/middle-east-and-africa/africas-path-to-growth-sector-by-sector
29. http://gpcafertilizers.com/wp-content/uploads/2017/10/05-Dr.-Kang-Wu-KAPSARC.pdf
30. McArthur, John, McCord, Gordon. "Fertilizing growth: Agricultural inputs and their effects in economic development." Journal of Development Economics
31. https://ngi.stanford.edu/sites/default/files/NGI_EAfrica_LitReview%284-17%29.pdf
32. Giordano, P., Assogba, M., and Rahnema, A. "Accelerating the Green Revolution in Cote d'Ivoire: Fertilizers Against Undernourishment and Deforestation." IESE Business School, 2018.
33. https://ngi.stanford.edu/sites/default/files/NGI_EAfrica_LitReview%284-17%29.pdf

Over the last decade, high energy prices, combined with new technologies, business models, and policies, helped drive unprecedented growth of global gas markets.

GLOBAL GAS MARKET DEVELOPMENTS

The global energy system is going through a period of profound change. The energy mix is diversifying, with decreasing shares of oil and coal; international consensus around decarbonizing the economy is affecting energy investments as the energy sector represents nearly 80% of global emissions; the world population is expected to reach 9.8 billion by 2050, up from today's 7.6 billion, with two-thirds of people living in urban areas; increasing frequency and severity of extreme weather is directly impacting energy infrastructures; and growing proliferation of digital technologies is changing the way energy systems operate, especially with more of a technology focus.

Natural gas will continue to be a major energy source for the foreseeable future. Natural gas is an abundant, relatively clean energy carrier that offers unique solutions for fuel, heat, and electricity in both developed and emerging markets. In most countries, natural gas is easy to produce, store, and transport at various scales. Due to its high level of flexibility, natural gas supports increased energy security, power system reliability, robust industrial sectors, and sustainable residential energy markets, while at the same time acting as a relatively low carbon option for most systems.

Over the last decade, high energy prices, combined with new technologies, business models, and policies, helped drive unprecedented growth of global gas markets. On the supply side, most growth has come from advances in shale drilling technology in the United States. Between 2008 and 2017, annual global gas production grew from 107.8 Tcf to 130 Tcf by 2017 (Figure 6), with U.S. annual shale gas production increasing from 2.1 Tcf to 17.0 Tcf during that same time period.[34]

Gas demand has also grown rapidly in nearly every region of the world. This is primarily due to the increased availability of natural gas, new energy policies that promoted gas as a cleaner alternative to oil and coal, and the massive gas demand spike following the 2011 Fukushima disaster. Since 2008, China has seen the largest demand growth by-far, with gas consumption increasing by 5.6 Tcf, larger than the total current gas demand in Africa.[35] In the last year alone, there was a 15% surge in Chinese gas demand, accounting for one-third of the global increase in gas consumption.[36]

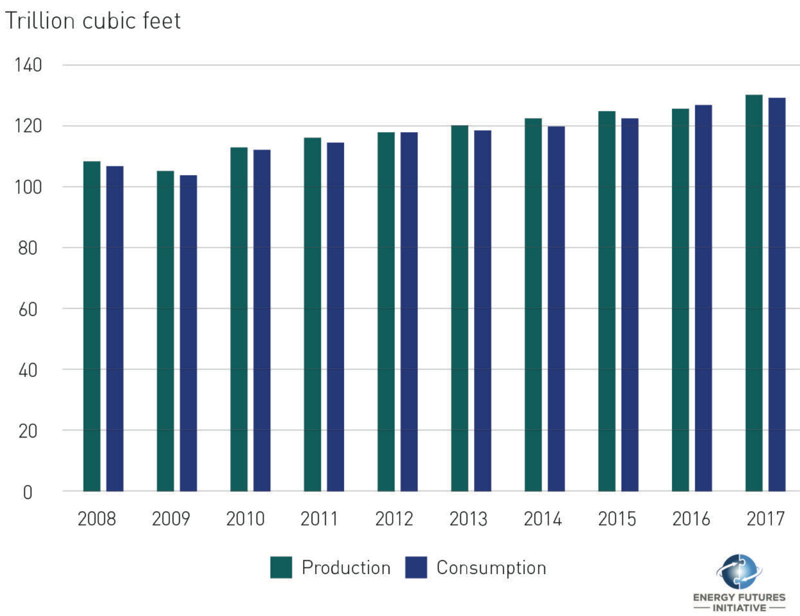


Figure 6. Global natural gas production and consumption

EFI, 2018. Compiled using data from EIA.

34. https://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm
35. https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf
36. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/chief-economist-analysis.html

World Gas Markets and LNG

The globalizing gas market, which is becoming increasingly connected by LNG, is unlocking new opportunity for countries looking to develop gas resources or import supplies at various scales. Due to the many benefits of natural gas to an economy, including offering reliable, affordable, and relatively clean energy supplies during a period of major change, investing in new gas-driven industries can be the rising tide that lifts all boats. The development of natural gas demand in emerging markets can incite new interest from natural gas developers to engage in long-term gas projects as there is tremendous market upside for gas in the long-term.

World natural gas markets have historically been divided into three primary regional markets—North America, Europe, and Asia—each with distinct pricing structures. While regional gas markets are expanding, the growing LNG trade is making disparate regions more connected. LNG is natural gas that has been converted to a liquid through cooling for more efficient, safe, and simple transportation. Between 1990-2000, there were fewer than 20 LNG exporting and importing countries. Since then the market has grown to 19 exporters and 40 importers in 2017,[37] trading 38.2 billion cubic feet per day (Bcf/d) of LNG. Six of those exporters are in Africa, only one of which was exporting LNG before 1999. LNG now accounts for roughly 35% of natural gas trade movements worldwide.[38]

In the last decade, there have been a significant number of new LNG supply projects (Figure 7). Qatar has remained, by far, the world's largest LNG exporter since the early 2000s. Following Qatar's major capacity additions in 2009-2011, Australia and the United States have accounted for the largest increases in both liquefaction capacity and LNG exports. In the last year, global LNG exports increased by 3.5 Bcf/d, with Australia and the United States contributing a combined 2.7 Bcf/d, while Nigeria, Malaysia, Algeria, Russia, and Brunei added another 1.4 Bcf/d.[39] The large number of projects that were sanctioned in the last decade led many to predict the emergence of an LNG surplus.[40] However, the result has been relatively short bouts of low prices in certain markets and no evidence of idle LNG facilities due to a lack of demand.

