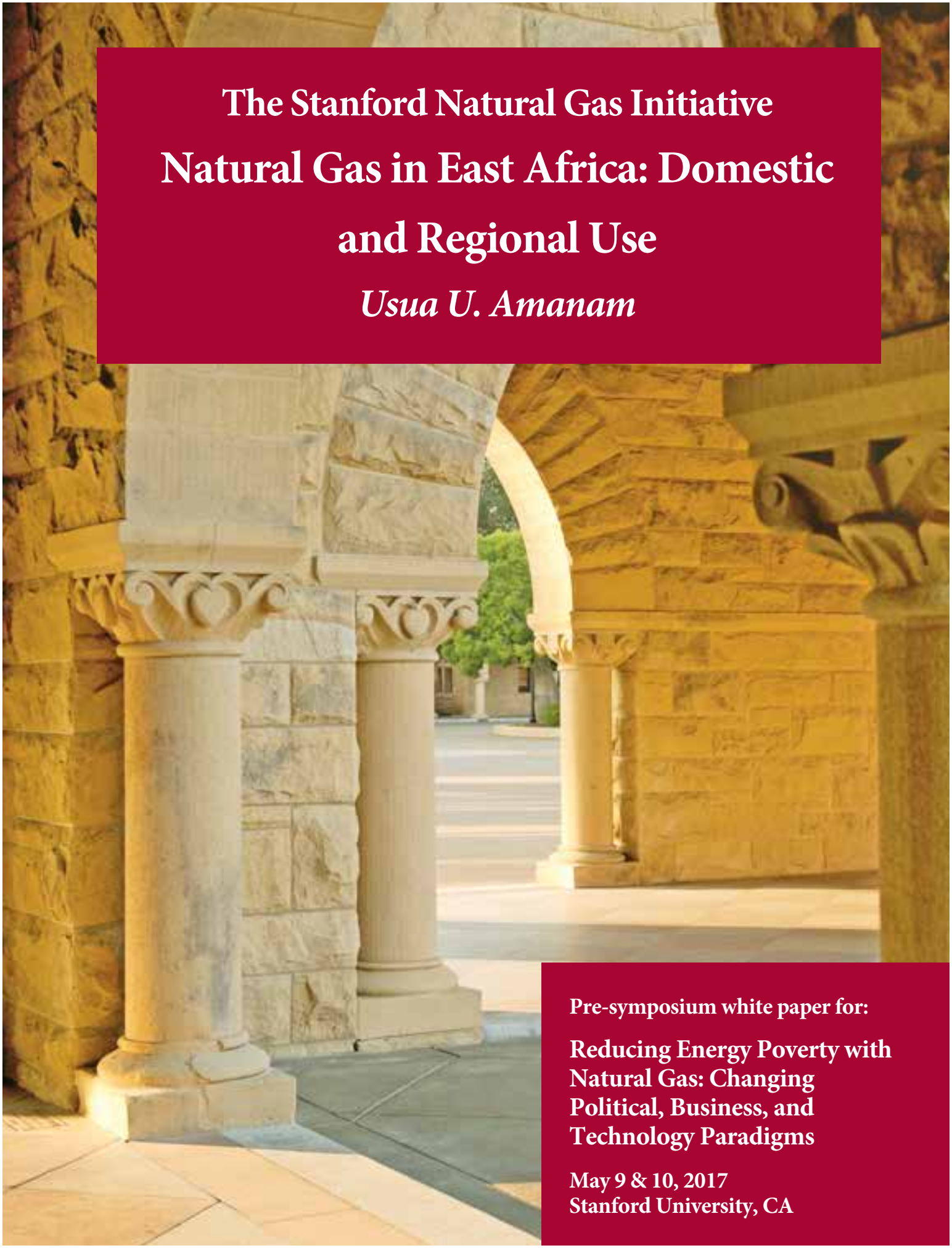

The Stanford Natural Gas Initiative

Natural Gas in East Africa: Domestic and Regional Use

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Natural Gas in East Africa: Domestic and Regional Use

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1 Introduction

The world's natural gas demand is projected to grow by 50% [1] by 2040, with much of that driven by developing regions like non-OECD Asia and Africa [2]. Africa's natural gas demand, in particular, is anticipated to grow by more than a factor of two [3]. Because natural gas is relatively cheap and abundant as a result of advances in technology, it plays a large role in shaping how countries plan to meet their rising energy needs. East Africa is a region that has benefited greatly from improvements in exploration and drilling techniques [4]. The large discoveries of natural gas in offshore Mozambique and Tanzania will contribute to meeting the rapidly growing worldwide energy demand while also serving as an effective energy solution in a region whose per capita power consumption is less than that needed to continuously power a 50-watt lightbulb [5].

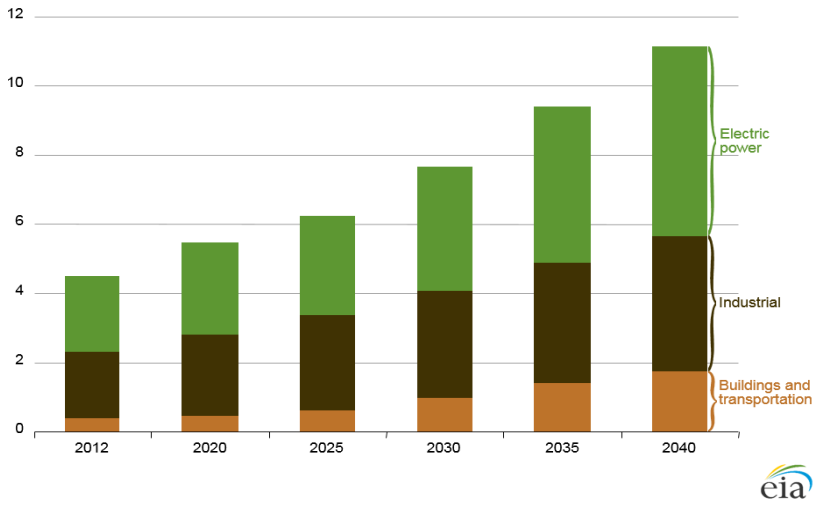

Figure 1: Africa's natural gas consumption by end-use sector, 2012-2040 (trillion cubic feet) [3]

