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Invigorating Kenya's absorptive capacity for health, safety and environmental technology in the upstream petroleum sector

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INVIGORATING KENYA'S ABSORPTIVE CAPACITY FOR HEALTH, SAFETY AND ENVIRONMENTAL TECHNOLOGY IN THE UPSTREAM PETROLEUM SECTOR

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this of any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

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15th June 2020

Approval

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ABSTRACT

Health, safety and environmental concerns have accompanied oil and gas operations in fields across the world. The rise of digital technology and its successful application across various industries has presented hope for the identification, prevention and mitigation of traditional upstream concerns. While there is rapid development of technological innovations geared towards making oil fields safer, improving efficiency and increasing compliance with environmental regulations, their deployment within the African oil and gas sector is disappointingly low. Financial constraints, lack of awareness of the technology's existence and apprehension at making the digital leap have already been blamed for the low uptake. This thesis traces the low deployment of HSE technology to legal and institutional gaps, arguing that the already identified factors do in fact flow from lacunas in these two fields.

Employing qualitative review on the growing body of literature in relation to oilfield HSE technology, the thesis elevates technology absorption over technology transfer, demonstrating its superiority as a sustainable approach to technology acquisition. The active involvement of the recipient country in determining its upstream HSE risks, identifying technological innovations capable of addressing those needs and developing capacity to assimilate and customize imported technology are found to be particularly helpful to Kenya as both a developing nation and emergent oil producer.

By evaluating the key drivers of technology absorption in terms of awareness, availability, affordability and accessibility, the study is able to identify the specific challenges constricting Kenya's absorptive capacity to HSE technology. The legal and institutional reforms proposed in the study provide emphasis and practical means of invigorating Kenya's capacity to absorb HSE technology in its upstream sector.

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LIST OF ABBREVIATIONS

3-D	Three-dimensional
4-D	Four-dimensional
BAT	Best Available Technology
BBLS/D	Barrels per day
DOSHS	Directorate of Occupational Safety And Health Services
EMCA	Environmental Management and Co-ordination Act
EPRA	Energy and Petroleum Regulatory Authority
EU GDPR	European Union General Data Protection Regulation
GDP	Gross Domestic Product
HSE	Health Safety and Environment
Ksh.	Kenya Shilling
MIT	Massachusetts Institute of Technology
NACOSTI	National Commission for Science Technology and Innovation
NEMA	National Environmental Management Authority
UN	The United Nations
TRIPS	Trade-Related Aspects of Intellectual Property Rights

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DEDICATION

To James Karanja, the wind beneath my wings.

CHAPTER 1: INTRODUCTION

1.1 Background

The exploration and production activities carried out in upstream oil and gas sectors are inculpated as having the greatest extent of negative impacts on health, safety and environment (HSE) throughout the petroleum industry.[1] Oil spills, gas flares and unsafely discharged effluents directly compromise the integrity of the environment, placing the health, livelihood and survival of workers and surrounding settlements at risk.[2] As many as one hundred and sixty seven deaths have been recorded in a single oil well blow out, with many more cases of occupational injuries and diseases observed to be rife particularly among oil drillers and manual labourers on the drilling floor. [3]

Petroleum exploration efforts in Kenya date back to the 1950's during which time the first wells are said to have been dug.[4] However, oil was only discovered in March 2012 in Turkana County by Tullow Plc, a UK based firm in consortium with Marathon Oil and Africa Oil.[5] Although the proven oil reserves are estimated at about 600 million barrels, the positioning of the oilfields near Uganda where larger reserves have been discovered, raises optimism for more significant findings.[6]In May of 2016, the Cabinet Secretary in charge of Energy and Petroleum gazetted the constitution of sixty three petroleum blocks for exploration, with the majority of those blocks falling within the Lamu Basin.[7]

While the country's revenue is expected to grow from the proceeds of oil, there is concern around the negative impacts with which upstream operations are traditionally associated.[8]

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[1] Oppong S, Jonah S, 'Common health, safety and environmental concerns in upstream oil and gas sector: Implications for HSE management in Ghana' 9, *Academicus International Scientific Journal*, 2014, 92-105.

[2] Christou M, Konstantinidou M, 'Safety of offshore oil and gas operations: Lessons from past accident analysis' *Joint Research Centre Scientific and Policy Reports*, EUR- 25646, 2012, 16-27.

[3] Valentic D, Stajanovic D, Micovic V, Vukelic M, 'Work related diseases and injuries on an oilrig' 1 (56) *International Maritime Health*, 2005, 59-62.

[4] Mwabu G, 'Kenya's oil governance regime: Challenges and policies' Centre for Research on Peace and Development, CRPD working paper no. 71, 2018, 7-<https://soc.kuleuven.be/crpd/files/working-papers/crpd-no-71-mwabu-full.pdf> on 28 October 2019.

[5] IHRB, 'Human rights in Kenya's extractives sector: Exploring the terrain', *Institute for Human Rights and Business*, London, 2016, 15-<https://www.ihrb.org/uploads/reports/IHRB%2C_Human_Rights_in_Kenyas_Extractive_Sector_-_Exploring_the_Terrain%2C_Dec_2016.pdf > on 28 October 2019.

[6] Mwabu G, 'Kenya's oil governance regime: Challenges and policies', 7.

[7] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya' 2(1) *Kenya Petroleum Technical Assistance Project*, 2016, 11.

[8] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 72-151.

Tragedies in the upstream petroleum industry have been imputed to several factors, including: the loss of well control; failure of safety components; inadequate detection parameters for potentially hazardous situations; poor communication frameworks and scanty emergency response training.[9]

The employment of digital technology on the oilfield has been fronted as one of the ways of mitigating upstream HSE concerns.[10] Digital technology connects disparate elements of production, presenting the opportunity for the collection of real time information and directing attention from routine activities to decision making functions.[11]3-D and 4-D visualization and modelling, remotely steerable down-hole tools, fiber-optic fitted well sensors and real-time facility and worker monitoring capabilities are some of the technological tools revolutionizing exploration and production of petroleum companies.[12] The implementation of these technologies across oil and gas operations has created what is now called the digital oilfield.[13] The term is generally understood to encompass both the tools and processes involved in managing the production and safety of personnel and environment, while at the same time reducing costs and improving production efficiency within the petroleum sector.[14]

The value of the digital oilfield in relation to HSE is represented by technology's ability to minimize the incidence of human error; detection of critical system overshoots; provision of early warning signals and hastening of communication speeds.[15] Wearable sensor technology has been developed to measure the vitals of oilfield workers and to detect fatigue, ill health and accidents.[16]

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[9] Christou M, Konstantinidou M, 'Safety of offshore oil and gas operations' 20.

[10] Motorola Solutions, 'White paper-Protecting operations in the energy sector against cyberattacks', *Motorola Solutions*,2014,3 < https://smartcom.motorolasolutions.com/protecting-operations-in-the-energy-sector-against-cyber-attacks/> on 3 October 2019.

[11] Motorola Solutions, 'White paper', 3.

[12] Steinhubl A, Klimchuck G, Click C, Morawski P, 'Unleashing productivity: The digital oilfield advantage' *Booz & Company*, 2008, 5 <http://oilproduction.net/files/DigitalOilfield.pdf > on 25 September 2019.

[13] Motorola Solutions, 'White paper',3.

[14] GE, Accenture, Junewarren-nickel's Energy Group, *Digital Oilfield Outlook Report*, USA, GE, Accenture, Junewarren-nickel's Energy Group, 2015, 24.

[15] GE, Accenture, Junewarren-Nickel's Energy Group, *Digital Oilfield Outlook Report*, USA, 2015, 24.

[16] Reid C, Schall M, Amick R, Schiffman J, Lu M, Smets M, Moses H, Porto R, 'Wearable technologies: How will we overcome barriers to enhance worker performance, health and safety?' Proceedings of the Human Factors and Ergnomics Society Annual Meeting, Austin-Texas, 9-13 October 2017, 1026-1028 - <https://www.researchgate.net/publication/320093937_Wearable_Technologies_How_Will_We_Overcome_Barriers_to_Enhance_Worker_Performance_Health_And_Safety/link/59f7ae6c0f7e9b553ebeeaa9/download> on 3 October 2019.

While the existence and manifold benefits of these HSE technologies is not in question, their utilization and deployment across the world's oilfields, and particularly on the African continent, remains very low.[17]A 2018 review of digital technology use in the African oil and gas sector found evidence of HSE technology only in Angola and South Africa, where drones are used to inspect remotely located platforms.[18]

Within the Kenyan context, Tullow oil PLC, one of the companies involved in the exploration and production of oil in Turkana County, announced its intention to adopt predictive analytics and robotics in its 2019 oil operations.[19] It is however unclear whether the digitisation effort is constitutive of HSE considerations.

In spite of a clear mandate under Section 59 (2) (b) of the Kenyan Petroleum Act[20] obligating the deployment of the 'best available technology' to address HSE concerns in Kenya's upstream sector, the industry is characterized by ill protected workers, insufficient safety controls and waste disposal systems largely run by the informal sector, raising fears of water contamination.[21] Because the Mandera, Lamu and Anza basins straddle locations prone to flooding,[22] fears that oil spills and unsafely discharged fluids and wastes could be carried over many kilometers and could contaminate neighboring water sources including rivers, lakes and the Indian Ocean are prevalent.[23] The proximity of the oil blocks in the arid Turkana County to the few aquifers scattered around the region, the loose sandy soil and the geographical slope of the land towards River Turkwel also raises genuine concerns in the eventuality of water contamination.[24] The contamination coupled with the sheer rarity of water would spell death to thousands of animals kept by the inhabitant pastoralist community and a survival crisis for the community.[25]

[17] PwC, 'Taking on tomorrow: Africa oil and gas review', *PricewaterhouseCoopers*, 2018, 20< https://www.pwc.co.za/en/assets/pdf/africa-oil-and-gas-review-2018.pdf> on September 4 2019.

[18] PwC, 'Taking on tomorrow: Africa oil and gas review', 20.

[19] Tullow Oil PLC, 'Technology Innovation' *Tullow Oil Plc*, 2019 < *https://www.tullowoil.com/media/case-studies/technology-innovation*> on 29 April 2019.

[20] Section 59 (2) (b), *The Petroleum Act* (2019).

[21] Online: Wassuna M, 'How Kenya can protect health and safety of oil sector workers' Business Daily, 29 October 2018 <https://www.businessdailyafrica.com/analysis/ideas/How-Kenya-can-protect-health-and-safety-of-oil-sector-workers/4259414-4828220-ucfwe4z/index.html> on 25 October 2019.

[22] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 90.

[23] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 90.

[24] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 92.

[25] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 92.

Section 50 (3) of the Petroleum Act as well as Section 23 of the model production sharing contract under the Act elect technology transfer as the mode of acquisition of the necessary technology and operational expertise.[26] While technology acquisition is an important step in increasing the efficiency and safety of upstream operations, this thesis argues that the acquisition of the technology and attendant operational capacity is limited in its ability to ensure the successful deployment and utilization of the transferred technology. This is because, technology transfer is chiefly concerned with acquisition processes with less attention to the actual absorption of the technology and acquired skill into the fabric of the sector's operations. Secondly, technology transfer limits the participation of the recipient to a secondary and almost passive role, while technology absorption places the recipient as the lead in the exercise, appreciating its familiarity with its domestic needs and the technological products capable of addressing those needs.

Technology absorption in contrast with technology transfer seeks to add value at every stage of the process and is characterized by a recognition of prevalent needs and available technology capable of addressing those needs, an acquisition process guided by technological products addressing identified needs, an assessment of the performance of the transferred technology in addressing the needs already identified and an eventual modification of the technology to better address current and anticipated needs.[27]

In relation to HSE risks, technology absorption processes are informed by an evaluation of the HSE risks posed by upstream processes unique to Kenya's situation, an assessment of the available technological solutions existent to address those risks, an evaluation of the performance of the transferred technology in addressing the risks and a modification of the technology to better address present and future HSE risks.

In essence then, technology absorption as contrasted with the present technology transfer framework presents a holistic manner of addressing HSE challenges. The deficiency of technology transfer models in addressing technological and operational modalities in the absence of a prior needs evaluation basis, designation of a criteria for technology addressing identified needs and post-acquisition assessments and modifications has been identified as the chief hindrance for successful absorption.[28]

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[26] Section 50 (3), *The Petroleum Act* (2019).

[27] Fransman M, 'Technological capability in the third world: An overview and introduction to some of the issues raised in this book' in Fransman M, King K, (eds.), *Technological capability in the third world*, Palgrave Macmillan London, 1984, 10.

[28] Selmi N, 'The difficulties of achieving technology transfer: Issues of absorptive capacity' 2013, *Communications of the IBIMA*, 2013, 3-7.

This thesis makes a case for the superiority of technology absorption over technology transfer in the deployment of HSE technology and identifies legal and institutional gaps hindering HSE technology absorption in Kenya's upstream sector by focusing on the key drivers of technology absorption and providing recommendations for legal and regulatory reform.

1.2 Objectives of the study

The primary objective of the study is to evaluate the legal and institutional gaps hindering the absorption of HSE technology within Kenya's upstream petroleum operations with a view to making a case for legal and institutional reform.

As a secondary objective, the study makes a case for the superiority of technology absorption over technology transfer as a form of sustainable HSE technology acquisition.

The study also evaluates the key drivers of technology absorption in order to explain the poor uptake of HSE technology in the Kenya's upstream sector.

1.3 Problem statement

While Section 59 (2) (b) of the Petroleum Act mandates contractors carrying out operations in the upstream petroleum sector to deploy the best available HSE technology, access and deployment of this technology remains a challenge. [29]

The study ascribes Kenya's constricted absorptive capacity to three key factors: first, the election of technology transfer as the primary and exclusive mode of technology acquisition, as opposed to the more sustainable technology absorption approach; secondly, the absence of research and development efforts by the Ministry of Petroleum and Mining and other relevant players on the key drivers of technology absorption and the hurdles rendering access to HSE technology challenging; and lastly, the existence of legal and institutional gaps which make compliance with Section 59 (2) (b) of the Petroleum Act, difficult.

[29] Section 59 (2) (b), *The Petroleum Act* (2019).

1.4 Hypotheses

H1: Evaluation of the key drivers of technology absorption by the Ministry of Petroleum and Mining can be used to explain the poor deployment of HSE technology within Kenya's upstream sector.

H2: Legal and institutional gaps are key contributors to the limited absorptive capacity of HSE technology within Kenya's upstream sector.

H3: Legal and institutional reform of identified gaps will ease compliance with the requirement for the deployment of the best available HSE technology within Kenya's upstream sector.

1.5 Research questions

1) To what extent does the evaluation of key drivers of technology absorption explain poor deployment of HSE technology within Kenya's upstream sector?
2) What legal and institutional gaps contribute to the limited absorptive capacity of HSE technology within Kenya's upstream sector?
3) What legal and institutional reforms will ease compliance with the requirement for the deployment of the best available technology within Kenya's upstream sector?

1.6 Literature review

1.6.1 Normative framework

Section 59 (2) (b) of Kenya's Petroleum Act elects technology transfer as the main source of acquisition of HSE technology in Kenya's upstream sector.[30] Section 23 of the model production sharing contract specifies the ambit of technology transfer to include knowledge and skills transfer in all upstream activities.[31]

Technology transfer has received increasing recognition as one of the key pillars of achieving sustainable development goals.[32] Technology transfer has been defined broadly as comprising both the conveyance and adoption of technology as well as the exchange of technical knowledge on its operation, usually between companies or governments.[33]

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[30] Section 59 (2) (b) *Petroleum Act* (Act No. 2 of 2019).

[31] Section 23 of the model production sharing contract, *Petroleum Act* (Act No. 2 of 2019).

[32] Mohieldin M, ' Leveraging technology to achieve the sustainable development goals' *World Bank Group*, 2018- < https://blogs.worldbank.org/voices/leveraging-technology-achieve-sustainable-development-goals> on 7 January 2020.

[33] Shepherd J, 'The future of technology transfer under multilateral environmental agreements' 53, *ELR News and Analysis*, 2007,10547.