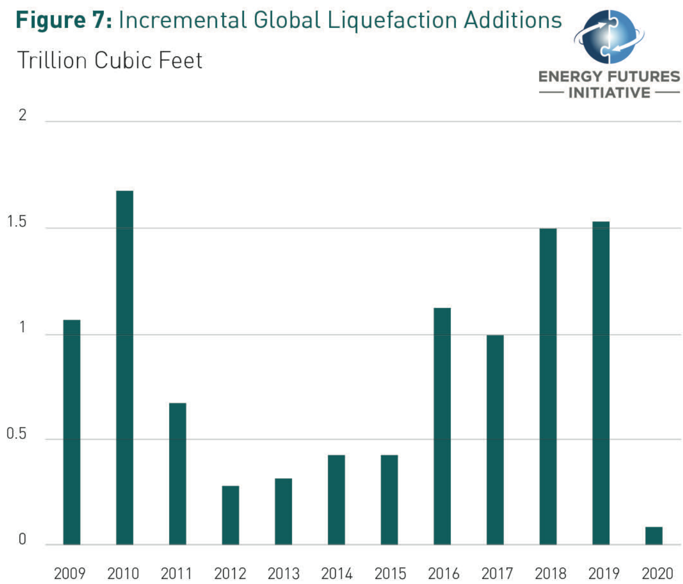
U.S. LNG.

The growth of the U.S. LNG export market is a major driver of change in the gas sector. The United States began exporting LNG for the first time in 2016. By the end of the year, 186 Bcf of LNG was exported from Sabine Pass in Louisiana. By the end of 2017, Sabine Pass exported 707 Bcf of LNG to 25 countries, more than half of which was shipped to Mexico, South Korea, and China.[41] In addition to the new volumes, the structure of U.S. contracts has led to a paradigm shift in the global gas market (Figure 8). Most U.S. export contracts are with gas consumers, or portfolio players, with 25-year terms, no destination clauses, and pegged to Henry Hub with a small fee for liquefaction.

These new volumes and contracts have helped

Figure 7: Incremental Global Liquefaction Additions

Trillion Cubic Feet



EFI, 2018. Compiled using data from EIA.

37. https://www.eia.gov/todayinenergy/detail.php?id=36452
38. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/chief-economist-analysis.html
39. https://www.eia.gov/todayinenergy/detail.php?id=36452
40. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/chief-economist-analysis.html
41. https://www.eia.gov/todayinenergy/detail.php?id=35512

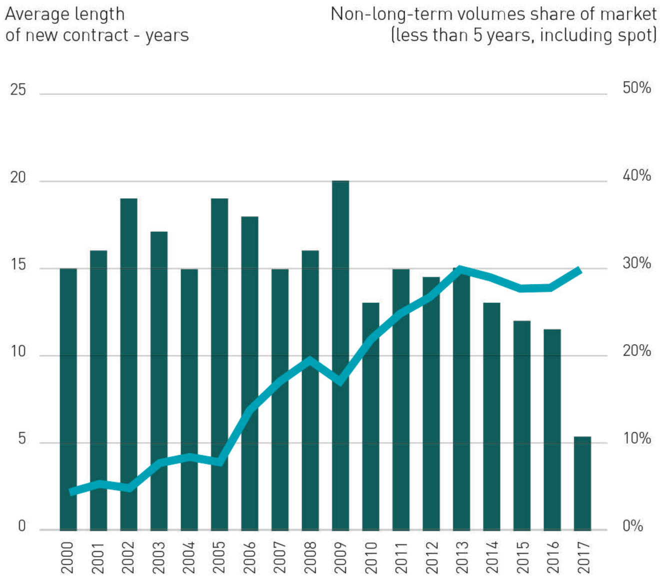
other gas buyers, such as China, renegotiate their long-term contracts with other major producers to make them more competitive.[42] In 2017, 60% of total exports were sold on a spot basis to more than 20 countries in Asia, North and South America, Europe, the Middle East and North Africa, and the Caribbean.[43] Even though Sabine Pass is fully contracted under long-term contracts to various buyers, flexibility in those contracts' destination clauses allows U.S. LNG to be shipped to any market in the world. Four more U.S. projects are scheduled to come online in the next two years. Once completed, U.S. LNG export capacity is expected to reach 9.6 Bcf/d by the end of 2019. As export capacity continues to increase, the United States is projected to become the third-largest LNG exporter in the world by 2020, surpassing Malaysia and remaining behind only Australia and Qatar.

It should be noted that the entry of the U.S. into the global LNG export market has been enabled by the technology-driven development of shale gas, with assists from a large internal gas market supported by a robust industry, and a long history of natural gas production, distribution, and consumption. This changed profile has far-reaching implications, including reduced CO2 emissions from coal-to-gas fuel-switching; a significant role in the development of global gas markets; domestic manufacturing advantages from low cost gas; and increased NGLs for feedstocks and LPGs for domestic use. Recognizing the relative ease of creating these opportunities in one country, this profile demonstrates the potential value of natural gas development in Africa but also the importance of a robust infrastructure to support these opportunities. Africa needs a different pathway than the U.S. for optimizing its abundant gas resources, matched to its unique urban and rural needs.

African LNG Exporters

The African LNG export market is largely comprised of LNG from Nigeria, Algeria, and to a lesser extent Equatorial Guinea, Angola, and Egypt.[44] In recent years, sub-Saharan Africa has emerged as an important region for the development of small-scale LNG projects. While small in terms of capacity, commercial momentum achieved during the last two years indicates the ability of some projects to potentially move forward in today's market. For example, Cameroon's 57.6-Bcf floating LNG (FLNG), which reached final investment decision (FID) in 2015, began commercial operations in June 2018.[45] Equatorial Guinea's Fortuna 105-Bcf FLNG reached FID in 2016, though it has experienced project delays.[46] Both projects are based on a vessel conversion and have prompted significant cost reduction and offtake discussions. Additionally, the large offshore dry gas discoveries in 2010 have underpinned several floating and onshore LNG projects in Mozambique and Tanzania.

Figure 8: Trade of short-term cargoes is increasing as average contract length is decreasing



ENERGY FUTURES INITIATIVE

EFI, 2018. Compiled using data from EIA.

42. http://country.eiu.com/article.aspx?articleid=1403477324&Country=Qatar&topic=Economy&subtopic=Forecast&subsubtopic=Policy+trends&u=1&pid=561808840&oid=561808840
43. https://www.eia.gov/todayinenergy/detail.php?id=35512
44. https://www.igu.org/sites/default/files/103419-World_IGU_Report_no%20crops.pdf
45. https://www.reuters.com/article/us-golar-cameroon-flng/golars-cameroon-flng-project-starts-commercial-operations-idUSKCN1J029H
46. https://www.reuters.com/article/us-lng-golar-fortuna/equatorial-guinea-lng-project-stumbles-as-schlumberger-quits-idUSKCN1IW27M

CHALLENGES TO OPTIMIZING AFRICAN GAS RESOURCES

The pursuit of natural gas projects for power generation and other end-uses could help to stimulate regional integration of infrastructure and markets, an important factor for attracting investment.[47] Current energy sector investments in Africa are roughly $8-9.2 billion per year, which are well short of the estimated need of $43-55 billion per year until the 2030 to 2040 timeframe.[48]

There are, however, significant challenges to a major buildout of natural gas infrastructure in sub-Saharan Africa, including the relatively small size of existing markets and long distances between markets that inhibit the financial viability of future projects. Aside from coastal Nigeria and a few sub-regional projects, natural gas infrastructure in sub-Saharan Africa is sparse.[49] This absence of a larger regional markets can lead to investment uncertainty and cause financing difficulties. As mentioned above, problems with complementary infrastructure such as roads and electrical grids also create obstacles.