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Both countries stand to benefit and can become regional energy hubs[1] if the gas and money generated from fields is properly allocated and invested. Since 2000, two out of every three dollars put into the Sub-Saharan Africa energy sector have been committed to the development of resources for export [5]. While this is not inherently bad, the inept financial management of resources across the region show the difficulty in circumventing the 'resource curse' [6]. The lack of robust infrastructure in the area has made it difficult to properly utilize energy resources for domestic benefit [7]. For these two countries, the quality of service for domestic markets is contingent upon adequate infrastructure and

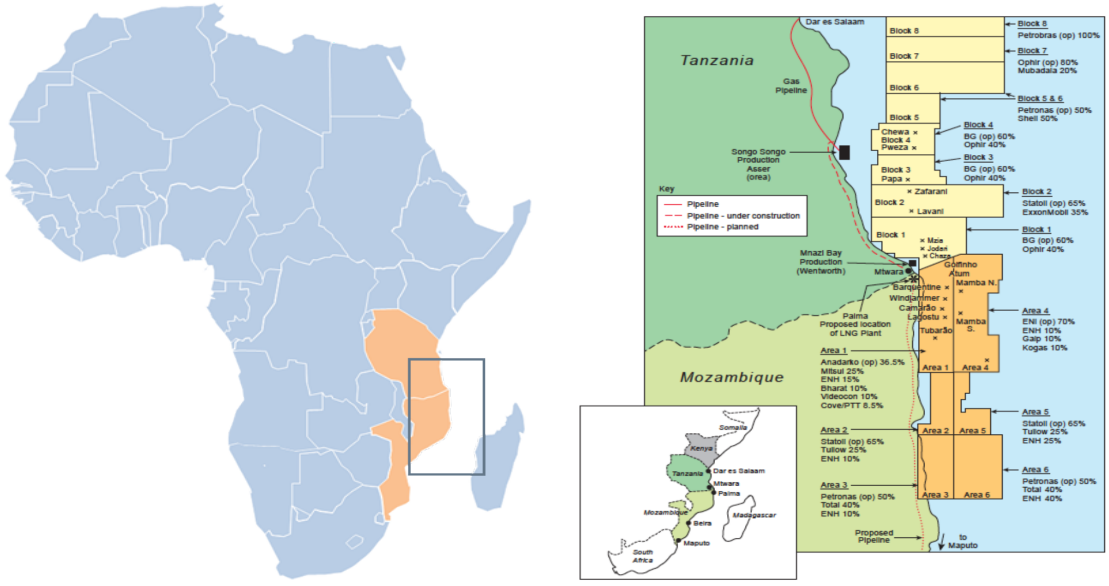
Contributions from Mark Caine, Tisha Schuller, and Mark Thurber

[1]Due to the location of both nations, Tanzania and Mozambique can serve as links between and sources for the Southern African Power Pool (SAPP) and the Eastern Africa Power Pool (EAPP).

gas mobility[2]. This paper provides an overview of the natural gas resource in East Africa, includes an update of the energy market in both countries, and reviews the governmental policies for effective natural gas utilization. Potential natural gas markets discussed include the power sector, residential cooking, and the fertilizer industry.

2 Offshore Resource Size

Natural gas reserve estimates in East Africa have grown substantially over the past decade, materializing into one of the most prolific gas plays on the African continent. Currently, the 160 trillion cubic feet (TCF) of recoverable gas in the Rovuma Offshore Basin (Mozambique) [8], rivals that of Africa's largest natural gas reserve holders: Nigeria, 180 TCF, and Algeria, 160 TCF [9]. In addition, the 57 TCF [10] of gas in the neighboring Tanzania Mafia Deep Basin [11] has made this an area of focus for regional and international energy solutions. The geological areas of interest sit directly offshore to the east of Northern Mozambique and Southern Tanzania, as shown in Figure 2.



(a) Tanzania's (northern) Mafia Deep Basin and Mozambique's (southern) Rovuma Basin both sit directly offshore of each respective country [12].

(b) East Africa offshore licensing [4].

Figure 2: Offshore East Africa natural gas play.

[2]The transportation of natural gas from fields to end-use markets is a challenge in regions with limited pipeline infrastructure. Natural gas liquids and gas-to-liquids projects play an important role in increasing utilization.

Despite exploration efforts, Mozambique was devoid of any large-scale gas development projects throughout the 20th century [13]. Anadarko's use of improved geologic mapping techniques and deepwater drilling over the past 10 years, however, have shown the potential of the offshore region. Continued knowledge transfer from experiences in other deepwater areas has helped reduce risk, allowing for the increased activity that has led to numerous successful exploration projects and resulting development plans [4]. Table 1 shows drilling and licensing activity from the region.

Country/Block	**Operator**	**Exploration and appraisal wells completed**	**Wells reported commercially successful**	**Success rate**
Mozambique Block 1	Anadarko	32	26	81%
Mozambique Block 4	ENI	13	12	92%
Mozambique Block 2/5	Statoil	2	0	0%
Mozambique Block 3/6	Petronas	1	0	0%
Mozambique Other	Sasol	2	0	0%
Tanzania Blocks 1, 3, &4	BG/Shell/Ophir	17	17	100%
Tanzania Block 2	Statoil	10	10	100%
Tanzania Other	Ophir, Petrobras	4	0	0%

Table 1: Offshore East Africa activity as of 2015 [14]. Total assumed operatorship of Petronas' blocks in 2016.

