VULNERABILITY, IMPACTS AND ADAPTATION ASSESSMENT IN THE EAST AFRICA REGION

CHAPTER 6: ENERGY, TRANSPORT, AND ASSOCIATED INFRASTRUCTURE BASELINE FOR EAST AFRICA

OCTOBER 2017

This report was produced for review by the United States Agency for International Development. It was prepared by Camco Advisory Services (K) Ltd. under subcontract to Tetra Tech ARD.

This report was produced for review by Camco Advisory Services (K) Ltd. under subcontract to Tetra Tech ARD, through USAID/Kenya and East Africa Contract No. AID-623-C-13-00003.

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CONTENTS

ACRONYMS

BEST	Biomass Energy Strategy
CGIAR	Consultative Group for International Agricultural Research
COMESA	Common Market for Eastern and Southern Africa
DRC	Democratic Republic of Congo
DRRM	Disaster reduction and risk management
EAC	East African Community
EAPP	Eastern Africa Power Pool
ERA	Electricity Regulatory Agency
ESA	Eastern and Southern African
ESDA	Energy for Sustainable Development Africa
FiT	Feed-in-Tariff
GDP	Gross Domestic Product
GIZ	*Die Deutsche Gesellschaft für Internationale Zusammenarbeit*
GVEP	Global Village Energy Partnership
IEA	International Energy Agency
IGAD	Inter-Governmental Authority on Development
INDC	Intended Nationally Defined Contributions
IPCC	Intergovernmental Panel on Climate Control
KPLC	Kenya Power and Lighting Company
KRC	Kenya Railways Corporation
Kw	Kilowatts
LAPSSET	Lamu Port-South Sudan-Ethiopia Transport Corridor Project
LCPDP	Least Cost Power Development Plan
LIDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LPG	Liquified propane gas
LTA	Lake Tanganyika Authority
LVB	Lake Victoria Basin
MEM	Ministry of Energy and Mines
MEMD	Ministry of Energy and Mineral Development
MEP	Mtwara Energy Project
MW	Megawatts
MWe	Megawatt of electricity
MWp	Megawatt peak
NAPA	National Adaptation Programme of Action
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Subsidiary Action Plan
NEMA	National Environment Management Authority
NFA	National Forestry Authority
NRB	Non-renewable Biomass
OECD	Organization for Economic Co-operation and Development
PPP	Public-private partnership

PV	Photovoltaic
RCMRD	Regional Centre for Mapping of Resources for Development
REMA	Rwanda Environmental Management Authority
SAPP	Southern Africa Power Pool
SDG	Sustainable Development Goal
SOLAS	Safety of Life at Sea
SREP	Scaling Up Renewable Energy Program
SRTM	Shuttle Radar Topography Mission
SWERA	Solar and Wind Energy Resource Assessment
TANESCO	Tanzania Electric Supply Company
TaTEDO	Tanzania Traditional Energy Development Organization
TAZAMA	Tanzania-Zambia Mafuta
TAZARA	Tanzania Railway
TEDAP	Tanzania Energy Development Assistance Programme
TPDC	Tanzania Petroleum Development Corporation
TRL	Tanzania Railway Limited
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
USAID	United States Agency for International Development
UV	Ultraviolet
VAT	Valued added tax
VIA	Vulnerability, Impacts and Adaptation Assessment
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping methodology

EXECUTIVE SUMMARY

Energy and transportation are key sectors for economic and social development. Without energy, countries cannot eradicate extreme poverty or attain sustainable development. At the same time, increased energy use contributes to greenhouse gas emissions, which exacerbates global warming. Transport, meanwhile, is a driver of social and economic development because, among other things, it enables citizens to access health care, education, and jobs, and unlocks growth potential for cities and countries.

Energy Sector

Renewable energy technologies are becoming increasingly important for power generation, largely due to concerns about increasing greenhouse gas emissions associated with fossil fuels. In 2012, CO_2 emissions globally from the power sector were 13.2 gigatons (IEA 2014). Renewable technologies not only hold promise for reducing this global hazard they also make economic sense to countries with poor energy resources.

Globally, much attention has been given to accelerating sustainable energy access and addressing energy challenges. The United Nations (UN) has launched two important frameworks—Sustainable Energy for All (SE4ALL) and the 2030 Sustainable Development Agenda—with an objective of providing access to electricity for all.

Africa is well endowed with energy resources, including fossil energy resources such as oil, coal, and gas reserves. Renewable energy resources, including geothermal, hydropower, biomass, and wind and solar are also available. Despite its enormous potential in fossil and renewable energy sources, Africa suffers from major energy deficits and supplies available for local populations are largely insufficient.

The development visions of all East African Community (EAC) Partner States recognize that energy is a vital input to socioeconomic development. Energy is identified as a foundation and an infrastructural "enabler" upon which to build economic, social, and political development.

The vulnerability of the energy sector is likely to be worsened by the challenge of climate change. To address this, the UN's Sustainable Development Goal (SDG) 13 calls for urgent action to combat climate change and its impacts and proposes to "strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; integrate climate change measures into national polices, strategies, and planning; and improve education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning."

Large hydropower generation currently accounts for 37–90 percent of total power generation in the EAC Partner States. To improve security of the power supply, the Partner States have developed Power Master Plans (PMPs) aimed at increasing power generation and diversifying the sources to include geothermal, natural gas, wind, solar, and coal.

All five Partner States have low access to electricity and high dependence on hydropower. Hydro and thermal electricity remain the main sources of electricity in the region; however, power generation is generally increasing across the region. Installed hydroelectricity capacity increased by 2.5 percent since 2012. Thermal electricity capacity increased by 8.6 percent compared to 1.3 percent in 2012. Uganda recorded an increase of 18.7 percent in installed hydroelectricity in 2013, while cogeneration capacity more than doubled to 36 Megawatts in the period. Kenya realized an increase of 18.7 percent in geothermal installed capacity. Meanwhile, thermal installed capacity in Kenya and Tanzania increased by 13.5 percent and 22.4 percent, respectively (EAC 2014). To meet current and future demand of power, and improve power supply security, the EAC Partner States participate in the Eastern Africa Power Pool (EAPP), East Africa Community Power Pool, as well as the Southern Africa Power Pool (SAPP). Imports and exports of electricity are examples of the regional integration of the power sector.

In 2009, the EAC Strategy on Scaling-up Access to Modern Energy Services was developed to address energy challenges. Both the EAC Climate Change Strategy (2011) and Master Plan (2011–2031) recognize energy as a priority sector that is vulnerable to climate change. Biomass dependence in the EAC Partner States is between 80 and 90 percent. Charcoal demand is growing while forest cover is diminishing. Due to climate change and unsustainable management of biomass resources (especially wood) in the Partner States, forest cover and wood growing stock per unit area has declined both in total standing volume and mean annual increment per unit area.

The energy sector in the EAC Partner States is especially sensitive to climate influences, since a large component of the energy mix is generated from climate-sensitive energy sources (biomass and hydro). East Africa is prone to periodic extreme climatic events, including flooding and prolonged dry spells. Climate variability and change may cause serious shortages of electricity and affect the entire economy. Climate variability and change may have economic impacts, especially on the generation costs, tariffs, and power purchases with impacts on the overall economy. Temperature rise may have a negative impact on hydropower generation. Rainfall variability has the greatest impact on the hydropower generation as trends in precipitation are correlated with trends in hydropower generation and transmission. Climate change is a major cause of loss of vegetation and wood biomass, affecting energy access for local communities.

The main policy focus in the energy sector has been on electricity generation and transmission. The major milestone in regional policy is the EAPP. The EAC Climate Change Strategy (2011) and Master Plan (2011–2031) recognize energy as a priority issue vulnerable to climate change. Additional policy suggestions for the energy sector are:

1. Fast-track diversification of energy resources, which would include:
    - Alternative sources such as hydro, natural gas, geothermal, solar photovoltaics and thermal energy, and wind.
    - Hybridization (combinations of the energy sources above within one power plant) to insure a reliable and sustainable supply of electricity to users (residential, commercial, and industrial).
2. Implement a large-scale energy efficiency program to adopt modern technologies, including household energy efficiency (improved cookstoves, solar cookers, solar water heaters), inverters in commercial buildings, domestic and industrial biogas, cogeneration. Support this effort with and intensive public awareness campaign as well as with strong support from political decision makers who will the model adoption of these technologies.
3. Reforest catchment areas of hydropower plants to retain underground water, mitigate erosion and landslides, and reduce siltation, which can damage equipment in hydropower plants.
4. Enhance regional interconnectivity of electrical networks through regional power pools and tariff harmonization.
5. Strengthen the institutional framework and capacity in planning and management of the energy sector.
6. Review standards and specifications to cope with extreme events of due to climate change on the national and regional levels.

7. Train technicians in the design and development of energy infrastructure resilient to the effects of climate change at district, province, national, and regional levels.
8. Develop curricula for and train specialists in climate change prediction to ensure the availability of reliable information for decision making at district, province, national, and regional levels.

Transportation Sector

The transport sector in East Africa can be divided into three broad categories: water transport, surface transport, and air transport. Most citizens rely on surface transport, which includes road, rail, and pedestrian travel. In East Africa, major lakes—Lake Victoria (Kenya, Uganda, and Tanzania), Lake Tanganyika (Tanzania and Burundi,) and Lake Kivu (Rwanda)—are important travel and trade routes. Lake Victoria is the principal commercial waterway and train ferries operated by the railway companies of Uganda and Tanzania serve ports around the lake.

The EAC Transport Strategy, the main planning document for the region, guides policymaking and investments in the Partner States. The goals and objectives of the Regional Road Sector Development Programme, a comprehensive, multi-year effort, are defined in the strategy, which also specifies the use of a regional demand model. The strategy has established the concept of the East African transport corridors as an organizing principle for transport. The corridors are not just transport arterial but also routes for development that attract complementary industrial and utility investments.

The East African Railway Master Plan proposes rejuvenating and extending the railways serving Kenya, Tanzania, and Uganda, initially to Burundi and Rwanda and eventually to Ethiopia and South Sudan . The EAC Climate Change Master Plan (EAC CMP) acknowledges that adequate and well-maintained infrastructure, including roads, significantly contributes to economic growth as well as builds a society's resilience to climate extremes. The Master Plan is of the view that infrastructure in EAC Partner States is "generally regarded as 'poor and underdeveloped' hence unable to cope, adjust or bounce back in the face of climate extremes as a result, disaster risk is increased resulting to adverse effects on the economy." Transport of hydrocarbons (oil and natural gas) is expected to increase in the region following recent discoveries of the deposits. Currently, two major oil pipelines serve the region. The Kenya pipeline that runs from Mombasa to Nairobi and extends to the Kisumu and Eldoret depots (in Kenya). The Tanzania-Zambia Mafuta (TAZAMA) pipeline runs from Dar es Salaam to Ndola in Zambia. The governments of Kenya, South Sudan, and Uganda have agreed to prepare designs for a pipeline that will be used to transport crude oil from Hoima via Lokichar to Lamu Port.

The EAC Partner States are experiencing growth in air transport. Total interstate traffic in East Africa is about 766,000 passengers. The major interstate routes in the region are Nairobi–Entebbe and Nairobi–Dar es Salaam.

The transport sector and its infrastructure in East Africa are generally affected by three key climatic factors: precipitation, temperature and wind. Precipitation, in the form of floods (flash floods, river floods, mudslides, landslides, and silting), destroys roads, pipelines, and railway lines and causes silting, hampering shipping. Lake and sea level changes affect ship and boating docking; while fog and mist impair visibility for road, air, and water transport. Winds, especially gusty winds and sand storms, pose great danger to air and road transport and strong wind speed and variable directions can severely affect air transport. Finally, high temperatures and heatwaves can result in the melting of road asphalt and buckling of metal railway, while freezing temperatures can loosen road particles.

Impacts of climate change on the transport sector have negative effects on other sectors of the economy. There is a well-structured road network in East Africa, but the condition of most rural roads makes it difficult to travel or move goods, especially during the wet season. The state of infrastructure and ability to bounce back also directly affects other sectors driving the economy of the EAC Partner States.

Like the energy sector, the transportation sectors are also sensitive to biophysical as well as socioeconomic factors. The biophysical indicators used to map sensitivity were anthropogenic land use/land cover change, slope, and soils. The socioeconomic indicators included population density and poverty index. Compared to exposure, the sensitivity component has greater influence on the overall EAC energy/transport vulnerability index. The overall impression is that EAC is medium to highly sensitive to climatic stressors. The sensitivity map shows that the areas with high population and soil vulnerabilities coupled with high rates of vegetation loss for the most significant components for overall sensitivity.

The EAC policy on transport has largely been captured in the EAC Treaty, which covers all modes of transport except pipelines. The Transport and Communications Strategy and Priority Investment Plan was developed in 2010 by Eastern and Southern African (ESA) states, represented by the EAC, Common Market for Eastern and Southern Africa (COMESA), Inter-Governmental Authority on Development (IGAD), Indian Ocean Commission, and Southern African Development Community as observer.