Analysis suggests that the "chicken and egg" issues associated with natural gas infrastructure in the developing countries and cities of Africa can be resolved with appropriate policy interventions.

"It is possible to build the infrastructure outwards one country at a time, and keep overall initial investments low, however the longer term total costs of building out incrementally would be higher and the gas producers would not be assured long term bulk markets...At the time of the final investment decision for the upstream project, long-term supply agreements will be put in place between field developer and gas buyers (e.g. liquefaction plant, transmission pipeline operator). After this phase, there is no flexibility to change significantly where the gas is supplied. With good coordination of the activities between the different stakeholders, the development of the domestic market at large scale together with LNG development will be possible. Also, a part of the revenues generated with LNG exports may be used to partially finance the domestic gas infrastructure."[50]

47. https://www.icafrica.org/fileadmin/documents/Publications/Africa_Energy_Atlas.pdf
48. https://www.icafrica.org/fileadmin/documents/Publications/Africa_Energy_Atlas.pdf
49. https://www.gsb.uct.ac.za/files/HarnessingAfricanGasFINAL.pdf
50. http://energypolicy.columbia.edu/sites/default/files/Potential-for-Regional-Use-of-East-Africas-Natural-Gas-SEL-SDSN.pdf

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47. https://www.icafrica.org/fileadmin/documents/Publications/Africa_Energy_Atlas.pdf
48. https://www.icafrica.org/fileadmin/documents/Publications/Africa_Energy_Atlas.pdf
49. https://www.gsb.uct.ac.za/files/HarnessingAfricanGasFINAL.pdf
50. http://energypolicy.columbia.edu/sites/default/files/Potential-for-Regional-Use-of-East-Africas-Natural-Gas-SEL-SDSN.pdf

Regional integration could provide a more certain energy supply to promote energy security and also reduce costs for both businesses and consumers through economies of scale,[51, 52] creating a more favorable investment environment to help narrow the investment gap for energy infrastructure. The West African Power Pool (WAPP) offers an example. WAPP is a cooperative agreement between 19 national electricity companies and 14 member nations in Western Africa, and is currently working to integrate its members' national electricity systems into a regional power market to improve grid reliability. To facilitate this process, WAPP has implemented a set of measures such as common operating standards and more efficient transaction mechanisms. It has also increased investments for grid expansion with an emphasis on cross-border projects.[53] These investments will be crucial to the WAPP region, as power demand is expected to triple which will require an additional 18 GW of installed capacity and related transmission capacity.[54] Similar opportunities and lessons learned could be applied to the other four regional power pools that include the Central Africa Power Pool, East Africa Power Pool, Southern Africa Power Pool, and Electricity Committee of the Maghreb.

Enhanced regional integration could also help increase trade between regions, with estimates suggesting that only 10-12% of current trade occurs between African countries.[55] This may be due in part to regional trade corridors that lack adequate infrastructure to maximize trade opportunities. For example, trade along the Northern and Central Transport Corridors in East Africa, which connect the countries of Burundi, Kenya, Rwanda, Tanzania, and Uganda, has had a positive impact on the region. However, these corridors are hindered by degraded infrastructure and high transport costs. To help address these issues, 17 priority infrastructure projects totaling $1.8 billion have been identified as being in need of funding, including five port projects ($990 million), four railway projects ($465 million), and eight roadway projects ($377 million). Although the region has already attracted funding interest in the amount of $1.2 billion for the projects, a gap of $560 million remains.[56]

Another way that investment in uses for gas in Africa can eliminate risk is in upstream parts of the natural gas supply chain. Extraction in the gas fields in East Africa are operated by U.S. and European companies such as Anadarko, ENI, and Shell, as well as South African state energy company Sasol.[57] The newly discovered Tortue gas field off the coasts of Mauritania and Senegal are being developed by BP and Kosmos Energy, an American company. Establishing a ready-made market for natural gas—in the form of domestic use, or regional or intra-African trade—could make domestic investment more attractive to companies that are currently focused almost exclusively on export potential. While there are some commitments to local investment on the part of foreign developers, a stable investment environment could enhance these efforts.

51. https://www.icafrica.org/fileadmin/documents/Publications/Africa_Energy_Atlas.pdf
52. http://www.powermag.com/power-in-africa-prospects-for-an-economic-foothold/
53. https://www.icafrica.org/en/topics-programmes/west-african-power-pool/
54. https://www.icafrica.org/en/topics-programmes/west-african-power-pool/
55. http://www3.weforum.org/docs/WEF_Risk_Mitigation_Instruments_in_Infrastructure.pdf
56. https://www.icafrica.org/en/topics-programmes/eastern-and-central-transport-corridors/
57. https://ngi.stanford.edu/sites/default/files/NGI_EAfrica_LitReview%284-17%29.pdf

With innovation and infrastructure investments, these additional value-added products can support new industries and substantial economic development.

NATURAL GAS TECHNOLOGIES FOR IMPORTED AND INDIGENOUS GAS RESOURCES

Creating demand for gas is an essential strategy for optimizing the development and value of Africa's indigenous gas resources. A suite of technologies can be used to address a range of demand-limiting infrastructure issues, creating new natural gas options for both urban and rural consumers. In particular, innovation in distributed technologies can especially impact the delivery of new energy services in rural settings. Key investments in technologies and infrastructures will increase sub-Saharan gas demand and grow national economies; gas-fired power generation is especially important in this regard.

There is a suite of new technologies that could help bypass or minimize the need for certain high-cost infrastructures while providing some essential benefits, especially in rural Africa. These include microgrids and distributed generation, small-scale gas processing, and virtual pipelines. Solutions will vary based on location (urban or rural), access to power generation grid, degree of electrification, etc. – one size does not fit all and templates are needed for a range of options.

Imports of LNG can also help to increase demand in the near- to mid-term, an essential step for attracting investment in developing Africa's indigenous gas resources. The development of floating regasification facilities offers a relatively inexpensive approach to LNG imports.

In short: 1) demand creation is essential for developing Africa's gas resources; 2) imports are important for demand-creation in the near- to mid-term, and; 3) rural and urban environments have distinct technology needs for natural gas technologies.

