International Journal of Oil, Gas and Coal Engineering
2022; 10(3): 68-81
http://www.sciencepublishinggroup.com/j/ogce
doi: 10.11648/j.ogce.20221003.11
ISSN: 2376-7669 (Print); ISSN: 2376-7677 (Online)

An Outlook of Oil and Gas Drilling Operations in Kenya – Trends and Challenges

Antony Fundia Simbiri[1], Ogbonna Friday Joel[1], Emmanuel Emeka Okoro[2], Daniel Okang'a Oyoo[3]

[1]World Bank Africa Center of Excellence, Center for Oilfield Chemicals Research, University of Port Harcourt, Port Harcourt, Nigeria

[2]Department of Petroleum Engineering, Covenant University, Ota, Nigeria

[3]Department of Gas and Petroleum Engineering, Kenyatta University, Nairobi, Kenya

Email address:

simbiri.anthony@ku.ac.ke (A. F. Simbiri), emeka.okoro@covenantuniversity.edu.ng (E. E. Okoro), oyoo.daniel@ku.ac.ke (D. O. Oyoo)

To cite this article:

Antony Fundia Simbiri, Ogbonna Friday Joel, Emmanuel Emeka Okoro, Daniel Okang'a Oyoo. An Outlook of Oil and Gas Drilling Operations in Kenya – Trends and Challenges. *International Journal of Oil, Gas and Coal Engineering*. Vol. 10, No. 3, 2022, pp. 68-81. doi: 10.11648/j.ogce.20221003.11

Received: December 15, 2021; **Accepted**: January 15, 2022; **Published**: May 31, 2022

Abstract: In 2012, Kenya has discovered oil deposits that have placed it among the global oil exporters. Huge expectations from this discovery among all the stakeholders have ignited unmatched interest both locally and internationally. The expected socio-economic changes for the nation, however, need to be surgically addressed and assessed. This paper, therefore, aims to explore and assess the drilling division of the upstream sub-sector of the oil and gas industry in Kenya. It analyses the history, exploration, development, and future potential of drilling in the oil and gas industry. To achieve this objective, the article begins by explaining the historical review of oil and gas operations in Kenya, the legal ecosystem of drilling operations, and the drilling operations. Additionally, definitions, types of drilling fluids, and drilling additives are discussed. Finally, the article evaluates the challenges facing oil and gas drilling operations in Kenya and outlines the necessary recommendations for its potential development.

Keywords: Additives, Drilling, Lokichar, Ngamia, Petroleum Act 2019, Rift Valley Tertiary Basin, Waxy Crude Oil

1. Introduction

1.1. Oil and Gas Operations in the World

Oil and gas operations play a crucial role in the global economy. Oil is the world's leading fuel accounting for approximately one-third of the total world energy consumption, [1]. According to the BP Energy Outlook, 2017, the world economy will double over the next 20 years with an annual growth of 3.4% driven by China and India. Oil, gas, and coal will account for more than 755 of energy supplies in 2035, despite the growth of renewable resources. Oil, demand will shoot from 94.4 Mbbl/day in 2015 to 100Mbbl/day in 2021, while gas will overtake coal as the second positioned source of fuel source by the year 2035 with an approximate growth of 1.6% [2].

While many developing and developed nations rich in hydrocarbon resources continue to rely on this sector for growth and revenue, the entire global economy holistically relies on fossil fuels. From the hot and dusty deserts of the Middle East, and the frozen permafrost regions of Russia, to the deep waters of the Gulf of Mexico and the stormy weather, tossed the North Sea near the Arctic, oil and gas companies around the world are tirelessly quenching the ever-growing energy thirst of the world. That oil and gas fuels have been the engine of commerce since the industrial revolution is a well-known fact. The oil and gas industry is among the most complex and strategic industries in the world with a series of upstream, midstream, and downstream operations happening including exploration, drilling, production, refining, transportation, marketing, distribution, and consumption. Of late, however, climate change seems to be the waterloo of the oil and gas industry, with fossil fuels being blamed for contributing hugely to greenhouse gases, (EIA, 2016).

1.2. Oil and Gas Operations in East Africa

After years of operating in the shadows of West and North Africa, East Africa finally is coming of age as one of the

most vital players in the African oil and gas industry. Huge gas discoveries offshore Mozambique and Tanzanian together with large oil discoveries around Uganda's Lake Albert have significantly changed economic attitudes about East Africa, altering it into an attractive destination for extractive industry investments.

Figure 1 shows the number of oil wells drilled in East Africa or from 2000 to 2015.

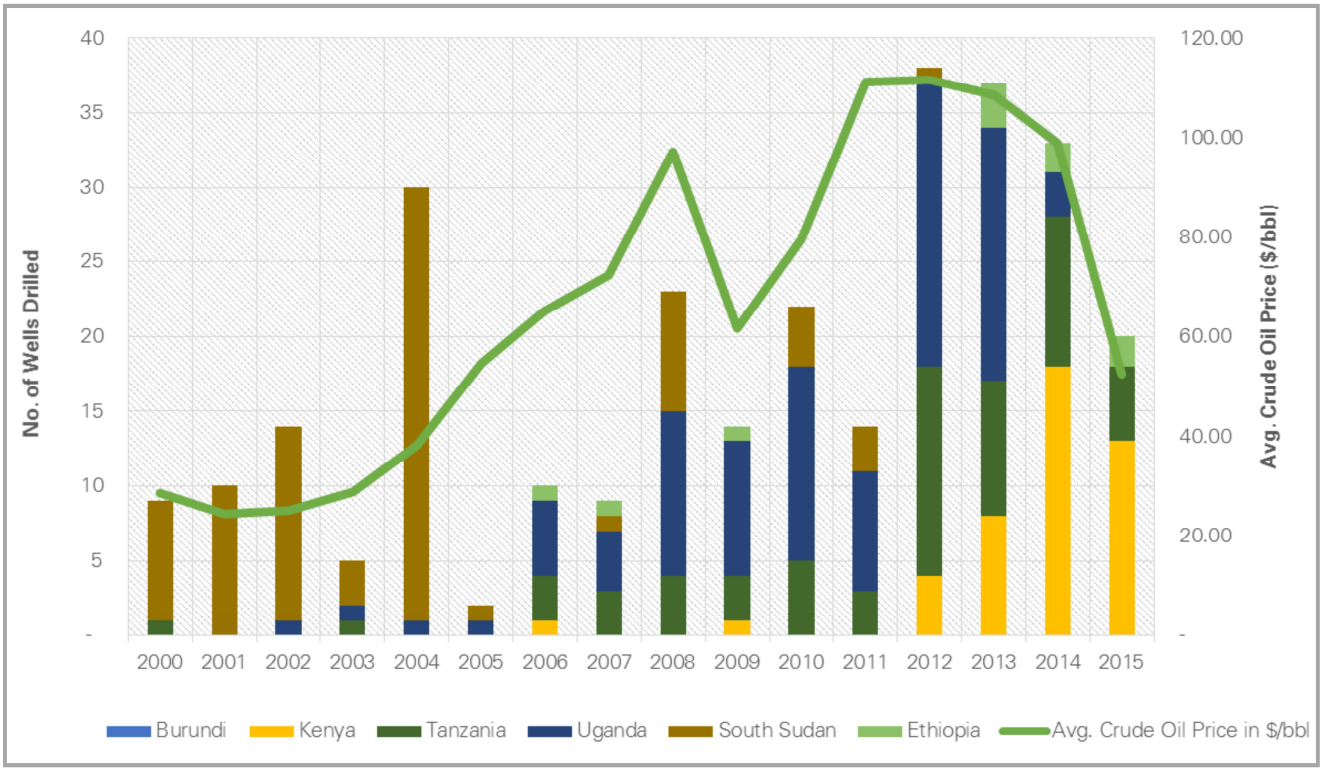

Figure 1. *The number of wells drilled per year in East Africa (2000 – 2015). (Source: BP Statistical Review 2015, Wood Mackenzie).*

1.3. Oil and Gas Drilling Operations in Kenya

Oil and gas exploration in East Africa began in the early 1930s by the British colonialists although they encountered multiple challenges until the 1990s when the first few oil wells were discovered [3]. This was the first wave of oil explorations in Kenya led by Shell and BP. Seismic surveys, gravimetric and aeromagnetic surveys identified Mandera in the East, Anza in the North, Lamu in the South-east which is both offshore and onshore, and the Tertiary Rift basin to the North-west. In 1985, when Kenya established its Petroleum Act, the second wave of explorations began. Total and Amoco led the way with a total of 15 wells. They focused on Anza and Mandera basins, discovered indications of oil and gas, but this had no commercial value.

