

Innovation Ecosystem for Sustainable Energy in Low-income Countries of Africa towards the Goal of the Agenda 2030 of the UNEP and the Agenda 2063 of the AU: A Critical Review

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ABSTRACT

Global Innovation Index (2019) recognised Burundi, Malawi, Mozambique and Rwanda, four low income countries in Sub-Saharan Africa who have performed impressively in innovation against their respective Gross Domestic Product (GDP). Identification of technology needs of any country plays a key role in preparing policy measures and effective action towards sustainable development. Technology Needs Assessments Project, implemented through the United Nations Environment Programme with Technical University of Denmark (UNEP DTU) sponsored by the Global Environment Facility between 2010 and 2018, completed two phases of Technology Needs Assessments (TNAs) in these four countries. There is one common technology need for mitigation in all these four countries has been chalked out i.e., “Ensuring access to affordable, reliable, sustainable and modern energy for all” which adheres to the 7th goal of Sustainable Development Goals (SDG) of the Agenda 2030 of the UNEP and the goal of Agenda 2063 of the African Union (AU) for the transformation of traditional sources to modern sources of energy for ensuring the access of clean and affordable electricity to all the people of Africa. Access to electricity remains very low, ranging from 11.02% to 34.72% of their population with lowest in Burundi and highest in Rwanda. They are not only energy stressed countries but they are also among the poorest nations of the world. This article critically investigates and reviews the Science, Technology and Innovation Policy (STIP) and programmes, S&T infrastructure, Tertiary education, R&D investment, Patent profiles for sustainable or clean energy from 2000-2020 in these four low income countries of Africa. Present study indicates how the development trajectory of the innovation ecosystem of these countries can be a root enabler to achieve the goals formulated in SDG 7 of the UNEP and the Agenda 2063 of the AU as well.

Keywords: Burundi, Malawi, Mozambique, Rwanda, Sustainable energy, Clean Energy, Access to Electricity, Patent, Innovation, STI, AU 2063, SDG7, Agenda 2030.

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Received: 26-08-2020

Revised: 25-02-2021

Accepted: 28-04-2021

DOI: 10.5530/jscires.10.3.62

INTRODUCTION

The Agenda 2063 of the African Union (AU) outlined seven aspirations in achieving the *Africa We Want* mission.^[1] Of those, goal seven that demonstrates “Environmentally sustainable and climate resilient economies and communities”. It further corresponds to Sustainable Development goals Seven (SDG 7) that too has narrated “Ensure access to affordable, reliable, sustainable and modern energy for all”. It is well known that science, technology and innovation (STI) are main factors behind the economic growth and sustainable development of any part of the world such as Africa. Global Innovation Index (2019), recognised Burundi,

Malawi, Mozambique and Rwanda—four low income countries in Sub-Saharan Africa who have performed remarkably in innovation vis-à-vis their Gross Domestic Product (GDP).^[2] Identification of technology needs of any country play a pivotal role in preparing policy measures and effective action on climate change towards sustainable development. Technology Needs Assessment Project (TNA), implemented through UN Environment and United Nations Environment Programme with Technical University of Denmark (UNEP DTU), sponsored by the Global Environment Facility in between 2010 and 2018 and completed two phases of TNA in more than 60 countries including all these four countries.^[3] TNA identified that ensuring access to affordable, reliable, sustainable and modern energy is the one common technological need in these four countries for their sustainable development. Access to electricity remains very low ranges from 11.02% to 34.72% of their population with lowest in Burundi and highest in Rwanda.^[4] They are not only energy poor but they are also among the poorest nations of the world.

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Innovation does not occur in a vacuum. Rather, drivers across an economy enable or stifle innovation. Situation calls for identification of the enablers and barriers in the existing system, synergy among the actors, opportunities, possibilities and potential challenges. The article is divided into five sections. *First* section attempts to understand multiple facets of sustainable or clean energy and Environmentally Sound Technologies (ESTs), *Second* section sheds light on the innovation ecosystem and its African perspectives, *Third* section digs into Science, Technology and Innovation Policy (STIP) in these four Sub-Saharan African nations, *Fourth* Section investigates S&T infrastructure, tertiary education, R&D investment, Patent profiles for sustainable or clean energy from 2000–2020 in Burundi, Malawi, Mozambique and Rwanda and *Fifth* section discusses potential root enablers to achieve the goals formulated in SDG 7 of the UNEP and the Agenda 2063 of the AU and concluding remarks.

Sustainable Energy and Environmentally Sound Technologies (ESTs)

Sustainability as a concept of grand synthesis between environmentalists and development experts was originated in seventies. In 1987, the United Nations under the aegis of World Commission on Environment and Development published a report- ‘Our Common Future’ which is also popularly known as Brundtland Report in the name of the Chairperson of the Commission Gro Harlem Brundtland. This report popularised and defined the sustainable development for the first time.^[5] Sustainability has become the critical goal for contemporary humanity and sustainability science is widely viewed as the primary means of achieving sustainability.^[6] John R. Ehrenfeld of the International Society for Industrial Ecology considered the possibility for human and other life to flourish on the planet forever as sustainability.^[7]

Energy is the basic of human civilization and existence. To make this planet sustainable, the UNEP in 2015, sets 17 Sustainable Development Goals (SDGs) with 169 targets.^[8] Of which, SDG 7 focussed on “affordable, reliable, sustainable and modern energy for all”. SDG target 7.1 is “universal access to affordable, reliable, sustainable, and modern energy services”; with 7.1.1 focusing on access to electricity and 7.1.2 “focusing on access to clean cooking solutions”. Target 7.2 aims to “increase substantially the share of renewable energy in the global energy mix.” Target 7.3 seeks to “double the global rate of improvement in energy efficiency.” Target 7.a wants to “enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy.” Target 7.b aims at “expanding infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries facilitate access to clean energy research and technology.”^[9]

Electricity is the backbone of modern civilization. Global demand for electricity is expected to double by 2030 primarily due to increasing growth in developing economy. But share of sustainable energy should be considerably enhanced replacing our unsustainable fossil fuel consumption. In a simpler term, sustainable energy is a kind of energy which meets the demand of present without compromising the future needs.^[10] This energy is refilled during our lifetime and causes no long-term damage to the environment and eco-friendly. Sustainable energy includes all renewable energy sources, such as hydroelectricity, biomass, geothermal, wind, wave, tidal and solar energies etc.

