The Natural Gas Value Chain: Potential for National Economies

2021

AFRICAN DEVELOPMENT BANK GROUP

African Natural Resources Centre

This report is a reprint of a 2019 hard copy published report

Table of Contents

List of Figures and Tables

1. Introduction

1.1. Motivation for the study

The African Natural Resources Centre (ANRC) of the African Development Bank (AfDB) was created to provide technical assistance, advisory services, and knowledge and advocacy initiatives in renewable and non-renewable resources to the bank's regional member countries.

This report and analysis of gas sector value chains and downstream policy trade-offs will enhance the African Natural Resources Centre's ability to help regional member countries strike the right balance between maximising revenue from natural resource primary production, and integrating them into national economies through downstream processing. This assistance contributes to the African Development Bank's renewed drive towards industrialisation.

Many African countries aspire to derive greater economic value from raw materials. One obvious way of achieving this is by leveraging nature's assets and capitalising on their economic advantage of possessing these raw materials. Potentially significant entry barriers to downstream processing for both private firms and governments implies that policymakers should seek the right balance between focusing on the barriers to, as well as the economic benefits from, downstream processing in order to make better-informed policy choices. The desire for downstream processing needs greater understanding of these and other considerations.

1.2 Objectives of the study and the study approach

This report focuses on evaluating the capacity of the natural gas value chain to:

- Generate employment
- Contribute to public income (fiscal and non-fiscal revenues)
- Support infrastructure development
- Create domestic linkages at the various stages in the value chain

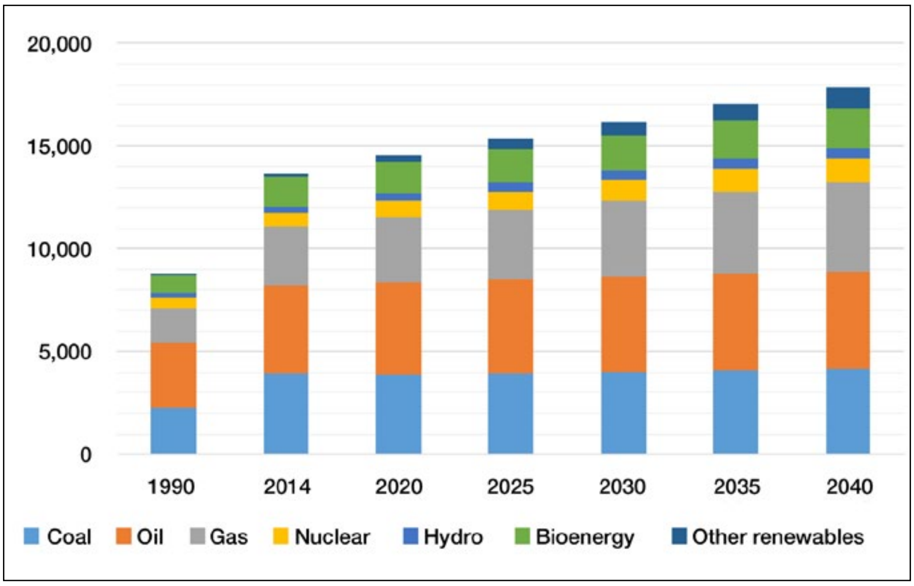
This study undertakes economic analysis of the resource value-chain to inform policy options. The study was completed through a review of current literature and an assessment of selected industrial activities, particularly in the African context. It also emanated from creating descriptions of the specific value chains, analysis of identified projects, as well as interviews and collaboration with industry experts and investment analysts, where possible.

2. The Natural Gas Commodity

2.1. The importance of natural gas in global markets and in Africa

The World Energy Outlook 2016,[1] produced by the International Energy Agency (IEA), estimates that under its New Policies Scenario, natural gas consumption will grow by 1.5 percent annually until 2040, with a doubling of liquified natural gas (LNG) trade contributing to this growth. The IEA expects natural gas demand to grow faster than demand for other fossil fuels, with gas increasing its share of global primary energy demand from its current 21 percent to 24 percent in 2040.

Figure 1:
Global Energy Demand (mtoe)



Source: IEA World Energy Outlook 2016, New Policies Scenario

Some highly attractive features of natural gas as a fuel that contributes to making demand for it the fastest growing of all fossil fuels include:

- Relative abundance of the resource
- Lower carbon content, resulting in an environmental advantage as global energy systems gradually decarbonise
- Flexibility and adaptability, making it a necessary and valuable backstop fuel to complement rapidly growing, but intermittently reliable, renewable energy sources

Nevertheless, natural gas continues to face many challenges. They include:

- Highly competitive markets with other competing fuels
- Low energy density relative to other fossil fuels, increasing its transportation costs
- Water safety concerns due to the geology of some low-permeability gas deposits and the use of hydraulic fracturing to recover that gas
- Fugitive emissions of methane, a potent greenhouse gas (GHG), during gas production and transportation which can negate the environmental advantages of natural gas if not mitigated

2.2. End market and market trends

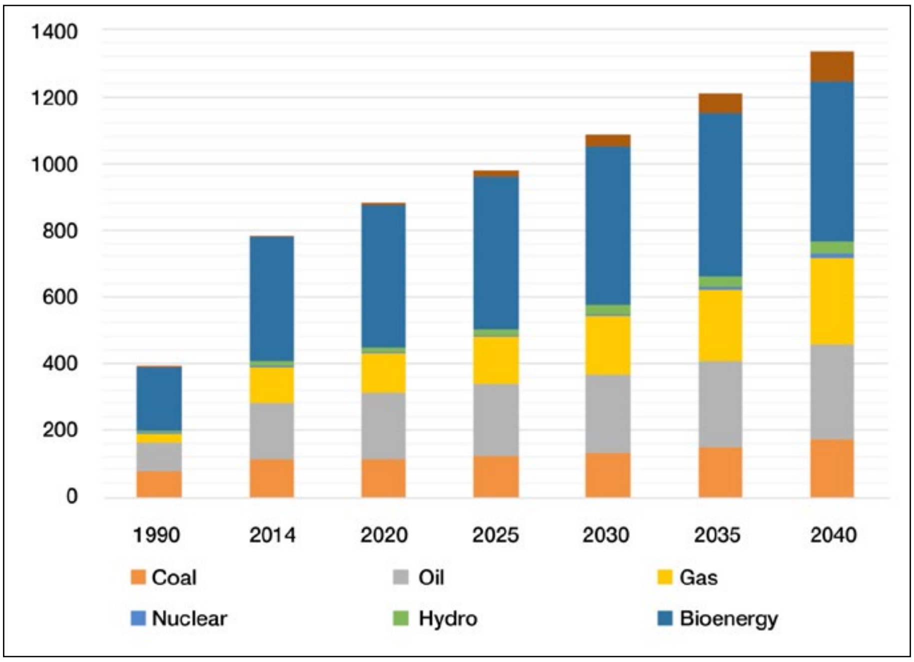
2.2.1. Main consumption and production markets and trends

The IEA's World Energy Outlook 2016 expects African gas consumption to increase at an average annual growth rate of 3.4 percent from 2015 to 2040, more than double

1 *(International Energy Agency, 2016)*

the rate of global demand growth for natural gas. African natural gas production is expected to increase faster than African demand for natural gas.

Figure 2:
African Energy Demand (mtoe)



Source: IEA World Energy Outlook 2016, New Policies Scenario

Several existing major natural gas producers -- Nigeria, Algeria, Angola and Egypt -- account for 86.6 percent of African production. Tanzania and Mozambique are expected to emerge as major gas producers, developing East Africa's offshore gas resources, and joining major existing producers to double Africa's gas production by 2040. In the next few years, increased African production will be primarily from Egypt's newly discovered Zohr field. In the coming decades, Mozambique and Tanzania are expected to dominate production growth, together accounting for more than 35 percent of the continent's additional annual gas production in 2040. The IEA expects Africa's gas exports to increase to over 130 bcm annually, mostly in the form of liquified natural gas. The IEA expects gas-fired power generation to be the biggest source of domestic demand growth for gas in Africa.[2]

Table 1:
Gas Demand and Supply (bcm/year)

(bcm)	2014	2020	2025	2030	2035	2040	CAAGR
Africa Gas Demand	131	143	171	208	255	312	3.39%
Africa Gas Supply	214	230	282	341	395	447	2.87%
Global Gas Demand	3,502	3,802	4,106	4,466	4,858	5,219	1.55%
Global Gas Supply	3,536	3,802	4,106	4,466	4,858	5,219	1.51%

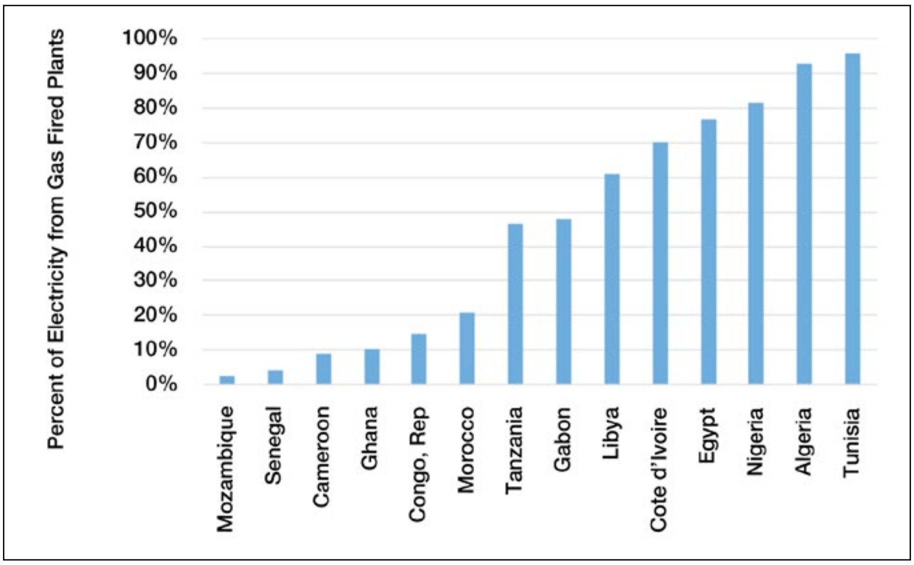
Source: IEA World Energy Outlook 2016, New Policies Scenario

2.2.2. Competition, market prospects and challenges

Notwithstanding Africa's fossil fuel endowment, including natural gas, most African nations suffer from energy poverty and have low energy access. There is a big gap between energy supply and potential energy demand, especially in the area of electric power generation.[3, 4]

2 (International Energy Agency, 2016)
3 (OPEC Fund for Inernational Development, 2008)
4 (International Energy Agency, 2014)

Figure 3:
Gas-Fired Electricity as Percentage of Total Electricity Generation, 2013[5]



Source: Plotted from Sustainable Energy for All (SE4ALL) database, World Bank, Global Electrification database

Figure 3 shows the relative share of gas-fired power plants of the respective country's total electricity generation.

Some key challenges for natural gas endowed countries in Africa, especially those in sub-Saharan Africa, include:

- Low level of energy access and commercial energy use
- The ability to attract investment to improve both grid and off-grid energy supply
- Stable and accessible natural gas supply[6]

2.3. Production trends in Africa

2.3.1. Regional production, growth and opportunities for expansion

The IEA's 2016 World Energy Outlook indicates that Algeria will struggle to maintain its export capacity at current levels. Most of its current production is reliant on a few large mature fields that have started to deplete. Algeria has also struggled to attract foreign investment due to unattractive fiscal terms and other security concerns.

The IEA also observes that discovery of the Zohr gas field in Egypt has raised prospects for a turnaround in Egypt's production. An official start-up date has been set for 2017-2018, with output expected to reach 27 bcm by 2019. Initial production from Zohr is to supply the domestic market, which is facing severe shortages.

The IEA expects Nigeria's natural gas production to decline, as investments are slow amidst the low energy prices and the deadlock in Nigeria's new petroleum industry legislation, which has caused uncertainty around the fiscal and legislative framework. Address the flaring issue in Nigeria could unlock significant natural gas resources, as more than 60 percent of associated gas is flared, which represents about one-third of total Nigerian natural gas marketed production.

In Cameroon, the 14 bcm Kribi natural gas field will provide gas for exports from a new Floating LNG plant. The gas is being produced by GDF Suez and SNH from a relatively small field, but there is a potential for discovering additional gas reserves nearby.

5 (World Bank, 2016)
6 (Oliver Wyman, 2016)

Eastern Africa has an estimated 4.7 tcm of recoverable natural gas reserves. This region's gas reserves rival many existing and potential LNG exporting nations, and it could become a formidable supplier of LNG, perhaps post 2020. In East Africa, Tanzania and Mozambique are the two biggest players of natural gas supply growth. Electrification needs could play the biggest role in these two countries, and remains a top priority for the governments of both Tanzania and Mozambique. The natural gas resources in these two countries are large enough to exceed demand for the domestic markets. Several gas monetisation options are being considered, with high priority being given to LNG exports.

Some challenges in these countries are regulatory, political, and fiscal in nature. Project needs stability, and resolving these uncertainties would be key to success development. Managing local expectations is important, since any natural gas value added plant may be able to provide plenty of jobs during construction, but many of the workers may be foreigners, who have the skills, and not nationals. In addition, just a few hundred workers may be required to operate a plant.

There is potential LNG export growth from Angola from the Chevron LNG export facility. The design capacity for this facility is 5.2 mtpa, however the combination of current low natural gas prices globally and lack of off-take contracts could delay the project from reaching its full capacity.

2.3.2. Comparisons among world gas leaders

Table 2 below shows the top countries in the world ranked by 2014 gas production. There were 95 countries in the world with gas reserves in 2013,[7] with these top 50 countries representing 98.4 percent of global gas reserves. The seven African countries included in the top 50 countries account for 8.6 percent of global reserves. Table 2 shows that African countries' natural gas reserves are relatively modest in the global context. These countries will not become dominant market players, because they do not have the resources to do so. But that does not preclude them from developing and benefiting from the resources they have.

Table 2:
2014 Country Rankings by Gas Production

African Rank	Global Rank	Country	Reserves (TCM)	% of Global Reserves	Production (bcm/yr)	% Global Production
	1	United States	9.6	5%	889.3	21%
	2	Russia	47.8	24%	637.8	15%
	3	Iran	33.8	17%	244.5	6%
	4	Canada	1.9	1%	193.0	4%
1	5	Algeria	4.5	2%	186.7	4%
	6	Qatar	25.1	13%	166.0	4%
	7	Norway	2.1	1%	154.6	4%
	8	China	4.4	2%	123.5	3%
	9	Saudi Arabia	8.2	4%	116.7	3%
	10	Indonesia	3.0	2%	89.5	2%
2	11	Nigeria	5.1	3%	86.3	2%
	12	United Arab Emirates	6.1	3%	83.7	2%
	13	Malaysia	2.4	1%	80.3	2%

7 (US Department of Energy, 2015)

	14	Turkmenistan	7.5	4%	77.4	2%
	15	Venezuela	5.6	3%	76.7	2%
	16	Netherlands	1.0	0%	70.3	2%
	17	Mexico	0.5	0%	67.5	2%
	18	Australia	1.2	1%	62.9	1%
	19	Uzbekistan	1.8	1%	61.7	1%
3	20	Egypt	2.2	1%	54.0	1%
	21	Thailand	0.3	0%	46.2	1%
	22	Trinidad and Tobago	0.4	0%	43.6	1%
	23	Argentina	0.4	0%	41.5	1%
	24	Pakistan	0.8	0%	41.2	1%
	25	Kazakhstan	2.4	1%	40.5	1%
	26	United Kingdom	0.2	0%	39.8	1%
	27	Oman	0.5	0%	37.9	1%
	28	Brazil	0.5	0%	31.9	1%
	29	India	1.4	1%	31.2	1%
	30	Yemen	0.5	0%	31.1	1%
	31	Colombia	0.2	0%	29.5	1%
	32	Azerbaijan	1.0	1%	28.1	1%
	33	Bangladesh	0.3	0%	23.9	1%
	34	Bolivia	0.3	0%	22.1	1%
	35	Iraq	3.2	2%	21.9	1%
	36	Bahrain	0.1	0%	21.5	0%
	37	Ukraine	1.1	1%	20.1	0%
	38	Peru	0.4	0%	18.4	0%
4	39	Libya	1.6	1%	17.0	0%
	40	Burma (Myanmar)	0.3	0%	16.8	0%
	41	Kuwait	1.8	1%	15.3	0%
	42	Brunei	0.4	0%	11.9	0%
	43	Romania	0.1	0%	11.6	0%
5	44	Angola	0.3	0%	10.4	0%
	45	Germany	0.1	0%	10.4	0%
	46	Vietnam	0.7	0%	10.2	0%
6	47	Congo (Brazzaville)	0.1	0%	9.3	0%
7	48	Equatorial Guinea	0.0	0%	8.9	0%
	49	Timor-Leste (East Timor)	-	0%	8.6	0%
	50	Syria	0.2	0%	7.1	0%

Source: US Dept of Energy, EIA

2.4. Natural gas pricing methods

There is no global price for natural gas. In most parts of the world, consumer prices for natural gas are set by formula rather than determined in a gas market. This has major implications for African countries, as they must choose a method for determining gas prices. It also means the gas price itself may become a policy lever to enhance the competitiveness of alternative gas value chain nodes. Natural gas pricing is among the most important policy decisions that African countries may face in seeking to develop the natural gas value chain.

The International Gas Union (IGU) has described alternative methodologies for natural gas price formation, as follows:[8]

Oil Price Escalation (OPE) - The price is linked, usually through a base price and an escalation clause, to competing fuels, typically crude oil, gas oil and/or fuel oil. Sometimes, coal prices can be used as base price, as can electricity prices.

Gas-on-Gas Competition (GOG) - The price is determined by the interplay of supply and demand – gas-on-gas competition – and the gas may be traded over a variety of different periods (daily, monthly, annually or other periods). Trading typically takes place at physical hubs (eg, Henry Hub) or notional hubs (eg, NBP in the UK). Prices in these markets are set on major exchanges (NYMEX or ICE), including futures prices. Not all gas is bought and sold on a short-term fixed price basis, and there will be longer term contracts that will use gas price indices to determine the monthly price, for example, rather than competing fuel indices. Also, included in this category is spot LNG, any pricing which is linked to hub or spot prices, and also bilateral sales agreements in markets where there are multiple buyers and sellers.

Bilateral Monopoly (BIM) - The price is determined by bilateral discussions and agreements between a large seller and a large buyer, with the price being fixed for a period of time – typically one year. There may be a written contract in place but often the arrangement is at the government or state-owned company level. Typically, there would be a single dominant buyer or seller on at least one side of the transaction, to distinguish this category from GOG, where there would be multiple buyers and sellers trading bilaterally.

Netback from Final Product (NET) - The price received by the gas supplier is a function of the price received by the buyer for the final product the gas produces. This may occur where the gas is used as a feedstock in chemical plants, such as ammonia or methanol, and gas is the major variable cost in producing the product.

Regulation: Cost of Service (RCS) - The price is determined, or approved, formally by a regulatory authority, or possibly a government ministry, with the level set to cover the cost of producing the gas, including the recovery of investment and a reasonable rate of return.

Regulation: Social and Political (RSP) - The price is set, on an irregular basis, probably by a government ministry, on a political or social basis, in response to the need to cover increasing costs, or possibly as a revenue raising exercise – a hybrid between RCS and RBC.

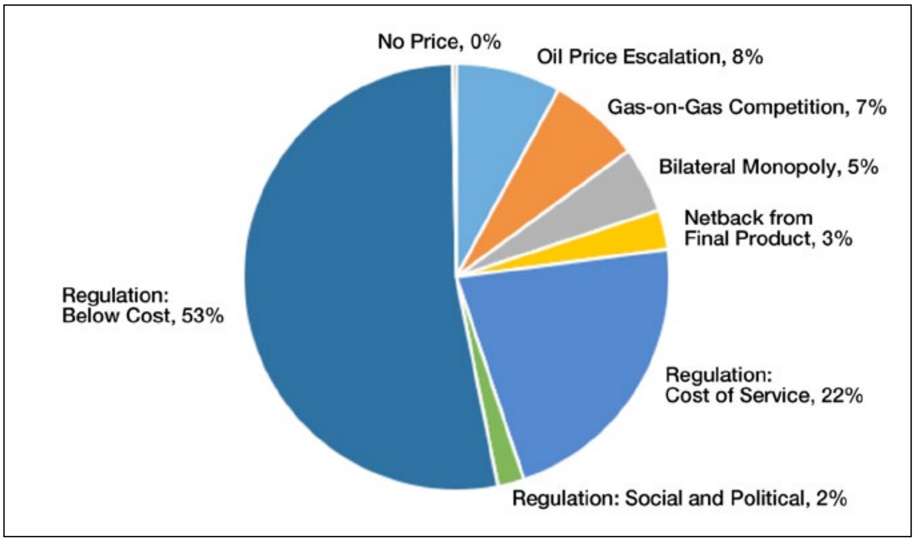
Regulation: Below Cost (RBC) - The price is knowingly set below the average cost of producing and transporting the gas, often as a form of state subsidy to the population. This would generally only happen where the government owns and produces the gas.