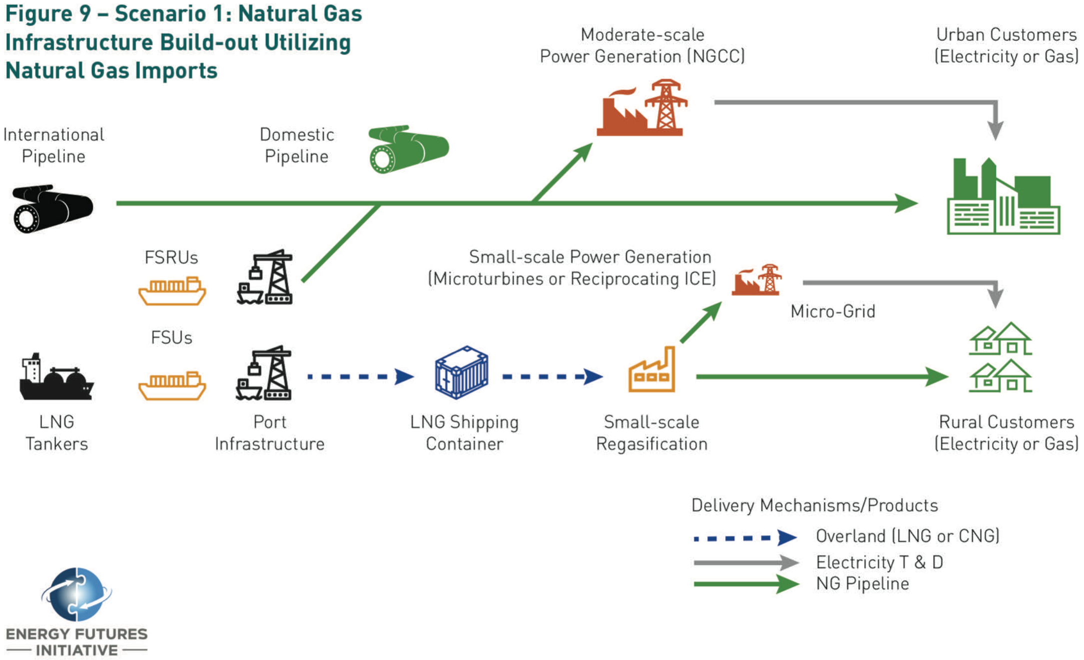
Natural Gas Supply Chains

For purposes of informing this discussion, two natural gas supply chain scenarios have been developed to highlight opportunities to optimize Africa's natural gas resources through a combination of technologies and infrastructures. The associated supply chain figures are simple in their depiction but complicated in the real-world replication; they illustrate the range of options for urban and rural areas using both imported and indigenous natural gas.

Scenario One focuses on the near/mid-term option of imported natural gas via international pipelines or LNG to help create demand for natural gas in key African countries and regions; as well as to enable Africa to take full advantage of growing – and over-supplied – global LNG markets. It shows the range of technology and infrastructure options that are needed to support robust supply chains for both urban and rural areas.

It should be noted that uses of imported LNG would primarily be for power generation, although LNG can support the same uses as pipeline gas, including cooking, heating and transportation, and in industrial boilers. Imported LNG does not, however, support an LPG or gas-to-liquids (GTL) market (one which converts natural gas to various liquids fuels) that could replace more expensive diesel generation and unhealthy cooking fuels, nor would it support the range of industries enabled by refining; these would need to be developed from onshore or offshore indigenous production of wet natural gas. While it may seem counterintuitive, importing LNG in the near- to mid-term could provide a major assist to developing Africa's indigenous gas supplies over time. African integration with global LNG markets and supplies could help develop demand for natural gas, that would support indigenous production and associated infrastructures. It also helps integrate Africa into the growing global gas marketplace, providing key price benchmarks and trading opportunities.

Figure 9 – Scenario 1: Natural Gas Infrastructure Build-out Utilizing Natural Gas Imports



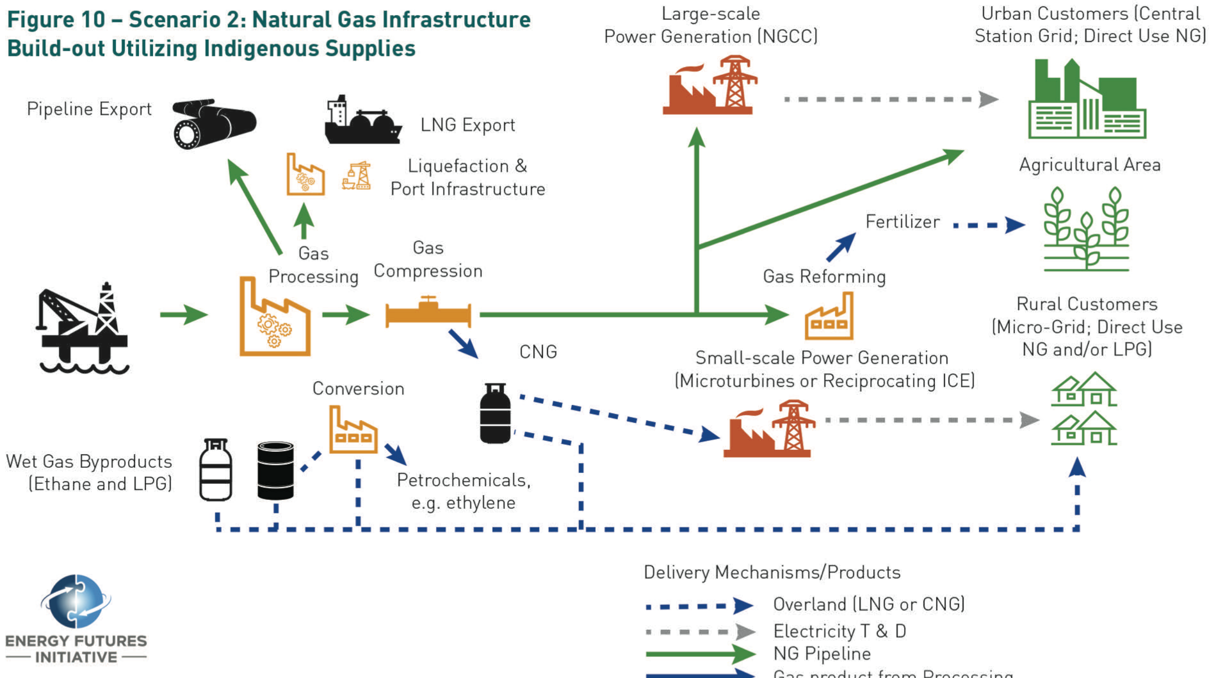
Source: EFI, 2018. Compiled using Noun Project

Scenario Two focuses on technology and infrastructure needs associated with large-scale production of Africa's indigenous gas supplies. This is much more complicated than the first scenario because indigenous wet gas production has many more uses than imported LNG that, as noted, is largely limited to power generation absent significant gas distribution systems; heavier, higher value hydrocarbons are removed from raw gas when it is liquefied. Indigenous gas can be used for power generation. If it is wet gas, it can be used for producing propane, butane and ethane and as a feedstock for petrochemicals.

With innovation and infrastructure investments, these additional value-added products can support new industries and substantial economic development. This is not just the case for urban areas; depending on proximity to production, small-scale gas processors can produce pipeline quality gas and support the production of cleaner cooking fuels and replace dirtier, more expensive diesel generators that support rural microgrids.

The following section highlights natural gas technologies and infrastructure options that merit significant attention to policymakers and investors in Africa. This is not intended to be an exhaustive list but it does represent technologies that are key to addressing trends – increased population and energy demand, improving economies; as well as for meeting policy goals – economic development, lower cost energy, and cleaner energy. These technologies also address time-scales, e.g. FSRUs to meet and create gas demand in the near- to mid-term, as both urban and rural options.