The UNEP recognised that sustainable energy is a potential game-changer that can transform human lives and economies. It has laid the foundation for resilient, low-emission economies and societies around the world including Africa which indicates that continuous progress on SDG 7 will help to achieve the 2030 Agenda for Sustainable Development. The UNEP work on energy focuses on four areas:^[11]

1. *Improving understanding of science and the links between energy and the environment*
2. *Providing Governments with environmentally sound policy advice*
3. *Catalysing public and private finance for clean energy*
4. *Supporting the uptake of clean energy technologies.*

Defining clean energy technologies or Environmentally Sound Technologies (ESTs) is a challenging task. According to the United Nations Environment Programme, “ESTs encompass technologies that have the potential for significantly improved environmental performance relative to other technologies”. Broadly speaking, these technologies:^[12]

1. *Protect the environment*
2. *Are less polluting*
3. *Use resources in a sustainable manner*
4. *Recycle more of their wastes and products*
5. *Handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes.*

Furthermore, as argued in Chapter 34 of Agenda 21 of the United Nations with regard to sustainable development, Environmentally Sound Technologies are not just “individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures”.^[13] This calls for both the human resource development including gender related issues and capacity building in terms of technological choices. Importance of ESTs in resource efficiency, mitigating

pollution and reducing waste are of paramount importance and it plays a pivotal role in achieving sustainable goals. ESTs was first recognised as means to attain sustainability in the Convention of Biological Diversity of 1992.

Innovation Ecosystem and its African Perspectives

Innovation has plethora of understandings and certainly lacks clarity. But for intelligibility, Schumpeterian viewed of innovation is the ability to use knowledge for creating new application based ideas in order to bring changes in the production and organizational structure of a organization. Schumpeter defined several of these applications that qualify as innovation:^[14]

- a) *Introduction of a new product or modifications to an existing product*
- b) *A new process or technology in an industry*
- c) *The discovery of a new market*
- d) *Development of new sources of supply of inputs and raw materials*
- e) *Changes in industrial organization.*

Despite, contested and with limited consensus, innovation system and innovation ecosystem are in vogue for some time. Innovation system refers to all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion and use of innovations. There can be national, regional, sectoral and corporate innovation system. *An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.*^[15]

For proper execution of global programmes like Agenda 2063, escalation of investments in the sectors like technology, science and innovations by African countries should be needed. To adhere this amount, huge cost for investment resource mobilization should get raised.

African economy, similar to the global economy where technological development plays a key role in economic growth like any other nations. Solow-Swan model advocated the rate of growth is simply the rate at which technology advances.^[16,17] Technological dynamism should be accompanied by knowledge based economic growth.

Etzkowitz and Leydesdorff^[18] introduced the Triple Helix model as a “*laboratory for knowledge based economic development.*” Policymakers provide opportunities and encourage academic institutions or universities engaging with industries to step beyond the conventional roles of cultural memory, education, and science, and contribute more directly to wealth formation. Government has an essential role in creating the conditions

for a thriving innovation ecosystem. The development of research sphere of the universities will define future socio-economic development in the form of human capital, tacit knowledge, and intellectual property. Foray and Lundvall^[19] first introduced the notion of a ‘knowledge-based economy’. Lot of times knowledge of the researchers for research and innovation could not meet its fullest utilization due to the absence of proper policy, education system and institution. It highlights towards the need of having various policies such as R&D subsidies or tax incentives, matching grants, and the creation of non market institutions such as public research institutes or universities. The National Innovation System (NIS) of any country should put emphasis on the interconnection among different stakeholders involved in knowledge creation and diffusion in the society to advance an innovation system that promotes nonlinear nature of knowledge creation unlike the Triple Helix model.

Triple Helix model stresses the dynamic interactions between university, industry, and government.^[20] Edquist stresses that there is no linear path from basic research to applied research and then to the implementation of new processes and products but rather innovation is characterized by complicated feedback mechanisms and interactive relations.^[21]

Linkages of universities-industries-governments, as suggested by the triple helix theory,^[18] are crucial for the production of new knowledge. Earlier universities were known to responsible for generating new knowledge with their internal research mechanisms. But now, in addition with production innovation requires assimilation of new knowledge. With the changing perspectives it is now recognised that the triple helix institutions (university-industry-government) are not separate functional spheres, but entwined with institutional entities. Contemporary workers favour scientific discourse of innovation where triple system of helices is perceived as the co-evolving entities.^[22] Saad *et al.* using examples from Malaysia and Algeria, showed that the triple helix model can serve as a guideline to enhance the role of universities as agents of innovation and sustainable development in developing countries.^[23] Science, technology and innovation (STI) like other countries is also key driver of development for most African countries. When properly diffused and adapted to local contexts, STI can bring a competitive innovation system but it should be accompanied by robust STI infrastructure. Besides, it creates new openings for entrepreneurship which aids the development of sustainable energy related infrastructure.^[24]