The third wave and present wave of exploration in Kenya's oil and gas industry came in 2000, after state-sponsored geological surveys in the Tertiary Rift basins and Lamu. Coupled with onshore oil discoveries in 2006 in Uganda [4] and offshore gas finds in Mozambique and Tanzania and prevailing high global prices, a wide array of oil companies swiftly arrived on the Kenyan oil and gas landscape, including Africa Oil, Apache, Anadarko, BG Group, Centric, Cove Energy, Pancontinental, Premier Oil, Simba Energy, CNNOC, Total, and Tullow Oil, (Table 1).

Table 1. *Licensed Petroleum Exploration Companies in Kenya as of June 2014.*

No.	Exploration Companies	Exploration Block Nos	No of Blocks
1	Tullow Oil Corporation	10A, 10BB, 10BA, 13T, 12A & 12B	6
2	Anardarko	L-5, L-7, L-12, L-11A, L-11B	5
3	BG Group	L-10A, L-10B	2
4	Ophir/Dominion	L-9, L-5	2
5	Apache (now withdrawn)	L-8	1
6	Vanoil Resources	3A, 3B	2
7	Africa Oil Corporation		1
8	Zarara	L-4, L-13	2
9	FAR/Flow Energy	L-6	1
10	Lion Petroleum	2B	1
11	NOCK	14T	1
12	Simba	2A	1
13	Afren	L-17/L-18, 1	3
14	A-Z Petroleum	L-1A, L-3	2
15	CAMAC Energy	L-1B, L-16, L-27, L-28	4
16	Rift Energy	L-19	1
17	Imara Energy Corp	L-2	1
18	Adamantine Energy Ltd	11A	1
19	Pacific Seaboard Investments Ltd	L-20	1
20	ERHC Energy Inc.	11B	1
21	Lamu Oil Exploration	L-14	1
22	Total Kenya B. V	L-22	1
23	ENI Spa	L-21, L23, L-24	3

Since late March 2012, when Tullow Oil, a UK-based company announced the discovery of an oil potential of 300 million barrels of oil in Turkana, it rekindled Kenya's hopes of joining the oil-producing group of nations. Since then, Tullow announced a further discovery of 300 million barrels, thus bringing the total commercially viable reserves to 600 million barrels and has a potential for 1 billion barrels (Tullow, 2014). Even though the current discoveries remain limited to the Lokichar area, in Turkana county, Tullow estimates that Kenya could hold as much as 10 billion barrels of oil, [5] (Eduard, 2013). Additionally, indications of slicks on the surface of Lake Turkana and oil seeps on its northern shore suggest that drilling in the lake is yet another potential oil frontier (Figure 2). Profile reports by Tullow Oil Plc (2013, 2014) give insights into its oil exploration activities in Turkana county. In 2013 alone, Tullow spent Kshs 23.4 billion ($23.4 million) on their operations in Kenya, with the bulk of it on Turkana county exploration operations, (Figure 2).

These successful exploration and appraisal drilling activities in the last eight years (since 2012) Kenya have resulted in the oil and gas industry in Kenya, evolving and segmenting into three distinct sections: upstream, midstream, and downstream. While the midstream and downstream sections have a fairly developed economic and technical ecosystem, the upstream is still in its toddler stage. Traditionally, the upstream segment of the oil and gas industry is made up of the exploration, drilling, and production sectors. Despite the low level of drilling and cementing activities in the Kenyan oil and gas industry, in comparison with major world oil and gas producing nations, geothermal drilling has however been ongoing in Kenya. Combined with proven geothermal reserves of up to 10,000MW (GDC, 2018), that need to be drilled, oil and gas drilling in Kenya is an area for more intense research.

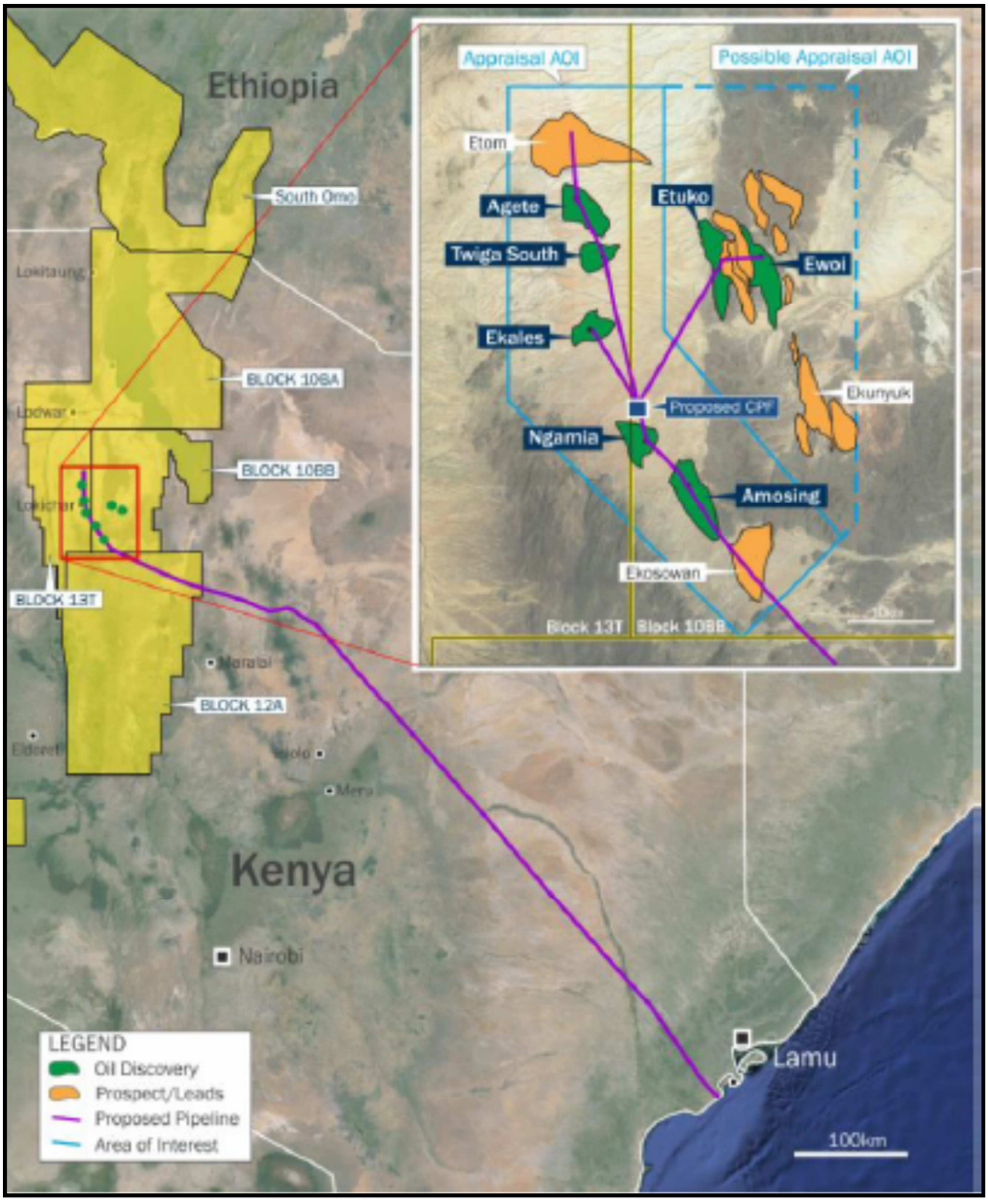

Figure 2. *Turkana county oil development projects. (Source: Tullow, 2014).*

In 2012, Kenya discovered commercial amounts of oil deposits at Lokichar, Turkana county, northern Kenya. Oil and gas production in Kenya, therefore, is a new industry with much to be learned. Although the downstream and midstream sectors of the oil and gas industry have been operational for some time now, the upstream sector has just been born. Consequently, what is challenging now is the insufficient information on upstream operations like drilling and cementing of oil wells in this new industry. Best practices in well-developed oil and gas industries in other countries e.g. Nigeria show the use of readily available local materials as components of additives of drilling fluids and oil cement, which consequently reduced the CAPEX cost of oil production. The need to investigate and understand concepts and principles of petroleum production like drilling fluid additives and cement slurry additives is now more appropriate than ever before.

Case studies in the oil and gas industry in different countries show that additives of drilling fluids and cement slurries in oil wells improve rheological properties (Alcheikh, 2017). Starch is one of these additives which serve as a viscosifier and fluid loss control agent. However, the evaluation of different starches, more specifically, cassava, on the rheological properties of drilling fluids and cement slurries remains an area of low academic research activity in Kenya. The wide availability of cassava and its abundance make it an attractive potential source of starch. More specifically, fundamental questions like the effect of the particle sizes of different additives on their performance in oil drilling fluids and oil cement slurries are unanswered.