Figure 10 – Scenario 2: Natural Gas Infrastructure Build-out Utilizing Indigenous Supplies



Source: EFI, 2018. Compiled using Noun Project

Large-Scale Gas Turbines

With the current, long-term projections of low priced natural gas, low capital cost, and short construction timeline, large-scale natural gas has become the generation technology of choice compared to other central station or baseload options. Five Africa50 shareholder countries alone (Senegal, Ghana, Ivory Coast, Nigeria and Kenya) could use 8300 MW of gas-fired power generation by 2030.

The large-scale natural gas generation market is dominated by simple cycle combustion turbines (CT) and combined cycle plants (NGCC). Like other generation technologies, the decision on which to deploy depends upon multiple factors including demand requirements, technical feasibility, and cost. Table 1 illustrates the advantages of natural gas capital costs and fixed operation and maintenance (O&M) compared to other traditional central station generation technologies. Natural gas generation technologies have a clear advantage over other large-scale generation technologies in terms of capital and O&M costs.

Table 1. U.S. Estimates of Power Plant Capital and Operating Costs (2016)[58]

Technology	Capacity (MW)	Capital Cost ($/kW)	Fixed O&M ($/kW-yr)	Construction (Estimated)
Natural Gas Combined Cycle	702	978	11	2-3 years[59]
Advanced Natural Gas Combined Cycle	429	1,104	10	2-3+ years
Combustion Turbine	100	1,101	17.5	18 months+
Advanced Combustion Turbine	237	678	6.8	18 months +
Advanced Nuclear	2,234	5,945	100.28	5.5-7.5 years[60]
Ultra Supercritical Coal	650	3,636	42.1	5+ years

Source: EIA, 2016

Natural Gas Combined Cycle Plants

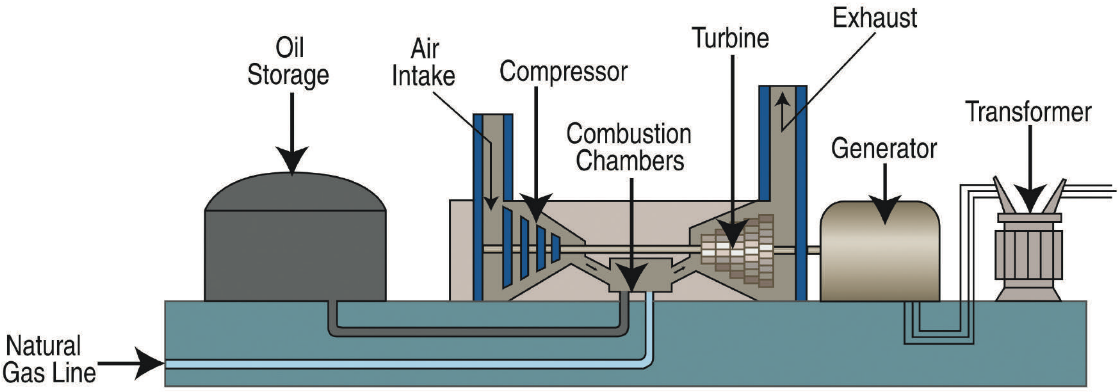
Because of very high efficiencies, the NGCC unit generates 50% more electricity from the same amount of fuel compared to a single cycle system by using a combustion turbine followed by a steam turbine. The steam turbine uses the hot exhaust from the combustion turbine to convert water into steam for the second turbine to produce additional electricity.[61] Current combined cycle gas plants are highly flexible, high-capacity, and capable of fast ramping. At least two vendors, GE and Alstom, offer 400+ MW plants that start in fifteen minutes, change load quickly and ramp down economically. Note that second-to-second response times are associated with smaller gas turbines, the aero-derivative turbines.

As shown by the data in Table 1, NGCC power generation is an attractive option for African markets due to its high capacity relative to cost as well as capacity adaptability to meet individual country demand. Construction of NGCC power plants is currently occurring in Africa. For example, the Kinyerezi II plant with 240 MW generating capacity and total cost of $353.72 million in Dar es Salaam, Tanzania,[62] and a mega-project involving three 4.8 GW NGCC plants in Egypt are both under construction. Combined with 12 wind parks, the Egyptian project will produce 14.4 GW of power, increasing Egypt's generation capacity by 45%.[63, 64] These two cases show the adaptability of NGCC technology in the power generation mix depending on the country-specific needs and capabilities.

58. https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capcost_assumption.pdf (p. 7)
59. https://www.energy.siemens.com/US/pool/hq/energy-topics/publications/Technical%20Papers/Gas%20Turbines/Siemens-Technical-Paper-Life-Cycle-Value-for-combined-cycle-power-plants.pdf
60. http://euanmearns.com/how-long-does-it-take-to-build-a-nuclear-power-plant/

Simple Cycle Natural Gas Plants

The most common use of simple cycle natural gas plants is for providing additional electricity when demand "peaks," i.e. rises above the average daily demand (Figure 11).[65] These "peakers" are more expensive and less efficient but their electricity is sold when demand exceeds central station supply, or to balance non-dispatchable renewable energy. At these times, electricity is typically selling for higher rates or meeting demand as a regulatory obligation, justifying the use of the peaker. Unlike peakers, using plants designed for baseload use in these situations is not economic.



Source: Tennessee Valley Authority

Combustion turbines are designed to meet peaks in power demand very quickly. They operate much like a jet engine, drawing in air at the front of the unit, compressing it, mixing it with fuel and igniting it. The combustion occurs immediately—allowing gases to then expand through turbine blades connected to a generator to produce electricity.

Combustion turbine power plants are normally run on natural gas as a fuel; however, they may also be run on low-sulfur fuel oil if needed.

Implications of Investment in **Large-Scale Gas Turbines** for African countries

- Historically, the desirability of natural gas generation has been tempered by widely fluctuating natural gas prices; however, with conventional and unconventional long-term gas supply, this concern is greatly diminished.
- For large, sustained daily demand, natural gas combined cycle technology offers a low cost, reliable option.
- For meeting variable demand, natural gas peaking technology offers an economical, flexible option.
- Large-scale gas generation can replace more carbon-intensive fuels like coal and oil, while complementing zero-carbon fuels by providing more stability of supply.