STIP on Sustainable Energy in Burundi, Malawi, Mozambique and Rwanda

As per the latest estimation of 2018 that still 789 million people in the world today have no access to electricity, 2.18 billion people without access to clean cooking.^[18] This

is primarily in Africa. Traditional biomass and inefficient technologies have serious health, social and environmental consequences. Thus, following the triple helix model, Burundi, Malawi, Mozambique and Rwanda—four low income countries in Sub-Saharan Africa need to develop their Science, Technology and Innovation Policy (STIP) and other STI infrastructures. In the Global Innovation Index 2019 of the WIPO ranked Burundi, Malawi, Mozambique and Rwanda in 128th, 118th, 119th and 94th position. Despite their a number of barriers and financial limitations their performances in developing innovation system is quite encouraging and were able to place them in world innovation landscape. This is the second time after 2017 Burundi finds place in the Global Innovation Index. However, Malawi, Mozambique and Rwanda were very consistent in achieving this milestone for seven years in a row (2019, 2018, 2017, 2016, 2015, 2014, 2012).^[2] Institutions within a country need to complement and collaborate each other and work in coordination to optimum use of innovation. Technology policy that creates efficient institutional instrument for integrating the functions of knowledge generation and knowledge commercialization enhances a country's long-term competence to sustain an innovative ecosystem.^[25]

Burundi is a landlocked country in the middle of Central Africa in the great lakes' region with a population of 11,175,378 (2018) and 87% people live in rural areas. Burundi is basically an agriculture-based nation depends primarily on subsistence farming. Agriculture contributes 40% of GDP and provides livelihood of more than 84% of the population.^[26]

Burundi's energy consumption depends mainly on biomass. With 94% of the total consumption, households in Burundi are the main consumers of energy but their demand mainly fulfilled by traditional biomass (99%). Hydropower is the chief source of power generation and constitutes almost 95% of the total capacity. Most strikingly, people of Burundi have no access to clean cooking.^[27]

Burundi lacks an entrusted governmental body for STI and there is no systematised infrastructure for innovation research. Although, in June 2011 Burundi has adopted a national policy for scientific research and technological innovation. This policy emphasized on several governmental plans to escalate R&D and innovation activities with proper funding. In this regard, government has established a national foundation for research. In Burundi, STI related issues are falling under the Committee on Agriculture, Livestock, Environment and Communal Development. The Bureau Burundais de Normalisation et Contrôle de la Qualité (BBN)—an agency in Burundi plays a key role in organizing national statistics and making them available for policy making.^[28]

Malawi is a landlocked and densely populated country located in south eastern Africa, including the majority of Lake Malawi^[29] with a population of 18,143,315 (2018) and 83% people live in rural areas. Economy of the country mainly depends on agriculture that accounts for one third of the GDP and almost 80% of employment.^[29]

Electricity and gas are very infrequent in energy-stressed Malawi. Energy projects can have a great impact on holistic growth of the nation and can be proved as gamechanger for industries too. Firewood and charcoal in Malawi are considered as the major cooking fuels with 50% in urban and nearly 100% in rural areas. Charcoal in Malawi is mostly produced from live trees that badly affects air as well as forests and protected areas.^[30] Most dams in Malawi are with single purpose, e.g. supplying water for human consumption and industrial use only.^[31]

Malawi invested poorly in R&D but the rate of productivity is higher than neighbouring countries with much higher GDP. National science and technology policy of Malawi came on 1991 and got revised in 2002. In 2003, a Science and Technology Act was further enacted by the government to facilitate the implementation of the policy. The National Commission for Science and Technology (NCST) was born by the unification of the National Research Council of Malawi with the Department of Science and Technology of the Ministry of Science and Technology (MIST). The Commission's role is to advise the government and other stakeholders on all Science, engineering, technology and innovation (SETI) matters.^[32]

Mozambique is located on south-east Africa, having a long coastline of Indian Ocean. The population of Mozambique is 29,495,962 and 64% of the population lives in rural areas. Climate change is adversely affecting Mozambique. More than 80% people are engaged in subsistence agriculture.^[33]

In recent years Mozambique has made considerable efforts to electrify the region. The rate of electrification rose from 5 per cent in 2001 to 31.10% in 2018. Access to electricity, however, remains low and is mainly geared towards urban areas. Forest woods still meet more than 85 % of total domestic energy requirements, even more than 95% in rural areas. Biomass is primarily used for cooking although it is also used for lighting. The vast majority of households make use of obsolete cooking technologies like three-stone fire and traditional stoves.^[34]

Because of long colonial history under Portugal, Mozambique doesn't have well-laid innovation policy. Settlers have greatly influenced higher education system to present innovation frameworks in Mozambique.^[35]

Mozambique chooses STI as a key agent in the progressive development and for a better future of the country.

The National Science and Technology Policy (NSTP) was founded in 2000 and followed by the Science and Technology Policy in June 2003. The policy zeroed in on encouraging research, education, innovation and diffusion that fuels creativity and innovation from the ground level.^[35] In June 2006, Mozambique formulated the Science, Technology and Innovation Strategy (STIS) and Information and Communication Technology Strategy (ICTS) for channelising the technology and innovation development for assisting growth process of the nation.^[35]

Rwanda is situated in Central and East Africa and is one of the smallest countries on the African continent^[36] with a 12,301,939 (2018) and 83% people live in rural areas. Agriculture remains the nation's growth engine like other three countries. 87 percent of the population lives on agriculture.

