Landscape and Political Economy Analysis of Emerging Health Technologies in Sub-Saharan Africa

Report prepared by AFIDEP

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Executive Summary

The objective of the landscape and political economy analysis of emerging health technologies in Sub-Saharan Africa (SSA) was to generate information needed to refine the design of a new project, the Health Technologies Advocacy Project, to be implemented by the African Institute for Development Policy (AFIDEP). The Health Technologies Advocacy Project seeks to create an African-driven advocacy platform to facilitate informed, objective, transparent, open and balanced discussions on development and use of transformative technologies and tools to address key health challenges in SSA. The platform's purpose is to ensure that Africans are meaningfully involved in driving conversations about the need for transformative technologies and tools, their design, development, testing, and uptake by African governments and communities.

The study aimed to generate information on: ongoing efforts on design, development, and/or piloting of key/priority health technologies in SSA, and the stakeholders behind these efforts (their interests and power dynamics); the status of ongoing efforts on gene drive mosquitoes for the control and elimination of Malaria in Africa, including the stage of technology development, the activities and interaction of stakeholders involved in these efforts, the knowledge and involvement of key stakeholders in these efforts, and the views and concerns of key stakeholders on the gene drive mosquitoes technology; and ways and mechanisms through which a wide range of stakeholders in SSA can be effectively involved in designing, developing and/or piloting emerging health technologies, such as the gene drive mosquitoes technology for the control and elimination of Malaria.

The study adopts a qualitative design, drawing from the applied political economy analysis approach. Key informants included in the study were selected purposively through an initial mapping exercise that was complemented with snow-balling during the interviewing process. Thirty (30) key informants participated in the study drawn from: policymaking institutions at both the regional and national level in SSA; research consortia and networks; ethicists; advocacy groups at the regional and global level science and media networks. Additional data was collected through documents review. Data analysis adopted a thematic approach guided by the political economy analysis framework.

Findings show that there are a number of new tools and technologies that are under development across SSA to respond to persisting and emerging health challenges in the region. For Malaria, some of the technologies being designed include: gene drive mosquito technology; Ivermectin drug, malaria vaccine; sterile insect technology; piperronly butoxide (PBO) nets; Attractive Toxic Sugar Baits (ATSB); and drones for larvicide control. Other health technologies and tools being tested in SSA include: genome editing, synthetic biology, data analytics, monoclonal antibodies, and mechanical ventilator.

The other objective was on the status of on-going efforts on gene drive mosquitoes technology for the control and elimination of malaria in SSA. Data shows that research in Burkina Faso, Uganda and Mali on this technology is at the initial stage. While this technology has been developed and tested under laboratory conditions, trials at the community level may take longer given regulatory bottlenecks as well as cultivating community acceptance. Countries in SSA are at varied levels in relation to biosafety regulation, and with very little experience in regulating environmental release for genetically modified organisms and in particular animals. Uganda, for instance, is yet to develop regulations that can offer guidance for testing the gene drive mosquito technology beyond containment level.

AUDA-NEPAD is supporting regional efforts on regulatory reform in view of gene drive mosquitoes for malaria control and elimination, while organizations like PAMCA are building the capacity of research scientists on this technology. Global institutions like FNIH/GeneConvene are also helping build capacity of a number of stakeholders on this technology. However, very little if at all, is being done on creating awareness on gene drives, as well as, enhancing regulatory capacity on other emerging health technologies in SSA.

Knowledge and awareness on gene drive mosquitoes for malaria control and elimination is also low among government policymakers, general public as well as science journalists. Concerns raised in regard to gene drive mosquitoes technology revolve around risks to human safety, ecological considerations, and inadequate capacity by national biosafety agencies in SSA countries to effectively regulate the technology. Other concerns touch on equity, power and justice in the governance of gene drive mosquitoes technology; intellectual property rights; and transparency and stakeholder engagement. Similar set of concerns are being levelled against a range of health technologies related to genome editing in SSA. An important issue relating to power is the issue of trust and ownership, with some stakeholders expressing wariness that work on emerging health technologies such as gene drives in Africa is driven by external or foreign interests, and Africans therefore have little or no influence in this work, and neither will they own the resulting technologies/tools (if these are proven to work and safe).

The study findings have implications for the design of the Health Tech Advocacy Platform. They give useful pointers to potential audiences as well as the key gaps in on-going advocacy efforts on gene drive mosquitoes technology. Key among the advocacy issues is sharing information that empowers the various stakeholders to address their fears, but also sharing information on complementary tools for malaria control and elimination in SSA. Another advocacy gap is on the need to strengthen the internal capacity among various stakeholders to understand this technology and thereby contribute to informed decision-making. A glaring gap is on the capacity of the media to effectively report on emerging health technologies in an informed, objective, and balanced manner.

Further, there are no current information-sharing efforts focused on emerging health technologies in SSA, apart from a few that have a much narrower focus, and in particular on gene drives and targeting a few stakeholders. For instance, AUDA-NEPAD is mainly reaching out to regulators, PAMCA is largely focused on vector scientists; while AAS is mainly focused on research on health technologies, but with limited outreach to the public. This is a gap, that the envisioned Health Tech Platform can help address. Importantly, the Health Tech Platform will need to be deliberate in generating and sustaining trust and ownership by key stakeholders on the continent if it is to achieve its envisaged outcomes. Further, the Platform may need to consider fostering conversations around lack of internal funding for health research and innovation and how to leverage existing investments to address this gap. This is an important issue underpinning the issue of trust and ownership.

List of Abbreviations

AAS	:	African Academy of Science s
AFIDEP	:	African Institute for Development Policy
AI	:	Artificial Intelligence
AMMREN	:	African Media and Malaria Research Network
APET	:	African Union high Level Panel on Emerging Technologies
AUDA	:	African Union Development Agency
CSO	:	Civil Society Organization
GM	:	Genetically Modified
GMO	:	Genetically Modified Organism
GTS	:	Global Technical Strategy
MESHA	:	Media for Environment, Science, Health and Agriculture
NAS	:	National Academy of Science
NEPAD	:	New Partnership for Africa's Development
PI	:	Principal Investigator
SSA	:	Sub-Saharan Africa
TTs	:	Transformative Technologies and Tools

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1. INTRODUCTION

1.1. Background

Health is a critical measure of development. In Africa, millions of people die every year of preventable and/or treatable communicable and non-communicable diseases because of weak health systems, inadequate resourcing of the health systems, limited access to health services and technologies, and extreme poverty (STISA 2024). If not addressed, this challenge will stand in the way of Africa achieving meaningful social and economic development.

Among the many ongoing efforts to respond to these health challenges in Africa is a focus on the role of new or emerging technologies. For instance, in the African Union (AU) Agenda 2063 and countries' long-term national development strategies, African leaders recognize that technology is key to accelerating the continent's development trajectory. The 2013 Abuja Special Summit on HIV/AIDS, Tuberculosis, and Malaria noted the need for Africa "to utilize and build on [its] research capacities to produce new and effective medicines, diagnostic tools, vector control tools and vaccines, and to promote research, invention and innovation in traditional medicine and strengthening local health ecosystems, taking into account the socio-cultural and environmental situation of the people" (STISA 2024, p.22).

The emerging complex transformative technologies such as genetically modified mosquitoes, mRNA/DNA vaccines, RNAi, drones, and artificial intelligence have potential to change the trajectory of disease and general well-being if they are successfully developed, accepted, and effectively deployed. For example, gene drive mosquito technology could herald a new dawn in the fight against malaria especially in Sub-Saharan Africa (SSA) where the disease is endemic.

Recognising the potential of gene drive mosquitoes in controlling Malaria in Africa, the AU in 2017 committed to invest in the development and regulation of the gene-drive technology (AU Assembly of the Union, 29th Ordinary Session, 3-4 July 2020). In 2018, the AU Development Agency (AUDA)-NEPAD released a report that recommended various actions to operationalize the AU recommendation (African Union and NEPAD 2017). One of the recommendations was the need to establish a network of Africa-based scientists and technology developers to register their studies, self-regulate, share information, and peer-review all ongoing field-testing of the technology on the continent. The report also called on African countries to develop the necessary legal and policy framework and guidelines for regulating the development of gene drive technologies; experts to model the potential risks of gene drive technology on the environment; and increased advocacy

and proactive involvement of policymakers and private sector in the development and deployment of gene drive technology if proven effective and safe.

Furthermore, the gene drives technology for the control and elimination of Malaria has been prioritized by the African Academy of Sciences (AAS) and AU's NEPAD/AUDA. Currently, there is ongoing gene drive mosquito research in Burkina Faso, Mali and Uganda, and ecological observatory work in Ghana led by the Target Malaria consortium, funded largely by Bill and Melinda Gates Foundation. However, this research is in very early stages and mosquitoes involved do not have a gene drive. Laboratory research has demonstrated that gene drive techniques are effective in altering the *Anopheles* mosquito populations so that they can no longer transmit Malaria parasites (Gantz et al., 2015), and crashing entire mosquito populations (Hammond et al., 2016). However, the release of genetically modified mosquitoes into wild mosquito population was only done for the first time in Africa in July 2019 in Burkina Faso. This research therefore still has a long way to go in testing the effectiveness of gene drive mosquitoes in controlling and eliminating Malaria in Africa.

Despite advances in the development of new health transformative technologies, there are concerns in adopting some of these technologies. There is notable opposition to the use of gene drive mosquitoes in controlling Malaria by various stakeholders including the African Centre for Biodiversity, Gene Watch UK, the Third World Network, and various CSOs across Africa (Africa Centre for Biodiversity et al 2018; 2019). Among the main concerns raised by these actors include: lacking risk assessments to humans and to the environment before the release of genetically modified mosquitoes, and that they could pose adverse dangers to the ecology and to humans.

In 2019, NEPAD held workshops conducted with a wide range of stakeholders (including scientists, ethicists, health professionals, government regulators in the fields of environment health and biosafety and government policymakers) to define the problem of using gene drive mosquitoes. Insights from the workshops revealed that the main concerns by these stakeholders were the need for the protection of human health and biodiversity during the development of gene drive mosquitoes (Teem et al 2019).

Concerns about adopting some of these technologies may be in part due to limited or different understanding of these technologies by those outside the research community directly spearheading these research efforts including other scholars, policy makers, ethicists, general public, and development actors. For example, one study on 'perspectives of people of Mali towards genetically modified mosquitoes for malaria control' observed that 'many participants preferred that mosquitoes be killed rather than modified (Marshall et al., 2020). The participants feared that gene drive mosquitos will not work in

reducing malaria infections (ibid). This different understanding may undermine buy-in especially on the development and/or deployment of such technologies. Like other new technological innovations, this is a challenge that the developers of these technologies must confront, but in a way that enhances rather than stifles the innovation.

To respond to these challenges above, the African Institute for Development Policy (AFIDEP) will implement a three-year project entitled 'Health Technologies Advocacy'. The project aims to create an African-driven advocacy platform –the Health Tech Platform (HTP). HTP will facilitate informed, objective, transparent, open and balanced discussions on development and use of transformative technologies and tools to address key health challenges in SSA. The overall purpose of the project is to ensure that Africans are meaningfully involved in driving conversations about the need for transformative tools and technologies, their design, development, testing, and uptake by governments, other development actors, and communities including youth and women.

1.2. Health Technologies Advocacy Project

The Health Technologies Advocacy Project is a three-year project aimed at creating an African-driven advocacy platform –the Health Tech Platform– to facilitate informed, objective, transparent, and balanced discussions on development and use of transformational tools and technologies to address key health challenges in SSA. The project's expected primary outcome is to realize increased African leadership in promoting discourses and actions on the development and use of transformative technologies and tools (TTs) for tackling health challenges in Africa. Three intermediate outcomes will contribute to the realization of the primary outcome, namely:

i. Increased understanding, commitment and action by policymakers to facilitate the development and use of transformative technologies/tools for tackling health challenges at national and regional levels in Africa.

ii. Increased voices and engagement of African scientists, media, development experts, and Civil Society Organizations (CSOs) in discourses to promote development and use of transformative technologies/tools for tackling health challenges in Africa at national, regional and global levels.

iii. Strengthened advocacy capacity of African Institutions in promoting discourses and actions on the development and use of transformative technologies and tools for tackling health challenges in Africa.

1.3. Why Landscape and Political Economy Analysis

The design of an effective platform that will promote and enable a wide range of stakeholders in SSA to be involved in the ongoing efforts on designing, development, and/or piloting of new health technologies requires several considerations. First is an in-depth understanding of the current landscape including mapping of TTs that have the potential for improving health outcomes in Africa. Second is stakeholder knowledge, interests and perceptions on the TTs, and the interaction of key stakeholders (or lack of) in the ongoing efforts and their implications. Third, is an understanding of the existing policy framework for supporting or governing the development and adoption of the health TTs where these are proven effective and are safe. This kind of background information is needed to inform the development of an effective health technologies advocacy platform. Despite the need for this information, the literature review showed that we do not know much about these key aspects, including:

- How the limited knowledge and understanding of the emerging health technologies and especially on gene drive mosquitoes technology for malaria control among stakeholders in SSA is being addressed, if at all.
- What other key stakeholders, apart from the AU and NEPDA-AUDA, are doing in relation to these technologies and in particular regarding the gene drives technology for malaria control (including national-level policymakers, scientists, ethicists, civil society, media, and the public/communities). For instance, if and how the researchers leading the design or development of these technologies are engaging the public/communities to create awareness and enhance understanding of the technologies; how civil society and media are involved or engaged in the ongoing efforts on the development of the technologies to contribute to enhancing the knowledge of key stakeholders (including the public) on these technologies; etc.
- Mechanisms through which key stakeholders (including a wide range of national-level policymakers, scientists, ethicists, civil society, media, and the public/communities) could be effectively involved in designing, developing, and/or piloting these technologies to tackle health challenges on the continent.

1.4. Objectives of the Landscape and Political Economy Analysis

1.4.1. Broad Objective

The overarching objective of the landscape and political economy analysis of emerging health technologies in SSA is to generate information needed to refine the design of the

interventions of the Health Technologies Advocacy project including: the key health technologies being designed, developed or piloted; the involvement of key stakeholders in these efforts; and the ways/mechanisms through which key stakeholders can be effectively involved in these efforts to ensure that the technologies are responsive to their needs and contexts.

1.4.2. Specific Study Objectives

The study has three specific objectives, including:

1. Map ongoing efforts to design, develop, and/or pilot key health technologies in SSA, and the stakeholders involved.

2. Document the status of ongoing efforts on gene drive mosquitoes for the control and elimination of Malaria in Africa, including the stage of technology development, the activities and interaction of stakeholders involved in these efforts, the knowledge and involvement of key stakeholders in these efforts, and the views and concerns of key stakeholders on the gene drive mosquitoes technology.

3. Identify mechanisms through which a wide range of stakeholders in SSA can be effectively involved or engaged in the process of designing, developing and/or piloting emerging health technologies.

2. OVERVIEW OF LITERATURE

2.1. Malaria Burden in SSA

The World Malaria Report 2020 shows that twenty-nine countries in SSA and India accounted for 95% of the malaria cases globally. Six African countries, namely Nigeria (27%), Democratic Republic of Congo (12%), Uganda (5%), Mozambique (4%) and Niger (3%), contributed to 51% of the malaria cases globally (WHO, 2020: 21).