Anadarko and ENI oversee and operate the largest volumes of gas. Anadarko's Area 1 is estimated to contain 75 TCF of recoverable natural gas [15], while ENI's adjacent Area 4 holds 85 TCF [16]. In 2013, ENI discovered a 160-meter thick pay zone of wet gas[3] in the southern part of Area 4 [17]. The type of gas contained in the fields helps determine how that resource will be used. Though natural gas liquids complicate the management of reservoirs [18], they are important because of their ability to be deployed more easily for domestic use, like residential cooking.

Tanzania is similar to Mozambique in that much of the original exploration in the 20th century did not result in any large-scale field developments. A successful 2D seismic survey of deepwater offshore areas in 2000 by the Tanzania Petroleum Development Corporation and Western Geco attracted some of the largest exploration and production companies in the world to perform due diligence on the basin's potential [19]. Efforts from Ophir Energy/BG/Shell, Petrobras, and Statoil have resulted in a dramatic increase in the country's natural gas resource size. Comparatively less substantial than those in Mozambique, the finds come at a critical time for a country committed to transitioning to more reliable sources of energy[4]. BG Group, which has since been acquired by Royal Dutch Shell, reports upwards of 15 TCF of recoverable natural gas in their leased land, while a Statoil-ExxonMobil joint venture in Block 2 found up to 22 TCF of natural gas in-place [20, 21]. The aforementioned basin also has been cited for its liquid potential

[3]Wet gas contains a large portion of methane but also has a percentage of heavier hydrocarbons like propane and butane. These heavier components are more commonly known as liquefied petroleum gas (LPG).

[4]Hydroelectric power has stagnated as a result of consistent drought.

based on seismic data [19], though nothing conclusive has been publicly released by operators or stakeholders.

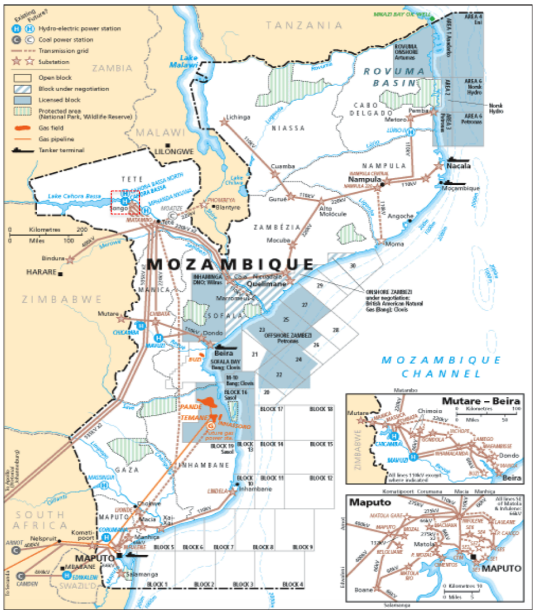
The size of the resource has the potential to transform both nations. An added benefit of the location of the gas plays is its accessibility to large, potential markets in Asia. The presence of wet gas in offshore fields also proves advantageous because of the liquids demand throughout the region. The following section reviews each country's energy industry and sheds light on potential areas of improvement. Within that, the current and potential future use of natural gas is discussed.

3 Energy Sector Consumption Trends

3.1 Mozambique

Mozambique's primary energy demand is currently met by various fuel sources, but the overwhelming majority is supplied through biomass and hydropower. Bioenergy is the prevailing form used in both urban and rural populations and is responsible for 75% of the energy supplied and consumed. Oil products, which constitute the majority of the fuel used in the transportation sector, are imported and account for 8% of the total domestic demand [22]. The burgeoning natural gas supply has had a minimal impact on the domestic energy market thus far, constituting 3% of the total energy used in 2014 [22]. Roughly 90% of the natural gas from Mozambique is immediately exported to South Africa [22] as a part of the sales agreement with field operator Sasol (South Africa). As a result, the domestic market only has access to 15% of the energy produced annually from certain gas fields [23].

Hydropower, the second most important source of energy within the country, accounts for 12% of the total supply. It is also the main source for power generation. Over 90% of the electricity generated in Mozambique comes from the Cahora Bassa Dam [24]. The dam sits in the northwestern part of the country and generates over 2,000 MW of power. There are inherent limitations to this system, though, due to the location of the generation source and a transmission network that is currently unfit to efficiently transport electricity to all population centers.



(a) Transmission network in Mozambique. [25].

(b) Mozambique population map [26].

Figure 3: Delivery of electricity in Mozambique. The Cahora Bassa Dam is located in the Zambezi River basin and is outlined in red in each figure.

The dam was originally established as a joint venture with Eskom, a South African public utility, which is partly why most of the power is exported to South Africa[5]. Though much of the electricity is eventually sold back, 15% [24] of the total power is still lost to net exports. Low electrification rates means that any power lost is substantial. One way the government combats low rates is by expanding the reach of transmission lines. In fact, it has one of the highest rates of new connections in Sub-Saharan Africa [28]. The government's plan to increase sector utilization also involves multiple power generation projects. As is shown in Section 5.1, decentralization as a result of increased generation capacity is already underway. Most of the new power stations are and will be serviced by natural gas, and will be located in different regions throughout the country.

The majority of the energy consumed in Mozambique occurs in the residential sector. In 2011, household energy use accounted for close to 60% of the total [24]. For those that live in rural areas (67%), biomass has historically been the sole source of energy for nearly all households [24]. In urban areas, there is still a large dependence on this type of energy resource. Charcoal accounted for roughly 50% of energy consumption expenses in cities in 2015 [24]. Household fuel consumption is an important figure within the country because of the relatively small size of the economy. Thus, focusing on ways to target the residential sector with cheap, more efficient alternatives will be important as the government looks to utilize the natural gas resource to improve the living standard of its populace.