2. Oil and Gas Drilling Laws in Kenya

Kenya as a nation has several legal and regulatory instruments meant to govern the oil and gas industry. From the mid-1990s when the Electric Power Act of 1997 was enacted, the Energy Act of 2006 followed later. Energy Act of 2006 assembled all the legislation affecting the energy sector and set up the Energy Regulatory Commission (ERC) as the only statutory regulator of the energy sector. To further unbundle the energy sector, energy policies were laid out in the Sessional Paper Number 4 of 2004. This lays the foundational policy framework of the provision of quality and sustainable energy services, cost-effective, affordable, and adequate to the Kenyan economy from 2004 to 2023. The specific objectives outlined include:

1. Enhancing security of energy supply.
2. Promoting the development of indigenous energy resources.
3. Providing sustainable quality energy services for development.
4. Providing energy efficiency and conservation as well as prudent environmental, health and safety practices.
5. Providing an enabling environment for the provision of energy services.
6. Utilizing energy as a tool to accelerate economic empowerment for urban and rural development.
7. Improving access to affordable energy services.

2.1. Kenya Vision 2030

This is a new long-term development blueprint for the nation. The aim of Kenya Vision 2030 is to set up, "A globally competitive and prosperous country with a high quality of life by 2030." On energy, it prioritizes the growth of energy generation and increased efficiency in energy consumption. The Vision outlines goals that must be pursued to achieve necessary institutional reforms including acceleration of infrastructure development, focusing on quality, aesthetics, and functionality of the infrastructure services developed, building infrastructure development to support identified flagship projects to ensure contribution to the economic growth, and social equity goals.

2.2. Oil and Gas Sub-Sector

2.2.1. Petroleum Act

Unlike the other component of the Petroleum Act, 2019, which are explicitly detailed on how firms should operate, the drilling aspect remains hazy in this Act. The need for a robust legal framework by the Kenyan government remains vital in this sector [6]. As per his observation, this would go a long way in averting the perennial, 'resource curse' that has bedeviled many nations across the globe.

2.2.2. International Standards and Best Practices in the Oil and Gas Industry

The International Finance Corporation (IFC) and World Bank Group (WBG) have developed guidelines and policies, performance standards, and directives for use globally in the extractive industry, oil and gas included. The eight IFC Performance Standards (PS) on Social and Environmental Sustainability are meant to manage social and environmental risks and impacts and are as follows:

1. PS1 (Assessment and Management of Environmental and Social Risks and Impacts).
2. PS2 (Labour and Working Conditions).
3. PS3 (Resource Efficiency and Pollution Prevention).
4. PS4 (Community Health, Safety and Security).
5. PS5 (Land Acquisition and Involuntary Resettlement).
6. PS6 (Biodiversity Conservation and Sustainable Management of Living Natural Resources).
7. PS7 (Indigenous Peoples).
8. PS8 (Cultural Heritage).

2.2.3. Local Content in Oil and Gas Industry in Kenya

IPIEC[1] defines 'local content' as the added value brought to a host nation (or region or locality) through (i) workforce development, namely employment and training of local workforce; (ii) investments in supplier development, namely

1 International Petroleum Industry Environmental Conservation Association (IPIECA) – the global oil and gas industry association for environmental and social issues.

developing and procuring supplies and services locally while Grossman (1981) defines the local content program as, "a given percentage of domestic value-added or domestic components be embodied in a specified final product". Melo et. al (2006) emphasize that local content program is viewed as a form of productive development policies whose aim is to "strengthen the productive structure of a particular national economy". They are therefore designed to increase local participation in foreign direct investment by channeling the utilization of native companies in goods and services procurement, employment of locals, and the use of local raw materials by investors.

Table 2. *Legal Framework on Local Content.*

Law/Policy	Relevant Provisions on Local Content
Current Legal and Regulatory Provisions	
Constitution of Kenya, 2010	Article 66 (2) mandates Parliament to 'enact legislation ensuring that property investments benefit local communities and their economies.' Article 69 (1) also requires the State to 'ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits', and to 'utilize the environment and natural resources for the benefit of the people of Kenya.' Local Content requirements are essentially meant to give effect to these constitutional requirements.
Petroleum Exploration, Development and Production (Local Content) Regulations, 2014	The Regulations require foreign companies to give Kenyan citizens first consideration for employment and training in any upstream petroleum project executed by them. First considerations must also be given to locally available goods and services. The Regulations adopt a quantitative approach to Local Content by specifying the minimum Local Content targets that upstream petroleum operators must meet from the date of effectiveness of license or petroleum agreement (see the table below), as well as levels to be achieved in areas such as engineering, fabrication and construction, materials and procurement, well drilling services, R&D, Exploration, subsurface, petroleum engineering and Seismic services, transportation, supply, and disposal services. Item / Start / 5 Years / 10 Years 1 Goods and Services / 10% / 50% / 60%-90% Recruitment and Training 2 Management staff / 30% / 50%-60% / 70%-80% Technical staff / 20% / 50%-60% / 70%-80% Other staff / 80% / 90% / 100% (Source: First Schedule of the Petroleum (Local Content) Regulations 2014)
Petroleum Act (2019)	Further, to be qualified to enter into a petroleum agreement or get a petroleum license, a petroleum entity must ensure a 5% equity participation of an indigenous Kenyan company other than the National Oil Corporation. Foreign companies seeking to provide goods, works, or services to entities engaged in upstream petroleum operations are required to incorporate joint ventures with indigenous Kenyan companies and afford them the participation of at least 10% of equity or contract value. PART VI—LOCAL CONTENT AND TRAINING 50. (1) A person carrying out any undertaking or works under this Act shall (a) comply with local content requirements in all operations; (b) give priority to services provided and goods manufactured in Kenya where the goods meet the specifications of the petroleum industry as prescribed by the Kenya Bureau of Standards or in absence of a Kenyan standard any other internationally accepted standard that the Authority shall approve; and (c) ensure that priority is given for the employment or engagement of qualified and skilled Kenyans at all levels of the value chain: Provided that the cost of local content shall be at the prevailing market rate. (2) For the purpose of subsection (1) the contractor shall before engaging in petroleum operations prepare and submit a long-term and annual local content plan which corresponds with the work program to the Authority for approval. (3) Without limiting the generality of subsection (2), a local content plan shall address – (a) employment and training; (b) research and development; (c) technology transfer; (d) industrial attachment and apprenticeship; (e) legal services; (f) financial services; (g) insurance services; (h) succession plans for positions not held by Kenyans; (i) consultancy services; (j) construction services; (k) hospitality services; (l) transport services; (m) security services; (n) clearing and forwarding services; (o) Inspection services; and (p) other goods, works, and services as may be prescribed in the regulations. (4) The Cabinet Secretary may make Regulations regarding local content in petroleum operations.

(Source: Author, 2021).

2.2.4. Definition of "Local"

LCPs can aid local companies to integrate themselves into the worldwide economic networks. In the 1990s, both local and state support to local development assisted East Asian

companies to attain tremendous positions in the global trade networks. LPC's can contribute to the productivity and competitiveness of domestic firms through knowledge transfers [7]. On the other hand, local content programs help to correct market failures which happen, "when there is a distortion that keeps the market from allocating resources efficiently and adjusting to a steady-state, the consequence being, "domestic industries cannot gain the necessary technology and capacity to compete on the open market without outside intervention and protection [8, 72]. Whitfield (2015) suggests that many industrialized nations used economic policies akin to LPCs to lift their domestic economies while in the early stages of their industrial development.

Several authors have sought to understand local content issues in the oil and gas industry in Kenya [9-12]. They observe that there is a relationship between local capabilities, local employment, training of the local workforce, domestic sourcing of goods, infrastructure, successful implementation of local content policies, and operational efficiency of oil and gas firms. Their conclusions include that firms have moderately initiated, adopted, and implemented provisions of local content policies and that these policies have the potential of improving sustainable local development despite numerous challenges and therefore, there is a need for the development of a clear policy framework on local employment as part of local content policies.

Likewise, in their Paper No. 2 (2018), the Kenya Extractives Policy Dialogues, content that Local content has become a crucial issue, the basis being to encourage the use of local labor, goods, and services are different stages of the oil and gas value chain in Kenya [13]. However, lack of specialized or technical skills and poor infrastructure pose significant challenges for Kenyans to obtain the greatest benefits in terms of local content from the oil and gas resources.

In Table 2, the relevant provisions on local content are shown.