Malaria spending is also concentrated in the SSA. Between the years 2000 and 2016, 69.7% of all malaria spending was in the region (Haakenstad et al., 2019). In addition to countries contributions, the dominant external sources of financing for malaria initiatives in the region are: Global Fund, World Bank, USAID and United Kingdom. A substantial portion of development assistance (13.1%) for health sector is meant for malaria interventions (Haakenstad et al., 2019).

The Global Technical Strategy (GTS) for Malaria 2016 – 2030 provides a framework to guide and support regional and country level programmes in their malaria control and

elimination efforts. The Strategy (GTS) is also in line with the African Union Agenda 2063 target of achieving malaria elimination by 2030. To achieve this goal, the scientific community engaged in malaria research needs to develop new tools and techniques in the fight against malaria.

Current strategies for malaria control focus on vector control and drug therapy (National Academies of Sciences, 2016: 53). Some of the specific interventions in the fight against malaria have focused on insecticide treated bed nets, indoor residual spraying, and artemisinin-based combination therapies. Other technologies such as the Malaria vaccines are also under development, these are in the process of trials and may take years before they can be fully recommended for wide application (National Academies of Sciences, 2016: 53). To reduce the global malaria burden, scientists have been working on new vector control strategies aimed at interrupting transmission.

Emerging transformational technologies such as genetically modified mosquitoes, have the potential to change the course of malaria if they are successfully developed and effectively deployed. However, given the lack of a precedent on such technologies, there are many unknowns and fears relating to the social, environmental, economic and ethical implications and impacts of these technologies. In this regard, the World Health Organization (WHO) has been rallying the global community to provide regulatory guidance for the development and deployment of these new tools.

2.2. Emerging Health Technologies

The global community has made great strides in the fight against the global burden of disease. This has been occasioned by unprecedented advances in science and technology that has offered new frontiers in furtherance of health outcomes across the world. The focus of this review is about some of the emerging health technologies whose successful development, deployment and use could make a significant contribution in addressing health challenges in the world. According to the WHO, health technologies refer to the 'application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures and systems developed to solve a health problem and improve quality of lives' (WHO, 2010: 8). In turn, these technologies are crucial for the services offered in prevention, diagnosis, and treatment of illness, disease, and disability (WHO, 2010: 6).

Regarding health, the discovery of drugs, diagnostics, vaccines and medical devices have resulted in a global improvement in human health and quality of life (AUDA-NEPAD, 2019:20). To seize the emerging opportunities in enhancing health care, Africa's Health Research and Innovation Strategy 2018 – 2030 has identified 'advocacy for the adoption of emerging technologies and supporting platforms to improve health' (AUDA-NEPAD,

2019:6). The Africa's Health Research and Innovation Strategy has prioritized a number of health technologies. These technologies include E-health solutions; "omic" technologies (e.g. genomics, transcriptomics, proteomics, and metabolomics); geospatial modelling; artificial intelligence; and finally, additive manufacturing. Drones have also been considered by AUDA-NEPAD as a game-changer for the African continent (e.g. for precision agriculture).

Artificial intelligence is another health technology that is seen as providing a pathway to improve health services, diagnostics and personalized medicine in Africa (Sallstrom, Olive and Halak, 2019:2). This technology can play a role in eliminating inefficiencies such as misdiagnosis, shortage of health workers, wait and recovery time. Inclusion of African researchers in the development of such technologies as well as infusion of African data sets to inform their development, greater attention to data privacy and security are additional issues that should be addressed if Africa is to fully benefit from artificial intelligence technology (Sallstrom, Olive and Halak, 2019:5).

2.2.1. Gene Drives Technology

The National Academies of Sciences (2016:15) defines gene drives as 'systems of biased inheritance in which the ability of a genetic element pass from a parent to its offspring through sexual reproduction is enhanced'. This new biotechnology development enable humans to alter or even drive to extinction entire populations or whole species of organisms.[1] Given this characteristic, gene drives can entirely re-engineer ecosystems, create fast-spreading extinctions, and intervene in living systems at scale far beyond anything ever imagined.[2] It is a technology that has given rise to new optimism given the potential for application to solve some of the challenges that people have faced in public health, agriculture, conservation, among other applications. On the flipside, this new technology has been dodged with concerns around ethical, ecological and regulatory implications. It is in view of this that the National Academies of Sciences have called for the applications of gene drives to be tempered by a number of scientific, ethical, legal and social factors (2016:18). Box 1 illustrates some examples of application of gene drive technology across the world.

[1] Source: https://www.synbiowatch.org/gene-drives/ , accessed on March 11, 2021.
[2] Source: https://www.synbiowatch.org/ , accessed on March 11, 2021

Box 1: Examples of application of gene drives technology across the world

Some examples of the application of gene drives technology around the world

1) Use of *Aedes Aegypti* and *Aedes Albopitcus* mosquitoes to manage dengue *(Aedes Aegypti)* has been developed by a UK-based company, Oxitec.

2) Use of *Anopheles gambiae* mosquitoes to combat malaria in Sub-Saharan Africa.

3) Use of the *Culex Quinquefasciatus* mosquitoes to combat the spread of avian malaria to threatened and endangered honeycreeper birds in the Hawaiian Island.

4) Controlling populations of non-indigenous *Mus Musculus* mice to protect biodiversity on Islands.

5) Controlling non-indigenous *Centaurea maculosa* knapweeds to protect biodiversity in rangelands and forests in the United States.

6) Controlling *Palmer Amaranth* to increase agriculture productivity in the Southern United States. Developing a vertebrate model for gene drive research using *Zebrafish* to further knowledge on gene drive mechanisms in a vertebrate animal.

Source: *National Academies of Sciences (2016). Gene drives in the horizon: Advancing uncertainty, and aligning research with public values, pp. 49 – 62.*

A closely associated technology is gene editing. This is a technique that allows researchers to insert, delete, or modify DNA to silence, activate, or otherwise modify an organism's specific genetic characteristic (National Academies of Sciences, 2016:22). While gene editing and gene drives share common techniques, genome editing is not necessarily designed to result in a gene drive (National Academies of Sciences, 2016: 22). Research around gene drives has largely outpaced the regulatory systems that govern biosafety and biosecurity.

Gene drives has been applied in the development of genetically modified mosquitoes, a technology that researchers hope will contribute significantly to the control of malaria especially in SSA where the disease is endemic. Given the promise it holds, gene drive mosquitoes technology has already been prioritized by the AAS and AU's AUDA-NEPAD. Laboratory research has demonstrated that gene drive techniques are effective in altering the *Anopheles* mosquito populations so that they can no longer transmit Malaria parasites (Gantz et al., 2015), and crashing entire mosquito populations (Hammond et al., 2016). Table 1 provides an overview of the genetically modified mosquitoes technologies currently under development.

Table 1: Genetically modified mosquitoes technologies currently under development

Strategy	Approach	
	Self-limiting	Self-sustaining
Population suppression	• Modification reduces the number of progeny • Possesses either no gene drive or weak drive that will pass the modification through only a limited number of generations. • Not intended to persist in the absence of continued releases.	• Modification reduces the number of progeny. • Possesses strong gene drive. • Intended to spread the modification indefinitely or until the mosquito population is eliminated.
Population replacement	• Modification limits pathogen replication, thereby reducing transmission • Possesses weak gene drive that will pass the modification through only a limited number of generations. • Intended to persist only until diluted out of the population.	• Modification limits pathogen replication, thereby reducing transmission. • Possesses strong gene drive. • Intended to spread the modification through the population indefinitely.

Source: *World Health Organization (2014). Guidance framework for testing of genetically modified mosquitoes, p. 5.*

3. METHODOLOGY

3.1. Study Design

The study adopts a qualitative design to examine the landscape of emerging priority health technologies in SSA. It draws on the applied political economy analysis approach, which provides the lenses in which to analyze not only the regulatory context, but also the actors involved in emerging health technologies, including an exploration of what incentivizes their behavior relative to emerging health technologies. In addition, the study assesses the regional and national policy-level regulatory context of gene drive mosquitoes technology in SSA; identification of key players in gene drive mosquitoes technology in SSA; and on-going advocacy efforts on gene drive mosquitoes technology in SSA.

3.2. Study Site and Population

This study focuses on SSA. The study population includes:

- Policymakers within continent-wide and regional governmental organisations/ economic blocs that formulate science, innovation and technology policies.

- Technical leads or Principal Investigators (PIs) overseeing regional research consortia researching transformative health technologies and tools, including gene drive and other priority health TTs.
- Relevant regional networks of researchers focused on emerging transformative health technologies and tools.
- Ethicists i.e. people who specialize in ethics or are devoted to ethical principles.
- Leaders of regional CSOs and CSO networks that focus on advocating for or against emerging transformative health technologies and tools.
- Representatives of regional media networks.
- Leaders of global advocacy networks that focus on advocating for or against emerging transformative health technologies and tools.
- Representatives of funding agencies that support regional consortia/networks of researchers undertaking research on transformative health technologies and tools.

3.3. Sampling and Data Collection

Purposive sampling was used to identify research participants. Initial key informants were identified through a mapping of relevant stakeholders through literature search. Additional respondents were identified using the snowballing technique. Data from the key informant interviews was supplemented by a review of evidence in existing literature. The literature included a review of global, regional and national policies on research and adoption of transformative health technologies in SSA, and with a focus on gene drive mosquitoes.

Table 2: Distribution of interviews by aggregate categories

Category	Number of interviews
Regional policy making bodies	4
National regulatory bodies	2
Global advocacy networks	4
Research consortia and networks	11
Ethicists	1
Regional CSOs networks (SSA)	2
Funding agency	1
Science media networks	5
Total	30

Interviews were conducted using a semi-structured interview guide that was tailored for different groups including: researchers involved in research on health TTs including gene drive mosquitoes and other high priority TTs; researchers conducting other research; health sector policymakers; policymakers in charge regulatory policies and frameworks for health technologies; ethicists; media; and advocacy groups that are for or against transformative health technologies. The interviews were conducted online.

3.4. Data Analysis

Data was analyzed using a thematic approach guided by the political economy analysis framework and the specific objectives of the study. Interview notes were read and re-read to identify emerging themes, sub-themes, patterns and relationships.

3.5. Ethical Considerations

The study procedures presented minimal risk of harm to participants' wellbeing and to the image of their respective institutions. For compliance with established ethical procedures, the study was reviewed and cleared by the Strathmore University ethics review board in Kenya (reference number: SU-IERC0983/21).

4. LANDSCAPE ANALYSIS OF EMERGING HEALTH TECHNOLOGIES IN SSA

4.1. Emerging Health Technologies in SSA

Across SSA, there are numerous on-going efforts to develop and test new tools and technologies for better health outcomes on the continent. These research efforts are being undertaken in various research institutions across the region. Although this study does not provide a comprehensive listing of all the new health technologies that are being tested, the interviews point to several technologies that have the potential to transform health in the region.

For malaria control, the most commonly cited emerging technologies by the key informants include: gene drive mosquito technology; Ivermectin drug, malaria vaccine; sterile insect technology; piperronly butoxide (PBO) nets; Attractive Toxic Sugar Baits (ATSB); and drones for larvicide control (Table 3).

Table 3: List of emerging tools for Malaria control in SSA

Type of technology	Stage of research	Stakeholders and locations
Gene drives mosquitoes	Lab trials	Target Malaria (Burkina Faso, Mali, Uganda and Ghana)
Ivermectin drug	Lab trials	Burkina Faso, Senegal, Liberia
Attractive Toxic Sugar Baits (ATSB)	Field trial	KEMRI/CDC, ICIPE, Mali
Malaria vaccine	Clinical trials	Kenya, Burkina Faso GSKBio, the PATH Malaria Vaccine Initiative
Sterile Insect Technology	Lab trials	Wits Research Institute for Malaria
Drones for larvicide control	Field trials in rice fields	Rwanda
Biocontrol / larvicide control		Zimbabwe, Tanzania, and Rwanda

Besides new tools for malaria control, key informants pointed to other technologies with the potential to contribute to positive health outcomes in SSA. These technologies include genome editing; synthetic biology; data science /analytics (e.g. digital certificate for Covid-19); monoclonal antibodies; artificial intelligence, and mechanical ventilator (see Table 4).

While some of the emerging technologies can be regulated within the existing national and regional frameworks, some of the emerging technologies are challenging regulators across SSA to reconfigure their policies, guidelines and laws to accommodate these new realities. For instance, while the existing policies and laws in a number of countries in SSA can govern genome editing and gene drives research at the lab trials level, open release is confronted with inadequate regulatory frameworks. Unlike in regulating genetically modified crops, some of these new technologies (e.g. genome editing) present an additional challenge for regulators in SSA for lack of capacity as observed by one of the key informants:

> "*When genome editing started, there was a lot of push for this kind of research. However, Africa is more heterogeneous as compared to other parts of the world. Up to now, there is very little knowledge within regulatory bodies on risks and signals to be monitored as recommendations for future studies. There is need to build local expertise on regulating this kind of technology and reduce reliance on the west. There should also be open discussions around technology transfer*". (Key Informant Interview, 13 May, 2021).

For technologies such as data analytics, there is further challenge of lack of enabling policy framework for data sharing and weak mechanisms for data protection. As one of the key informants observed, governments are not comfortable with sharing data:

> *"Countries are not comfortable with sharing data. At the individual level, there is also the issue of privacy and no one likes to have their data in public. Given these challenges, there should be discussions as to what level of data countries are willing to share. There is also need to think of a regional data policy, even though countries want to share data at the aggregate level. It is also important to scale-up advocacy on the need to share individual data*". (Key Informant Interview, 13 May, 2021).

Table 4: List of emerging other technologies in SSA

Type of technology	Potential applications	Stakeholders involved / country
Genome editing	Livestock diseases, cancer treatment	Centre for Tropical Livestock Genetics and Health & International Livestock Research Institute; research is also being done in Nigeria
Synthetic biology	Novel drugs and vaccines; genetically engineered organisms / viruses to fight diseases[3]	International Service for the Acquisition of Agri-biotech Applications & Imperial College, London;
Data science / data analytics	To track child immunization in border regions (e.g. a project by Broadreach in the IGAD region); developing a digital certificate for Covid-19	BroadReach Healthcare in West Africa (with WAHO) and Eastern Africa region (IGAD)
Monoclonal antibodies	Cancer treatment	IAVI/KAVI, Gambia, London School of Tropical Medicine; This was also mentioned by researchers at the Kenya Medical Research Institute
Artificial intelligence	Diagnostics; precision medicine	No information
Mechanical ventilator	Oxygen supply device	African Academy of Science under Grand Challenges Africa; Kenyatta University

[3] König, H., Frank, D., Heil, R., & Coenen, C. (2013). Synthetic genomics and synthetic biology applications between hopes and concerns. *Current genomics*, *14*(1), 11–24, p. 14.