Chesnais observes that the core purpose of technology transfer is not the technology itself nor its operation, but the creation of capacity in the recipient to autonomously customise the technology to address specific challenges within its environment.[34] Wahab *et al* have underscored the fact that technology transfer is a compounded and potentially arduous process even when it is just between different production lines in one company.[35]

Various international agreements have incorporated technology transfer articles in their provisions. Article 66 (2) of the Trips Agreement requires developed nations to provide incentives to institutions domiciled in their countries in a bid to encourage technology transfer to least developed members states.[36] Article 10 of the Paris Agreement recognizes the contribution of technology transfer in strengthening resilience and building mitigation capacity to address climate change.[37] The 2016 Marrakesh Action Proclamation For Our Climate and Sustainable Development echoes the provision of the Paris Agreement in calling for increased volumes of technology transfer to developing nations.[38]

Notwithstanding the progressive nature of international law on technology transfer, criticism on the absence of objective yardsticks to measure the quantity of technology transferred, existence of gaps in reporting procedures and incapacity of international institutions to evaluate submitted reports and corresponding technological development in the recipient country have been raised.[39]Even in the face of increased volumes of technology transfer and renewed pledges by developed nations towards the injection of more financing and capacity building to support technology transfer exercises,[40] the rate of deployment of the transferred technology in African countries, particularly with reference to HSE technology is disappointingly low.[41]

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[34] Chesnais F, 'Science and technology competitiveness' 1, *OECD STI Review*, 1986, 86.
[35] Wahab S, Rose R, Osman S, 'Defining the concepts of technology and technology transfer: A literature analysis' 1(5), *International Business Research*, 2012, 65.
[36] Article 66(2), Agreement on Trade-related Aspects of Intellectual Property Rights, 01 January 1995.
[37] Article 10, *Paris Agreement*, 12 December 2015.
[38] *Marrakesh Action Proclamation For Our Climate and Sustainable Development*, 17 November 2016.
[39] Barder O, Krylová P, 'Are we doing enough to support technology transfer to Developing countries?' *Center for Global Development*, 2014 - < https://www.cgdev.org/blog/are-we-doing-enough-support-technology-transfer-developing-countries > on 7 January 2020.
[40] UNEP, 'Countries pledge $23 million to support technology transfer in developing countries' United Nations Environmental Programme, 16 November 2016-< https://www.unenvironment.org/news-and-stories/press-release/countries-pledge-23-million-support-technology-transfer-developing> on 6 February 2020.
[41] PwC, 'Learning to leapfrog: Africa oil and gas review' *PricewaterhouseCoopers South Africa*, 2017, 22-33 -< https://www.pwc.co.za/en/assets/pdf/africa-oil-and-gas-review-2017.pdf > on 6 February 2020.

Weak technology absorption capacity has been held responsible for this phenomenon.[42] Technology absorption has been defined as the process through which technology itself and operational know-how is first, acquired, then developed and lastly assimilated to meet the needs of the recipient agency.[43]

Contrasted with technology transfer which is seen as concentrating effort on the acquisition process, absorption is more concerned with the success of the entire value chain, culminating in successful utilization of the transferred product and the creation of capacity to modify the product to fit current local challenges.[44] Fransman outlines five key components of technology absorption: a search for the most appropriate and available technology; an acquisition of expertise in the operation of the technology; an assessment of the technology's adaptability to project specific challenges; a modification of the product to better suit prevalent conditions and continued research to make the product technologically relevant in the face of anticipated challenges.[45]

According to Narula, technology absorption is rationalized on the basis of technology's inability to precisely address the needs to the transferee, thereby laying upon that agency the mandate to customize the product to address its specific requirements.[46]

From the foregoing, the role of the technology transfer beneficiary as a passive participant in the transfer process is disabused. The recipient bears the responsibility of identifying challenges to which technological solutions can be applied, carrying out assessments of the technological products best fitting the situation, acquiring the necessary permits and clearances for importation of the technology, facilitating learning and acquisition of operational expertise, evaluating the performance of the technology in light of its purpose and modification of the technology to achieve optimal performance for present and anticipated challenges.[47]

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[42] Olawuyi D, 'From technology transfer to technology absorption: addressing climate technology gaps in Africa' 36 (1), *Journal of Energy and Natural Resources Law*, 2018, 65-68.

[43] Rastogi P, 'Technology absorption' in Rastogi (ed), 2nd ed, *Management of technology and innovation: Competing through technological excellence,* Sage Publications India Pvt Ltd, 2009, 73.

[44] United Nations, 'Climate change: Technology development and technology transfer' *UN Department of Economic and Social Affairs,* 2008,6- <- https://sustainabledevelopment.un.org/content/documents/tec_technology_dev.pdf > on 5 February 2020.

[45] Fransman M, 'Technological capability in the third world: An overview and introduction to some of the issues raised in this book' in Fransman M, King K, (eds.), *Technological capability in the third world*, Palgrave Macmillan London, 1984, 10.

[46] Narula R, 'Understanding absorptive capacities in an innovation system's context: Consequences for economic and employment growth' Danish Research Unit for Industrial Dynamics, DRUID working paper 04-02, 2003, 9- <http://webdoc.sub.gwdg.de/ebook/serien/lm/DRUIDwp/04-02.pdf> on 05 February 2020.

[47] Hoffman L, 'The transfer of technology to developing countries: Analytical concepts and economic policy aspects' 20 (2) *Intereconomics*, 1985, 73-79.

While literature on technology transfer processes and principles abound, an evaluation of the elements constituting digital technology absorption in an African oil and gas context are scarce.[48] Secondly, given the nascence of most digital technology particularly in the area of HSE, there is a dearth of research on the key drivers fueling absorption of the technology in an oil and gas context. Lastly, a connection between legal and institutional barriers as key contributors to the limited absorptive capacity of HSE technology within Kenya's oil and gas sector has not been the subject of previous study.

This thesis identifies legal and institutional gaps impeding the successful absorption of HSE technology in Kenya's upstream sector by focusing on the key drivers of technology absorption and proposing reforms in line with the identified gaps.

1.6.2 Theoretical framework

In making a case for the invigoration of Kenya's technology absorptive capacity, the study fronts two theories: the absorptive capacity theory and the access theory as the most relevant to the subject.

The *absorptive capacity theory*, first advanced by Cohen and Levinthal in 1990, outlines the key elements involved in the acquisition and assimilation process of new information.[49]The theory suggests that the acquisition of new external information coupled with a firm's internal ability to assimilate and apply that information in meeting its business goals, increases the firm's competitive edge and contributes to its innovative potential.[50]

Absorptive capacity is thus defined as a firm's ability to identify the utility of new information from outside sources and the ability to assimilate it for the purpose of applying it in meeting its business targets.[51] Later studies have revisited the theory and extended the three absorptive capacity processes identified by Cohen and Levinthal. Zahra and George for example include transformation as an additional step in the absorption process preceding application of the information collected.[52]

[48] Olawuyi D, 'From technology transfer to technology absorption: addressing climate technology gaps in Africa', 65.

[49] Cohen W, Levinthal D, 'Absorptive capacity: A new perspective on learning and innovation' 35 (1), *Administrative Science Quartely*, 1990, 128-152.

[50] Cohen W, Levinthal D, 'Absorptive capacity: A new perspective on learning and innovation', 128.

[51] Cohen W, Levinthal D, 'Absorptive capacity: A new perspective on learning and innovation', 128.

[52] Zahra S, George G, 'Absorptive capacity: A review, reconceptualization and extension' 27 (2) *Academy of Management Review*, 2003, 185-203.

Lane, Koka and Pathak propose a five step process starting with recognition of the need for the new information, followed by its acquisition, its assimilation, transformation and eventual exploitation.[53]

The absorptive capacity theory has been extended to technology transfer models creating an assessment platform for the recognition of needs calling for technological intervention, acquisition of the befitting class of technological solutions, assimilation and evaluation of the technology in line with assessed needs and eventual transformation of the technology to better address present and future concerns.[54]

In connection to the absorptive capacity theory, the *access* theory, first propounded by Roy Penchansky and J. William Thomas in 1981 sets out the key drivers of technology absorption.[55] The theory posits that while the term 'access' is ubiquitously invoked in various research and policy discussions, it remains a general and nebulous concept unless its specific dimensions: availability; accommodation; affordability and acceptability, are discussed in a constitutive manner.[56]

Although the theory was developed in the context of health care policy, its applicability has been extended successfully to the fields of human rights[57], energy and energy security.[58] In the face of technological advancements on the digital oilfield holding out the promise for cleaner, healthier and safer production processes, the question of whether these technologies are in fact accessible is a valid concern.

The legal requirement for the utilization of the best available technology must be backed up with evidence of the accessibility of these technologies. The breakdown of the concept of accessibility to smaller, measurable constituents enables a thorough examination of technological accessibility. Donabedien suggests that the litmus of access is the utilization of the given service or product.[59] As such, it is not enough to conclude that the existence of these technologies somewhere in the world translates to their access.

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[53] Lane P, Koka B, Pathak S, 'The reification of absorptive capacity: A critical review and rejuvenation of the construct' 31 (4), *Academy of management review*, 2006, 833-863.

[54] Lerch F, Wagner R, Mueller-Seits G, 'Technology transfer and absorptive capacity: Processual insights from four cases in optics in the US and Germany' International Conference on Organization and Learning, Boston, 3-6, June 2010, 3-11.

[55] Penchansky R, Thomas J, 'The concept of access: Definition and relationship to consumer satisfaction' 2(19), *Medical Care*, 1981, 127-140.

[56] Penchansky R, Thomas J, 'The concept of access',127-138.

[57] Office of the High Commissioner for Human Rights, *CESCR general comment no.14: The right to the highest attainable standard of health (Art.12),* UN Committee on Economic, Social and Cultural Rights, 11 August 2000, 4-5.

[58] Cherp A, Jewell J, 'The concept of energy security: Beyond the four As',75, *Energy Policy,* 2014, 415-421.

[59] Donabedian A, 'Models for organizing the delivery of personal health services and criteria for evaluating them' 50 (4), *The Milbank Memorial Fund Quarterly*, 1972, 103-154.

In addition to the five dimensions of accessibility developed by Penchansky and Thomas, Saurman proposes the inclusion of an additional constituent, being that of awareness of the existence of the good or service.[60] Saurman proposes that effective communication and notification to the relevant users is likely to increase product visibility and utilization.[61] This modification is timely, particularly in the context of the petroleum industry, where a lack of knowledge of the existence of environmentally sound and occupationally safe products features as one of the key barriers to technology uptake.[62]

It has also been suggested that the concept of access and its underlying dimensions must address themselves to the target recipient of the good or service.[63] This argument is anchored on the diversity of the participants in each field and the unique contexts in operation. For example, the challenges of access to an operator working in the African continent may be radically different from those encountered by his European counterpart.

In the petroleum industry, the quality, quantity and characteristics of various oil wells dictates the befitting technology to be employed. In that sense, discussions around access must, of primary importance, identify the referent object and circumstances of operation.[64] With respect to the African continent, Alzouma argues that the benefits of technological advancement have often been axiomatically accepted without the need to demonstrate empirical evidence of their adaptability to the social and economic fabric.[65] He argues that an appreciation of the existent digital divide, first between the developed and developing nations and secondly within the developing nations themselves in the context of rural and urban societies will greatly enrich and guide decisions around technology adoption.[66]

This study proposes the use of the absorptive capacity theory and its related access theory and the relevant modifications made thereto to evaluate the absorptive capacity of HSE technology within Kenya's upstream sector.

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[60] Saurman E, 'Improving access: Modifying Penchansky and Thomas's theory of access', 21 (1), *Journal of Health Services, Research and Policy*, 2016, 36-39.
[61] Saurman E, 'Improving access', 37-38.
[62] Petroleum Technology Alliance Canada (PTAC), *Barriers to the deployment of environmental technology in the upstream oil and gas industry*,15-21.
[63] Cherp A, Jewell J, 'The concept of energy security',416.
[64] Cherp A, Jewell J, 'The concept of energy security',417-412.
[65] Alzouma G, 'Myths of digital technology in Africa: Leapfrogging development?' 1 (3), *Global Media and Publication,* 2005, 339-356.
[66] Alzouma G, 'Myths of digital technology in Africa',343-344.

1.7 Approach and methodology

This study is premised on qualitative review of primary, secondary and tertiary sources of literature. In evaluating the hypotheses put forth, relevant textbooks, authoritative journal articles, current statistics on the subject and legislative authority are employed. Desktop research is elected as the most effective source of data collection based on the novelty of HSE technology to the global oil and gas sector and the absence of evidence on the deployment of HSE technologies in companies involved in Kenya's upstream operations.

1.8 Assumptions

This thesis is written on the assumption that Kenya will continue in its oil and gas exploration and production operations. Given that Kenya is currently at the appraisal stage of oil production specifically in the Ngamia, Amosing and Twiga fields, the decision to move to commercial production will present a platform for greater realization of the study's recommendations.

1.9 Limitations

The nascence and novelty of the deployment of digital technologies in oil and gas operations around the world limits the amount of quantitative data available on the subject. In addition, none of the companies involved in Kenya's upstream operations have demonstrated evidence of the utilization of HSE technologies. While quantitative data is scarce, qualitative evaluations on the potency of HSE technologies in addressing traditional upstream concerns are on the rise. The study thus focuses on desktop review of primary, secondary and tertiary sources of data relating to the manner in which absorptive capacity for HSE technology products can be invigorated, with a special emphasis on the Kenyan upstream sector.

1.10 Chapter breakdown

Chapter 1 is the introductory chapter and lays out the problem statement, hypotheses and conceptual underpinnings of the study.

Chapter 2 provides an overview of occupational HSE risks within Kenya's upstream sector and evaluates the availability, affordability, awareness and acceptability of HSE technology as key drivers of technology absorption.

Chapter 3 provides an analysis of the legal and institutional gaps constricting the absorptive capacity of HSE technology within Kenya's upstream sector.

Chapter 4 lays down a framework for legal and institutional reform in response to the gaps identified in the previous chapter.

Chapter 5 sets out the study's recommendations and conclusion.

CHAPTER 2: EVALUATING THE KEY DRIVERS OF HSE TECHNOLOGY ABSORPTION WITHIN KENYA'S UPSTREAM PETROLEUM SECTOR

2.1 Introduction

The upstream sector is characterized by exploration activities aimed at investigating the existence of commercial quantities of oil and gas underground or under the sea, followed by production processes geared at extracting the discovered crude oil and natural gas deposits and transporting them to the surface.[67]

As discussed in chapter 1, technology absorption exercises involve two preliminary steps: identification of prevalent risks and assessment of technology available to address the identified risks. This chapter focuses on these two steps by presenting a brief overview of the HSE risks obtaining in Kenya's upstream sector, identifying some of the technological solutions developed in mitigation of those risks and assessing the key drivers of technology absorption relative to Kenya's upstream sector.

2.2 HSE concerns related to the upstream petroleum sector in Kenya

Upstream exploration and production activities are observed to frequently occur in regions proximate to human settlements.[68] At the end of 2018, it was estimated that about six million people lived or worked near the estimated 40,000 oilfields around the world.[69] The pollution impacts of oil production flowing from gas flares, unsafe disposal of drilling bits and fluids and oil spillages have resulted in numerous deaths, occupational diseases and extensive environmental degradation, particularly in developing nations.[70]

Workers on the oilfield are the primary victims of unsafe production processes, sometimes paying the cost with their lives.[71]

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[67] Productivity Commission, 'Review on the regulatory burden on the upstream petroleum oil and gas sector' Productivity Report Research Commission, Melbourne, 2009, 11 - <https://www.pc.gov.au/inquiries/completed/upstream-petroleum/report/upstream-petroleum.pdf> on 28 October 2019.

[68] Johnston J, Lim E, Roh H, 'Impact of oil extraction and environmental public health: A review of the evidence' 657 (1) *Science of the Total Environment*, 2019, 187.

[69] Johnston J, Lim E, Roh H,, 'Impact of oil extraction and environmental public health: A review of the evidence',187.

[70] Ngene S, Maharaj K, Eke P, Hills C, 'Environmental and economic impacts of crude oil and natural gas production in developing countries' 3 (1) *International Journal of Economy, Energy and Environment*, 2016, 64-73.

[71] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries' Issues paper for discussion at the Sub-Saharan African Tripartite Workshop on Occupational Safety and Health in the Oil and Gas Industry, Maputo, Mozambique, 17−18 May 2017, 16.

The following section provides an analysis of the occupational health, safety and environmental concerns commonly associated with upstream petroleum production.

2.2.1 Occupational health concerns associated with the upstream petroleum sector

Health hazards in the upstream oil sector are usually classified into physical, chemical, ergonomic and psychological hazards.[72]

Physical hazards are described as environmental factors capable of harming the body without necessary contact between the body and the hazard itself.[73] Chemical hazards include substances, materials and mixtures which pose a health risk to the persons coming into contact with them.[74] Ergonomic hazards refer to health problems occasioned by the posture adopted in order to reach and operate various tools at work for a certain length of time.[75]

Psychological hazards refer to relational factors at the workplace with a bearing on the worker's mental health, including stress, fatigue and lack of clarity on the assignment given.[76]

The prolonged exposure of oilfield workers to dangerous toxins and poor working conditions predisposes them to various occupational diseases associated with the upstream petroleum sector.[77] Occupational diseases have been described as those contracted on the basis of exposure to a set of unhealthy conditions at the work place.[78]

For a condition to be classified as an occupational disease, a causal relationship between the disease and the conditions prevalent in the work environment needs to be established, as well as the fact that the frequency of the disease among exposed workers presents itself at a higher morbidity rate in comparison to the rest of the population.[79]

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[72] Niven K, Leod R, 'Offshore industry: Management of health hazards in the upstream petroleum industry' (59)5 *Occupational Medicine*, 2009, 304-309.