About 85% of its overall primary energy consumption of Rwanda is based on biomass. Up to 2004, hydropower remains the chief source of power in Rwanda but poor infrastructure and scattered network couldn't attract much investment in the following years to enhance the generation capacity.^[37]

Article 83 of the Constitution of Rwanda also speaks in favour of innovation and provides that "the members of the Senate shall be highly skilled in the fields of science, among others." In 2004, Rwandan President Paul Kagame aptly narrated his vision for STI in Rwanda in the following terms: "We will continue to invest in our people and strive to open up the frontiers of science, technology, and research as we broaden our trade links with our neighbouring countries and beyond".^[28]

Rwanda's Vision 2020 stemmed up out of this vision with some prominent initiatives like rewarding best students and girl students in science and maths, promoting student exchanges with UK in the field of science and technology etc. It is aiming to shift Rwanda's economy from agro based to knowledge driven and raise the country into a middle-income country. The Committee on Education, Technology, Culture and Youth is entrusted with handling all issues related to technology and research. The Rwanda Innovation Endowment Fund (RIEF) is administered by the Ministry of Education (MINEDUC) with the support of the United Nations Economic Commission for Africa (UNECA) provides fund for innovation activities. Rwanda recognizes ICT as a potential area that can draw a massive amount of investment. Rwanda Bureau of Standards (RBS) works as one of the pivotal organization to provide statistical data for formulating national policies and higher level decision making.^[28]

Landscapes of STI infrastructures in Burundi,

Malawi, Mozambique and Rwanda

Africa's STI landscape is in formative stage. Many challenges still remain unaddressed for the congenial environment for advancement of STI infrastructure.

Access to Electricity and provide clean fuel for Cooking

Providing the access to electricity is considered as an essential factor behind STI infrastructure. It facilitates in transformation of the economy and society. Without secure access to electricity, Internet access, lighting and essential services such as heating, transportation, and manufacturing high-tech are compromised. Access to electricity % of population in Burundi, Malawi, Mozambique and Rwanda from 2000-2020 is compared (Figure 1). Data for 2019 and 2020 was inadequate. Access to electricity remains very low even in 2018, 11.02%, 18.02%, 31.10% and 34.72% of their population in Burundi, Malawi, Mozambique and in Rwanda respectively.^[4]

In Burundi, Malawi, Mozambique and Rwanda, between 2000-2020 percentage of the population to whom clean fuels and technologies for cooking is available have been compared

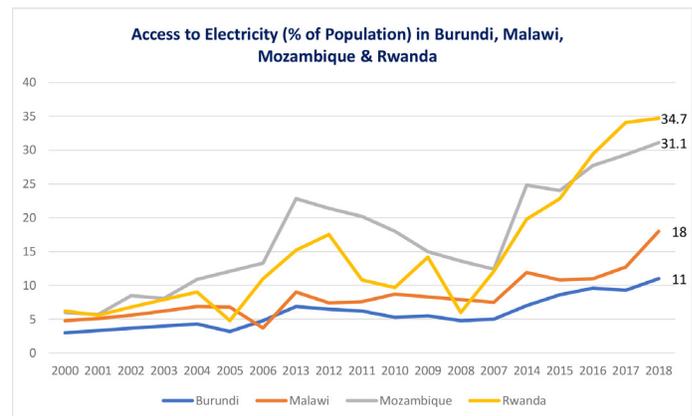


Figure 1: Access to electricity % of population in Burundi, Malawi, Mozambique and Rwanda from 2000-2020. (Source: World Bank)^[4]

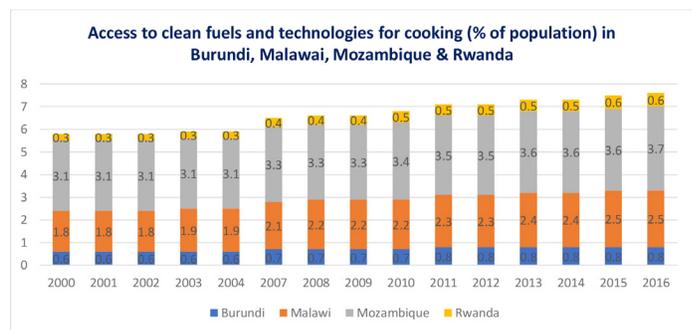


Figure 2: Access to clean fuels and technologies for cooking % of population in Burundi, Malawi, Mozambique and Rwanda from 2000-2016 (Source: World Bank)^[38]

in Figure 2. Data for 2017–2020 was inadequate. Further, result shows the percentage are 0.85%, 2.5%, 3.69%, and

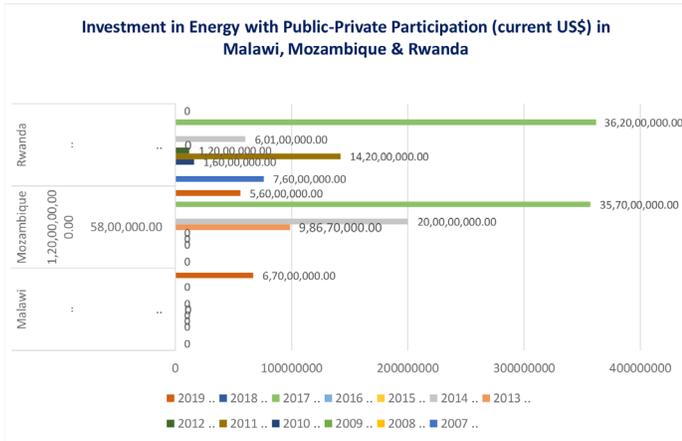


Figure 3: Investment in Energy with Public-private Partnership (in US\$) in Malawi, Mozambique and Rwanda. (Source: World Bank)^[39]

0.57% of their population in Burundi, Malawi, Mozambique and in Rwanda respectively.^[38] This is quite low in real term.