4.2. Focus on Gene Drive Mosquito Malaria Intervention in SSA

4.2.1. Diversity of Malaria Interventions in SSA

Drug therapy and vector control have been two main strategies for malaria control. Treating malaria while plausible, requires detection of the parasite and access of infected persons to healthcare, a challenging aspect in most of the malaria-endemic countries (NAS, 2016:53). Eliminating breeding sites, spraying insecticides, using insecticide-treated bed nets are the key vector control measures in malaria-endemic regions. Despite these interventions, malaria remains a challenge in SSA. The situation is worsened by the spread of insecticide resistance in *Anopheles gambiae* populations (NAS, 2016: 53).

Vector control strategies such as environmental management and larvae source management, have not been prioritized in SSA, while donors have not been supportive of this approach. As the interviews show, this bio-control approach is being tried in Zimbabwe, Tanzania and Rwanda. In the case of Rwanda, the malaria control programme is testing the applications of drones in larviciding. Furthermore, for success, malaria vector control measures require organized campaigns and sustained resource availability (NAS, 2016: 53).

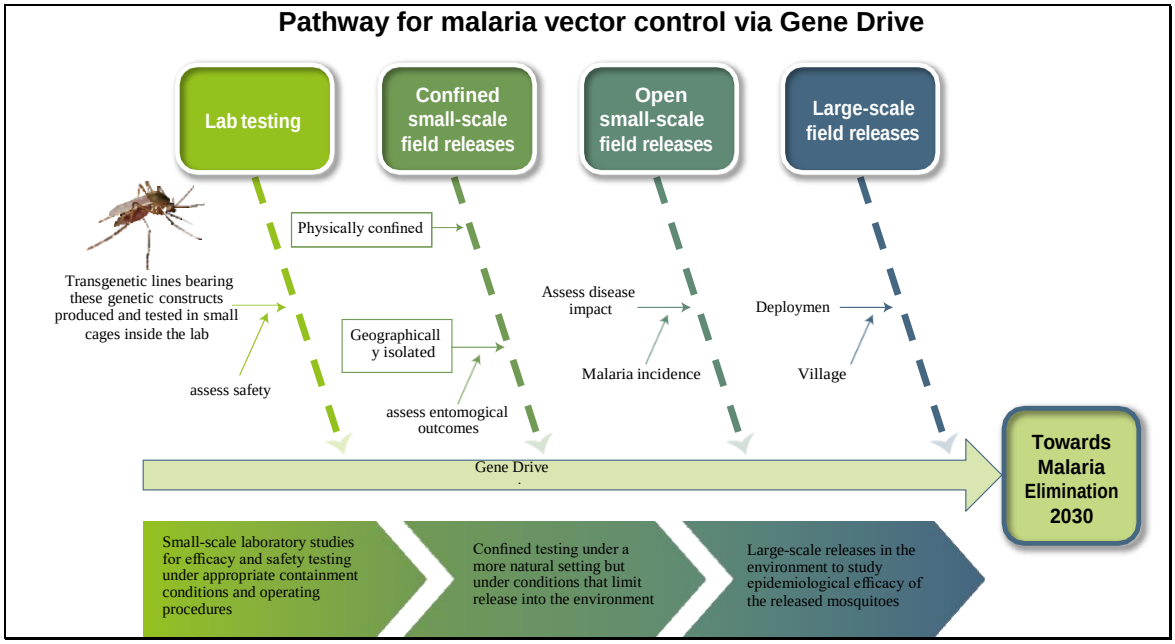
Given the inherent limitations on the vector control and drug-based approaches in the fight against malaria, two new complementary tools are being tested and at various levels of development. First, there is the gene drive mosquitoes technology. In this technology, 'a gene drive alters the female mosquito's ability to become infected with the malaria parasite, or one that prevents parasite development within the mosquito, could block malarial transmission without affecting mosquito populations' (NAS, 2016:53). This technology is at the initial level of development with a timeline of possible deployment from 2029. Second, is the malaria vaccine. While efforts to develop malaria vaccine have been on-going for decades, the latest initiative by the Jenner Institute of Oxford University, has shown up to 77% efficacy in a trial of 450 children in Burkina Faso (Oxford University News April 23, 2021). Separately, GlaxoSmithKline has also been spearheading the development of yet another malaria vaccine, but with less efficacy as compared to the one by Oxford University.

4.2.2. Stage of Gene Drive Mosquitoes Research

Interviews with the various stakeholders involved in gene drive mosquitoes research in SSA show that development of this technology is in its initial stages. The project is being implemented in four countries in SSA, under the Target Malaria Project. These are Burkina Faso, Mali, Uganda and Ghana. Given the uncertainties and the novelty of this technology, the WHO has called for a phased testing (see Figure 1). Another initiative on application of

gene drive for malaria control and elimination in Africa is led by the University of California Irvine Malaria Initiative (UCIMI).[4] As of 2020, UCIMI was conducting field research including sampling and analysis of local mosquito populations and initial phases of engagement with stakeholders and community leaders in the Democratic Republic of Sao Tome and Principle, and the Union of the Comoros.

Figure 1: Phased testing for malaria vector control via gene drive



Source: AUDA-NEPAD (2018) Gene drives for malaria control and elimination in Africa, p. 16.

It should be noted that at the initial phase, the focus is on genetically modified mosquitoes and not gene drives. Burkina Faso achieved a milestone by releasing genetically modified sterile male mosquitoes in July 2019, the first of its kind in the African continent. Unlike the research in Burkina Faso, Mali and Uganda, the project in Ghana focuses on studies of *Anopheles gambiae* behavior and ecology. Box 2 summarizes the key milestones in each of the four countries.

[4] Source: https://ucimi.org/, accessed on 28 May 2021

Box 2: A brief on the stage of gene drive mosquitoes research in SSA

1. Target Malaria Burkina Faso

- Established in 2012. Collection of baseline entomological data to understand what species of mosquitoes are present, seasonal dynamics and behavior in the wild.
- Establishment of a community reference group to spearhead the design of acceptance model on the basis of transparency, inclusiveness and openness.
- Working on genetically modified sterile male mosquitoes (the first stage of a stepwise approach to develop Target Malaria's genetically-based technologies for malaria vector control).
- Milestone thus far: Release of genetically modified sterile male mosquitoes in July 2019 in the country, the first of its kind in the African continent.

2. Target Malaria Mali

- Established in 2012 and based at the Malaria Research and Training Centre at the University of Bamako. Current research is still in its early stages.
- Milestone thus far: the first import of genetically modified mosquitoes in September 2019 after the Malian Government authorized the experiments. In its Anthropod Level 2 Insectary in Bamako, the scientific team is working on genetically modified sterile male mosquitoes (the first stage of a stepwise approach to develop Target Malaria's genetically-based technologies for malaria vector control). Also trying to understand local mosquito species that are responsible for malaria transmission / studying wild mosquitoes in their natural environment.

3. Target Malaria Uganda

- The project is based at the Uganda Virus Research Institute. Target Malaria Uganda is still in its early stages focusing on entomological mosquito collections from field sites to enable studies on mosquito dynamics and behavior.
- Milestones thus far: Construction and inauguration of a new insectary Antropod Containment Level 2 at Uganda Virus Research Institute in July 2019. Since the facility was opened, the researchers have been conducting experiments with local wild mosquitoes. In future, this facility will be used for genetically modified mosquitoes under containment. Currently working on the facility readiness at the insectary, including testing functioning all aimed at audit and approvals to ensure the new insectary is fit for purpose to conduct future studies on genetically modified mosquitoes.

4. Target Malaria Ghana

- Established in 2018 and based at the University of Ghana. The goal of the project in Ghana is to undertake extensive studies on *Anopheles gambiae* behavior and ecology. Currently, ecological consequences for reducing or eliminating *Anopheles gambiae* population is not well known. This is done by conducting the following studies: Anopheles Gambiae Ecological Observatory and Mosquito rearing and male fitness studies of Anopheles gambiae complex.
- As part of investigating the ecological implications of reducing *Anopheles gambiae* populations, researchers at the University of Ghana are engaged in creation of DNA Barcode Library by using DNA barcodes. The ecological research taking place in Ghana is an international collaboration between the University of Oxford, the Centre for Biodiversity Genomics at the University of Guelph and Target Malaria. The goal is the creation of an "ecological network", a map of how the different organisms in the ecosystem interact with *Anopheles gambiae*.

4.2.3. Key Players in Gene Drive Mosquitoes Technology in SSA

Gene drive mosquito research agenda is a space with diverse set of actors at global, regional, national and local level. In this space are funding agencies, development partners, research institutions, governments and the public. Given the propensity of the mosquitoes to spread across borders, there is a vast body of literature that points at the need for various stakeholders to embrace a regional strategy especially on policy and regulatory level (James et al., 2018).

Gene drive mosquitoes have already been prioritized by the African Union's AUDA-NEPAD and the AAS. As noted above, there is ongoing gene drive mosquito research in Burkina Faso, Ghana, Mali and Uganda led by the Target Malaria consortium, funded largely by Bill and Melinda Gates Foundation (for the work in Burkina Faso, Mali and Uganda), and by Open Philanthropy (for the work in Ghana). As also noted, the University of California Irvine Malaria Initiative is also spearheading gene drive research for malaria control and elimination in the Democratic Republic of Sao Tome and Principle, and the Union of the Comoros.

The terrain of gene drive mosquitoes research in SSA is a space with diverse set of stakeholders, who often have varied interests. While the goal is on the fight against malaria, at stake is how the new technology is likely to impact on the spaces of different stakeholders. For instance, barring any adverse safety and ecological effects, this technology would find easy support among many stakeholders. However, for some stakeholders (e.g. those in pharmaceuticals), the impact to their bottom-line is an issue for consideration.

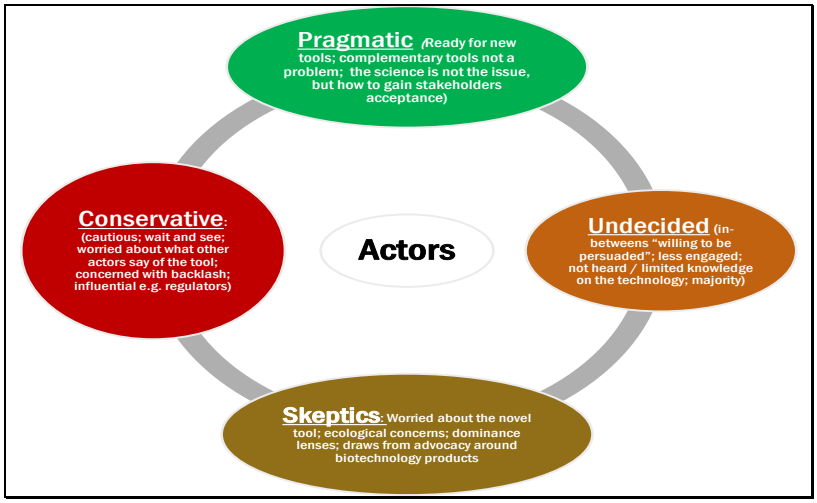
Box 3 provides a summary of the key players in gene drive mosquitoes research in SSA. The table is an attempt to map out the various players in the field of gene drive mosquitoes technology in SSA against power-interests dynamics. The classification is a best-fit approximation of the level of influence or interest that a particular actor has on that technology. From interviews conducted, we map out four sets of actors.

First are actors that in our view wield a lot of influence in the decision-making space in SSA, but at the same time are keen on the outcome of the development of gene drive mosquitoes technology. For countries where malaria is endemic, if successful, this technology would further help in reducing deaths linked to malaria. Various institutions at the national level tasked with regulation of biotechnology are also keen on this technology in as far as risk assessment is concerned. At the regional level, AUDA-NEPAD is spearheading efforts in helping build regulatory capacity of the countries in the region in regard to this technology.

Second, are actors who wield a lot of power and influence, but are not keen on this technology either out of business interests (e.g. pharmaceuticals companies) or out of lack of knowledge or awareness on this new technology (e.g. media). The media (traditional and social media) occupies a special space given its primacy in informing the people, thus presenting a very powerful resource that remains untapped in raising awareness about this technology. Third is a set of actors who are keen on complementary tools for malaria control, but their place in their society power/influence dynamics is low (e.g. research consortiums on malaria). A final set of actors are those with low level of influence and equally have low interest on the technology and may include other academics, the general public.

Through a mapping of interests and power matrix of the various stakeholders involved in gene drive mosquitoes technology, we identify four broad set of stakeholders. These are: 'pragmatics' (are ready to embrace this new tool; for them science is not the issue, but the question is how to gain stakeholders acceptance; they see the tool as complementing existing tools e.g. researchers in malaria control and elimination). Second, are 'conservatives' (these are very cautious; employ a wait and see attitude; their main concern is with backlash from other stakeholders; hold positions of influence e.g. government regulators). Third are 'skeptics' (are worried about the new tool; raise concerns about dominance, hidden costs, values and ecological implications; draw a lot from their work on genetically modified crops e.g. advocacy groups against GMOs). We label the last category as 'undecided' (are in-betweens; willing to be persuaded; less engaged; have limited or no knowledge at all on this technology; are the majority). This categorization is important in helping dissect the interests of the various stakeholders and how to appropriately frame messages.

Figure 2: Categorizing actors and their interests in gene drive mosquitoes technology



Box 3: Summary of the key players in gene drive mosquitoes research in SSA

High Power /Influence; Low Interest

- Pharmaceutical companies in malaria control
- Media in science and technology associations (MESHA, Africa Health Journalists Association, Science Africa, SciDev, etc.)

High Power/influence; High Interest

Policy Making (National level)

- National biosafety agencies
- National malaria control programmes
- Departments/ ministries of environment
- Departments / ministries of science and technology
- National institutional ethics committees
- Technical Working Groups on biotechnology

Policy Making (Regional level)

- African Union (AUDA-NEPAD, Africa CDC)
- West Africa Health Organization; East Africa Health Research Commission; Association of Central Africa States; Southern Africa Development Community / SADC Elimination 8
- World Health Organization (Africa)
- Africa Group of Negotiators to Conference of Parties on Biosafety
- African Biosafety Network of Expertise

Development partners

- USAID, European Commission, FCDO
- University of California Irvine Malaria Initiative
- Various funding agencies for health technologies (e.g. Bill and Melinda Gates, Open Philanthropy)

Low Power / Influence; Low Interest

- Other academics
- General public
- Researchers not working on gene drive

Low Power / Influence; High Interest

- Science and technology journalists
- Researchers conducting gene drive trials
- Groups working to enhance capacity on the technology for informed decision making (e.g. FNIH/GeneCconvene)
- Advocacy groups opposed to the technology (e.g. Africa Centre for Biodiversity, Friends of the Earth, Kenya Biodiversity Network)
- Ethicists
- Pan Africa Moquito Control Association (PAMCA)
- African Academy of Sciences
- Malaria Consortium
- Research institutions at national or regional level e.g. Malaria Research Capacity Development in West and Central Africa (MARCAD); West Africa International Centre of Excellence for Malaria Research (ICEMR); Developing Excellence in Genomics for Malaria Elimination; Plasmodium Diversity Africa; African Genetic Biocontrol Consortium

There is notable opposition to the use of gene drive mosquitoes in controlling Malaria by various stakeholders including the African Centre for Biodiversity, Gene Watch UK, the Third World Network, and various CSOs across Africa (Africa Centre for Biodiversity et al 2018; 2019). Among the main concerns raised by these actors include: no risk assessments to humans and to the environment have been conducted before the release of GM mosquitoes, and that GM mosquitoes could pose adverse dangers to the ecology and to people. Workshops conducted by NEPAD in 2019 for a wide range of stakeholders (including scientists, ethicists, health professionals, government regulators in the fields of environment health and biosafety as well government policymakers) to define the problem of using gene drive mosquitoes revealed that the main concerns by stakeholders were the need for the protection of human health and biodiversity during the development of gene drive mosquitoes (Teem et al., 2019).