[73] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 17.

[74] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 19.

[75] Niven K, Leod R, 'Offshore industry: Management of health hazards in the upstream petroleum industry', 305.

[76] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 19.

[77] Mulloy K, 'Occupational health and safety considerations in oil and gas extraction operations' *National Academy of Engineering*, 2014,1 < https://www.nae.edu/114886/Occupational-Health-and-Safety-Considerations-in-Oil-and-Gas-Extraction-Operations > on 15 November 2019.

[78] ILO, 'Identification and recognition of occupational diseases: Criteria for incorporating diseases in the ILO list of occupational diseases' 74(1) *International Labour office*, 2010,7.

[79] ILO, 'Identification and recognition of occupational diseases: Criteria for incorporating diseases in the ILO list of occupational diseases',7.

Noise and high temperatures are recorded as the primary physical hazards affecting upstream oil and gas workers.[80] Noise and vibrations are occasioned by helicopters during the course of seismic surveys, the use of heavy machinery in the course of site preparation, operation of drilling rigs, firing of the diesel engines and gas flares.[81] Hearing loss induced by noise is reported to be the most common occupational disease in the upstream sector at 25.3%.[82]

When exposed to extremely hot environments, whether from prevalent weather conditions, heat radiating machinery, poor ventilated working spaces or a combination of one or more of these factors, oilfield workers have been seen to suffer from heat rashes, heat syncope or even heat strokes.[83] Reduced visibility of fogged- up glasses or the slipperiness of sweaty palms caused by the high temperatures predisposes the workers and their colleagues to accidents and resultant injuries.[84]

With regard to chemical hazards, Hydrogen Sulfide gas, occurring naturally in oil and gas deposits and classified as one of the most toxic gases in the production cycle causes irritation to the nose, eyes and throat, resulting in rapid breathing failure and death, on exposure. [85]

Drilling fluids employed in drilling operations, and in particular the non-aqueous drilling fluids, when agitated in the course of recirculation have a tendency to pose serious health risks in the nature of skin irritations, inflammation of the respiratory system and even carcinogenicity in the case of oil mists.[86]

Oilfield workers carrying out blasting, cementing and drilling operations have been found to be at a higher risk of inhaling fine silica dust coming from the rocks and sand.[87] The inhalation of the dust results in silicosis, a disease presenting in thickened and scarred lung tissue, causing shortness of breath and eventually, death.[88]

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[80] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 17.

[81] Allison M, 'Occupational hazards in onshore upstream unconventional natural gas extraction' University of Pittsburgh, Pennsylvania, 2013, 27-28.

[82] Naafs M, 'Occupational diseases in the petrochemical sector and offshore upstream petroleum industry' 2(2) *Progress in Petrochemical Science*, 2018, 190.

[83] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 17.

[84] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 17.

[85] Johnson D, 'Oil and gas industry safety', 27-30.

[86] Bediako E, Amorin R, 'Effects of drilling fluid exposure to oil and gas workers presented with major areas of exposure and exposure indicators' 2(8) *Research journal of Applied Sciences, Engineering and Technology*, 2010, 710-719.

[87] Bediako E, Amorin R, 'Effects of drilling fluid exposure to oil and gas workers presented with major areas of exposure and exposure indicators',711.

[88] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries', 19.

Ergonomic health concerns usually center around the upper limbs, the neck and the back of the oilfield worker.[89] Repetitive labour that forces the worker to adopt a certain posture in order to access the equipment necessary to carry out the desired operation, poor designing of the workplace or faulty equipment design has been recorded to place strain on the worker's musculoskeletal system.[90]

On the psychological hazards front, burnout resulting from work overloads, limited contact with the outside world, diminished sleep quantity and quality as a result of revolving work shifts and unclear job descriptions have been reported to increase the stress levels experienced by oilfield workers.[91]

While research on the specific occupational diseases recorded in Kenya's nascent upstream sector is yet to been undertaken, an assessment of Kenya's petroleum sector singled out respiratory infections as one of the most primary concerns of government and surrounding communities resulting from upstream operations.[92]

2.2.2 Occupational safety concerns associated with the upstream petroleum sector

The 2019 International Association of Oil and Gas Producers Report recorded the African region as one with the second highest number of fatalities in its oil and gas sector for the year 2018, after the Middle East region.[93] The fatalities in Africa were attributed to falls from height, being struck by equipment and getting caught in between machinery.[94]

67% of the fatalities were attributed to human error and specifically the unintentional violation of set safety procedure.[95] Research demonstrates that a higher percentage, 53%, of the total oil and gas fatalities among oil and gas workers involved workers with less than one year's experience on site.[96] Estimates place human error as the largest constituent of all workplace accidents, accounting for about 80% of the total number of accidents.[97]

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[89] Niven K, Leod R, 'Offshore industry: Management of health hazards in the upstream petroleum industry', 306.
[90] ILO, 'Occupational safety and health in the oil and gas industry in selected sub-Saharan African countries',18.
[91] Niven K, Leod R, 'Offshore industry: Management of health hazards in the upstream petroleum industry', 306.
[92] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 131.
[93] IOGP, 'Safety performance indicators- 2018 Data: Fatal accidents report' (1)1 *International Association of Oil and Gas Producers*, 2019, 5-33.
[94] IOGP, 'Safety performance indicators- 2018 Data', 5-33.
[95] IOGP, 'Safety performance indicators- 2018 Data', 5-33.
[96] Hill R, 'Improving safety and health in the oil and gas extraction industry through research and partnerships' MAP ERC Energy Summit, Denver, 12 April 2012-< https://www.nae.edu/114886/Occupational-Health-and-Safety-Considerations-in-Oil-and-Gas-Extraction-Operations> on 15 November 2019.
[97] Alkhalid M, Pathirage C, Kulatunga U, 'The role of human error in accidents within oil and gas industry in Bahrain' University of Salford, Manchester, 2017, 824.

Human error has been described as flowing from the absence of awareness of the interaction of the various components at hand and a poor projection of the situation of those components in future.[98]

Reason divides human error into three categories: slip, lapse and mistake.[99] He observes that slip occurs when a certain action is carried out, but is not done in the manner that it was planned, while lapse occurs when the prescribed action is not carried out at all.[100]

Mistake on the other hand refers to the perfect execution of an action as prescribed and planned, with the fault that the plan as laid out is inherently inadequate in achieving the intended outcome.[101] Apart from human error, accidents on the oilfield are attributable to inadequate communication, equipment failure, inadequate maintenance and inclement weather.[102]

2.2.3 Environmental concerns associated with the upstream petroleum sector

Upstream oil operations have increasingly been the subject of concern around the negative impacts posed on the atmosphere, aquatic life and terrestrial systems.[103] Gas flaring is considered the primary source of air pollution in the upstream sector, accountable for the emission of carbon monoxide, carbon dioxide, methane and nitrogen oxides into the atmosphere.[104] The culture of flaring and venting thrives in the absence of gas storage and processing infrastructure and where the market for the associated gas is not easily accessible.[105]

A 2018 World Energy Outlook Report estimates the total oil and gas sector emissions at 5,200 million tonnes, amounting to about 15 % of the total energy sector's emission.[106] The upstream sector accounts for up to 37% of the total emissions.[107]

[98] Mattia D, 2013. 'Evaluation and mitigation of human error during LNG tanker offloading, storage and revaporization through enhanced team situational analysis' *ExxonMobil Production Company*, 2013, 2-4-<https://pdfs.semanticscholar.org/6712/5c6a5976699909e19dab286a8e36293970bf.pdf >on 14 November 2019.
[99] Reason J, *Human error*, Cambridge University Press, Cambridge, 1990, 19-52.
[100] Reason, *Human error*, 19-52.
[101] Reason, *Human error*, 19-52.
[102] Blancett J, Deore P, Khadse G, Rajaram R, 'Digital business: A human centric approach to oil and gas industrial safety' *Cognizant 20-20 Insights*, 2019, 10-< https://www.cognizant.com/whitepapers/a-human-centric-approach-to-oil-and-gas-industry-safety-codex4209.pdf > on 15 November 2019.
[103] Borthwick I, Balkau F, Read T, Monopolis J, 'Environmental management in oil and gas exploration and production' 37(1) *Joint E&P Forum/ UNEP*, 1997, 11.
[104] Borthwick I, Balkau F, Read T, Monopolis J, 'Environmental management in oil and gas exploration and production', 11.
[105] Borthwick I, Balkau F, Read T, Monopolis J, 'Environmental management in oil and gas exploration and production', 11.
[106] IEA, 'World Energy Outlook', 2018 <https://www.iea.org/weo2018/oilandgas/ > on 25 November 2019.
[107] World Resources Institute, 'Upstream emissions as a percentage of overall lifecycle emissions' *World Resources Institute*, 2016-<https://www.wri.org/resources/data-visualizations/upstream-emissions-percentage-overall-lifecycle-emissions > on 25 November 2019.

Leakage of gas from pneumatic equipment and the operation of diesel engines is also responsible, albeit to a less significant degree, to the total upstream emissions.[108]

The global warming effect of increased greenhouse gases in the atmosphere is a multitude of wide ranging issues, including: increase in sea level as a result of the melting glaciers and ice caps, directly threatening the survival of low lying islands and their populations; climate shifts, responsible for increased incidents of flooding, hurricanes, wildfires and drought and an elevated incidence of cardiovascular, respiratory and malnutrition diseases.[109]

Oil spillages and the unsafe disposal of drilling fluids and sanitary wastes account for the greatest extent of negative impacts on aquatic and terrestrial systems in upstream operations.[110]

Drilling fluids are used in production to carry rock fragments to the surface, to cool the drilling bit, to lubricate the drilling pipe and to balance the downhole pressure.[111] The fluid may be oil based, water based or synthetic based, with various chemical additives incorporated into the fluid to achieve the desired viscosity.[112] Oil based drilling fluid is regarded as containing the greatest percentage of toxicity in relation to the other two types.[113] Indiscriminate discharge of drilling fluid threatens the contamination of ground water, soil pollution and death of aquatic life, especially where the fluid contains huge amounts of heavy metals.[114]

Various types of wastes including sewage, scrap metal, contaminated rags, organic food waste and packaging material are generated in upstream processes.[115]

Some of these wastes are hazardous while others are not.[116] Unsafe disposal has the potential of contaminating soil and water.[117]

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[108] Borthwick I, Balkau F, Read T, Monopolis J, 'Environmental management in oil and gas exploration and production', 11.

[109] Khan Z, 'Causes and consequences of greenhouse effect and its catastrophic problems for earth' (3)4 *International Journal of Sustainability Management and Information technologies*, 2017, 34-39.

[110] Borthwick I, Balkau F, Read T, Monopolis J, 'Environmental management in oil and gas exploration and production', 11.

[111] Devold H, *Oil and gas production handbook*, 1ed, ABB ATPA Oil and Gas, Oslo, 2006, 23.

[112] Ismail A, Alias A, Sulaiman W, Jaafar M, Ismail I, 'Drilling fluid waste management in drilling for oil and gas wells' 56 (1) *The Italian Association of Chemical Engineering (AIDIC)*, 2017, 1352-1353.

[113] Ismail A, Alias A, Sulaiman W, Jaafar M, Ismail I, 'Drilling fluid waste management in drilling for oil and gas wells', 1352-1353.

[114] Sharif A, Nagalakshmi N, Reddy S, Vasanth G, Sankar U, 'Drilling waste management and control effects' 1(7), *Journal of Advanced Chemical Engineering*, 2017, 2.

[115] World Bank Group, 'Environmental, health and safety guidelines for offshore oil and gas development' *World Bank Group*, 2015, 2-17- <https://www.ifc.org/wps/wcm/connect/e2a72e1b-4427-4155-aa8f-c660ce3f2cd5/FINAL_Jun+2015_Offshore+Oil+and+Gas_EHS+Guideline.pdf?MOD=AJPERES&CVID=kU7RMJ6 > On 25 November 2019.

[116] World Bank Group, 'Environmental, health and safety guidelines for offshore oil and gas development', 8-10.

[117] World Bank Group, 'Environmental, health and safety guidelines for offshore oil and gas development', 8-10.

Oil spillages in the upstream sector usually occur when the downhole pressure exceeds the mud weight, followed by the malfunction or failure of the blow out preventer.[118] Although these incidences are infrequent, their effects, especially on the offshore arena have been observed to span years and vast geographical regions.[119]

Death of aquatic life and in particular the eggs and larva as well as the coral reefs and mangroves, reduced reproductive rates and changes in migration routes are some of the effects of offshore oil spills.[120]Contamination of drinking water, soil sterilization and death of plant life are some of the onshore effects.[121]

While Kenya has not reported significant environmental impacts of its upstream oil and gas operations yet, concerns around the production operations on the quality and quantity of water are the most pressing.[122] It is reported that the Mandera, Lamu and Anza basins straddle locations prone to flooding.[123] Oil spills and unsafely discharged fluids and wastes could be carried over many kilometers and could contaminate neighboring water sources including rivers, lakes and the Indian Ocean.[124] The proximity of the oil blocks in the arid Turkana County to the few aquifers scattered around the region, the loose sandy soil and the geographical slope of the land towards River Turkwel raises genuine concerns in the eventuality of water contamination.[125] The contamination coupled with the sheer rarity of water would spell death to thousands of animals kept by the inhabitant pastoralist community and a survival crisis for the community.[126]

[118] Devold, *Oil and gas production handbook*, 23.
[119] Ramseur J, 'Oil spills: Background and Governance' *Congressional Research Service*, 2017, 1-2- <https://fas.org/sgp/crs/misc/RL33705.pdf > On 25 November 2019.
[120] Ramseur J, 'Oil spills: Background and Governance',8.
[121] Ramseur J, 'Oil spills: Background and Governance',8.
[122] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 90.
[123] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 90.
[124] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 90.
[125] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 92.
[126] Ministry of Energy and Petroleum, 'Strategic environmental and social assessment of the petroleum sector in Kenya', 92.

2.3 Utility of HSE technology in addressing HSE concerns in the upstream petroleum industry

In view of the numerous risks facing oil and gas workers, countries and companies alike have continuously developed protective clothing, engineered sealed systems, prescribed acceptable exposure limits to toxic elements, substituted extremely toxic elements with less toxic ones and conducted training on safety procedure and disaster management.[127] Valiant as these efforts are, gaps in occupational health and safety and environmental protection persist. Questions around remote facility monitoring, predictive maintenance, individual worker monitoring, notification of critical system overshoots and data management continue to press.[128] The advent of what has now been described as the fourth industrial revolution, geared towards connecting operational technology to information technology and creating possibilities for big data management, cloud storage, remote monitoring and predictive maintenance, seems to hold the answers to the challenges that have heretofore remained unaddressed.[129]

The proceeding section discusses the technological advances made in eliminating occupational health, safety and environmental degradation within the upstream petroleum sector.

2.3.1 Occupational health and safety technology for the upstream petroleum sector

Occupational health and safety in the upstream sector can no longer be limited to personal protective clothing and safety manuals.[130] There is increased realisation that the proper province of health and safety efforts is the anticipation and prevention of the crystallization of the various risks surrounding oilfield workers.[131] Mere protection only scratches the surface of the true objective of occupational health and safety.

While research around the area of personal protective equipment continues to make great strides, such as in the recent development of the HyperKewl Evaporative Cooling material developed by TechNiche to protect workers from heat stress through its unique evaporating

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[127] Niven K, Leod R, 'Offshore industry: Management of health hazards in the upstream petroleum industry', 306.

[128] Rex A, 'How digital technology is making safety smarter' *Oil and Gas Middleeast*, 2009, < https://www.oilandgasmiddleeast.com/35327-how-digital-technology-is-making-safety-smarter> on 4 November 2019.

[129] BDO, 'How industry 4.0 is transforming the oil and gas supply chain' *BDO*, 2018, 1 <https://www.bdo.com/insights/industries/natural-resources/how-industry-4-0-is-transforming-the-oil-gas-sup >. On 4 November 2019.

[130] Rex A, 'How digital technology is making safety smarter', 2.

[131] Rex A, 'How digital technology is making safety smarter', 2.

properties, wearable technology seems to hold the key to anticipatory and preventative capabilities of health and safety equipment.[132]

Wearable technology has been described as a device with computing properties worn on or attached to the body and vested with the ability to process various inputs.[133] The device could take the form of an accessory or a clothing.[134]Wearable technology is thought to have first been invented in 1961 by two MIT mathematics professors with the goal of giving wearers an advantage in the game of roulette.[135]Since then, various wearable devices have been developed for fitness, education, health and industrial safety.[136]

Examples of these wearable technologies include smart glasses, smart watches, smart shoes, fitness bands and smart personal protective equipment.[137]

The ability of occupational health and safety wearable technologies to warn the worker of impending danger, to monitor worker's vitals in the course of duty and to provide workers with the needed real time information to enable them complete tasks makes them priceless in managing health and safety concerns in the oilfield.[138] Each of these capabilities are discussed in turn below.