Data related with the Investment in US \$ on Energy with private-public partnership is not available for Burundi and for others, this is meagre and non-significant (Figure 3).^[39]

Education and Skills Development

A good educated population always plays a pivotal role in successful diffusion of STI. In these four countries situation of education system pointing a valid issue of whether these nations under invest in education. Government expenditures (% of total GDP) on education (Figure 4),^[40] (Data for 2019 and 2020 was inadequate). Gross Enrolment in primary education (% gross) (Figure 5) in Burundi, Malawi, Mozambique and

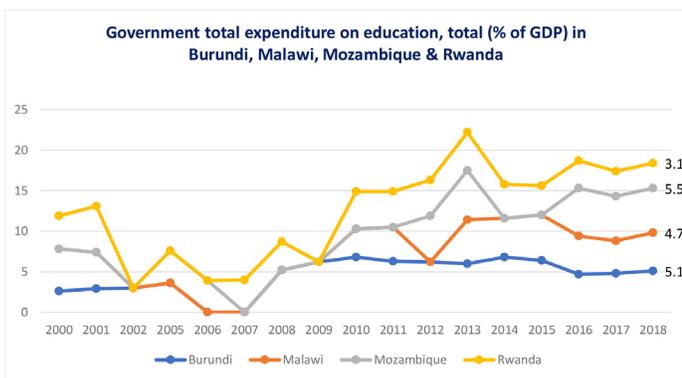


Figure 4: Government Total Expenditure on Education % of GDP in Burundi, Malawi, Mozambique and Rwanda (Source: World Bank)^[40]

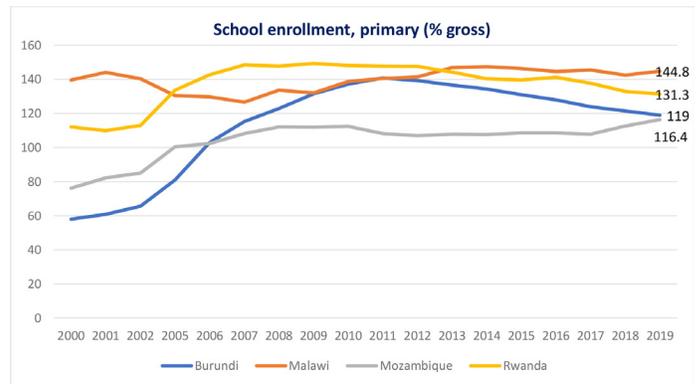


Figure 5: Enrolment in Primary School (% gross) in Burundi, Malawi, Mozambique and Rwanda (Source: World Bank)^[41]

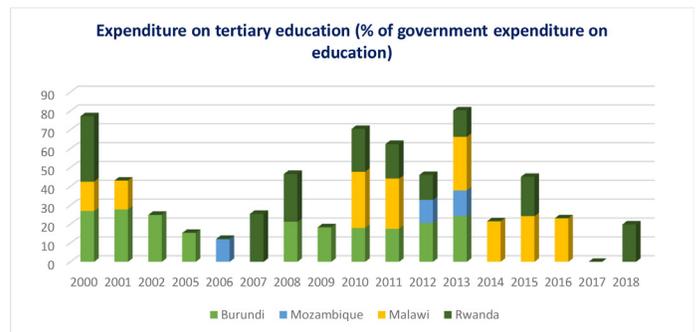


Figure 6: Expenditure on tertiary education (% of Government expenditure on education) in Burundi, Malawi, Mozambique and Rwanda (Source: World Bank)^[42]

Rwanda have been juxtaposed from 2000–2020.^[41] Data for 2020 was inadequate.

Expenditure on tertiary education explains very poor investment. In Figure 6,^[42] it is compared among these four countries. Data is inadequate for many years and expenditure is very poor in real terms in every cases.

Access to the Internet and Mobile

Access to internet gives immense support to the research works and enable strong collaboration among scientists. Although the accessibility of internet is increasing but it requires wider coverage to achieve the desired result. Number of subscriptions with public internet in Burundi, Malawi, Mozambique and Rwanda have been compared (Figure 7) and in 2018 number of this subscription is very insignificant in Burundi, Malawi and Rwanda which are 3935, 11358, and 7501 respectively but in Mozambique situation is relatively better in which the number of subscriptions is 70142.^[43] Data for 2019 and 2020 was inadequate.

Very similarly, access to mobile cellular subscriptions that provides access to the PSTN (Public Switched Telephone

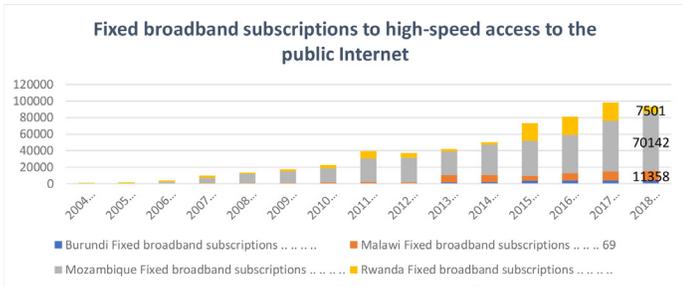


Figure 7: Fixed broadband subscriptions to high-speed access to the public internet in Burundi, Malawi, Mozambique and Rwanda (Source: World Bank).^[43]

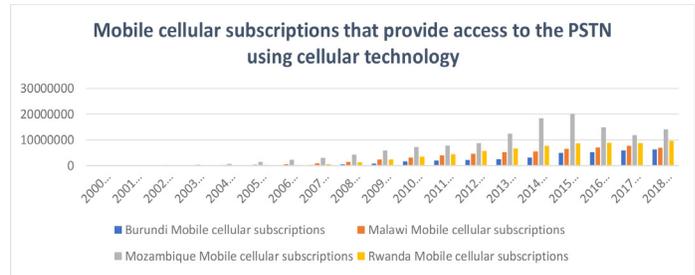


Figure 8: Access to Mobile Cellular Subscriptions in Burundi, Malawi, Mozambique and Rwanda (Source: World Bank).^[44]

Table 1: Number of Researchers in per million people in Burundi, Malawi, Mozambique and Rwanda.