Policy suggestions on possible adaptation options to current vulnerability and impacts of climate variability and change for the transport sector include:

- **Policies:** Update national and subnational transport policies to take into consideration climate change issues, especially adaptation measures in line with the Paris Agreement, the EAC Climate Change Master Plan and Policy and other relevant policies.

- **Planning:** Prioritize national projects and programs in response to climate change impacts as well as mitigation and adaptation measures for financing.

- **Mainstreaming:** Domesticate the various agreements and protocols on road transport in the region, including strengthening the implementation and monitoring mechanisms in respect of transport agreements.

- **Institutional Capacity:** Strengthen the institutional framework and capacity of transport institutions and stakeholders in risk-based approaches for identifying, analyzing, planning, and implementing transport projects.

- **Financing:** Provide budgetary allocation for climate adaptation activities including climate vulnerability assessments, climate resilience transportation planning, design and construction, as well as projects to protect, upgrade, or overhaul assets based on criticality.

- **Risk Management and Planning:** Develop risk-based asset management plans and allocate resources to secure critical assets and review disaster preparedness and emergency planning considering vulnerability to climate change as well as early warning systems.

- **Data and Information:** Develop tools, guidelines, and protocols for pilot projects for national and subnational adaptation in the transport sector working with other relevant sectors to enhance shared benefits, enhance sustainability, and support economic development and poverty reduction.

- **Capacity Building:** Engage in long-range transportation planning and land use with climate change as an influencing factor and enhance awareness of climate change among all actors (strategic and effective communication).

1. ENERGY SECTOR

1.1 INTRODUCTION

Energy is vital to economic and social development. Without it, countries cannot eradicate extreme poverty or attain sustainable development.

> "[The] global energy landscape must change to ensure shared prosperity and that modern energy is made available to all and is provided as cleanly as efficiently as possible." (UN Secretary-General Ban Ki-moon, Vienna, 3 November 2014).

Fossil fuels have long been a major source for energy generation in much of the world, however, the use of fossil fuels emits greenhouse gases that contribute to climate change. In 2012, CO_2 emissions globally from the power sector were 13.2 gigatons (IEA 2014). The demand for energy typically grows with development; however, the use of energy can now be made more efficient by using other energy technologies.

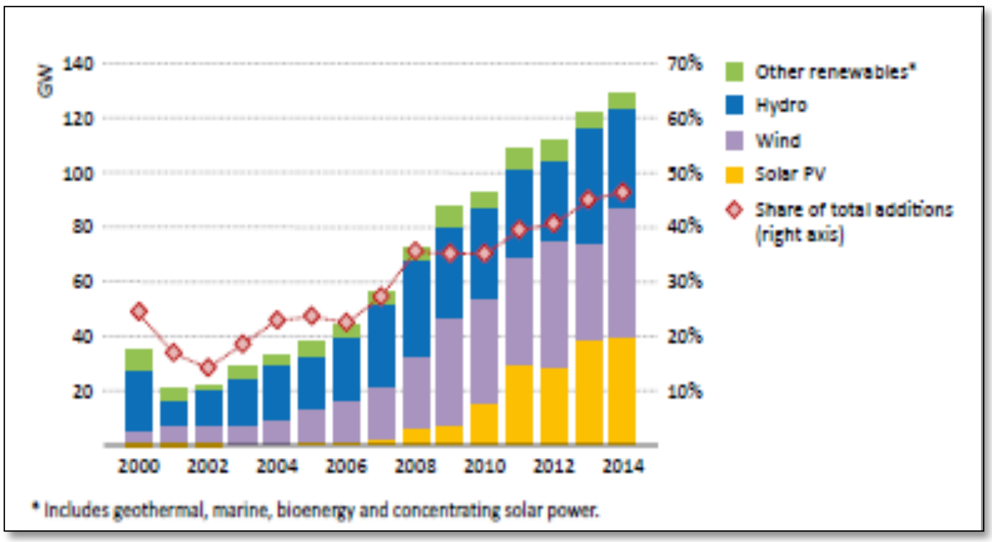

Figure 1: Global renewables-based power capacity increases by type and share of total capacity increases

Renewable energy technologies are becoming increasingly important largely driven by concerns about greenhouse gas emissions. According to Frankfurt School (Frankfurt-UNEP Centre 2015), global investment in renewable power and fuels in 2014 was nearly 17 percent higher than in 2013, with a boom in solar installations in China and Japan. Investments in developing countries grew by 36 percent and almost reached the level of investments in developed countries. Renewables make economic sense for all countries, including those that are energy resource-poor. IEA estimates that renewables-based power generation capacity increased by 128 gigawatts in 2014, of which 25 percent is wind power, 20 percent solar, and 15 percent hydropower (IEA 2014) (Figure 1).

1.2 Context

1.2.1 Global

Energy is a major challenge for the world, but especially for least developed countries, which are at a huge disadvantage (WHO 2009). Some of the challenges include the availability, accessibility, and affordability of modern energy services. For those living in extreme poverty, lack of access to energy services significantly affects their benefits from other sectors, such as health, water, and agriculture, and this limits their socioeconomic opportunities.

Globally, a lot of attention has been given to accelerating sustainable energy access and addressing energy challenges. The United Nations (UN) has launched important frameworks to address energy challenges. These include the following:

- Sustainable Energy for All (SE4ALL) focuses on three goals: "ensuring universal access to modern energy services, doubling the share of renewable energy in the global energy mix, and doubling the rate of improvement in energy efficiency"—all to be met by 2030. It seeks to accelerate the share of modern renewable energy in total energy consumption. Renewables accounted for 8.8 percent of total global energy consumption in 2012 (World Bank 2015).

- The 2030 Sustainable Development Agenda includes 17 Sustainable Development Goals (SDGs), one of which aims to "ensure access to affordable, reliable, sustainable and modern energy for all by 2030, ensure universal access to affordable, reliable and modern energy services, increase substantially the share of renewable energy in the global energy, and double the global rate of improvement in energy efficiency."

- The Paris Agreement aims to strengthen the global response to the threat of climate change in the context of sustainable development and efforts to eradicate poverty. Specifically, it seeks to:

  - hold the increase in the global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit it to 1.5°C above pre-industrial levels;
  - increase the ability to adapt to climate change and foster climate resilience and development with low greenhouse gas emissions;
  - make financial flows consistent with a pathway toward low greenhouse gas emissions and climate-resilient development;
  - establish a global goal to enhance adaptive capacity, strengthen resilience, and reduce vulnerability to climate change.

The adoption of both SDGs and Paris Agreement in June and December 2015, respectively, sent a clear message that the transition to sustainable energy is central to meeting development and climate objectives. With the adoption of the Paris Agreement, all parties to United Nations Framework Convention for Climate Change, including EAC Partner States, are expected to help achieve the ultimate objective of the Convention as stated under Article 2.

The major global initiatives provide the development context that helps to guide the short- and long-term trajectory of energy sector development. They also note with concern that 3 billion people rely on solid fuels for cooking in developing countries (World Bank 2015). A large proportion of those people are in sub-Saharan Africa. Moreover, only 27 percent of those who rely on solid fuels use improved cookstoves (Figure 2).

Among the promising adaptation and mitigation options are energy generation using renewable resources and improvements in energy efficiency, but both need to be accelerated. Renewables accounted for 8.8 percent of total global energy consumption in 2012, but to meet the 2030 SE4All objective renewables need to grow at an annual rate of nearly 7.5 percent (World Bank 2015).

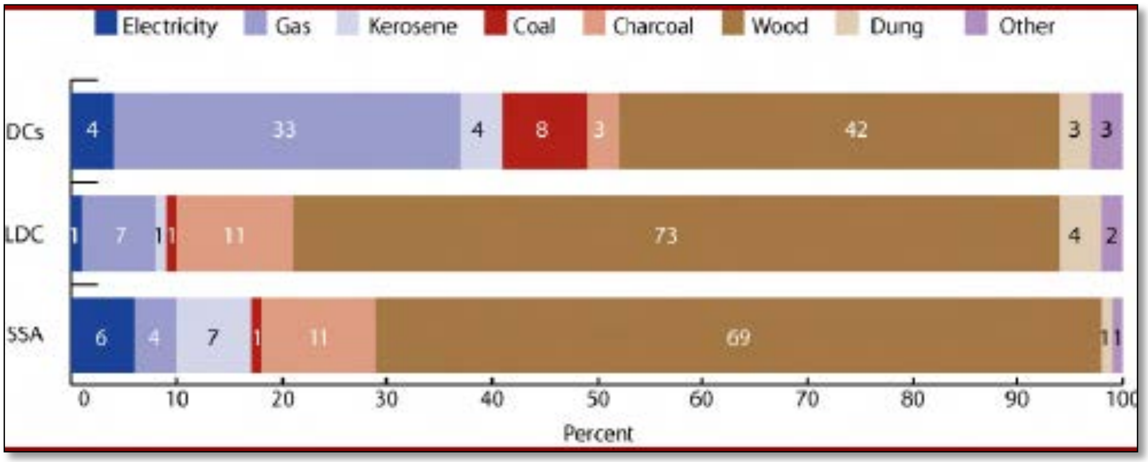

Figure 1: The share of population relying on different types of cooking fuels in developed countries, least developed countries, and sub-Saharan Africa (source: WHO 2009)

1.2.2 Africa

Africa is well endowed with energy resources, including hydropower, biomass, geothermal, wind, solar, coal, oil, and natural gas. Other sources, such as uranium and methane are also available. Despite its enormous energy resource potential, Africa continues to suffer from major energy deficits. This can be attributed to the under-exploitation of most of these energy resources. Table 1 shows the comparative electricity installed capacities for the various regions in Africa. Notably, East Africa has the lowest levels of electricity production. Furthermore, the total installed capacity for Africa is low by world standards—as of 2015, Germany had 177,072 MW of installed capacity.

Table 1: Africa electricity installed capacity as of the end of 2015

Region	Installed Capacity (MW)
Western Africa	12,360
Central Africa	4,407
Southern Africa	53,613
Northern Africa	60,578
Horn of Africa	5,860
East Africa	**4,304**
Total	**142,736**

Source: KPLC 2016.

In Africa, energy supplies are mainly from biomass (47 percent), oil (24.8 percent), coal (16.5 percent), natural gas (10.4 percent), and other renewable sources, such as large and small hydropower dams, solar, and geothermal sources (1.3 percent). Against the foregoing, Africa has solar irradiation ranging from 5 to 7 kWh/m^2, year round, and it has relatively strong wind power potential in the northern, southern, and eastern regions. The continent also has an estimated geothermal energy potential of more than 10,000 MW.

While Africa accounts for 12 percent of the world's population, it consumes a meager 3 percent of the total global electricity.[1] Incidentally, the bulk of this electricity consumption is shared between North Africa and South Africa at 33 percent and 45 percent, respectively. The remainder is shared out among the rest of sub-Saharan African states. In addition, electricity connectivity in sub-Sahara Africa remains relatively low, averaging 43 percent compared to 99 percent in North Africa (Table 2).

Table 2: Electricity access in 2010—Africa regional aggregates

Region	Population without electricity millions	Electrification rate %	Urban electri-fication rate %	Rural electri-fication rate %
Developing countries	**1,265**	**76.1**	**92.1**	**63.7**
Africa	590	43	72	24
North Africa	*1*	*99*	*100*	*99*
Sub-Saharan Africa	*589*	*32*	*64*	*13*
Developing Asia	628	83	96	74
China & East Asia	*157*	*92*	*98*	*88*
South Asia	*471*	*70*	*92*	*61*
Latin America	29	94	98	76
Middle East	18	91	99	75
Transition economies & OECD	**2**	**99.8**	**100.0**	**99.5**
World	**1,267**	**81.5**	**94.7**	**68.0**

Source: IEA 2012.

In terms of electricity access, 620 million people, 67 percent of the population of sub-Saharan Africa are without access to electricity. This is the lowest rate of all developing country regions.

Bioenergy dominates the sub-Saharan energy mix, mainly accounted for by the traditional use of solid biomass in the residential sector, while the modern use of solid biomass and biogas for power generation and heat make up only a very small share. In sub-Saharan Africa, biomass energy accounts for more than 70 percent of the energy demand. Also, access to improved cookstoves is low; only 6 percent of those who use traditional biomass (solid fuels) are using such option.

1.2.3 East Africa

East Africa is endowed with abundant but diversified energy resources. The principal energy resources are hydropower, biomass, geothermal, solar, wind, liquid natural gas, peat, and coal. Biomass is the predominant form of energy used by rural population while electricity and petroleum are the key drivers of modern economic sectors. Table 3 summarizes the energy resource potential for each EAC Partner State and the corresponding levels of exploitation. All five Partner States have low access to electricity and high dependence on hydropower. Hydro and thermal electricity remain the main sources of electricity in the EAC.