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[132] Atanasova S, 'HSE special report: Safety matters' *Oil and gas middleeast,* 2016, 1- < https://www.oilandgasmiddleeast.com/article-15445-hse-special-report-safety-matters> On 4 November 2019.

[133] Cicek M, 'Wearable technologies and its future applications' 3(4) *International Journal of Electrical, Electronics and Data Communication*, 2015,46.

[134] Consumer Intelligence Series, 'The wearable life 2.0: Connected living in a wearable world' *PwC,* 2016, 2- <https://www.pwc.se/sv/pdf-reports/the-wearable-life-2-0.pdf > On 4 November 2019.

[135] Kumar S, 'Technological and business perspective of wearable technology' Centria University of Applied Sciences, 2017, 11.

[136] Wilson S, Laing R, 'Wearable technology: Present and Future' University of Otago, New Zealand, 2018, 6-10.

[137] Kumar S, 'Technological and business perspective of wearable technology', 9-20.

[138] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation' *GE, Accenture, Junewarren-nickle's,* 2015, 37- <https://www.accenture.com/t20151210t215032__w__/us-en/_acnmedia/pdf-2/accenture-digital-oilfield-outlook-jwn-october-2015.pdf > On 27 August 2019.

2.3.1.1 Wearable technology's ability to provide warning signals on potential physical and chemical hazards

Various wearable technologies have been developed to notify the oilfield worker of potentially hazardous situations and to prompt them to take urgent remedial steps to avert catastrophes.[139] Smart helmets for example come fitted with sensors for humidity, fire and noxious gases and contain alarm systems which are triggered by overshoots above the minimum exposure limits, warning the worker to evacuate.[140]

Smart glasses have features which enable the display of information relevant to the worker's environment.[141] When used together with augmented reality head displays, the worker is provided with information relevant to the exact context of operation and guided through the task at hand on a virtual platform.[142]

This piece of technology enables the worker to look through the required checklist for the task and to confirm that each action has been undertaken, thereby minimizing the incidence of injury.[143]

Safety gloves and shoes are now fitted with chips to ensure that the worker is wearing the correct gear in relation to the present hazardous zone in which they are operating.[144]

Smart exoskeletons have been developed to augment the strength and endurance of limb movement, enabling workers to use less physical effort, avoid injury and assume the correct posture for carrying out the assigned manual tasks.[145] In this way, the incidence of musculoskeletal disorders resulting from anti-ergonomic postures is greatly minimised.[146]

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139 Wilson S, Laing R, 'Wearable technology', 6-10.

140 Behr C, Kumar A, Hancke G, 'Smart helmet module for air quality and hazardous event detection for the mining industry' 4(1*) International Journal of Innovative Research in Technology, Science & Engineering*, 2018, 2026-2031.

141 Fitzgerald J, Cook A, DeMarinis T, Smetana K , 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation' *Deloitte Development LLC*, 2018, 4-13- <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-cons-using-smart-glasses-and-augmented-reality-head-mounted-displays-to-drive-supply-chain-innovation.pdf > On 4 November 2019.

142 Fitzgerald J, Cook A, DeMarinis T, Smetana K 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation', 4-13.

143 Fitzgerald J, Cook A, DeMarinis T, Smetana K 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation', 6.

144 Rex A, How digital technology is making safety smarter < https://www.oilandgasmiddleeast.com/35327-how-digital-technology-is-making-safety-smarter> on 4 November 2019.

145 Romero D, Mattsson S, Berglund A, Wuest T, Gorecky D, Stahre J, 'Digitalizing occupational health, safety and productivity for operator 4.0' Researchgate, 2018, 5.

146 Romero D, Mattsson S, Berglund A, Wuest T, Gorecky D, Stahre J, 'Digitalizing occupational health, safety and productivity for operator 4.0', 5.

2.3.1.2 Wearable technology's ability to monitor the worker on the oilfield

Location sensors fitted within the worker's smart helmet, smart glasses or smart clothing is able to give an indication as to the position of the worker throughout the day.[147] In the case of danger, it becomes relatively easy to evacuate workers and to account for their current position.[148] Panic buttons fitted within the smart clothing will, when engaged by the worker, enable their quick location and rescue.[149] The authentication of the workers on field can easily be assessed and any intruders identified.[150]

Bio-sensing technology in the smart devices worn by workers are equipped to keep track of the worker's vitals, including their heart rate, blood pressure levels, body temperature and oxygen levels, to assess their fitness to work.[151] A multisensory harness developed by Zephyr for example is worn around the chest and is able to determine the worker's heart rate through fabric electrodes and to measure the rate of respiration through a capacitive sensor.[152] The level of worker fatigue or disorientation can be tracked though the use of computer fitted googles, by monitoring the worker's eye movements.[153] The interconnectivity of the device worn by the worker and a computer device managed by the relevant health and safety personnel allows for the flow of real time communication, enabling the halting of the activity being undertaken in the face of compromised health and safety.[154]

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[147] Mardonova M, Choi Y, 'Review of wearable device technology and its application to the mining industry' 11(1) *Energies*, 2018, 5.

[148] Mardonova M, Choi Y, 'Review of wearable device technology and its application to the mining industry', 5.

[149] Bennet M, 'The role of wearable tech in the oil and gas industry' *I-CIO*, 2016,1- <https://www.i-cio.com/strategy/digitalization/item/the-role-of-wearable-tech-in-the-oil-and-gas-industry> On 28 August 2019.

[150] Imarc Group, 'Industrial wearable devices market: Global industry trends, share, size, growth, opportunity and forecast 2019-2024' *Imarc Group*, 2019- < https://www.researchandmarkets.com/reports/4775698/industrial-wearable-devices-market-global?utm_source=CI&utm_medium=PressRelease&utm_code=zrpk9m&utm_campaign=1277536+-+Global+Industrial+Wearable+Devices+Market+Report+2019%3a+Market+Reached+a+Value+of+US%24+1.64+Billion+in+2018+and+is+Projected+to+Exceed+%242.78+Billion+by+2024&utm_exec=chdo54prd> on 4 November 2019.

[151] Romero D, Mattsson S, Berglund A, Wuest T, Gorecky D, Stahre J, 'Digitalizing occupational health, safety and productivity for operator 4.0' Researchgate, 2018, 5.

[152] Wilson S, Laing R, 'Wearable technology', 8.

[153] Imarc Group, 'Industrial wearable devices market: Global industry trends, share, size, growth, opportunity and forecast 2019-2024',1.

[154] Deloitte, 'Augmented reality and wearables in oil and gas', D*eloitte-US,* 2019 1-<https://www2.deloitte.com/us/en/pages/consulting/articles/augmented-reality-wearables-digital-oil-gas.html>on 21 November 2019.

2.3.1.3 Wearable technology's ability to provide on the job training and guidance to workers

Estimates predict than the next ten years will witness a loss of approximately two hundred and thirty one years of skilled experience in the oil and gas field as a result of the mass retirement of geophysicist and other petroleum engineers, the bulk of whom were set to reach retirement age around the year 2018.[155] Christened, 'the great crew change,' the phenomena portends disruption in the traditional manner of conducting business and foreshadows negative impacts on production levels and safety.[156]

The challenge posed by the great crew change phenomena on safety and productivity can be addressed through the adoption of augmented reality devices, usually embedded on smart helmets or other head-mounted displays.[157] Augmented reality is operationalized through the projection of virtual images onto real life objects and equipment, guiding the worker on the actions needing to be undertaken and the manner of doing so.[158] The information to be imparted is of crucial importance to new workers or on the operation of new equipment.[159] Video-conferences between a worker on site and an expert in a remote location is able to provide a step by step guidance to the worker and to enable the creation of a process map to be stored for posterity.[160] The information given to the worker through this system enables real time decision making and greater standardization across the organization of dealing with similar sets of circumstances.[161] Research shows that the active on the job training presented by the use of augmented reality results in up to 80% of retained skills, after three months.[162]

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155 DISYS, 'Bridging the gap: The digital oilfield and its data' *DISYS*, 2016, 5-< https://www.disys.com/wp-content/uploads/2016/02/Whitepaper-The-Digital-Oilfield-and-its-data.pdf> On 11 March 2019.
156 DISYS, 'Bridging the gap: The digital oilfield and its data', 5.
157 Fitzgerald J, Cook A, DeMarinis T, Smetana K 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation', 6.
158 Fitzgerald J, Cook A, DeMarinis T, Smetana K 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation', 4-13.
159 Fitzgerald J, Cook A, DeMarinis T, Smetana K 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation', 6.
160 Deloitte, 'Augmented reality and wearables in oil and gas', D*eloitte-US,* 2019, 1.
161 Fitzgerald J, Cook A, DeMarinis T, Smetana K 'Using smart glasses and augmented reality head mounted displays to drive supply chain innovation', 4-13.
162 Marr B, 'The amazing ways Honeywell is using virtual and augmented reality to transfer skills to millennials, *Forbes Media LLC,* 2018- < https://www.honeywellprocess.com/en-US/online_campaigns/connected-plant-skills_Insight/Documents/Immersive-Comeptency-Forbes.pdf> on 21 November 2019.

2.3.2 *Environmental digital technology for the upstream sector*

Big data, predictive maintenance and remote monitoring are the key digital capabilities holding the key to environmental protection in the upstream sector.[163] Big data has been defined as a set of data exceeding the typical database's capacity to store, manage and analyze.[164]

The amount of data held by oil and gas companies including seismic data, exploration and production data, data on health, safety and environmental impacts in completed projects easily spans over 20 Petabytes.[165] It is trite knowledge that the lifeline of oil industries is access to information.[166] International oil companies are occupied with uncertainties relating to geological data, production capacity, commercial viability, well location and the nature of crude oil; for purposes of making investment decisions.[167] The lack of information on this fundamentally critical bases has traditionally heightened the risk associated with oil exploration.[168]

3-D and 4-D visualisation and modelling, remotely steerable down-hole tools, fiber-optic fitted well sensors and real-time facility monitoring capabilities in remote locations are some of the technological tools revolutionizing exploration and production and allowing faster and real time access to previously opaque information.[169] Shell for example reports digitization of its Champion West oilfield in the South China Sea and notes that the technology allows for an increased oil recovery of 10 % and gas recovery by 5%.[170] BP, through its installation of sensors in the Gulf of Mexico estimates an additional 3,000 bbls/d of production in its Schiehallion Field.[171]

[163] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation',14.

[164] Hanuska A, Chandramohan B, Bellamy L, Burke P, Ramanathan R, Balakrishnan, 'Smart clothing market analysis' *Sutardja centre, Berkley University of California*, 2018, 34-< https://scet.berkeley.edu/wp-content/uploads/Smart-Clothing-Market-Analysis-Report.pdf> On 26 November 2019.

[165] Tan K, Gallardo V, Perrons R, 'Using big data to manage safety-related risk in the upstream oil and gas industry: A research agenda' (1)1, *Energy Exploration and Exploitation*, 2016, 4.

[166] Bindemann K, 'Production-sharing agreements: An economic analysis' *Oxford Institute for Energy Studies*, 1999, 5-9- <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/WPM25-ProductionSharingAgreementsAnEconomicAnalysis-KBindemann-1999.pdf?v=518f4a738816 > On 11 March 2019.

[167] Bindemann K, 'Production-sharing agreements: An economic analysis', 5-9.

[168] Bindemann K, 'Production-sharing agreements: An economic analysis', 5-9.

[169] Steinhubl A, Klimchuck G, Click C, Morawski P, 'Unleashing productivity: The digital oilfield advantage' *Booz & Company*, 2008, 5- <https://docdrive.co/unleashing-productivity-the-digital-oil-field-advantage-p620482.html > On 12 March 2019.

[170] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 36.

[171] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 36.

The integration of these digital technologies in the upstream sector, coupled with the use of the industrial internet is estimated to push the amount of data in the industry to 2.7 Zetabytes.[172] These technologies are creating the capacity to collect bigger volumes of varied information at high velocities requiring for facilities to store, organize and analyse the collected information.[173] Big data creates the opportunity to break down information silos and to connect patterns across the sector's value chain.[174] Chief among the uses of big data is the capacity for predictive maintenance.[175] Collation and organization of the data collected coupled with the activation of sensors along the production equipment makes it possible for the system to predict when and where maintenance is required.[176] Predictive maintenance allows for the prior notification of an impending equipment malfunction allowing for its remedy before the occurrence of an unscheduled failure.[177] Since every piece of the equipment is constantly under surveillance, gas leakages and oil spills which have catastrophic consequences on the environment can be prevented from happening.[178]

Remote asset monitoring, usually conducted by use of drones has been found to hold two key benefits: first, by removing the human workforce from dangerous platforms and replacing their functions with robotics; and secondly the ability to get a continuous stream of real-time information to experts who can inform on the decisions that need to be undertaken on a priority basis.[179]

A 2017 World Economic Forum report predicts that digital transformation of oil and gas companies will translate to $10 billion in cost savings at the production phase, $30 billion in reduced water usage, a reduction of approximately 1,300 million tonnes of carbon dioxide equivalent emissions and a reduction of oil spillage by about 230,000 barrels over the 2016-2025 period.[180]

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172 DISYS, 'Bridging the gap: The digital oilfield and its data', 6.
173 Tan K, Gallardo V, Perrons R, 'Using big data to manage safety-related risk in the upstream oil and gas industry: A research agenda',4.
174 Tan K, Gallardo V, Perrons R, 'Using big data to manage safety-related risk in the upstream oil and gas industry: A research agenda',4.
175 Tan K, Gallardo V, Perrons R, 'Using big data to manage safety-related risk in the upstream oil and gas industry: A research agenda',4.
176 GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 36.
177 Clark N, Anvar A, 'Not your father's oil and gas business: Reshaping the future with upstream digitization' *Strategy &,* 2016,12-< https://www.strategyand.pwc.com/gx/en/reports/not-your-fathers-oil-and-gas-business.pdf > On 25 November 2019.
178 Clark N, Anvar A, 'Not your father's oil and gas business: Reshaping the future with upstream digitization',14.
179 Clark N, Anvar A, 'Not your father's oil and gas business: Reshaping the future with upstream digitization',12.
180 World Economic Forum, 'Digital transformation initiative -Oil and gas industry' *World Economic Forum,* January 2017, 5- <http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/dti-oil-and-gas-industry-white-paper.pdf > On 25 November 2019.

2.4 Key drivers of HSE technology absorption within Kenya's upstream petroleum sector

2.4.1 Awareness of the existence of HSE technology

In spite of the manifold benefits held out by HSE technology in the upstream sector and the ongoing research and innovation to address traditional HSE issues related to the industry, the level of awareness of the existence of these products is relatively low.[181]

Traditional perceptions in relation to technology adoption have relegated technological issues to the IT department.[182] Preference for tried and tested methods take the day in most oil and gas operations, based on the high level of risks in the industry.[183] A convincing case has to be made for a change in the ways that have worked, been understood and laid down over the years.[184] In an industry survey conducted by GE, Accenture and Junewarren-Nickle's Group, 46% of the participants indicated that they lacked knowledge or experience in oilfield technology.[185]

The survey revealed that the information asymmetry between technology companies and oil and gas senior decision makers often results in less investment considerations for oilfield technology.[186]

Research reveals that greater advocacy for oilfield technology, its benefits and the cost saving nature of its installation to senior oil and gas company executives needs to be undertaken.[187]

That way, it will be possible to establish a company-wide digital culture in order to fully maximize the benefits of digital technology.[188]

Lack of awareness of the existence of HSE technology among the oil workers themselves poses a great barrier to their adoption and use.[189] A recent study conducted in Kisumu County in Kenya revealed that 26% of the respondents were not even aware of the existence of the Occupational Safety and Health Act, their rights under the Act and industry requirements in

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[181] Karev A, Preiss A, Shong F, Casteneda L, Ene I,Navratil P, 'Why it's time to invest in digital oil' *Ernst & Young LLP*, 2016,6-8-< https://www.ey.com/en_gl/oil-gas/why-it-s-time-to-invest-in-digital-oil > On November 2019.

[181] Karev A, Preiss A, Shong F, Casteneda L, Ene I,Navratil P, 'Why it's time to invest in digital oil',7.

[182] Karev A, Preiss A, Shong F, Casteneda L, Ene I,Navratil P, 'Why it's time to invest in digital oil',7.