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Burundi	DNA	DNA	DNA	DNA		DNA	20.92	DNA	DNA	DNA	DNA	DNA	23.43
Malawi		30.40		DNA	50.35		DNA						DNA
Mozambique	15.98	DNA	19.92	11.90	38.77					42.96			
Rwanda	DNA		10.89	12.59				15.54		DNA	13.86		

(Source: World Bank);^[45] DNA-Data Not Available

Table 2: R&D expenditure (% of GDP) in Burundi, Malawi, Mozambique and Rwanda.

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Burundi	DNA	0.200	0.154	0.140	0.137	DNA	0.107	DNA	DNA	DNA	DNA	DNA	0.210
Malawi	DNA	DNA	DNA	DNA	DNA		DNA						DNA
Mozambique	0.455		0.152		0.422					0.337	0.666		
Rwanda	DNA		DNA		DNA		DNA			DNA	DNA		

(Source: World Bank);^[46] DNA-Data Not Available

Network) using cellular technology in 2018 is comparatively higher in Mozambique with 14074248 subscriptions whereas access to mobile subscriptions in Burundi, Malawi and Mozambique are 6317965, 7076906 and 9700609 respectively (Figure 8).^[44] Data for 2019 and 2020 was inadequate.

Expenditure on R&D

R&D is a crucial source of knowledge creation contributing for country’s well-structured innovation ecosystem. Thus, R&D investments are basic parameters of a dynamic innovation system. Investment may come from both the private and the public sectors. Recognising the value of R&D for STI infrastructure, Agenda 2063 appealed to all African nations to allocate at least 1 % of GDP to R&D. Unfortunately, Africa’s R&D investment in most of the countries fall below 0.5 per cent of GDP.^[24] Statistics for Rwanda and Burundi were mostly not available. However, it is assumed that Rwanda and Burundi do not have more 5,000 fulltime researchers.^[28] These four countries severely resource-stressed in science,

technology, engineering and mathematics including priority areas such as agriculture, health sciences and clean energy.

Number of Researchers in R&D (per million people)- The number depicted in Table 1 for all four countries are quite alarming.^[45]

R&D expenditure

Table 2. Represents the expenditure made by these contries on R&D, expressed as percent of GDP.^[46] R&D comprises all basic, experimental and applied researches.^[46]

Research Output as Research Publications

In the study, scientific and technical articles from various areas like physics, chemistry, life sciences, medicine, engineering and life sciences etc have been counted to perform a comperative analysis. Malawi performed better in comparison to others whereas Burundi performed very poorly with 21.12, 231.21, 139.25 and 169.52 articles in Burundi, Malawi, Mozambique and Rwanda respectively in 2018 (Figure 9).^[47]

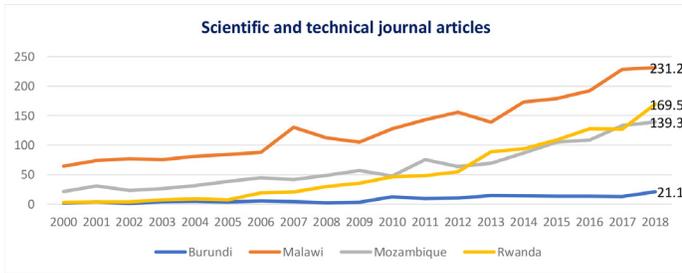


Figure 9: Scientific and technical journal articles published in Burundi, Malawi, Mozambique and Rwanda (Source: World Bank)^[47]

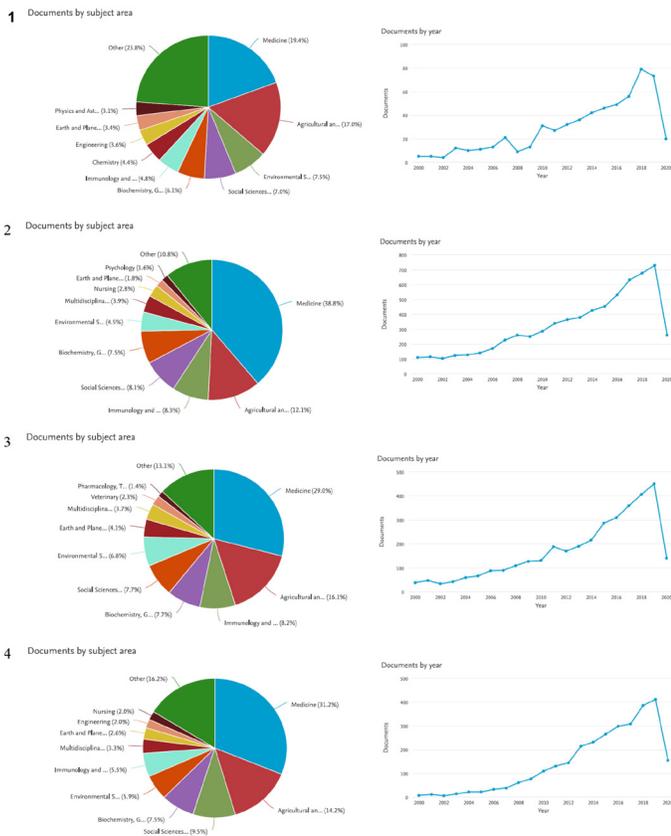


Figure 10: Journal Articles Published Subject and Year wise in Burundi (1), Malawi (2), Mozambique (3) and Rwanda (4) from 2000-2020 (Source: SCOPUS)^[48-51]

Research outcomes of these countries have been further analysed subject-wise as well as year-wise from SCOPUS database to assess their innovativeness at a microlevel (Figure 10).^[48-51]

Patent Profile

Patent plays a pivotal role in inventiveness and creativity of a nation. Patent statistics is hardly available for Burundi, Malawi, Mozambique and Rwanda. Most of the cases, data is incomplete and inadequate. Total patents granted to residents, non-residents and in abroad from 2009-2018 in

Table 3: Patents Granted from 2009-2018 in Burundi, Malawi, Mozambique and Rwanda.