Also playing a key role on gene drives research in Africa is the African Biosafety Network of Expertise (ABNE)[5], a programme of the African Union/NEPAD. The overall goal of the ABNE service network is to build functional regulatory systems in Africa. ABNE biosafety services include information resources; training and education (workshops, short courses, on-line courses, internships, and regulatory study tours); and technical support and networking. These are aimed at empowering African regulators with science-based information, targeting the National Competent Authority/Focal Points, including members of National Biosafety Committees (NBCs), Institutional Biosafety Committees (IBCs), and Plant Quarantine Officers (PQs) so that they can make informed decisions on biotechnology (NEPAD, 2018: 27).

In drawing lessons to inform the design of the Health Technologies Platform, we briefly profile three actors. These are AUDA-NEPAD, PAMCA, and GeneConvene (see Box 4 and Table 5). AUDA-NEPAD[6] has been spearheading conversations on gene drive mosquitoes technology in Africa, with a focus on reforming the regulatory frameworks to accommodate the development (and deployment if proven effective and safe) of these new tools for malaria control.

[5] For more details see: http://nepad-abne.net/

[6] Information in Box 3 is sourced from AUDA-NEPAD webpage and key informant interviews. https://www.nepad.org/programme/emerging-technologies

Box 4: Brief on African Union Development Agency (AUDA-NEPAD)

AUDA-NEPAD is a development agency of the African Union that coordinates and executes priority regional and continent development projects to promote regional integration, as well as strengthening the capacity of Member States and regional bodies. The Agency is mandated to coordinate the provision of technical advice, capacity building and policy reform for member states in harnessing emerging technologies for the socio-economic development of the continent. In undertaking this mandate, the Agency uses a four-pronged approach:

1. Establishment of the AU High Level Panel on Emerging Technologies (APET), which advises the African Union and Member States on harnessing emerging technologies.

2. Support the domestication of protocols for regulating emerging technologies such as gene drive mosquitoes.

3. Adopt an integrated vector management approach to the adoption of emerging technologies and innovation, e.g. West Africa Integrated Vector Management Strategy.

4. Build the capacity of African policymakers, regulators, researchers, academia, youth and other relevant stakeholders in order to increase knowledge, acceptance of emerging technologies.

Gene drives research for malaria control is one of the emerging technologies that AUDA-NEPAD has prioritized. In view of this, the Agency has produced a report titled 'Gene drives for malaria control and elimination in Africa'. Since the release of that report, the Agency has been working on regulatory strengthening, and working with national regulators as they go through the different stages of development of the gene drive mosquitoes technology. The Agency has been working in Burkina Faso, Uganda, and Mali in this regard. The Agency also engages with the policymakers and scientists through the Calestous Juma Executive Dialogue on Innovation and Emerging Technologies forum.

As part of the regulatory strengthening, *'AUDA-NEPAD has worked with the West Africa Health Commission to develop the West Africa Integrated Vector Management strategy and now thinking of a continental level IVM. When we deal with regulatory strengthening, you give guidance on how to assess risks associated with the technology. The Agency has also established the African Biosafety Network of Expertise that support member countries on biosafety issues.* (Key Informant Interview, AUDA-NEPAD).

Two critical platforms: convenings of ministers of science and technology from Member States as well as the Open Forum on Agricultural Biotechnology in Africa.

FNIH/GeneConvene, on the other hand, is supporting capacity building interventions to ensure improved understanding of best practices and informed decision-making for development of genetic biocontrol technologies to improve public health.[7] This is done through identification and addressing key questions; providing technical advice as well as strengthening capacity and sharing information with scientists, regulators, policymakers, other stakeholders and the publics.[8] FNIH/GeneConvene also organizes webinars and online panel discussions on scientific, regulatory, policy and ethics topics and is currently developing GeneConvene Virtual Institute as an open online source of information about

[7] Cited from https://fnih.org/our-programs/geneconvene, accessed on 16 May 2021.
[8] Consultation meeting with FNIH/GeneConvene Collaborative, March 2021.

gene drive and genetic biocontrol.[9]. A key lesson from GeneConvene's work for the development of the Health Technologies Advocacy Platform is to 'understand what the challenging questions people have about this technology and [use] the platform to help overcome these questions'.[10]

Finally, there are also lessons to be drawn from the work of PAMCA. Of interest is the *Africa Gene Drive for Vector Control Network* project that was commissioned by Target Malaria in 2017 to conduct training on gene drives for vector scientists.[11] The goal is to create a platform for networking, knowledge sharing, regional collaboration and cooperation. The network targets African scientists, regulators, public health professionals, academia, policymakers, students, and media, among others. [12]

Table 5: Overview of some actors working on gene drive mosquitoes in SSA

Organization	Target Audience	Issues Addressed
AUDA-NEPAD	Policymakers, regulators, scientists	1. Outreach activities targeting policymakers and scientists 2. Regulatory framework strengthening
PAMCA	African scientists, regulators, public health professions, academia, policymakers, students, media, CSOs, women in vector control	1. Capacity building for scientists on vector-borne diseases 2. Strengthening regional collaborations and partnerships
FNIH/ GeneConvene	Scientists, regulators, policymakers, other stakeholders and publics	1. Identify and address key questions 2. Strengthen capacity and share information 3. Provide technical advice

4.2.4. Biosafety Profiles of Countries in SSA

The biosafety profiles of countries in SSA vary considerably in the adoption of biotechnology products. The countries draw the biosafety governance framework from the Cartagena Protocol or the Convention on Biological Diversity.[13] This is an international

[9] Consultation meeting with FNIH/GeneConvene Collaborative, March 2021.
[10] Key informant interview, 29 April, 2021
[11] Consultation meeting with PAMCA, 22 March 2021.
[12] Consultation meeting with PAMCA, 22 March 2021.
[13] Source: https://bch.cbd.int/protocol/, accessed on 16 May 2021

agreement whose goal is to ensure safe handling, transport and use of living modified organisms resulting from biotechnology.

As figure 3 shows, three countries have made considerable progress in the area of modern biotechnology in Africa. [14] Out of these, South Africa is the most advanced in this regard and as of 2017, the country had commercialized three biotechnology crops (Bt maize, Bt cotton and Bt soybean). Two other countries that have made notable progress are Burkina Faso and Sudan. Sudan has commercialized Bt cotton, while Burkina Faso has commercialized Bt cowpea.

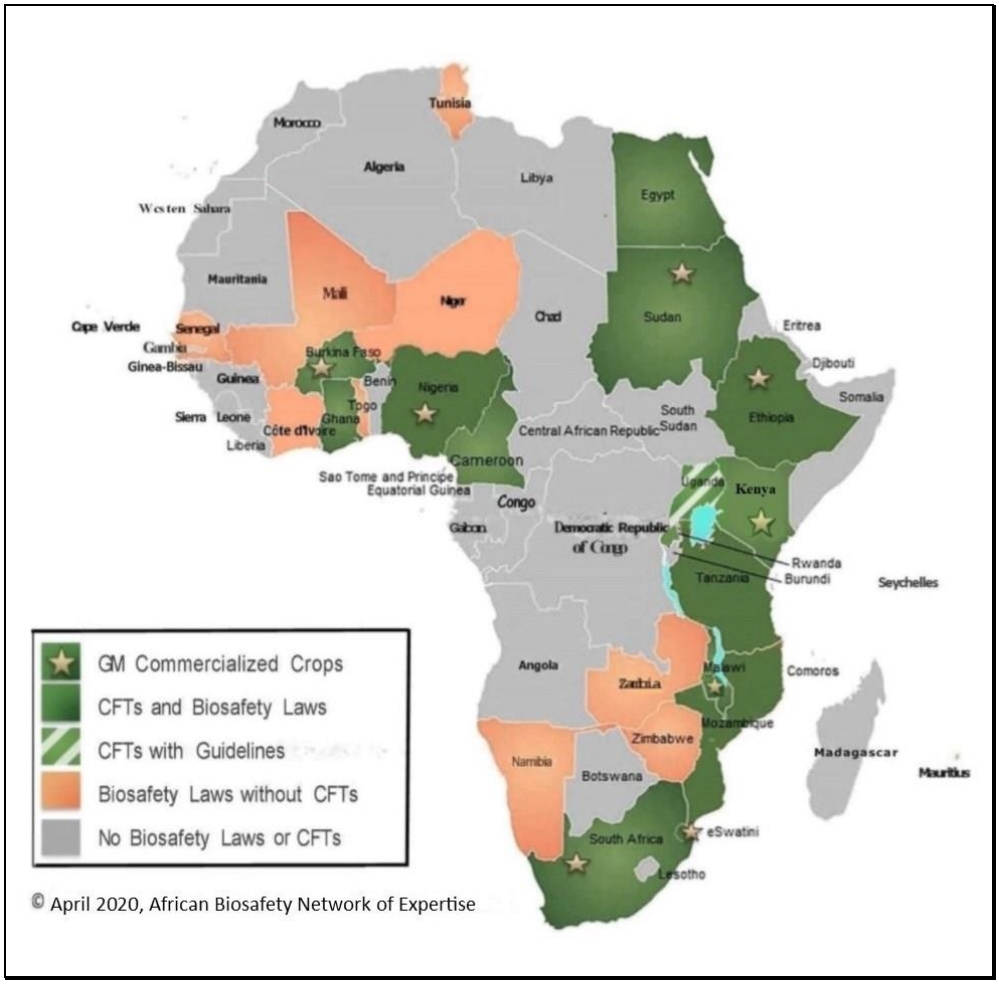
A unique development in Africa was the formation in Burkina Faso in 2016 of civil society groups aiming to support biotechnology and advocate for its access as part of farmers' right to benefit from improved seeds of their choice.[15] Another eleven countries have biosafety laws in place and have embarked on confined field trials of various biotechnology crops. The eleven countries are: Egypt, Nigeria, Ethiopia, Kenya, Malawi, Mozambique, Swaziland, Ghana, Cameroon, Uganda, and Tanzania. As of 2017, Togo, Zambia, Tunisia, Mali, Namibia, Senegal, Côte d'Ivoire, and Zimbabwe had enacted biosafety laws, but had not commenced confined field trials. The remaining thirty three other African countries had not enacted biosafety laws or started confined field trials on any biotechnology product.

These variations in regulatory contexts from country to country across Africa occasion in delays in introduction of such new tools for public health and scale up. For instance, in the case of Target Malaria's consortium on gene drive mosquitoes in Africa, Burkina Faso, Ghana and Mali have made considerable progress in researching on this technology as compared to Uganda where the process of passing a legislation on biotechnology and biosafety has been a protracted one.[16]

The regulatory agencies in Africa are also under-resourced (Sithole, et al., 2020: 1319) and over-burdened, compounding their ability to strengthen their capacity in regulating the development of new health technologies.

[14] Source: http://nepad-abne.net/contry_report/south-africa/, accessed on 4 March, 2021
[15] Source: http://nepad-abne.net/contry_report/burkina-faso/, accessed on 4 March, 2021
[16]For more details see: https://targetmalaria.org/category/blog/page/4/ accessed on 19, February 2021

Figure 3: Biosafety Profile of African Countries



Source: http://nepad-abne.net/country_report-2/, accessed on 16 May 2021

It has also been observed that even though national biosafety authorities in several SSA countries have experience in regulating genetically modified crops, few have experience with genetically modified insects and none presently has experience with gene drive mosquitoes (James et al, 2018:12). This view was accentuated in a number of interviews during the study as is evident in this excerpt from one of the interviews:

> *"In South Africa, our regulatory framework has been developed to take care of genetically modified organisms, but with a focus on plants. It's easier for agricultural things, but one that directly affects humans, that is an issue. It's a tedious process when dealing with animals because no one has done it. To market that technology, one has to overcome the governance huddles e.g. getting people in government to understand how that technology works*." (Key Informant Interview, 7 April, 2021).

The daunting task is for countries in SSA to develop regulations, acceptable to various stakeholders on 'regulation for environmental release of the genetically modified organisms (GMO)'. As illustrated by the above excerpt, while it is easier to develop regulations for 'contained use regulation', it is in the space of 'restricted field release regulation' and 'regulation for environmental release' where there is dearth of regulatory capacity in the region.

4.2.5. Media landscape on gene drive mosquitoes research

Across SSA, there are associations and networks of science and technology journalists. These are at either national or regional level. Some of the associations include: Science Africa; Media for Environment, Science, Health and Agriculture (MESHA); South African Science Journalists Association; Health Journalists Network; Uganda Science Journalists; and the African Media and Malaria Research Network (AMMREN), among others.

Interviews done with science journalists in SSA show that media coverage of gene drive mosquito technology is at best limited. The various science journalists rated the knowledge and awareness on gene drive mosquitoes among science journalists in the region as low:

> *"On a scale of 1 – 3, with 1 being the lowest, I would rate the level of awareness and knowledge of journalists and editors on gene drive mosquitoes as low. Even where there is coverage, there is a lot of misinformation. Some journalists fail to fully explain what gene drives is all about. Explaining the efficacy is also a challenge. There is need for more training for these journalists to equip them with more knowledge of the technology and make them more analytical."* (Key Informant Interview, 12 April, 2021).

A notable science media association in the region is AMMREN. This is a network of African journalists and scientists working together to reduce the burden of malaria in Africa.[17] The network has presence in Ghana, Burkina Faso, Tanzania, Malawi, Mozambique, Senegal, Nigeria, Kenya, Gabon and Gambia.[18] AMMREN seeks to build the capacity of African journalists to cover issues on malaria and reduce the misinformation.[19] The Network runs a publication titled 'Eyes on Malaria' whose aim is to create awareness on the dangers of malaria on productivity in Africa. [20]

[17] Cited from: http://www.ammren.org/about-us/, accessed on 16 May 2021
[18] Cited from: http://www.ammren.org/about-us/, accessed on 16 May 2021
[19] Key informant interview, 30 April, 2021
[20] Key informant interview, 30 April, 2021

The changing media landscape in the region is also having implications on science and technology reporting. The shift from mainstream media (e.g. print and electronic media), to new media sites (e.g. social media) are redefining the media terrain across the region. However, there is improved coverage of science and technology as compared to some years back.[21]

4.2.6. Concerns Levelled Against Gene Drive Mosquitoes Technology

Despite advances in the development of new health transformative technologies, there are concerns in adopting some of these technologies. This is in part informed by lack of understanding of some of these technologies by those outside the research community directly spearheading these research efforts including other scholars, policymakers, ethicists, general public, and development actors. In turn, this lack of understanding undermines buy-in especially on the deployment of such technologies.