[1] http://www.afdb.org/en/blogs/afdb-championing-inclusive-growth-across-africa/post/renewable-energy-in-africa-8829/

Table 3: Energy resources potential and rate of exploitation in East Africa, by source and country

	Burundi		Kenya		Rwanda		Tanzania		Uganda	
	Potential/ demand	Installed/ supply	Potential/ demand	Installed/ supply	Potential/ demand	Installed/ supply	Potential/ demand	Installed/ supply	Potential/ demand	Installed/ supply
Hydropower	1,700 MWe	51 MWe	6,000 MWe	827 MWe	313–400 MWe	98.5 MWe	4,700 MWe	562 MWe	2,000 MWe	695 MWe
Woody biomass		64,000,000 M^3	35 million tons							
Geothermal	Unknown	Nil	10,000 MWe	619 MWe	Unknown	Nil	>5,000 MWe	Nil	450 MWe	Nil
Thermal	N/A		N/A	829 MWe	N/A	41.8 MWe	N/A	495 MWe	N/A	
Solar	5.5 $kWh/m^2/day$		4-6 $kWh/m^2/day$	716 MWe	5.2 $kWh/m^2/day$	8.25 MWe				
Wind			>4,000 MWe 346 W/m^2	25 MWe						
Natural gas (LNG)			N/A	60 MWe			553.28 TCF	501 MWe		
Peat	50 million tons			Nil	155 million tons	15 MWe				
Coal			>400 million tons	Nil			1.9 billion tons			
Others			120 MWe	40 MWe[2]	350 MWe[3]					

Blank cells indicate lack of data.

[2] 38 MWe from bagasse co-generation, 2 MWe from biogas

[2] Potential from methane

The EAC total installed electricity generation capacity was 4,832 MW at end of 2015 (Table 4).

Table 4: East Africa regional installed electricity capacity (end 2015)

Country	Installed capacity (MW)
Burundi	55
Kenya	2,298
Rwanda	135
Tanzania	1,490
Uganda	854
Total	**4,832**

As mentioned earlier, electricity access in the individual Partner States (Table 5) is low compared to other regions of the world.

Table 5: Rate of electricity access in East Africa (end 2015)

Country	Electricity access rate (%)
Burundi	10
Kenya	50
Rwanda	18
Tanzania	24
Uganda	9

The relative proportions of the various energy sources in the overall national energy supply for each of the Partner States is as follows:

- **Burundi:** Biomass dominates with 95 percent split as follows: 70.8 percent firewood, 18.36 percent agriculture residues, 5.8 percent charcoal, 1 percent bagasse, and 0.04 percent peat. Electricity contributes 1.5 percent while petroleum products account for 2.5 percent.
- **Kenya:** Biomass accounts for 68 percent, petroleum 22 percent, electricity 9 percent, with the remaining 1 percent accounted for by solar, wind, and other small-scale renewables.
- **Rwanda:** Biomass accounts for 80 percent, followed by petroleum at 11 percent, peat at 5 percent, and electricity at 4 percent.
- **Tanzania:** Biomass accounts for 90 percent of the total energy demand; petroleum/and gas accounts for 8 percent, and electricity is only 2 percent.
- **Uganda:** Biomass accounts for 92 percent of the total energy demand, petroleum accounts for 6 percent and electricity only 2 percent.

1.2.4 Lake Victoria Basin

Hydroelectric Resources

The Lake Victoria Basin (LVB) is well endowed with significant amounts of renewable energy sources, including biomass, hydropower, solar, wind, and cogeneration. The basin has a high hydroelectric energy potential—2000 MW for Uganda, 100 MW for Rwanda, 1,370 MW for Burundi, 4.7 GW for Tanzania, and

30,000 MW for Kenya. Many rivers drain into Lake Victoria, including Kagera, Mara, Simiyu, Gurumeti, Nyando, Migori, and Sondu rivers. However, the hydropower potential is underexploited. The contribution of renewable energy sources to total energy supply is currently very low. High costs, lack of awareness among users, and destruction of catchment areas are among the key factors contributing to the low level of exploitation. A shortage of data on hydrology and on comparative economics of these power sources, as well as lack of infrastructure for local manufacture, is a major drawback to the exploitation of the small hydro resources.

Biomass

Traditional biomass energy is a major livelihood source for the population in both rural and urban areas in the LVB. Woody biomass is the preferred source, with others such as agricultural residue consumed only when woody biomass is in short supply. Increasingly, woody biomass is being converted to charcoal and deforestation is gradually degrading the catchment area of the lake.

Solar

The LVB receives insolation all year round, coupled with moderate to high temperatures. Solar energy has become competitive under varying conditions for water heating and crop drying. In most areas, it is viable for refrigeration and as a substitute for diesel-powered water pumping. The use of solar thermal energy is not widespread. More widespread use of solar water heaters would make a significant impact on electricity use for water heating, especially in urban areas where such heating is mostly by electricity. Solar driers have a huge potential in the agricultural sector in food preservation. In many developing countries, the use of solar drying devices is becoming an important part of agriculture or business, especially where the product can be sold at a higher price or transported more easily when dried. This is aimed at adding value to the products. The potential for solar drying in the lake basin region is huge.

Wind

Wind is an important resource in the LVB, with vast potential for water pumping, grain milling, and in future power generation. The resource is, however, relatively under-used and mainly has been used for water pumping and to some extent grain milling. A major limitation in the development of wind energy in the region is the lack of adequate wind resource data and information to assist investors in decision making.

In summary, renewable energy sources have the potential to meet energy demand for various sectors of the economy and to substantially meet national social objectives. The potential of renewable energy sources is, however, limited by several factors, the most common of which are high costs and limited priority.

Cogeneration

Cogeneration, attractive and cost-effective as it may be, has not been exploited in East Africa for the benefit of the communities. There is, however, a growing interest in producing electricity as part of the commercial outputs with a view to selling it to improve economic performance.

In Kenya, there are several sugar milling factories and other agro-based companies that have the capacity to increase their cogeneration levels but have not made any significant contribution in the supply of electricity to the public. These are Sony Sugar, Nzoia Sugar, Mumias Sugar, Chemelil Sugar, Muhoroni Sugar, Agrochemical and Food Company, and the Spectre International Plant (formerly Kisumu molasses plant). All these companies are in western Kenya and can supply the region with a substantial amount of electricity. They are all close to Lake Victoria and together with other sugar companies such as Kagera Sugar Company in Tanzania and Kakira Sugar Company in Uganda, which are also close to the lake, could effectively serve much of the Lake Victoria region with electricity. Already, by 2013, Kakira had prepared to increase its electricity generation capacity to over 50 MW with the aim of selling the surplus to the Uganda Electricity Board.

1.3 Analysis of Energy Sector in the East Africa Partner States

1.3.1 Electricity Supply and Generation

Large hydropower generation currently accounts for 35–90 percent of the total power generation in the EAC Partner States—Burundi, 90 percent; Rwanda, 60 percent; Kenya, 35 percent, Tanzania 37 percent, and Uganda 81 percent. Hydropower and thermal electricity remain the main sources of electricity in the EAC region (Figure 3). To improve the security of power supply, the EAC Partner States have developed Power Master Plans (PMPs) aimed at increasing power generation and diversifying the sources to include geothermal, natural gas, wind, solar, and coal. The Partner States also participate in the EAPP as well as the Southern Africa Power Pool (SAPP). Imports and exports of electricity are examples of the regional integration.

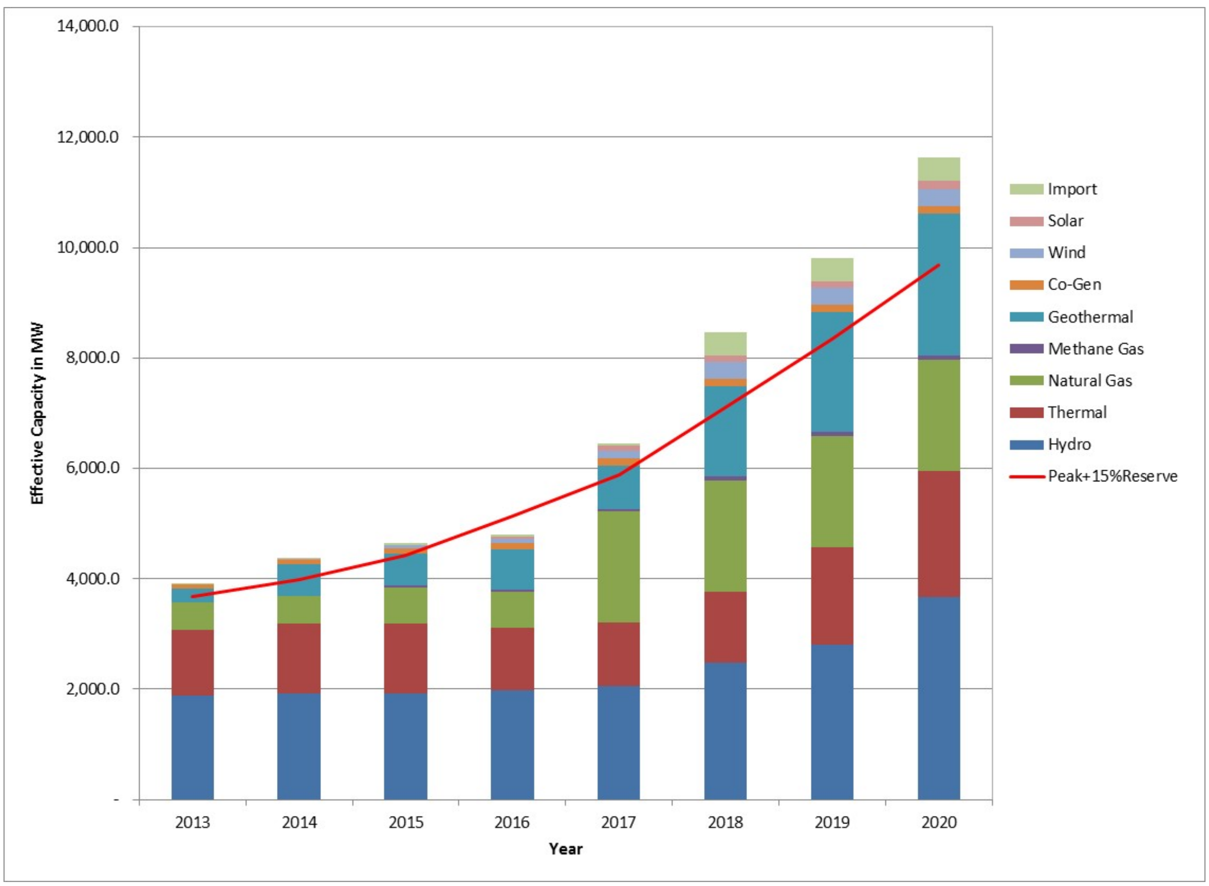

Figure 2: Projected effective electricity generation capacity growth (source: EAC 2015)

The EAC Partner States have about 60 small hydropower plants with an installed capacity of at least 158 MW. The EAC estimates that up to 140 new small hydropower plants (between 250 kW and 10 MW) could become operational by 2020 with a total capacity of more than 500 MW (EAC 2015).

In 2009, the EAC Strategy on Scaling-up Access to Modern Energy Services was developed to address energy challenges. The strategy set up a framework for Partner States to move away from the "business-as-usual" scenario to an approach that addresses key barriers to increased access to modern energy services. The strategy set four targets that are crucial for the Partner States to fight against poverty, improve living standards, and achieve development goals:

- **Target 1**: Provide access to modern cooking practices for 50 percent of the population that currently uses traditional cooking fuel.
- **Target 2:** Provide access to reliable electricity for all urban and peri-urban poor.
- **Target 3:** Provide access to modern energy services for all schools, clinics, hospitals, and community centers.
- **Target 4:** Provide access to mechanical power to serve the heating and productive needs of all communities.

In addition, both the EAC Climate Change Strategy (2011) and Master Plan (2011–2031) recognize energy as a priority sector that is vulnerable to climate change. That vulnerability is primarily due to its lack of diversification. Opportunities exist for growth in renewable energy and to scale-up the exploitation and development of less carbon-intensive and more climate change-resilient energy infrastructure in the region. To support sustainable development, including through green economy and low-carbon development pathways, the Climate Change Strategy encourages Partner States to increase availability and accessibility of sustainable, reliable, and affordable renewable energy resources.