Country	Resident	Non-Resident	Abroad
Burundi	29	20	25
Malawi	14	1	4
Mozambique	61	131	1
Rwanda	14	186	2

(Source: WIPO statistics database).^[52-55]

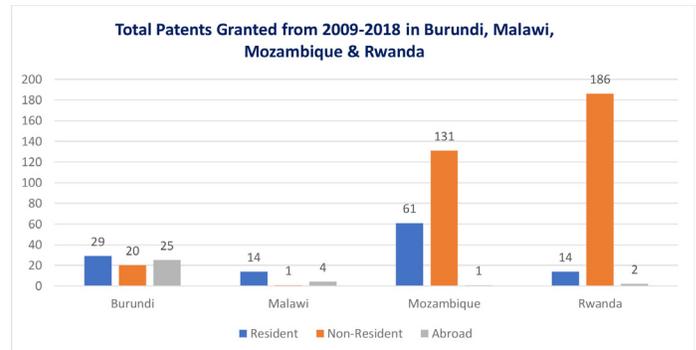


Figure 11: Patents Granted from 2009-2018 in Burundi, Malawi, Mozambique and Rwanda (Source: WIPO statistics database)^[52-55]

Table 4: Sustainable or Clean Energy Patents from 2001-2016 in Burundi, Malawi, Mozambique and Rwanda.

Name of the Country	Patents on Clean Energy
Burundi	00
Malawi	02
Mozambique	46
Rwanda	02

(Source: African Regional Intellectual Property Organization (ARIPO) Regional IP Database)^[56]

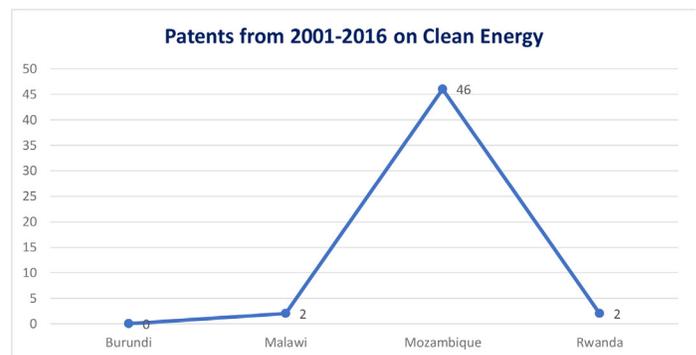


Figure 12: Sustainable or Clean Energy Patents from 2001-2016 in Burundi, Malawi, Mozambique and Rwanda (Source: African Regional Intellectual Property Organization (ARIPO) Regional IP Database)^[56]

these four countries have been analysed from the WIPO statistics database (Table 3) (Figure 11).^[52-55] Patents from 2001 to 2016 on sustainable and clean energy data analysed from African Regional Intellectual Property Organization (ARIPO) Regional IP database. Burundi is not a member of ARIPO and therefore data for Burundi is lacking here. Overall, Mozambique has outperformed all three nations in terms of total patents and the patents on clean energy (Table 4) (Figure 12).^[56]

POTENTIAL ROOT ENABLERS TO ACHIEVE SDG 7

The analysis of the previously discussed data suggests that STI infrastructure in Burundi, Malawi, Mozambique and Rwanda is improving, but the growth rate is not remarkable.

Access to electricity is one of the most important parameters and key driver of progress in any country. Access to electricity in Burundi, Malawi, Mozambique and in Rwanda is far below than global average which is at present is 87%.^[57] Effective use of mini grids and standalone system, running by renewable energies, can help to expand electrification in rural areas.^[58] Prospect of public funding for ESTs is not bright and it must be supported by adequate private funding. Otherwise, it will be very difficult to meet SDGs and equal access to electricity in these four sub-Saharan nations of Africa within 2030.^[59]

Various international bodies like the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the World Health Organization (WHO) etc are trying to achieve SDG 7 to provide affordable, sustainable and modern energy for all including Africa. The onset of COVID-19 pandemic has necessitated for more reliable, affordable access to electricity in health institutions than earlier before, including water pumping for agriculture, educational institutions, and community resilience.^[59]

Access to electricity plays a crucial role in poverty eradication for women and girls. Increasing accessibility to electricity uplifts the chances of employment and give a quality leisure time.^[59] Energy policy must be targeted at women particularly in order to avoid gender inequality because of our deep-rooted socio-cultural practices in the society.^[60] Electric light facilitates time savings by increasing efficiency and adding flexibility in the scheduling of domestic chores of women. Therefore, women can utilize their free time by investing it in productive works like education and can involve themselves in social life too.^[32] This kind of programs must be influenced by broader agenda of social transformation.^[59]

Among all the SDG 7 targets, progress toward *clean cooking* in Burundi, Malawi, Mozambique and in Rwanda is not satisfactory. Improvement of access to clean cooking needs political commitment at appropriate level, strong national and

subnational policy frameworks, and investment by public as well as private sectors. To achieve this, household energy use surveys must become more comprehensive. As per the latest report published in March 2020 that in Sub-Saharan Africa, the access deficit has upsurged by around a factor of 50 percent since 2000.^[59] Without access to clean fuel and technologies for cooking has a serious impact on women's health as well as emission of toxic gases in environment which further escalates expenditures on health and health infrastructures.