The development, deployment and use of some of the emerging health technologies in Africa is not without challenges. For instance, the uptake of "omic" technologies in Africa is constrained by low educational levels, lack of disease registries, poor funding and fiscal policies, lack of bio-specimen repositories and political unrest (Adeola et al, 2017: 2). The debate on the benefits and risks of gene drive mosquitoes has often been polarizing (WHO, 2020: 2).

While researchers involved in gene drive mosquitoes research believe that there is potential of this technology to become a game changer in the fight against malaria, there are technical, democratic and diplomatic challenges that this technology has to contend with (Famakinde, 2020: 60). Further, as the National Academies of Sciences (2016: 177) observes, there is insufficient evidence available at this time to support the release of gene drive organisms into the environment, despite the proven significant potential in basic and applied research. The novelty and the hitherto untried techniques employed in gene drive mosquitoes have continued to make this technology controversial, hampering the securing of public trust and acceptance.

The research and development funding landscape for health technologies (e.g. gene drive mosquitoes) across Africa is dominated by Europe and America. This weakens the continent's bargaining power in the development, deployment and use of these technologies. Funding agencies also determine the research agenda. The issue of funding and how it impacts on research agenda has been highlighted by Mitchella, Brown, and McRoberts (2017). The authors observe that if the gene drive research initiative is being funded by a profit company, it is logical to expect a profiteering motive, without which,

[21] Key informant interview, 29 April, 2021

the agency may pull out. This is the dilemma in view of 'self-sustaining' versus 'self-limiting' gene drives.

For self-sustaining gene drive, the initial release alters the entire population of the species, thus the need to generate the entire required economic return from that initial release. The authors note that the economic incentive from such an investment would be minimal given the small size of the market unless the individual contracts are of very high value. On the other hand, with self-limiting gene drive applications, individual releases would have spatial and temporal limits, which would necessitate multiple releases over time in the same region. This would create an incentive for commercial gene drive industry to meet the demand. According to some ecological groups in SSA, commercial use of the gene drive mosquito technology would lead to more dependence. [22]

Although there is evidence to back up plausibility of gene drive solution to improve public health, agriculture, conservation as well as in basic research, realization of this potential depends on human values (National Academies of Sciences, 2016: 63). As the authors note, values are reflected in our views about what morality requires of us, our views about what is in our interests, both individually and as society (p. 63). In responding to the issue of values, stakeholders in gene drive research are confronted with three broad concerns. First, is the issue of potential benefits and harms of gene drive research for people. Second, is the potential impact of gene-drive modified organisms on the environment (i.e. in terms of outcomes for people, and the environment in its own right). Third, is on who will be affected by gene drives and make decisions about them.

For new technologies like gene drive mosquitoes, regulation is also an issue. There is no precedence on the regulatory framework for gene drive mosquitoes, it is a new start for all the countries. There is dearth of robust, international regulation and oversight to determine the safety of the use of gene drives. Thus, the main challenge is not the science behind the technology, but one of politics and how to govern the deployment and use of the technology. In response to the concerns raised about this technology, the World Health Organization has developed 'a guidance framework for testing of genetically modified mosquitoes' including on aspects such as regulation (WHO, 2014). In Africa, NEPAD has called on various African Union Agencies and regional economic communities to facilitate the development, coordination and harmonization of regulations and guidelines for the development, approval and use of the final product (AUDA-NEPAD, 2019: 2).

[22] Key Informant Interview, 21 April, 2021.

Perhaps the most vocal voices in regard to gene drive mosquito technology are those from various ecological groups (e.g. Friends of Earth, ETC Group, African Biodiversity Network etc.). These groups have called for the global community to be mindful of the potential impact of gene drives to the general ecosystem. In 2018, ETC Group and Friends of the Earth successfully lobbied signatories to the UN Convention of Biodiversity for imposition of a moratorium on gene drive field trials as well as some lab experiments on gene drives. As a consequence, the signatories to the UN Convention on Biodiversity noted 'uncertainties regarding gene drives'[23].

Ecologists and ethicists argue that complete elimination of a specie on earth might have unintended consequences. There is also a possibility that the modified mosquitoes cross geographical boundaries into other communities that are not under the trial (ACRES, 2019). Hence, there is the fear that deployment in one country could easily spill-over to other countries or risk of unintended continent-wide deployment. Others have pointed out that reduction in number of mosquitoes could lead to reduced pollination and a lack of food for fish, thus reducing the fish population (ACRES, 2019). The issue of cross-border challenge in case of a release of gene drive mosquitoes was mentioned in most if not all the interviews conducted. It is one issue that regulatory agencies especially at the regional level have to address.

> "*If gene drive mosquitoes are released in one country, you can't recall. They would easily spread to other countries, just like the fall army worms came through shipment and now have been decimating our crops and wreaking havoc. In this regard, the African Union needs to adopt a precautionary approach."* (Key Informant Interview, 21 April, 2021).

> "*We need to consider trans-boundary effects. When we release the gene drive mosquitoes, you are not sure whether the neighboring country will accept them. If the gene drive mosquitoes find themselves in a neighboring country that was not party to the initial release, what would be the consequences. Have we thought of potential inter-state conflicts that could arise*?" (Key Informant Interview, 4 May, 2021).

Given the lack of evidence, ecologists fear that release of gene drive mosquitoes to the wild could have possible irreversible effects to the ecosystem, hence the need for further guidance on areas such as molecular characterization, environmental risk assessment and post-market environmental monitoring. However, among the ethicists, some are calling

[23] For more details see: https://www.reuters.com/article/us-burkina-malaria-idUSKBN1W310X

for caution as the technology unfolds and carefully evaluate the risks against the benefits of this technology:

> "*Is the gene drive mosquitoe technology bad? It's good. The intention is good. It's a tool to fight malaria, one of our biggest health challenges in Africa. However, while the technology may be good, we need to be aware of the environmental risks that we still do not know and these come later. The issue at hand is not the efficacy of the technology, but ecological risks, perhaps the mosquitoes could be useful. Also, gene drive mosquitoes could end up creating other risks that we do not know. We also do not know what positive things the mosquitoes have in the environment. It's a biosafety issue. I think if it's properly managed, gene drive mosquitoes is a good technology. At the end, there is need to balance the risks and benefits*." (Key Informant Interview, 22 April, 2021).

Further, there are concerns that the technology may fail, or pose increased transmission for other mosquito-borne diseases. Similar concerns on gene drive mosquito technology have been identified by Famakinde (2020:57). These concerns relate to the failure of the gene drive mosquito techniques to work expectedly; evolution of more virulent pathogen strains; alteration of the gene drive mosquito blood-feeding behavior; susceptibility of gene dive mosquitoes to other mosquitoe-borne pathogens; gene drive mosquito resistance to insecticides; and the spread of gene drive mosquitoes beyond release sites.

Public knowledge and acceptance is also an issue for some of these transformative technologies (e.g. Marshall et al., 2010: 7). In their study on 'perspectives of people of Mali towards genetically modified mosquitoes for malaria control', the authors observed that 'many participants preferred that mosquitoes be killed rather than modified. They feared that gene drive mosquitoes will not work in reducing malaria infections. Like other new technological innovations, this is a challenge that the developers of these technologies must confront, but in a way that enhances rather than stifles the innovation.

In the case of gene drive mosquitoes, social factors play a key role, particularly public perception, especially in a context of weak regulation and governance (Mitchella, Brown, and McRoberts 2017). Given the fact that gene drive applications have the potential of generating unintended negative social impacts, which may offset benefits, adoption of an engagement framework that enhances understanding and cultivate the buy-in of various stakeholders is key. Since this is a new technology that is being refined, the stated social impacts are at perception level and are yet to be verified through the rigor of science. At stake are people's concerns about the safety and efficacy of the gene drive technology. Marshall et al. (2010: 7-9) have documented some of these concerns as raised by the

general public, doctors, scientists as well as traditional healers as necessary conditions for a release of gene drive mosquitoes.

In addressing the challenge of perceptions; engagement, communication and outreach can play a pivotal role in tilting the balance in favor of more public confidence and trust in the gene drive technology. As James et al. (2018) observe, 'good communications materials, translated into the appropriate language(s), will be vital for explaining the technology, and therefore will underpin engagement efforts at all levels'. Unpacking the highly technical information from gene drive research to a format and language that can be consumed by various stakeholders would help in creating greater understanding of the technology. This way, some of the perceptions may be addressed.

Box 5: Additional concerns on gene drive mosquitoes documented through interviews

- Fear that the mosquitoes will transmit more malaria or worse forms of malaria
- If gene drive mosquitoes turn out to be vectors for other diseases
- No certainty on the future trajectory of the technology, e.g. what happens with genetic modification
- What risks does the technology pose to the people and the environment?
- Are there options for recall after release in case there are adverse effects?
- Limited knowledge of the technology
- Issue of lack of transparency and public participation in the development of this technology at the community level
- Risk of countries where trials are on-going being treated as labs
- Fear of weaponisation of the gene drives technology

Source: Key informant interviews (March – May, 2021).

The National Academies of Sciences (2016:147) poses two questions that are critical for the future of gene drive research and deployment into the environment. First, is what general principles could guide the evaluation and improvement of governance systems as gene drive research matures? Second, is on whether existing governance systems adequately promote and protect public health, the environment, and other societal interests. In turn, governance of gene drives is impacted upon by two features inherent in this technology that are not in other types of biotechnology: they intentionally spread a genetic trait through population, and their effects on ecosystems are potentially irreversible (National Academies of Sciences, 2016: 149). Besides, the anticipated trans-boundary effects of gene drive organisms give rise to the need for international policies or regulation that build agreements between countries.

5. COUNTRY CASE STUDIES

5.1 Introduction

The country case studies provide a snapshot of biosafety profile of each of the countries, experience with genetically modified organisms (GMOs), voices for and against GMOs and their main arguments, and finally prospects for gene drive mosquitoes technology in the country. These case studies draw from existing literature on the regulatory context for each of the countries. The case studies are also informed by data from a limited number of key informants in each of the countries. While we planned to conduct five country case studies, including the Democratic Republic of the Congo (DRC), Kenya, Mali, South Africa and Uganda, we failed to get the required key informants for DRC and Mali; we therefore conducted three case studies for Kenya, Uganda and South Africa. The criteria for the selection of the 5 countries included: countries where there is gene drives research underway (Mali and Uganda), country that accounts for a huge Malaria burden (DRC), country that is a leader on GMOs in the region (South Africa), and countries where progress on GMOs is often undermined by political opposition or lack of political leadership on GMOs (Kenya and Uganda). It should be noted that since Burkina Faso is already a country of focus for the Health Tech Platform, we did not include it in the case study countries for the regional analysis because we have a full-scale landscape analysis underway in the country; the Burkina Faso study will therefore be presented as a separate country report at end of June 2021. This section is organized as follows: section 5.2 presents the case studies, while section 5.3 distils lessons from the case studies.

5.2 The Country Case Studies

5.2.1 Uganda

The regulatory context for GMOs in Uganda dates back to 2004 when the country ratified the Cartagena Protocol. Since 2004, the country has been taking steps to address gaps in her regulatory instruments so as to adequately cater for biosafety issues in relation to the application of modern biotechnology. Such efforts include the establishment of the National Agricultural Research Organization in 2005; establishment of Uganda National Council of Science and Technology in 2008; adoption of the National Biotechnology and Biosafety Policy in 2008, and formation of the Uganda Biotechnology and Biosafety Consortium in April 2011. Back in the mid-1990s Uganda established the National Environmental Management Authority, part of its mandate being to conduct environmental impact assessment before any project likely to have an impact on the environment is undertaken. The country has also developed the National Guidelines for Field Trials of Genetically Engineered Plants (2011); and the National Guidelines for Containment (2007) (Komen et al., 2020).

The mandate of the Uganda National Council for Science and Technology is to formulate policies and strategies for science in all fields of science and technology. On the other hand, the Uganda Biotechnology and Biosafety Consortium brings together different stakeholders, both public and private in advancing the role of biotechnology in improving livelihoods of the people of Uganda. The prevailing regulatory context for GMOs in Uganda is supportive for laboratory research purposes and not for environmental release. The National Biotechnology and Biosafety Bill, currently referred to as the Genetic Engineering Regulatory Bill, is meant to cure this gap. The Genetic Engineering Regulatory Bill 2018 seeks to provide a regulatory framework for safe development and application of biotechnology and release of GMOs.[24] However, as literature shows, this Bill has turned out to be the most debated in the history of Uganda.

Even though the National Biotechnology and Biosafety Bill was passed by Parliament in 2017, the President declined to assent to it, citing concerns about containment, impacts on indigenous species, labeling and patents.[25] Even when Parliament passed the Bill for a second time, again the President declined to sign it, this time citing health concerns. Other concerns that the President has cited with the Genetic Engineering Regulatory Bill 2018, include benefit sharing between the breeder, inventor and indigenous communities; the scope of the law isolation measures; use of poisons and dangerous enzymes and bacteria and the issue of liability. There is also the subtle debate by the political class on linking GMOs with national security and sovereignty of the country.[26]

Despite this regulatory setback, Ugandan scientists have developed a number of genetically engineered crops.[27][28] These include confined field trials for pro-vitamin A banana and wilt resistant banana; drought tolerant and disease/pest resistant maize; brown streak disease-resistant and mosaic resistant cassava; herbicide-tolerant and boll worm resistant cotton; nutrient efficient rice; and disease-resistant Irish potato.[29] These innovations have the potential to improve food security and general productivity in the country's economy. However, opponents argue that these are indicative of the interests of the American biotech multi-nationals to control the seed system.