[5]There is also 10.5¢/kWh of avoided generation cost when inverting the power in South Africa that the nation's publicly owned Electricidade de Mozambique (EdM) uses to ensure long-term financial security [27].

3.2 Tanzania

Tanzania and Mozambique share many commonalities in the way primary energy is used. At 85%, bioenergy accounts for the majority of the energy consumed due to its heavy use as cooking fuel [29]. The residential sector is responsible for 70% of total final consumption. Finally, the oil products that are utilized (11% of primary energy), are all provided through imports. In recent years, rapid population growth and increased dependence on biomass have led to high rates of deforestation and degradation [30]. The Biomass Energy Strategy (BEST) Tanzania Project, carried out by the European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF)[6], concluded that the accelerating yearly demand of biomass energy is unsustainable for the country [31]. Among the recommendations offered by EUEI PDF is fuel switching by making non-biomass cooking alternatives, like LPG, "more competitive on a non-subsidized basis in terms of availability and price" [31].

Though Tanzania's primary energy supply is more than double that of its southern neighbor, it consumes 60% less electricity [32]. Hydroelectric power plants, which were the sole source of electricity until 2002, operated at a 20% capacity factor by the end of 2015 [33]. More specifically, increased frequency of drought has limited generation and has contributed to the country's 24% electrification rate [34, 35]. Sole dependence on hydroelectric power is not a sustainable and effective path to universal electrification, and as such, over the last 15 years the government has diversified and increased generation capacity by way of natural gas, diesel, and coal. Most importantly, increased production of natural gas has helped to provide a more consistent form of base load energy. Figure 4 shows a growing trend – 42% [32] of the electricity now generated comes from gas produced in the Songo Songo and Mnazi Bay gas fields. An increase in domestic natural gas production from onshore and offshore fields will help increase generation capacity, which currently totals less than 2,000 MW.

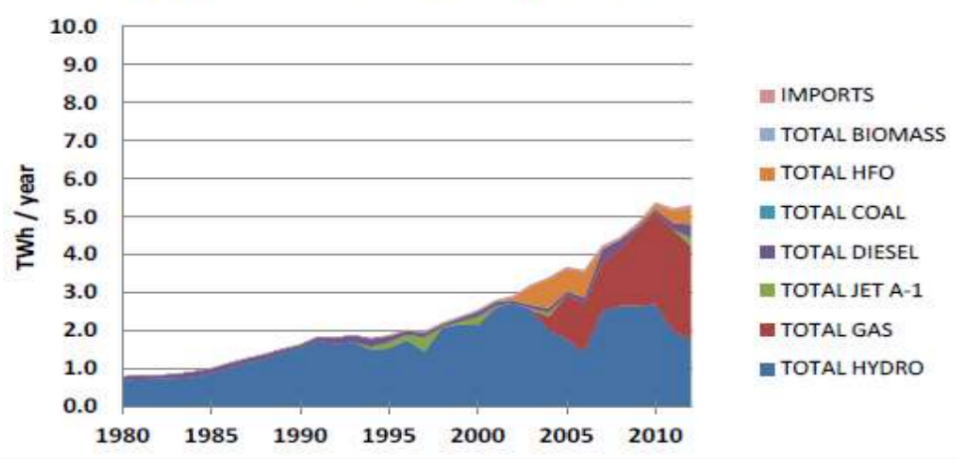


Figure 4: Power generation by source in Tanzania (1980 - 2012) [36, 37].

[6]This was done on behalf of the Ministry of Energy and Minerals (MEM).

4 Natural Gas Policies for Effective Utilization

The discovery of oil, gas, or minerals in low-income countries sometimes leads to what is known as the 'resource curse' or the 'paradox of plenty'. The Natural Resource Governance Institute defines this as "the failure of many resource-rich countries to benefit fully from their natural resource wealth, and for governments in these countries to respond effectively to public welfare needs" [38]. This has been the case in some Sub-Saharan Africa nations with energy resources [6]. In order to circumvent common pitfalls, there are two points of focus for the Mozambican and Tanzanian governments: transparency and follow through on proactive, domestic programs and initiatives. Both countries are members of the Extractive Industries Transparency Initiative (EITI), which mandates information and accountability from resource extraction up to revenue management within the government. Each also has policies in place to ensure the long-term improvement of the given communities by explicitly outlining investment opportunities beyond the extractive sector. If these plans are adhered to properly and an appropriate pricing structure is put in place, the success of domestic utilization of natural gas will materialize in both countries.

4.1 ICF International Mozambique Natural Gas Master Plan

The *ICF International Mozambique Natural Gas Master Plan* outlines the management of the nation's gas resource. Three sectors constitute the focus of the domestic market: large industry, small and medium enterprises, and power generation. Table 2 is a slightly altered reproduction of Table 9 from the government's plan and shows the opportunities for gas utilization[7].

[7]The Action Plan in the original document (Table 10) provides a concise overview of deliberate steps the government will take to ensure proper use of the natural gas resource. This is also accompanied by a timeline.