No Price (NP) - The gas produced is either provided free to the population and industry, possibly as a feedstock for chemical and fertiliser plants, or in refinery processes and enhanced oil recovery. The gas may be associated gas, produced as a by-product with oil and/or liquids production, thereby allowing no price.

8 *(International Gas Union, 2016)*

Gas prices in North America are based on Gas-on-Gas Competition with contract and spot priced gas traded on NYMEX based on transactions at Henry Hub (a gas trading hub located in southern Louisiana USA). Traditionally, most long-term prices for sales of LNG to Asia contain an Oil Price Escalation (OPE) mechanism, although prices in that market may now be in transition as the North America natural gas market transitions from being a net importer to a net exporter of LNG. Domestic gas prices in Africa are predominantly by regulation below cost (RBC), with low gas prices, in effect, serving as a subsidy.

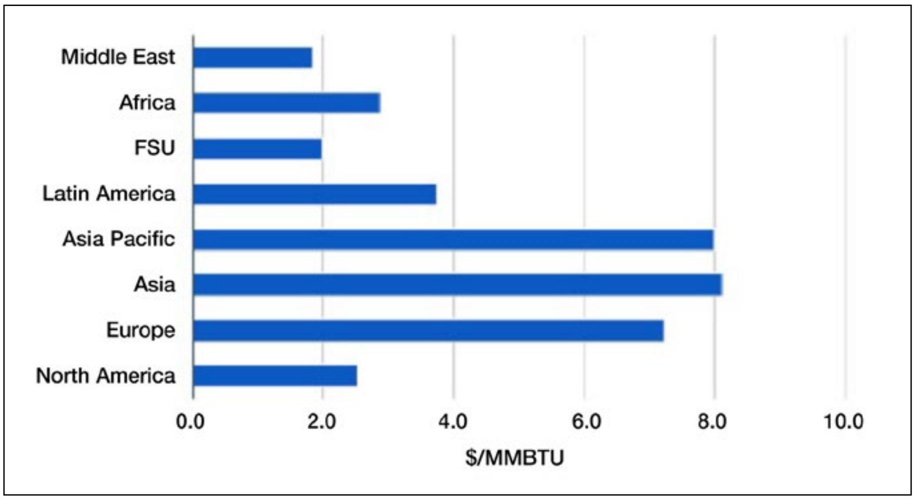
Figure 4:
African Natural Gas Pricing Methods by Volume



Source: IGU

The figure below provides a snapshot of wholesale gas prices in 2015, indicating African gas prices are in the order of $3.00 per MMBTU delivered to plant gate.[9] Figure 6 provides country-specific prices.

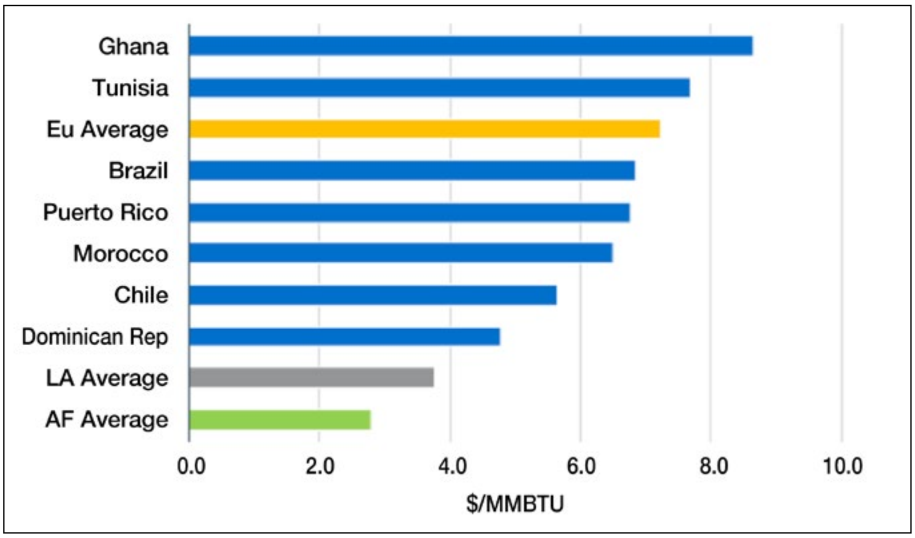
Figure 5:
International Gas Prices



Source: IGU

9 *(International Gas Union, 2016)*

Figure 6:
Sample Country Gas Prices in Latin America and Africa



Source: IGU[10]

2.5. Value chain overview

The economic activities of exploring for gas and extracting the gas through a well are referred to as the upstream portion of the industry. Not all gas discovered is recoverable, for technical and/or economic reasons. Only the portion of the discovered gas resource that is both technically and economically recoverable is included in gas reserves. Gas reserves will change over time due to depletion, discoveries, technological innovation and economic conditions.

The gathering, processing and transporting of natural gas are referred to as the midstream industry. Natural gas processing plants serve two functions. First, they remove impurities from sour gas streams for environmental reasons, such as sulfur, to provide a clean gas for transportation and consumption. The impurities have no economic value, but must be removed to avoid contamination during transportation and pollution from combustion.[11] Secondly, gas plants typically remove NGLs from rich gas streams, as they are also hydrocarbons and valuable sources of energy and industrial feedstocks. Extracting natural gas liquids from the gas stream is generally done for economic reasons, although removal of liquids may also be necessary for the gas to be transportable and consumable.

The downstream portion of the gas value chain involves the direct consumption of the gas and/or conversion of the gas into other useful consumer and industrial products. The most common direct consumption of gas is burning it as a fuel. Given the low energy density of natural gas, it is often converted into other fuels such as methanol or is liquefied. Natural gas is also converted into valuable non-energy industrial products, including the feedstocks for polymers.

This report focuses on the downstream portions of the natural gas value chain, described above. The value chain is illustrated in the figure below:

10 (International Gas Union, 2016)

11 These impurities represent negative externalities, and would not generally be removed voluntarily by the producer in the absence of regulations. The need to remove them for environmental reasons is a reason why effective regulation is so important, as will be briefly discussed below.


LPG

3. Natural gas value chain analyses

Our descriptions of each gas value chain node include Michael E. Porter's Five Factors[12] for analysing competitive advantage and competitive strategy for each of the potential gas value chain nodes. These five forces are:

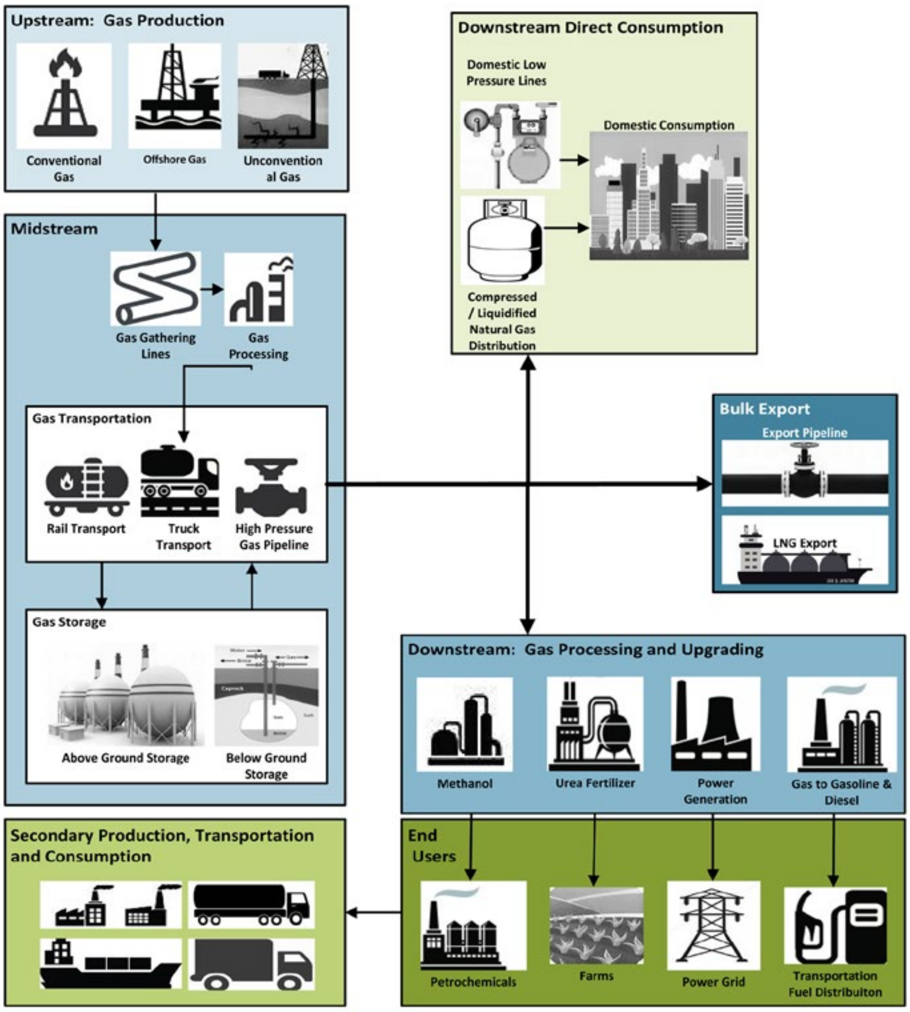
1. Threat of new entry
2. Rivalry among existing competitors
3. Threat of substitutes
4. Bargaining power of suppliers
5. Bargaining power of customers

3.1. Urea production

Urea is granular nitrogen fertiliser and a globally traded commodity. Benchmark prices for urea are set at market locations in New Orleans (NOLA) and the Black Sea.

The three basic "NPK" fertilisers are nitrogen (N), phosphorus (P) and potassium (potash or K). Urea is produced by burning natural gas to supply energy and hydrogen while pulling nitrogen from the atmosphere to create liquid ammonia which can be processed into ammonium nitrate or the more stable urea. The three fertilisers, NPK, are typically blended into field specific mixtures. While phosphorous and potassium fertilisers do not have to be applied every year to increase agricultural yields, nitrogen fertiliser needs to be applied every year. Nitrogen fertiliser can dramatically increase both crop yield and nutritional value.[13] Deposits of potash and phosphorus are not uniformly

Figure 7:
Natural Gas Value Chain



12 (Harvard Business School, 2016)

13 (Government of Saskatchewan, 2014)

distributed around the world, and trade in these fertilisers is tightly controlled by a few major players. Nitrogen fertiliser is potentially available anywhere there is natural gas.

The global price of agriculture commodities is a key contributor to agricultural revenues. When agricultural commodity prices are strong, farmers are able to increase their use of fertiliser and improve crop yields, as fertiliser application is an optional fixed input cost that can increase production yields. As prices rise, the marginal benefit of fertiliser increases, which effectively provides farmers with the ability to purchase more inputs in order to increase crop yields. While commodity prices are global, agricultural production costs are local, and specific to each farmer. As a result, agricultural profits are impacted by both movements in (global) commodity prices and (local) costs of production. Urea fertiliser prices generally move in tandem with agricultural commodity prices and natural gas prices.

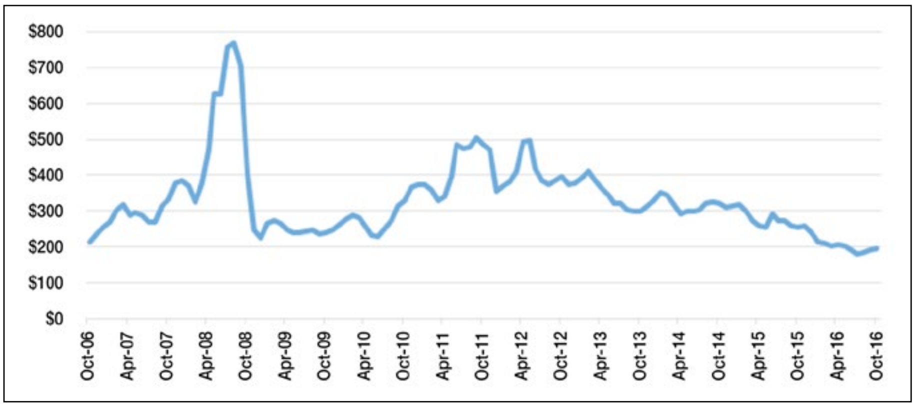
Urea is also an ingredient in other industries including explosives, plywood, internal combustion systems, beauty products and as a supplement to animal feed.

3.1.1. Industry analysis

Industry rivalry and barriers to entry: Urea processing plants benefit from economies of scale. A doubling of production capacity requires only an 80 percent increase in capital cost. Capital costs comprise over 50 percent of the life-cycle costs of a urea plant, with fixed operating costs at 20 percent and marginal variable production costs at 30 percent.[14] Consequently, like most large scale capital-intensive processing plants, both the technology and profit margins require full utilisation of plant capacity to be viable. With this economic reality and competitive global pricing of urea, producers are very responsive to new entrants into the market, and will lower prices to maintain market share and full production. As a commodity, urea's price can fluctuate dramatically, as the figure below shows.

Egypt dominates urea production in Africa. It produces just under half of Africa's production (ranked 9th globally) and is also the largest consumer of nitrogen fertiliser on the continent. Africa's production capacity is estimated to be 8.3 million metric tons per year, although production is only at 6.3 million metric tons per year. With demand of only 4.4 million metric tons per year, roughly 30 percent of nitrogen fertiliser is exported.[15] Egypt and Morocco are Africa's chief urea exporters, with markets in France and United States respectively, while Algeria exports ammonia primarily to Spain.[16, 17]

Figure 8:
Historical NOLA Price US$/mt



Source: Index Mundi[18]

14 Based on economic models used in this report.

15 (Agrium, 2015)

16 (ICIA, 2015)

17 (African Fertilzer Organization, 2016)

18 (Index Mundi, 2016)

Threat of substitutes: The production of ammonia and urea are the only viable large-scale sources of nitrogen fertiliser. Nitrogen fertiliser use is a valuable, but optional, expense for farmers. Perceived as a fixed cost, the use of nitrogen fertilisers depends on expected crop prices and farmers' access to financing to enable them to purchase and apply fertiliser months before crop harvest.

Buyer power: If a plant is located near agricultural producers, is it not uncommon for farmers to pick up urea direct from the manufacturer by the truck load. In developed markets, urea producers typically sell their product in bulk to large wholesale agricultural firms or co-operatives. These firms will blend NPK fertilisers on site to suit local soil and economic conditions, and sell directly to farmers. Nitrogen application rates range between 5 to 140 lbs per acre depending on soil conditions and crop.[19] As a result, urea is generally sold in bulk by the truck load to farmers, with bagging occurring only for smaller farms, subsistence farming and horticulture.

The industry is seeing some horizontal consolidation of wholesalers who are also investing in upstream and downstream linkages to provide farmers with complete service coverage. This includes transportation, storage and marketing of crops. These vendors may also broaden and sell other agricultural services and products to farmers, including machinery, equipment, herbicides, pesticides, and financial services.

Current demand in Africa for nitrogen fertiliser is approximately 4.4 million metric tons per year. Egypt consumes approximately 30 percent, South Africa 10 percent, and Morocco 5 percent.[20] These nations are also Africa's largest producers of nitrogen fertiliser. This implies that if more African countries with natural gas production produced urea fertilisers, their agricultural producers would consume more fertiliser, thereby increasing agricultural yields and incomes.

Globally, at 32 percent, China is the largest consumer of nitrogen fertiliser. India follows at 15 percent, the United States at 11 percent, Brazil at 3 percent and Indonesia at 3 percent. While China is a net exporter of urea, India, United States and Brazil are net importers.[21]

Supplier Power: There are only a few proven technology providers for the urea process.[22] However, given that new plants generate significant revenues for the engineering-equipment provider, both during initial construction and on-going support, they are very competitive with each other and now have no current oligopoly tendencies.

The natural gas feedstock for most world class plants is purchased in competitive spot markets or through long-term contracts. The plants are located either near cheap natural gas and ideally near large agriculture centres. Given the difficulties in shipping natural gas, and the relative ease of shipping an inert solid urea granule, plants are generally more likely to be located near the feedstock. This suggests opportunities for African countries with large and relatively under-developed gas reserves, especially if they are willing to use gas pricing as a policy lever to attract investment, if necessary.

19 Alberta Agriculture and Forestry, 2004)

20 (Agrium, 2015)

21 (Agrium, 2015)

22 See appendix for provider listing.

To be viable, world-class urea plants require good infrastructure to get their bulk product to market. This , includes infrastructure like roads, railways and shipping ports. Plants consume significant electrical power, and they process water that is usually treated after use on site. As with any large processing facility, supporting skilled trade specialists and contractors are necessary. These include millwrights, welders, electricians and general construction contractors. While each plant will have its own internal maintenance department, it can never be large enough to support annual plant turn arounds where major overhauls take place.

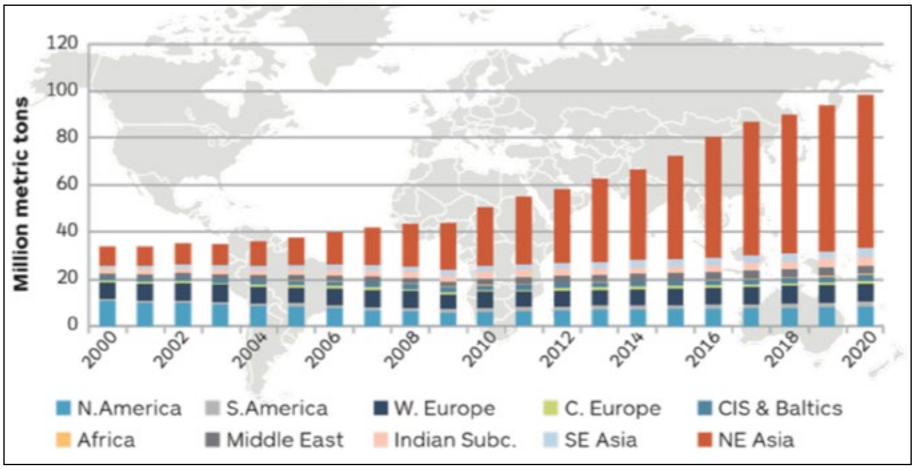
Modern urea plant operations are highly automated, limiting the need for significant labour. During operations, the plant will need a variety of well-paid skilled trades, including steam engineers, millwrights, electricians, process engineers and plant equipment operators. Ideally these skills are drawn from the local labour pool, or can be trained from the local market. In addition to these skilled trades, each plant will require lower skilled labor for material handling, shipping and receiving. In North America, these positions would require high school level numeracy and literacy as well as equipment-specific training (eg, fork lifts, shunting rail engines or trailers).

3.2. Methanol processing

Methanol is a liquid that is both a feedstock for a variety of chemical products and a fuel source. Methanol is typically produced on an industrial scale. It uses natural gas as the principal feedstock, which is reformed with steam. The resulting synthesis gas is put through conversion into liquid methanol. Worldwide, over 90 methanol plants have a combined production capacity of about 110 million metric tons. Global methanol demand reached 70 million metric tons in 2015. Methanol is almost exclusively made where low cost natural gas feedstocks are available. There are methanol plants in three countries in Africa:

- Equatorial Guinea, with annual production capacity of about 1.4 million tons, produces entirely for an export market. The plant is 10 percent owned by SONAGAS, the National Gas Company of Equatorial Guinea.[23]
- Egypt, with annual production capacity of 1.3 million tons, where the methanol plant is 50 percent owned by Egyptian government partners.[24]
- Libya's methanol plant has an annual production capacity of 680 thousand ton. It is 100 percent owned by Libya's national oil company.[25]

Figure 9:
Global Methanol Demand by Region



Source: IHS CERA[26]

23 http://www.atlanticmethanol.com/home.html.
24 https://www.methanex.com/location/middle-east/egypt.
25 http://noc.ly/index.php/en/about-us-2.
26 (IHS Chemical Bulletin, 2016)

A world-scale methanol plant typically produces 1.8 million metric tons per annum, so the current plants in Africa may be marginal by this standard. Asia (China and India) is the source of most growth in methanol demand.