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[24] The Independent, 17 May, 2021. https://www.independent.co.ug/ten-controversial-bills-passed-by-the-10th-parliament/ , accessed on 29 May, 2021

[25] https://allianceforscience.cornell.edu/blog/2020/03/ugandan-president-wants-gmo-bill-passed/, accessed on 30 May, 2021

[26] The Independent, 23 September, 2019. https://www.independent.co.ug/american-interest-in-ugandas-gmo-law/ , accessed on 29 May, 2021

[27] The Independent, 5 November, 2019 https://www.independent.co.ug/former-minister-buturo-hits-proponents-over-gmo-comments/, accessed on 29 May, 2021

[28] https://allianceforscience.cornell.edu/blog/2020/03/ugandan-president-wants-gmo-bill-passed/, accessed on 30 May, 2021

[29] http://nepad-abne.net/contry_report/uganda, accessed on 29 May, 2021

At the Uganda Virus Research Institute (UVRI), researchers are engaged in the initial trials in a project aimed at producing gene drive mosquitoes for malaria control and elimination. However, like in the case of GMO crops, the new tools will remain an academic exercise at the confined field trials level, given the gap in regulations for environmental release. This is aptly captured by the sentiments expressed by two of the key informants, when engaged on the issue of gene drive mosquitoes technology for malaria control and elimination:

> *"Uganda does not have the capacity to manage the release and development of this technology. For the last ten years, Uganda has been discussing the biosafety bill. Lack of proper regulatory framework is a challenge. The current regulations largely focus on research on crops. We even have not internalized the first generation technologies. Delays in finalization of the biosafety bill are really about clauses included in the bill. For instance, there are loopholes in the clause on liability. There are also other loopholes where the regulators are also acting as marketers. The law is also very clear on public participation. We had a clause on companies that are introducing GMOs to be liable, however, this was deleted. There is lack of trust in this process."* (Key informant interview, 4 May, 2021)

> *"We do not have a law that can regulate gene drives mosquitoes technology in the country. What we have is the Genetic Engineering Regulatory Bill, but this has not been approved. But even then, the law largely applies to plant based applications and not on insects and animal based applications which perpetuate themselves across generations. For the preliminary parts of the gene drives mosquitoes technology, the existing framework is fine. Under the environmental regulations of 1998, one would rank this project as falling under Risk Category A. Delays in approving the bill is on account of the failure to address the issue of allocation of liability to the developer of the technology, that the developer and the scientists involved should take liability. The President also says that the bill does not address the issue of native rights such as indigenous seeds so that even GMOs not every native will be made to rely on these companies for seeds."* (Key informant interview, 17 May, 2021)

The debate on biosafety regulations to govern research and possible application of GMOs in Uganda has attracted a strong anti-GMOs movement in the country. Some of the civil society organizations that have been vocal in this debate include: Food Rights Alliance; Caritus Uganda; Family Participatory Ecological Land Use Management; Hivos East Africa; and Family Farmers Agro-ecology Movement Uganda. In addition, there is a presence of

active science journalists associations in the country e.g. Health Journalists Network and Uganda Science Journalists Association. Importantly, there is an ongoing initiative at Makerere University that is creating a forum to discuss the need to strengthen the governance of gene drives mosquitoes technology for control and elimination of malaria in Africa.[30] The initiative brings together regulators, legislators, academia, and the researchers at the Uganda Virus Institute involved in the gene drive research for malaria control.

This brief about Uganda contains valuable insights about the regulatory terrain the country considering that UVRI is in the very initial stages of setting up gene drives mosquitoes research for the control and elimination of Malaria as part of the Target Malaria. First the gap in law that defines regulations beyond contained field trials. Until this lacuna in regulation is addressed, research on GMOs in Uganda will remain constrained at confined trial level, and with no opportunities to test the technologies in a natural environment. Second is the inherent distrust of GMOs on the part of the Executive, given the delays in finalization of the Genetic Engineering Regulations bill. Third is the opportunity for fostering public conversations on the ongoing gene drives research in the country through the existing health and science media networks and the initiative at Makerere university for the discussion gene drives research.

5.2.2 South Africa

In the African context, South Africa is undeniably the most advanced in terms of modern biotechnology on the continent. The country embraced biotechnology way back in the late 1980s, with first field trials of genetically modified crops in the country, followed by first approved commercial release of genetically modified, insect-resistant cotton and maize in 1997. Some of the key policy instruments with implications for the governance of GMOs in South Africa are: Genetically Modified Organisms Act, 1997; Genetically Modified Organisms Act, 1997 (Regulations); National Environmental Management Act, 1998; and the National Environmental Management Biodiversity Act, 2004. Others are Consumer Protection Act; and the Foodstuffs, Cosmetics and Disinfectants Act. South Africa became party to the Cartegena Protocol in August 2003. These tools define the country's legal infrastructure for contained use, trial release, commercial release as well as trans-boundary movement of GMOs.

In tapping on the modern advances in science and technology, South Africa has commercialized Bt cotton; Bt maize and Bt Soybean, while there are ongoing confined

[30] Key informant interview, 17 May, 2021.

field trials for insect-resistant potato.[31] Other crops that have been approved in South Africa are drought-resistant canola; herbicide-tolerant canola, and herbicide-tolerant rice.[32] Further, as of 2016, 91% of maize crop in South Africa used Bt cultivars (Ala-Kokko et al., 2021). More than 80% of South Africa's maize and soya is genetically modified.[33]

In spite of this progress, data shows that the regulatory frameworks in the country have much more focus on GMO crops, and much more complicated in regulated applications that have direct effects on humans.

> *"Our regulatory framework has been developed to take care of genetically modified organisms, but with a focus on plants. It's easier for agricultural things, but one that directly affects humans, that is an issue. It's a tedious process when dealing with animals because no one has done it. To market that technology, one has to overcome the governance handles e.g. getting people in government to understand how the technology works*." (Key informant interview, 7 April, 2021).

A vital lesson from South Africa is the political will to integrate biotechnology solutions into the country's development process. For instance, country's Bio-economy Strategy was launched way back in 2014. This new Strategy is a successor of the National Biotechnology Strategy 2001 whose intent was to provide a coordinated approach for the country to tap on science based innovations in the health, industrial and agricultural sectors of the economy. South Africa Bio-economy Strategy 2014 offers a broad-based approach that provides linkages between biotechnology and various sectors of the economy including health. In the health sector, the Strategy seeks to support and strengthen the country's local research, development and innovation capabilities in development of new and improved therapeutics, diagnostics and medical devices.

It is also important to note that South Africa, despite being a producer and consumer of Bt maize, the country also exports a substantial amount of genetically modified maize and maize-seed to her neighbors in the Southern Africa region (Muzhinji and Ntuli, 2021: 29). However, the journey has not been without skeptics. Some have pointed out that adoption of GMO crops would create a 'particular relationship between smallholder farmers and corporations supplying these technologies' (Beumer and Swart, 2021: 9-10). Such conversations invoke the issue of dependency and control. Some of the vocal voices

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[31] http://nepad-abne.net/contry_report/south-africa/, accessed on 29 May 2021

[32] https://allianceforscience.cornell.edu/10-things-everyone-should-know-about-gmos-in-africa/, accessed on 30 May, 2021

[33] https://allianceforscience.cornell.edu/blog/2018/08/south-africa-tells-continent-learn-biotech-example/ , accessed on 29 May, 2021

against GMOs in South Africa is the African Centre for Biodiversity, the Alliance for Food Sovereignty in Africa, and Friends of the Earth.

The ability of the media in South Africa to provide objective and balanced information on these technologies is critical in informing and potentially shaping public discourse. However, these advances in science and technology are happening in a context where in South Africa, 'there is a diminishing reporting for science and technology, very limited advertisement on science, with a lot of science and technology reporting work being done by freelance journalists'.[34] To address these challenges, there are calls for enhanced science education targeting journalists:

> *"There is a huge demand for science education in the media and for editors and science journalists to understand the importance of science related topics, for instance, climate change which is affecting the continent. Journalists act as a conduit for information to the people. We need to build the capacity of the journalists. We need to get people in the media to understand these new technologies. There is need to train journalists to tailor science reporting. There is also need to train science journalists how to talk to science researchers, talk with ease on science and the need to show people why science".* (Key informant interview, 20 April, 2021).

Researchers at the Wits Research Institute for Malaria are working on a new tool that they think can add value to existing tools for malaria control and elimination in Africa. The researchers are also keen on gene drive mosquitoes technology, given the rising resistance that is developing in malaria control in the region and hence the need for additional tools in vector control.[35] Wits Research Institute new tool that is under development is the sterile male mosquitoes technology, that researchers at the Institute believe has the potential of eliminating mosquitoes that spread malaria.[36] However, the development of this technology has been stymied by the challenge of generating community trust.

> *"In South Africa we have been involved in a project on sterile male mosquitoes, not gene drive mosquitoes, but one in which we can sterilize the male mosquitoes and release them to the field. South Africa has a long history of vector control technology beginning way back in 1950s, but for the sterile male mosquitoes technology, we began in 2011. We have not yet released these mosquitoes to the environment because we need sufficient community*

[34] Key informant interview, 20 April, 2021
[35] Key informant interview, 7 April, 2024.
[36] Key informant interview, 7 April, 2024.

engagement and build the trust of the community and help the public understand the concept. For South Africa, the challenge is not on whether the technology works, but how to build community trust. Building community trust is a continuous exercise, with regular meetings with the chiefs in the village, village leaders, hold talks in radio stations, visit school, use drama pieces as well as visiting clinics in the area. Our experience also shows that the young people are very open to these technologies, as compared to old people, yet it is this latter category that occupies leadership positions. We also put a whole cage of sterile mosquitoes in the community village for people to experience the science and see for themselves that these mosquitoes do not bite." (Key informant interview, 7 April, 2021.

Apart from the initiative by the Wits Research Institute for Malaria, there is also the South Africa Malaria Initiative that was started way back in 2006. This is an integrated research and development programme to develop new tools to improve malaria prevention and control. There is also the Biosafety Platform that provides regulatory guidance and support for product development in third-generation plant and animal biotechnologies. Further, there is the National Genomics Platform, which provides genomics research facility to both South Africa and international clients, and to facilitate knowledge productions. There is also the PATH-supported South Africa Health Technologies Advocacy Coalition (SAHTAC) that advocates for an enabling environment for research, development, and access to life-saving technologies and innovations; SAHTCA was established in 2016[37]. It consists of stakeholders involved in health research and development advocacy.

This brief about South Africa contains valuable insights about the pathway to development, deployment and use of new biotechnology tools. One key lesson from South Africa's experience is on the importance of national leadership in allowing space for seizing up opportunities accorded by modern advances in biotechnology. South Africa's regulatory and policy instruments on biotechnology attest to this observation. A second lesson is on integration of biotechnology with the other sectors of the economy. This makes it easier to assess the potential impacts of new technologies to the broader economy. A third lesson is for the government to be proactive in creating structures that facilitate innovation. This is evidenced by numerous initiatives and platforms that South Africa has established to support bio-economy.

[37] https://www.path.org/resources/south-african-health-technologies-advocacy-coalition-sahtac/ Accessed on May 31, 2021.

5.2.3 Kenya

Kenya is a signatory to Cartagena Protocol and ratified the international instrument in 2003. In 2006, the country developed a Biotechnology Development Policy. The policy outlines the safety procedures for biotechnology research and development, technology transfer and commercialization of products of such research conducted in Kenya.[38] However, at the outset the policy contained a 'strong line on the ethical, environmental and biosafety concerns of biotechnology'.[39] The Biosafety Act, 2009 is a further instrument meant to govern activities in genetically modified organisms as well as anchoring the establishment of the National Biosafety Authority. The implementation of the Biosafety Act began in 2011.[40]

The National Biosafety Authority provides regulatory guidance on GMOs research and commercialization in the country. The Authority has published four regulations to guide various aspects of GMOs regulations. The four are: import, export and transit regulations, 2011; contained used regulations, 2011; environmental release regulations, 2011; and labeling regulations, 2012. However, the country has largely handled plant-based GMOs. Bt cotton has been approved for commercial release, while Bt maize is undergoing testing.[41] For animals, including research on new areas such as genome editing and gene drives, the regulations can handle the initial trials and confined field trials[42] However, what is needed is enhanced capacity of the regulators to carry out risk assessments of these new technologies. For commercial release of products out of technologies like genome editing and gene drives, there is a vacuum.[43] There is also the challenge of low public awareness on biosafety matters, absence of regulations and inadequate expertise in New Breeding Techniques and socio-economic issues (Muchiri, Mutui and Ogoyi, 2020).

Kenya hosts a number of research institutions whose infrastructure augments the country's research efforts. Some of these include the Kenya Agricultural and Livestock Research Organization; Kenya Medical Research Institute; International Livestock Research Institute; International Centre of Insect Physiology and Ecology; Consultative Group on International Agricultural Research, home to Biosciences Eastern and Central Africa. This research infrastructure provides the country with the wherewithal to tap into in accelerating the role of biotechnology in the economy. For instance, the Kenya Medical

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[38] https://www.scidev.net/global/news/kenya-approves-a-national-policy-on-biotechnology/, accessed on 30 May, 2021.
[39] https://www.scidev.net/global/news/kenya-approves-a-national-policy-on-biotechnology/, accessed on 30 May, 2021.
[40] http://nepad-abne.net/contry_report/kenya/, accessed on 30 May, 2021
[41] Key informant interview, 12 April, 2021
[42] Key informant interview, 12 April, 2021
[43] Key informant 19 April, 2021

Research Institute has been involved in conducting trials on the Oxford University vaccine for Covid-19. The Institute has also developed a rapid test kit for malaria as well as developed capabilities for cloning.

However, commercialization of research products by researchers in Kenya is hampered by lack of funding. In this regard, the Kenyan government has prioritized funding research and development across all sectors of the economy. The country has set a target of 2% of the GDP every year for this purpose. However, over the years, Kenya has not managed to meet this target. Poor financing undermines R&D activities in the country. In the health sector, the bulk of research financing is through external collaborations.[44] For organizations like KEMRI whose key mandate is on health research, underfunding stifles the contribution of the agency in the development of new tools for public health. Key informants pointed at the need for the country to prioritize funding R&D.

> *"We also need to put money for research and development. The donors have their own priorities. There are standards on the funds to be allocated for R&D by countries. For instance, in the case of the Africa Union's 1% of the GDP, Kenya is at around 0.8%. However, this is also very little. For our premier health research institutions, government funding is very low and cannot meet operational costs."* (Key Informant Interview, 11 May, 2021)

Failure to prioritize funding research has implications for the kind of research priorities by various research institutions. The effect is skewed research prioritization in view of what various donors have identified as research priorities for funding. The extent to which these donors research funding priorities align with those of the country is often an issue. Furthermore, with externally funded research, the intellectual property is lost.[45] As noted external funding of health research affects prioritization and intellectual ownership of the research products (GoK, 2018:42). To correct this anomaly, the government has set up the National Research Fund, even though the resources allocated are still very low given the research demands.

For gene drive mosquitoes technology for control and elimination of malaria, there are concerns about potential risks to people's health as well as to the environment. It is noted that there are global discussions on this technology, but there exists glaring gaps on risk assessment.[46] There are also calls to address the trans-boundary nature of this technology, since mosquitoes do not know boundaries.

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[44] Key informant interview, 26 April, 2021
[45] Key informant interview, 26 April, 2021
[46] Key informant 12 April, 2021

"The technology is good. However, we need to look at environmental risk assessment. Look at whether there could be gene flows to other species. Could we be eliminating beneficial mosquitoes? In case there are adverse effects, is it possible to reverse? Could there be other inadvertent effects. For instance, the fear that the vector may become more of a problem to people? What if it reaches the food chain one way or another? We need more bioinformatics analysis. The safety of the gene drive is critical. There is need to have a well thought out pathway to harm in regard to this technology." (Key Informant Interview, 12 April, 2021).

"There are also concerns about the possibility that the gene drive mosquitoes cross borders of another country. AUDA-NEPAD is trying to address this issue by calling for harmonization of regulations. The best scenario is to have regionally harmonized regulations. This discussion is on-going." (Key Informant Interview, 12 April, 2021).

There is strong opposition to GMOs from a number of civil society groups. A leading voice in this regard is the Kenya Biodiversity Coalition (KBioC). The coalition works closely with organizations like the Kenya Organic Agriculture Network; Participatory Ecological Land Use Management; and Resources Oriented Development Initiatives, among others. Anti-GMOs voices in Kenya point at the relationship between the farmers and producers of seeds (dependence and costs) as well as increased reliance on pesticides in crop production as captured in the sentiments expressed by one of the key informants:

"Crossing over from one species to another is an issue. Also, we need to look at how livelihoods are effected by the issue of food e.g. for Bt cotton, the first seeds were donated, after some years, what happened? The price of Bt cotton seeds skyrocketed. It may look cheap at the beginning, but it turns out to be too expensive. Also, there is intensive use of pesticides. Some companies help the farmers by donating pesticides to help farmers spray their cotton, but is this sustainable. Further, some of the chemicals like Glyphosate have been linked to cancer. The cost of getting the seeds is high. Farmers are desperate." (Key informant interview, 12 April, 2021).