Industrial Sectors	**Project**	**Products**	**Reasoning**
Fuel Sector	LNG_1	Liquefied Natural Gas	Large-scale LNG projects lead to the implementation of other potential downstream industrial projects
	GTL Projects	Diesel/ LPG/Nafta	Reduces Mozambique's dependence on imported refined petroleum products; Potential for regional export of products derived from GTL; Stable demand for diesel fuel and its by-products
	Project for the distribution of gas through pipelines	Natural Gas	Provides necessary means to transport gas and enables the fulfillment of the fuel demand for different sectors: industry, transport, commercial and residential; Enables consistency in the supply of gas and relatively low operational costs; Enables the formation, in a sustainable manner, of industrial hubs across the country
	LPG Project	LPG	Reduces Mozambique's dependence on imported refined petroleum products; Replaces the more traditional fuels used in Mozambique's domestic and commercial sectors (wood and coal); Enables the penetration of natural gas to areas without pipelines
	DME Project	Dimethyl ether (DME)	Potential to replace other fuels. Can be used as a replacement for propane in LPG and diesel for electricity generation
	LNG_2	Natural Gas Surplus	Export the surplus gas once the domestic demand has been met
Base Chemicals Sector	Ammonia /Urea Project	Ammonia/ Urea (Fertilizers)	The government's strategies for the agricultural sector and the great international demand encourage investments in this area; Will provide a reduction in fertilizer imports; The urea plant in Mozambique can be the distribution center for Africa
	Methanol Project	Methanol /Various sub-products: (Paints, plastics, varnishes, resins, DME, etc.)	Methanol is the base material for a wide range of products used in almost all areas of modern life; As a product that adds some of the most value to natural gas, priority will be given to methanol projects that produce other sub-products.
	Olefins Project (C2/C3)	Polyethylene /polypropylene	International market demand
Power Sector	Combined-Cycle gas power plant project	Electricity	The availability of reliable electricity will catalyze industrialization and rural electrification; There is currently a high demand for electricity in the country; Energy efficiency of flexible operation

Table 2: Top 3 priority investment areas from the Natural Gas Master Plan.

4.2 The National Natural Gas Policy of Tanzania

The National Natural Gas Policy of Tanzania provides a framework for resource management. The government's approach, encouraged by the possible oversaturation of the international market, is to provide priority to domestic and regional markets over LNG exports [39]. The biggest constraint and most important concern is adequate infrastructure. Within the scope of this policy, the government has also provided quantitative details on gas utilization in the coming years[8] [40]. This is known as the Natural Gas Utilisation Master Plan. The list below is a summary of that plan.

Natural Gas Utilisation Master Plan[9]

1. The revised Power System Master Plan (PSMP) projects that the installed capacity of gas-fired power plants will increase from 711 MW to 1,774 MW by 2020. The natural gas fields are forecasted to provide roughly 9 TCF of gas over a 30-year period.
2. According to the Ministry of Energy and Minerals, 10% of households in Tanzania will cook with natural gas by 2045, amounting to 0.5 TCF of gas over a 30-year period.
3. It is assumed that 20% of all petrol vehicles will be converted to natural gas vehicles by 2045. As a result, the total demand for natural gas in the transportation sector is projected to reach 0.6 TCF in 30 years.
4. Fertilizer demand will be met by a plant that will produce 2,300 tons/day of ammonia and 4,000 tons/day of urea. This is enough to satisfy growing demand while also providing a surplus for exports. Based on estimates from the Ministry of Agriculture on tonnage needed (885,000 tons by 2025), projected natural gas demand over a 25-year period is 0.7 TCF[10].
5. Nearly 1 TCF of natural gas will be needed for methanol over a 23-year period.
6. Demand for gas-to-liquids (GTL) products is projected to consume 1.8 TCF of the natural gas over a 20-year period.
7. Developments in the United States, Australia, and Mozambique make the international LNG environment more difficult to maneuver. Though Tanzania's location gives it easy access to large markets in India, South Korea, Japan, and China, final investment decisions on LNG trains depend on supply/demand and price forecasts. Over the next 20 years, LNG trains with 5 million tons per annum (MTPA) capacity each are projected to use 11.1 TCF (x2), 15.8 TCF (x3), or 19.5 TCF (x4) of gas, depending on demand.
8. The future state of the international LNG market mandates a consideration of the transport of gas through pipelines throughout the country and the region. Trans-

[8] The Action Plan in the original document (Appendix A) provides a concise overview of deliberate steps the government will take to ensure proper use of the natural gas resource. This is also accompanied by a timeline.

[9] All of the plans to develop the reserves are based on 0.7 recovery factor. This results in 38.6 TCF of the 55.08 TCF (as of July 2015) of gas that can be included in domestic, regional, and international strategies.

[10] See Section 5.3 for information on the construction of the fertilizer plant.

mission pipelines are proposed in phases that span five years. Each successive phase moves the gas from the coastline, west to the interior and rest of the country. The first phase includes providing transmission lines from Dar es Salaam to Mwanza and Arusha. Remote areas will be serviced by tank trucks and trains to satellite stations that can regasify the LNG.

9. Gas will be supplied to regional markets like the East Africa Community and the Southern African Development Community, though this is contingent upon proper infrastructure. Four hundred million standard cubic feet per day (MMscf/d) of gas has been dedicated for export between 2025-2045. This totals 3.1 TCF.

The policy also stresses the importance of stakeholder participation in the economy, and the government has encouraged international oil companies to get involved in domestic corporate finance. For example, changes in the mining sector mandated companies with at least $100,000 in subscribed capital to put 30% of their shares on the domestic stock exchange [41]. Investors are also required to explicitly state corporate social responsibility plans in their proposals. The policy also creates the Natural Gas Revenue Fund (NGRF). This transparent fund will be overseen by the Bank of Tanzania and will be the ultimate benefactor of the natural gas revenue stream, as opposed to the government's treasury. The establishment of a transparent sovereign wealth fund has shown to be effective in Norway, thus Tanzania looks to develop their gas fields responsibly by following the same steps.