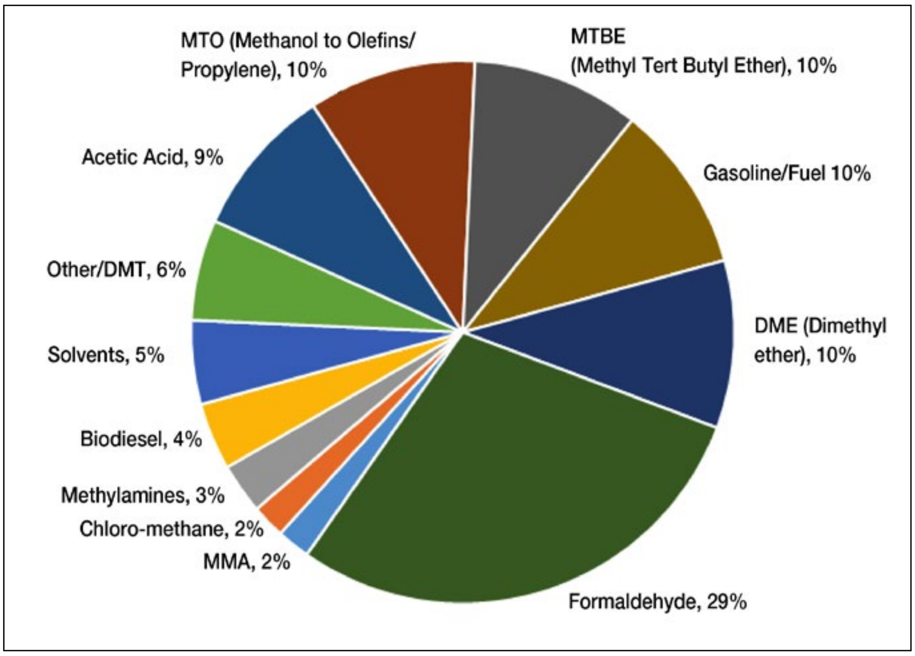
The following chart shows 2015 methanol consumption. Uses for methanol include:

- Formaldehyde: laminated wood products, resins, medical vaccines, paint, ink, textiles, automotive parts, building materials, industrial processing
- MTO (Methanol to Olefins / Propylene): plastics
- MTBE (Methyl Tertiary Butyl Ether): anti-knocking additive in fuels, solvent
- Gasoline / Fuel: automotive and marine transportation
- DME (Dimethyl ether): aerosol propellant and additive to diesel and LPH fuel
- Acetic Acid: metal/cellulose/vinyl acetate, solvents, paint/ink, plastics, textiles
- DMT (Dimethyl terephthalate): polyester, plastic (PET)
- MMA (Methyl Methacrylate: automotive parts, LCD screens

Methanol demand growth derives largely from emerging applications for methanol as a fuel source or fuel additive, which now account for 40 percent of methanol consumption. Uses for methanol include:

- Formaldehyde: laminated wood products, resins, medical vaccines, paint/ink, textiles, automotive parts, building materials, industrial processing
- MTO (Methanol to Olefins / Propylene): plastics
- MTBE (Methyl Tertiary Butyl Ether): anti-knocking additive in fuels, solvent
- Gasoline / Fuel: automotive and marine transportation
- DME (Dimethyl ether): aerosol propellant and additive to diesel and LPH fuel
- Acetic Acid: metal/cellulose/vinyl acetate, solvents, paint/ink, plastics, textiles
- DMT (Dimethyl terephthalate): polyester, plastic (PET)
- MMA (Methyl Methacrylate: automotive parts, LCD screens

Figure 10:
2015 Global Methanol Consumption, 70 million metric tons



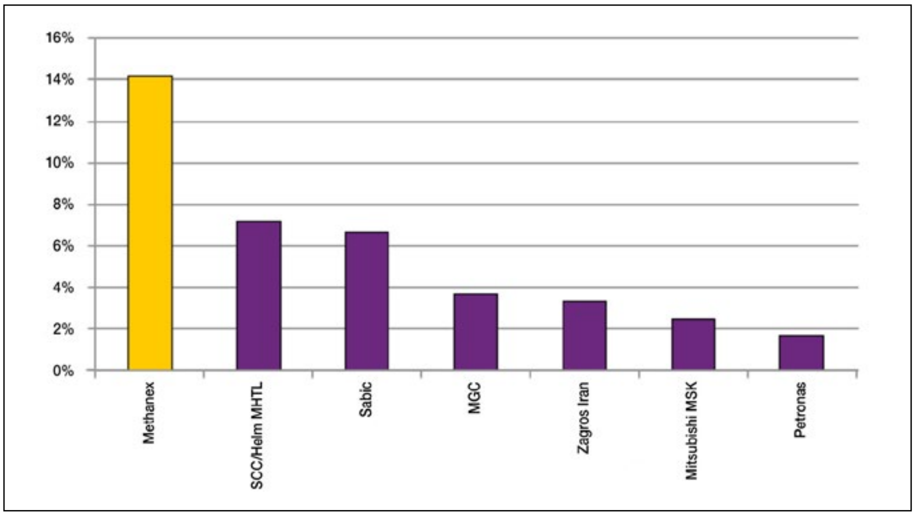
Source: IHS CERA[27]

27 *(IHS Chemical Bulletin, 2016)*

3.2.1. Industry analysis

Industry rivalry and barriers to entry: Methanol production occurs near feedstock supply and is shipped by tankers to further processing locations. Methanex is the world's largest producer of methanol, as the figure below shows:[28]

Figure 11:
Top Producers Market Share of Global Methanol



Source: Methanex[29]

Similar to urea plants, methanol production requires large-scale capital-intensive processing plants, which benefit from economies of scale, with a doubling of production capacity that results in only an 80 percent increase in capital cost. Like urea, capital costs, directly and indirectly, comprise over 50 percent of the life-cycle costs of a methanol plant, with other fixed costs comprising 20 percent, and marginal variable production costs at 30 percent.[30] Because both the capital-intensive technology and profit margins require full production to ensure plant viability, producers are very responsive to new entrants into the market and will lower prices to maintain market share and full production.

Threat of substitutes: Methanol is a very useful chemical building block used in a large variety of processes. While natural gas is the primary feedstock for making methanol, other fossil fuels like coal can be used. Use of these other feedstocks involve more complex processes, and are likely to be more expensive.

Buyer power: Methanol is largely an industrial commodity and is purchased in quantity by other large processors for whom it becomes an input into further value-adding. Methanol producers have both long-term supply contracts and they sell on the spot market. China is the largest consumer of methanol globally. Depending on the province or district, China requires methanol based/blended fuels ranging from 5 percent to 100 percent. China both imports and produces significant methanol as a feedstock for methanol-to-olefin production (or MTO).[31]

Supplier power: There are only a few proven technology providers for the methanol process.[32] However, because constructing a new plant generates significant revenue for the engineering-equipment provider, both during initial construction and in on-going support, they are very competitive with each other and there are no current tendencies to restrict access to the technologies.

28 (Methanex, 2016)
29 (Methanex, 2016)
30 Based on economic models used in this report.
31 Olefins are synthetic plastics.
32 See appendix for provider listing.

The natural gas feedstock is typically purchased in competitive spot markets or through long-term contracts. The plants are located near inexpensive and abundant natural gas deposits as methanol is cheaper and easier to transport than LNG.

Methanol plants have the same operating and capital characteristics as urea plants. Both processes consist of large compressors, high pressure reactors, pressure vessels, complex computer control systems and similar supporting infrastructure. The same skilled labour requirements required for a urea production facility will be required for a methanol production facility.

3.3. Gas-fired power plants

Gas turbine engines generate power by injecting a mixture of compressed air and natural gas into a combustion chamber. These engines relying on the resulting combustion of these gases to drive a turbine, analogous to a high pressure steam turbine. This is called a single electrical generation system. Combined cycle power plants are more efficient as they take the waste heat from the combustion process to generate steam to drive a secondary steam turbine. While the capital costs of combined cycle turbines are higher, their greater efficiency at converting natural gas into electricity makes them the attractive low-cost life-cycle gas value chain technology that this report will focus on.

Natural gas generated 33 percent of Africa's electricity in 2014. The IEA expects it will remain at that level to 2040, with electricity generation growing at an annual average of 2.9 percent in that period.[33] Coal is currently the largest fuel used for electricity in Africa, and by 2040 the IEA expects natural gas will be the largest, followed by coal and other renewables, such as wind and solar. We believe natural gas-fired electricity generation is one of the best opportunities for African countries with natural gas. A recent World Bank study concluded: "Clearly, the gas resource base itself is large enough to support whatever power sector demand could plausibly materialise. And the cost of gas-fired power competes very favourably against liquid fuels and, in a surprising number of cases, against coal and even high-cost hydropower".[34]

Electricity is a prerequisite for a modern and prosperous economy, and is required for almost every aspect of residential, commercial and industrial progress. African electricity power supply and distribution is substantially below that of other industrialised nations and this limits development. The proportion of households with access to electricity is an important indicator of energy poverty, and African countries lag badly on this indicator.

Natural gas turbines provide a relatively low-cost, low-GHG emission method of electricity production. Power plants provided by Siemens and General Electric are becoming off-the-shelf packages that can be placed almost anywhere. This is certainly true of small power plants that may come skid-mounted and truck portable. The table below provides a high-level comparison of the economics and key characteristics of the main methods of generating electricity.

33 *EA, World Energy Outlook 2016.*

34 *Santley, David; Schlotterer, Robert; Eberhard, Anton. 2014. Harnessing African Natural Gas: A New Opportunity for Africa's Energy Agenda?. World Bank, Washington, DC, p.58.*

Table 3:
Comparison of Electricity Generation Method

Technology	Levelized Cost of Energy[35] US$/kwh	Dispatch-ability[36]	Location Requirements	GHG Emissions	Environmental Consequences
Coal	$0.027	Low	Cooling water	High	Smog, health, ash disposal
Natural Gas (combined cycle)	$.017	High	Cooling water	Low	None
Natural Gas (simple)	$0.106	Very high	None		
Nuclear	$0.052	Low	Seismic constraints	None	Long term disposal of radioactive materials
Geothermal	$0.056	Medium	Limited	Renewable	None
Solar	$0.11	Very Low	Limited	Renewable	Land use
Wind	$0.54	Very Low	Limited	Renewable	Land use
Tidal	$0.19	Low	Limited	Renewable	Marine life
Hydro	$0.06	High	Very limited	Renewable	Ecosystem disruption

Source: US Dept of Energy, EIA

3.3.1. Industry analysis

Industry rivalry and barriers to entry: Storage of electricity at meaningful quantities is difficult. Long distance transmission typically results in a 30 percent loss of power. As a result, most nations require their own power grids for producing and distributing electricity. The power grid is normally a regulated industry, as it is an essential service required for a modern economy. While Europe has some deregulated power grids with power providers selling electricity to consumers with price based on market supply and demand, much of North America is retreating to a regulated model. Even in the deregulated regimes, a central entity typically has a monopoly power wherein power producers sell to the grid and are paid by the central entity, who collects fees from users. This central agency dictates the nature of the power in the grid (voltage, amperage, frequency, alternating or direct current) and manages the interaction between producers, distributors, transmitters and consumers. The high capital costs and regulated nature of power plants result in central planning tendencies. In this environment, power producers tend to be regionally based with a low degree of competition.

Unlike processing plants, combined cycle turbine power plants scale almost linearly, meaning that a plant twice as large typically costs twice as much.

Threat of substitutes: There are competing methods of energy production but none rival the universal applicability of electricity. Electricity competes with gas, oil, coal and solar for heating, cooling and industrial applications. Gas-fired electricity is generally more cost-competitive than oil or coal-fired, and environmentally more benign in terms of lower GHGs and other emissions. The economics of solar and wind energy and electricity have improved considerably, and may be attractive for many reasons in addition to the relative economics. Some analysts have suggested that

35 *(US Energy Information Agency, 2016)*

36 *Electricity is simultaneously produced and consumed. Dispatchability is the ability of the unit to increase or decrease power production in response to demand. Simple cycle gas turbines can provide power in six-minute intervals.*

off-grid solar electricity may now be more cost-effective than wide-scale electricity distribution in Africa.[37, 38] But for large consumers for whom reliability is critically important, solar and wind energy are not sufficiently reliable. Gas-fired electricity is not only economically attractive, but its high "dispatchability" allows it to effectively serve as the back-up electricity source necessitated by less reliable energy sources.

Buyer power: In most regulated environments, power is purchased directly by consumers who are "price-takers" on a short-term basis. Depending on the regulatory regime, electricity prices are either set by an agency or by bidding by suppliers. In established markets, some producers may "brand" their power and charge a premium for "green" energy. Western consumers' concerns about climate change have supported this branding. While electricity production can be "green", once the energy is in the distribution grid it cannot be distinguished, and physically behaves as a homogeneous pool.

Supplier power: There are numerous technology providers for the natural gas turbines. The technology is well established and vendors aggressively compete for business.

The natural gas feedstock for most world class power plants is purchased in competitive spot markets or through long-term contracts. The plants are located either near cheap natural gas or adjacent to large population centres, ideally both. Regardless of siting, power plants typically need access to significant cooling water to dissipate surplus heat and provide water for the steam turbine.

To be viable, large power plants require supporting power transmission and distribution infrastructure. Typically, the right-of-way for this infrastructure is secured or provided by government agencies. Ownership can be both public and private. Plant construction requires contractors and supporting trades (millwrights, welders, electricians and general construction contractors). Unlike processing plants that can last indefinitely with sufficient capital renewal budgets, combined cycle plants are built around turbines that have a 20 to 30 year life span, after which they typically require major capital overhauls or outright replacement.

Modern power plants are highly automated, limiting the need for significant labor. During operations, the plant will need various well paid skilled trades persons including steam engineers, millwrights, electricians, process engineers and plant equipment operators. Ideally these skills can be drawn from the local labour pool or can be trained up from the local market. While each plant will have its own internal maintenance department, it can never be large enough to support annual plant turnarounds when major labour-intensive overhauls take place.

3.4. Gas to Liquids (GTL)

The advantage of gas to liquid (GTL) over liquified natural gas (LNG) is that liquids are highly fungible, do not require long-term off-take agreements or cryogenic methods for transportation and storage. There are two commercially available technologies to produce gasoline and diesel transportation fuels from natural gas. They are:

- Fischer-Tropsch GTL technology
- Natural Gas to Methanol to Liquids technology.

37 (The Economist, 2016)
38 (The Economist, 2015)

3.4.1. Fischer-Tropsch GTL technology

The Fischer-Tropsch GTL technology was developed in Germany using coal as feedstock and commercialised by Sasol and Shell. It reacts methane feedstock with oxygen or steam to produce a syngas, which is a mixture of hydrogen and carbon monoxide. The syngas is then used to make liquid hydrocarbons (such as diesel and naphtha) using Fischer-Tropsch catalytic synthesis. The table below shows the location and size of existing gas to liquid facilities in the world.

Table 4:
Global Fischer-Tropsch GTL Plants

Country	GTL Plant	Capacity b/d
South Africa	Sasol I, Sasolburg	5,600-8,000
South Africa	Sasol II & Sasol III, Secunda	124,000-154,000
South Africa	Mossga, Mossel Bay	22,500
Malaysia	Bintulu	14,700
Qatar	Oryx, Ras Laffan	32,400
Qatar	Oryx, Ras Laffan	140,000
Total		**339,200-371,600**

Source: Author's knowledge

The Shell Pearl GTL Project Trains I and II in Qatar were constructed between 2006 and 2011, and Train II started up in 2012. The total Pearl GTL project investment is estimated at $19 to 25 billion. Several projects were announced when the price of natural gas to oil ratio was high. With the drop in the price of oil compared to the price of natural gas, recently announced projects have either been put on hold or canceled all together.

3.4.2. Natural gas to Methanol to liquids technology

The second commercially available technology to convert natural gas to liquid transportation fuels is Gas-to-Methanol-to-Gasoline. Mobil developed the technology in the early 1970's to convert natural gas to syngas, and then methanol. The methanol is dehydrated to give dimethyl ether (DME).

Dimethyl ether (DME) is a substitute for propane and can be used as fuel in households and industry. DME is also a fuel in diesel engines, petrol engines (30 percent DME / 70 percent LPG) and gas turbines. For diesel engines, the advantage of DME is the high cetane number of 55 (greater energy density), compared to that of diesel fuel from petroleum, which is 40 to x53. Only moderate modifications are needed to convert a diesel engine to burn DME.

The advantages of gas to methanol to liquids technology is that the products can be substituted for gasoline and diesel imports. In addition, the capital requirements are less than large-scale LNG or FT-GTL technology, as offered by Shell and Sasol. The capital requirements are incremental to those of a methanol plant (section 3.2).

3.4.3. Small scale gas to liquids technology

Several companies are developing small-scale gas to liquids technology including Velocys, Compact gas to liquids (GTL) and Greyrock Energy.

- Velocys has built demonstration plants in different regions of the world, including Austria, Australia and Brazil. Velocys does not produce finished products. The produced diesel requires blending with petroleum-derived diesel in order to be used as transportation fuel.
- CompactGTL has a demonstration plant in Brazil, and has announced plans for a commercial gas to liquids project in Kazakhstan. Like Velocys, CompactGTL technology does not produce finished products. Its diesel product requires blending with petroleum derived-diesel in order to be used as transportation fuel.
- Greyrock Energy, has developed a direct-to-diesel gas to liquids technology which does not require blending after Fischer Tropsch synthesis. Greyrock Energy's process has been proven at its demonstration plant in Ohio. Additionally, the company recently announced plans to construct a commercial gas to liquids plant in Houston, Texas.

In comparison to large-scale gas to liquids, small-scale gas to liquids projects offer:

- Lower capital investment: instead of the approximate $20 billion estimated capital cost for a mega-scale plant, a 2,500 barrels per day (bpd) smaller scale GTL plant would cost around USD250 million (or roughly USD100,000 for every bpd of installed capacity).
- Lower risk of cost overruns and delays, and easier to permit, supply and operate.
- Faster to build: smaller scale gas to liquids plants can create high value product within as little as two years after final investment decision, thereby reaping the benefits of the shale gas boom and price arbitrage faster and for a longer period of time.
- Deployment on smaller fields, at more locations, by a wider range of developers – alleviating the challenge of securing massive quantities of gas on long term contracts.
- Modular construction: can be deployed at remote locations and/or integrated with existing facilities, improving plant economics.

3.4.4. Industry analysis

Industry rivalry and barriers to entry: As a processing plant, gas to liquids production benefits from economies of scale, with a doubling of production capacity resulting in only an 80 percent increase in capital cost. As with other capital-intensive processing plants, capital costs, directly and indirectly, comprise over 50 percent of the lifecycle costs of a methanol plant. Other fixed costs comprise 20 percent, and marginal variable production costs at 30 percent.[39] Like other large-scale capital-intensive gas value chain processing plants, the technology and profit margins require full production to ensure viability. Gas to liquids will compete with more traditional petroleum based transportation fuels. Gas to liquids producers have the same production constraints of other process industries and have some ability to lower prices to maintain production levels. Since most African countries import transportation fuel priced in US dollars, domestic production using domestic natural gas a feedstock can have a significant cost advantage.

The fact that there are only three countries with commercial gas to liquids plants suggests some barriers to entry exist. South Africa pioneered in gas to liquids because

39 *Based on economic models used in this report.*

of its geopolitical isolation during the apartheid years. Malaysia and Qatar developed gas to liquids plants because large reserves of stranded gas were available at low cost. This suggests that apart from geopolitical reasons, that a prerequisite for conventional scale gas to liquids is availability of large reserves with low opportunity cost.

Small-scale gas to liquids projects, along with developing small-scale gas to liquids technology, are currently being developed to address the problems of large capital investments, large gas pools, long schedules and complex business arrangements. As these technologies become commercialised, they should make gas to liquids more accessible and more attractive to many African countries with gas resources.

Threat of substitutes: Gas to liquids products are substitutes for traditional petroleum based fuels. Gas to liquids products are easily blended into the gasoline and diesel pools and are readily marketable. The current low oil price environment makes it difficult for gas to liquids to compete with traditional petroleum products, at least for the short-term.

Buyer power: Competitively priced gas to liquids products can be readily blended into the local gasoline and diesel pools and will result in lower imports into countries producing gas to liquids.

Supplier power: The technology is available from a number of suppliers[40] and there are no significant technology barriers.

GTL plants would utilise existing distribution infrastructure to get their product to market, including roads, and railways. As with any large processing facility, the availability of contractors and supporting trades is required (millwrights, welders, electricians and general construction contractors). In addition to its own internal maintenance department, more workers will be required to support annual plant turnarounds.

Modern gas to liquids plants are highly automated, limiting the need for a large labour force. Operating plants will require well paid skilled trades persons, including steam engineers, millwrights, electricians, process engineers and plant equipment operators. Ideally these skills can be drawn from the local labour pool or be trained up from the local market.

3.5. Natural gas distribution

The viability and attractiveness of low pressure, high pressure, compressed and liquified natural gas distribution networks are a function of:

- Size of resource pool
- Size of market
- Distance to market
- Price mechanism for determining wholesale gas price
- Technology used to deliver gas to market

The relationships between resource pool size, distance to market and the technology used to deliver the gas to market is summarised below. Countries with temperate

40 See appendix for provider listing.

climates typically have well developed gas distribution systems. They provide natural gas to most urban households in the country, and often to rural areas as well. This is because the most important demand for natural gas in the residential, commercial and much of the industrial sectors is for space heating. Space heating is a very seasonal demand, and only exists in countries that exerience a distinctly colder winter season. In North America, the need for space heating is combined with a large natural gas resource that can support large diameter high pressure transmission pipelines that span the entire continent.