3. Upstream – Drilling

3.1. National Oil Company of Kenya (NOCK)

Globally, most governments have set up national oil and gas companies that operate oil and gas operations in their nations on behalf of their governments, [14]. In Kenya, the National Oil Corporation of Kenya plays this vital role. The National Oil Corporation of Kenya, formed in 1981, is a fully integrated State Corporation involved in all aspects of the petroleum supply chain covering the upstream oil and gas exploration, midstream petroleum infrastructure development, and downstream marketing of petroleum products.

In drilling, National Oil facilitates and directly participates in oil and gas exploration and drilling activities in Kenya. As a facilitator, National Oil is tasked with the marketing of Kenya's exploration acreage, management of gas and exploration data, and the running of the National Petroleum Laboratory among other attendant responsibilities. National Oil is among the few African national oil companies directly involved in the search for oil and gas. National Oil operates its exploration acreage in Block 14T which is located within the Tertiary Rift Basin and runs from the shores of Lake Bogoria down to Lake Magadi Basin on the border of Kenya and Tanzania. National Oil is currently setting up a Seismic Processing Center and a Geochemical-Petrophysical analysis laboratory within the new premises in Kawi House, South C, Nairobi.

Worldwide, many national oil companies are evolving not only into joint venture partners with global major oil firms but are increasingly becoming competitors to the international oil companies [14]. Many NOC's are now more active in mergers and acquisitions (M & A), thereby increasing the number of NOC's seeking international upstream and downstream acquisition and asset targets. This growing trend has seen the shift of the balance of control over most of the world's hydrocarbons resources. In the 1970s NOCs controlled less than 10% of the world's hydrocarbon resources, while in 2012, they control more than 90%. This has enabled the NOC's to increase their ability to access capital, human resources, and technical services directly and to build in-house competencies.

3.2. Drilling

Oil drilling is the process by which tubing is bored into the Earth's surface and a well is set up. A pump is connected to the tube and the oil and gas under the surface is forcibly removed from the underground. During oil and gas drilling, various drilling fluids are utilized mainly to provide several functions [15-18]. These include:

1. Lubrication and cool the drilling bit.
2. Hydrostatic pressure control.
3. Geology and lithology data information mining.
4. Transport cuttings to the surface.
5. Preserve wellbore stability.
6. Minimize formation damage.
7. Minimize risk to personnel, the environment, and drilling equipment.

A drilling fluid is defined as the fluid that entwines all the compositions used to help in the production and removal of the cuttings from a borehole in the Earth, [16]. On the other hand, the American Petroleum Institute (API) defines the drilling fluid as a circulating fluid used in rotary drilling to perform any or all of the various functions required in drilling operations, [19]. Drilling fluids have traditionally been categorized based on their principal component into water, oil, and gas base drilling fluids, [20]. At this point, it is crucial to point out that the functionality of drilling fluids depends much on drilling fluid properties [20]. Since drilling fluid is a critical ingredient of the oil and gas CAPEX [73], the selection of appropriate drilling fluid additives for optimal drilling fluid properties, [69], is critical for successful drilling. Furthermore, drilling fluids can as well be defined as a complex fluid that consists of a multitude of

additives, or as all compositions that are used to remove the cuttings from a borehole, [71].

So far, most of the drilling in Kenya has been for geothermal resources and more so in the Tertiary Rift Basin, [21-23]. These studies highlight the need for cement classes A and G to be manufactured to be API standards and the addition of silica flours in the design of cement slurry for prevention of strength retrogression in the elevated temperatures encountered in geothermal wells and the need for controlled directional drilling using computer programs. In addressing these pertinent issues, however, the issue of drilling wastes disposal is sourly missing.

Further, the high matrix compressive strength, rapidly changing and complex lithology, abrasive, fractured, and high temperatures of around 350°C of the subsurface formation of Tertiary Rift are reported, [23]. Consequently, this study notes on the numerous challenges encountered in drilling operations including total loss of circulation, low penetration rate, high-temperature damage of directional drilling steering tools and mud motors, breakdown of drilling foam structure at high temperatures, high drilling string torque, loss of cement slurry and many others. These scholars assert that by integrating conventional oil and gas drilling technology, implementation, and air and foam drilling technology, it is possible to solve the loss of circulation problems, improve on hole cleaning and cutting recovery and consequently improve the penetration rates.

Furthermore, they allege that the application of directional drilling technology has produced wells that reach a greater portion of the reservoir by intersecting more fractures increasing geothermal good productivity. Through proper bit selection, improved hole cleaning efficiency, reduced drill string torque, the penetration rate improved, and also reduced total days per well. A total of fifty-seven (57) geothermal wells have successfully been drilled between May 2007 and April 2012. The drilling operation has been 100% successful with wells being 98% productive. Conclusively, the report authors state that this integrated high-temperature geothermal drilling technology can be implemented in the entire East African Great Rift Valley system for geothermal resources development.

These drilling fluids are selected in accordance with reservoir pressure, temperature, and the drilling technique being utilized. The main types of oil and gas drilling fluids are water-based mud, oil-based mud, and synthetic-based mud. Specialized aerated and foam drilling is also techniques that are widely deployed in oil and gas drilling. Subsequently, due to the readily available information and data on geothermal drilling operations in Kenya, a brief overview of it is instructive in this paper.

The examination of geothermal drilling fluids deployed in Olkaria well 38 (OW-38) located in Naivasha sub-county, Nakuru county, Kenya exhibited serious loss circulation, [71]. Using GWDC 120 (Great Wall Drilling Company), the well was drilled to a depth of 3000m. It was drilled using aerated water and foam and water-based mud as drilling fluids at different sections of the well and the daily losses. This data was extracted from the daily drilling reports and is shown in Table 3.

Table 3. *Summary of Olkaria Well 38 Drilling Fluids and Losses.*

Hole Size	Bottom Hole Assembly	Casing Size	Depth	Casing Depth	Drilling Fluid	Losses
26″	26″ Bit, 1 sub, 1 STB, 3 X 8″ DCs, X/O and 5″ DPs	20″	63 m	62 m	Mud (10.7-42 m) at 50 l/s. Water (42-63 m, at 70 l/s	Total loss at 42 m. Drilled blind with water.
17½″	17½″ bit, 1 STB, 2 subs, 3 X/O, 9 X 8″ DCs, and 5″ DPs	13 ⅜″	306.45m	305.5 m	Water at 65 l/m	The loss was not measured (circulation returns at about 80%).
12¼″	12¼″ bit, 1 STB, 1 sub, 3 X/O, 9 X 8″ DCs and 5″ DPs.	9⅝″	753 m	751.7 m	Water (292.3-334 m) at 60 l/m. Aerated water and foam (334 m – 753) at 60 l/s.	Lost circulation at 334 m and switched to aerated water and foam. The loss was not measured when drilling with aerated water and foam
8½″	8½″ bit, 1 STB, 2 subs, 3 X/O, 15 X 6½″ DCs, and 5″ DPs.	7″ (liners)	3000 m	3000 m	Drilled out cement using water (686-787 m), at 60 l/s. Aerated water and foam (787- 3000 m), at 55 l/m.	Total loss between 1403 and 2562 m

(Source: Sichei, 2011).

Table 4. *Summary of Basins and Wells Drilled in Kenya.*

No.	Basin	Area (Km^2)	Drilled Wells	Ave. Sediment Thickness
1	Tertiary Rift	105,673	34	40,000
2	Anza	81,319	15	10,000
3	Mandera	43,404	2	10,000
4	Lamu	26,100	19	12,000

(Source: MOPM, 2019).

Oil drilling firms in Kenya don't have to reinvent the wheel. The Turkana oil reserves lie in the same Tertiary Rift where the geothermal resources are located. The lessons learned from the many years of geothermal drilling can be replicated in the oil drilling in the entire Tertiary Rift where most of the oil blocks are located. Drilling fluid loss emphatically stands out as a major challenge, possibly due to the numerous faults in the Tertiary Rift, thus highlighting the

need for special drilling fluid loss additives, advanced tools, and technologies, [24]. The estimates of a World Bank Report (2013)[2] put the cost of drilling a single oil well in Turkana at $574 million while the same in India costs $57.4 million. With these astronomical CAPEX figures, it remains a mystery how Africa Oil will recover its initial investment. However, despite this, other IOC's are busy drilling both onshore and offshore,[3]

Similarly, the drilling of oil and gas involves the generation of drilling waste, which forms a major source of pollution in the environment. In studying how to dispose-off drilling wastes, many factors come into play. Cost is only one among several factors that need to be taken into account when choosing the best technology for drilling waste management; other factors include the local environment, safety aspects and, the relevant regulatory framework, [25, 26]. The materials are discharged in various forms into the environment thus polluting it. A management approach through solids control, slim-hole drilling, and mud system monitoring should be adopted during drilling waste generation, [27]. Further, an emphasis on the treatment and disposal of oil and gas drilling waste using burial, land farming, thermal treatment, slurry injection, and bioremediation is advocated. This approach is similar to the conclusion that technologies like directional drilling, slim-hole drilling, coil-tubing drilling, and pneumatic drilling as possible avenues of generating substantially fewer amounts of drilling waste, [28].