[183] Karev A, Preiss A, Shong F, Casteneda L, Ene I,Navratil P, 'Why it's time to invest in digital oil',8..

[184] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 33.

[185] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 33.

[186] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 33.

[187] World Economic Forum, 'Digital transformation initiative -Oil and gas industry', 4-5.

[188] World Economic Forum, 'Digital transformation initiative -Oil and gas industry', 4-5.

[189] World Economic Forum, 'Digital transformation initiative -Oil and gas industry', 4-5.

their field of operation.[190] A 2016 safety training workshop noted that more than half of the industrial accidents occurring in Kenya are not reported.[191] Where the workers are not informed of the basic laws setting up their right to be informed of the hazards prevalent in the workplace, the protective equipment to be issued and the reporting procedure for injuries sustained, it is clear than conversations around HSE technology are unlikely to ever have taken place.

2.4.2 Availability of HSE technology

The key industry players in the manufacture of HSE technology include Apple, Honeywell, Fujitsu, Google and Samsung among others.[192] Most of these companies are domiciled in Asia, Europe and North America with very few having regional subsidiaries in Africa. The service companies involved to a large extent in the development of HSE technology are Schlumberger, Weatherford, Halliburton and Baker Hughes General Electric.[193] Again, these companies are domiciled in North America and Europe and none in Africa.[194] Projections put the market for wearable devices in Africa at 25.42 million by 2020, being the smallest market after the Asia Pacific Region and even the Latin America region.[195]

Present and future projections therefore indicate that the availability of HSE technology will be more of a challenge to the African continent than to any other region.

While Tullow oil PLC, one of the companies involved in the exploration and production of oil in Turkana County, announced its intention to adopt predictive analytics and robotics in its oil operations.in 2019, it is unclear whether HSE considerations are at the center of the digitization exercise.[196]

[190] Oluoch I, Ndenda J, Njogu P, 'Effect of occupational safety and health awareness on work environment in the water service industry within Kisumu County- Kenya' 11(6) *IOSR- Journal of Environmental Science, Toxicology and Food Technology*, 2017, 35-41.

[191] Nyakong'o J, 'Summary Status of occupational health and safety in Kenya' Workshop on the IUPAC-UNIDO Safety Training Program, Part of the IUPAC Congress in Bejing, on August 17 2016.

[192] Imarc Group, 'Industrial wearable devices market: Global industry trends, share, size, growth, opportunity and forecast 2019-2024',1.

[193] Imarc Group, 'Industrial wearable devices market: Global industry trends, share, size, growth, opportunity and forecast 2019-2024',1.

[194] Singh S, 'Digital oilfield market' *Market and Markets*,2019, 1- < https://www.marketsandmarkets.com/Market-Reports/digital-oilfield-market-904.html?gclid=EAIaIQobChMI-MCtrPOH5gIVgbHtCh2ohwdPEAAYASAAEgLDYfD_BwE > on 26 November 2019.

[195] Kumar S, 'Technological and business perspective of wearable technology',66.

[196] Tullow Oil PLC, 'Technology Innovation' *Tullow Oil Plc,* 2019, 1- < https://www.tullowoil.com/media/case-studies/technology-innovation > On 11 March 2019.

2.4.3 Affordability of HSE technology

Price has been singled out as the biggest barrier to the adoption of HSE technology.[197] The average cost of a smart watch is quoted at £200[198] and the cost of a pair of smart glasses, customised to the oil and gas sector at about $2,700,[199] translating to approximately Ksh. 20,000 and Ksh. 270,000 respectively. The high prices have been attributed to the developmental stage of the technologies and the costs involved in research and manufacturing.[200]For companies to agree to incur such high costs, the manufacturers must provide concrete proof of their value addition to oil and gas processes.[201] It has been suggested that the low uptake of HSE technology particularly in Africa can be rationalized against competition for more pressing issues such as the construction of roads, installation of electricity, drilling of boreholes and construction of wells, which are seen as having a more direct connection with operations.[202] The type of international oil company engaged and its financial muscle also have a bearing on the level HSE technology deployment. BP for example, has been on the forefront of research and innovation around HSE technology and is able to onboard technologically advanced service companies such as Schlumberger and Baker Hughes to digitize its field processes.[203]

Kenya's upstream sector is relatively nascent, is at the developmental stage and has less fantastic reserves in comparison to other sub Saharan countries.[204]

Additionally, the oil field blocks are situated in infrastructure impoverished regions, requiring cost intensive ground work prior to production. With these set of circumstances, it might be understandable why evidence of HSE technology in its upstream sector is largely non-existent.

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[197] Consumer Intelligence Series, 'The wearable life 2.0: Connected living in a wearable world', Consumer Intelligence Series, PWC, 2016,11.

[198] Epstein Z, 'Another big barrier blocking widespread wearable tech emerges' *BGR*, 2013,1- < https://bgr.com/2013/10/31/wearable-technology-adoption-price-barrier-gfk/> On November 21 2019.

[199] Blum J, Smart glasses change the view in the oil and gas industry, *Houston Chronicles*, 2016, 1- < https://www.houstonchronicle.com/business/energy/conferences/article/Smart-glasses-change-the-view-in-the-oil-industry-7394261.php> on November 21 2019.

[200] Kumar S, 'Technological and business perspective of wearable technology',55.

[201] Consumer Intelligence Series, 'The wearable life 2.0: Connected living in a wearable world',11.

[202] African Climate Policy Centre, 'Fossil fuels in Africa in the context of a carbon constrained future' United Nations Economic Commission for Africa, Working Paper 12, 2011, 14-15.

[203] GE, Accenture, Junewarren-nickle's, 'Digital oilfield outlook report: Opportunities and challenges for digital oilfield transformation', 18.

[204] IHRB, 'Human rights in Kenya's extractives sector: Exploring the terrain', 15.

2.4.4 Acceptability of HSE technology

HSE technology and in particular wearable technology has faced sharp criticism on the basis of its infringement on the privacy of the worker and the potential for function creep by the recipients and users of the personal data collected.[205] Vulnerabilities in wearable devices have been the subject of extensive review by security organizations, with evidence pointing to unsecured login credentials, data visibility to potential hackers, potential for loss of the device and subsequent data harvesting as the main concerns.[206] Ethical considerations such as the collection of unnecessary personal data and the subjection of the collected data to undisclosed secondary use, pose additional barriers to the acceptability and usage of HSE technology.[207]

Employers are also concerned about the secret recording capabilities of some of the devices and the potential for breach of confidentiality and theft of the company's intellectual property.[208] Google glass for example was introduced to the market in 2013 and later withdrawn in 2015 on the basis of complaints about the potential for the embedded video in the glass to compromise the privacy of persons who are not even aware that they are the subject of an ongoing recording.[209]

It has been emphasized that worker surveillance and monitoring ought to be respectful of their right to be informed of the monitoring exercise, their right to privacy, their right to disclosure of the use of the information obtained and the intendent recipients and the right to refuse to accede to invasive monitoring.[210]

Further, the data collected must not be used to discriminate against or prejudice the interest of the worker.[211]

Kenya's Data Protection Act, 2019 lays out stringent requirements on the collection and dissemination of personal data, including requiring that the data processor and data controller be registered as such, obtain express consent from the data subject for collection of the data and report on the usage of the data collected.[212]

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[205] KPMG, 'Privacy and wearable technologies-A POPI dilemma' *KPMG South Africa*, 2016, 3- <https://home.kpmg/za/en/home/insights/2016/08/privacy-and-wearable-technologies.html> On 22 November 2019.

[206] KPMG, 'Privacy and wearable technologies-A POPI dilemma', 3.

[207] Habibipour A, Padyab A, Ståhlbröst, 'Social, ethical, and ecological issues in wearable technologies' Twenty –fifth Americas Conference on Informational Systems, Cancun, July 16 2019, 4.

[208] Habibipour A, Padyab A, Ståhlbröst, 'Social, ethical, and ecological issues in wearable technologies',4.

[209] Kudina O, Verbeek P, 'Ethics from within: Google glass, the Collingridge dilemma, and the mediated value of privacy' 44(2) *Science, Technology and Human Values*, 2019, 298-306.

[210] Alli B, *Fundamental principles of occupational health and safety*, 2ed, International Labour Office, Geneva, 2008, 72-78.

[211] Alli, *Fundamental principles of occupational health and safety*,75-78.

[212] Sections 18-43, *Data protection Act* (Act No. 24 of 2019)

The additional legal and regulatory compliances brought in by the Act may deter or slow down the uptake of wearable technology within Kenya's upstream sector.

Apart from privacy concerns, the short battery life associated with wearable technology also creates a barrier to the technology's acceptability.[213] Given that mobility is of crucial significance to wearable devices, efforts are geared towards making the device as small, light and unobtrusive as possible.[214] This will usually mean that a small battery be used, resulting in less power storage capabilities.[215] Some companies have attempted to use screens with low power requirement in order to lengthen the battery life, but this has been found to compromise on the display components of the devices, and client dissatisfaction.[216]Interoperability of various HSE technology with other electronic devices also presents a challenge.[217]

Differing application platforms might hinder the transfer of data from a wearable device to a phone or tablet, making the storage and sharing of the data difficult.[218]

2.5 Conclusion

The chapter has identified HSE risks prevalent in Kenya's upstream sector and demonstrated the existence of HSE technology capable of addressing these risks. More importantly, an evaluation of the key drivers of technology absorption in terms of availability, awareness, affordability and acceptability within the Kenyan market has been undertaken and the challenges obtaining under each head identified as contributing to the low deployment of HSE technology.

An appreciation of the risks, technological products and drivers of technology absorption provide important background knowledge towards technology transfer processes, ensuring that the process is enlightened and that the technological products transferred are indeed capable of addressing identified risks, providing an opportunity for the monitoring of their performance. The risk and technology availability identification process enables the Kenyan government to participate fully in the technology transfer negotiations and to assess its present operational capabilities as well as the additional help required. This knowledge is also instrumental in formulating local content policies in relation to technology transfer on the basis of verifiable present capacity and the required foreign capacity to make the process successful.

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213 Kumar S, 'Technological and business perspective of wearable technology', 43.
214 Kumar S, 'Technological and business perspective of wearable technology', 44.
215 Kumar S, 'Technological and business perspective of wearable technology', 44.
216 Kumar S, 'Technological and business perspective of wearable technology',44.
217 Kumar S, 'Technological and business perspective of wearable technology',44.
218 Kumar S, 'Technological and business perspective of wearable technology',44.

Having addressed the first arm of technology transfer, the next chapter evaluates the legal and institutional gaps impeding the acquisition, assimilation and modification tenets of technology absorption.

CHAPTER 3: LEGAL AND INSTITUTIONAL GAPS LIMITING THE ABSORPTIVE CAPACITY OF HSE TECHNOLOGY WITHIN THE KENYAN UPSTREAM SECTOR

3.1 Introduction

While African development discussions prominently feature scientific and technological advancement as central themes, it has been observed that there is little in the way of background activity to anchor the pronouncements.[219] Ogbu points out the copious legislative efforts in the nature of the Lagos Plan of Action and the Addis Ababa Declaration which sought to affirm technology's potential to address some of Africa's challenges and their ill performance at achieving the scientific advancements envisioned.[220]

While acknowledging the historical demonstrations of Africa's innovative capacity, Mohammed *et al* attribute the continent's technological drawbacks to the uncoordinated and disorganized nature of its innovative efforts.[221] At present, Africa accounts for a meagre 2% of the global research generation; 0.1% of the global patents pool; 1.3 % of funding channeled to research and a contribution of only 3% of the global GDP in spite of the fact that it houses 15% of the global population.[222] The sluggishness in embracing technology has been chalked up to a number of factors including regulatory opacity, corruption and poor governance.[223]

Administrative, regulatory and policy reforms observed in various places on the continent have already borne fruit in making operations more efficient, with the telecommunications industry being singled out as the poster child for this type of success.[224]

Kenya's commitment to technological deployment is hailed as one of the oldest in Africa, dating back to the enactment of the Science and Technology Act in 1977.[225] Kenya is currently the regional headquarter for Google, IBM, Intel and Microsoft offices in Sub-Saharan Africa.[226]

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[219] Ogbu O, 'Can Africa develop without science and technology?' (9) *African Technology policy Centre*, 2004, 1.

[220] Ogbu O, 'Can Africa develop without science and technology?', 3.

[221] Mohammed A, Hui Y, Latif A, Lukman S, Nadege M, Paul N, 'Barriers to innovation and public policy in Sub- Saharan Africa' 8(4), *Public Policy and Administration Research*, 2018, 57-58**.**

[222] Fakim A, Lopes C, Technology and development in Africa: Innovation for sustainable growth, *The Royal Institute of International Affairs*, 2017, 2_ <https://www.chathamhouse.org/sites/default/files/events/Transcript%20-%20Technology%20and%20Development%20in%20Africa%20%20Innovation%20for%20Sustainable%20Growth.pdf > on13 December 2019.

[223] Mohammed A, Hui Y, Latif A, Lukman S, Nadege M, Paul N, 'Barriers to innovation and public policy in Sub- Saharan Africa', 57.

[224] Forster V, Garmendina C, 'Africa's infrastructure: A time for transformation' *World bank Group*, 2010, 12-13_<https://openknowledge.worldbank.org/handle/10986/2692> on 10 December 2019.

[225] UNCTAD, 'Africa's technology gap: Case studies on Kenya, Ghana, Uganda, and Tanzania' *United Nations Publications*, 2003, 19.

[226] Patey L, 'Kenya: An African oil startup in transition' (53) *The Oxford Institute for Energy Studies*, 2014,3.

These impressive achievements notwithstanding, technological absorption of HSE technology in Kenya's nascent oil and gas industry is worrying.

Ensuing portions of this chapter evaluate legal and institutional gaps suppressing HSE technology absorption within Kenya's upstream sector.

3.2 Legal gaps hindering the uptake of HSE technology in Kenya's upstream sector

3.2.1 Lack of clarity on the scope and applicability of the best available technology standard

Once the HSE risks obtaining in an upstream oil and gas environment have been identified, the second step in the technology absorption process is the evaluation of the technology available to address the identified risks.

Section 59 (1) of the Petroleum Act obligates contractors carrying out upstream operations in Kenya's oilfields to utilise the best petroleum industry practices and specifically, to deploy the best available technology (BAT) to safeguard HSE concerns.[227]

The election of the technology standard to be applied, while seemingly progressive in relation to addressing HSE risks is fraught with opacity.

First, the definition of the technological products satisfying this standard is not provided for under Section 2 of the Act, nor in the model production sharing contract under the Act. While Section 2 of the Act defines best petroleum industry practices to include methods, standards and procedures followed internationally by skilled and diligent operators in a bid to optimise production and minimise operational impacts, no definition is assigned to the best available technology standard.[228]

Secondly, it is not immediately clear who the party charged with the determination of the attainment of the required standard is; whether the Kenyan government or the international oil company.

Thirdly, given the fast-paced nature of technological evolution, it is unclear whether the standard calls for multiple re-installations of the latest most superior technological products available in the global market.

Lastly, it appears that technology transfer modalities are left to be resolved by the contractor and its subcontractors under the model sharing agreement, seemingly without active input of the government, save at the regulatory compliance level.[229]

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[227] Section 59 (1) (b), *Petroleum Act* (Act No 2 of 2019).

[228] Section 59 (1) (b), *Petroleum Act* (Act No 2 of 2019).

[229] Section 23 (1), *Model production sharing agreement of the Petroleum Act* (Act No 2 of 2019).

Research has demonstrated that emerging countries in petroleum production, largely characterized by weak regulatory systems and little experience lack technical advancement in operational technology and usually leave operators to self-regulate on technical matters.[230]

Technology absorption principles call for proactiveness on the part of the host state in evaluating the technological products available in line with the HSE risks already identified and not merely awaiting the transfer of whatever technology is deemed fit by the contractor.

3.2.2 Deficient legal support for HSE technology innovation

The Petroleum Act seems to rely on technology transfer as the primary and exclusive mode of HSE technology acquisition, with no focus on incentivizing locally developed technology adaptable to Kenya's upstream sector.[231] The effect of this lacuna is the stifling of homegrown technological solutions likely to increase the efficiency and affordability of the transferred technology.

As seen from chapter one, any successful technology absorption process must be underpinned by a strong capacity to modify and customize the transferred technology to address current and anticipated HSE risks. The need to have technological performance in tune with the desired outcome is the core reason for transferring technology in the first place.[232]As such, innovation is one of the central themes to any technology absorption exercise.

Given the infancy of Kenya's upstream industry, competing infrastructural interests, and relative hardship in assessing HSE technology, strengthening local capacity to develop the requisite technology seems to be the most logical step.