61. https://www.tva.gov/Energy/Our-Power-System/Natural-Gas/How-a-Combined-Cycle-Power-Plant-Works
62. https://journals.assaf.org.za/jesa/article/view/4389
63. https://www.siemens.com/eg/en/home/company/topic-areas/egypt-megaproject.html#Download
64. https://businesstech.co.za/news/industry-news/130702/an-african-energy-revolution-driven-by-gas-to-power-technology/
65. https://www.tva.gov/Energy/Our-Power-System/Natural-Gas/How-a-Combustion-Turbine-Plant-Works

Small-Scale Gas Generation

The small-scale power market is driven by a growing need for technologies capable of meeting fluctuating demand rapidly and efficiently. A range of small gas turbines with a capacity between 25kW to 80MW have high efficiency, fast installation and simplified operation and maintenance (O&M). These small-scale generation technologies could support the deployment of microgrids in remote areas of Africa and help close the electrification and infrastructure gaps for rural residents. Aero-derivative gas turbines, reciprocating internal combustion engines (RICE), and microturbines form the bulk of the small-scale gas turbine market.[66]

Gas-Based Microgrids

Microgrids are smaller localized grids that can either connect to the main grid or operate autonomously,[67] and have the potential to play a major role in improving electricity access across Africa due to their ability to be deployed in remote locations. A recent analysis suggests that microgrids could be the cheapest way to provide electricity to 100 million people in Africa,[68] which could provide the opportunity for natural gas to play significant role for microgrid power generation. Natural gas-based microgrids are typically larger in size (average 3.8 MW) and offer several advantages including low capital costs, and are typically the cheapest option for fossil fuel-based microgrids.[69] Natural gas also has a relatively low levelized cost of electricity across different microgrid technologies, with a range of $0.052 to $0.148 per kWh.[70]

Aero-Derivative Simple Cycle Gas Turbine (AERO)

At 4MW to 70 MW capacity, these turbines (Figure 12)[71] are compact, light-weight, and designed for rapid continuous cycling and ramping. Their ability to start and stop frequently during a 24-hour period is accompanied by relatively low O&M costs.[72]

Reciprocating Internal Combustion Engines (RICE)

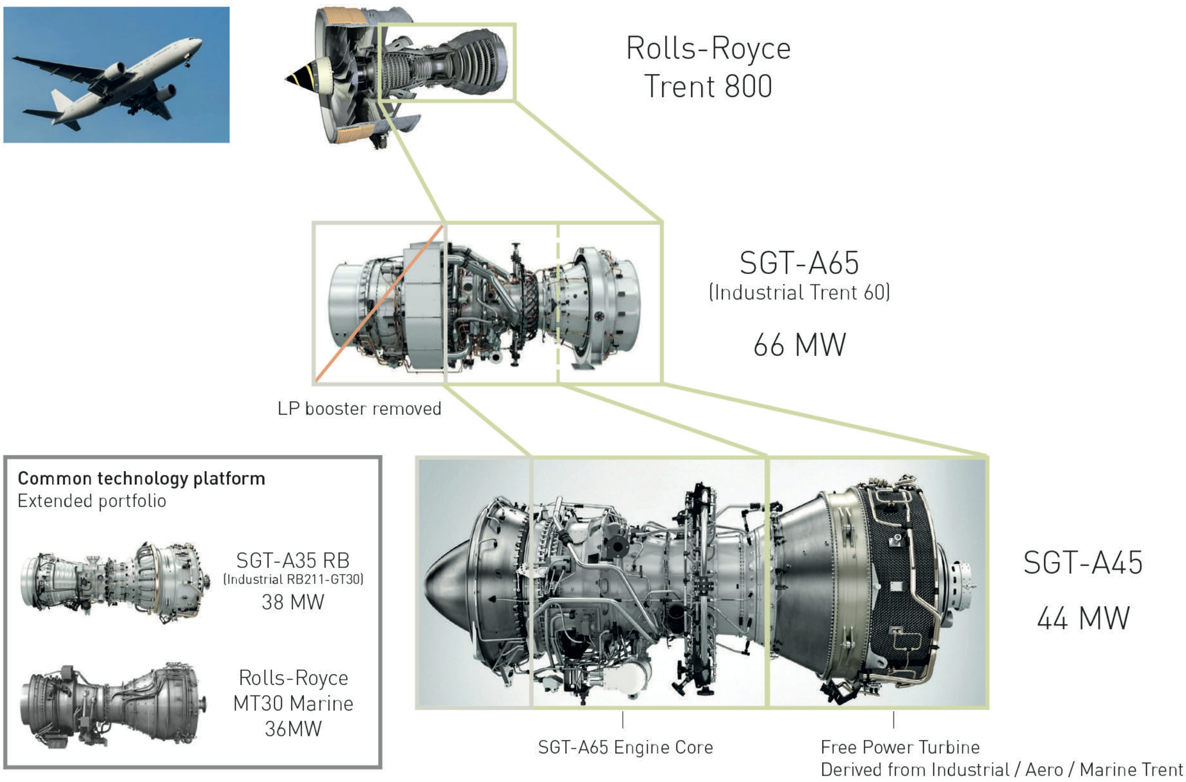
With a range of 5 MW to 18 MW and some capable of 20 MW output, these engines are relatively large and heavy and while capable of ramping quickly they must sustain a warm idle to achieve fast start capability. With their lower output, multiple RICE engines are needed to equal the capacity of a single aero-derivative engine, but this arrangement allows for using some as baseload and some in idle mode with the ability to ramp up as needed. This flexibility results in higher O&M costs which may or may not be offset by savings associated with the ability to match supply with fluctuating demand.

Microturbines[73]

These gas turbines range from 25-500 kW and are about the size of a refrigerator. Simple cycle microturbines consist of a compressor, combustor, turbine, alternator, and a generator. Recuperated microturbines include the same components as a simple cycle microturbine but they also include a recuperator which is a device that captures waste heat to improve efficiency. The efficiency of a simple cycle microturbine is around 15% compared to a recuperated microturbine which ranges from 20-30%.[74]

66. https://www.ge.com/content/dam/gepower-pgdp/global/en_US/documents/product/2018-gps-product-catalog.pdf
67. https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping
68. https://www.greentechmedia.com/articles/read/minigrids-are-the-cheapest-way-to-electrify-100-million-africans-today#gs.q0BSBoA
69. https://www.wri.org/sites/default/files/accelerating-mini-grid-deployment-sub-saharan-africa_1.pdf
70. https://www.usaid.gov/energy/mini-grids/economics/levelized-cost
71. https://www.powermag.com/siemens-launches-44-mw-aeroderivative-gas-turbine-model-for-fast-power-demand-surge/
72. https://www.power-eng.com/articles/print/volume-121/issue-11/features/comparing-aeroderivatives-and-reciprocating-engines-for-fluctuating-power-demand.html
73. http://www.powermag.com/microturbine-technology-matures/?pagenum=1
74. https://www.wbdg.org/resources/microturbines

Figure 12. Example of the Origin of Aero-derivative Turbines



Source: POWER Magazine, 2017

Implications of Investment in **Small-Scale Gas Generation and Microgrids** for African countries

- These small-scale natural gas generation technologies offer flexibility within their class as well as through the technology range, enabling matching a variety of needs to specific technology capabilities based on size, operational flexibility and cost.
- Small-scale generation can be coupled with microgrids to provide power to rural areas that would be impractical to connect to the main electric grid.