In Africa, relatively short high pressure pipelines are built to support large industrial users and gas-fired power plants in the domestic market. Industries that use significant amounts of natural gas for heating processes include metal processing (steel, alumium), pertoleum processing, petrochemcial processing, drying (lumber, pulp and paper, ceramics, cement), and cooking / sterilisation (food processing). Access to reliable, inexpensive heating fuels are a key economic advantage for many industires. Low pressure pipelines may also be used to serve local markets, which also have access to relatively small pools of natural gas. There is no need for space heating in African countries, and gas distribution systems serving households would not likely be viable if the only household uses for natural gas are cooking and water heating. Anchoring a distribution network with key industrial users can reduce the system costs and possibly make some residential and commercial distribution viable.

41 *(Clean Cities, 2014)*

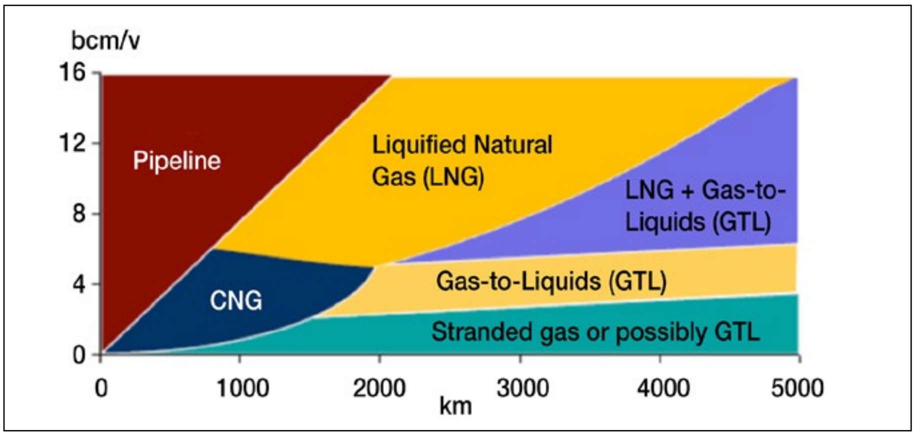
Compressed natural gas (CNG) can be used in lieu of a gas pipeline or distribution system, typically when the market is relatively small and distances to market are relatively short. Some countries have also had success in using compressed natural gas as a transportation fuel.[41] Compresses natural gas for vehicles is especially popular in countries with abundant natural gas, resulting in high concentrations of compressed natural gas vehicles in countries like Argentina, Brazil, Bangladesh and Iran. It requires compressed natural gas refueling stations, so probably needs at least a limited natural gas distribution system to serve these refueling stations. CNG vehicles can be retrofitted, or provided by an original equipment manufacturer. However, these vehicles will be more expensive than conventional gasoline engine vehicles. Compressed natural gas must therefore be priced lower than gasoline to be economically attractive, which would probably require a government pricing policy. Urban centres in some countries with high pollution from automobiles have mandated CNG-fueled taxis and buses with exclusive access to the urban centre areas, because of their lower emissions. The distribution system to serve compressed natural gas refueling stations can also serve other major commercial and industrial consumers who would find access to natural gas attractive.

Small-scale liquefied natural gas facilities are also being developed to supply local markets, with liquefied natural gas typically being transported by truck. Electricity generation is often the market for liquefied natural gas transported by truck. The discussion in section 2.5 above regarding natural gas transportation economics and its implications for natural gas use is relevant, and is also illustrated in the figure below.

3.5.1. Industry analysis

Industry rivalry and barriers to entry: Natural gas distribution can take several forms: low pressure gas pipelines, compressed natural gas and liquefied natural gas. The latter two are container-based, as the natural gas is compressed or liquefied into pressure vessels and transported as a commercial product either in specialized trailers or tanker cars and ships or in individual pressurised containers similar to propane tanks. This mobility allows for high levels of market competition and fairly widespread market access. For low pressure distribution networks, the ownership and operation tends to be that of a utility and state-sanctioned monopoly.

Figure 12:
Gas Transmission Volume and Distance Relationship



Source: International Gas Union[42]

42 (International Gas Union, 2016)

Threat of substitutes: Natural gas distribution primarily provides a heating source (space heating, water, cooking) and can compete with electricity, other fossil fuels or biofuels such as wood. For some uses, it may also compete with solar energy.

Buyer power: Most gas distribution systems operate as regulated utilities, where natural gas is purchased directly by consumers who are "price-takers". Depending on the regulatory regime, prices are either set by an agency or by bidding by suppliers, and consumer prices may vary with the spot market, or may be fixed for a contractual period.

Compressed natural gas requires minimal investment from buyers whose ability to switch Compressed natural gas suppliers is relatively easy. Switching from compressed natural gas to diesel or electricity is more difficult. Liquefied natural gas requires material capital investment from users. This will result in longer contract timeframes and more commitment between vendor and customer.

Supplier power: The technology for low pressure gas destruction is well established and of fairly low technical complexity. Typically, the systems may have trunk lines that are steel, but laterals, loops and connections tend to be high density polyethylene (HDPE) tubulars.

Small-scale LNG facilities are also being developed to supply local markets, with LNG typically being transported by truck.[43] The technology for small-scale LNG is emerging with limited vendors. However competition from other fuels for heating makes the market competitive.

The natural gas feedstock for gas utility distribution systems is typically secured through long-term contracts with producers.

To be viable, gas distribution systems require regulatory support from governments in the form of monopoly franchise rights. In return for these rights, the utility provider's rates and prices are dictated by regulation, limiting price flexibility but ensuring reasonable economic returns on employed assets in the 5-10 percent range. Typically, the right-of-way for this infrastructure is secured or provided by government agencies, and ownership can be both public and private. The system will need supporting trades professionals and contractors.

3.5.2. Gas distribution economics

The economics of gas distribution networks is highly variable and geographically dependent. The key drivers of system viability and profitability are the number of connections, demand levels of connections (higher is more profitable), geography (higher density of connections is better), right-of-way access cost (lower is better), line security from damage and theft. Generally large scale gas distribution systems in African will not be viable unless anchored by large industrial or commercial demand, for example a cement plant. These anchor consumers would allow for expansion to nearby customers at more viable marginal costs.

3.6. LNG exports

Natural gas is a useful fossil fuel, but unlike coal, it is not uniformly dispersed throughout the world. Natural gas deposits are not always near the demand centres.

43 An example of a small LNG facility is the Fortis LNG plant in British Columbia, Canada. Fortis supplies LNG by truck from Vancouver to serve full gas distribution systems to small communities in remote regions in Canada's northwest territories several thousand km away. See https://www.fortisbc.com/NaturalGas/Business/Pages/Liquefied-Natural-Gas.aspx.

This creates the opportunity for global trade in natural gas. Given the volume and energy density of natural gas, it is often liquefied to increase the density and thereby improve the logistics and economics of transportation.

The top liquefied natural gas exportersare typically countries with large natural gas resources and small domestic markets. Qatar is by far the largest exporter.Middle Eastern countries accounted for 37.3 percent of global LNG exports in 2015. Nigeria, Algeria and Equatorial Guinea are the largest African LNG exporting countries, with Africa accounting for 14.4 percent of global LNG exports in 2015.

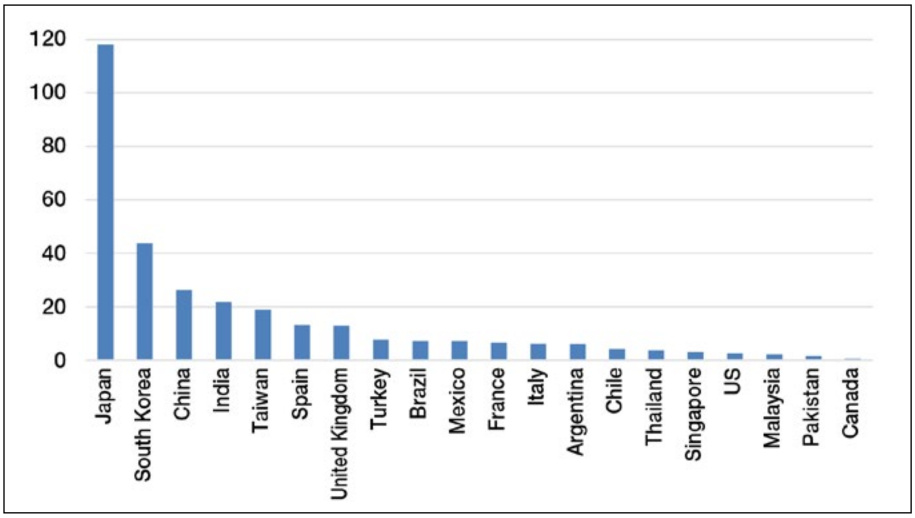
Table 5:
Top LNG Exporting Countries, 2015

	Annual Exports (bcm)	Share %
Qatar	106.4	31.4%
Australia	39.8	11.8%
Malaysia	34.2	10.1%
Nigeria	27.5	8.1%
Indonesia	21.9	6.5%
Trinidad & Tobago	17.0	5.0%
Algeria	16.2	4.8%
Russian Federation	14.5	4.3%
Oman	10.2	3.0%
Papua New Guinea	9.7	2.9%
Brunei	8.7	2.6%
United Arab Emirates	7.6	2.3%
Norway	6.0	1.8%
Peru	5.0	1.5%
Equatorial Guinea	5.0	1.5%

Source: 2016 BP Statistical Review of World Energy

The top importing nations are shown below. Japan is by far the largest LNG importing country, and together with South Korea and China, accounts for over half of current global LNG imports. While some of these nations have negligible natural gas reserves, like Japan and South Korea, others have substantial reserves but import some natural gas due to geographic disparities.

Figure 13:
2015 Top Importing Countries of LNG



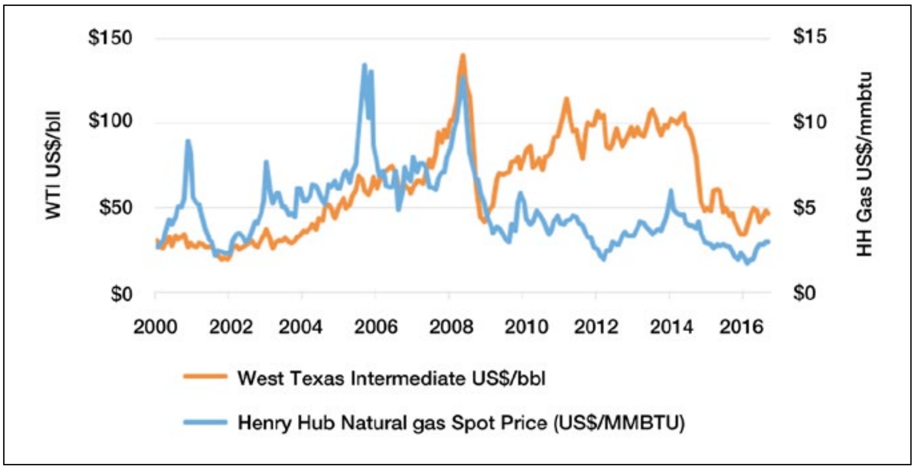
Source: 2016 BP Statistical Review of World Energy

The majority of Asian LNG import contracts are long-term with oil-indexed pricing. A large tranche of new projects either in development or about to come on line has put pressure on traditional oil-indexed pricing models. The key to this change is the transition of the United States from being an LNG importer to being an LNG exporter. The US gas market has experienced a supply glut in recent years, causing gas prices to plummet. To alleviate this excess supply of gas, LNG export facilities being constructed in the US are selling LNG at currently very low Henry Hub prices[44] plus costs of liquefaction and transportation.

Oil and natural gas are energy commodities whose heating value in the US is measured in British Thermal Units (btu).[45] Oil is priced with the reference price of West Texas Intermediate (WTI) in US$/bbl. One barrel of oil equivalent is 5.8×10^6 btu.[46] A cubic foot of natural gas has a heating value 1000 btu and is priced in $US/MCF (thousand cubic feet).[47] For energy-equivalent consumer pricing between oil and gas, oil per barrel should be 5.8 times the price of gas per thousand cubic feet. Since oil is easier to store and transport, it typically sells as a premium. Producer netback prices may differ significantly between oil and gas producers and oil and gas producing countries, because of much higher transportation costs for natural gas.

The figure below shows the long-term tracking of US natural gas prices in US$/MCF (a thousand cubic feet of natural gas) and oil prices US$/bbl. The gap from 2009 to 2014 is a result of shale gas developments in the United States.

Figure 14:
Natural Gas and Oil Prices



Source: NYMEX [48]

Globally, sellers and buyers have been pressured to adopt different pricing policies and secure more flexibility and shorter terms in the LNG contracts.

The International Energy Agency (IEA) clearly expects the traditional practise of indexing LNG import prices to oil prices in Japan to diminish, and for a convergence between US prices and gas import prices in Japan and Europe to occur. The consequence of this is important for potential LNG exporters in Africa, as they cannot expect to receive a netback from oil equivalent prices for LNG exports to Asia. Globally, LNG pricing expectations will need to be tempered.

44 *Henry Hub, in southern Louisiana near the US Gulf Coast, is the pricing point for gas contracts trading on the New York Mercantile Exchange (NYMEX). Pricing at Henry Hub is based on gas-on-gas competition. Because of its proximity to the huge petrochemical cluster on the US Gulf Coast, Henry Hub prices are very close to being a wholesale price for natural gas in that market.*

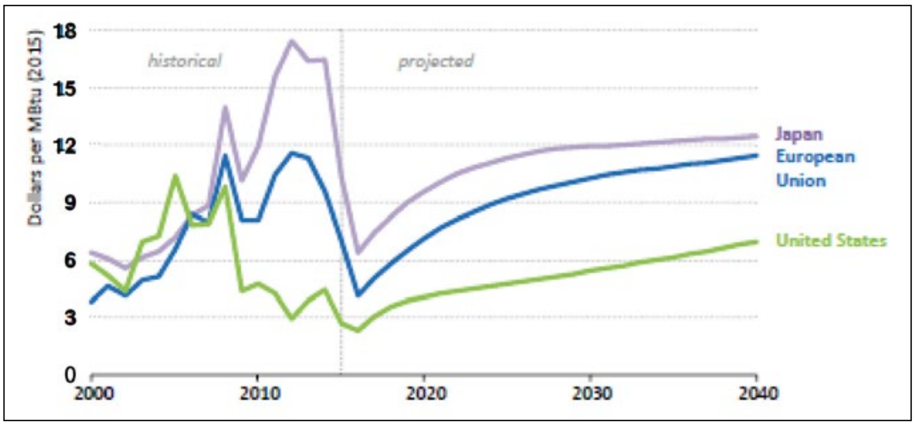
45 *British Thermal Unit. The USA is the only major country that still uses Imperial measurements. Because of its importance in world trade, discussions of oil and gas prices and volumes often reference these units.*

46 *(US Internal Revenue Service, 1998).*

47 *(National Energy Board of Canada, 2016)*

48 *(New York Merchantile Exchange (NYMEX) CME Group, 2016)*

Figure 15:
Regional Natural Gas Prices



Source: IEA World Energy Outlook 2016, New Policies Scenario[49]

Tempered price expectation notwithstanding, the IEA still expects Sub-Saharan gas exports to triple by 2040, and those exports will all be LNG. North African gas exports, partly by pipeline and partly as LNG, are expected to remain relatively flat.

Table 6:
Forecast of LNG Exports by Region

Net exporting regions	Net exports (bcm/year)		
	2014	2025	2040
Russia	178	235	307
Caspian	79	108	168
Middle East	117	134	145
Australia	25	100	136
North America	1	58	127
Sub-Saharan Africa	29	47	79
North Africa	53	64	54
South America	8	7	18

Source: IEA World Energy Outlook 2016, New Policies Scenario

3.6.1. Industry analysis

The gas-based pricing methods being adopted for US LNG exports are undermining the oil-based pricing contracts traditionally used in Asia. This structural change in LNG pricing will have global implications, including tempering the price expectations of African LNG exporters.

Industry rivalry and barriers to entry: The barriers to entry in the LNG export market are massive. While there may be thousands of gas processing plants, the number of LNG export terminals is relatively small, with under 50 worldwide. Given the magnitude of natural gas needed and the capital investment required, the required time to negotiate and build a LNG export plant can easily be in excess of 10 years. Over half of this duration can be taken up in negotiating terms, sales contracts and arranging financing. Given the stakes involved, many of the key actors are risk adverse, and country risk is a big factor. Exporting nations are in intense rivalry to secure long-term contracts and build export facilities.

Threat of substitutes: As discussed in previous sections, there are limited options for the transportation of natural gas over long distances. LNG is the main option for distances over 5,000 kms or for overseas transportation.

49 (International Energy Agency, 2016)

Buyer power: The primary driver for the export of LNG is to provide natural gas to regions that are bereft of the resource. This would be Southeast Asia, India, China, Taiwan, South Korea and Japan. The objective of LNG exporters is to take advantage of these regional shortages of gas. The importing nations enter into long-term contracts with suppliers, matching their receiving ports to the LNG export ports. The fact that East Asian countries were paying crude oil price equivalency for LNG imports implied limited buyer power at the time these imports were contracted. Improved technologies for liquefaction and transportation of LNG has increased the number of potential suppliers of LNG in recent years, with greater competition among sellers and increased buyer power.

Supplier power: The technology for liquefaction of natural gas is non-proprietary and can be assembled from numerous global providers. The number of potential companies that can succeed in developing an LNG project will be severely limited by the magnitude of capital investment, and the time required to negotiate contracts, obtain regulatory approvals and arrange financing.

The viability of world-class LNG plants requires supporting infrastructure to get the product to market, especially pipelines and shipping ports. In markets without transparent gas-on-gas competition (section 2.6) the natural gas producers will likely be closely involved with the LNG plant, port facility and possibly the gas buyer. The producers will often be bound by long term production contracts with the LNG facility, port and buyer.

As with any large processing facility, access to contractors and supporting trades professionals is necessary (millwrights, welders, electricians and general construction contractors). Again, each plant will have its own internal maintenance department for routine and breakdown repairs. They will be augmented to support annual plant turnarounds where major overhauls take place and require hundreds of workers on the site, potentially costing tens of millions of dollars.

Capital-intensive modern LNG plants are highly automated, with a limited need for significant labor. The labor required during operations will generally be well paid skilled trades professionals including steam engineers, mill wrights, electricians, process engineers and plant equipment operators. Ideally these skills are drawn from the local labor pool or can be trained up from the local market. In addition to these skilled trades professionals, each plant will require lower skilled labor for material handling, shipping and receiving. In North America, these positions would require high school level numeracy and literacy as well as equipment-specific training (fork lifts, shunting rail engines or trailers, tugboat operators).

3.6.2. LNG economics

The nature of a world-scale LNG plant is uniquely based on tide-water access, accessibility to large gas field, shipper/buyer requirements, host nation regulatory framework and geography. Given their tens of billions of dollar costs, LNG plants can create their own micro-economic climate and cost-escalation boom. As there are no "typical" plant economics, each must be considered on its own. Cost ranges are shown below.

Table 7:
LNG Plant Capital Cost Factors

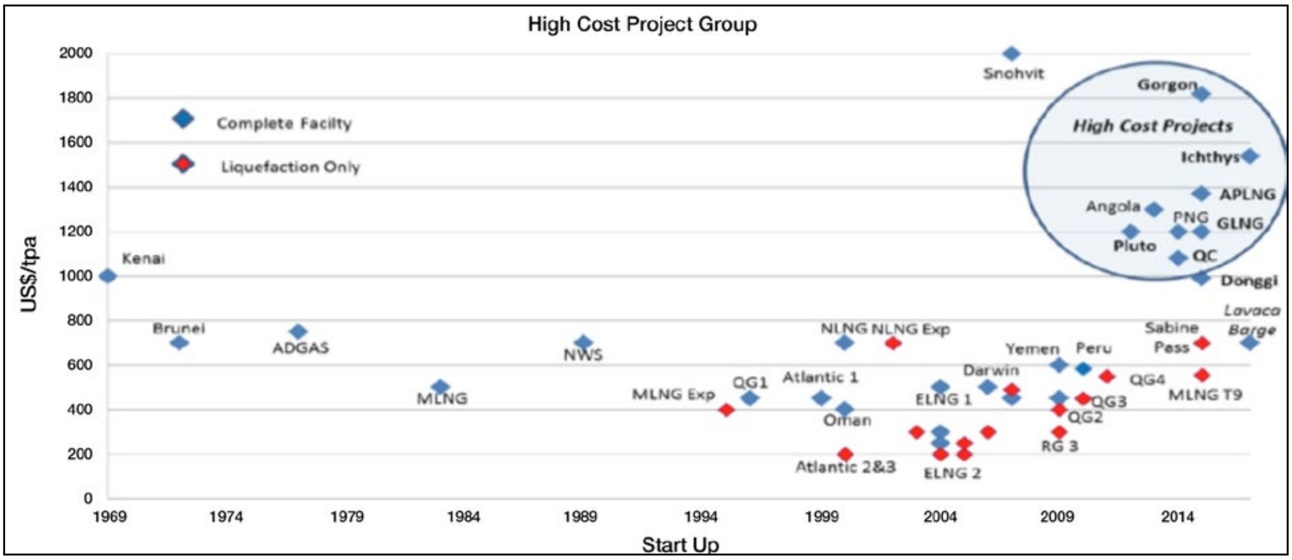
	Low Range US$ / TPA	High Range US$/ TPA
Complete Facility	$1000 - $1200	$1400-$1800
Liquefaction Only	$600-800	$1000-1200

Source: Songhurst 2014[50]

50 (Songhurst, 2014)

Figure 16:
Capital Cost of LNG Projects

Historic capital costs of selected LNG plants are shown below.