In reviewing the current options for the treatment and safe disposal of drill cuttings, comparison of bioremediation technologies and non-biological technologies for the treatment of contaminated drill cuttings, new design layout, operating principles, equipment, and planning for new wastewater management are presented as crucial, including corral systems, drying-shaker, and auger, [25, 29].

During drilling, it is not just the drilling solids that pose danger to the environment. Rather, a large volume of fluids is circulated through the well and into open, partially enclosed, or completely enclosed systems at elevated temperatures, [30]. When these drilling fluids are agitated during the circulating process there is significant potential of the drilling fluid being discharged to the environment. Drilling discharge affects the marine environment, thereby affecting fishing activities which is the major occupation among the coastal communities, [31].

For instance, on the question of drilling waste in Nigeria, studies show that the concentrations of total dissolved solids (TDS), salinity, total suspended solids (TSS), biochemical oxygen demand (BOD), Chemical Oxygen demand (COD), Pb, and Fe^{3+} were made less harmful after thermal desorption process and hence fit for disposal, reuse, or recycle after environmental evaluation and biodegradability [32, 33].

The estimated accumulation of drill cuttings ranges within 130 to 560m^3 per well [27] which contain the following potential constituents:

1. Waste lubricants: heavy metals, organic compounds.
2. WBM cuttings: heavy metals, inorganic salts, biocides, hydrocarbons.
3. OBM cuttings: heavy metals, inorganic salts, hydrocarbons, solids/cuttings.
4. Spent OBM: heavy metals, inorganic salts, hydrocarbons, solids/cuttings, BOD, surfactants.
5. Spent WBM: Metals including heavy metals, inorganic salts, hydrocarbons, biocides, hydrocarbons, solid/cuttings BOD.

Anthracene, Arsenic, Chromium, Copper, Diuron, Flouranthene, Naphthalene, Nickel, Phenanthrene, Pyrene, and Zinc are environmentally significant chemicals present in drilling wastes that pose an eco, [34-36]. According to the European Union Waste Framework Directive 2008/98/EC, drilling hazardous waste is classified into List I and List II. A similar legal ecosystem is simply absent in Kenya.

Biodegradation of oil pollutants is new as an increasingly effective and potentially inexpensive clean-up technology, [33]. Additionally, solid wastes that are properly treated, can serve as raw materials for cement producing plants, bricks, and expanded clay-producing plants and can also be used in land restoration projects. These approaches were also advancements in the disposal and reuse of drilling solid waste from a massive gas field [23].

In researching on drill cuttings and fluid disposal in Kenya, the choice of the method of disposal is largely determined and affected by the government policy and also by economic, technical, and operation conditions and barriers, [37]. Additionally, the methods of disposal include injection, thermal treatment, bioremediation, and land application. Conclusively the paper suggests that it is better if Kenya can pass its laws to regulate disposal in the future.

Drilling remains one of the major chemical-intensive operations in the oilfield and has a significant source of chemical exposure and subsequent health effects, [38, 39]. Apart from ensuring proper disposal of drilling wastes, the drilling operations in Kenya need to have proper occupational and safety measures in place for their workers.

In determining the occurrence of occupational physical injuries among workers in onshore oil drilling operations in Turkana County, Kenya, a study shows that among the sampled workers, 9.8% had experienced occupational physical injuries, [40]. The research study further reveals that an equal proportion (18.75%) of the respondents missed either 1-7 days or more than 1 month due to occupational injuries. The work shows that workers in onshore oil drilling operations in Turkana County, Kenya were affected by physical injuries with the most common types being lacerations and cuts. Fingers and wrists were the commonly affected body parts. The number of days workers miss work due to the reported occupational physical injuries is an important injury severity metric in terms of the direct and indirect costs incurred. It is therefore critical that oil drilling workers should be protected from occupational physical injuries that are at risk of disability and fatalities. This

2 World Bank Report (2013)

3 Offshore Staff Journal, 10th September, 2012

position is upheld by Wasunna[4] et. al (2018) in exploring what Kenya needs to do to better protect those working in the oil sector.

Drilling Additives

Drilling fluids are critical to drilling success, simultaneously maximizing recovery and minimizing the duration it takes to achieve the first oil. Since the mud system represents one of the greatest ingredients of CAPEX, minimizing its cost and ensuring smooth and efficient drilling operationally means continuous main logical chronic concern once of the fluid properties throughout the drilling program. Some additives even perform more than one traditional role, [41]. Even more vital is when high temperature and high pressure are encountered during drilling, catalyzing the degradation of drilling fluids. To counter and maintain these properties, special additives are usually added to the drilling fluids to significantly drilling parameters like lost circulation, filter cake formation, wellbore hydraulics, fluid stability, rate of penetration, and hole cleaning, [42-48].

Drilling fluid additives, therefore, include: viscosifiers, filtration control additives; Ph/alkalinity control chemicals, lost circulation material (LCMS)/bridging agents, dispersants/deflocculants/thinners, weighting materials, shale inhibitors, surfactant and emulsifiers, corrosion inhibitors/oxygen scavengers'/hydrogen sulfide scavengers and lubricants.

4. Challenges

4.1. Environment

The oil and gas industry is known to consume colossal amounts of water during its operations, even during drilling. Spent drilling fluid, produced water and drill cuttings, each unique from the previous one in terms of characterization and composition. In the European Union for, instance, Waste Framework (WFD), new legislations have been implemented in the EU member nations including the United Kingdom for recycling of wastes to prevent and reduce landfilling of waste, [49]. In Kenya, this role, according to NEMA, waste management is mostly the responsibility of county governments[5].

However, these authorities have neither prioritized this duty nor allocated sufficient resources for effective implementation. Even more worrying are cases where some of the community members are using used chemical containers to store water during droughts! And so poor waste management which includes indiscriminate dumping, uncollected waste, and lack of waste segregation is occurring across Turkana county and the entire nation.

Simiyu et. al (2016) explore the health, safety, sustainability, and social responsibility during disposal of cutting and drilling fluids in Kenya regarding to what affects the choice of method of disposal, the Kenyan government's regulatory requirements on disposal of the drilling wastes, methods of addressing drilling wastes, ways of reducing the volume of wastes, the hierarchy of drilling wastes and the pros and cons of various methods of addressing drilling wastes. The study concludes that the choice of method of disposal is determined and affected largely by the government policy and also by economic, technical, and operational conditions and barriers. Assessed methods of disposal included injection, thermal treatment, bioremediation, land application.

4.2. Capacity Building

Morendat Institute of Oil and Gas (MIOG) - It is sponsored by Kenya Pipeline Company Ltd and was created in 2014 to offer capacity building to support the Northern Corridor Integration Projects (NCIP). The Institute offers competency-based training in oil and gas pipelines management, operations, and maintenance to develop human resource capacity for partner states (Kenya, Uganda, Rwanda, and South Sudan). MIOG being a vocational education and training institute falls under the Directorate of Technical and Vocational Education and Training (TVET) and is required to comply with the Kenyan TVET Act and related rules and regulations. To ensure training is linked to industry requirements in the oil & gas sector, MIOG provides training addressing the midstream segment of the oil and gas value chain. The courses currently offered include oil pipeline mechanical maintenance, oil pipeline laboratory technology, pipeline instrumentation, and control maintenance, pipeline operations course, and firefighting.

Through the Science, Technology, and Innovation Act – 2013, a platform for partnership initiatives like Linking Industry with Academia (LIWA) – a regional forum that seeks to create and institutionalize linkages between academia (universities, research institutions and TVET's), industry and government in areas of research, science, innovation, skills, and technology. Currently, two public universities and one private university are offering petroleum engineering courses. However, even these best-intended efforts are largely hampered by a lack of modern laboratory facilities, insufficient faculty, and inadequate exposure to the latest oil and gas industry technical software packages. In a rare incident, Bentworth Ltd, an oil-well cementing firm, sponsored an engineering student whose research work was on the use of local bentonite in oil-well cement operations,

Since 2016, UNEP and the Norwegian government have been collaborating in capacity building and empowering the environmental management entities of fourteen nations globally, Kenya included[6]. This is under Norway's Oil for Development Program and UN –the Environment for Oil Development Partnership. However, this is not enough. More on risk assessment needs to be done, apparently with the World Bank supporting a consultant to work with KRA in developing a risk matrix for the oil and gas industry. Additionally, it is funding the development of a database to

4 Melba K. Wasunna and Laura Muniafu, "What Kenya needs to do to better those working in the oil sector". October 24, 2018.