As with the Uganda and South Africa case studies, it is important to reflect on the place of the media in emerging health technologies in Kenya. The media landscape in Kenya is rapidly changing. The traditional mainstream media (newspapers, television) is facing challenges as a result of the rapidly increasing alternative sources of information (e.g. social media). The growth and penetration of the Internet across Kenya has made it possible for people to access information away from the traditional mainstream media.

Science journalism is also growing in the country. As data shows, coverage of science and technology items has greatly improved compared to the past when mainstream media largely covered political news. In newspapers like the *Daily Nation*, which is the leading mainstream newspaper in the country, they have even devoted a space in one of the days of the week where health matters are featured, i.e. Health Nation magazine.

However, a key challenge for the media coverage of science news is on the issue of quality of the coverage.[47] A particular concern is on how to link the featured stories with policy or cover in a way that generates debate and hopefully potential buy-in by the policy makers. Aware of this gap, some science media associations have embraced capacity building interventions such as through internships, training, mentorship as well as deliberations through science cafés. There are also regional-wide initiatives to build the capacity of science journalists to report on new and emerging often complex technologies such as on biotechnology.

> *"Cornell Alliance for Science is funding a project dealing with Africa Media Science Centre. Under this platform, we have science journalists meeting together to discuss how to cover various issues on science. We invite different stakeholders to peak on topical issues e.g. on COVID-19; biotechnology crops, among other topics. Last week we had an expert from West Africa. In these forums, we ensure we get an African view."* (Key Informant Interview, 18 May, 2021).

Unlike other coverage for other health technologies, some of the emerging health technologies such as gene drives and genome editing are complex and not easy to cover. Thus, there is an awareness and knowledge gap among science journalists in Kenya on these kinds of technologies. Further, unless local journalists understand the science, their ability to report on such technologies will be hampered. However, in the case of tools for reproductive health including on HIV/AIDS, these are popular with science journalists. A key difference between researchers involved in reproductive health and other researchers is the willingness of the former to engage journalists in the process of designing their interventions.[48] Those in reproductive health seem more open and are keen to involve journalists at all stages of their interventions.[49] In this case, journalists are able to understand the research at inception and are thus better equipped to report on the same. There is also need for better communication between science journalists and the researchers.

[47] Key informant interview, 29 April, 2021
[48] Key informant interview, 18 May, 2021
[49] Key informant interview, 18 May, 2021

Various science journalists association in the country also offer additional platforms for sharing and growth in reporting on new and complex health technologies. Some of the associations include: Media for Environment, Science, Health and Agriculture (MESHA); SciDev; Science Africa, and the Kenya Science Journalists Association (KENSJA). Through these and other associations, science journalists learn to grow their art of reporting and demystifying the complexities in some of these technologies. Besides individual researchers, they are also able to learn on various other sources of science news.

A key lesson to pick from this Kenyan case study is on the role of politics in driving or undermining uptake of the science and products of biotechnology. According to Oloo, Maredia and Mbabazi (2020: 696) a moratorium placed on GMOs in 2012 by the Ministry of Health, impacted on the development, promotion and adoption of GMOs in Kenya. As noted by AUDA-NEPDA, the ban was pronounced by the executive arm of the government and the same channel would be instrumental in removing the ban.[50] In addition, unlike in the case of South Africa, and like is the case with Uganda, there is no clarity from the country's top executive on the need to prioritize GMOs in the country. As reported in Oloo, Maredia and Mbabazi (2020: 696), the latest direction from the government is that GMO activity in the country will be handled on case by case basis.

5.3 Lessons from the Case Studies

The three case studies depict varied trajectories in regard to research and application of GMO products. South Africa has made considerable progress and easily passes as a leader in adoption of GMOs across Africa. Uganda and Kenya are grappling with the final phase of application of biotechnology products i.e. commercialization or environmental release. Way back in 1997, South Africa's political leadership made a conscious decision to embrace biotechnology as a driver for the country's economic growth. There are questions as to the extent to which the top political leadership in Uganda and Kenya have openly embraced GMOs. The regulators in both Uganda and Kenya, while they may have the technical capacity to offer guidance on not only research, but also on potential application of GMOs, the issue of fear of political reprisal is ever present in their work especially when science crosses with what the society considers as ethical. There is need to nurture political will and provide the scientists with leeway to operate (Komen et al., 2020).

For Uganda and Kenya, there is need to address regulatory gaps so that various GMO crops currently under confined field trials have a clearer pathway for environmental release. As stated, this will require not just the technical knowhow of the regulators, but

[50] http://nepad-abne.net/contry_report/kenya/, accessed on 30 May, 2021

the goodwill and clarity in the direction offered by the country's political leadership. For new technologies like gene drive mosquitoes technology for malaria control and elimination, there is need for a review of the national and regional policies to explore opportunities for regional harmonization of risk assessment and governance of this technology.

In the three case studies, there are notable opposition voices in regard to GMOs. As noted in the Uganda case study, President Museveni has failed to assent the Genetic Engineering Regulations Bill severally and cited a number of reasons. Some of these concerns are also to be found among anti-GMO advocacy groups in each of the three countries. It is possible that the GMOs space is permeated by fear, and uncertainty. As Oloo, Maredia and Mbabazi (2020: 698) note, some of the fears may be real or imagined. In this regard, it is important that there are mechanisms put in place so as to objectively respond to these fears by empowering people with knowledge on these new technologies (e.g. GMOs). Such information should be objective on both the benefits and associated risks.

Finally, tapping on the opportunities presented by the various associations of science journalists could help in connecting with the public, policy-makers and other stakeholders in a manner that furthers an objective conversation on emerging health technologies.

6. POLITICAL ECONOMY ISSUES OF EMERGING HEALTH TECHNOLOGIES

In this section, we highlight key political economy issues that can be discerned from a landscape analysis of emerging health technologies in SSA with particular reference for gene drive mosquitoes research. In identifying the key political economy issues, we are guided by the study design that focus on applied political economy analysis. These key messages have been identified by sifting through notes from the key informants and complemented by the literature review.

6.1. Regulatory Reforms

As noted, the regulatory framework for gene drive mosquito technology at SSA level is weak, but NEPAD is currently spearheading efforts to address the gaps. First, given the novel nature of gene drive mosquito technology, there is lack of precedent regulatory framework, thus, it is beginning anew for all countries. There is dearth of robust, international regulation and oversight to determine the safety of the use of gene drives. Thus, the main challenge is not the science behind the technology, but one of politics and how to govern the deployment and use of the technology. Besides, like was the case with genetically modified food crops, there is the fear that regulation acts more like a promotion of the technology other than regulation, hence the need for caution on critical scrutiny. [51]

Given the trans-boundary nature of this technology and the variations between the regulatory frameworks of different countries in SSA, data points to the need to adopt a regional approach in regulating this technology. This calls for harmonization of regional instruments to govern this technology, adoption of multilevel governance, ownership of the technology and control. But even with the option for harmonization of regional regulatory instruments, policymakers have also to grapple with the issue of accountability mechanisms.

It is not just the inadequacy of the regulatory instruments for gene drive mosquito technology that SSA has to address, but even the gap in knowledge about gene drives among those in the policy-making space. This calls for capacity strengthening at both the regional and national level, but with a differentiated country focus. The sequence is to first address knowledge gaps among key policymakers critical for this technology.

> *"First we need to ensure that we have capacity strengthening and knowledge enhancement. This should be followed by regulation of the technology. However, regulation will need to be region and country specific. For instance,*

[51] Source: https://dailypost.ng/2020/07/07/groups-warn-against-release-of-genetically-engineered-mosquitoes-in-nigeria/

in South Africa malaria is not a big challenge as compared to Central Africa and West Africa. There is no need for regulations at the continental level, but for regions and countries most affected by malaria hence necessitating this kind of technology." (Key Informant Interview, 14 April, 2021).

"*Even as we think of regulations, we do not have clear decision making processes. If policymakers will make decisions on the basis of risks, that will be a tragedy. We need a robust discussion with stakeholders."* (Key Informant Interview, 12 April, 2021).

"*A number of countries in SSA do not have biosafety laws. They need to conform to the Cartagena Protocol. South Africa has made tremendous progress in biosafety legislation, but then, the country does not have malaria burden. Ghana, Nigeria, Kenya Burkina Faso have also made progress in developing enabling biosafety laws. However, countries need to review these laws to align them with the demands of this and other emerging technologies on gene editing*." (Key Informant Interview, 30 April, 2021).

Even though countries across SSA are making progress in reforming their regulations to accommodate new tools such as gene drives, having the political will to maintain the momentum is a key factor for consideration. As was the case with genetically modified crops, public backlash can easily erode any gains made as a way of legislating enabling frameworks for gene drives for malaria control (Komen et al., 2020). Thus, possibilities for political opposition is a reality for this technology. It is on this basis that some of the stakeholders are calling for following the precautionary principle in engaging with this technology.

"*As a scientist a key should be that it has been proven beyond doubt that gene drive mosquito technology does work. However, what is important is for field-based trials and the African governments should allow this to happen so that we can generate evidence. The scientists should also ensure that they take measures to address any kind of challenge that may arise in the process of field trials of that technology. We need more consolidated field trial evidence so that we are able to compare the benefits as a result of that technology. We should only go for this technology if the evidence generated demonstrates that the tool is the best strategy to fight malaria under the existing technological options*." (Key Informant Interview, 9 April, 2021).

There is also dearth of capacity to manage the field release of this technology, with countries in SSA more experienced in GM crops. A further handicap is their capacity to

conduct risk assessment on this technology. This is an area for further capacity intervention.

> "*The same kind of challenge is being witnessed with biologics research. Biologics have been used in the west for cancer and rheumatoid treatment. However, if you were to put an application with the regulatory authorities, they may be at pains to provide direction because they do not have expertise. I remember when I was working with a pharmaceutical company, we wanted to bring a drug to treat rheumatoid, the Poisons Board was not able to offer direction, for lack of capacity*." (Key Informant Interview, 10 May, 2021).

How to bring on the table influential countries in the various regional economic groups in SSA also need to be addressed.[52] For instance, while for South Africa, malaria is not a burden, tapping on the voice of that country could add value in generating greater conversation on this technology.

6.2. Intellectual Property Rights and the African Academy

The process of development of the gene drive mosquitoes technology will yield new sets of intellectual assets and these will need to be secured through patents in the context of international norms such as the Nagoya Protocol. NEPAD (2019:13) points out that despite carrying the heaviest burden as a result of HIV, TB and malaria, Africa owns less than 0.2% of patents in this disease area. The NEPAD (2019) report identifies poor funding, lack of research and innovation ecosystem as key impediments to Africa's capacity to find solutions to its health challenges. Some stakeholders are fearful that even with observations from the technology developers that, the new technology will not attract any royalty,[53] there could be hidden costs as was the case with what the proponents of the GMO crops made people to believe, only to get a different reality at a later date.[54]

> *"In the case of Bt cotton, the first seeds were donated to the farmers. After some years, what happened? The price of Bt cotton seeds skyrocketed. It may look quite cheap initially, but it's too expensive. Burkina Faso eventually banned Bt Cotton, with Bt cotton strands there being shorter and unable to meet market standards."* (Key Informant Interview, 12 April, 2012).

> *"There is also the issue of ownership of the technology. It's not clear how the technology will be transferred to Africa. Who will own the patent? How will the*

[52] Key informant interview, 20 May, 2021.
[53] Key informant interview, 16 April, 2021
[54] Key informant interview, 12 April, 2021

transfer happen if at all the public in Africa is going to have control?" (Key Informant Interview, 12 May, 2021).

As part of building the capacity of the African Academy on gene drives mosquitoes research, Target Malaria made a deliberate effort to work with African researchers in Burkina Faso, Uganda, Mali and Ghana. According to one key informant, the gene drive mosquitoes research process is following a path 'like what happens with vaccine development, and the goal was not to have a technology that is just brought to continent, but being part of those developing the new tool.'[55] The goal is to bridge the skills gap and provide knowledge to scientists as the technology unfolds.

In further building the capacity of the African academy to engage in a robust debate on gene drive mosquitoes research to inform decision making, organizations like PAMCA are running training programmes to fill this gap. The idea is to build local capacity on this technology.

> *"PAMCA has been offering capacity building training among members on gene drive mosquitoes research. This training has been on-going since 2017 and up to now, 75 members have been trained. We are also planning to start the African Gene Drive Network for Vector Control, with a goal of having a community of practice that is well trained to ensure that our people do not just jump to technologies that they do not fully understand."* (Key Informant Interview, 09 April, 2021).

6.3. Equity, Power, and Justice in Governance of the Technology

The African Union Development Agency has demonstrated leadership in driving science, technology and innovation in Africa through various initiatives. One of these is the establishment of the AU High Level Panel on Emerging Technologies which advises the African Union and Member States on harnessing emerging technologies.[56] AUDA-NEPAD has also identified a number of emerging technologies relevant for SSA. These include drones in agriculture; gene drives for malaria control and elimination; artificial intelligence; block chain technology; micro-grids and finally, next generation batteries.

On the other hand, the African Academy of Sciences has also shown leadership in strengthening research capacity in the continent.[57] Like AUDA-NEPAD, AAS has also identified a number of priority areas for research in Africa. These include maternal, neonatal and child health; data and biospecimen governance; gender and science;

[55] Key informant interview, 30 April, 2021
[56] Source: https://www.nepad.org/programme/emerging-technologies, accessed on 28 May, 2021
[57] Source: https://www.aasciences.africa/, accessed on 28 May, 2021

genomics and precision medicine; mental health; food security and nutrition; climate change; epidemic preparedness and global health security and finally, the fourth industrial revolution.

However, despite these interventions, funding for the identified research and innovation priorities continues to undermine the contribution of African scientists in the global knowledge repository. Thus, substantial funding for health research in Africa is from external support. This in turn affects the research prioritization as often, the funded research has to connect with the funding agency priorities. It is in this view that some observers argue that such dominance by external sources of financing for health research, perpetuates inequalities in the governance of the resultant health products, including the patents and potential for bias on discussions about such technologies.

> *"Funding for the research, policy reform and advocacy are all by one donor. What does this mean in-terms of people in SSA having the guts to speak their mind? This creates a potential conflict of interest. My concern is on equity in governance and the resultant power dynamics. Currently, the funding agency wields a lot of power and influence in Africa, yet it's not accountable to the people of this region. Some of the countries are poor (e.g. Mali and Uganda) and politically vulnerable, and may not have the freedom to speak about this technology*". (Key Informant Interview, 12 May, 2021).

Interviews further show that development of new technologies is largely a suppliers market and this poses questions around equity and justice as the technology is deployed for use in the society. Unless, certain regulatory measures are taken, this puts other stakeholders at a point of disadvantage.