Source: Songhurst 2014[51]

3.7. Pipeline export

The traditional method of shipping natural gas is by high pressure steel pipeline. Buried at least one metre under the ground, most export pipelines are destined to adjacent terrestrial regions or countries. However, there are some cross substantial bodies of water. Gas pipelines start at a compressor station that increases the pressure of the natural gas. The gas then flows from the high-pressure point at the compressor station to lower pressure locations. The initial requirements are filling the pipeline with gas (i.e, line-fill) and then maintaining the pressure in the pipeline, which may require multiple compression stations located every 75 to 150 kilometres throughout the pipeline.[52] The volume of gas that can be transported in a pipeline depends on pipeline diameter and operating pressure. Given the nature of a gas flowing from high pressure to low pressure, in transmission pipeline networks, natural gas can enter at any point and effectively shipped in both directions simultaneously, based on need.

West African Gas Pipeline – the case for integrated regional infrastructure projects

The West African Gas Pipeline (WAGP) project was initiated in September 1995 but started commercial production from March 2011. It links 678 kilometres of onshore and offshore pipelines to transport gas from Nigeria to power generation plants in Benin, Togo, and Ghana, and associated processing and receiving facilities. The pipeline connects to power plants in Ghana, Togo, and Benin to large gas resources in Nigeria to generate electricity.

WAGP transports purified natural gas free of heavy hydrocarbons, liquids and water, ideally suited as fuel for power plants and industrial applications. About 85 percent of the gas is for power generation and the remaining is used for industrial applications. The West African Gas Pipeline Company limited (WAPCo), a limited liability company, was formed to own and operate the West African Gas Pipeline. To boost the operational capacity of WAPCo, the West African Gas Pipeline

51 (Songhurst, 2014)

52 (Energy Information Administration, 2007)

Authority, based in Abuja, was set up as the regulatory body for WAPCo through a treaty signed by the heads of states of Benin, Ghana, Togo and Nigeria on September 5, 1995.

The gas supply from Nigeria is received by its foundation customers: Volta River Authority's Takoradi Thermal Power Plant in Ghana, Communaute Electrique du Benin (CEB) (Benin Electricity Company) and Togo. The WAGP project makes a stronger case for integrated infrastructure development across Africa. It remains one of the largest public-private partnership projects in Africa. The project has yielded positive outcomes to the economies of Ghana, Benin and Togo in terms of cost and expansion of electricity generation. During 2011, when the supply of gas continued without interruption, the wholesale generation cost in Ghana decreased by 14 percent (in line with the target of 10 to20 percent) and in Benin and Togo by 12 percent (compared to a target of 40 percent).

The World Bank (2014) argues that the provision of natural gas for power generation has enabled Ghana, Benin and Togo to produce electricity at competitive costs compared to liquid fuels, and limit the tariff increases which would have otherwise been necessary. In Ghana, the growth in electricity consumption is around 7.2 percent per annum, while commercial sector (small businesses, shops and small-scale production) growth has been 7.93 percent. The provision of electricity to customers in Ghana has been a contributing factor to help reduce poverty by 5 percentage points from 29 percent in 2005 to about 24 percent in 2012 (World Bank, 2014).

But has the West Africa Gas Pipeline project mattered for regional political and economic integration? The project has fostered economic and political integration between the countries by providing a common platform to resolve energy crises that all the countries face. The World Bank predicted (2014) that West Africa Gas Pipeline has the potential to further foster regional economic and political integration through the development of the West Africa energy market. In May 2017, the Committee of Ministers of the West African Gas Pipeline met in Accra, Ghana to discuss operational and financial issues that are crucial for WAPCo to operate efficiently.

The key challenge confronting project development objectives include power sector reforms in Nigeria. The country has the ambition to increase its own thermal power generation capacity. Local needs will have to be satisfied, before contemplating external markets.

3.7.1. Industry analysis

Industry rivalry and barriers to entry: The barriers to entry into the pipeline gas export market are significant, and similar to LNG projects, except at a smaller scale. The investment is driven by supply and demand imbalances between two regions, with the pipeline company serving as an intermediary between these markets. The pipeline company will arrange contracts with producers and consumers, respectively, and then construct the pipeline to serve them. Given the magnitude of the gas resource and the capital investment required, as well as the importance to the national economy, the time to negotiate and build a gas export pipeline can be between three to seven years. Half of this duration could be spent negotiating terms, pricing, arranging financing, route section and evaluation.

Threat of substitutes: As discussed in previous sections, there are limited options for the transportation of natural gas over long distances. The main option is LNG for longer routes with access to tidewater, or small-scale LNG transported by truck, where volumes cannot support a pipeline.

Buyer power: Export pipelines tend to be international, or often continental. All parties typically need to see economic benefits from completing the pipeline in order for it to proceed. Pipelines are normally regulated utilities, to prevent monopoly pricing, and thereby protect buyers. The regulatory structure will also normally prevent the pipeline from being owned by any individual producer or consumer, and require open access to the pipeline to all potential shippers. These measures prevent any discriminatory treatment of shippers, in terms of transportation rates or access.

Supplier power: The technology for high-pressure natural gas transmission lines is non-proprietary and can be assembled from numerous global providers. The steel pipe is sourced globally and construction equipment is geographically mobile and relatively common. Construction of pipelines is analogous to a production factory several kilometres long that moves across the countryside. The route is cleared, a ditch is dug, the pipe is "strung" next to the ditch (40'-80' sections are laid out, welded and coated for corrosion resistance), lowered into the ditch, and back filled. In environmentally sensitive areas like river crossings and wetlands, the ditching approach may not be permitted. Here the pipeline may be horizontally and directionally drilled, for a distance of up to 3 to 5 kilometres, by specialised contractors and equipment. There are many pipeline contractors, and they bid competitively on all work. Construction workers will be mobilized and hosted on or near the route.

One possible limiting factor with gas pipelines is their power requirements. Large gas transmission lines require significant power (several 5000 hp motors at each site are common[53]) to compress the natural gas in the high-pressure pipeline. It is not uncommon for new power transmission lines to be built in remote areas to power compressor stations. The lead time for these power lines can exceed that of the pipeline. Alternatively, gas can be drawn off the pipeline and used as fuel for onsite power generation to alleviate this possible constraint.

Operating pipelines requires very few operators and a small number of plant workers at compression stations along the route. Typical workers include various well paid skilled trades professionals, including millwrights, welders, electricians, and network operators. Ideally, these skills are drawn from the local labour pool or can be trained up from within the local market. Pipeline systems typically have very sophisticated computer controlled systems (supervisory control and data acquisition - SCADA) to ensure safe operations. They require trained operators at a central control center. While oil pipelines can have spills, high-pressure gas pipelines can explode.[54] Pipelines have come under increasing public scrutiny over their environmental impact and safety.

53 *(Energy Information Administration, 2007)*

54 *Like the 2010 San Bruno explosion, see (Wikipedia, 2016).*

3.7.2. Pipeline economics

Each gas pipeline is unique, based on shipper orbuyer requirements, regulatory frameworks (possibly transnational) and geographical terrain. Pipelines cost around USD100,000 per diameter inch mile,[55] with a typical gas export pipeline being at least 36 iches in diameter with a cost of USD5.5 million per kilometre, including compressor stations. Typically, one-third of this cost is steel pipe and equipment, one-third labor and one-third engineering, regulatory, environmental, land access and other soft costs. Most pipelines have a useful life of 50 years, although with proper maintenance and replacement of corroded and otherwise damaged sections, they last indefinitely. The period from conception to commissioning for service usually takes no less than three years, with 2/3 being design, routing and materials lead time (compressor stations motor sets typically require one year to acquire). The length of the pipeline typically does necessarily add construction duration. The entire route is broken into segments, each can be built independently and even by separate contractors.

55 *(Compass International, 2016)*

4. Potential economic development impacts of natural gas value chain nodes in African countries

This section addresses a number of questions regarding how the natural gas value chain path can help African countries diversify their production and export structures.

The full natural gas value chain includes the upstream component (i.e, exploration and production). Realisation of any portion of the gas value chain requires the presence of natural gas resources in that country. While the focus of the study is on the downstream nodes of the gas value chain, access to the upstream component is a prerequisite for any portion of the remainder of the gas value chain to be realised. Once that prerequisite is established, the greatest potential for economic benefits from the gas resource comes from the downstream linkages portion of the gas value chain, as discussed extensively in the preceding sections.

Lateral linkages may occur where capacity and expertise acquired in the gas value chain, or products produced in the gas value chain, are used by another sector of the economy. For example, developing capacity and expertise in areas such as process control, trades, construction equipment, and materials handling may also benefit sectors outside the gas value chain, thereby adding value in other sectors of the economy. Use of gas for electricity generation can lead to significant lateral linkages, as access to reliable and economic electricity sources can foster many kinds of economic activity and economic development. Use of gas for producing urea fertilisers can lead to significant positive lateral linkages with the agricultural sector, as fertiliser use can lead to significant productivity increases in agricultural production.

Lateral linkages generally only emerge with a very successful and fairly well developed natural gas value chain. A number of examples of potential lateral linkages will be provided in the discussion below.

- **Entry barriers and key successful factors for each value chain path**

Gas distribution

The simplest gas value chain development is perhaps direct consumption as a fuel, through gas distribution by pipeline. The feasibility of low pressure gas distribution will be severely limited in most African countries by the small volumes of gas most consumers will require. The largest barrier to gas distribution in Africa is simply economic viability, because of limited demand for distributed natural gas in African countries.

In countries with extensive gas distribution networks, the largest number of gas consumers are in the residential and commercial sectors. These consumers use the gas for space heating. The climate of Africa typically precludes this as an investment driver. Other principal uses in those sectors are water heating and cooking, which may be potential uses in Africa. Competing with gas for water heating is solar thermal, which is more cost-effective in most parts of Africa. As in most parts of the world, cooking in Africa is generally done over an open flame (i.e, burning wood, charcoal, LPGs) and can also be accomplished by electricity.[56] The volumes required for these water heating and cooking uses would likely be insufficient to warrant investments in a low-pressure gas distribution system, and would be better suited to compressed (bottled) natural gas.

56 Alberta Canada, where the study author resides, has 95 percent of residences served by natural gas, perhaps the highest gas distribution saturation rate in the world. Yet only 10 percent of residences use natural gas for cooking. The most common energy source for cooking, by far, is electricity.

Without the large numbers of consumers to offset capital costs, gas distribution is likely to be viable only for industrial users who require large volumes of gas. It would be especially viable where there is a cluster of such industrial users in a major industrial park, for example. In these cases, the "distribution" would be more similar to low volume gas transmission in high pressure steel gas lines.

Electricity generation

The gas value chain node that perhaps has the fewest entry barriers is electricity generation. It uses technology that is widely available, and is currently widely used in many parts of Africa. The technologies and major components are readily available throughout the world, and are linearly scalable in terms of plant capacity required. While there are skilled labour requirements in constructing and operating these plants, these are skills that are available or can be acquired in most African countries.

Whether the electricity generation plants should be located near the gas field or near the consuming centres (assuming they are different locations, which is generally the case) will depend on the relative economics of transporting gas (eg, pipeline) versus transporting electricity by high voltage power transmission lines.

Other gas value chain nodes

The other downstream gas value chain nodes will face a number of entry barriers, discussed more fully in the preceding industry analysis sections. These barriers will include technology, high financial requirements, skilled labour requirements, as well as general economic and regulatory barriers.

- ***Types of economic benefits African countries can derive from alternative gas value chain paths***

The most obvious economic benefits will include:

- Royalties and profit sharing opportunities for governments under production sharing contracts associated with the upstream component of the gas value chain.
- Corporate income tax revenues for governments from corporate profits earned at all stages of the value chain.
- Employment opportunities at all stages of the value chain, which will mostly be high quality jobs that utilise skilled labor, and pay salaries above the national averages; these employees will contribute indirectly by paying taxes on their incomes and expenditures, and by contributing to the local economy by higher than average consumer spending levels and purchasing power.
- Forward, backward and lateral linkages with other sectors of the economy, resulting in economic multiplier effects and strengthening of the national economy.

Other benefits may include:

- Reduced energy poverty – The International Energy Agency's (IEA) Africa Energy Outlook – a Special Report in 2014 – described sub-Saharan Africa as the epicentre of the global challenge to overcome energy poverty. It observed: "More than 620 million people live without access to electricity and nearly 730 million people use hazardous, inefficient forms of cooking, a reliance which affects women and children disproportionately."[57]

- Reliable electricity – Besides addressing and relieving energy poverty, electricity provides lateral linkages throughout the economy, making other types of economic activities viable and attractive. While electricity from renewables such as wind and solar sources are attractive for a number of reasons, they are not typically 100 percent available-on-demand, and a reliable energy grid requires back-up sources of electricity. With its potential short cycle times, natural gas fired electricity is likely the most efficient form of back-up, in addition to providing base-load electricity.
- Fertiliser production – Fertiliser manufacturing is an attractive node of the gas value chain (via urea manufacturing) for most African countries, and fertilisers can be used domestically as well as exported. To the extent they are used domestically, they also provide lateral linkages by raising productivity and efficiency in the domestic agricultural industry.
- Export earnings – Almost all gas value chain nodes will be partly, often primarily, producing products for export, or alternatively reducing imports. Not only do these nodes generate employment and other direct benefits as components of the economic base of the country, exports also earn foreign exchange, which can be used to obtain needed imports from other countries. The ability to import goods which are not available domestically will increase the standard of living of the exporting country.

- ***Type of public/private investments required for the value chain paths to be competitive***

Geological information systems – For upstream gas development - the base component of the gas value chain and the prerequisite for any further portions of the value chain to be realised - geological information systems and geological maps are generally required. These may often be developed by direct investment in geological research by government, and especially during the very early stages of private exploration and development this form of public investment may be necessary. As private investment in exploration for gas occurs, the first step will always be obtaining geological information. Exploration licences can require this information to be shared with the government, and it can be made available to other prospective explorers who will contribute further information through their exploration activities. Gradually, the data base will grow and become more valuable, contributing to more efficient investment decisions and greater likelihood of exploration success and lessening the need for public investments for this purpose.

Transportation infrastructure – Once gas has been discovered and development is underway or about to proceed, an area where government can often appropriately and effectively invest is in transportation infrastructure. Pipelines are low risk investments, appropriate to governments, and getting the gas to market is a prerequisite for gas development. Good highways, railroads and ports are also a general necessity for gas value chain developments, and these are generally public investments.

Educational institutions – Depending on what kind of educational institutions currently exist in the country, and on the skills required for specific gas value chain development

57 *(International Energy Agency, 2014)*

to occur, there is a high likelihood that new educational institutions and new programs at existing institutions will be required. These educational institutions would not only need to provide craftsmanship training, but operations and management education. Stronger educational institutions are a valuable asset in any Africa country.

Regulatory institutions – Most African countries do not currently have sufficiently strong regulatory frameworks and regulatory institutions. While there are many good models that can be adopted, a very deliberate initiative will be required to adapt and develop these frameworks and institutions to the specific country. Without a clear, robust and stable regulatory structure, international companies will be unwilling to invest the funds required to create downstream plants in the natural gas value chain. Most African countries need to focus on investing in institutional as well as physical infrastructure.

- ***Opportunities for African domestic innovative capabilities in alternative natural gas value chain paths***

Generally, all nodes of the gas value chain are technologically complex, and successful implementation requires higher skills though their entire life cycles than many other developmental activities. Many African economies are currently not able to offer suitable employment opportunities to their post-secondary graduates that utilize the skills and knowledge acquired during their education. The gas value chain will provide opportunities for these currently under-employed graduates, leading to improved economic livelihoods as well as career satisfaction and fulfilment.

Gas value chain development will also likely lead to training needs for more personnel to assume skilled and semi-skilled roles in the industry. This means expanding existing educational institutions, adding new programmes, hiring more academic staff and accommodating higher student enrolment. Stronger educational institutions in these countries will strengthen innovative capacities and create new opportunities for innovation, directly within the gas value chain nodes present in that country, and in many spin-off areas, which may or may not be directly related. Partnership with private enterprise in support of public education for skills and trades directly applicable to the energy sector is relatively common in the industrialised world.

Expansion of the gas value chain will also create business opportunities for local businesses and entrepreneurs. This may be facilitated and expedited, at least initially, by requiring gas value chain investors to provide opportunities to local businesses to provide goods and services. A stronger business community in these countries will serve as a catalyst for capitalising on more business opportunities, and further extend the forward and lateral linkages arising from the gas value chain itself.

- ***Main obstacles faced by African countries when trying to upgrade in the value chain for natural gas***

The OECD's African Economic Outlook 2014[58] focussed on global value chain opportunities, and how Africa might capitalise on these opportunities. The key identified strengths of African countries are their attractive natural resource endowments and

58 *(African Economic Outlook, 2016)*

their low labor costs. The key obstacles to participating and upgrading in global value chains identified by the OECD were:

- Inadequate infrastructure -- including access to transnational infrastructure (roads, ports, airports and railways connecting to foreign markets), access to and reliability of telecommunications and power supply, and internal transport infrastructure.
- Inhospitable business environments -- including regulatory certainty, ease of doing business (red tape, administrative hurdles), access to finance and corruption.
- Domestic response capacity constraints – including availability of local supply, domestic businesses' ability to meet international standards and certification requirements, integration between multinational enterprises and local businesses, innovation capacity and availability of adequately skilled labor.[59]

- ***Impact of private codes and standards, including those imposed by leading firms in the gas value chain***

Patent protected technologies could represent a potentially major barrier to implementation of some gas value chain nodes. However it is typical for the owners of the technology and intellectual property to be in the business of selling the technology and equipment, not directly owning and operating the equipment. Some technology vendors may form joint ventures with local partners to support increased sales of their technology. It is common in developed countries for vendors to license their technology, however some may be reluctant to license it in jurisdictions with weak intellectual property rights.

We do not believe private company operating standards are generally likely to present significant barriers. The most important standards in any country are those imposed by regulation, and they will always take precedence over the private standards of any company. If the private standards exceed the regulatory requirements, that should be beneficial. If they do not meet the regulatory standards, they will of course have to be revised accordingly.

59 Ibid, p.156ff.

5. Potential social and environmental impact of development of natural gas value chain paths in African countries

Many of these impacts and implications are discussed more fully in the preceding sections. This section summarises the key social and environmental impacts of the gas value chain.

5.1. Potential Social Impacts

- ***Potential employment, skills and the gender gap impacts of the natural gas value chain***

The labour requirements in the industries comprising the natural gas value chain generally require relatively few workers, due to the technical complexities of these industries. But those workers required are generally high-skilled workers. These are capital intensive industries. They have high technical content because of the need for precision in design, construction and operation in order to handle fluids at high pressure at many stages of the value chain. The need for qualified engineers is pervasive throughout, especially during the design phase. The construction activity requires skilled tradespersons, to ensure proper assembly of processing equipment that can withstand high operating pressures and ensure process safety. The operations phase generally involves a combination of engineers, technicians and tradespersons to ensure operating efficiency and safety.

The natural gas value chain comprises industries that must operate in the formal sector of the economy. The employees will be subject to the labor code and to the occupational health and safety regulations and standards of the respective countries in which the industries are located. Employees of large corporations, especially those from western countries, may also be subject to corporate standards for safety and social responsibility. Of course, corporate standards are only applicable to the extent they exceed the regulated requirements in the respective country.

As employment will be mostly skilled labour, these will be good jobs that can be expected to exceed the level of average incomes in most African countries. They will provide opportunities for educated Africans to apply and expand their skills. Highly skilled jobs contribute to the economy in a number of ways:

- strengthening local markets through their consumption of goods and services;
- paying taxes as members of the formal economy;
- providing role models to youth, students and aspiring professionals.

The UNDP's 2016 Africa Human Development Report states that "significant economic and workplace disparities between men and women continue to be the norm rather than the exception in many African countries."[60] More relevant to the gender opportunities afforded by gas value chain development in African countries, we see that sub-Saharan Africa's Gender Development Index (GDI) lags behind the global GDI, indicating that females in Africa are not as well positioned to take advantage of opportunities created. Gender inequalities in oil, gas and mining operations are generally attributed to gaps in education, discrimination in hiring processes and the traditional role of men as primary breadwinners.[61] These are issues that governments can address through appropriate policies, but some of these changes may take time to achieve, even with well-conceived and highly concerted policy initiatives.