Table 6: Highlights from the EAC Partner States

Country	Installed capacity (MWe)	Hydroelectric potential (MWe)	Hydropower supply (MWe)	Access (% of population)
Burundi	50	1,700	35.35	10
Kenya	2,294.8	6,000	829	50
Rwanda	145	400	78.9	18
Tanzania	1,490	4,700	553	24
Uganda	853.5	2,200	695	9

In **Burundi**, demand for electricity is expected to grow from 46 MW in 2012, to 92 MW by 2018, ultimately reaching 192 MW by 2025. To meet future demand for electricity, several projects are under way, in various stages from planning to implementation. These include the Jiji and Mulembwe hydropower projects with a combined capacity of 48 MW. Rehabilitation of the Ruzizi I and II hydropower plants is expected to generate an extra 7.6 MW and Ruzizi II will expand with 7.8 MW. The project is expected to start in late 2015 or early 2016. According to an EAC report (2015), Burundi has 159 potential sites for small hydropower generation. Technical potential of these sites is about 414 MW. To date, there are seven small hydropower stations with installed capacity of 14.7 MW (EAC 2015). Most of the existing small hydropower plants are owned by the power utility, REGIDESO, indicating that the government is the main player for small hydropower projects. However, this situation may change due to new developments in the energy sector including new energy policies (under development), which may establish enabling environment to attract private investors. The government plans 12 sites with potential to generate 19 MW by 2020 (EAC 2015).

In **Kenya**, the Kenya Electricity Generating Company (KenGen) remains the largest electricity generator, contributing 68.37 percent to the national grid. In addition to KenGen, about seven Independent Power Producers (IPPs) account for approximately 24 percent of the country's installed capacity (Ministry of Energy Kenya (Kenya MoE 2014). The peak load is projected to increase to about 2,500 MW by 2015, and to 15,000 MW by 2030. To meet this demand, installed capacity should increase gradually to 19,200 MW by 2030 (Kenya MoE 2014).

Hydropower potential is in five geographical regions, representing Kenya's major drainage basins: Lake Victoria (295 MW), Rift Valley (345 MW), Athi River (84 MW), Tana River (800 MW), and Ewaso Ng'iro North River (146 MW). A major challenge to hydropower generation has been variations in hydrology. Poor rains result in power and energy shortfalls, reducing the capacity of hydropower. Yet, during the rainy season, water is lost due to inadequate storage capacity in the existing reservoirs (Kenya MoE 2014).

Kenya's economic growth is spurring demand for power. The government's development plan, Vision 2030, includes provision for boosting electricity generating capacity from 1,664 MW (2014) to 17,500 MW by 2030. The second Medium-Term Expenditure Plan (2013–2017) aims at realizing 5,000 MW by 2017.

Kenya has more than 260 potential small hydropower sites in the Tana River drainage basin. Potential for small hydro is over 3,000 MW, of which only 35.1 MW have been installed from 16 power plants (EAC 2015). The government introduced the Feed-in-Tariff (FiT) policy in 2008 to promote involvement of private investors in the development of renewable energy to supply villages, small businesses, and farms, as well as connecting to the grid.

In **Rwanda,** electricity accounts for only 4 percent of the national energy, while oil products contribute 11 percent. According to the National Energy Sector Strategic Plan 2008–2020, Rwanda has targeted an installed capacity of 563 MW by 2018 while increasing access from 4 percent in 2008 to 50 percent by 2017. About 300 MW is planned to come from domestic hydro projects—Nyabarongo (28 MW), Giciye (4 MW), and Rukarara V (5 MW)—all of which under implementation. The Giciye and Rukarara V projects are being developed by private developers, Rwanda Energy Group Limited. The installed capacity in 2020 is projected to include 340 MW from hydropower, 310 MW from geothermal power, 300 MW from methane generation, 200 MW from peat, and 20 MW from thermal plants

According to EAC report (2015), Rwanda has 271 micro and pico hydro sites with a combined capacity of 83MW. To date, there are only 14 small hydro power plants with installed capacities of 27MW. It is expected that 32 additional plants with combined capacity of 62MW will be operational by 2020.

In Tanzania, to achieve the desired socioeconomic transformation the government plans to increase the connectivity level to 30 percent by 2015, 50 percent by 2025, and at least 75 percent by 2033 (United Republic of Tanzania, 2013). Peak demand is projected to increase rapidly to about 4,700 MW by 2025 and 7,400 MW by 2035 (MEM 2012).

Tanzania also plans to develop coal and uranium resources for electricity generation along with renewable technologies. Presently about 4.9 percent of total generation capacity in Tanzania is from renewable sources, including grid and off-grid generation (biomass, solar, and small hydro plants). Tanzania has a goal to increase the share of renewable energy (excluding large hydro) in the electricity mix to 14 percent by 2015 (MEM 2011). When large hydropower is included, the total renewable energy generation capacity is about 40 percent.

Tanzania has more than 300 small hydro sites with potential to generate 400 MW (EAC 2015). Currently, 12 plants have an installed capacity of 16.2 MW of which 85 percent are owned by private institutions such as companies and the church missions while 15 percent is owned by Tanzania Electric Supply Company (TANESCO; EAC 2015). The installed grid-connected small hydro projects contribute only about 15 MW. It is estimated that up to 140 new small hydropower plants with a total capacity of 190 MW could become operational by 2020 (EAC 2015). The Rural Energy Agency and the World Bank are supporting these investments in grid and mini-grid projects through the Tanzania Energy Development Assistance Programme (TEDAP).

In **Uganda,** most of the electricity is generated along the Nile, which makes the electricity subsector highly vulnerable to severe climate change–related risks. Even with this limitation, less than 10 percent of the potential hydropower is currently exploited. The total installed capacity increased from 380 MW in 2003 to 852 MW in 2013 with hydropower sources contributing 80 percent, generated mainly from Jinja and Bujagali stations on the Nile (Electricity Regulation Authority 2013).

Uganda has 630 MW of its installed capacity along the Nile, and is supplied from its three major hydropower stations. Owen Falls complex comprises the 180 MW Owen Falls Power Station and a 200 MW Owen Falls extension. The third is the commissioning of the 250 MW Bujagali hydropower station in 2012 (Electricity Regulatory Agency (ERA) Strategic Plan 2014–2015 to 2023–24) to provide much-needed relief from expensive sources of generation and eliminate load shedding. Progress in increasing electricity generation capacity of large dams includes the development of a 600 MW Karuma Hydropower Project, Isimba Hydropower Project (183 MW) and the 600 MW Ayago Hydropower Project.

Currently, Uganda has a relatively stable electricity supply, provided by large and mini-hydropower resources and cogeneration plants. The existing supply from renewable energy sources is sufficient to meet the current demand of the connected consumers. Uganda has reserve capacity of 100 MW from two plants based on heavy fuel oil (Tororo and Namanve). However, this is expensive generation, which must be put on the grid only as a last resort, as demand continues to grow.

Uganda's Vision 2040 recognizes that energy, especially electricity is a key driver of the socioeconomic transformation of a nation. Vision 2040 envisages that Uganda will require 41,738 MW by 2040 with electricity consumption per capita of 3,668 kWh. It highlights the need to increase access to the national grid to 80 percent. The National Development Plan, 2010/11–2014/15 envisages that Uganda will require 8,601 MW by 2020, 14,670 MW by 2025, and 41,738 MW by 2040. It should be noted, however, that the demand referred to covers demand in both served and unserved areas of Uganda. It has considerable unexploited renewable resources that can be used to produce energy and provide energy services, including biomass, geothermal, large-scale hydro, mini/micro/pico hydro, wind, and solar energy.

According to the State of Environment report, the commissioning of the newly built 250 MW Bujagali hydropower dam in early 2012 and the ongoing development of the 650 MW Karuma hydropower dam, together with the planned use of some of the newly found oil resource for thermal power generation are expected help Uganda adequately address power needs over the next decades. According to Vision 2040, importation of power from neighboring countries under power trading arrangements, and development of nuclear power and other renewable energy sources, will complement the above sources.

The small and mini hydro sites are mainly in the hilly and mountainous east and west of the country. Various studies have identified 59 mini-hydropower sites in the region with a potential of about 210 MW. Some of the sites have potential to serve isolated grids, while others may be connected to the national grid. Several small hydropower plants already operate, providing a combined capacity of over 60 MW. Detailed feasibility studies for small hydro sites totaling more than 237 MW have been completed and are due for implementation.

1.3.2 Biomass

Due to climate change and unsustainable management of wood supply resources in EAC Partner States, forest cover and wood growing stock per unit area has declined both in terms of total standing volume and mean annual increment per unit area. Already non-climatic factors have led to increased habitat loss; and degradation; climate change will compound the situation.

The demand for charcoal is increasing, causing over-harvesting of existing natural forests contributing to serious deforestation and biomass scarcity. The deforestation rate for EAC Partner States is between 73,000 to 133,600 hectares per year. Charcoal demand is growing while forest cover is diminishing. This has affected peoples' livelihoods and the price of charcoal has almost doubled in the past five years in all the Partner States. Suitable tree species for charcoal are becoming scarce or unavailable; rural charcoal producers are forced to use other trees, including mango, cashew, and others (EAC 2011).

Biomass dependence in the Partner States is between 80–90 percent. Wood for charcoal is normally extracted from natural forests and harvested unsustainably; there is little awareness of the need to use efficient charcoal kilns. The demand for charcoal is increasing causing over-harvesting of existing natural forests and contributing to serious deforestation and biomass scarcity.

In **Burundi**, biomass resources account for 2 percent to gross domestic product (GDP) and 6 percent of employment. Biomass is an energy source for households and community institutions (schools, military barracks), as well as small industries and businesses (bakeries, tea factories, restaurants), the latter accounting for 6 percent of the total demand. In 2007, the total sustainable biomass supply from all sources, including firewood and agro-waste, was estimated at 64,000,000 cubic meters. The deficit is estimated to 3.3–4.5 million tons per year (Ministry of Energy and Mines 2012). Non-climatic variables, such as population density and bush fires, as well as such climatic causes, such as droughts, are the main causes of biomass depletion, which is occurring at an average rate of 0.5–2 percent annually. According to the World Bank, losses in biomass were estimated at 289,000 hectares in 1990 and increased to 133,600 hectares in 2007.

To reduce the biomass deficit, especially the use of wood-based charcoal, agricultural wastes are used either directly or transformed into briquettes for domestic cooking. Burundi also has large deposits of peat, about 50 million tons, which can be carbonized with agricultural waste in small, cost-efficient, and widely distributed stoves, or used to generate electricity.

In **Kenya**, biomass, mainly in the form of firewood and charcoal, has been the leading source of primary energy for decades. In the most detailed government report, the Ministry of Energy showed that close to 89 percent of rural and 7 percent of urban households regularly used firewood as a source of cooking and heating, giving a national average of 67 percent of all households. The study also showed that use of charcoal was about 47 percent at the national level, representing 82 percent of urban and 34 percent of rural households (MoE 2002). This translated to about 31 million tons of wood used for firewood and as charcoal raw material.

Although charcoal as part of biomass energy it is ranked lowest in the energy pyramid and usage statistics show a different pattern from that of firewood. According to Kenya Institute of Public Policy Research and Analysis (KIPPRA, 2010), with rising income, most Kenyans are likely to replace kerosene and wood with cleaner fuels, such as electricity, biogas, and off-grid solar. However, charcoal is an exception because its use does not decline with rise in income. A survey conducted by Energy for Sustainable Development Africa (ESDA) in 2005, estimated the amount of charcoal produced each year in Kenya at 1.6 million tons while a Kenya Forest Service study (Wanleys Consultants 2013) projected an increase in supply of both firewood by 10 percent and charcoal by 9.5 percent by 2032. The report also projected an increase in demand for firewood by 16.1 percent and charcoal by 17.8 percent.

(a) Power generation

The proportion of biomass in the energy mix has remained virtually unchanged, with Kenya's energy sector investment plan indicating that biomass contributed to 70 percent of the national energy demand and provided more than 85 percent of rural household energy needs over the past decade (Republic of Kenya 2011). While significant investments were made in power generation over the same period, nearly doubling national electricity connections from 15 percent of the total population in 2002 to about 30 percent now, the relative proportions for biomass energy have remained the same. The Kenya Institute of Public Policy Research and Analysis estimated that the national connectivity to the power grid by 2010 was about 28.9 percent, while biomass accounted for 70 percent of total energy consumption (KIPPRA 2010). This indicates that growth in the power sector as well as investment in renewable energy other than biomass has not kept pace with demand or population growth.

In recent years, biomass has been increasingly used for power generation. A FiT Policy was formulated in 2008, revised in 2010 and again in 2012, to promote the generation of electricity using renewable energy resources including wind, small hydro, and biomass. A pre-feasibility study completed in 2007 by the Ministry of Energy on cogeneration by sugar companies established potential for generating up to 120 MW of electricity for export to the national grid with minor investments and about 200 MW with modest investments in expanding cane fields and cane crushing capacity. Mumias Sugar Company has installed a 38 MW cogeneration power plant that supplies 26 MW to the national grid. Other sugar companies have shown interest in diversifying into cogeneration and bio-ethanol production. The planned generation capacity from all sugar companies is estimated to be 60 MW by 2016 (MEP 2015).