> "*When gene drives mosquitoes are eventually released to the field, this will likely be under some regulations. However, I am unsure whether there will be a public debate on this technology or on the basis of regulatory risk assessment alone. The question is: who is developing the regulatory risk assessment? More often these are developed by the EU and America and are likely to be adapted by Africa due to issues such as funding. Hence my concerns are not about the technology, but the issue of equity, power, and justice in the governance of these new tools.*" (Key Informant Interview, 12 May, 2021).

> "*Provision of new technologies is a suppliers market. It's the supplier who decides what kind of technology goes to the market. The supplier also decides what kind of technology is needed. It is in very rare instances where we have*

the targets of the technology making the determination." (Key Informant Interview, 10 May, 2021).

To address the issue of equity, power and justice in the governance of gene drive mosquitoes technology as well as other emerging health technologies, countries in SSA should improve funding for health research and development. Currently, the funding for development of new health technologies is by Europe and America, thus weakening SSA's bargaining power in the development, deployment and use of these technologies. Funding for health research and development in Africa remains below the pledged 1% of the GDP by each member state and below the 2% of national health budget for research (NEPAD, 2019: 12). As such, external funding agencies wield much more influence and determine the research agenda for the continent.

6.4. State Legitimacy

State-society relations in a number of countries in SSA is wanting. This is despite the critical linkage between state legitimacy and government performance (Redie, 2020), and the intersectionality between the two. Where the state is unable to control her territory and where citizens do not adhere to the rules as set by the state, institutions are indicative of state legitimacy deficit. There is an active armed conflict in Mali; tensions between the francophone Cameroon and Anglophone Cameroon; civil war in the Democratic Republic of Congo (DRC); insurgency in northern part of Nigeria; and unsettled political transition in Chad. There are also questions about the legitimacy of the current regime in Uganda following the contested presidential elections early this year. Unless, this is addressed, a state with legitimacy deficit is likely to focus attention on retaining power at the expense of service delivery, including investment in new health technologies.

It should also be noted that Nigeria, DRC and Uganda account for a significant portion of malaria burden in SSA, thus, weak state legitimacy is likely to adversely impact on interventions for malaria control in those countries. As one of the key informants observed, "in a country like Uganda, weak accountability and legitimacy remains a challenge, especially given what transpired in the period before, during and after the contested presidential elections early this year."[58] In such societies, citizens voice is at best muted and often trampled upon, thus further limiting opportunities for the public to engage and raise any issues that they may have with a new technology such as gene drive mosquitoes.

[58] Key informant interview, 12 May, 2021

6.5. Transparency and Engaging the Publics

Stakeholder engagement in driving the conversation on gene drive technology is a key parameter in the successful development, deployment and use of such a technology. This is an issue that has been amplified in three key publications seeking to provide guidance on gene drive mosquitoes research (NAS, 2016; WHO 2014 and NEPAD, 2018). Both the WHO (2014) guidance framework and the NAS (2016) publication '*Gene drives on the horizon*' provide explicit framework and recommendations related to stakeholder engagement in the deployment of this technology.

Engaging different stakeholders helps create trust and confidence in the new technology. Such stakeholders may include policymakers and persons who live in or near sites where such a technology is being piloted. Relevant information pertaining to this technology should be shared with these sets of stakeholders. While, part of the information may be technical, projects should enlist the services of communicators who can package the information in a language and frame that the audience can understand. This may include working closely with people who are known to the community members as one way of cultivating community trust.

> *"The public has to trust the scientists. We as scientists have a moral responsibility to demonstrate that the product we are developing is good science. That is, if an animal has genetic editing characteristics, that this is not as dangerous. In some instances, there is need to engage people who are known locally, so that they make people understand the science."* (Key Informant Interview, 22 April, 2021).

An approach where information is openly shared will also enhance the buy-in of the technology in the community. This will also create a sense of co-ownership, a critical ingredient in the success of novel technologies with many uncertainties. Such a process would also lead to better understanding of the concerns and needs of the intended beneficiaries of the technology. The emphasis should be on the basis that the developers of the technology can learn something regarding their technology from the intervention community. This is the essence of co-development and a more focus on 'knowledge engagement' lens to allow these additional sources of knowledge to shape the research on gene drive mosquitoes (Hartley et al. 2019: 2). This is also in line with calls by the African Union on the need for co-development approach that places emphasis on engaging African experts, stakeholders, and publics (Ibid, 2).

The issue of engagement has to go hand-in-hand with the kind of framing that connects with specific audiences. As Hartley et al. (2017) points out, framing helps analyze how

groups articulate and promote a particular understanding of an issue, why they exclude alternatives. Framing would help make a difference on how to reduce skepticism levelled against a new technology. However, even with the right framing, the space should be democratic enough to allow for critical voices, even though in both Uganda and Mali, there is concern about people being able to speak openly.[59] Transparent and broad-based public engagement and debate on this technology would also add value to the resultant regulatory frameworks governing gene drive mosquitoes technology, like it has done with 'heritable genome editing' in the case of the United Kingdom (Rosemann et al., 2019: 3).

6.6. Embracing Complementary Technologies for Malaria Control

As noted in the section on emerging health technologies, there are a number of new tools currently under consideration for malaria control. Besides gene drive mosquitoes, others include: attractive toxic sugar baits (ATSB), Ivermectin drug, malaria vaccine, and sterile insect technology. All these technologies are at varied levels of development. Interviews pointed at some level of optimism in each one of these new tools for malaria control. In this case, gene drive mosquito technology is going to be part of the tools for malaria control that target the vector itself, while others like malaria vaccine targets the human hosts. [60]

However, whether some of these technologies make it to full application depends not only on success in laboratory and field trials, but the availability of resources for their market application. A case in point is the sterile insect technology (sterile male mosquitoes) for malaria control, whose full application has been stifled by lack of funding and government's buy-in in South Africa.

> "*In South Africa, we have been involved in a project on sterile male mosquitoes, not gene drive mosquitoes, but one in which we can sterilize the male mosquitoes and release them to the field. This project began around 2011. I would say that a lot is happening in the lab where it's easier to test technologies. Our concern is that even if that technology is successful at the lab, then, who will pay for its rollout? To get that technology out of the lab to an operational level, then the government has to buy-in and fund its implementation. However, government funding for research is decreasing every year*." (Key Informant Interview, 7 April, 2021).

Tied to the issue of limited government funding of these new technologies, is the question of prioritization. Interview data points at the need for countries in malaria endemic

[59] Key informant interview, 12 May, 2021
[60] Key informant interview, 30 April, 2021

regions of SSA to learn to prioritize new tools for malaria control even where these are not being funded by the development partners. Some of these technologies (e.g. larvae source management etc.) for malaria control have produced positive results in countries like Brazil and Panama and can be prioritized in the SSA context as part of the cocktail of tools for malaria control.

> "*Some technologies are neglected because of finances and non-prioritization by African countries as well as the donors. If you look at the history of malaria control in Brazil, Panama, Italy, and USA, they have applied one key strategy i.e. environmental management and larvae source management. However, there is no appetite for funds to support this strategy yet it is a key strategy for malaria control. If African governments invested in such a strategy, it would offer a plausible route to reduction of malaria in the continent. Tanzania and Rwanda are applying this strategy*." (Key Informant Interview, 9 April, 2021).

6.7. Media Capacity

As the interviews show, the capacity of science journalists in SSA to cover the gene drives technology and other emerging complex health technologies is low. Their level of knowledge and awareness on gene drive mosquitoes technology is low. In countries like Uganda where gene drive mosquitoes research is on-going, there is dearth of robust media discussion on this technology. The media should be at the forefront of providing information to inform debate on this technology.

To build the capacity of science journalists to effectively report on gene drive mosquitoes, two initiatives are worth noting. One is by Cornell Alliance for Science that is currently training Uganda Science Journalists on how to report on gene drives.[61] However, the concern in this kind of initiative is the likelihood of very strong pro-gene drives journalism, which in turn has the potential of undermining objectivity in reporting about the technology.[62]On the converse, it is also possible that the media can easily be used by opposing groups to publish negative stories on some of these health technologies. To counteract these two possibilities, a space like the envisioned Health Tech Platform can be used to rally the media to undertake balanced and objective reporting on these technologies and on the basis of evidence.

The second initiative is the Scientific Communication and Africa Science Desk by the AAS. The AAS runs a series of communications activities to advocate support for science and

[61] Key informant interview, 12 May, 2021
[62] Key informant interview, 12 May, 2021

resource mobilization. This includes a three-year communications strategy, science journalism training for African journalists, and high-impact storytelling.[63]

6.8. Countermovement on GMOs

Advocacy groups against gene drives technology are banking on past experience in advocacy efforts on genetically modified crops to build momentum in raising concerns about this technology. The fear over gene drives is also founded on earlier experiments on genetically modified crops (e.g. cotton) that farmers abandoned by arguing that it was poor quality.[64] Interviews point to a space filled with calls for caution before the actual rollout of such a technology. The fear of countermovement has continued to stymie the adoption of technology around genetically modified organisms around the world.

Anti-GMOs groups across the world have mobilized around alternative framing discourses to counter narratives championed by the scientific communities. In Europe, for instance, some social movements involved in anti-GMO debate through alternative framing of issues managed to shift the discussion 'away from control-oriented approach of molecular biology/genetics to a more uncertainty-oriented approach of ecology in risk assessment and policy making in general' (Pieter, 2009: 64). Such organizations include the Greenpeace, farmers trade unions, as well as Friends of the Earth. Such movements also find support among independent (dissenting) scientists (Pieter, 2009: 62). In addition, such organizations emphasize the importance of social justice and ecological sustainability in the choice of GMO.

The anti-GMOs advocacy groups borrow heavily from the experience of their peers in the West to frame their messaging. For instance, in a study on biotechnology in Ghana, Braimah et al., (2017:10) identify the rhetoric on fear of adverse health effects, environmental destruction, farmer sovereignty and reduced farmer incomes as key issues in their opposition to GMOs in Ghana. Anti-GMOs in the South (including Africa) introduce another dynamic in their campaigns i.e. politics of control in GMOs and dominance by the West. While anti-GMOs groups may not be as powerful in the African context in framing their issues as organizations like Greenpeace, they have the potential to "contaminate" the environment with alternative messaging, that if not addressed with objective information on these technologies, can breed contempt for such new tools. The Health Tech Platform will need to be innovative in producing and normalizing alternative evidence-based framings/narratives that either respond to the opposing narratives or provide comprehensive information to put the opposing narratives into context.

[63] Health Technologies Advocacy Project consultation meeting, March 2021.
[64] https://www.reuters.com/article/us-burkina-malaria-idUSKBN1W310X

7. CONCLUSION

This study has identified a number of emerging health technologies that are being developed across SSA. A deep dive on gene drive mosquito technology has brought to the fore hopes and concerns that various stakeholders have about this technology. The study has also highlighted some of the on-going advocacy efforts on gene drive mosquito technology for the control and elimination of Malaria in SSA. The most visible advocacy platforms for this technology are provided by AUDA-NEPAD; FNIH/GeneConvene, and PAMCA. Further analysis on other emerging health technologies in SSA shows certain gaps, where the Health Tech Platform can help add value.

7.1. Key Issues for Advocacy

This section identifies some broad areas that can inform advocacy about this technology. Some of the issues for consideration include:

a. Need for strong evidence to demonstrate the limitation of the current tools for malaria control and elimination, and the opportunity cost if additional tools are not considered. This will make many stakeholders understand the limitations of the available options and thus the need for new tools to complement the existing ones.

b. Concerns and fears relating to the gene drives technology for the control and elimination of Malaria.

c. The potential benefits and risks of gene drives for Malaria control and elimination.

d. Getting the relevant government officers (policymakers and regulators) to better understand the gene drives technology. The discussions should also focus on how to address trans-boundary issues connected with this technology as well as the need for policy reforms to accommodate the regulatory demands of the new technology. Reaching consensus on a regulatory instrument to address trans-boundary concerns is a task that may take time. Reaching out to the policymakers is one of the biggest gaps in the current advocacy terrain.

> *"The biggest gap is on public engagement and reaching out to the policymakers. Regulators do not make laws. We need to reach out to those who make laws i.e. parliamentarians. There is always a huge challenge in reaching this category of policymakers."* (Key Informant Interview, 30 April, 2021).

e. Sharing information with the general public about emerging health technologies so as to help address gaps in knowledge that people may have about these technologies, including their concerns and fears.

f. Reaching out to the media to equip science journalists with the information and framing of the key issues around gene drive mosquito technology.

g. Provide information on other emerging health technologies in SSA. This would be a useful resource to create awareness on these technologies, generate information that the developers of these technologies can use in their ongoing development, and inform investment decisions on these technologies.

7.2. Lessons for the Design of the Health Technologies Advocacy Platform

As documented in this study, there is a lot that is being done by different stakeholders to create awareness and knowledge on gene drives mosquito technology in SSA. A reflection on the various on-going advocacy efforts on gene drive mosquito technology reveals some issues that the Health Technologies Advocacy Project has to address.

a. Who will be the target stakeholders of the envisioned platform? Is it policymakers at regional and national level; general public; research community or all? Available evidence points at the need to target all the three sets of stakeholders. The need is for a multi-stakeholder platform.[65] As the data has shown, there are really no current information-sharing efforts focused on emerging health technologies in SSA. The existing efforts have a narrow focus on gene drives, and have a limited reach to a few stakeholders. For instance, AUDA-NEPAD is mainly reaching out to regulators, PAMCA is largely focused on vector scientists; while AAS is mainly focused on the health technologies research, but with limited outreach to the public.

b. What will be the format of the platform? Borrowing from on-going advocacy efforts, the available options include: general information sharing online, direct engagement with various stakeholders on specific issues; webinars, blogs, expert advisory write-ups, question and answer segments. Among others, the Platform should work closely with other health advocacy groups in the region and globally to expand the reach of its efforts and influence. Some of the advocacy groups that the Platform needs to seek close links include: Speak Up Africa, the Coalition on Health Research and Development (CHReaD), the Global Health Advocacy Partnership, the West African Think Tanks Initiative (WATHI), WACI Health, among others.

[65] Key informant interview, 22 April, 2021

c. What kind of content will be shared? There are two parts to this, and it is important to note that the Platform's content should be guided by its target audiences. First is that besides the gene drive mosquitoes technology, the platform should also prioritise other emerging health technologies in SSA given that there is currently no platform that is mapping and sharing information on emerging health technologies and their potential in tackling health challenges on the continent. Second is the need for the Platform to ensure it is providing objective, balanced, open and informed information on health technologies, as well as, providing opportunity for diverse voices on health technologies to be heard. This is crucial for the realization of the platform's outcomes. If the Platform ends up being seen by stakeholders as an advocacy tool for promoting the use of emerging health technologies in Africa, then it will not be able to have the influence it hopes to have because stakeholders will view it as a space that is compromised as opposed to being a neutral space for balanced conversations on emerging health technologies.

d. The issue of trust and ownership of the emerging technologies and how the Platform can contribute to nurturing them (trust and ownership).

e. The need to foster meaningful conversations around lack of internal funding for health research and innovation, and how to leverage existing investments to address this gap.

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