60 *(United Nations Development Reports, 2016)*

61 *(African Economic Outlook, 2013)*

Re-balancing gender: expanding technical, vocational education and training (TVET) for beneficiation in Africa's oil and gas sector

Women play a catalytic role in the mining sector. In Africa alone, women constitute 40 to 50 percent of the artisanal mining workforce. But the same cannot be said for the oil and gas sector, where women make up less than 10 percent of the oil and gas industry workforce, and even lower representation in engineering and other technical roles. A PWC study in 2013 indicated that women occupy only 11 percent of seats on the board of directors of the world's 100 largest listed oil and gas companies.

Women's limited role in the oil and gas sector is more pronounced in Africa. In Ghana, between 2010 and 2015, 221 men received scholarships to study oil, gas and energy-related courses. This was in contrast to 49 women over the same period. Also, across boards of oil and gas sector institutions, only 12 women were appointed to leadership positions in downstream companies, compared with 165 males.

Women face social, cultural, economic and political barriers in their participation in the oil and gas sectors. They are part of the historically marginalised groups that are often the least engaged in shared value opportunities that can arise in the development of the value chain of the oil and gas sector. They also suffer from negative impacts that oil and gas projects bring to local communities, including loss of farmlands, pollution of water resources and the large dislocation of livelihood structures. Land is a key productive asset and a security, so legal or customary barriers to women's land ownership both hamper the growth of businesses at the community, and increase vulnerability to shocks (Scott et al. 2013).

The integration of gender equality into Africa's oil and gas sector is thus a pressing matter. The mainstreaming of women in the various nodes of the oil and gas value chain could yield economic gains. In 2007, women were directly involved at the negotiation table for revised compensation agreements on OK Tedi mine in Papua New Guinea. Through their involvement, the country secured an agreement giving women 10 percent of all compensation, 50 percent of all scholarships, cash payments into family bank accounts (to which many women are co-signatories), and mandated seats on the governing bodies implementing the agreement (including future reviews of the agreement) (World Bank 2012).

At the heart of the core problem behind lower representation of women in oil and gas jobs is inadequate education infrastructure and policy-level support for education and training. Educational infrastructure and general support meant to provide skills for the oil and gas job market has mostly been driven by oil and gas companies. In Kenya and Uganda, Tullow Oil has established a scholarship scheme that has enrolled a number of girls in postgraduate courses. In Uganda, eight out of the twenty beneficiaries for the 2012/2013 scholarship scheme were female.

Implicit or overt bias in the oil and gas industry workforce also sidelines women participation. Scott et al (2013) in their studies in Papua New Guinea and Peru found that there is a perception that the oil and gas sector presents a masculine work culture and potential sexual harassment issues would make the workplace more challenging and less welcoming to women. While education interventions by oil and gas companies are a good step, the piece-meal nature of these interventions disrupts structural transformation of the sector to better train in technical roles. African countries must initiate and implement local content policies that are gender-smart and consistent with company plans. These policies must set targets for gender equality, and provide business-development supports that are anchored in national development frameworks of countries. Local content policies should require local and international oil and gas companies to employ local-level workers and set a minimum quota of female hires.

Skilled labour jobs generally require some form of training following completion of secondary education, generally in a trade school, a technical institute or a university. Sub-Saharan African countries have very low post-secondary participation rates, with only 8 percent of tertiary school-age population enrolled in school. This compares to 32 percent globally and 71 percent in OECD countries.[62] Even with low levels of post-secondary education, which implies skill shortages, many graduates in African countries cannot find suitable employment in their country. Part of the strategy, and potential benefit of gas value chain development, must be to provide these employment opportunities.

Employment opportunities by themselves may not reduce the gender gap if females are under-represented in post-secondary education. More proactive strategies by governments and industry will be required. Some strategy suggestions from the World Bank for governments to pursue to address gender inequalities include the following:[63]

- Develop programmes to breakdown social and cultural stereotypes that discourage women from pursuing professions within the gas value chain (eg, by providing educational scholarships, mentoring and apprenticeship opportunities).
- Proactively support women and girls to study engineering, geology, and other topics to support their engagement in the gas value chain industries.
- Adopt targets or quotas to ensure that women are promoted to decision-making and leadership roles within government; reward companies that implement similar career advancements for women.
- Include gender impact assessments in the regulatory process to complement social and environmental impact assessment, and social impact management plans. This will identify vulnerable groups in the community and complement gender issue strategies.

The World Bank also offers some strategy suggestions for oil and gas companies to pursue in developing countries to address gender inequalities. They include the following:

- Include both women and men when negotiating the terms of an operation in the community (e.g, these may include negotiating community agreements, land access, cultural heritage management and royalty sharing).
- Set targets and/or quota systems to promote women into decision-making and leadership roles; these should be accompanied by flexible working conditions, mentoring programs and safe working environments.
- Ensure the protection of women in the workplace, and in the community, by creating a ‘Zero Tolerance’ approach to sexual harassment and discrimination.

62 *(United Nations, 2015)*
63 *(World Bank Group, 2015)*

- Partner with local community organisations to increase awareness of sexual and gender based violence in the company and community.
- Create social programmes to challenge social and cultural biases that exclude women from pursuing and leading business opportunities related to the gas value chain.
- Provide more flexible and supportive procurement processes to engage women in small- to medium-sized enterprises.
- Foster women's involvement in a strong and diverse SME sector by encouraging or providing incentive to greater participation, building capacity and financing women's businesses.

- ***Potential for social and political conflict associated with exploitation of natural gas***

Upstream gas development

Generally, natural gas exploitation has been seen as a benign activity. It entails limited land use loss from other uses, with well pads of several hectares serving to recover gas from a much wider area. Gas does not spill like liquid fuels, so there is less risk of contaminating land or water. When natural gas does have an uncontrolled release it goes straight into the upper atmosphere, assuming no source of ignition (potentially resulting in environmental damage, but no damage to persons or property). Gas is generally transported over land by buried pipeline, making pipeline corridors almost invisible. The pipelines have little impact on agricultural land users in rural areas, although there are restrictions on placing permanent structures on the typically 30m wide right of way.

There may sometimes be political issues regarding whether the government is obtaining its fair share of revenues from natural gas production, as the resource owner. This relates to production royalties and the terms of the production sharing agreement. While expectations may differ, full transparency throughout the process is generally the best strategy for the government to follow on this.

Hydraulic fracturing

Some gas developments have recently become more controversial, with the increasing use of large-scale hydraulic fracturing to recover shale gas. Hydraulic fracturing has become a lightning rod for political and social conflict associated with its use in gas development. Hydraulic fracturing can be conducted without causing undue geological and environmental problems. The proviso is that it must be conducted carefully and correctly, and in accordance with the very best regulatory practises. The following are some examples of good practice in hydraulic fracturing:

- Testing of all potable water wells within a prescribed diameter of the well prior to hydraulic fracturing testing, and monitoring of these wells during and after hydraulic fracturing operations.
- Ensuring well-bore integrity, with proper casing and cementing.
- Conducting geological studies to understand the fracture zone.
- Proper transport, treatment and disposal of recovered water.

These practises will reduce the risks of environmental damage from hydraulic fracturing, within a good regulatory framework and with a strong regulator.

Natural gas and Greenhouse gas emissions

While gas is seen as the most benign fossil fuel in terms of its lower carbon content and lower CO2 emissions, the very fact that it does emit some greenhouse gases has generated some social and political conflict, at least from those advocating urgent elimination of all Greenhouse gases.

More recently, there has been increasing evidence of fugitive emissions of methane, particularly throughout upstream and midstream gas production processes, from the wellhead through gathering, processing and transmission. Regulatory approaches are being developed in developed countries to address this.[64, 65] African countries need to monitor these initiatives to manage fugitive emissions, determine best practises, and adopt them.

Downstream gas processing facilities

There may be concerns in some quarters about the risks of explosions during gas distribution by pipeline. With proper safety regulations and proper maintenance these are rare events.

Most other natural gas value chain nodes are more akin to highly technical manufacturing activities, and less likely to generate social and political conflict.

The most important method of avoiding conflict is having a robust and effective regulatory framework. The regulatory framework will include requirements for:

- Public disclosure and consultation by resource development proponents at the application stage.
- Transparent decision-making processes and publication of reasons for decisions by the regulator.
- Incident reporting and follow-up investigation.
- Publicly available reports and data on production, emissions, industry non-compliance.

Gas flaring in Nigeria mapping the real cost

Nigeria has a vast amount of oil and gas reserves. This made it the largest oil producer in Africa and the world's fourth-largest exporter of liquefied natural gas (LNG) in 2015 (EIA 2016). Oil and gas revenues are the main drivers of Nigeria's economy. According to the International Monetary Fund (IMF), government export revenue from oil and gas was about US$87 billion in 2014, accounting for 58 percent of total government revenue that year. Oil and natural gas revenue is the country's main source of foreign exchange, constituting more than 95 percent of Nigeria's total exports to the world in 2014.

Nigeria consumed 602 billion cubic feet (Bcf) of dry natural gas in 2014, which is about 40 percent of its production. It also exports the vast majority of its natural gas in the form of liquified natural gas, and a limited amount is exported through the West African Gas Pipeline (WAGP) to neighbouring countries like Ghana. The LNG facility on Bonny Island is Nigeria's only operating LNG plant. Nigeria LNG Limited (NLNG) operates the facility. Partners include the Nigerian National

64 *(US Environmental Protection Agency, March 2014)*

65 *(David Picard, 2015)*

Petroleum Corporation (NNPC) (49 percent), Shell (25.6 percent), Total (15percent), and Eni (10.4 percent) (EIA 2016).

However, the production and utilisation of these gas resources faces structural challenges. The lack of infrastructure to monetise natural gas has engendered gas flaring. Nigeria is ranked the fifth-largest natural gas flaring country. This is down from the second position it held in 2011. In 2014, Nigeria flared 379 Bcf of its associated gas production, an equivalent of 12 percent of its gross gas production. This accounts for 8 percent of the total amount of gas flared globally.

With the natural gas industry mostly located in Nigeria's Niger Delta area, the recent upsurge in military attacks on oil and gas installations has affected the industry. In November 2008, for example, Shell declared a force majeure on natural gas supplies to the Soku gas-gathering and condensate plant. The Soku plant provides a substantial amount of feed gas to Nigeria's only LNG facility. Shell shut down the plant to repair damage to a pipeline connected to the Soku plant that was sabotaged by local groups siphoning condensate (IEA 2016).

The core of the complex challenges facing Nigeria's gas sector has to do with the flaring of gas, already mentioned above. As noted, a large amount of the country's gas is flared due to inadequate infrastructure,is essential for capturing natural gas (i.e. associated gas) with oil. Nigeria experiences a large extent of 'open pipe flare', a method that is obsolete in other resource-rich countries. According to Clarke (2008), 'many flares have run 24 hours a day and some have been active for 40 years with over 8 million cubic feet per day burnt'. This has severe economic, social and environmental consequences.

Natural gas flaring significantly contributes to climate change. The release of a substantial amount of methane has very high global warming potential. These contaminants acidify the soil, hence depleting soil nutrient (Donwa et al 2015). A study undertaken in southeastern Nigeria showed evidence of acid rain due to gas flaring, which contaminates water bodies and soil (Akpan 2003). Kingston (2011) finds a statistically significant relationship between gas flaring, foreign direct investment and environmental pollution in the Niger Delta. These contaminants that come from gas flaring affect agriculture, which is the mainstay of the people in the Niger Delta region. Ubani (2013) argues that there is no vegetation in the areas surrounding the flaring, due partly to the tremendous heat that is produced, and the acid nature of soil pH (a level of acidity and alkalinity in soils). It has been concluded that the soils of the study area are fast losing their fertility and capacity for sustainable agriculture due to the acidification of the soils by the various pollutants associated with gas flaring in the area (Orimoogunje et al. 2010). A United Nations Environment Programme (UNEP) report has captured the environmental impacts that oil spillage and gas flaring present. The UNEP study on Ogoniland confirmed community concerns about oil contamination across land and water resources. It found that the damage is ongoing and estimated that it could take 25 to 30 years to repair.

In 2016, the Federal Government of Nigeria, through the Ministry of Petroleum Resources, drafted a new national gas policy to help grow and transform the country's gas sector. This new gas policy mainly proposes new legislation to regulate the gas industry, as well as the treatment of gas on a stand-alone basis. The fiscal terms in the petroleum sector set a penalty of USD3.5 per 1,000 standard cubic feet of gas flared in the country. Nigerian National Petroleum Corporation's (NNPC) annual statistics bulletins in 2016 revealed that from 2008 to October 2016, oil and gas companies operating in the country flared a total of 4.085 trillion standard cubic feet of gas. By value – and based on the penalty set for gas flaring – Nigeria could have earned USD14.3 billion.

5.2. Potential environment impacts

The use of good environmental, health and safety practices in production processes will enhance a nation's reputation and often make its exports more marketable. It is possible as more countries adopt strategies to address climate change, that products from countries using "green" production practises will be favoured. It is also possible that products from countries that do not have modern, environmentally friendly production practices may face trade barriers. New multi-national trade agreements focus more on eliminating non-tariff barriers, such as production practices and regulatory standards, than on tariffs.

The most important channel to improve and sustain the environment is by relying on the visible hand of the regulator, rather than the invisible hand of the market. That is why this report emphasises the need for a good regulatory framework, administered by a regulator that is competent, has proper authority to carry out its responsibilities and has high integrity.

The resource developer will develop optimal resource development and resource depletion strategies and plans. In a country with a good resource regulatory framework and regulatory institutions, resource development plans should always be subject to consultation with and approval by the resource regulator. Effective resource regulatory framework and regulatory institutions may not exist in all African countries, and development of the natural gas resources should not proceed without the requisite regulatory frameworks and regulatory institutions in place. The regulator will normally require upstream gas development to adopt and follow good production practises. This means it occurs in a manner that does not impair the ultimate recovery of natural gas from the reservoir. The regulator will also want to ensure that resource development does not cause environmental damage and can be done safely. Safety to the resource regulator means process safety, not necessarily occupational health and safety, as the latter may fall under the purview of a separate regulator. Process safety essentially means that no fluids are allowed to escape during any part of the process. This is important because of the pressures encountered throughout the natural gas life cycle of exploration, transportation and processing.

Natural gas is a non-renewable resource. Producing gas from any individual reservoir will naturally lead to physical depletion of the reservoir. Therefore, development of natural gas supply chains may lead to depletion of individual reservoirs. Any investments and developments in the natural gas supply chain will demonstrate the presence of the resource and the existence of a market for natural gas in the country. These are important to avoid depletion. Demonstrating the existence of a market for natural gas, and that natural gas development is economically viable in that country, will provide an incentive for further natural gas exploration. It will also prevent depletion by the successful discovery of new reservoirs. It is generally the case that one discovery of natural gas in a country, especially if that gas is developed, leads to more gas to being discovered and developed in that country. This is because the underlying geological conditions of the first discovery are generally continuous throughout other parts of the region. New technologies like hydraulic fracturing can increase the total recoverable gas.

There are alternative regulatory approaches to consider to mitigate the environmental impacts of natural gas exploitation. However, perhaps the biggest issue for most African countries is simply regulatory uncertainty. This has been ranked by PWC as the biggest challenge in oil and gas development in recent years.[66] Regulatory uncertainty can arise because the regulatory framework is incomplete, out of date, unclear or unevenly applied. It can also arise because the regulatory institutions created to administer the regulatory framework do not have the capacity to properly administer the regulations, either because of a shortage of skills or shortage of numbers. A critically important prerequisite for a country with natural gas resources, whether a current producer or an aspiring producer, is to ensure that a modern, comprehensive regulatory framework is in place. It should be one with regulatory institutions that are adequately resourced, and with knowledgeable and capable personnel.

An aspect of the regulatory framework that is important in providing regulatory certainty is ensuring that the regulator has adequate authority and independence from politicians. The regulatory institution should be legally established as an independent agency with authority delegated to the agency by legislation. The agency is often a board or commission, and its authority is often described as quasi-judicial, based on its delegated authority. Formal processes are followed in making regulatory decisions. The independence is important, as the government and minister may have conflicted interests regarding gas development. The simplest conflict will arise from the resource being owned by the state and representing a potential revenue source for the state. The government will see gas development from a commercial perspective, as it manages its resource ownership. While the public interest is not necessarily or always in conflict with commercial interests, there will be times when public and private interests are not fully aligned. The government and minister may be in in conflict if they have to make decisions where their commercial interests differ from the public interest, for example on environmental or public safety issues.

Having an independent regulator protects the government from actual or perceived conflict with itself. The extent of independence may be limited to giving the regulator authority to provide independent recommendations on a resource development issue, but giving the government the final decision-making authority. The government, armed with a recommendation from an independent source who utilises a quasi-judicial process, creates transparency, supporting fair and objective decision-making.

A full discussion of regulatory approaches is well beyond the scope of this study, but will be referenced briefly here. This an important issue for those jurisdictions just establishing a regulatory framework, or those renewing their regulatory framework

66 (PWC, 2016)

because their existing regulations are obsolete or not sufficiently comprehensive. A common distinction is between performance-based regulations and prescriptive regulations, which may be defined as follows:[67]

- **Performance-based regulations** are generally "regulations that set performance goals and allow individuals and firms to choose how to meet them," or "standards that specify measurable outcomes or performance goals and leave the means of achieving those outcomes or goals largely to the discretion of the regulated firm or entity."
- **Prescriptive regulations** "specify the means of accomplishing a regulatory goal, that is, what is to be done, by whom, and precisely how it is to be accomplished" and, "specify what was to be done, what would be inspected, and when it would be inspected, and who would conduct the inspection."

In fact, the most common and preferable approach is to have regulations which contain a mix of prescriptive and goal-based (performance-based) requirements. To be clear, performance-based regulations do not imply the absence of regulatory oversight or regulatory approvals. But the nature of regulatory oversight changes, and the skill set required by the regulatory agency will be different than under a prescriptive regulatory framework. There are many good regulatory models in the world to emulate.

The regulatory framework must complement the market, as regulations should only be needed or used for issues where the market operates ineffectively or not at all. The market is often referred to as the "invisible hand" and the regulator serves as the "visible hand" to complement where the market does not work. The areas where upstream natural gas development is generally subject to regulation are:

- Resource conservation – ensuring socially optimal allocation of production over time.
- Environmental protection – standards and requirements for emissions, abandonments and reclamation.
- Health and safety – protection of workers and the general population.
- Natural monopolies – approving market entry and setting prices where the market does not provide a socially optimal solution (e.g., pipelines are often described as natural monopolies, and sometimes gas processing plants are).

These include many areas where the regulator can use regulatory approaches involving incentives and competition to emulate the market, and resulting in greater efficiency of regulated operations. Performance-based regulatory frameworks are also seen as more complementary to the market, as they allow the operator greater flexibility in how to conduct operations, resulting in more innovative approaches and efficient operations.

One aspect that is normally subject to market forces in countries with well-developed natural gas industries and markets is the pricing of natural gas. The price of natural gas may not be amenable to market forces in many African countries, especially where natural gas development is in early stages and there are limited number of buyers and sellers, or the gas is subject to transfer pricing. These situations are not amenable to market forces or market discipline, and natural gas prices may need to be subject to approval, either by the regulator or the Government. As indicated earlier, natural gas pricing may also be used as a policy lever to provide incentives to downstream gas value chain development.

67 *Lloyd's Registry and Stewart, McKelvey, Sterling, Scales, Goal Oriented Regulation of Canadian East Coast Oil and Gas Activity, Petroleum Research Atlantic Canada, November 2004. (Petroleum Research Atlantic Canada, 2004)*

6. Governance of the natural gas value chain

This section addresses how the governance structure of the natural gas value chain can affect the possibilities of African countries to adopt sustainable and inclusive practices in natural gas exploitation. It also looks at how they can build knowledge and domestic linkages around this natural resource.

The governance of gas production and development is determined by each country in which any component of the gas value chain is present. We would strongly encourage full transparency of these agreements, as means of imposing discipline and accountability on the respective government. Coumtries with natural gas resources are strongly encouraged to become members of the Extractive Industries Transparency Initiative (EITI).[68] Of the 52 countries that are current EITI members, 27 are from Sub-Saharan Africa (of which three are currently suspended). This level of participation in EITI is encouraging, and African Development Bank member countries would be well served by joining EITI.

While EITI may focus primarily on the upstream sectors, countries that practice transparency in the upstream are more likely to have transparency in other sectors.

Transparency imposes greater discipline on governments and makes them more accountable to their citizens. Rent is generally obtained from primary resource production, in other words in the upstream sector where the state is the resource owner. This is the area for which EITI is particularly designed to increase transparency.

Transparency and predictability are often presented as important characteristics of successful petroleum management and regulatory frameworks.[69] Transparency generally means the openness, clarity and ease of being able to understand a process. Predictability refers to the stability of the process, and the ability to foresee the outcome of the process. African countries should strive for governance frameworks that are transparent and predictable. These characteristics will encourage investors to compete for licences and take advantage of investment opportunities.