The exclusive nature of inventions considered patentable and the length and associated costs of a patent registration process in Kenya presents a further hindrance to technology innovation.[233] Patents form one of the subsets of intellectual property law in Kenya and are governed by the Industrial Properties Act.[234] Intellectual property law is concerned with the recognition, protection and promotion of creativity.[235] Patent protection relates to a section of intellectual property law involving products and processes.[236]

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[230] Marcel V, 'Guidelines for good governance in emerging oil and gas producers 2016' Chatham House-The Royal Institute of International Affairs, 2016, 12-17.

[231] Section 23, *Model production sharing agreement of the Petroleum Act* (Act No 2 of 2019).

[232] Vandenbussche V; Thylander E; Millet D, 'Best available techniques applied to the offshore oil and gas industry' 2014 International Oil Spill Conference, Norway, 2014, 389.

[233] Conde D, *The Intellectual property review*, 6th ed, Law Business Research, London, 2017,181.

[234] Section 21, *The Industrial Properties Act* (Act No. 3 of 2001).

[235] Wekesa M, Sihanya B, 'Intellectual property rights in Kenya', 222.

[236] Wekesa M, Sihanya B, 'Intellectual property rights in Kenya', 222.

For an invention to be patentable, it must qualify in three respects; first it must be novel, second it must demonstrate an inventive effort and lastly, it must be applicable at an industrial scale.[237] Section 21(3) of the Industrial Properties Act lists a number of inventions incapable of patent protection in Kenya.[238] Inventions around business methods and the usage of any substance whatsoever for the purpose of preventing any disease fall in the category of non-patentable inventions.[239]

The choice of wording gives an unduly wide construct to inventions falling in the latter category, making the argument for non- patentability of wearable oilfield technology, developed to prevent occupational diseases, plausible. The TRIPS agreement, applying to members of the World Trade Organization of which Kenya is part, qualifies all inventions as patentable, subject to the three step test above.[240] The agreement only excludes from patentability inventions that have a direct link to the protection of human and plant life, on the basis of morality.[241]

The lengthy process associated with patent registration in Kenya, spanning an average of two years, in the absence of any procedural setbacks, is a great hindrance to patent registration.[242] On average, it has been observed that the statutory costs of a patent registration process is about Twenty Thousand Kenya Shillings.[243] While this cost in itself is reasonable, the almost inevitable engagement of a patent agent to guide the inventor through the application process and to draft the necessary documentation significantly increases the costs associated with the process.[244]

Mbote attributes the sluggish pace of growth in Kenya's patents jurisprudence to the fact that intellectual property begun to be taught in Kenyan law schools in 1992, making the majority of current judges and senior lawyers inexperienced in the field.[245]

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[237] Section 22, *The Industrial Properties Act* (Act No. 3 of 2001).
[238] Section 21 (3), *The Industrial Properties Act* (Act No. 3 of 2001).
[239] Section 21 (3), *The Industrial Properties Act* (Act No. 3 of 2001).
[240] Article 27(1), *Agreement on the Trade-Related Aspects of Intellectual Property Rights* (Annex 1C of the Marrakesh Agreement Establishing the World Trade Organization -15 April 1994).
[241] Article 27 (3), *Agreement on the Trade-Related Aspects of Intellectual Property Rights* (Annex 1C of the Marrakesh Agreement Establishing the World Trade Organization -15 April 1994).
[242] Conde, *The Intellectual property review*, 181.
[243] KIPI, 'How to apply for a patent' Kenya Industrial Property Institute, 2017, 1- <https://www.kipi.go.ke/index.php/how-to-apply-for-a-patent > on 18 December 2019.
[244] Conde, *The Intellectual property review*, 181.
[245] Mbote P, 'Intellectual property protection in Africa: An assessment of the status of laws, research and policy analysis on intellectual property rights in Kenya' International Environmental Law Research Paper, Working Paper 2005-2, 2005, 22< http://www.ielrc.org/content/w0502.pdf > on 18 December 2019.

3.2.3 Unbalanced data protection provisions

Kenya's Data Protection Act, which came into effect in November of 2019, seeks to lay out protective measures for the protection of personal data in line with the right to privacy under Article 31 (c) and (d) of the Constitution.[246] Personal data is defined to span the totality of information relating to a person which identifies that person or makes their identification possible.[247] Data processors are seen to collect, store and disseminate personal data to data controllers who in turn determine the purpose and usage of the personal data.[248]

The wearable technology discussed in chapter 2 is built to collect personal information on the oilfield worker's location, biometrics and exposure to hazardous situations for the purposes of assessing their safety and effectiveness to keep working.[249]

While the protection of privacy is of crucial importance, certain provisions in the Act seem to sacrifice the rights of the data controller or data processor at the altar of the data subject's protection. Section 32 (2) of the Act for example, provides an absolute right of the data subject to withdraw consent previously given, allowing for the processing of their personal data.[250]

This withdrawal seems not to require any prior warning and certainly does not take into account the interests of the controller or processor.

In the case of wearable safety technology, a worker can simply decide to stop using the safety technology prescribed while on site, potentially compromising their own safety and the safety of other workers. Further, the wording in Section 30 of the Act listing the circumstances to be satisfied before personal data is processed seems to indicate that the listed conditions have to be satisfied cumulatively.[251]

The EU General Data Protection Regulation (GDPR) in contrast requires that only one of the conditions listed, among them: data processing on the basis of explicit consent; data processing to satisfy a contractual obligation; data processing for the protection of the data subject's vital interests and most importantly, data processing for the purpose of assessing the working capacity of an employee, be satisfied.[252]

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[246] Section 3, *The Data Protection Act* (Act No. 24 of 2019).
[247] Section 2, *The Data Protection Act* (Act No. 24 of 2019).
[248] Section 2, *The Data Protection Act* (Act No. 24 of 2019).
[249] Behr C, Kumar A, Hancke G, 'Smart helmet module for air quality and hazardous event detection for the mining industry' 4(1*) International Journal of Innovative Research in Technology, Science & Engineering*, 2018, 2026-2031.
[250] Article 32(2), *The Data Protection Act* (Act No. 24 of 2019).
[251] Section 30, *The Data Protection Act* (Act No. 24 of 2019).
[252] Article 9(2), *EU General Data Protection Regulation* (Regulation (EU) 2016/679).

Also, while the GDPR at Article 42 provides a system of voluntary certification demonstrating compliance with the regulation's requirements, Section 18 of the Data Protection Act mandates all persons handling personal data to first be registered as either data processors or data controllers, and thereafter to renew their certificate at a time to be decided on at the time of application.[253] The GDPR requires renewal of the certificate of compliance within three years, providing legal predictability to the process.[254]

In essence then, the GDPR's definition and description of the rights of the data subject in contrast to Kenya's provisions are reasonably balanced against the processor or controller's duties, allowing for both parties to reap benefits from the legislation.

3.3 Institutional gaps hindering the uptake of HSE technology in Kenya's upstream sector

The primary purpose of regulatory policies is to ensure an equilibrium in relation to the multiple competing interests, while at the same time creating an environment conducive to economic growth.[255] It has been proposed that regulators should concentrate on four critical bases: public protection, effective and sustainable use of resources, collection of royalties due to the government and independence in decision making.[256]

Haidari notes that the petroleum sector remains unmatched in the intricacies of its challenges to produce energy at an affordable, sustainable and profitable manner while at the same time observing regulatory compliance.[257]

Swart points out that the governance of regulatory bodies has a direct impact on technology, primarily based on its ability to generate the required momentum in entrepreneurial growth, to stimulate innovation and to ensure that the rewards attaching to innovation are protected.[258]. Lack of intergovernmental coordination, defective regulatory capacity and corruption are the key barriers to the uptake of HSE technology in Kenya's upstream sector. Each of these is discussed in turn below.

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[253] Section 18, *The Data Protection Act* (Act No. 24 of 2019).

[254] Article 42(7), *EU General Data Protection Regulation* (Regulation (EU) 2016/679).

[255] EY, 'Alberta's oil and gas sector regulatory paradigm shift: Challenges and opportunities' 2015, 2 _<https://www.ey.com/Publication/vwLUAssets/EY-albertas-oil-and-gas-sector-regulatory-paradigm-shift-challenges-and-opportunities/$FILE/EY-albertas-oil-and-gas-sector-regulatory-paradigm-shift-challenges-and-opportunities.pdf > on 10 December 2019.

[256] EY, 'Alberta's oil and gas sector regulatory paradigm shift: Challenges and opportunities, 2015', 2.

[257] Haidari A, 'Disruption is here in the energy industry: Are you ready' 2018, 1< https://www.engineeringwhitepapers.com/companies/ansys/disruption-is-here-in-the-energy-industry-are-you-ready/ > on 10 December 2019.

[258] Swart D, 'Africa's technology futures: Three scenarios' The Pardee Papers (14) 2011, 7.

3.3.1 Non-intergovernmental coordination between the multiple regulatory agencies

Upstream petroleum operations in Kenya fall under the Ministry of Petroleum and Mining, presided over by the Cabinet Secretary in charge of petroleum and mining.[259]

Section 12 of the Petroleum Act establishes the National Upstream Petroleum Advisory Committee mandated to advise the Cabinet Secretary on matters touching on upstream petroleum operations in Kenya.[260] The Advisory Committee is thus directly in charge of advising the Cabinet Secretary on the best available HSE technology to be deployed in the upstream sector.[261]

The Energy and Petroleum Regulatory Authority established under Section 9 of the Energy Act, 2019 is tasked with the function of regulating, monitoring and providing supervision to upstream operations in Kenya, including the assessment of the effectiveness of deployed HSE technology.[262]

Occupational health and safety considerations fall under the regulatory mandate of the Director of Occupational Health and Services in accordance with Section 23 of the Occupational Health and Safety Act.[263] The Director is tasked with the promotion of occupational safety and health in workplaces and compliance oversight on stipulated health and safety provisions.[264] The Act also establishes the National Council for Occupational Safety and Health to advise the Director in policy formulation, analysis of work related injuries and death and the establishment of a preventative culture on occupational health and safety.[265]

Environmental protection is chiefly regulated by the National Environment Management Authority (NEMA) established under section 7 of the Environmental Management and Co-ordination Act (EMCA)with the mandate to integrate environmental considerations into projects being undertaken in Kenya and to issue environmental impact assessment licenses.[266]

The Science, Technology and Innovation Act establishes the National Commission for Science, Technology and Innovation under Section 3, vesting it with the regulatory mandate to oversee quality assurance in the fields of science, technology and innovation and to advice the government on related matters.[267]

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[259] Section 2, *The Petroleum Act* (Act No. 2 of 2019).
[260] Section 13, *The Petroleum Act* (Act No. 2 of 2019).
[261] Section 59, *The Petroleum Act* (Act No. 2 of 2019).
[262] Section 10 (b), *The Energy Act* (Act No. 1 of 2019).
[263] Section 23, *The Occupational Safety and Health Act* (Act no. 15 of 2007).
[264] Section 23(8), *The Occupational Safety and Health Act* (Act no. 15 of 2007).
[265] Section 27, *The Occupational Safety and Health Act* (Act no. 15 of 2007).
[266] Section 63, *Environmental Management and Co-ordination Act* (Cap 387).
[267] Section 4, *The Science, Technology and Innovation Act* (Act No 28 of 2013).

As discussed in the previous section, the gathering of personal data through the use of wearable safety technology requires the registration of the data processor, which falls under the regulatory jurisdiction of the office of the Data Protection Commissioner established under Section 5 of the Data Protection Act.[268]

From the foregoing, it is apparent that the operation of HSE technology in the upstream sector is surrounded by a heavily regulated environment, featuring disparate pieces of regulation and unrelated regulatory instruments. The above narration does not even touch on the importation procedures of the technology or the licensing requirements for use in Kenya.

The multi-regulated field poses two main barriers to the deployment of HSE upstream technology: firstly, un-coordination between the fragmented regulatory divisions, usually resulting in a duplication of roles and secondly, the time consuming and cost ineffective nature of applying for the various clearances required.[269]

Stephen *et al*, also note that a multiplication of regulatory authorities engender a culture of laxity and sluggishness in the carrying out of the relevant mandates because of a lack of accountability along the decision making value chain from one regulator to the next.[270]

The absence of a designated body mandated to interpret the constituents of the best available HSE upstream technology augments the problems associated with the regulatory environment.

3.3.2 Inadequate regulatory expertise relevant to the deployment of HSE technology

An evaluation of the regulatory structure in place to oversee the deployment of HSE technology in Kenya demonstrates a yawning gap in technological experience and expertise.

The composition of the National Upstream Petroleum Advisory Committee established by Section 12 of the Petroleum Act does not include a HSE technological expert, nor does it create a slot for an occupational health and safety expert.

While the Section allows the Committee to co-opt additional members deemed necessary, the absence of this key personnel is an indication of the prevalent blindside to the centrality of HSE technology in the production process.[271] It is however encouraging to see that the Director General of NEMA or his representative is included in the membership list.[272]

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[268] Section 18, *The Data Protection Act* (Act No. 24 of 2019).

[269] Mohammed A, Hui Y, Latif A, Lukman S, Nadege M, Paul N, 'Barriers to innovation and public policy in Sub- Saharan Africa', 63.

[270] Stephen O, Uchenna E, Isaiah O, Philip A, 'Innovations in Africa: Why institutions matter'83(3) South Africa Journal of Economics, 2014, 6.

[271]Section 12, *The Petroleum Act* (Act No. 2 of 2019).

[272] Section 12 (1) (f), *The Petroleum Act* (Act No. 2 of 2019).

The membership of the Energy and Petroleum Regulatory Authority established under Section 9 of the Energy Act again does not reflect any HSE expertise in its composition.[273]

The absence of HSE knowledge and experience in petroleum production processes deprives the decision making organ of the necessary checks and balances in relation to HSE considerations, running the risk of decision making with a disproportionate focus on financial gain.[274]

Expertise in HSE technology will also be invaluable in providing background knowledge and proficiency in the development of cyber security systems, an area that is speedily gaining traction in the oil and gas digital world.[275]

It has been suggested that the quality of regulatory institutions is measurable against their ability to formulate and carry out wholesome policies including anticipatory and preventive measures in the environment that they seek to regulate.[276] Studies on the deep water horizon accident for example, have concluded that regulatory policy needs to incorporate lessons learnt from previous accidents and to reflect genuine effort in attempting to shield present industries from a similar fate.[277]

It is of crucial importance that HSE expertise be reflected in regulatory compositions in a bid to integrate HSE considerations in upstream operations in Kenya and to realize effective compliance.[278]

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[273] Section 12, *The Energy Act* (Act No. 1 of 2019).

[274] Huudeman A, Rozhkova A, ' Balancing petroleum policy: Toward value, sustainability and security' The World Bank, 2019, 2 < http://documents.worldbank.org/curated/en/326461556725810981/Balancing-Petroleum-Policy-Toward-Value-Sustainability-and-Security > On 19 December 2019.

[275] ONG SCC, NGC, 'Defense-in-depth: Cybersecurity in the natural oil and gas industry' Oil Natural Gas Sector Coordinating Council/ Natural Gas Council, 2018, 12 - <https://www.api.org/~/media/Files/Policy/Cybersecurity/2018/Defense-in-Depth-Cybersecurity-in-the-Natural-Gas-and-Oil-Industry.pdf > On 19 December 2019.

[276] Mohammed A, Hui Y, Latif A, Lukman S, Nadege M, Paul N, 'Barriers to innovation and public policy in Sub- Saharan Africa', 57.

[277] Petroleum Safety Authority 'Concluding report on its follow up of the deep water horizon accident' Petroleum Safety Authority of Norway, 2014,18.

[278] OECD 'Reducing the risk of compliance failure: Challenges for regulatory compliance' Organization for economic cooperation and development, 2000,14-20.