Education and Skill Development is another important enabler towards the goal of the Agenda 2063 and the Agenda 2030 on sustainable and clean energy. Current dismal situation of total expenditure on education, enrolment in primary education, expenditure on tertiary education and other infrastructural development can be improved in all these four countries with much commitment from the government to meet the SDG 7 and with more public as well as public-private partnership, making regional alliances and collaboration. Education determines the success and the ability to meet up those goals. Burundi has 21 universities whereas the University of Burundi is only public university located in Bujumbura. It is the only publicly funded university and all are private universities. In Malawi, there are four public universities and 21 private universities. The Eduardo Mondlane University and Pedagogic University (UP) are two public universities in Mozambique along with 13 other private universities. Situation in Rwanda is more or less same with having only one public and 23 private universities and few technical colleges.

Ranga and Etzkowitz concluded that “*from a triple helix systems perspective, the articulation and the non-linear interactions between the spaces can generate new combinations of knowledge and resources that can advance innovation theory and innovation system, especially at the regional level*”.^[61] Universities can play entrepreneurial role in knowledge transfer in the regional knowledge and innovation ecosystem. Based on absorptive capacity-based conceptual framework as suggested by Miller *et al.*, open innovation from diverse stakeholders can facilitate and advance regional innovation ecosystem.^[62] Sá *et al.* explored the dynamics of triple helix for rural entrepreneurship. He opined that while assessing the value and effects of this concept at the microlevel, wide range of results and factors should be considered altogether.^[63] Loet Leydesdorff, argued that the fourth industrial revolution driven by technological innovations build firm and robust national systems of innovation. Strong national systems of innovation will then grow into a regional system of innovation.^[64] *Access to internet* is another critical enabler of sustainable development by disseminating proper information to the sectors like health, finance and education. Once Rwandan President Paul Kagame aptly declared that, “*The internet is a needed public utility as much as water and electricity.*” His aspiration is quite significant

and equally applicable for all these four nations. Present study indicates that internet access and mobile subscriptions need to be improved and Mozambique has a little better situation than others. On the other hand, internet speed determines digital transaction and access to resources efficiently and effectively. As per the *Speedtest Global Index* data of September 2020,^[65] Burundi has the lowest internet speed (fixed broadband, no data for mobile broadband) with 8.21 MB /sec(169thrank), Malawi has 13.47 MB/sec (146th rank) (fixed broadband, no data for mobile broadband), Mozambique has 8.29MB/sec in fixed broadband (167th rank) and has 27.78 MB/Sec (76th rank) in Mobile broadband , Rwanda has the highest internet speed 19.85 MB/sec (125thrank) in fixed broadband and 18.67 MB/Sec in Mobile broadband (109th rank). *Lack of ICT skills as per the International Telecommunication Union (ITU) is an important impediment for people to access the Internet.*^[66] Internet stakeholders should participate and understand the relationship of internet and sustainability for proper implementation and execution of policies towards the SDG7. Interconnection among internet and sustainable development should be studied more exhaustively for utilizing maximum gain.^[67] National physical infrastructure as well as capacity building and training programmes for accessing to internet is a need of the hour in all these Sub-Saharan countries. They should adopt a long term strategy to assess how internet can aid in the process of implementation of sustainable energy at the ground level.

Analysis suggests that expenditure in these four nations on R&D proportion to the GDP is negligible and this is in a poor shape particularly in Burundi. Publications dominate primarily from three disciplines like health, agriculture and other. Engineering and environmental science related publications are non-significant. Moreover, the amount of investments in R&D, one of the main propelling forces behind STI, are far below the global average and targeted limit for the Agenda 2063. Policymaking bodies should attest the value of building institutions for R&D with sufficient research funding. Effective legal system and a congenial environment for creation and innovation is crucial in attracting foreign and private investments in addition with public outlay to boost the R&D.

CONCLUSION

Investments both from public and private are meagre to meet the SDG 7 in all these countries. There are several reasons that can explain why funding agencies were not interested to invest. Proper execution of the programmes like Agenda 2063 and 2030 Agenda for Sustainable Development depends on strong political commitment, inclusivity, regularly updated sound database with robust statistical system and participation of diverse stakeholders in a concerted way to achieve the target-

based goals. Better informed policymaking always requires correct data support in tandem to envision and meet any future policy goals.^[24] Only three years to go before meeting the first of seven aspirations in 2023 for the first 10 years of the AU Agenda 2063 implementation plan and 10 years to meet the SDG 7's call for 'universal access to affordable clean or sustainable energy'. Availability and accessibility of affordable and sustainable energy has become imperative and even more compelling for today and beyond because of this COVID-19 pandemic. This unprecedented crisis calls for a continuous flow of power which is indispensable to continue essential services and vital infrastructures of the countries seamlessly and in an uninterrupted manner. Critical investment for the infrastructural development, generation, distribution and sustenance of clean energy backed by relevant statutory acts and catalysing measures to facilitate economic reconstruction post COVID-19 will invigorate the premise of sustainable development.^[68] Present study indicates, Mozambique is little more innovative and has comparatively performed better through different indicators. Other nations may learn from Mozambican experiences. All these four Sub-Saharan African countries are highly deprived of energy and need a judicious and immediate step to fill-up the deficit to reach the global average in terms of access to electricity. Clean energy can unlock and induce sustained economic growth supporting major social sectors including health, education, clean cooking, digital transactions and reducing poverty. Above all, affordable and clean energy besides meeting SDGs, can also light up these poor nations in every step and offer productive and meaningful lives to their members of the citizenry.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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