4.3 Pricing Challenge

An in-depth discussion of the domestic pricing structure for natural gas is absent from both plans. Mozambique's includes some information on the gas that will leave the proposed Palma processing plant; however, there are no details about how this gas will be priced in relation to other available fuels and other types of currently available natural gas. Similarly, there is no true discussion on price in either of Tanzania's natural gas-related policy plans, although the government has noted a requisite for a natural gas pricing policy that will be established sometime in the near future. Both countries should consider the common pitfall of pricing domestic gas and electricity too low. In other countries, like Nigeria, this has led to gas and electricity shortages, as well as financial problems for national gas and electricity companies. Nigeria has drafted many natural gas master plans over the years that discuss all the valuable ways gas will be put to use domestically, but they never materialize because gas is priced too low to incentivize supply to be directed to domestic uses. This is the biggest struggle in the development of reliable gas-fired generation and other domestic gas applications. Proper pricing is the deterministic factor, so each government should be sure to consider the experiences of other nations while pricing the gas in order to make effective domestic utilization a reality.

5 Domestic Gas Markets

5.1 Power Generation

For East Africa, turning the natural gas resource into a sustainable growth mechanism for regional development is heavily dependent on improving power generation. Currently, hydro is the main source of power in Mozambique and Tanzania, but poor transmission networks, weather liability, and limited installed capacity has rendered the sector ineffective in both countries. Both nations have among the lowest per capita energy demand in the world [5].

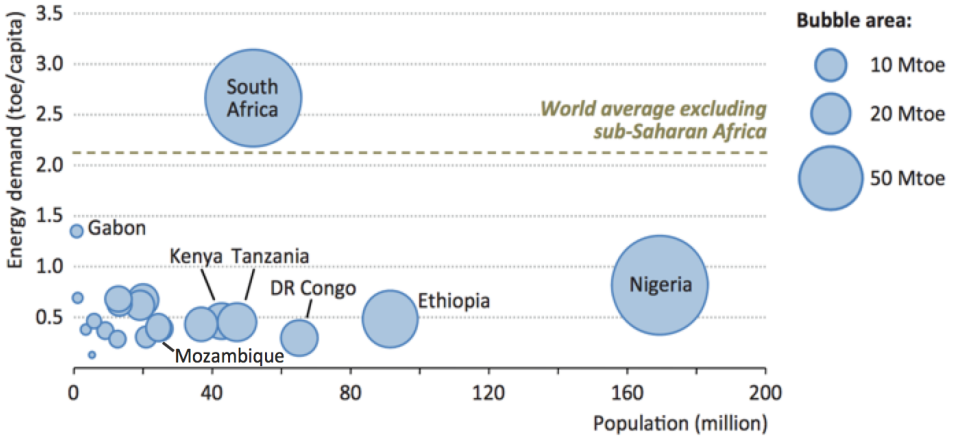


Figure 5: Population and per capita energy demand by country in Sub-Saharan Africa, 2012. The size of the bubble indicates the size of total primary energy demand [5].

The government's solution in Mozambique has been to bring more gas-fired power plants online. The operation of the newly built 120 MW gas-fired power station in Ressano Garcia commenced in 2016. The power produced will go to the nation's publicly owned electric company, Electricidade de Mozambique (EdM) [42]. Construction of a 100 MW gas-fired power station near Maputo began in the same year. The plant, which will cost between $150 million - $180 million, has an operational date of 2018 [43]. In February of 2017, Mozambique's energy minister called for a meeting to ensure the financial security of Sasol's proposed 400 MW gas-fired power plant in Inhambane [27]. Two other proposed projects, the 75 MW plant in Palma [44] and the 40 MW plant in the Gaza province, are clouded with uncertainty. Since the announcement of the plant in Palma in 2014, no updates have been released. Similarly, the project in the Gaza province has sat idle, awaiting EdM to sort gas supplies. For the latter, the financial state of EdM is the most likely cause. The company continues to suffer as a result of the low cost of electricity and cannot meet debt repayments and interest costs. This has led to the foregoing of maintenance work on the country's distribution network, leaving large areas without a grid [27]. Contrary to the current state of the electric

grid, the gas transmission network is expanding. In 2016, an agreement was reached for a consortium to begin development on the $6 billion, 2,600 km, African Renaissance natural gas pipeline that will transport gas from the Rovuma Basin (Palma district) to the Johannesburg provincial area [45]. The project will enable the delivery of gas to many cities and areas within Mozambique along the way. Gas infrastructure projects like such will need to continue to progress to ensure full utilization of newly built and proposed power plants.

Tanzania has already succeeded in increasing the nation's gas-fired generation capacity, adding roughly 600 MW in the last 10 years. This effort has greatly decreased the country's dependence on hydroelectric power, naturally increasing power generation security. The country's newest plant, the 240 MW Kinyerezi natural gas combined cycle power plant (NGCC), situated roughly 30 km south of Dar es Salaam, has a planned commission date of 2018 [46]. The Ministry of Energy and Minerals is also focused on an expansive natural gas distribution network. In 2015, the 532 km Mtwara–Dar es Salaam Natural Gas Pipeline was completed [47]. This pipeline transports natural gas from the Mnazi Bay gas fields to the capital of Dar es Salaam. Because of commitments to export at least 3.1 TCF of gas over the next 30 years, the government will extend the pipeline domestically and regionally. The Power System Master Plan provides a detailed list of all current and planned gas transmission projects that should greatly improve the mobility of gas within the next few years.