3.3.3 *The effects of corruption in hindering successful deployment of HSE technology in Kenya's upstream sector*

The term 'corruption' has been assigned a battery of definitions in various places around the globe.[279] According to Khan, corruption denotes a deviance in behavior from the laid down rules of conduct governing the actions of a public authority in relation to motives such as wealth, status or power.[280] Tanzi defines corruption as the intentional decision not to comply with arm's- length principles with a view to deriving an advantage for the individual or conferring the advantage upon some other person of the individual's choice.[281] The world bank views the term as encompassing all actions in which public office is abused for private gain.[282] The foregoing definitions unearth a discordance in the efforts towards a uniform definition of corruption.[283] Brooks *et al* attribute the disparity in definition to the diverse categorizations of the forms, effects and causes of corruption.[284] Andvig *et al* on the other hand, conclude that the multiplicity in the definition of corruption results from the fact that the subject has been approached from a multi-disciplinary perspective, thus incorporating political, economic, moral and hybrid definitions in its discussion.[285] In spite of the lack of a universal definition, there is general consensus that corruption finds its latching in a disintegrating moral fabric.[286] Within the Kenya context, the term corruption encircles a horde of offences including: bribery; fraud; embezzlement; abuse of office; breach of trust; secret inducements for advice; improper benefits to trustees for appointment; bid rigging offences involving dishonesty in connection with taxes, levies or rates or in connection with election to public office.[287]Various factors have been observed to continually fan the flames of corruption: unreasonably tedious bureaucratic processes, opacity in procedural rules and guidelines, low public sector wages, unduly harsh penalty systems and a general laxity in institutional controls.[288]

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[279] Ackerman S, 'Democracy and grand corruption' (48)149, *International Social Science Journal*, 1996, 365-375.
[280] Khan M, 'A typology of corrupt transactions in developing countries (27)2, *IDS bulletin*, 1996, 12-21.
[281] Tanzi V, 'Corruption around the world: Causes, consequences, scope and cures, International Monetary Fund Working Paper, WP 98/63, 1998, 8-10< https://www.imf.org/external/pubs/ft/wp/wp9863.pdf> On 20 December 2019.
[282] Begovic B, 'Corruption: Concepts, types, causes and *consequences' (3)26, Cadal*, 2005, 1-6.
[283] Ackerman S, 'Democracy and grand corruption', 375-380.
[284] Brooks G, Walsh D, Lewis C, Kim H, *Preventing corruption: Investigation, enforcement and governance*, Palgrave Macmillan, UK, 2013, 11-26.
[285] Andvig J, Fjeldstad O, Amundsen I, Sissener T, Søreide T, 'Research on corruption: A policy oriented survey' Norad Final Report, Chr. Michelsen Institute (CMI) & Norwegian Institute of International Affairs (NUPI), 2000, 9-14 <http://www.icgg.org/downloads/contribution07_andvig.pdf > on 20 December 2019.
[286] Brooks *et al*, *Preventing corruption: Investigation, enforcement and governance*, 12-25.
[287] Section 2, *Anti-corruption and Economic Crimes Act* (Act No. 3 of 2003).
[288] Tanzi V, 'Corruption around the world: Causes, consequences, scope and cures', 10-20.

Kenya has perpetually performed badly on the corruption index. In the 2018 Corruption Perceptions Index for example, Kenya ranked number 144 out of 180 countries participating in the survey.[289] Kenya's transparency score on the index was a paltry 27%, demonstrating that the percentage of corruption levels stood at a staggering 73%.[290]

Huang and Yuan have published findings demonstrating that corruption has a direct impeding effect on a country's innovation culture, with the innovation industry being a prime target for corrupt officials.[291] Three reasons have been advanced for this observation: first, because of the industry's frequent contact with government agencies in search of licenses and permits; second, because the innovations if successful risk the survival of technological products from politically connected firms and lastly because the nature of innovative processes usually take a long time, thereby providing a steady supply of kickbacks to corrupt officials.[292]

Inspite of Kenya's innovation statistics set out above, corruption risks to undo the strides achieved and to hinder both HSE technology transfer processes as well as homegrown HSE innovative solutions.

3.3.4 Conclusion

The potential for technology to mitigate HSE concerns in Kenya's upstream sector is likely to be made ineffective in light of the discussed legal and institutional gaps prevalent in the Country. Lack of clarity on the constituents of the best available standard, insufficient incentives for innovation, biased data protection provisions and uncoordinated regulatory structures diminish Kenya's role in technology absorption processes as secondary and passive, leaving contractors to self- govern in an area characterized by catastrophic eventualities.

Should these hindrances be removed and straightened out, Kenya stands to benefit from its innovative culture and to be an example of successful HSE technology transfer processes in the region. The next chapter lays out a framework for policy reform in relation to the identified legal and institutional gaps.

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[289] Transparency International, 'Corruption perceptions index 2018' Transparency International, 2019, 2-6 <https://www.transparency.org/files/content/pages/2018_CPI_ExecutiveSummary.pdf > on 20 December 2019.

[290] Transparency International, 'Corruption perceptions index 2018', 2.

[291] Huang Q, Yuan T, 'Does political corruption impede firm innovation?' Journal of Financial and Qualitative Analysis, 2015, 2 <https://www.cambridge.org/core/journals/journal-of-financial-and-quantitative-analysis/article/does-political-corruption-impede-firm-innovation-evidence-from-the-united-states/574E82AB09E1E50B13D1E3187BC793A0 > on 20 December 2019.

[292] Murphy K, Shleifer A, Vishny R, 'The allocation of talent: Implications for growth.' 106(2) *The Quarterly Journal of Economics*,1991, 515–527.

Chapter 4: Legal and institutional reforms towards invigorating technology absorptive capacity in Kenya's upstream sector

Following up on the legal and institutional gaps identified in the preceding chapter hindering the absorption of HSE technology, this chapter lays out a framework for legal and institutional reform towards the strengthening of Kenya's absorptive capacity in the area of HSE technology.

4.1 Clarifying the scope and applicability of the best available technology standard

4.1.1 Definitions assigned to the best available technology standard

Vandenbussche and Millet trace the origins of the best available technology standard to the 1984 EU Air Framework Directive which sought to regulate air emissions from large industries.[293] Article 4 of the Directive provided that authorisations for the operation of plants or the modification of installations with the potential for air pollution would only be given when an industrial plant has satisfied the relevant authority of its preventive measures, including the application of the best available technology.[294] Article 8 donated power to the Council to fix emission limits based on the use of the best available technology but required that the technology in question must not involve excessive cost.[295]

Article 13 enumerated the considerations to be taken into account in assessing the entails of the best available technology, including, the technical features of the industry in question, the type and volume of emissions and the economic status of the relevant class of undertakings, so as to ensure that the technology required did not call for excessive costs.[296]

The standard is then seen to have been incorporated into the 1996 Integrated Pollution Prevention and Control Directive, whose objective was to eliminate, or at least control emissions into air, soil and water.[297] Preamble 17 discouraged the prescription of a singular type of technology as being the best available and instead called for considerations around the installation itself, the geographical location and the prevalent environmental conditions.[298]

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[293] Vandenbussche V; Thylander E; Millet D, 'Best available techniques applied to the offshore oil and gas industry' 2014 International Oil Spill Conference, Norway, 2014, 389.
[294] Article 4, *The Air Framework Directive* (Council Directive 84/360/EEC).
[295] Article 8, *The Air Framework Directive* (Council Directive 84/360/EEC).
[296] Article 13, *The Air Framework Directive* (Council Directive 84/360/EEC).
[297] Preamble 8, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).
[298] Preamble 17, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).

Preamble 20 of the Directive recognised the evolving nature of technical advances and obligated competent authorities to keep abreast of the developments.[299]

Article 2 of the Directive defined 'best' in terms of the efficacy of the technology or technique to offer a high protection level against emissions.[300]

The Industrial Emissions Directive succeeded the Integrated Pollution Prevention and Control Directive in 2010, adopting the definition of the term 'best' in relation to technology and techniques.[301].

The Directive adopted the best available technique standard, defining techniques to include technology and the manner in which that technology is designed, built, installed and decommissioned.[302] Article 15 reiterates that the best available technique does not refer to a singular type of technology or installation methodology and adopts the factors to be considered in assessing compliance.[303]

The BAT standard has been extended to offshore activities through the Convention for the Protection of the Marine Environment of the North-East Atlantic, requiring that the standard, along with best environmental practices, including clean technology, be adopted in the measures and programmes of the contracting parties.[304]

The Integrated Pollution Prevention and Control Directive prescribes the best available techniques standard, which differs from the best available technology standard in that the former focuses on a wider scope outside the technology itself, to include the manner in which that technology is designed, subsequently built and ultimately installed.[305] The Directive notes that the term points to the effectiveness and degree of advancement of the technology in eliminating, or at least reducing emission levels.[306] Additional considerations to be taken into account in evaluating the BAT standard include whether the technology enables a reduction in the utilisation of raw materials, the substitution of hazardous substances and the recycling of materials.[307]

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299 Preamble 20, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).
300 Article 2, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).
301 Article 2, *The Industrial Emissions Directive* (Council Directive 2010/75/EU).
302 Article 2, *The Industrial Emissions Directive* (Council Directive 2010/75/EU).
303 Article 15(2), *The Industrial Emissions Directive* (Council Directive 2010/75/EU).
304 Article 2 of Annex III, Convention for the Protection of the Marine Environment of the North-East Atlantic (1992).
305 Article 2, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).
306 Article 2, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).
307 Annex IV, *The Integrated Pollution Prevention and Control Directive* (Council Directive 96/61/EC).

The term 'best' in the BAT standard has been interpreted to include the optimization of work performance allowing for the achievement of the highest level of results.[308] In the area of HSE considerations, the definition proposes that the best technology is one capable of ensuring the greatest extent of protection, while at the same time allowing for the optimization of production processes.

It has been noted that 'best practices' are not universally applicable given the differences in various aspects including the organisation's geographical location, volume of production and financial stature, but that the term must be encompassing of the technology's ability to generate superior results after a systematic review and a final determination as to its demonstrated success.[309] Chevron for example links best practice in the oil and gas sector to a proven capability to adequately satisfy customer and stakeholder interests.[310]

The Canadian Association of Petroleum Producers suggest that the benchmark for what is 'best' involves both effectiveness and practicability in resource development while at the same time ensuring that adverse effects are minimised.[311]

The term 'best' has additionally been emphasised to not necessarily entail the most sophisticated or highly priced technology, suggesting that the real test is one of reliability in meeting safety concerns and in addressing the composite purpose of the stipulating legislation.[312]

'Available technology' has been defined as that type of technology which is accessible to the operator.[313] Article 3 of the Industrial Emissions Directive makes it a condition for available technology to be in a scale allowing for integration at an industrial level on both economic and technical terms.[314] Leak detection systems and technology allowing for remote sensoring capabilities have for example, been included in the definition of what constitutes 'best technology' under the Norwegian Pollution Control Act.[315]

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308 Dani S, Harding J, Case K, Young R, Cochrane S, Gao J, and Baxter D, 'A methodology for best practice knowledge management' 220(10) *Journal of Engineering Manufacture*, 2006, 1718.
309 Dani S, Harding J, Case K, Young R, Cochrane S, Gao J, and Baxter D, 'A methodology for best practice knowledge management',1718.
310 Jarrar Y, Zairi M, 'Best practice transfer for future competitiveness: A study of best practices' Total Quality Management (11) 4-6, 2000,735.
311 AECOM, 'Considerations in developing oil and gas industry best industry practice in the North' Environmental Studies Research Funds, (175)1, 2009,4.
312 National Academy of Sciences, 'Implementing best available and safest technologies for offshore oil and gas' Panel on Best Available and Safest Technologies, National Research Council, Washington DC, 1979,7.
313 Department of Environment, 'Best available techniques guidance document on the oil and gas industry' 2014,1-<http://www.doe.gov.my/portalv1/wp-content/uploads/2014/07/BEST-AVAILABLE-TECHNIQUES-GUIDANCE-DOCUMENT-ON-OIL-AND-GAS-INDUSTRY.pdf > on 3 December 2019.
314 Article 2, *The Industrial Emissions Directive* (Council Directive 2010/75/EU).
315 Vandenbussche V; Thylander E; Millet D, 'Best available techniques applied to the offshore oil and gas industry', 399.

A US Senate report discussing the meaning of the term 'available technology' in relation to the 1977 amendments to the Federal Water Pollution Control Act noted that availability could not merely be measured by the existence and use of the technology somewhere in the world, but must be viewed through the lens of actual availability to the user of the technology at a cost and time at which the same is required by the user.[316]

In totality, the Industrial Emissions Directive lists twelve key characteristics of a BAT standard.[317]These include that the technology in question and the associated techniques: utilise technology with low waste components; minimise on the usage hazardous substances; make recycling of materials used and wastes generated possible; compare favourable to other systems developed on an industrial scale; reflect advances in scientific innovations; record lower emission levels in comparison to other products on the market; efficiently utilise water and energy; be capable of minimising accidents and negative environmental impacts and be featured in international publications.[318]

From the foregoing it is clear that the best available technology standard needs to be interpreted in light of the technology's effectiveness in addressing the HSE risks identified, the reliability of the technology and the availability of that technology on both economic and technical terms.

4.1.2 Assessment methodology for the BAT standard in oil and gas

Vandenbussche, Thylander and Millet propose a three step assessment methodology to determine whether an oil and gas technique or technology falls within the BAT standard.[319] The first step involves the vetting of available alternatives, enumerated in order of HSE protection capabilities, availability and economic considerations.[320] The relevant information on the set of technologies to be evaluated could be generated by various stakeholders including the technology developers, engineering firms, operator experiences and other publicly available information on the product.[321]

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[316] National Academy of Sciences, 'Implementing best available and safest technologies for offshore oil and gas', 22.

[317] Annex III, *The Industrial Emissions Directive* (Council Directive 2010/75/EU).

[318] Annex III, *The Industrial Emissions Directive* (Council Directive 2010/75/EU).

[319] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 392.

[320] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 392-393.

[321] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 392-393.

In the case of *Save Lamu & 5 Others v National Environmental Management Authority (NEMA) & Anotherr,*[322] the Tribunal emphasised the importance of evaluating various technological products in order to provide a justification for the choice of preferred technology and to ably demonstrate its ability to mitigate identified risks.

Marcel points out that emergent oil producing frontiers usually have low capacity on the regulator's side to appreciate the different technical risks, making the operator the main contributor of technical information.[323]

It has been suggested that these countries can seek out technical advice from experts across their region, usually domiciled in established oil producing nations.[324]

The purpose of the vetting exercise is to narrow down the alternatives to be evaluated and to allow for more meaningful comparison.[325]

The economic availability of the technology is the second consideration.[326] The place from which the technology is to be sourced, the cost of the technology and the relation of these two factors to the capital and operational expenditure costs of the operator and whether any of these costs are recoverable.[327]

Vercaemst suggests four practical measures in economic costing of BAT: the financial information available on the relevant technology or technique; the validation of the cost data; definition of the cost components of the candidate BAT and processing of the primary data on costs.[328]

These measures have the ability to give a quantification of whether the costs of the candidate BAT are excessive in relation to the HSE benefits achieved.[329] Ultimately, the economic availability litmus seeks to strengthen the competitiveness of the company and industry both in the short and long term.[330] It has been suggested that the economic availability criteria may be unnecessary where the BAT is proposed by the operator or where there is already widespread deployment of the technology within the industry.[331]

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[322] *Save Lamu & 5 Others v National Environmental Management Authority (NEMA) & Another* [2019] eKLR.
[323] Marcel V, 'Guidelines for good governance in emerging oil and gas producers 2016', 49.
[324] Marcel V, 'Guidelines for good governance in emerging oil and gas producers 2016', 50.
[325] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 392-393.
[326] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 393.
[327] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 393.
[328] Vercaemst P, 'Abstract BAT: When do best available techniques become barely affordable technology?' Flemish Institute for Technological Research, (2) 26, 2002,8.
[329] Vercaemst P, 'Abstract BAT: When do best available techniques become barely affordable technology?'9.
[330] Vercaemst P, 'Abstract BAT: When do best available techniques become barely affordable technology?'10.
[331] Vercaemst P, 'Abstract BAT: When do best available techniques become barely affordable technology?'11.

The US Congress for example mandated the Environmental Protection Agency to ensure that technological costs are considered to avoid the imposition of unbearable regulatory burdens on industries.[332] It was noted that in some industries, it would be unrealistic to thoroughly eliminate all forms of pollutants without having to close shop.[333]

In other industries, the trickle-down effect of complying with unrealistic technical impositions would result in exorbitant final products and massive layoffs.[334]

In the US appellate case of *American Petroleum Institute v. EPA* (787 F.2d 965, 972 (5th Cir. 1986) [335], the Court in agreeing with the Petroleum Institute declared that excessively costed technological requirements should not be imposed on industry players, particularly when the benefits to be achieved by the said technology were negligible.[336]

Again, in the US Ninth Circuit Appellate Court in the case of the *Association of Pacific Fisheries v. EPA* (615 F.2d 794, 818 (9th Cir. 1980)[337,] the court observed that extremely costly technology could not be said to fit within the BAT standard, given the unreasonable nature of the associated costs.[338]

In the case of *Rodgers Muema Nzioka & 2 Others v Tiomin Kenya Limited,*[339] in defining 'best available techniques' to be employed in relation to the prevention of environmental pollution, noted that excessive costs immediately disqualified the technique in question from the class of what is best. The court upheld practicability of the technique in preventing or reducing pollution as the key elements of the standard, particularly on the back of sound scientific information and risk analysis.