Virtual Pipelines

Building out a large gas distribution infrastructure, similar to what exists in the U.S. and Europe, would not be economically feasible for most African countries. It would be especially impractical for reaching the rural areas that would be powered by the small-scale gas generation and microgrids discussed above. One of the alternative solutions for supplying those rural areas with gas is a "virtual pipeline," which involves LNG or compressed natural gas (CNG) that is transported on existing transportation infrastructure: rail cars, barges, trucks, etc.[75]

A key innovation allowing for these virtual pipelines is the development of International Standards Organization (ISO) shipping containers that have been modified for LNG or CNG. The advantage of these containers is their standard size, which means they can be used for intermodal transportation; i.e., they can be moved from one form of transportation to another with ease.[76] Countries that are already liquefying gas for export could use the shipping containers produced by Chart Industries. These containers come in different sizes; the largest, a 40-ft container can hold the equivalent of 0.95 million cubic feet (Mcf) of gas (43,500 liters of LNG), stored for up to 65 days.[77] Smaller models store less gas, but for a longer duration (up to 75 days).

Shipping ISO containers of LNG to remote areas is facilitated by small-scale regasification plants (also known as vaporizers). The most popular type of small-scale regasification is ambient air vaporizers (AAVs).[78] AAVs have low operating costs because they use natural or forced draft air as the heating medium (meaning no fuel costs),[79] they require little maintenance, and are often unmanned.[80] They also operate well, even in adverse weather, and have minimal environmental impact. Capital costs have been high, relative to large regasification facilities, but are coming down. AAVs coupled with LNG tanks (between 20,000 and 300,000 liters in size) are the major components of small-scale LNG satellite stations which have been used in the U.S. and elsewhere to serve remote areas and regions without pipeline infrastructure. In the sub-Saharan context, these satellite stations would probably be paired with a small gas generator as well. Co-locating these two facilities would minimize the costs associated with regasification, since only minor amounts of connective infrastructure would need to be built.

ISO containers could also be used to create a virtual pipeline with CNG in lieu of LNG. Hexagon Lincoln produces a 40-foot ISO container modified to hold four CNG cylinders.[81] As with LNG containers, these can be used for intermodal transportation. The advantages of CNG are that it does not need to be stored at the same very low temperatures as LNG, and that facilities for regasification are not needed. LNG would also only be feasible for a virtual pipeline if a country has facilities for importing LNG, or if the country is itself liquefying gas for export. Otherwise, the cost of liquefaction would be prohibitive.

The disadvantage of CNG is that it occupies more volume, and therefore is less efficient for transporting higher volumes of gas. Hexagon Lincoln's ISO container for CNG is the same size as Chart Industries' LNG container, but it holds about one third the amount of gas (the equivalent of 0.36 Mcf at standard pressure).[82] Because of this volume discrepancy, CNG is less cost-effective at the scale of overseas shipments. For virtual pipelines, either CNG or LNG might be more feasible, depending on the distance and quantity of gas involved.[83]

Finally, there are technologies in development to create an airborne "virtual pipeline" – a new design for large-scale transport of gas liquids and associated products that can address Africa's flared and stranded gas issues. This could create significant new value and address a range of issues for rural Africa (e.g., access to electricity, cleaner cooking fuels, economic development).

75. https://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2016/10_27/
76. http://files.chartindustries.com/14732510_LNG_ISO.pdf
77. http://www.4is-cnmi.com/knowledge-pge-research/LNGContainerReport.pdf 21
78. http://cryoind.com/wp-content/uploads/2015/03/2015-Winter-CQP-Advantages-of-Using-Ambient-Air-Vaporizers-thru-LNG-Mkt1.pdf
79. http://documents.worldbank.org/curated/en/299861484716073109/pdf/112131-WP-MiniMicroLNGforcommercializationofsmallvolumesofassociatedgas-PUBLIC-v2.pdf
80. http://www.igu.org/sites/default/files/node-page-field_file/SmallScaleLNG.pdf
81. http://documents.worldbank.org/curated/en/210571472125529218/pdf/104200-V2-WP-CNG-commercialization-PUBLIC-Main-report-REPLACEMENT.pdf
82. http://documents.worldbank.org/curated/en/210571472125529218/pdf/104200-V2-WP-CNG-commercialization-PUBLIC-Main-report-REPLACEMENT.pdf
83. http://documents.worldbank.org/curated/en/210571472125529218/pdf/104200-V2-WP-CNG-commercialization-PUBLIC-Main-report-REPLACEMENT.pdf

Implications of Investment in **Virtual Pipelines** for African countries

- Modified small-scale shipping containers for LNG or compressed natural gas (CNG) for intermodal transportation offer affordable, technologically feasible alternatives to traditional natural gas pipeline infrastructure.
- LNG virtual pipelines would feature small-scale regasification (vaporizer) facilities.
- CNG or LNG carried by virtual pipeline would be primarily used for small-scale power generation, but could serve other end uses such as transportation, heating, and cooking.
- New airborne technologies, tailored to Africa's needs, are being developed that could provide an alternative to overland transport of natural gas products associated with Africa's flared/stranded gas.
- Given the multiple technologies associated with the virtual pipeline, from source to use, the economics of each project will vary significantly and be subject to price fluctuations associated with the global markets.

Floating Storage and Regasification Units

For countries in Africa with no gas resources of their own, and no access (or limited access) to gas via pipeline, importing liquified natural gas is a viable option. Uses of imported LNG would primarily be for power generation, although LNG can be used for cooking, heating and transportation, and in industrial boilers. Imported LNG does not, however, support a GTL market that could replace more expensive diesel generation and unhealthy cooking fuels, nor would it support the range of industries enabled by refining; these would need to be developed from onshore or offshore indigenous natural gas production, as well as feedstocks from the gas byproducts associated with indigenous liquefaction.

One relatively new technology that can facilitate participation in the global gas market is floating storage and regasification units (FSRUs) or floating storage units (FSUs) for LNG. FSRUs are the more common of the two technologies. They can be purpose-built or converted from a conventional LNG vessel. They are faster to build and deploy and significantly less expensive than land-based terminals.[84] They usually have a capacity of 120,000-180,000 cubic meters but can be larger or smaller if they are purpose-built.[85] They can be moored in a port, offshore, or in open ocean; the most common way to build them is offshore with a jetty and breakwater. They also require the building of a pipeline to shore, and an interchange with land-based gas distribution or use infrastructure.[86] Capital costs for a new FSRU are around $240 million (roughly half of an onshore regasification unit). LNG tankers can also be converted to FSRUs in about a year to 18 months, with construction costs in the $80-$100 million range. Port facilities add additional costs for either new or converted FSRUs.[87]

FSRUs are almost exclusively owned and operated by LNG shipping companies, then leased to energy companies or governmental entities. Contracts typically run 5-20 years; a five-year contract costs $200-400 million.[88] The contracts are based on capital cost recovery and the operating costs. Whether through owning or leasing, an FSRU is still a cheaper option than a land-based terminal. New FSRUs are often associated with gas-to-power schemes.

84. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/07/The-Outlook-for-Floating-Storage-and-Regasification-Units-FSRUs-NG-123.pdf
85. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/07/The-Outlook-for-Floating-Storage-and-Regasification-Units-FSRUs-NG-123.pdf
86. https://www.energy.gov/sites/prod/files/2017/11/f46/Understanding%20Natural%20Gas%20and%20Lng%20Options%20October%2011%202017_1.pdf
87. Ekong, Mayen, FSRUs for Africa's Growing Energy Needs, Saliclub, 2018
88. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/07/The-Outlook-for-Floating-Storage-and-Regasification-Units-FSRUs-NG-123.pdf

In Africa, there are already two operational FSRUs, both located in Egypt.[89] Two projects in Ghana have recently been canceled due to delays and lack of onshore infrastructure.[90] Another project in Côte D'Ivoire has started work but has not completed. There are additional proposed projects in Benin, Egypt, Kenya, Morocco, Namibia, Senegal, South Africa, several of which would feature gas-to-power contracts.[91] It should be noted that a host of factors need to be considered when deciding between FSRUs and an onshore terminal including port space, water depth, and vessel size, among others.[92]

FSUs are similar to FSRUs, but lack regasification facilities. All current FSUs are converted tankers, with capacities between 120,000 and 140,000 cubic meters.[93] They are cheaper to produce and lease than FSRUs.[94]

An FSU could easily connect to a virtual LNG pipeline, since the gas is still liquefied when it is offloaded. There are currently no FSUs in Africa.

Implications of Investment in **Floating Regasification Storage Units** for African countries

- Low costs reduce barriers for new market entrants especially those without established infrastructure and which have lower volumes of gas demand.
- Reduced construction schedules increase ability to respond to emerging market conditions and/or energy needs.
- The ability of FSRUs to be moved to new, more favorable locations reduces risks to investors and promotes regional development.
- FSRUs can accelerate the LNG-to-Power Sector when integrated with natural gas turbines.
- FSRUs can be a bridge or temporary approach while a conventional land-based terminal is explored.
- The complexity of the transactions and individual attributes of each marine location require major due diligence at the front end.
- Floating Storage Units (FSUs) without regasification are cheaper and can facilitate the creation of an LNG virtual pipeline, allowing for small scale regasification at point of use.
- A range of factors must be considered when deciding between FSRUs and an onshore terminal including port space, water depth, and vessel size, among others.

89. https://store.rivieramm.com/ugc-1/1/14/0/fsru2017large.jpg
90. https://www.naturalgasworld.com/ngw-magazine-vol-3/11-w-african-lng-all-at-sea-61633
91. http://www.lngworldshipping.com/news/view,lngtopower-projects-drive-fsru-demand_49687.htm
93. https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/07/The-Outlook-for-Floating-Storage-and-Regasification-Units-FSRUs-NG-123.pdf
94. https://www.rigzone.com/news/oil_gas/a/138115/bumi_armada_lands_300m_lng_fsu_contracts_for_egm_in_malta/

Natural Gas Products.

As mentioned, natural gas is a highly versatile resource that can serve a variety of end use markets in Africa aside from power generation. Additional economic value can be unlocked through the processing of wet natural gas that produces commodity byproducts such as LPG, ethane, and ethylene which can serve end use markets in the buildings, power generation, and industrial sectors. Note that ethane can also be used for power generation in addition to natural gas (methane).

Liquefied petroleum gas (LPG).

The majority of global LPG production occurs through the processing of natural gas; LPG can be stored in steel cylinders and tanks of various sizes[95] for ease of transport. Flared gas associated with onshore oil production and stranded gas resources in interior regions paired with small scale gas processing can monetize this gas and create LPG products, such as household cooking fuel and industrial feedstocks for petrochemicals, food processing, metal processing, and ceramics.[96] A major opportunity for LPG use in Africa could be to promote fuel switching away from biomass for cooking in the residential sector, which would also help reduce air pollution and support decarbonization efforts through less deforestation.

Small scale, skid mounted gas processing units have been developed to produce LPG from, for example, associated gas that is flared in the oil production process. In Nigeria, for example, where there is significant associated gas, there is "hope for increased revenue from natural gas, if the gas being flared is monetized. Monetizing stranded gas reserves requires access to distribution infrastructure...Current technologies are fundamentally needed for monetizing stranded gas, and assessment of Nigeria's achievements in monetizing stranded natural gas reserves. The monetization technologies and projects reviewed are liquefied natural gas (LNG), gas-to-liquids (GTL), compressed natural gas (CNG), gas-to-wire (gas-fired power generation), and gas-to solid."[97]

One-thousand cubic feet of raw gas can contain 8 to 12 gallons of natural gas liquids (LPGs are a subset of NGLs), which include ethane, propane, butane or even natural gasoline. These units can condition dry gas for power generation and can also process gas to produce CNG. While anecdotal, industry exports suggest a cost for small scale gas processing units starting at $30 million.

Implications of Investment in **Small-Scale Gas Processing** for African countries

- The processing of wet natural gas, which consists of methane along with natural gas liquids, creates commodity byproducts such as liquefied petroleum gas (LPG) that can be used for cooking and heating; as well as ethane, that can be used as a feedstock for petrochemical production.
- A significant amount of associated and non-associated natural gas in Africa is flared because of lack of access to gas processing facilities or because the resource is of sub-optimal size, making it uneconomic to transport.
- Small scale, skid mounted gas processing units have been developed to produce LPG units can condition dry gas for power generation and can also process gas to produce CNG.

95. https://www.wlpga.org/about-lpg/production-distribution/
96. https://www.businesswire.com/news/home/20180109005856/en/Global-LPG-Market-Competition-Forecast-Opportunities-2012-2026
97. http://nsacc.org.ng/gas-monetization-and-flaring-in-nigeria-the-journey-so-far-and-policy-option-going-forward/

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95. https://www.wlpga.org/about-lpg/production-distribution/
96. https://www.businesswire.com/news/home/20180109005856/en/Global-LPG-Market-Competition-Forecast-Opportunities-2012-2026
97. http://nsacc.org.ng/gas-monetization-and-flaring-in-nigeria-the-journey-so-far-and-policy-option-going-forward/

Investment in Africa's natural gas resources for Africans will do good for Africa's population, while at the same time helping investors do well

CONCLUSION

Natural gas is a critical bridge fuel for the global transition to a low carbon future. An abundant, relatively clean energy carrier that is easy to produce, store, and transport at various scales in most countries. As a result, natural gas has many uses for electricity, transportation, industry, and households in both developed and emerging economies.

Africa's energy sector is also experiencing a period of change. Africa has significant renewable and hydrogen resources that are only at the early stages of development in most countries. Populations are growing rapidly, alongside increasing urbanization, expanding economies, electrification, and rising living standards—which are all driving overall energy demand. To meet this demand many African countries will need to invest in a range of efforts with both near- and long-term implications: 1) develop domestic natural gas resources to ensure increased energy access rates and sustainable economic development; 2) secure affordable and reliable natural gas imports to help establish local markets for gas in power generation, industry, transportation and households; and 3) plan for building natural gas export capabilities to profit from the rapidly-growing global gas market. Investment in Africa's natural gas resources for Africans will do good for Africa's population, while at the same time helping investors do well.

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