5.2 LPG as a Cooking Fuel

Over 20 million and 40 million people rely on traditional biomass for cooking in Mozambique and Tanzania, respectively [5, 22, 32]. Despite high rates of household air pollution (HAP), transitioning to cleaner, more reliable fuels like LPG present a few challenges. One of the most commonly cited issues throughout the literature is a lack of awareness of the hidden costs of biomass use. Part of the reason is difficulty in accurately quantifying money lost due to HAP and effectively communicating that to the public. Fuel stacking is another determinant for low uptake rates for LPG [48, 49]. The World Bank found that roughly 50% of clean stove owners still use baseline cooking technology [27]. Cost and availability of alternatives like LPG for cooking fuel are perhaps the most important factors for increasing market penetration. For supply, the liquids potential of each nation's natural gas resource has been noted by operators. Opportunities involving LPG/DME use have also been targeted by both governments in their respective utilization plans.[11]

Most recently, the Tanzanian government provided tax-exempt status for LPG fuel and gas cylinders [48] in order to increase usage rates. Within six months of passing that legislation, the small market grew by 50% [48]. Though this has made LPG more cost competitive against charcoal, taxes are still levied on cookers and other accessories, preventing continued accelerated growth past the initial spike [48]. The average start-up cost of $75 for the smallest cylinder (6 kg) available is still more expensive than

[11] Sasol's drilling activity in Inhambane (Mozambique) has resulted in a decision to build a 20,000 t/year LPG facility. Construction is expected to commence in 2017 [50].

that for charcoal [51], but the monthly cost of refills, makes it, on average, cheaper in the long run [48]. Additionally, the decreased accessibility and rising costs of wood and charcoal have created a more favorable environment for LPG [51]. For example in Mozambique, a 200% increase in the cost of charcoal [49], made LPG cost-neutral, if not more cost-competitive than charcoal, in the capital of Maputo [49].

Two courses of action have been noted to help overcome the barriers to LPG use in the residential sector: decreased cost constraint associated with constructing distribution and refilling networks and purchase flexibility for the diverse household user base [49]. Both can be aided and funded by the government through public infrastructure projects and subsidies, but those in the private sector can also make an impact. For example, for LPG accessibility, VidaGas (Mozambique) has provided an easy and smart solution to increase customer usage by specifically targeting underserved parts of the country and establishing plants in remote areas. While other suppliers have opted to transport LPG cylinders over 1,000 miles from the capital of Maputo, where much of the demand is concentrated, to outlets in the northern parts of the country, filling plants in those regions makes VidaGas more receptive to customer needs and wants [52]. Similarly, Petrogas LDA, a distributor of LPG in Maputo, has shown that the intermittent cash flows of potential low-income household customers have made it difficult for them to purchase standard-sized cylinders. By increasing variations in the bottle size, the smallest being 4.5 kg, the company has been able to better serve this portion of the customer base and notes that smaller cylinders better match the purchase trends of the customers' cash flows [49].

5.3 Natural Gas as a Feedstock for Fertilizer

The agricultural sector employs roughly 80% of Mozambique's labor force and produces nearly a quarter of the country's GDP [53]. Despite this, the sector uses less than 1% of the total energy consumed [22]. Subsistence farming constitutes a large portion of the sector, and, as such, inefficiencies with respect to fertilizer use, among other factors, have contributed to food insecurity and low levels of agricultural productivity [54, 55]. The Mozambique government believes that natural gas has the potential to catalyze the agricultural industry by addressing the inefficiencies that currently affect it [54].

Within Mozambique, 70% of the fertilizer that arrives at ports is sent to neighboring countries [56]. That which is retained constitutes the majority of the fertilizer used. However, at a 5% adoption rate [57], there is currently not a large fertilizer demand. In order to meet the consumption targets necessary for agricultural goals, two changes need to be made. The first involves increasing domestic fertilizer availability. The aforementioned industry was noted in the Mozambique master plan as a priority destination for gas. Secondly, improving awareness of agronomic and economic benefits of fertilizer use has been cited as an important corollary.

Country	Current Consumption (Mt/year)	Target Consumption (Mt/year)	Increase
Mozambique	51,600	225,000	4.4x
Tanzania	263,000	528,000	2x

Table 3: Estimated Fertilizer to Meet Feed the Future Country Agricultural Growth Targets [57].

In Tanzania, the agricultural sector is the main driver for the country's economy. It accounts for roughly 50% of the GDP, 85% of exports, and employs 90% of the workforce [58]. As such, the government has focused its efforts on creating a more robust and efficient farming sector. Tanzania, like Mozambique, imports the majority of the urea and diammonium phosphate (DAP) that is consumed domestically. From 2007 to 2011 fertilizer imports increased by 13.5% compound annual growth rate (CAGR) [59]. As international prices have risen, the government has taken steps to ensure affordability for increased demand. For example, the urea sourced from North America, along with other types of fertilizer, is subsidized through the National Agricultural Input Voucher Scheme (NAIVS) [59]. Tariffs and taxes on fertilizer are also nonexistent. This adds to the financial strain of the government due to subsidies aimed at making the products more affordable for consumers. Despite these efforts, additional costs associated with transport, credit, and other factors have increased retail prices by 41% [59]. The large supply of domestic natural gas, a feedstock used to create ammonia for nitrogen-based fertilizers, provides an effective way to boost production and help cut subsidized imports.

Both countries could benefit by increasing domestic fertilizer output. For fertilizers like urea that use ammonia as a feedstock, having easily accessible gas is critical to industry vitality. Both have already reserved large volumes of gas for boosting agricultural productivity, and they have both already begun the process to increase fertilizer output. In 2016, Tanzania started work on a $3 billion fertilizer plant that will, once completed, be Africa's largest, capable of producing 3,800 tons of urea per day. The plant is said to promise 5,000 jobs and be operational by 2021 [60]. Natural gas from adjacent offshore fields will be used as the hydrogen source for ammonia production. In Mozambique, a project site in the Beira New Industrial Area has been chosen for the Urea Fertilizer Complex [61]. However, no other developments have been made public since 2014.

6 Current State of LNG Prospects

Despite the decline of global LNG prices, exports from East Africa still show high levels of potential if contracts can be secured. Figure 6 provides a comparison of the price of two competing LNG sources.