(b) Biogas

Through the Kenya National Federation of Agricultural Producers (KENFAP), 11,690 biogas plants were to be implemented between the year 2009 and 2013 countrywide. The program constructed a total of 11,579 biogas plants and engaged over 100 biogas- related enterprises in construction, appliances, and parts.[4] In 2010, a German-funded study identified municipal solid waste and waste from sisal and coffee production as the most promising sectors, with a total average installed electricity generation capacity of 80 MW. In addition, a US$7.5 million Naivasha biogas power project is set to generate 2.2 MW, 50 percent of which will be sold to the Gorge Farm and the rest to Kenya Power. The plant will be fed 50,000 metric tons of plant waste a year sourced from VegPro Group (Fischer et al. 2010).

(c) Biofuels

Bio-ethanol and biodiesel are the two main sources of biofuels. Kenya has produced ethanol from sugarcane since the early 1980s. Biodiesel, on the other hand, is still a fledgling industry in Kenya; most activities are in the pilot, research, or demonstration phase and are predominantly undertaken by government agencies, nongovernmental organizations (NGOs), and research institutions. However, several initiatives in recent years have promoted both bio-ethanol and biodiesel and were spearheaded by both the Ministry of Energy and NGOs. Such initiatives have seen the creation of a National Biodiesel Strategy and a National Bio-Ethanol Strategy. The latest revisions to the National Energy Policy, although not yet enacted, emphasize the role of biofuels in helping to meet the country's increasing energy needs. The motivation for this development is both economic and environmental.

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4 http://africabiogas.org/kenya/

In **Rwanda**, biomass provides about 80 percent of household energy, in the form of wood used directly as a fuel (57 percent) or converted into charcoal (23 percent). Nearly three-quarters of Rwanda's urban population (72 percent) relies on charcoal for cooking and related purposes and the share is growing (Blodgett 2011). Despite the dominance of wood as an energy source and an annual turnover of US$115 million (5 percent of GDP) of which 50 percent remains in rural areas (Biomass Energy Strategy, Rwanda 2009), biomass energy has an estimated deficit of 3 million cubic meters annually. This results from stresses on forestry resources in various parts of the country, including Bugesera district, which is considered a hotspot for potential climate change impacts.

To address this deficit, especially for cooking needs, the valued added tax (VAT) on LPG (liquified propane gas) has been waived. This helped reduce charcoal consumption in urban areas (Law No 25/2010 of 28/05/2010 modifying and completing Law No 06/2001 of 20/01/2001 on the VAT code). Rwanda also aims to reduce fuelwood consumption through the installation of biogas digesters (National Domestic Biogas Program 2009), distribution of efficient cookstoves, and installation of solar water heaters in residences and institutions such as schools, hospitals, and prisons. This will be backed by efficient charcoal production countrywide.

The National Forest Policy (2010) has set a target of 30 percent forest coverage by 2020 through afforestation projects (with a first phase of 10,000 hectares under PAREF I and PAREF II) with support from the Netherlands. Decentralization of forest management to the local level and regulations on tree cutting are among actions to support sustainable use of biomass resources. The Forest Act, National Population Policy, and National Decentralization Policy that was revised in 2012, all seek to strengthen the management of biomass resources. According to the 2013 Rwanda Supply Master Plan, demand scenarios for fuelwood and charcoal indicate that under prevailing conditions the need for woody biomass for energy and construction will be 5.7 million tons in 2020 (compared to 4.2 million tons in 2009). In an alternative scenario with all effort taken to decrease demand and increase efficiencies (through high penetration of improved cookstoves, improved charcoal making, and increased use of LPG and household biogas), 4.41 million tons could be saved. Under that scenario, Kigali City will account for 19 percent of the national demand. It is necessary to look at additional interventions, such as additional tree planting through agro-forestry programs.

In **Tanzania,** wood in the form of firewood and charcoal is the main source of fuel for 90 percent of households (both rural and urban). An estimated 9.3 million households[5] and most public institutions use traditional cookstoves that use firewood and/or charcoal. Poor households spend a considerable share of household resources (up to 35 percent[6]) to meet their domestic energy needs using biomass fuels. Most households rely on inefficient stoves like the traditional 3-stone method for cooking. The annual per capita consumption of biomass fuels is about 1.0 cubic meters (BEST 2014). To meet current demand for biomass people are forced to over-harvest existing natural resources. Increased demand for wood for cooking, coupled with inefficient cooking technologies, have led to environmental degradation and created energy scarcity for the majority of the population, in both rural and urban areas.

Charcoal is one of the largest sources of cash income in rural Tanzania. Many rural and urban people are engaged in the production and supply of charcoal (BEST 2014). Charcoal and commercial firewood

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5 National Bureau of Statistics, Tanzania Census: 2012 Population and Housing Census General Report (Dar es Salaam, NBS, 2013).

6 SNV, Household energy survey in the Lake Zone Region (Dar es Salaam/Tanzania, SNV, 2012).

generated approximately TZS1.6 trillion (~US$1 billion) in revenues for actors along the value chain (BEST 2014). Charcoal demand has nearly doubled over the past ten years (NBS 2013) driven by rapid urbanization and high relative prices or scarcity or unavailability of alternative fuels, such as electricity, biogas, biomass briquettes, and LPG. A World Bank report (2010) on the charcoal situation in Tanzania indicated that 100,000–125,000 hectares of forest loss annually is attributable to unsustainable charcoal production.

Sawdust is produced in large quantities in areas with many sawmills, such as Iringa, Tanga, and Kilimanjaro, but it is not normally used. A small percentage is used to make biomass briquettes and burning bricks. According to the MEM, there are two companies—MENA Briquetting Company (Iringa) and Kilimanjaro Industrial Development Trust (Kilimanjaro)—use sawdust to produce biomass briquettes that are mainly used by institutions such as schools and hospitals. In 1990 and 2002, the Ministry of Agriculture and Livestock estimated that residues generated from major crops in Tanzania amounted to about 15 million tons per year. Since then, no other estimates have been published. However, crop-residue ratios can be used to estimate current amounts of residues. A few private companies have launched initiatives to convert agricultural residues, including coffee husks, coconut shells, rice husks, and rice straw, into briquettes and pellets as a substitute for firewood and charcoal. Most of the factories operate below their capacities due to low demand due to low awareness of this energy type among most Tanzanians (MNRT 2010).

(a) Biogas

Tanzania generates 25 million tons of animal waste per year, mainly from cattle, goats, and sheep (MEM 2003), which can be used to produce biogas using digesters. Two independent feasibility studies[7] in 2007 indicated that there was a potential market for around 165,000 bio-digesters in Tanzania. To tap this market potential, SNV and CAMARTEC, through the Tanzania Domestic Biogas Program, adopted a market-led approach that could lead to a viable, large, and sustainable domestic biogas market (Nes et al., 2009). Between 2008 and 2013, a total of 8,796 biogas plants[8] were installed countrywide.

(b) Biofuel

Tanzania has significant potential to produce crops that can be used to produce biofuels. Agricultural crops like sweet sorghum, cassava, and sugarcane have the most potential for ethanol production (GTZ 2005). The Petroleum Act of 2008 recognizes biofuels as a potential option for blending with petroleum products. In 2010, the government developed a Guideline for Sustainable Liquid Biofuels Development that stipulates the minimum requirements to ensure that biofuels development does not compromise environmental sustainability.

Ethanol production relies mainly on sugarcane. The potential for ethanol production from the four sugar industries in 2004/2005 was estimated to be 20 million liters per year (GTZ 2005). Currently, Kilombero Sugar Company produces uses molasses to produce about 750,000 liters of ethanol per year a large portion of which is for industrial use (especially Tanzania Breweries Limited). Recently, a small quantity (20,000 liters) has been reported to be supplied to SAFI Tanzania for domestic cooking. Kilimanjaro

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7 Feasibility study for the potential biogas in northern regions of Tanzania (F. Maree and Marloes, May 2007) and Feasibility study for a national domestic biogas program in Tanzania (Thomas Schmitz, GTZ, June 2007).

8 http://www.biogas-tanzania.org/tdbp/about/category/archievements

Biochem Ltd has set up a bio-ethanol plant with a capacity of 22,000 liters per day at Mwanga in Kilimanjaro Region. The company's distillery converts molasses, a waste product from Tanzanian sugar plants into extra neutral alcohol (96.4 percent) and technical grade alcohol (94 percent) for medicinal use and fuel. Also, EcoEnergy Africa AB, a Swedish company, wants to install a distillery with capacity to produce about 10 million liters of ethanol per year.

(c) Power generation

An estimated 58 MW of electricity is generated in Tanzania (Tanzania MEM 2014). Four sugar factories use bagasse to generate 12.5 MW for their own use and supply surplus to the national grid. Excess bagasse from the four factories had estimated energy generation potential of about 99.42 GWh per year (Ngeleja 2003, Gwang'ombe 2004). EcoEnergy Africa AB aims to use bagasse to generate 100,000 MWh and provide electricity to 100,000 rural households. Forest biomass is also used for cogeneration of electricity and heat. According to the Energy and Water Utilities Regulatory Authority, one power plant owned by Tanganyika Wattle Company used wood waste to generate 2.5 MW of electricity, of which 1.5 MW is supplied to TANESCO's national grid. Sisal wastes have potential to generate about 46 MW (MEM 2004). Mkonge Energy System, a private company[9] in Tanga Region has installed a unit of biogas plant in one of the estates[10] that produces 150 kW of electricity, enough for use in machines used for sisal processing.

In **Uganda**, natural forests and woody biomass cover 4.9 million hectares of the total land area of which 30 percent is in protected areas and 70 percent is private forest. Tropical high forests cover 924,208 hectares, forest plantations 35,066 hectares, and woodlands 3,974,102 hectares. The county's Permanent Forest Estate is in protected areas (NFA 2009), with 1.9 million hectares representing about 9 percent of the total land area of Uganda (UWS 2005). The Central Forest Reserves cover 1,270,797 hectares, forested regions in protected areas 731,000 hectares, and local forest reserves 4,997 hectares (Kayanja and Byaruhanga 2001).

With only 5 percent of the rural population having access to electricity, more than 90 percent of Uganda's total energy needs come from biomass sources. Of this, wood accounts for 80 percent, charcoal 10 percent, and crop residues nearly 4 percent. The use of dung for fuel is rare, although recent implementation of a national biogas program is seeking to use it more on a domestic scale.

The 2009–10 Household Survey (Uganda National Bureau of Statistics) showed that 82 percent of households use firewood for cooking and 15 percent use charcoal. Firewood was most commonly used by rural households (86 percent) while charcoal is commonly used in urban areas (70 percent). In Kampala, 76 percent of the population use charcoal as their main source of fuel for cooking. Firewood is the most highly consumed primary fuel with annual consumption of about 28 million tons of tree biomass. Another 16 million tons of wood is annually transformed into 1.8 million tons of charcoal using highly inefficient kilns (MEMD 2013). In 2006, annual biomass consumption per capita was estimated at 680 kilograms of firewood for rural areas and 240 kilograms for urban areas and 4 kilograms of charcoal for rural areas and 120 kilograms for urban areas. Charcoal is preferred to firewood (particularly by urban consumers) because it has a higher energy density than wood. Its high-energy content per unit weight makes it is easier to transport than wood, particularly for distant markets far from the forest. When used for cooking, it is

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[9] The company owns three sisal estates in Tanga region.

[10] Hale Sisal Estate in Korogwe District, Tanga Region.

substantially more efficient than wood and does not burn with much smoke. As a result, many people consider charcoal a relatively modern fuel rather than a traditional one.

However, Uganda's rapid population growth and rapid urbanization has increased energy demand, especially demand for cooking fuel. Unfortunately, the growing demand has not been matched by growth in the supply of alternative sources of fuel and concern about the deteriorating state of the country's forest cover is increasing. According to Uganda's National Forestry Authority (NFA), over 73,000 hectares of private forest is cleared every year and over 7,000 hectares of protected forest reserves is destroyed to obtain timber and charcoal. This is a significant increase from the estimated 50,000 hectares in 2004. The National Environment Management Authority (NEMA) reports that Uganda has lost 2.3 million hectares (about 76 percent) of its forest cover since the start of the 20th century.

Uganda's National Biomass Energy Demand Strategy 2001–2010 estimated that firewood, charcoal, and residues met more than 97 percent of the total energy requirements representing a rise in demand of 7 percent since 2008 (Republic of Uganda 2001). Further, the demand for biomass energy rose proportionally with the country's population, which was estimated to be increasing 3.6 percent per year in 2008. The NSE statistics add further to this scenario by concluding that the dominant use of biomass for household energy supply is the single most important cause of deforestation in Uganda and a major factor in household productivity as deforestation leads to increases in the distance and time required to gather fuelwood. Biomass resources are under threat because forests, the primary source of biomass, are being destroyed without corresponding investments in biomass production. There is very little effort to process and add value to the large amounts of agricultural residues left to rot in the fields.