Applegate concludes that the setting of a BAT standard cannot be reduced to an exclusively technocratic process but must demonstrate value for the operator and the society at large.[340]

The last step proposed by Vandenbussche, Thylander and Millet is the selection of a category of techniques and technological features fitting within the BAT standard.[341]

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[332] McCubbin P, 'The Risk in Technology Based Standards' Duke Environmental law & Policy Forum (16) 1, 2005,12.
[333] McCubbin P, 'The Risk in Technology Based', 12.
[334] McCubbin P, 'The Risk in Technology Based Standards', 12.
[335] *American Petroleum Institute v. EPA* (1986), The Fifth Circuit Appeals Court of the United States.
[336] *American Petroleum Institute v. EPA* (1986), The Fifth Circuit Appeals Court of the United States.
[337] *Association of Pacific Fisheries v.* EPA (1980), The Ninth Circuit Appeals Court of the United States.
[338] *Association of Pacific Fisheries v.* EPA (1980), The Ninth Circuit Appeals Court of the United States.
[339] *Rodgers Muema Nzioka & 2 Others v Tiomin Kenya Limited [2001] eKLR.*
[340] Applegate J, 'Worst things first: Risk, information and regulatory structure in toxic substances control' The Yale Journal on Regulation, (9) 277,1992, 315-316.
[341]Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 393.

Priority is afforded to the technological features capable of addressing HSE concerns while at the same time ensuring that the associated price tags are not unreasonable.[342]

Dani *et al* propose two additional steps in identifying candidate BAT: the identification of the key objectives in relation to the project and the organization of the industry's core performance indicators.[343] In an upstream oil and gas project, the ability of the technology to ensure HSE protection while at the same time augmenting production is a central theme. The identification of the main performance indicators is proposed as the second step in BAT assessment.[344] Keegan lists six considerations in mapping out the core performance indicators, including: the organisation's goals, its most important aspects, its measurables, the changes likely to be witnessed, the persons needing to be on-boarded and the best practices.[345]

BAT assessment methodologies also include considerations around the sufficiency of manpower to operate the technology, inter-organisational coordination and the capacity for research and development to augment present knowledge and to inform future decisions.[346]

It has been suggested that BAT assessments prove most profitable when they are done before the onset of an upstream production project.[347] This is because, most oil and gas installations, particularly in the offshore sector are designed for a life time spanning approximately 20 years.[348] Modifications in these installations mid-project present costly challenges in transporting the equipment to land, sometimes increasing the risk of oil spills during disengagement attempts.[349] The longevity of the time frames associated with oil and gas installations have been seen to encourage absorption of only tried and tested technology, locking out newer, more efficient innovations.[350] As search, rigorous research need to be undertake in electing a country's BAT candidate pool in order to give the highest level of assurance as to the working and efficacy of proposed technologies.[351]

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[342] Vercaemst P, 'Abstract BAT: When do best available techniques become barely affordable technology?'18.

[343] *S Dani, J A Harding, K Case, R I M* Young, S Cochrane, J Gao, and D Baxter, 'A methodology for best practice knowledge management',1721.

[344] *S Dani, J A Harding, K Case, R I M* Young, S Cochrane, J Gao, and D Baxter, 'A methodology for best practice knowledge management',1721.

[345] Keegan R, *Benchmarking facts: A European perspective,* European Company Publishing Forum, 1998.

[346] National Academy of Sciences, 'Implementing best available and safest technologies for offshore oil and gas', 24.

[347] Evrard D, Laforest V, Villot J, Gaucher R, 'Best available technique assessment methods: A literature review from sector to installation level', 2.

[348] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 391.

[349] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 391.

[350] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 391.

[351] Vandenbussche V, Thylander E, Millet D, 'Best available techniques applied to the offshore oil and gas industry', 391.

4.2 Strengthening legal support for HSE technology innovation

As already observed, the modification of technology to respond to local challenges is a key process in technology absorption. The utility of this capacity is essential in increasing accessibility to technological products and in making them more affordable.

The postulation that Kenya has the capacity to develop and customize HSE technological solutions is not merely steeped in patriotic optimism, but finds solid basis in its innovative track record.[352]According to the 2019 Global Innovation Index, Kenya is ranked at position 77 out of 129 countries, with an innovation ranking of 31.13%.[353]According to the rankings, Kenya is the second most innovative African nation after South Africa, with its performance being singled out as being above expectation relative to its GDP, for the ninth year running.[354] Evidence of progress up the rankings is demonstrated by its rise from position 78 at 31.07% innovation score in 2018 to beat Mauritius for the second African position in 2019.[355]

The establishment of IBM's research lab in Nairobi in 2012 places Kenya at an advantaged position to interact and learn from other research labs in Australia, Brazil, Ireland and eight other labs across the globe.[356] Nairobi's THINKLab is geared to bring together researchers, scientists and local communities from the Middle East and African regions to experience and develop cognitive, big data analytics and cloud storage backed technologies to find solutions unique to their regional problems.[357] The equipment of the lab with motion sensor devices, panel screens and most importantly, a hologram, has lent the lab to be taunted as the most advanced African facility.[358]

Kenya's interaction with other laboratories in technologically advanced oil producing countries coupled with the availability of the lab facility is likely, with governmental backing, to build capabilities for the development of HSE technology locally. Kenya's hosting of Intel, Microsoft and Google regional offices enlarges its technological capabilities in the area of HSE technology development.[359]

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[352] Cornell University, INSEAD, WIPO, 'Global innovation index 2019' (12) *Cornell University, INSEAD, World Intellectual Property Organization,* 2019, 6-23.

[353] Cornell University, INSEAD, WIPO, 'Global innovation index 2019', 17.

[354] Cornell University, INSEAD, WIPO, 'Global innovation index 2019', 22.

[355] Cornell University, INSEAD, WIPO, 'Global innovation index 2018' (12) *Cornell University, INSEAD, World Intellectual Property Organization, 2019,* 23.

[356] IBM, 'Developing solutions in Africa for Africa and the world' IBM,2012,1 <http://www.research.ibm.com/articles/africa.shtml>On 16 December 2019.

[357] IBM, 'Developing solutions in Africa for Africa and the world' IBM,2012,1 <http://www.research.ibm.com/articles/africa.shtml>On 16 December 2019.

[358] IBM, 'Developing solutions in Africa for Africa and the world' IBM,2012,1 <http://www.research.ibm.com/articles/africa.shtml>On 16 December 2019.

[359] Patey L, 'Kenya: An African oil startup in transition', 3.

The commercialization of mobile money transfer by Safaricom to address financial access to Kenya's remote areas, the development of Ushahidi software geared to solve electricity and internet shortages in rural Kenya and the proliferation of iCow, a technological innovation to help Kenyan dairy farmers improve their production stand as testament to Kenya's ability to solve its problems using technology.[360]

Tax incentives for firms engaged in research and development has been found to be an effective trigger in the broadening of innovation avenues particularly with reference to OECD countries.[361] Tax incentives for Kenyan firms involved in research and development efforts in the area of HSE technology would be an important means of encouraging innovation through governmental support.

Direct state aid in the form of a research and development fund specific to HSE technology will provide the much needed capital for the modification of existent and transferred technology to address Kenya's upstream concerns. The Training Fund established under Section 52 of the Petroleum Act for the purpose of training Kenyans on upstream petroleum operations could be a major source of the funds required for this exercise.[362]

Kremer and Williams have also identified prizing as an important incentive in encouraging innovation.[363] Innovators who are able to develop an invention meeting a pre-set criteria of technological specifications are awarded and assisted in patenting their technology.[364] Prizes for the development or modification of HSE technology adaptable to the Kenyan environment would spur innovation and contribute greatly in increasing the accessibility of these products in Kenya.

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[360] Ndemo B, 'Effective Innovation policies: The case of Kenya' *World Intellectual Property Organization, 131-133, 2015 <https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2015-chapter9.pdf > 16 December 2019.*

[361] OECD, 'Maximising the benefits of R&D tax incentives for innovation' *OECD Directorate for Science, Technology and Industry*, 2013, 1-6 -< https://www.oecd.org/sti/rd-tax-incentives-for-innovation.pdf > on 10 January 2020.

[362] Section 52, *The Petroleum Act* (No. of 2019)

[363] Kremer M, Williams H, 'Incentivizing innovation: Adding to the tool kit' 10, *Innovation Policy and the Economy*, 2010, 4-5.

[364] Kremer M, Williams H, 'Incentivizing innovation: Adding to the tool kit',5.

4.3 Balancing the rights of the data subjects against the needs of the data controller and data processor

While acknowledging the rights of the data subject in relation to the protection of their data, the biased overprotection afforded by various sections of the Data Protection Act 2019 identified in chapter 3 greatly hinder the utilisation of wearable technology in preventing occupational diseases to oilfield workers. Data processing for the protection of the data subject's vital interests and assessment of the the working capacity of an employee, provided for under Article 9 (2) of the EU GDPR ought to be permitted.[365] The withdrawal of consent by a data subject to the processing of their information should require a notice period, allowing the data controller, in the instance of wearable technology to ensure that the safety of other workers is not imperiled.

Since section 18 of the Act call for mandatory registration of data processors and data controllers, guidelines on the relevant procedural steps need to be developed.

4.4 Bolstering the regulatory sector in charge of HSE technology

The regulatory structure in charge of overseeing the deployment of the best available HSE technology in Kenya's upstream sector plays a crucial role in the success or failure of the exercise. This structure is in charge of carrying out evaluations of the HSE risks prevalent in the upstream sector, researching on the technology available to mitigate or extinguish the risks, oversee the technology acquisition process, carry out evaluations on the effectiveness of the imported technology and supervise the progress and efficiency of any necessary modifications. In order to carry out all these functions, intergovernmental cooperation and a streamlining of relevant process maps needs to be undertaken. As pointed out in chapter 3, the current regulatory framework is characterized by a multitude of agencies with little or no harmonization in the carrying out of their mandates.

Given the level of expertise required in the discharge of the technology absorption exercise as well as the constant monitoring, evaluation and research, the establishment of a body under the act charged with an oversight mandate over all technological matters appertaining to the petroleum sector would be a prudent step. The constitution of this body must feature expertise in technological aspects, HSE aspects, research and development aspects and industrial know-how in relation to oil and gas matters.

[365] Article 9(2), *EU General Data Protection Regulation* (Regulation (EU) 2016/679).

Multi-agency corporation between the established body and other relevant agencies including NEMA, EPRA, NACOSTI and DOSHS will need to be strengthened to allow for efficient correspondence, knowledge sharing and predictability on the procedural steps and associated timelines in relation to various aspects of the absorption exercise. The procedural steps, timelines and accompanying fees should be published and regularly updated in order to foster transparency and predictability into the process and to prevent incidence of corruption. A flaunt of the established procedure out to be penalized heavily so as to discourage corrupt dealings in the absorptive process.

4.5 Conclusion

The chapter has laid out legal and institutional reforms which will ease compliance with the requirement for the deployment of the best available HSE technology. Clarifying the scope of the 'best available technology standard', strengthening innovation processes and bolstering the regulatory structure in place provides opportunity for streamlined acquisition, assimilation and modification processes in relation to HSE technology absorption.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This thesis sought to make a case for the absorption of HSE technology in addressing the occupational HSE risks endemic to Kenya's upstream sector. In doing so, the study demonstrated the superiority and wholesome approach of technology absorption over technology transfer in providing a platform for the assessment and evaluation of all the relevant stages necessary for the successful assimilation and modification of acquired technology.

The study started off by providing an overview of the occupational HSE risks prevalent in Kenya's upstream operations, in line with needs recognition as the first step in technology absorption processes. The study then identified the technological solutions capable of addressing the identified risks as the second step in the technology absorption exercise. In making this identification, the study evaluated the accessibility of HSE technology to Kenya's upstream market using awareness availability, affordability and acceptability as benchmarks. This exercise satisfied the second ambit of technology absorption.

In the third chapter, the study identified legal and institutional barriers hindering the acquisition, assimilation and modification of HSE technology. The legal and institutional barriers were proved to contribute greatly to the limited absorptive technological capacity. Legal gaps in the delineation of the constituents of the 'best available technology' standard, insufficient support for technology innovation, unbalanced data protection laws and a constructive ban in the use of drones were identified as the legal barriers to technology absorption. Regulatory barriers in the nature of uncoordinated regulatory agencies, deficient expertise in the constitution of boards charged with oversight over HSE technology aspects and corruption were identified.

In reaction to the identified legal and institutional barriers, the thesis set out a foundation for policy reform. Clarity on the scope and applicability of the BAT standard was canvassed and recommendations on reviving support for innovation presented. A more balanced protection of both the data subject and data processors was recommended and a call for speedy enactment of the revised civil aviation regulations governing the use of drones in Kenya made.

The ensuing portions of this chapter evaluate the practical challenges in the implementation of the recommendations put forth, an assessment of the future potential of Kenya as a player in the field of HSE technology and suggested areas for further research.

5.2 Possible roadblocks to the implementation of suggested legal and institutional reforms

As demonstrated, technology absorption exercises call upon the Kenyan government to play a bigger and more pro-active role than is normally required under technology transfer frameworks. The place of political will as a key driver to the absorption exercise cannot be gain said.

Kenya's track record on government appointments has increasingly reflected cronyism over merit, the effect of which has been incompetence, inefficiency and a conducive environment for the mushrooming of all shades of corruption. The highly technical nature of digital technology and its novelty within the petroleum sector desperately requires skilled professionals in decision making and operational organs of the industry. An evaluation of the value added by employees in HSE technology related industries is likely to result in redundancies and political fall outs, but would be crucial in strengthening Kenya's absorptive capacity. Restructuring of governmental hiring policies will need to be undertaken to accord to transparent and meritorious appointments.

Secondly, the isolation of food security, affordable housing and healthcare and manufacturing as the key agendas for the present government may mean less investment in technology absorption in the oil and gas sector, translating into even lower levels of investment in research and development. It has already been demonstrated that research is the backbone of technology absorption, without which governments have played passive roles in accepting technology transferred, without regard for its domestic value, utility or future adaptation. Incentivizing HSE technology modification and innovation through taxes and prizes and rewarding its manifestations in increased investments will provide the momentum required to fast track the absorption process.

Lastly, siloed agency operation among the multitude of regulators governing aspects of HSE technology absorption creates uncertainty around the required processes, rendering compliance unattainable. Given that technology absorption is a process requiring the participation of multiple actors, operational harmony must be achieved as a matter of critical importance.

Commitment to efficient inter-agency cooperation needs to be developed, first by streamlining processes within agencies and clarifying their mandate and then by establishing clear process maps from one agency to the next, ensuring that the required deliverables are underscored. Constant review of the efficiency of the processes needs to be undertaken, with feedback from users, mainly the contractors in this case, being integrated. Publishing and updating of timelines, applicable fees and required permits will improve service delivery, increase contractor compliance and encourage HSE technology innovation.

5.3 Future potential of Kenya's role in upstream HSE technology

The broadening of Kenya's absorptive capacity for HSE technology spells a multitude of opportunities for Kenya and her neighbours.

The first apparent consequence is the prevention of HSE tragedies in its upstream sector, reducing the country's expenditure on occupational injuries, diseases and environmental clean-up cost. On the contractor's end, the absorption of HSE technology will enable workers, both foreign and those drawn from the local community to feel valued, a matter which would improve their acceptability and ease their acquisition of the social license to operate.

The development of a stronger innovative ethos in the area of HSE technology, as a necessary step in the absorptive exercise, will dilute the challenges associated with affordability and availability of the technology. The adoption of the suggested tax incentives and prizing frameworks in relation to HSE technology products will motivate entrepreneurship in designing and engineering sectors.

Corollary to increased entrepreneurship is an increase in employment levels especially among young people, who are viewed as being more adept to technology. In this way, more Kenyan's will have opportunity to be directly involved in the exploitation of the Country's natural resources and to benefit therefrom.

Should Kenyan's absorptive capacity in HSE technology broaden, and the capacity to modify incoming technology accessibility challenges characterising HSE technology in Africa's oil and gas context.

In response to the awareness, availability and affordability challenges rendering HSE technology inaccessible to many parts of Africa, the enlargement of Kenya's HSE technology industry will present the much needed cure. First, technology modified and developed in Kenya will most ably address HSE risks endemic to the African landscape using materials that may be more locally available. Secondly, the expertise developed through the absorptive process will present training opportunities to scholars and researchers, within and without Kenya.

This information will be invaluable to emerging producers particularly those within the band of developing states. The exportation of technology and expertise to other nations will mark Kenya's contribution to the attainment of sustainable development goals (SGDs) 7, 8 and 13 in relation to affordable and clean energy, decent work environments and climate action.

5.4 HSE technology in Kenya's petroleum sector: Avenues for further research

The study limited its focus to occupational HSE risks and their mitigation through technology. An evaluation of upstream HSE risks to the local community, coupled with an assessment of the utility of HSE technology in their prevention and mitigation presents an important area of research.

The thesis limited its attention to HSE risks within the upstream sector, leaving room for further study on the absorptive capacity of HSE technology in midstream and downstream sectors.

In light of the global cybersecurity challenges presented by the deployment of digital technology, further research on cyber resilience of absorbed HSE technology would provide a worthwhile area of research.

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