5 National Environment Management Authority, The National Solid Waste Management Strategy, 2015. 15 Id.

6 UNEP, 2016.

which oil companies will be able to upload real-time data to enable trend analysis[7], even though this isn't being adhered to by the IOC's.

4.3. Information Gap

Even though the Petroleum Act 2019 is a clear that, "contracts, permits, concessions, and licenses issued thereunder must be made public and a provision within the Act to that effect must be included and any perpetrator brought to book for failure to comply. The ministry has formulated, under section 119 of the Petroleum Act, a framework for reporting, transparency, and accountability in the upstream petroleum sector[8]" it remains on paper. For instance, in the US, Haliburton monitors the drill count[9] every week, serving the public at large, from potential investors to stern state regulators to young budding engineers. This is contrary to what is transpiring in Kenya, as regards oil and gas industry data. In Kenya, however, even the KNBS has no idea what the Kenyan drill count is.

The Kenyan government has signed at least 44 contracts with oil and gas companies, [50]. However, of these contracts, only 10 have been made public. The lack of disclosure of contracts denies a key oversight mechanism. While Tullow Oil has expressed support for contract disclosure, the government refuses to take this step. Even more, awakening is the fact that the state has declined to join the Extractive Industry Transparency Initiative (EITI) while at the same time claiming to support the Open Government Partnership (OGP), an initiative to improve transparency and reduce corruption, by enhancing openness and accessibility of the Public Procurement Information portal. This lack of detailed information is confirmed[10] apart from the data availed by the Petroleum Master Plan, funded by the World Bank and prepared by Price Waterhouse Coopers. On the other hand, the oil and gas industry firms are reluctant to upload their information to the Upstream Integrated Economic Planning System, which avails first-hand real-time information to state agencies in the oil and gas industry.

4.4. Resource Curse

Therefore, oil drilling in Turkana can lead to community greed for enrichment and grievances about social exclusion, relative deprivation, and inequalities like ethnic divides, [51] which can lead to amplified conflict [52]. This was witnessed[11] in 2020 when the Early Oil Pilot Scheme began to transport crude oil in iso-heated road tankers from Lokichar to Mombasa. Consequently, these theories call for well-designed resource management and benefit-sharing for inclusive development.

Nigeria's oil wealth, for instance, triggered massive urban migration, which drastically reduced the size of the rural labor force [53]. This in turn led to a fall in production and therefore a rise in food prices. A similar projection upon Kenya would be disastrous: 70% of Kenya's labor force jobs routinely be a risk as agricultural products would become very expensive for the global market and any job losses would only add to the current 40% unemployment. This in turn would force the state to support a huge unemployed population, at a time of rising food prices.

Resource curse mechanism can be generalized to conflicts over distribution, manifested in rent-seeking [54-57]. Despite the curse and disease originating from sudden resource wealth, they can propagate differently in form of problems. Having noted this, it remains to see how the Kenyan government will swallow the vaccine for this disease.

4.5. Security

Globally, security has been one of the most common challenges facing the oil and gas industry. This is due to the substantial change that communities have to undergo once oil or gas has been discovered. Land loss and other insecurities may intensify with oil extraction [58], igniting civil conflict with the Pokots. Insecurity has further increased because of the perceived unfair distribution of wealth and job opportunities; the new roads benefiting cattle rustlers; and because former community guards and the Kenya Police Reservists are now protecting Tullow Oil instead of the community.

The social, cultural, political, environmental, and security implications of oil and gas operations in Turkana impact conflicts, tensions, company and community flare-ups which may be catalyzed into full-blown violent confrontations due to the high prevalence of illegal small arms, unmet expectations, unfulfilled aspirations, suspended promises, perceived injustice and failed dreams unless quick and preventive measures are taken [59-66].

And these oil and gas confrontations are not limited to the internal boundaries of Kenya, but rather have spilled to the international arena, where Kenya withdrew from an important hearing at the International Court of Justice (ICJ) on its maritime boundary dispute with Somalia[12]. The dispute centers around a triangular piece of the maritime area believed to have oil and gas reserves. Therefore, if Kenya is to become the transit hub of East Africa's oil boom, then relative stability and security are paramount matters that must be tackled in the entire Northern frontier regions, [70].

4.6. Legal and Regulatory Framework

Current environmental legislation has gaps, revealed by evaluating the law and practice on environmental protection

7 World Bank, Kenya Petroleum Technical Assistance Project (KEPTAP). Projects and Operations (Washington, DC, 2016), http://projects.worldbank.org/procurement/noticeoverview?id=OP00038439&lang=en&print=Y; interview with Ministry of Petroleum and Mining, 23 April 2018

8 Extractives Baraza, Strathmore University, 2020

9 Haliburton Drill Count

10 Discussion paper, (Kenya Civil Society Platform on Oil and Gas, Resources for Development Consulting and Cordaid/Timu-Community Development Associates, 2016).

11 Hesboun Etyang, Star Newspaper, 27th June, 2018, the-star.co.ke/news/2018-06-27-no-oil-will-leave-turkana-without-security-and-jobs-protesters-say

12 Iain Esau, Business Daily, 18th March, 2021

during exploration and production of oil and gas in Kenya [67].

In assessing transparency in the management of oil and gas blocks, if only the Kenya legislative framework, would have a transparent licensing regime on oil and gas blocks, this would diffuse avenues of corruption and potential conflict between the community and the IOC and or the state. The study suggests that the powers of the Cabinet secretary in charge of oil and gas should be trimmed to minimize the effect of the slippery slope that such arbitrary power hide. Additionally, it recommends the definition and introduction of a clear-cut procedure for calling and conducting bidding rounds to breathe certainty into the system and promote transparency, proposes that in the absence of competitive bidding powers for direct negotiation be vested in an independent authority. The study, therefore, encourages the National Assembly to legislate on the same to enable the state to maximize benefits from the extractive industry.

5. Recommendations

This paper has therefore explored the drilling sub-sector of the oil and gas industry in Kenya. And indeed it has shown that this industry can either shape the Kenyan citizen to very high standards of living or shove an entire generation into the gallows of poverty reminiscent of the African continent. It is thus, without prejudice, recommend the following measures as vitally appropriate:

a) The academic research field in the drilling of the oil and gas industry in Kenya is virgin and green. From the classification of drilling wastes, innovation of new bio-additives to the application of nanotechnology in the nascent oil and gas industry, the range and array of novel research in this field is unparalleled.
b) With the onset of climate change, proper and adequate environmental adherence, supervision, and mitigation measures should be adopted by all stakeholders to benefit society, without the risk of stranded assets.
c) Quality investments should be done in the training institutions to produce knowledgeable human personnel able to manage, evaluate, monitor, and operate the oil and gas industry in all three sectors.
d) Analysis of all publications on oil and gas drilling in Kenya is grossly disappointing. Even more appalling is the lack of research on drilling fluids, drilling additives, and drilling wastes. Despite the global appetite for drilling operation, related publications, academic investigative interest in the Kenyan drilling scene remains scanty. Consequently, extensive research should be undertaken in this era of laser focus on fossil fuel establishment.
e) Further, sector-specific studies need to be undertaken to understand the intra and inter-dynamics of each sub-sector of the oil and gas industry, with clear legally permitted access to data and information. Despite the existence of an open government data portal, selective amnesia is present, with vital information on exploration, drilling and, production absurdly missing.

6. Conclusion

This paper reviewed the latest studies undertaken by various researchers and an attempt has been made to compare and contrast their results. I, therefore conclude that if Kenya desires to utilize its scarce and finite resource of oil and gas in a manner reminiscent of Norway, then, it has the opportunity of emulating, the real practices adopted and industry-proven over the years by simple adherence to the law. Only then, will the Dutch disease die a natural death in Kenya?

Conflict of Interest

All the authors do not have any possible conflicts of interest.

Abbreviations

BPR	–	Business Process Reengineering
COFEK	–	Consumer Federation of Kenya,
EIA	–	Energy Information Administration
EPRA	–	Energy and Petroleum Regulatory Authority
FPIC	–	Free, Prior, and Informed Consent
IPIECA	–	International Petroleum Industry Environmental Conservation Association
KEPTAP	–	Kenya Petroleum Technical Advisory Project
KPA	–	Kenya Port Authority
KCSPOG	–	Kenya Civil Society Platform on Oil and Gas
KNBS	–	Kenya National Bureau of Standards.
LAPSSET	–	Lamu-Port-South Sudan-Ethiopia Transport
LCP	–	Local Content Program
LIWA	–	Linking Industry with Academia
MC	–	Moisture Content
NCDMB	–	Nigerian Content Development and Monitoring Board
UPRA	–	Upstream Petroleum Regulatory Authority
PSC	–	Production Sharing Contract.