The Uganda Forestry Policy has an objective to establish an integrated forest sector that "achieves sustainable increases in the economic, social, and environmental benefits from forests and trees by the people of Uganda, especially the poor and vulnerable." The policy provides information that is relevant to biomass energy and sustainable forest management.

According to MEMD (2013), about 2.3 million tons of agricultural and forest wastes are consumed annually by households and rural processing industries. These wastes include bagasse, rice husks and straws, sawdust, maize cobs, and coffee husks. GVEP (Global Village Energy Partnership) International, through the Developing Energy Enterprises Programme, has promoted use of briquettes in Uganda. By September 2011 there were 139 small-scale briquettes businesses operating in Uganda. The total number of briquettes produced by these enterprises was 16,750 kilograms per month, over 200 tons per year, representing a very small fraction of national charcoal consumption (Ferguson 2012). However, this energy type needs concerted efforts to promote.

(d) Power Generation

Sugar factories consume significant amount of biomass in the form of bagasse for heat generation. Use of biomass in other industries is relatively low, but is increasing and many industries are switching from heavy furnace oil to agricultural wastes to meet their thermal energy and power requirements. They sell the surplus to the national grid. Kinyara has a 14.5 MW power plant with plans to increase it to 35 MW by 2015. Kakira commissioned a 52 MW high-pressure boiler plant in May 2013. Tilda has plans to install a 1 MW electric power plant that will use rice husks.

1.3.3 Solar Energy

Burundi has significant solar potential. Average annual insolation is approximately 2000 kWh/m^2. The government has plans to install photovoltaic (PV) systems countrywide in rural areas, especially in boarding schools, health centers, and households.[11] In 2006, 26 administrative centers were equipped with solar systems with support from United Nations Development Programme (UNDP) and from 2006 to 2011, 30 health centers and 20 community colleges were equipped with systems by the Directorate General for Energy. Since 2012, street lights along the main roads in Bujumbura have been powered by solar energy.

Kenya receives daily insolation of 4–6kWh/m^2. Solar energy is mainly used for PV systems, drying, and water heating. The PV systems are used for telecommunications, lighting, and water pumping. Among the barriers to greater exploitation of solar energy are high initial capital costs, low awareness of the economic benefits, and a lack of adherence to system standards by suppliers. The government has eliminated the import duty and the VAT on renewable energy equipment and accessories. The Energy Regulatory Commission has prepared the Energy (Solar Water Heating) Regulations 2012 and The Energy (Solar Photovoltaic) Regulations 2012 to provide a policy framework for enhanced utilization of solar energy.

Small PV systems with capacity of 12–50 Watt peak (Wp) have large-scale market penetration in Kenya. In 2014, more than 6 MW of solar PV system capacity was installed in residential and commercial sectors through the private sector initiatives. As of December 2014, solar PV systems had been installed in 2,050 primary and secondary schools, dispensaries, health and administrative centers, and other institutions. It is projected that the installed capacity of solar photovoltaic systems will reach 100 MWe generating 220 GWh annually by the year 2020 (MEP 2015).

Thermal applications of solar in Kenya include water heating systems, mainly used in homes, hotels, hospitals, and learning institutions. Demand for the systems is projected to grow to more than 800,000 units by 2020; this indicates a growth rate of 20 percent per year. This demand is due to increased awareness of the systems and operationalization of the Energy (Solar Water Heating) Regulations, 2012. The Government of Kenya promotes solar/wind hybrid electricity generation systems to replace isolated diesel power stations in off-grid areas.

In **Rwanda**, Solar PV systems (grid and off-grid) are also spreading in remote areas, especially in rural households and in boarding schools—more than 300 schools are already equipped with solar systems for lighting. The Commercial and Operational Date for the first independent power producer of 8.5 MW was launched on September 18, 2014, and connected to the grid.

Tanzania has high levels of solar energy with a global radiation of between 4–7kWh/m^2 per day.[12] This makes it suitable for the application of solar energy for lighting, heating, drying, and generating electricity. The solar energy subsector is still under development; its use is mainly in commerce, social centers, and domestic sectors. There are about 6 MWp of off-grid solar PV systems installed countrywide for applications in schools, hospitals, health centers, police posts, street lighting, telecommunication, small enterprises, and households. The Power Sector Master Plan envisages 120 MWp of solar in the power generation mix plan by 2016. Already, several private firms want to invest in 50–100 MWp of solar PV projects and connect to the national grid. TANESCO has signed two agreements for the 3 MWp solar projects (MEM 2014). Solar thermal is mainly used for drying crops, wood, salt, and water heating. Solar dryers are used in the agricultural sector for drying coffee, pyrethrum, pineapples, vegetables, and

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11 GIZ: EN-regional report, 2009

12 European Commission, Joint Research Centre, Photovoltaic Geographical Information System - Interactive Maps, http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?map=africa

mangoes. The Sokoine University of Agriculture, University of Dar es Salaam and the Tanzania Traditional Energy Development Organization (TaTEDO) are the pioneers and main promoters of this technology.

In **Uganda**, solar data indicate that the resource is high throughout the year. With mean insolation of 5.1 kWh per m^2 per day, Uganda has a potential 11.98 x 108 MWh of gross energy resources. At an estimated conversion efficiency of 10 percent, the country has available power of 11.98 x 107 MWh. According to the Renewable Energy Policy, the total new installed photovoltaic capacity annually is estimated at 200 kWp for households, institutions and commercial use and solar thermal has a great potential in the form of solar water heaters in electrified areas. Small solar water heaters are useful in remote areas, particularly for rural clinics and in areas with tourism, to provide cheap, reliable, and green energy (MEMD 2007).

Solar PV electricity is not generated in quantities worth connecting to the national grid. This may be changing, however. As a matter of policy, the government is seeking to increase energy security, in part through diversification into other sources, such as the use solar PV–generated electrical energy. In April 2014, the Board of ERA took action to assist this process and approved a FiT of 11 cents (US$) per kWh for grid-connected solar PV energy.

The Uganda program is part of the Global Energy Transfer Feed-in Tariffs (GET FiT) program, the main objective of which is to help countries in East Africa to pursue climate-resilient, low-carbon development that not only promotes climate change adaptation but also produces economic growth and long-term poverty reduction. The GET FiT Uganda Program, which was jointly developed by the Government of Uganda, the ERA, and KfW, was designed to leverage private investment into renewable energy generation projects in Uganda. Selection of the first 20 MW of solar PV projects to be developed has been completed. As the ERA expects that the grid can handle integration of some 50 MW of solar PV, GET FiT and the ERA are using the current window of opportunity and high developer interest to further strengthen Uganda's solar project portfolio (GET FiT 2014).

1.3.4 Wind Power

Burundi has wind power potential of less than 4.8 m/s. Hence, the source is not technical feasible for power generation. However, more feasibility studies are needed to verify wind potential (SWERA atlas[13]).

Kenya's draft National Energy Policy (2014) confirms the country's huge potential for wind electricity generation, estimated as 346 Watts per square meter and speeds of over 6 m/s in various parts of the nation. The Ministry of Energy developed a Wind Atlas in 2008 with indicative data. The installed capacity provided to the grid by wind energy was 5.45 MW as of November 2014. Wind projects are at different stages of development, including the 300 MW Lake Turkana Wind Farm Project, 100 MW Kajiado-Kipeto Wind Farm, 61 MW Kinangop Wind Project, 50 MW Meru Wind Project, and 150 MW Marsabit Wind Project.

In **Tanzania,** the preliminary results of a World Bank/ESMAP (2015) mapping exercise showed that more than 10 percent of Tanzania has high wind power potential for commercial electricity generation. Several ongoing initiatives are assessing potential wind sites. Kititimo (Singida) and Makambako (Iringa) areas have been identified as having adequate wind speeds for electricity generation at a scale sufficient for grid connection. The wind speeds average 9.9 m/s at Kititimo and 8.9 m/s at Makambako, at a height of 30 meters; while the generation potential for these areas ranges between 50 and 100 MW. In central

13 SWERA: Solar and Wind Resource Assessment—World Atlas developed by the National Research Energy Laboratory/ United Nations Environment Programme

Tanzania, especially Singida and Dodoma, wind energy is being used for mechanical works such as milling and water pumping.

In **Uganda**, the wind speed in most areas is moderate, with average speeds ranging from 2 m/s to about 4 m/s (Renewable Energy Report, 2012). The Meteorology Department has indicated that the country's wind resource is only sufficient for small-scale generation and for some special applications, such as water pumping. Small industries in rural areas where the energy requirements for a mill typically range from 2.5 kVA to 10 kVA could benefit from wind-based generation. In general, wind speeds in northeastern Uganda (Karamoja) and on the shores of Lake Victoria may be adequate for some level of generation. In these areas, wind speeds of 1.5 m/s–5 m/s have been recorded for reasonable periods (ERA 2012).

1.3.5 Geothermal Power

Burundi is in the Great African Rift Valley with high potential for geothermal energy. However, this energy source has not been well exploited and feasibility studies are needed to assess technical potential.

In **Kenya**, the Least Cost Power Development Plan 2011–2031 (GOK 2011), indicates a potential of about 7,000 MW from its geothermal resources. The proposal is to have most of the national power generated from geothermal resources to ensure sustainability in energy supply.

To actualize this plan, in 2006 the government set up a Geothermal Development Company to lead exploration of geothermal resources. Kenya projects to produce 1,400 MW by 2020, 2340 MW by 2025 and 5,000 MW by 2030 from geothermal resources. According to MEP, there are more than 14 sites with high temperature potential along the Rift Valley with an estimated potential of more than 10,000 MWe. Other locations include Chyulu, Homa Hills in Nyanza, Mwananyamala on the coast, and the Nyambene Ridges. Data from the Energy Regulatory Commission (ERC[14]) indicate that the share of electricity generated from geothermal sources stood at 48.6 percent of the total in February 2015.

Tanzania has significant potential for geothermal energy, with more than 50 sites identified within the East African Rift System. These are the in the northeast (Kilimanjaro, Arusha, and Mara regions), the southwest (Rukwa and Mbeya regions), and the eastern coastal belt, which is associated with rifting and magmatic intrusions (Rufiji Basin). The potential is estimated to be more than 5,000 MW (Mnjokava 2014). The Tanzania Geothermal Development Company Ltd (TDGC), a subsidiary of the TANESCO, has been established to develop and use geothermal resources. Geothermal projects are planned to add 100 MW to the grid in 2020, 500 MW in 2022, and 800 MW in 2025.

In **Uganda**, studies have been done on more than 40 geothermal sites, including theirfor parameters including temperature, chemistry, natural heat transfer, and fluid characteristics. These investigations identified three potential areas for more detailed investigation—Katwe-Kikorongo, Buranga, and Kibiro. All three are in or near the Western Rift Valley in a zone of recent volcanic activities. The Ugandan Rift System is estimated to have about 450 MW of geothermal resources.

A five-year strategic plan for the development of geothermal resources of Uganda has been developed. It will review the existing policy, institutional, and regulatory framework with a view to proposing the necessary legal and institutional framework to fast-track geothermal energy development. The overall

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[14] http://www.businessdailyafrica.com/Geothermal-share-falls-for-second-month-in-a-row/-/539546/2663390/-/oubw5lz/-/index.html

objective of the strategic plan is to carry out a pre-feasibility study of Katwe, Buranga, Kibiro, and Panyimur geothermal prospects, and to conduct a feasibility study for one selected prospect.

1.3.6 Oil and Gas

Kenya is undertaking on-shore and offshore petroleum exploration in four major Sedimentary Basins: Lamu, Mandera, Anza, and Tertiary Rift. Kenya has recently recorded success in oil and gas exploration. In March 2012, the first commercial reserves of petroleum were discovered in northern Kenya. Additionally, the API gravity of the oil discovered in Turkana County has been estimated to be between 30° and 35°, indicating high-quality oil. According to the MEP (2015), as of January 2015, Kenya had 46 gazetted exploration blocks, of which 41 had been licensed to Oil Exploration and Production Companies. Petroleum development is guided by the Energy Policy 2015 (in draft), Petroleum (Exploration, Development, and Production) Bill 2015 and the Energy Bill 2015. The government is undertaking upstream petroleum operations through petroleum agreements, which include production sharing contracts, concession agreements, and service contracts.

Natural gas exploration is ongoing. According to MEP (2015), between 2012 and January 2015, three exploration wells (Mbawa, Kiboko, and Kubwa) were drilled offshore. A discovery of natural gas was reported in Block L8, Lamu, though it was not commercially viable. Also, Africa Oil drilled the Sala-1 well in Block 9 that had discoveries of natural gas. Evaluation to determine significant appraisal sites is being undertaken.