Avoiding the Resource Curse: The Case of Norway

Norway is probably the best example of a country that has positively benefited from its oil and gas resources, and has among the best regulatory frameworks and petroleum fiscal regimes of any country in the world. Norway has advantages that few, if any, African country has, in terms of efficient governance, social democratic culture, homogeneous society, well-developed institutions, highly educated population. African countries may not be able to emulate Norway in those respects, but they can still learn many things from a country like Norway.

Norway was very focussed in developing policies to manage resource development and to successfully develop policies to avoid the "resource curse" and the "Dutch disease."

Some strategies pursued by Norway to achieve these goals have included:

- Achieving political consensus within the country on major goals of petroleum development, thereby avoiding political divisions and gaining investor confidence.

68 *(Extractive Industries Transparency Initiative, 2016)*

69 *(Al-Kasim, 2005)*

- Managing the pace of development by deliberately limiting the number of exploration blocks offered and the number of licences issued at any time.
- Open and competitive bidding for all licences.
- Issuing licences to groups of three to five co-licensees, with the government selecting the co-licensees and the operator.
- Rigorously screening out of non-qualified applicants.
- Designing fiscal terms that:
  - Provide investors with reasonable security of recovering their investments and earning return commensurate with risk.
  - Return the majority of economic rents to government endowment funds, and
  - Result in government taking a large share of risk through high fiscal take.
- Separating commercial interests of government from its regulatory roles.
- Taking significant direct interest in petroleum development, including risk-sharing and profitability, though a national oil company. This has supported significant national benefits in employment and industrial development.
- Developing and implementing a performance-based regulatory framework, which provided companies with maximum flexibility in how to meet the performance goals set by the regulator, thereby encouraging maximum efficiency and profitability.

These policies may be seen as “best international practices”. While they set a very high bar for most African countries, they are nevertheless worth striving for.

7. Assessment of political and business enabling environment

The World Bank Group has developed an index that measures the ease of doing business in individual economies in the world, and ordinarily ranks countries on their ease of doing business. A high ease of doing business ranking means the regulatory environment is more conducive to starting and operating a business in that economy. The rankings are determined by sorting the aggregate "distance to frontier" scores on 10 topics, each consisting of several indicators, with each topic having equal weight. The "frontier" scoring of 100 is the best a country can achieve. The World Bank Group's most current rankings for all economies are benchmarked to June 2016.

Table 8:
African Countries with Gas Reserves Ease of Doing Business Ranking

The table below shows a summary of the African countries with gas reserves. Overall ranking is shown out of a total of 190 countries. These African countries generally occupy the lower ranges of the rankings.

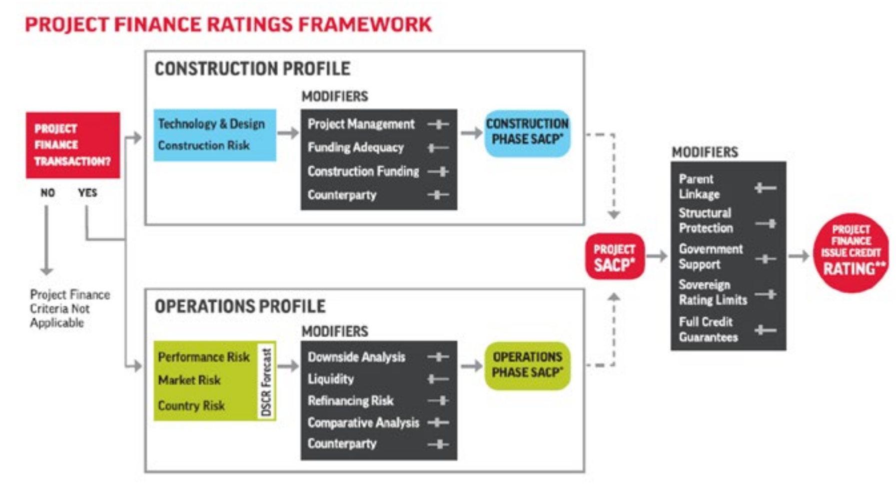
Nation	Over all Ranking	Starting a Business	Construction Permits	Getting Electricity	Registering Property	Getting Credit	Protecting Minority Investors	Paying Taxes	Trading across Borders	Enforcing Contracts	Resolving Insolvency
Rwanda	56	8	32	7	1	1	12	5	6	10	7
Morocco	68	3	3	6	9	6	5	12	3	2	11
South Africa	74	22	11	5	12	10	1	2	25	16	2
Tunisia	77	8	8	3	10	3	10	13	7	7	1
Ghana	108	17	15	9	5	4	7	16	29	17	35
Namibia	108	38	6	10	40	9	4	9	17	11	12
Uganda	115	36	28	28	17	5	14	10	22	4	17
Egypt, Arab Rep	122	2	9	11	14	1	8	18	15	19	9
Tanzania	132	25	22	1	22	6	35	29	40	3	14
Mozambique	137	24	1	32	13	38	18	19	10	46	5
Côte d' Ivoire	142	5	45	13	16	25	26	38	27	13	6
Senegal	147	12	23	29	27	32	21	39	19	24	15
Algeria	156	13	10	14	18	15	17	19	19	8	3
Ethiopia	159	41	40	12	23	42	43	20	34	6	23
Mauritania	160	9	16	19	11	37	17	46	23	7	38
Gabon	164	31	35	26	41	17	38	30	33	42	26
Cameroon	166	29	24	2	42	24	25	41	46	34	25
Sudan	168	34	26	6	6	40	47	22	44	26	34
Nigeria	169	27	38	41	46	8	3	40	41	23	28
Congo, Rep	177	40	19	39	38	22	28	42	42	31	21
Equatorial Guinea	178	46	33	18	33	18	23	44	38	14	41
Chad	180	43	21	40	31	31	37	47	36	30	31
Angola	182	28	13	34	37	45	6	23	43	47	44
South Sudan	186	42	41	47	45	44	45	15	39	5	39
Libya	188	16	20	16	20	19	20	20	9	17	20
Somalia	190		48	48				48			

Source: World Bank [70]

70 (World Bank, 2015)

The ease of doing business is a measure of country risk, as a poor business environment in a country will reduce the likelihood of an investment earning an acceptable rate of return. It is also an important consideration in the ability to obtain financing for individual projects. Firms such as Standard and Poor's have developed project finance rating methodologies, which the figure below summarizes.

Figure 17:
Standard & Poor's Project Finance Evaluation Method[71]



In summary, countries such as Somalia have a very high risk factor, and would have difficulty raising finance for infrastructure projects. On the other hand, countries like Rwanda would have relatively less difficulty raising finances for a well-managed infrastructure project.

Turning danger into opportunity: Rwanda's KivuWatt project

Lake Kivu, which straddles the borders of Rwanda and the Democratic Republic of Congo, was seen as a risk due to its high concentration of methane, carbon dioxide and hydrogen sulfide gas, with the potential for toxic release. Today though, Lake Kivu, through the KivuWatt gas project, provides an important source of energy for Rwanda, where only 16 percent of the population is connected to the grid. Rwanda has an installed capacity of 112 megawatts of energy.

The first phase of the KivuWatt gas project, which started operation in December 2015, is producing 26 megawatts of electricity for Rwanda's local grid, through the powering of three gensets. The next phase will deploy nine additional gensets at 75 megawatts to create a total capacity of over 100 megawatts. The KivuWatt gas project is owned and operated by US energy corporation Contour Global, which has signed a 25-year gas concession and power purchase agreements with the Rwandan government to extract up to 100 megawatts of electricity from Lake Kivu's methane gas.

The KivuWatt project cost is about USD128 million. The project sponsor is a private company - Contour Global, which has invested USD35.7 million in equity while attracting the Netherlands Development Finance Company (FMO) to contribute USD8.9 million in equity. The remaining USD83 million of the project

71 (Standard and Poor's, 2011)

cost is in the form of borrowing from the African Development Bank's Emerging Africa Infrastructure Fund (EAIF), the Belgian Investment Company for Developing Countries (BIO), FMO and the European Financing Partners (EFP).

KivuWatt's gas-extraction and power-production method will improve Rwanda's energy mix. Hydropower currently contributes 59 percent of the country's energy output. , Thermal or heat energy contributes 40 percent and methane 1 percent of output. Biomass dominates the country's energy use. It accounts for about 85 percent of primary energy use, while petroleum constitutes 11 percent and electricity just 4 percent.

7.1. Enabling infrastructure, policies, institutions and processes

The enabling policies and institutions required to develop a modern industrial economy depend on a strong and modern state that follows the rule of law and is accountable to its citizens. A strong and modern state is one that has a comprehensive legal framework developed by accountable political representatives and modern administrative structures staffed with a professional administration. The rule of law depends on an independent judiciary to ensure adherence by the government and by citizens to the comprehensive legal framework.

The top six challenges in developing an oil and gas business in Africa were referenced above, and they merit repetition. The ranking of these issues indicates that Africa generally, and most African countries may not have the enabling infrastructure, policies, institutions and processes that are required to attract the investment necessary for developing the gas value chain. These are all issues that African governments must address.

Table 9:
Ranking of Issues Facing Oil and Gas Companies from Investing in Africa

Issue	Year			
	2015	2014	2012	2010
Uncertain regulatory framework	1	1	3	1
Poor physical infrastructure/ supply chain	2	3	1	2
Corruption/ethics	3	2	2	3
Lack of skill resources	4	5	4	4
Taxation requirements	5	6	16	10
Local content requirements	6	7	5	

Source: PWC[72]

Addressing these issues and having appropriate enabling policies and institutions is important for the successful development of the natural gas value chain in any Africa country. The better that governments address these issues, the better the policy framework and institutions they wil produce. And the more likelihood there will be of gas value chain development, with ultimate benefit to the country from that development. This is an important topic, but it must be the subject of a separate study. It cannot be addressed within the more focussed scope of this study.

71 (PWC, 2015)

Breaking the extractive sector 'enclavity': economic structures and policy regulation in East Africa's oil and gas

East Africa holds one of the most prospective oil and gas regions in the world, with exploration activity stretching from the Red Sea through Ethiopia, Kenya, Uganda, Tanzania and to Mozambique. In recent years, significant onshore oil and gas reserves have been discovered in the Albertine Graben in Uganda and the Turkana Basin area of Kenya. In Uganda, discovery of 20 oil and gas fields is estimated at over 2.5 billion barrels of oil equivalent. In Kenya, exploration drilling estimates suggest that there are roughly 600 million barrels of oil that are likely recoverable in the onshore Tertiary Rift Basin.

Uganda and Kenya have set out to provide the economic policy measures to leverage the benefits that oil and gas revenues bring. In 2008, Uganda approved the National Oil and Gas Policy, which sets a direction for using the country's oil and gas resources for creating value to society. The policy aims to ensure collection of the right revenues and use them to create lasting value for the entire nation by supporting strategic areas:

- education and research and development of infrastructure to provide intergenerational equality.
- participation in the Extractive Industries Transparency Initiative (EITI).
- Promotion of state and national entrepreneurs' participation; employment of Ugandans; and use of the country's materials, goods and services.
- Ensuring that oil and gas activities are undertaken in a manner that conserves the environment and biodiversity, including requiring oil companies and their contractors and subcontractors to use self-regulation and best practices.

Following from the oil and gas policy, Uganda has further enacted the Oil and Gas Revenue Management Policy (2012), which provides a strategic framework towards managing the anticipated revenues to create macroeconomic stability and avoid risks associated with natural resources wealth. The Oil and Gas Revenue Management Policy includes measures for assessment and collection of revenues, governmental fiscal transfers, macroeconomic policy management, fiscal rules for managing revenues, and oversights and controls. Uganda has in place two important petroleum legislations: the Petroleum Exploration, Development and Production Act of 2013 and the Petroleum Refining, Gas Conversion, Transportation and Storage Act of 2013.

Kenya's petroleum sector is regulated by specific legal framework set out in the Petroleum (Exploration and Production) Act, Cap 308 of 1986, and the accompanying regulations under Section 6. In fiscal terms and based on production in the northwestern part, Kenya has a traditional production sharing system. In order to leverage benefits, provisions have been made in the country's petroleum act to increase local content. Kenya's Model Production Sharing Contract as contained in the Petroleum (Exploration and Production) Act of 1986 contains two clauses on local content. They stipulate that, "the contractor, where possible, shall employ Kenyan citizens in petroleum operations, alongside training those citizens," (s.13.1) and providing for, "a contribution on the part of the contractor for a negotiable sum to be contributed to the ministry's training fund" (s.13.3).

The regulations in the oil and gas sector in East Africa aim to create employment along the value chains. The German Federal Ministry for Economic Cooperation and Development (BMZ) and the United Kingdom´s Department for International Development (DfID) have established an initiative aimed at promoting local employment and addressing skills gaps in the natural resource-based industries and related sectors in East Africa. The multilateral initiative, Skills for Oil and Gas Africa (SOGA), is financed by BMZ, DFID, the Norwegian Agency for Development Cooperation (Norad), BG Group, and implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Under SOGA, the Employment for Sustainable Development in Africa (E4D), is a sub-initiative that started in 2015 and operates in four countries, namely Uganda, Kenya, Tanzania and Mozambique. This initiative aims to provide 32,000 people in these four countries with technical and vocational education and training (TVET), and to boost the operations of small- and medium-sized enterprises (SMEs).

Revenue transparency remains a challenge in the utilization of oil and gas revenues to ensure sustained growth and development. Uganda and Kenya are yet to be candidates of the Extractive Industries Transparency Initiative (EITI), which provides a global standard to promote open and accountable management of natural resources. EITI helps strengthen government and company systems, inform public debate, and enhance trust. The Ugandan government committed to joining and implementing the EITI standard. This was reflected in its 2008 National Oil and Gas Policy for Uganda and in its 2012 Oil and Gas Revenue Management Policy. Despite repeated public statements, however, the government has not yet taken any concrete steps towards actually joining the initiative.

7.2. Current status in many African countries of enabling infrastructure, policies, institutions and processes

- *Effectiveness of existing institutions in enabling gas value chain development in Africa*

In examining the potential for global value chains to contribute to Africa's industrialisation, the 2014 African Economic Outlook stated: "Better governance and social peace are essential for growth and development." Although it acknowledges some signs of progress, this progress is slow and uneven.

- ***Kinds of institutional capacities needed to negotiate contracts aiming at receiving higher revenues, increasing local linkages and spillovers, and enabling accountability and public participation in natural gas resource management policy matters***

An important prerequisite for obtaining higher government revenues and greater economic benefits is a good regulatory framework, as discussed above.

Another requirement is a robust production sharing contract (PSC) for upstream gas development. We note that many countries with production sharing contracts seek the

Five key considerations for global value chain development

The 2014 African Economic Outlook suggests five key considerations to guide policies towards achieving global value chain development. These considerations can guide polices to promote gas value chain development as well.

1. Be specific about the country's best position in the gas value chain – develop the infrastructure, skills and services to foster success for that position; seek to attract the right investors for that development.
2. Seek to maximize economy-wide opportunities and benefits – avoid disadvantaging other sectors or value chains, but recognize that trade-offs will be required.
3. Promote entrepreneurship and collaboration between public and private players – work with domestic business associations to identify needs and opportunities for local firms to participate in the value chain.
4. Recognize the power and ownership structures of value chains to determine which paths and nodes are most promising – avoid nodes where tight control is retained over processing activities by large owners.
5. Avoid relying on low tax rates and low social and environmental standards for competitiveness – this leads to a race to the bottom, rather than building a viable and sustainable economy benefits all citizens.

highest possible profit shares, and are often disappointed by apparent profitability being lower than expected. We think this is because of significant profit leakages, resulting from weak accounting principles and imprecise definitions of costs and revenues in the production sharing contract. It is recommended that the following areas of costs often be examined, tightened and made more precise to avoid these leakages:

- Non-arm's length transactions – buying from parent or associated companies at non-market costs; authority is needed to calculate profits as though these transactions had taken place at market costs, or had not taken place at all.
- Corporate overheads – these may be legitimate expenses for determining corporate taxable income, but are not project specific, and can end up with arbitrary allocations to individual projects (especially problematic if corporate overheads occur in another country); the safest strategy is to only allow only direct costs.
- Financing costs – generally done at the corporate level, not at project level; project profitability should not be a function of how it is financed.

If these cost definitions are tightened and loopholes eliminated, profitability increases and a high level of profit sharing should no longer be as important – i.e., getting a smaller piece of a bigger pie may be considerably more valuable than getting a seemingly large slice of a very small pie. We suggest that it may be easier and more valuable to negotiate tighter definitions in the production sharing contract than higher profit shares.

- ***More transparent information and participation mechanisms that can nurture local communities' rights and interests***

Ensuring that the information and mechanisms needed to promote community engagement are made broadly available on a timely basis is a joint responsibility of the industry and of government. The latter could be the independent regulator, rather than the government directly. Local consultation can be, and often is in many countries, a requirement in the regulatory process. Recent experience in North America indicates that companies may be strongly motivated to initiate these consultations on their own initiative. Many companies have learned that in addition to regulatory approvals, they also require a "social licence" to operate. A social licence for a project may be defined as "the ongoing approval within the local community and other stakeholders, ongoing approval or broad social acceptance and, most frequently, as ongoing acceptance."[74] The company itself needs to earn and maintain a social licence. In a country with a responsive and accountable political structure, having this social licence is a prerequisite for a successful investment in gas value chain development.

74 *(Social License, 2016)*

8. SWOT Analysis for African gas producing countries

SWOT analysis is a commonly used technique in strategic planning by corporations and by governments. It provides a context for a company or government to:

- identify and analyse the important factors, within its control (strengths and weaknesses) and beyond its control (opportunities and threats), that may influence its success; and
- devise strategies to capitalize on or neutralise these factors.

Table 10:
SWOT for African Countries with Gas Resources

	Positive	Negative
Internal (forces within control)	Strengths	Weaknesses
	• Availability of gas resources as basis for gas value chain development	• Under / mismatch skilled labor force
	• Large unemployed/ underemployed labor force	• Poor governance, high incidence of corruption; risk of resource curse
	• New opportunities for existing businesses	• Weak regulatory frameworks and regulators
	• Export earnings and foreign exchange	• Lack of infrastructure – roads, railways, ports, utilities, energy
	• Broadening and deepening of the economic base of the economy	• Inhospitable business environment – regulatory uncertainty, difficulty of doing business
	• Underdeveloped internal markets could absorb new global capacity	
	• Need for skilled workers can open doors for female training and employment	
	• Electricity production reduces energy poverty allowing development of other businesses	
External (forces beyond control)	Opportunities	Threats
	• Access to good quality skilled jobs can provide economic impetus	• Risk of Dutch disease – detrimental effect of exchange rate appreciation on other sectors of the economy
	• Ability to use gas price as an economic policy lever	• Global pricing competition
	• Potential lateral linkages arising from gas-fired electricity and urea fertiliser value chain nodes	
	• Direct government revenue from royalties and taxes to fund expenditures and programs	
	• Weak educational system can be expanded and/or strengthened	
	• Development opportunities for current weak and underdeveloped businesses and service industries	

We observe that the positive factors appear to outweigh the negative in the table above. The negative factors may be formidable, but the incentive for natural gas chain development should be strong.

9. Policy recommendations

A significant number of African countries have natural gas resources. These countries are often not obtaining the full economic benefit from their natural gas resources, as the gas may simply be under-underdeveloped, or the country may not be achieving the optimal value of gas development from the gas value chain. We have identified the principal nodes on the gas value chain, and extensively described the technologies, market characteristics and economics of each value chain node. We have also discussed the entry barriers that may exist for these various nodes, and the potential benefits from these various value chain nodes.

Before considering policy recommendations, we offer the following table, which summarizes each natural gas value chain node evaluated. The table shows two sizes of reserves, gas demand, and capital costs for each value chain node. These sizes indicate:

- A small plant, with gas provided from a "stranded asset" and typically supplied gas at cost or for free. Production would be destined for local markets.
- A world class plant, typically with sufficient economies of scale to compete on the world market with competitively priced gas.

This table can be used by policy analysts from various African countries to get a quick sense of which nodes of the gas value chain may be most appropriate for their country to pursue, based on the magnitude of their country's gas resource and its capacity to attract investment.

Table 11:
Gas Node Summary, Requirements, Barriers and Benefits

Gas Node	Reserve Size (BCM)		Annual Gas Demand (MCM)		Capital Cost (US$ B)		Required Capital Infrastructure	Barriers to Entry	Success Factors	Nature of Benefits	Economic Benefits
	Small	World Class	Small	World Class	Small	World Class					
Urea	4	33	206	1650	$0.6	$2.1	Shipping port, rail, highways, power, water	Global competition	Domestic Agriculture base	National	Increased crop yields
Methanol	8	30	375	1500	$0.7	$1.5	Shipping port, rail, highways, power, water	Global competition	Long term contracts, petrochemical industry clusters	National	Exports, taxes, foreign exchange
Power Plants	2	20	90	1000	$0.1	$0.6	Transmission and distribution grids	Domestic regulation of energy grid	Urban density, high energy poverty rates	Local	Increased electrification, economic diversification and growth
GTL	8	30	375	1500	$1	$2.1	Shipping port, rail, highways, power, water	Price of gas vs oil	Long term contracts, domestic consumption	National / Local	Displacement of imported liquid fuels
Gas Distribution	1	3	40	160	$0.1	$0.4		Urban density and gas demand	Industrial users, state-supported right-of-way acquisition	Local	Increased industrial efficiency, mass transit, quality of life
LNG		275+		14,000		$20	Shipping port, power	Global competition	Long term contracts	National	Exports, taxes, foreign exchange
Pipeline		130+		7000		$7	Power	Regional competition	Long term contracts, land access, pipeline security	National	Exports, taxes, foreign exchange

Many African countries have lower incomes and lag behind the rest of the world in their level of economic development. This is generally true regardless of whether or not these countries possess natural gas resources. Natural gas can be a lever to raise national incomes and levels of economic development. We strongly recommend that

African countries with natural gas resources implement policies that will address the relevant factors identified in Table 10: SWOT for African Countries with Gas Resources shown above. This will facilitate and encourage the development of natural gas.