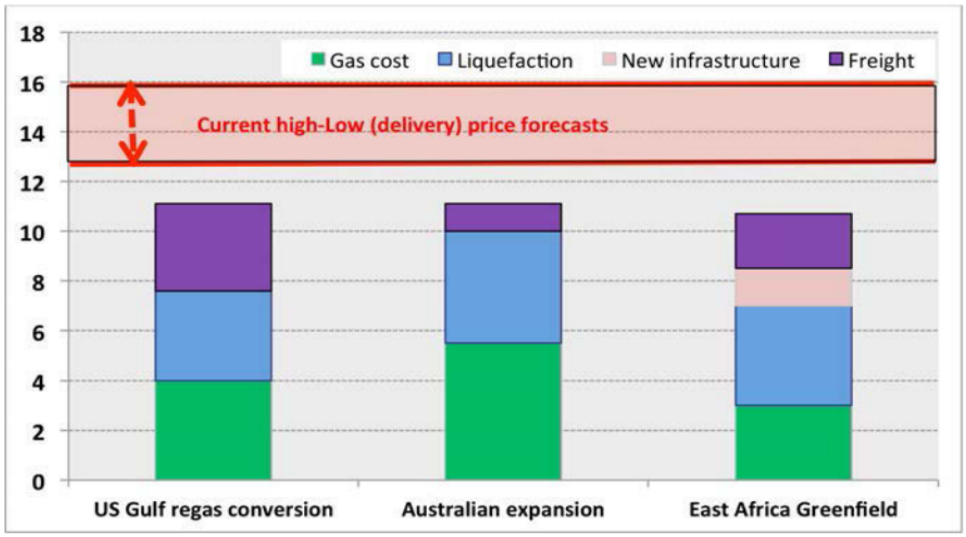


Figure 6: Break-even delivery prices for natural gas to Asia ($US per MMBTU [4, 62].

Even though new infrastructure costs will increase the per unit price, the nature of the gas and the location of the fields works to the advantage of both countries. In December 2015, ENI announced a Unitization and Unit Operating Agreement (UUOA) between them and Anadarko to develop their leased blocks as a joint venture [63]. Such activity adversely affects the swiftness of final investment decisions (FID) within either company because of the increased complexity of managing partnerships. This is important to note as questions about delayed FIDs on the Mozambique LNG Development Project persisted throughout the majority of 2016 amid the strain imposed on companies from the global oil downturn. Still, a 20-year offtake agreement by BP for ENI's Coral floating liquefied natural gas (FLNG) project and announcements by Anadarko show that the two largest stakeholders are still committed to the area.

In Tanzania, the government is in the process of drafting an agreement that would ensure the construction and operation of the Tanzania Liquefied Natural Gas Project (TLNGP) by Shell, ExxonMobil, Statoil, and Ophir [64]. The $30 billion LNG plant in the coastal Lindi Region will process gas from offshore blocks and is set to be operational by 2021. Despite a provision of land already made by the government for the construction of the export terminal, concerns and questions have risen about the certainty of the project [64]. A rapidly changing economic and investment environment driven by the president's desire to decrease reliance on foreign aid has slowed the FID considerably [64].

There has been no commercial production in either offshore area thus far. With FIDs still being resolved by Anadarko and ENI, target dates for commercial gas in Mozambique are estimated at 2022 at the earliest [65, 66]. Offshore operators in Tanzania are on a similar schedule as those in Mozambique. Ophir/Shell have just recently finished drilling their final exploration well and are entering pre-front-end engineering and design (pre-FEED) and FEED phases for block 1 [67]. Statoil has not reported any produced volumes in their most recent annual report either. In the meantime, current production in Tanzania comes from the Songo Songo field operated by Orca, which delivered a total volume of

30 BCF of natural gas in 2016 [68]. French consortium Maurel & Prom and Wentworth Resources Limited have majority ownership in the country's Mnazi Bay gas field. With the first gas delivered in 2015, production continues to climb. It reached 51 MMscf per day in the second quarter of 2016 [69]. Similarly, there are currently two onshore fields in production in Mozambique: Pande and Temane. Both are operated by Sasol and collectively produced 115 BCF of natural gas in the most recent fiscal year [70].

7 Conclusion

The potential of the natural gas resource in East Africa offers key opportunities for development if the associated challenges are met. Both countries have already begun adding significant amounts of gas-fired generation to their respective power plant fleets; however, improving electrification rates does not solely depend on generation capacity, but also on the robustness of gas distribution and electric transmission networks. For Mozambique and Tanzania, securing finances for expanding infrastructure can inhibit the speed at which electrification occurs despite the increased generation capacity. Among the other services offered by the natural gas is the ability to help transform residential cooking by introducing large amounts of a cleaner, more efficient, and, in some instances, cheaper fuel (LPG). Through the case study carried out in Mozambique, it is known that limited distribution/refilling networks and cost are the main barriers that need to be overcome to increase market penetration. The chemical sector is also a focus of both countries because of the potential growth of domestic fertilizer production. Each relies heavily on inefficient agricultural industries, while Tanzania specifically provides vast amounts of subsidies on these imported products. Natural gas (ammonia), a fundamental building block for some of the most widely used fertilizers, provides the means to help each country save money on imports while boosting agricultural output. This can only be done if the benefits of fertilizer use are articulated to the public and domestic production becomes a reality. For LNG, the current and projected status of the international market has forced both governments to think more carefully about regional gas exports through pipelines as an effective way to monetize the gas if foreign markets are oversaturated. Finally, if the pricing scheme is constructed properly, both Mozambique and Tanzania have plans in place to fully utilize the natural gas resource as a driver for development in their respective countries.

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