In **Tanzania**, Gas was first found in the 1970s. Two areas in the southern part of the country (Mnazi Bay and Songo Songo) have a capacity of 2 million and 100 million standard cubic feet per day, respectively. Current buyers are Songas power plant, TANESCO, Twiga Cement Company, and other small customers. Two natural gas power generation projects, totaling 501 MW contribute about 34 percent of the power generation mix. Other projects are under development and their completion will add about 1,500 MW by 2017 (MEM 2014). The Tanzania Petroleum Development Corporation (TPDC) is implementing a pilot project on the use of Liquefied Natural Gas (LNG)[15] for cooking. So far, 57 houses have been connected to domestic piped gas supply in Dar es Salaam. According to TPDC, the results have been impressive and this will result into significant savings on use of forest resources for cooking energy.

In **Uganda**, oil exploration started in the Albertine Rift in the 1920s. Since then, the Albertine region has become the main areas for oil prospecting in Uganda.Today, 20 oil fields support 64 wells, 59 of them productive. Exploration is continuing in 10 areas, including Rhino Camp (Arua District), Pakwach (Nebbi District), Semiliki, and around lakes Albert and Edward. The total potential oil volume in Uganda is estimated at 6 billion barrels. The National Development Plan (2010/11–2014/15) cites the oil and gas sectors as the primary sources of economic growth for the future.

1.3.7 Coal

In **Kenya**, coal deposits for power generation and other industrial uses have been recently studied. Between 2006 and 2014 consumption of coal averaged 172,000 metric tons per year. This is less than 1 percent of the total primary energy consumed in the country (MEP 2015). Explorations in Mui Basin in Kitui County have yielded positive results and the government has issued concessions for coal resource development with the objective of generating about 1,000 MW by 2017. Coal is projected to provide at least 4,500 MW of electricity by 2030 (Kenya 2011). In addition, the government is building a coal-fired

[15] LNG is the liquid form of the natural gas which can be used in homes for heating and cooking

power plant in Lamu County phase 1 of which will have a capacity of 960 MW. Construction of the plant was expected to commence in 2015 with commissioning expected in 2017.

Tanzania has significant quantities of coal with estimated reserves of 5 billion tons (IOL 2013). A total of 84,772 tons was mined in 2013 (BOT 2013). Most of this is being used for electricity generation. Increasing quantities are being sold commercially to institutions (prisons and schools to substitute charcoal and firewood) and to industry. Coal is not common as a source of household energy, due to uncertainties and lack of infrastructure for the promotion and marketing. The Ministry of Energy and Minerals and Tanzania Commission for Science and Technology are exploring coal as a household charcoal substitute and investigating health impacts.

1.3.8 Other Energy Sources

Rwanda is seeking to expand its energy sources, due to increasing energy demand. In addition to expanding the hydroelectric and solar energy capacity, the government is supporting development of methane gas near Lake Kivu. The first 25 MW phase of a total of 100 MW gas-fired power plant is under implementation. The government is also supporting geothermal exploration studies. An estimated 155 million tons of peat reserves are also available and can generate 260 MW. The 15 MW Gishoma project went on line in 2017 and the 120 MW Yumn Ltd project is planned for completion by 2020.

1.4 Impacts of Climate Variability and Change on the Energy Sector

1.4.1 Exposure

Analyses of the spatial and temporal trends in rainfall and maximum and minimum temperatures over the LVB between 1900 and 2014 were discussed in the climate change section. This chapter discusses how spatial patterns of rainfall and temperatures were incorporated with the other elements of vulnerability to devise an energy hotspot vulnerability map.

1.4.2 Sensitivity

The GIS data for sensitivity and adaptive capacity indicators were obtained from the Regional Centre for Mapping of Resources for Development (RCMRD).

For the sensitivity layers, land use and land cover data were drawn from the Anthropogenic Biomes of the World, which categorizes habitats based on their significance.[16] According to the overall sensitivity map, areas indicated as highly vulnerable based on land use and land cover change correlate with areas that experience climate extremes. Slope was derived from the 30-meter Shuttle Radar Topography Mission (SRTM) was normalized to represent areas where the slope was less than or equal to 30 degrees to fit the criteria defined for the energy subsector. Steep gradients increase the potential for damage resulting from fast moving water force and soil erosion. The soil map was derived from the Harmonized World Soil Database to develop a textures map, which was then normalized based on the soil properties and suitability.

The poverty index is based on data from the Demographic and Health Survey and Multiple Indicator Cluster Survey showing the distribution of poverty in the EAC. In general, more poverty means less energy penetration. Population data is based on projected population densities for 2015 from the Global

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16 http://ecotope.org/anthromes/v1/guide/

Populations of the World according to CIESIN/SEDAC. As shown in the map, areas around the lake region have a high projected population density compared to the rest of the EAC. High population leads to high biomass energy demands, making the system highly sensitive to population.

Table 7: Parameters and indicators used in vulnerability mapping of the Energy and Transportation Sector (Sensitivity)

SENSITIVITY LAYER			
Topography	Slope gradient (in %), DEMs SRTM 3 sec (30m)	Slope gradient (in %), DEMs SRTM 3 sec (30m)	❖ Slope and elevation also influence accessibility of biomass for energy
Locational geo-references	Power sites for the EAC	Waterbodies (rivers) road network	❖ Waterbodies affect bridge maintenance
Floods	Flood risk maps	Flood risk maps	❖ Increased flooding improves power generation but destroys surface transportation
Geology	Soil type	Soil type	❖ Soil type/particle size affects the stability, drainability, erodibility and hence suitability for road/dam construction, harbors, airports, etc.
Drainage and river basins	Rivers	Rivers	❖ Every hydropower station is associated with a drainage basin ❖ Presence of rivers increases potential for flooding, bridge construction, maintenance, etc.
Economic development	Poverty index	Poverty index	❖ Higher poverty levels lead to more biomass energy demand and hence degradation of land cover ❖ Reduces tax revenues for transport infrastructure repairs
Population	Population density	Population density	❖ Higher population leads to more biomass energy and transport demand and hence degradation of land cover

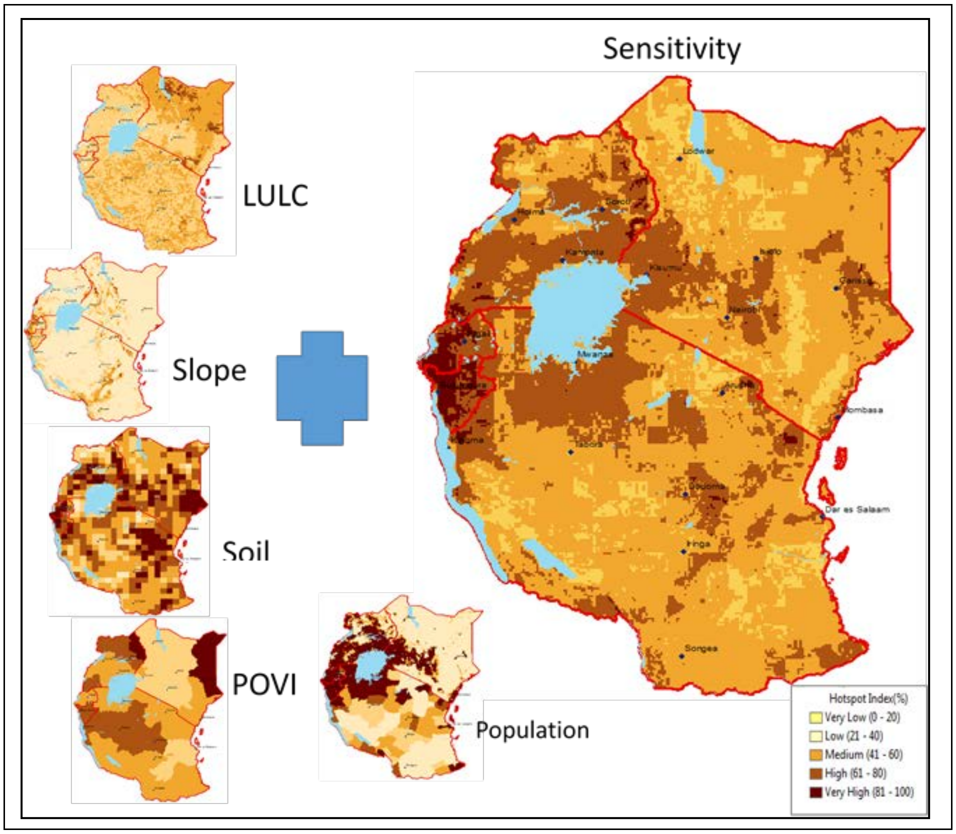

Figure 3: Sensitivity Map for the energy sector, LULC = land use and land cover, POVI = poverty index

1.4.3 Adaptive Capacity

The adaptive capacity map is based on two indicators: market access and water aquifer recharge. The proxy indicator for market access was travel time in minutes. The threshold used to define very high vulnerability was 12 hours of travel time to urban centers. In the EAC, areas around Lake Victoria generally are more accessible than the border areas north of Kenya and south of Tanzania.

Water recharge data were provided by FEWS NET and represents aquifer recharge. The areas of highest vulnerability are those that registered high water discharges. This data set is important for informing the location of potential energy power stations.

Table 8: Parameters and indicators used in vulnerability mapping of the Energy and Transportation Sector (Adaptive Capacity)

ADAPTIVE CAPACITY LAYER			
Water discharge and recharge	Water recharge	Water recharge	❖ High water discharge may imply more potential for power generation but high transport maintenance costs
Access	Market access	Market access	❖ Long travel time to an urban center significantly reduces adaptive capacity

Indicators were chosen according to their suitability and where the data set was not very good, alternatives had to be sought. Each indicator was normalized to a predefined range (0–100) to allow comparison of different data sets. Each data set was then evaluated for the "direction" it contributes to vulnerability (such as high value of poverty is high value of vulnerability, low variability in precipitation is low vulnerability). Weighting values were also based on the confidence that indicators were characteristic of the total population. Indicators that were not representative across the region or with the potential for redundancy in the explanatory power of the model were reduced in importance through weighting and were not always excluded.

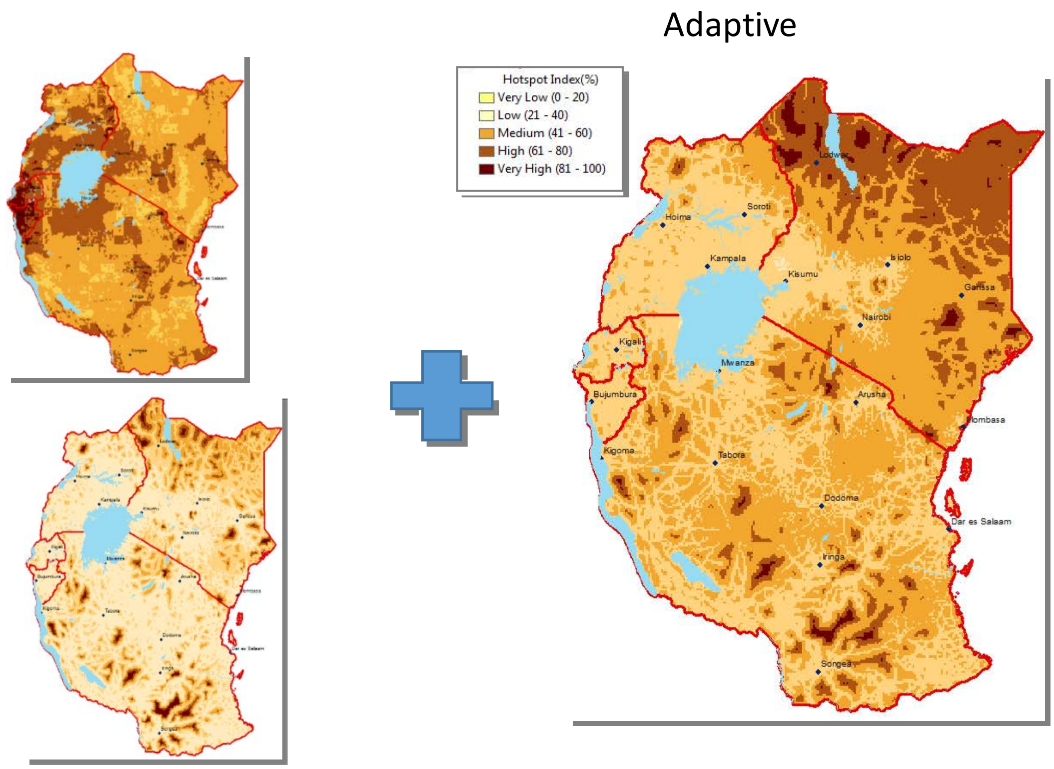

Figure 4: Adaptive capacity map for the energy sector

1.4.4 Vulnerability

All work was conducted using ArcGIS and QGIS software to map and visualize the data. Each theme was imported from statistical database files into separate layers in ArcMAP. Each theme layer was then converted to raster format and the overall score was calculated using map algebra and the appropriate weighting. Both adaptive capacity and livelihood sensitivity were modelled as positive conditions of resilience, while exposure risk was modelled as a negative condition. The vulnerability map was then produced by combining the exposure, sensitivity, and adaptive capacity layers using spatial analyst tools in QGIS. All layers were given equal weights resulting in the vulnerability maps for the energy sector shown in Figure 6.