We believe the most feasible and attractive natural gas value chain node for most African countries is to use the gas as a fuel for generating electricity. We note the high incidence of energy poverty among African countries, and that countries with natural gas resources are not immune from energy poverty. Gas-fired electricity:

- can be a valuable means to reduce energy poverty;
- has technologies which are not overly complex and are readily accessible and scalable; and
- like all electricity, has the ability to generate significantly positive lateral linkages throughout the economy.

If gas power electricity is the desired route for gas economic development, then supporting regulatory regimes would likely include gas at cost pricing policies. To attract private investment in power plants, African nations would require regulatory clarity and certainty on private power delivery. This could possibly be in conjunction with publicly owned or subsidised transmission and distribution grids and other risk absorption by the government such as demand risk.

We believe other attractive gas value chain nodes that are especially attractive and achievable in African countries are:

- development of urea fertiliser plants,
- export of natural gas to neighbouring countries by pipeline.

Nations that have fertile climates would benefit from the increased crop yields offered by urea fertiliser. This would either increase local food production and nutrition while decreasing imports, or increase food exports with their associated revenues. Conversely, exporting of natural gas is principally a means of transforming a non-renewable natural resource into immediate cash for governments and private corporations.

While other gas value chain nodes may be achievable, and may potentially yield significant economic benefits, we believe these are the low-hanging fruit and are most readily achievable by those countries with modestly sized natural gas resources and otherwise relatively weak infrastructure. Realising other value chain nodes may be more challenging because of the magnitude of gas resource required, the technological complexity and the high costs of development. They are not for every country.

Many African countries have histories of poor governance, weak institutions and inadequate infrastructure. Developing natural gas and moving up the natural gas value chain generally requires good governance, institutions and infrastructure. The economic benefits of natural gas development may aid in improving the functions of governance and the structure of the economy in these countries. But gas development should not be seen as a panacea that will solve these problems in the absence of broader and deliberate policy efforts by those African governments to address the weaknesses and threats and capitalise on the strengths and opportunities they face.

Appendix 1 - Case Study: Rwanda

This case study will provide an illustration of how to use the data provided in this report to assess the benefits of application of a natural gas value chain. First, a screen is applied to the various gas nodes. While not explicitly stated in this report, Rwanda's gas reserves are non-traditional, coming mostly from Lake Kivu. As such, its natural gas reserves are unlikely to appreciate over time, unlike countries with traditional fields that may indicate potential for additional undiscovered fields.

1. Rwanda has a population of approximately 12 million with negligible gas production <100 MCM but with reserves of 100 BCM. This would indicate that Rwanda has a significantly under-developed gas production market, but does have reasonable reserves. Digging deeper into the International Energy Agency data shows current production rates of 50 MCM, giving an estimated reserve life of 1000 years. For the gas value chain to be developed in Rwanda, increased production would be required.
   - There is some opportunity for development of natural gas reserves if production rates can be increased.

2. Rwanda's gas reserves of 100 BCM would not support LNG export or pipeline export but could support urea, methanol, and GTL, although this would require about half the country's gas reserves. Gas power plants are also viable, given the size of the reserves. Bulk export and LNG are not viable.
   - Urea, methanol, GTL, power plants and distribution networks are viable given the reserve size.

3. In terms of annual consumption, a single urea, methanol or GTL plant would require feedstock of 1-2 BCM, which is an order of magnitude over current production rates, and is not feasible in the short-term. At first glance, power plants would also not be viable. However, gas plants are almost linearly scalable, and the smaller gas-fired power plants require as little as 100 MCM. Increasing production to these levels may be feasible.
   - Urea, methanol and large-scale GTL are not viable.
   - Smaller gas power plants are viable with significantly increased gas production.
   - Gas distribution networks are viable given current production levels.

4. Rwanda's average daily temperature ranges from 18C to 20C, indicating no likely demand for home heating. Average household income in the range of $1000 indicates most households would not be able to afford the connection fees of a gas distribution network ranging from $600 to $1000 (source World Bank, data not included in report). Existing industrial uses for natural gas might include processing of existing ores (including cassiterite, wolframite and coltan) and agri-foods processing (coffee roasting and brewing such as the Bralirwa Brewery) or mass transit (buses).
   - Commercial and domestic gas distribution networks will not be viable.
   - Investigation of industrial distribution may be viable.

5. Rwanda's Gross Domestic Product is around $8B. Looking at capital costs, methanol or GTL plants are in the $1-2B range, and likely could not be supported by the local economy without significant disruption and foreign direct investment.
   - Urea, methanol and GTL are not attractive options.

6. Rwanda has high energy poverty with over 75 percent of the nation lacking access to electricity. This ratio means roughly 10 million out of 12 million Rwandans are without access to power, indicating that while unmet demand may be very high, current transmission and distribution infrastructure is likely lacking.
   - Power transmission and distribution networks would require investment.

7. Rwanda is a land-locked nation and has no sea ports or railway systems. This would preclude large-scale LNG export and would limit export opportunities for export of urea, methanol and GTL. Production of these commodities would have to be on a smaller scale, designated for local consumption.

The table below shows the result of this preliminary screening. Only gas-fired power plants and industrial distribution networks are potentially viable. For the sake of brevity, only power plants will be further explored.

Table 12:
Rwanda Gas Value Chain Screening

Node	Gas Reserves	Gas Production	Capital Cost	Household Income / Temperature	Energy Poverty	Industrial Users	Infrastructure Seaport / Export	Over All Attractiveness
Urea	✓	X	X				X	X
Methanol	✓	X	X				X	X
Power Plant	✓	?	✓		✓			✓
GTL	✓	X	X				X	X
Gas Distribution	✓	✓	✓	X		?		X
LNG Export	X	X	X				X	X
Pipeline Export	X	X	X				X	X

Regarding electricity, the current price of power in Rwanda is $18/MW (World Bank, 2016). The $20/MW pricing range is greater than most plants' breakeven price indicating potential commercial viability. Natural gas prices drive actual economic prices for gas-fired electricity. With power selling at $20/MW, only larger plants will be viable with a maximum gas price of $2.5/GJ. This may be below local market rates. At this low price, substantial economic rent from the natural resource may be unlikely, with gas being delivered at near cost. This suggests that natural gas pricing would not likely be market-based (gas-on-gas competition) and would likely need to be a Bilateral Monopoly (BIM), Netback from Final Product (NET), Regulated Below Cost (RBC) or No Price (NP). For this case study, it is assumed that gas is delivered at cost without economic rent at a cost of $1/GJ, making a 114 MW plant viable.

The capital cost of a 114 MW plant is approximately $180 MM, which represents a significant portion of Rwanda's GDP, but is likely obtainable as a national level project.

Of this, at least $65 MM of equipment would need to be imported, along with $38 MM of labor, leaving no more the $5 MM of local materials, a maximum of $72 MM of local labor, or at least 700 man-years during construction. During operations, the plant would employ about 30 employees with a payroll of about $3 MM. With a price of natural gas of $1-2/GJ, the plant would earn no more than $10 MM annually, providing corporate income of around $3 MM tax-based on Rwanda's 30 percent tax rate.

Rwanda's ability to do business score is ranked 1st within Africa as seen on *Table 8: African Countries with Gas Reserves Ease of Doing Business Ranking*, and a robust 56th globally. In looking at these details, the most difficult aspect of doing business in Rwanda is obtaining construction permits. Rwanda may need to review constraints in the regulatory framework to make a power plant more attractive. The construction time of a typical plant is one to three years, with a breakeven period of 17. Any delays to realizing cash flow would make this project non-viable.

Kigali is Rwanda largest city, with a population of 750,000. The next largest cities, Butare, Gitarama and Ruhengeri, have populations of 80,000 to 90,000. With only 2 million of Rwanda's 12 million people having access to power, this roughly corresponds to the population living in cities, and one would expect power distribution outside of major centres to be very limited. With 280 MW of existing power production, a new plant of 114 MW would almost increase power supply by 50 percent.I It is also very likely that the existing transmission and distribution grid would be inadequate. Given the already marginal economic case for private development of a plant, the power grid would likely require substantial public investment to make a plant viable.[75]

Clearly, this project is on the borderline of independent economic viability, and given the risks, it is unlikely that a private firm would start such a project. The direct economic impact is modest. However the larger potential benefits of increased electricity distribution and consumption within the nation are significant. With this in mind, bringing such a project to fruition may require some form of government participation. This could be in the form of: direct investment; tax relief; infrastructure for a private firm; partnering with a private firm in some form of public-private-partnership, where the government accepts key risks such as demand or transmission; or a special purpose state-owned corporation, such as a utility.

The conclusions of this case study are supported by a paper in the Massachusetts Institute of Technology (MIT) Technology Review (MIT Technology Review, Jonathan Rosen, 2016). Rwanda generates one-third of its 280 MW production from imported diesel and fossil fuels. Domestic production of electricity from natural gas fits well within Rwanda's stated national objectives of quadrupling power production.

75 *With only 280 MW of power in the country, a single world class urea, methanol or GTL plant would not be viable, as these industries require 28-47 MW of power, which is up to 25 percent of existing supply. Even smaller plants based on stranded gas assets would still require 5 to 14 MW, which would likely also excessively tax the electricity grid. Power requirements are shown in Table 4, Table 5, and Table 9. Even if these options were not excluded due to gas reserve and production rates, they would be eliminated due to power constraints.*

References

African Economic Outlook. (2013). African Economic Outlook 2013.

African Economic Outlook. (2014). *African Economic Outlook.*

African Economic Outlook. (2014). *African Economic Outlook 2014*. http://www.africaneconomicoutlook.org/en/.

African Economic Outlook. (2016). African Economic Outlook 2016.

African Fertilzer Organization. (2016). *http://africafertiliser.org/*. Retrieved from http://africafertiliser.org/statistics_glance.html

Agriculture and Agri-Food Canada. (2012, March). *Canadian Farm Fuel and Fertiliser: Prices and Expenses*. Retrieved 2013, from http://www.agr.gc.ca/pol/mad-dam/index_e.php?s1=pubs&s2=rmar&s3=php&page=rmar_04_01_2012-03-00

Agrium. (2015). *Agrium Fact Book*.

Alberta Agriculture and Forestry. (2004, June 1). *Fertiliser Application and Placement.* Retrieved from http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex621

Al-Kasim, F. (2005). *Transparency and Predictablity in Petroleum Management.* http://www.energy.eac.int/eapc2005/pdfs/confrence%20proceedings/East%20Africa%20Business%20Environment/Petroleum%20Sector%20Management/Transparency%20and%20Predictability%20in%20Petroleum%20anagement%20Mr.%20Farouk%20Al-Kasim.PDF. .

Association for the Advancement of Cost Engineering. (1997). 18R-97: *Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries.*

BP. (2106). *BP Statistical Review of World Energy 2016*. http://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf.

Central Intelligence Agency. (2014). *CIA Fact Book*. Retrieved from http://www.indexmundi.com/g/r.aspx?v=139&t=20

Clean Cities. (2014, October See https://cleancities.energy.gov/files/u/news_events/document/document_url/13/ngv_markets.pdf). NGVs Past & Prologue.

Compass International. (2016). 2016 Front-End / *Conceptual Estimating Yearbook, 15th Edition.* Morrisville, Pennsylvania, USA: Compass International.

DaMina Advisors LLP. (2016). Retrieved from http://www.daminaadvisors.com/

David Picard, C. E. (2015). *Fugitive Emissions from Oil and Natural Gas Activities.* http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_6_Fugitive_Emissions_from_Oil_and_Natural_Gas.pdf.

Electropadia. (2016). *Gas Turbine Power Plants*. Retrieved from http://www.mpoweruk.com/gas_turbines.htm

Energy Information Administration. (2007). *Natural Gas Compressor Stations on the Interstate Pipeline Network: Developments since 1996.*

EnergyPeida. (2011). *Fuel Prices Nigeria.* Retrieved from https://energypedia.info/wiki/Fuel_Prices_Nigeria

Extractive Industries Transparency Initiative. (2016). Retrieved from https://eiti.org/

Global Petrol Prices. (2016, November). *Gasoline prices*, liter. Retrieved from http://www.globalpetrolprices.com/gasoline_prices/

Government of Saskatchewan. (2014). *Nitrogen Fertilization In Crop Production.* Retrieved from http://publications.gov.sk.ca/documents/20/84107-eb5d4857-9c2a-4cb9-a6e3-ba55e4c8f137.pdf

Government of South Africa. (2016). *Department of Energy*. Retrieved from http://www.energy.gov.za/files/esources/petroleum/November2016/Basic-Fuel-Price.pdf

Harvard Business School. (2016). *Faculty & Research: Michael Porter.* Retrieved from http://www.hbs.edu/faculty/Pages/profile.aspx?facId=6532&facInfo=pub

IBIS World. (2013). *Agribusiness in the US*.

ICIA. (2015). *ICIC Feertilzer Resources - Trade Flow Map*. Retrieved from http://www.icis.com/resources/fertilisers/trade-flow-map-2015/

IHS Chemical Bulletin. (2016). *The Changing Face of the Global Methanol Industry.* Marc Alvarado.

Index Mundi. (2016, 11 11). *Index Mundi*. Retrieved from Urea Monthly Price US Dollars per Metric Ton: http://www.indexmundi.com/Commodities/?commodity=urea

International Energy Agency. (2014). *Africa Energy Outlook.* http://www.worldenergyoutlook.org/africa/. Retrieved from http://www.worldenergyoutlook.org/africa/

International Energy Agency. (2015). *International Energy Statistics*. Retrieved from EIA Beta: http://www.eia.gov/beta/international/rankings/#?prodact=53-1&cy=2013&pid=3&tl_type=a&v=B

International Energy Agency. (2015). *World Energy Outlook 2015*. http://www.iea.org/bookshop/700-World_Energy_Outlook_2015.

International Energy Agency. (2016). *International Energy Outlook 2016*.

International Energy Agency. (2016). *Medium Term Gas Report, 2016*.

International Gas Union. (2016). *Wholesale Gas Price Survey - 2016 Edition.* International Gas Union.

Jensen, A. (2016).

Methanex. (2016). *Methanex Investor Presentation*.

Methanex. (2016, November 11). *www.methanex.com*. Retrieved from https://www.methanex.com/

Methanol Market Services Asia. (2013). *Methanol MSA*. Retrieved from http://www.methanolmsa.com/

MIT Technology Review, Jonathan Rosen. (2016, April 16). Retrieved from Lake Kivu's Great Gas Gamble: https://www.technologyreview.com/s/536656/lake-kivus-great-gas-gamble/

National Energy Board of Canada. (2016). *Energy Conversion Tables.* Retrieved from https://www.neb-one.gc.ca/nrg/tl/cnvrsntbl/cnvrsntbl-eng.html#s2ss_auto3

Natural Resources Canada. (2016, November). *Daily Average Wholesale (Rack) prices for Regular Gasoline.* Retrieved from http://www2.nrcan.gc.ca/eneene/sources/pripri/wholesale_bycity_e.cfm

New York Merchantile Exchange (NYMEX) CME Group. (2016, November 21). Retrieved from http://www.cmegroup.com/company/nymex.html

Oliver Wyman. (2016). *World Energy Trilemma 2016*. http://www.oliverwyman.com/content/dam/oliver-wyman/global/en/2016/june/2016_Energy_Trilemma.pdf.

OPEC Fund for Inernational Development. (2008). Energy Poverty in Africa. *Workshop proceedings* (p. http://www.ofid.org/Portals/0/Publications/Pamphlet%20Series/ofid_pam39.pdf). Vienna, Austria: OFID.

Ozo-Eson, P. (2013). *Pricing of Pertroleum Products in Nigeria*. http://allafrica.com/download/resource/main/main/idatcs/00090420:6176ff2694df0407b96095a771b69f7d.pdf: Open Society Initiative for West Africa.

Petroleum Research Atlantic Canada. (2004). *Goal Oriented Regulation of Canadian East Coast Oil and Gas Activity.*

PWC. (2015). *From Fragile to Agile: Africa Oil & Gas Review*. PWC.

PWC. (2016). *Choice to change: Africa Oil & Gas Review 2016*. http://www.pwc.com/gx/en/industries/energy-utilities-mining/oil-gas-energy/publications/change-to-change.html.

Reuters. (2015, February 6). *Egypt's energy reforms spark rush of oil and gas deals.* Retrieved from Reuters: http://www.reuters.com/article/egypt-energy-investment-idUSL6N0VF26G20150206

Social License. (2016). *What is Social License*. Retrieved from http://socialicense.com/definition.html

Songhurst, B. (2014). *LNG Plant Cost Escalation*, OIES Paper NG83. Oxford Institue for Energy Studies.

Standard and Poor's. (2011). *Standard & Poor's Ratings Services.* McGraw Hll Financial. Retrieved from www.standardandpoors.com/ratingsdirect

TEPCO, T. E. (n.d.). 1985.

The Economist. (2015, January http://www.economist.com/blogs/economist-explains/2015/01/economist-explains-9). Why solar power is spreading so fast in Africa.

The Economist. (2016, October http://www.economist.com/news/middle-east-and-africa/21709297-small-scale-solar-power-surging-ahead-africa-unplugged). Africa unplugged.

Timera Energy. (2013). *Global gas price differentials.* http://www.timera-energy.com/global-gas-price-differentials/.

Union Gas Limited. (2016). *Annual Report.*

United Nations. (2015). *Human Development Reports.* http://hdr.undp.org/en/2015-report.

United Nations Development Program. (2016). Retrieved from See http://hdr.undp.org/en.

United Nations Development Reports. (2016). *Africa Human Development Report 2016*. http://www.undp.org/content/undp/en/home/librarypage/hdr/2016-africa-human-development-report.html.

US Department of Energy. (2015). Retrieved from https://www.eia.gov/beta/international/rankings/#?prodact=3-6&cy=2015

US Energy Information Agency. (2016). *Transparent Cost Database*. Retrieved from http://en.openei.org/apps/TCDB/

US Environmental Protection Agency. (March 2014). *Greenhouse Gas Reporting Rule.* https://www.gpo.gov/fdsys/pkg/FR-2014-03-10/pdf/2014-04408.pdf: 40 CFR Part 98, Vol.79 No.46.

US Internal Revenue Service. (1998). *Notice 99-18*. Retrieved from https://www.irs.gov/pub/irs-drop/n-99-18.pdf

Waterborne Energy Inc. (2015). *Creating a Global Spot Market in Liquefied Natural Gas (LNG).* http://www.russoonenergy.com/content/creating-global-spot-market-liquefied-natural-gas-lng.

Wikipedia. (2016). *2010 San Bruno pipeline explosion*. Retrieved from https://en.wikipedia.org/wiki/2010_San_Bruno_pipeline_explosion

Wikipedia. (2016). *Common-pool resource*. Retrieved from https://en.wikipedia.org/wiki/Common-pool_resource

Wikipedia. (2016). *Dutch Disease*. Retrieved from https://en.wikipedia.org/wiki/Dutch_disease

Wikipedia. (2016). *Public Interest*. Retrieved from https://en.wikipedia.org/wiki/Public_interest

Wikipedia. (2016). *Resource Curse*. Retrieved from https://en.wikipedia.org/wiki/Resource_curse

World Bank. (2015). *Doing Business*. Retrieved from http://www.doingbusiness.org/rankings

World Bank. (2016, February). *Doing Business*. Retrieved from http://www.doingbusiness.org/data/exploreeconomies/rwanda/getting-electricity

World Bank. (2016). Sustainable Energy for All (SE4ALL) database, Global Electrification database.

World Bank Group. (2015). *CNG for Commercialization of Small Volumes of Associated Gas*. World Bank.

World Bank Group. (2015). *Strategies for Mainstreaming Gender in the Extractives Industries.* https://olc.worldbank.org/sites/default/files/WB_Nairobi_last.pdf. Retrieved from https://olc.worldbank.org/sites/default/files/WB_Nairobi_last.pdf

AFRICAN DEVELOPMENT BANK GROUP

African Natural Resources Centre

Avenue Jean-Paul II -01BP 1387,
Abidjan - Côte d'Ivoire

ecnr_info@afdb.org
www.afdb.org