RTI	–	Radar Technologies International
SOGA	–	Skills for Oil and Gas in Africa
TAN	–	Total Acid Number
UNEP	–	United Nations Environmental Programme
WEC	–	World Energy Consumption

References

[1] World Energy Council, 2016.

[2] IEA, 2016.

[3] Peter Purcell, "Oil and Gas Exploration in East Africa: A Brief History, September 2014. P& R Geological Consultants Pty Ltd.

[4] John Yabs, "Potential Economic Effect of Oil and Gas in East African Countries. ISSN 2224-574X, Vol. 28, 2015.

[5] Eduard Gismatullin, "Tullow to Start Pumping Oil in Kenya After Resource Increase," 31st July, 2013.

[6] Justus Omollo, "Oil and Gas Sector in Kenya: The Legal Status on Exploration and Extraction, 2013.

[7] Lars Buur, Ole Therkildsen, Micheal W. Hansen, Mette Kjaer, "Extractive Natural Resource Development: Governance, Linkages and Aid, DISS Report 2013: 28.

[8] Alisa Di Caprio, Kevin P. Gallagher, "The WTO and the Shrinking of Development Space," January 2006, The Journal of World Investment & Trade 7 (5): 781-803. DOI: 10.1163/221190006X00397.

[9] Chilenye Nwapi, "A Survey of Literature on Local Content Policies in The Oil and Gas Industry in East Africa," April 2016, https://www.researchgate.net/publication/301542.261

[10] Mulati, Julius Wachiya, "The Effect of Local Content Policies on Sustainable Local Development by Upstream Oil and Gas and Companies in Kenya," 2019. http://hdl.handle.net/11071/6601

[11] John O. Kakonge, "Kenya's Turkana Oil and Gas Field Shows the Challenges of Implementing Local Content Policies," 25th May, 2020, LSE.

[12] James Okal Mobutu, Joyce Nzulwa, "Effect of Local Content and Security Issues on The Operational Efficiency of Oil and Gas Organizations in Kenya," International Journal of Strategic Management, ISSN 2519-0296, Vol, No. 1 pp 1-19, 2021.

[13] Kenya Extractives Policy Dialogues, Paper No. 2 (2018).

[14] Saud Al-Fattah, "The Role of National and International Oil Companies in The Petroleum Industry," USAEE Working Paper No. 13-137. 28th July 2013.

[15] A. T. Bourgoyne Jr, K. K Millheim, M. E. Chenevert and F. S. Young Jr, "Applied Drilling Engineering, 1991, Vol. 2 ISBN: 978-1-55563-001-0.

[16] R. Caenn, H. C. H. Darley, G. R Gray, "Composition and Properties of Drilling and Completion Fluids," January 2011, DOI: 10.1016/C2009-0-64504-9.

[17] M. Enamul Hossain, Abdulaziz Abdullah Al-Majed, "Fundamental of Sustainable Drilling Engineering, ISBN: 978-04-708-781-70. 2015 Scrivener Publishing LLC. ©All rights reserved.

[18] Abdelmjeed Mohamed, Salem Basfar, Salaheldin Elkatatny, Badr S. Bageri, "Impact of Perlite on the Properties and Stability of Water-Based Mud in Elevated Temperature Applications," December 2020, ACS Omega 5 (50), DOI: 10.1021/acsomega.0c04853.

[19] Johannes Fink, "Petroleum Engineer's Guide to Oil Field Chemicals and Fluids," 1st Edition – May 13, 2011. ISBN: 9780123838452.

[20] Ljones, T. (2013) Drilling mud property estimator. M.Sc dissertation. Norwegian University of Science and Technology. Available at: http://www.diva/portal.org/smash/get/diva2:649714/FULLTEXT01.pdf (Accessed: 20 December 2014).

[21] Evans Kiprotich Bett, "Geothermal Well Cementing, Materials and Placement Techniques." United Nations University, Geothermal Training Programme, Orkustofnun, Grensasvegar 9, IS-108 Reykajvik, Iceland, Reports 2010, Number 10.

[22] Miyora Thomas Ong'au, "Sensitivity Analysis of Geothermal Drilling Parameters – A Case Study OF Well Mw-17 in Menengai Kenya," Proceedings, 7th African Rift Geothermal Conference, Kigali, Rwanda 31st October – 2nd November 2018.

[23] Zijun Feng, Zhao Yangsheng, Anchao Zhou, Ning Zhang, "Development of hot dry rock geothermal resource in the Yangbajing Basin China," March 2012, Renewable Energy 39 (1): 490 – 495. DOI: 10.1016/j.renene.2011.09.005.

[24] John Finger, Doug Blankenship, "Handbook of Best Practices for Geothermal Drilling," May 2011.

[25] Andrew S Ball, Richard J. Stewart, Kirsten Schliephake, "A review of the current options for the treatment and safe disposal of drill cuttings." Waste Management & Research 30 (5) 457–473, © The Author(s) 2012 Reprints and permissions: sagepub.co.uk/journals Permissions. Any DOI: 10.1177/0734242X11419892 wmr.sagepub.co.

[26] Richard Haut, David Burnett, Thomas E. Willians, Gene L. Theodori, "Balancing Environmental Tradeoff Associated With Low-Impact Drilling Systems To Produce Unconventional Natural Gas Resources. October 2010, DOI: 10:2118/137430-MS.

[27] Onwukwe Stanley Ibuchukwu, M. S Nwakaudu, "Drilling Wastes Generation and Management Approach," International Journal of Environmental Science and Development 3 (3): 252-257. DOI: 10.7763/IJESD. 2012.V3.226.

[28] Ahammad Sharif MD, Nagalakshmu NVR, Srigowri Reddy S, Vasanth G, Uma Sankar K, "Drilling Waste Management and Control the Effects," Journal of Advanced Chemical Engineering, 2017, 7: 1. DOI: 10.4172/2090-4568.1000166.

[29] Afshin Davarpanah, Ali Razmjoo & Behnam Mirshekari | (2018) An overview of management, recycling, and wasting disposal in the drilling operation of oil and gas wells in Iran, Cogent Environmental Science, 4: 1, 1537066, DOI: 10.1080/23311843.2018.1537066.

[30] Broni-Bediako, E. and Amorin, R. (2010). Effects of Drilling Fluid Exposure to Oil and Gas Workers Presented with Major Areas of Exposure and Exposure Indicators. Research Journal of Applied Sciences, Engineering and Technology. 710 - 719.

[31] Anon. 2010a. Kosmos Energy to Pay a Fine for Spillage. http://www.ghana.gov.gh/index.php/ news/general-news/2854-kosmos-energy-to-paya-fine-for-spillage. Accessed: July 20, 2010.

[32] Obialo Solomon Onwuka, Ogbonnaya Igwe, Stnaley Ikenna Ifediogwu, Chinenyem Stella Uwom, "An Assessment of the Effectiveness of Drilling Waste Treatment Process in X-Gas Field, Niger Delta, Nigeria," Geology, Ecology and Landscape, Volume 2, 2018-Issue 4, https://doi.org/10.1080/24749508.2018.1473751.

[33] Emmanuel Imarhiagbe, Nosa Omoregbe Obayagbona, "Environmental Evaluation and Biodegradability of Drilling Waste: A Case Study of Drill Cuttings from Ologbo Oilfield Wells at Edo State, Nigeria" November 2019, DOI: 10.5772/intechopen.88612.

[34] Bignert A, Cossa D, Emmerson R, Fryer R, Füll C, Fumega J, et al. OSPAR/ICES workshop on the evaluation and update of background reference concentrations (B/RCs) and ecotoxicological assessment criteria (EACs) and how these assessment tools should be used in assessing contaminants in water, sediment, and biota. 2004.

[35] Dirce Pozebon, Eder Lima, Sandra Maria Maia, Jandyra M. G Fachel, "Heavy Metals Contribution of Non-Aqueous Fluids Used in Offshore Oil Drilling," January 2005, Fuel 84 (1): 53-61, DOI: 10.1016/j.fuel.2004.08.002.

[36] Mohamed Khodja, Malika Khodja-Saber, Jean Paul Canselier, Nathalie Cohaut, Fa Bergaya, "Drilling Fluid Technology: Performance and Environmental Considerations, November 2010, DOI: 10.5772/10393.

[37] Simiyu E. Lilian; Mburu Esther; Rukunga Allan, (2016) "Drill Cuttings and Fluid Disposal; A Kenyan Case Study." SPE/AAPG Africa Energy and Technology Conference, Nairobi City, Kenya. Paper Number: SPE-AFRC-2580389-MS. https://doi.org/10.2118/AFRC-2580389-MS.

[38] Philippe Coussot, F. Bertrand, Benjamin Herzhaft, "Rheological Behavior of Drilling Muds, Characterization Using MRI Visualization," January 2004, Oil and Gas Science and Technology – Revue de/IFP 59 (1): 23-29. DOI: 10:2516/ogst:2004003.

[39] Drilling Fluids and Health Risk Management, Report Number 396, IPIECA/OGP, 2009.

[40] Kamol CO, Akunga DN, Warutere P (2019) Occurrence of Occupational Physical Injuries among Workers in Onshore Oil Drilling Occupation in Turkana County, Kenya. Health Sci J Vol. 13. No. 1: 619.

[41] Nwaoboli Awele, "Investigation of Additives on Drilling Mud Performance with Tonder Geothermal Drilling as A Case Study," Aalborg University Esbjerg, January 6th 2014.

[42] M. Zamora, S. Roy, "The Top 10 Reasons to Rethink Hydraulic and Rheology," DOI: 10.2118/62731-MS. Corpus ID: 109407883.

[43] Sharath Savari, Sandeep Kulkarni, Jason Maxey, Kushabhau Teke, "A Comprehensive Approach to Barite Sag Analysis on Field Muds, Haliburton, AADE-13-FTCE-30, 2013.

[44] Isaac Gamwo, Mohd A. Kabir, "Impact of Drilling Fluid Rheology and Wellbore Pressure on Rock Cuttings Removal Performance: Numerical Investigation," Asia-PACIFIC Journal of Chemical Engineering 10 (6): n/a-n/a. DOI: 10.1002/apj.1917.

[45] T. P. D Silva, M. Naccache, "Enhanced Fluid Rheology Characterization for Managed Pressure Drilling Applications," 12th April, 2016, Geology. DOI: 10.2118/180070-MS. Corpus ID: 138409529.

[46] Ehsan Pakdaman, Shariar Osfouri, Reza Azin, Khodabakhsh Niknam, Abbas Roohi, "Improving the Rheology, Lubricity, and Differential Sticking Properties of Water-Based Drilling Muds at High Temperatures Using Hydrophilic Gilsonite Nanoparticles," Colloids and Surfaces, September 2019, DOI: 10.1016/j.colsurfa.2019.123930.

[47] Soham Pandya, Ramadan M. Ahmed, Subhash N. Shah, "Wellbore Cleanout in Inclined and Horizontal Wellbores: The Effects of Flow Rate, Fluid Rheology and Solids Density," September 2019, SPE Drilling and Completion 35 (01), DOI: 10.2118/194240-PA.

[48] Salem Basfar, Jaber Al. Jaber, Salaheldin Elkatatny, Badr S. Bageri, "Prevention of Hematitie Settling Using Perlite in Water-Based Drilling Fluid," Jpunra; Petrolume Science and Engineering, Vol. 210, March 2022, 110030.

[49] Aleksandra Jamrozik, Jan Ziaja, Andrzej Gonet, Jerzy Fijal, "Selected Aspects of Drilling Waste Management in Poland," AGH Drilling Oil Gas 32 (3): 565, January 2015, DOI: 10.7494/drill.2015.32.3.565.

[50] Kamau, "Civil Society Pushes for Amendments to Petroleum Bill to Open Up Contracts." 33 Oxfam, Contract Disclosure Survey 2018 (Oxford: Oxfam, 2018), https://www.oxfam.org/en/research/contract-disclosure-survey-2018.

[51] Christa N. Brunnschweiler, Erwin H. Bulte, "Natural Resources and Violent Conflict: Resource Abundance, Dependence and the Onset of Civil Wars," Oxford Economic Papers, New Series, Vol. 61, No. 4 (October 2009), pp. 651-674.

[52] Jason Switzer, Natural Resources: The Case of the Minerals Sector," Mining, Minerals and Sustainable Development, July 2001, No. 12. © 2002 IIED and WBCSD.

[53] Xavier Sala-i-Martin, Arvind Subramaian, "Addressing The Natural Resource Curse: An Illustration from Nigeria," ©July, 2003, International Monetary Fund, IMF Working Paper, WP/03/139.

[54] Raymond F. Mikesell, "Explaining the Resource Curse, With Special Reference to Mineral-Exporting Countries," Resources Policy, 1997, Vol. 23, Issue 4, 191-199.

[55] Jeffrey David Sachs, Andrew M. Warner, "The Curse of Natural Resources, European Economic Review 45 (4-6): 827-838. DOI: 10.1016/S0014-2921 (01) 00125-8.

[56] Ragnar Torvik, "Learning by Doing and the Dutch Disease," European Economic Review 45 (2): 285-306. DOI: 10.1016/S0014-2921(99)00071-9.

[57] Thorvaldur Gylfason, "Natural Resources and Economic Growth: What is the Connection?" Fostering Sustainable Growth in Ukraine. January 2002. DOI: 10.1007/978-3-642-57464-1 5.

[58] Kyra Bos, Joyeeta Gupta, "Inclusive Development, Oil Extraction and Climate Change: a Multilevel Analysis of Kenya," International Journal of Sustainable Development & World Ecology, 2016, Vol. 23 No. 6 482-492. http://dx.doi.org/10.1080/13504509.2016.1162217

[59] Kennedy Mkutu Agade, "Ungoverned Space and the Oil Find in Turkana, Kenya" The Round Table 103 (5), September 2014, DOI: 10.1080/00358533.2014.966497.

[60] Luke Patey, "Kenya –An African Oil Upstart in Transition" ©Oxford Institute for Energy Studies, 2014.

[61] Eliza M. Johannes, Leo C. Zulu & Ezekiel Kalipeni (2014): Oil discovery in Turkana County, Kenya: a source of conflict or development? African Geographical Review, DOI: 0.1080/19376812.2014.884466. http://dx.doi.org/10.1080/19376812.2014.884466.

[62] Mogaka Mokobi Dismas, "Oil and Gas – Society Relations and The Role of International Actors: A Case Study of the Kenyan State and The Northern Part of Kenya". UON – Institute of Diplomacy and International Studies, May, 2017.

[63] Janpeter Schilling, Raphael Locham, and Jürgen Scheffran, (2018), "A local to global perspective on oil and wind exploitation, resource governance and conflict in Northern Kenya. Conflict, Security & Development 2018, VOL. 18, NO. 6, 571–600 https://doi.org/10.1080/14678802.2018.1532642.

[64] Melba K. Wasunna, Extractives Baraza, Strathmore University October 9, 2018.

[65] Muchiri Naomi, "Oil Exploration and Security Dynamic in Kenya – A study of lokichar Oil Exploration Site, Turkana County," 2020. UON, Sch. Of Law. http://erepository.uonbi.ac.ke/handle/11295/154287.

[66] Cosmas Ekwom Kamais, Samson Wokabi Mwangi, Eric Kiprono Bor, "Emerging Security Management Issues Due To Oil Exploration Activities in South Lokichar Basin, Turkana County, Kenya," The International Journal of Humanities & Social Studies, Vol. 7, Issue 6, June 2019. DOI: 10.24940/theijhss/2019/v7/i6/HS1906-058.

[67] Nicole Kathini Nyamai, "Evaluation of Law and Practice on Environmental Protection During Exploration and Production of Oil and Gas in Kenya," UON, Sch. Of Law.

[68] Sheila Nandako, "Transparency in the Management of Oil and Gas Blocks: A Review of Kenya Legislative Framework" Strathmore Law School (SLS), 2020. https://suplus.strathmore.edu/handle/11071/10214.

[69] Ahmed, S., Patel, H., Salehi, S., Ahmed, R., and Teodoriu, C.: Numerical and Experimental Evaluation of Liner Dual Barrier System in Geothermal Wells, Proceedings, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, USA (2020a).

[70] Oxford Institute for Energy Studies, "Kenya: An African oil upstart in transition", October 2014. Copyright © 2014 Oxford Institute for Energy Studies (Registered Charity, No. 286084). ISBN 978-1-78467-011-5.

[71] Sichei Chepkech Chemwotei, "Geothermal Drilling Fluids" Kenya Electricity Generating Company Ltd. – KenGen P. O. Box 785-20117 Naivasha Kenya. Geothermal Training Programme Reports 2011 Orkustofnun, Grensásvegur 9, Number 10 IS-108 Reykjavík, Iceland 149. sicheichem@gmail.com, schemwotei@kengen.co.ke.

[72] Tordo et al (2013), supra note 19 at pp. 24–25.

[73] Vivas, C., Salehi, S., Tuttle, J. D., and Rickard, B.: Challenges and Opportunities of Geothermal Drilling for Renewable Energy Generation. GRC Transactions, 44, (2020) 904-918.