Figure 7 shows the map of the overall vulnerability (hotspots) with respect to the energy sector.

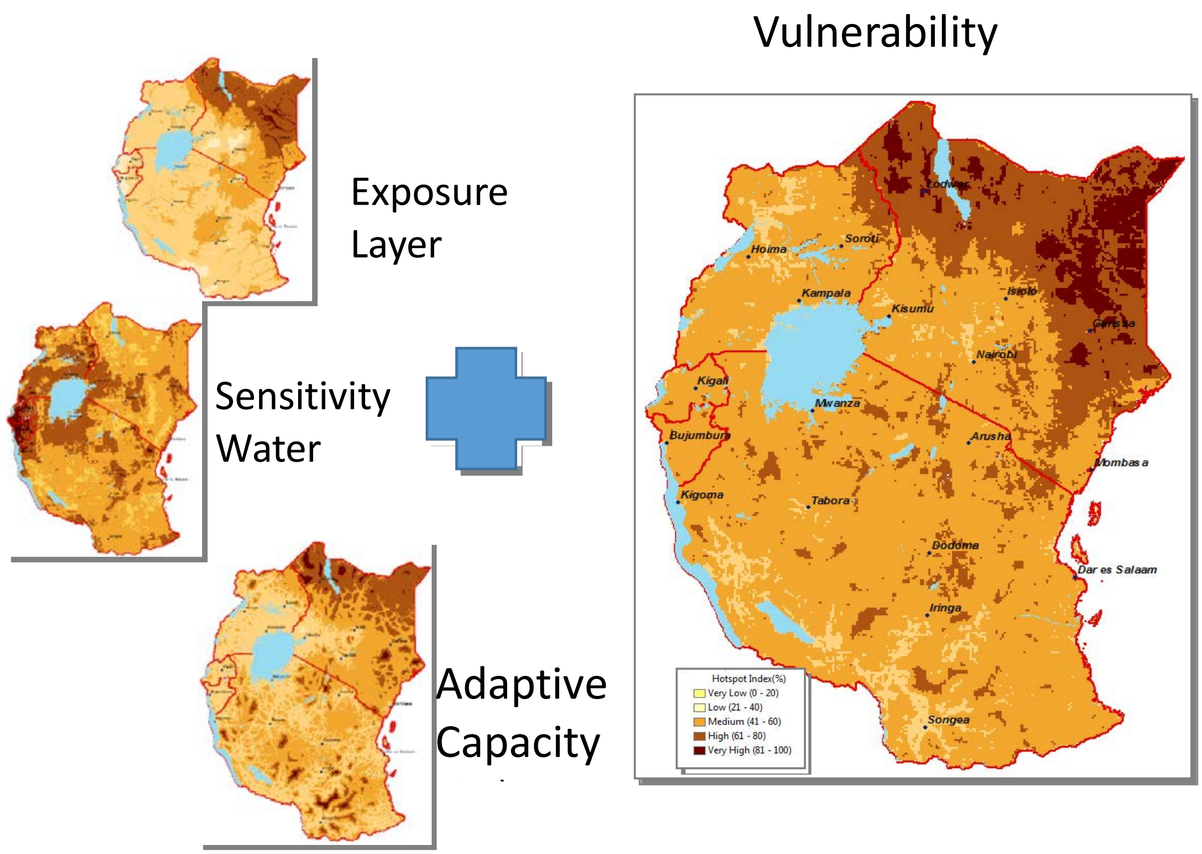

Figure 5: Overall vulnerability map for the energy sector

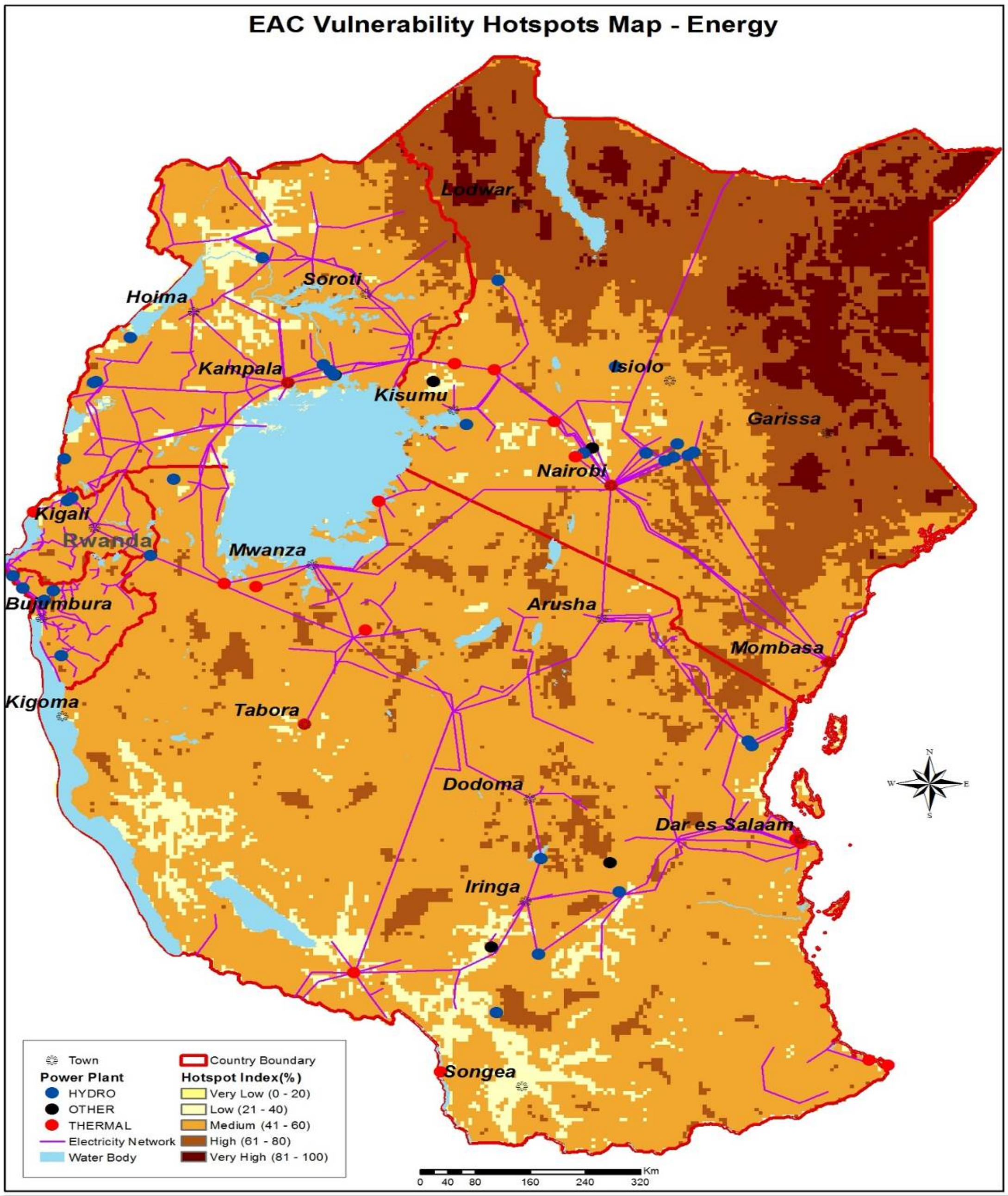

Figure 6: EAC vulnerability hotspot map – energy sector

All five East African states rely heavily on hydropower, which is vulnerable to changes in precipitation. Any predicted change in rainfall will therefore have a direct impact on power generation capacity. Within the LVB, hydropower stations within and with catchments in the basin are of particular interest. Other than existing installations, all five countries have plans to tap into the potential of hydropower, especially mini and pico-hydropower stations. Negative changes in precipitation will reduce their potential and hence are a risk for consideration during planning.

Proposed hotspots within the LVB are as follows:

- **Burundi:** Rwegura and Mugere rivers, which support the largest input of hydropower in Burundi are prone to floods and landslides. Mugere (5MW) and Rwegura (18MW) were hampered by droughts in 2012–2013 though they are not located in the LVB.

- **Kenya:** The Gogo Falls along Kuja River in Migori County and Sosian power station on River Sosiani in Uasin Gishu County are vulnerable. However, the biggest proportion of hydropower electricity is generated in the Upper Tana Basin along the Tana River, which is not in the LVB.

- **Rwanda:** Of major concern are the southern, western, and northern provinces, which are prone to floods, siltation, landslides, and falling water levels. Special attention will need to be given to new hydro plants that are now being constructed in the same areas (Nyabarongo commissioned with 29MW, Rukarara I commissioned with 9.5MW, Rukarara II commissioned with 5MW) and another 120MW planned in the near future on the Nyabarongo River.

- **Tanzania:** None of Tanzania's six hydropower installations are in the LVB. However, Nyumba ya Mungu power station and Nyumba ya Mungu water reservoir would serve as a suitable case study for climate vulnerability. Rufiji River remains the main source of hydropower generation through the Mtera and Kidatu hydropower plants. These installations are critically affected by changes in precipitation in the Rifiji catchment.

- **Uganda:** The main hydropower stations with an estimated potential of about 2,000MW lie along the While Nile, the source of which is Lake Victoria. The key installations include the Bujagali, Kiira, and Nalubaale hydropower plants. Water levels in Lake Victoria are key to their functioning. For example, the decrease in lake levels from 2004 to 2008 was reflected in the hydropower production and supply of the two plants (UNEP 2009). The sharp drop in levels was attributed to low rainfall in the headwaters of the rivers feeding the lake, combined with high evaporation from the lake surface and significant drawdown due to increased power generation from Nalubaale Dam to meet growing electricity demand. Several mini-hydropower stations in the western region of Uganda are served by rivers originating from the glaciers of Mount Rwenzori. The ice cap on the mountain is retreating, possibly due to climatic change. The melting of the ice caps on tropical mountains has a negative effect on both water catchments downstream and eco-tourism, as well as on the overall economy. While the focus of the VIA assignment is the LVB, the Ruwenzori Mountains would be worth analysis as well.

The following can be discerned from the vulnerability map:

- In certain cases, non-climatic variables contribute more to sectoral vulnerability than climatic variables. For example, soil types and slope contribute more to the vulnerability of the transportation sector, while population, poverty levels, and land use and land cover changes have more impact on the energy sector compared to the climate stressors.

- The concentrated population within the LVB leads to higher sensitivity to changes in the climate variables, and renders entire countries, like Burundi and Rwanda, highly vulnerable.

- The flat terrain of sections of western Kenya also makes them more sensitive to precipitation exposure and therefore more prone to flooding.

- Rising temperatures may lead to higher evapotranspiration, which reduces the amount of water available for hydropower dams.

- Certain climatic changes may represent opportunities for adaptation. A case in point is the opportunity for investment in the development of alternative energy sources like solar photovoltaics, solar heating, and wind power generation with rising temperatures. A comparison of the wind and solar map for Kenya shows that the northern and northeastern regions, which are vulnerable with respect to hydropower, have the highest potential for solar and wind power development.

- The vulnerability mapping also shows that some climate impacts manifest far from where the changes themselves are occurring. An example is the Tana River basin in Kenya where reducing rainfall in the Mount Kenya Region results in reduced power generation downstream in the Seven Forks system.

- Rainfall data correlated with power generation exhibit a direct relationship between the two. Temperatures changes, however, apart from being correlated with rainfall can also have localized impact by increasing evapotranspiration. The reduced river discharge may also have negative impacts downstream for irrigation.

- The displacement of impacts to areas far from the areas where they are occurring, and the fact that different variables affect different sectors in different ways also suggests the need for a multisectoral approach in evaluating adaptation options. For example, when considering precipitation, focus should not only be on the impact on power generation but must also consider planned irrigation activities downstream, planned infrastructure, as well as other water extraction activities. However, this is not to say that localized impacts should not be the focus. The case of Nyumba Ya Mungu and Mtera Dam (in Tanzania) and Ntaruka Dam Rwanda demonstrates localized impacts can just be as serious.

1.4.5 Impacts of Climate Variability and Change on the Energy Sector

Climate change will pose significant risks, challenges, and opportunities for the energy sector, particularly the renewable energy component. Beyond the challenge of variability in climate, factors such as changes in seasonality, changing patterns of demand, and the changing risk profile of extreme weather and climate events will also challenge the sector.

The energy sector in the EAC Partner States is especially sensitive to climate influences, since climate-sensitive energy sources (biomass and hydro) make up a large share of the energy mix.

The climate variables critical for performance of the energy sector include precipitation (frequency and intensity) and temperature (intensity). Frequencies and intensities of rainfall and temperature determine reliability of hydropower and quantity of hydropower generated. Hydroelectric power plants are sensitive to the volume and timing of river flows. Decrease in precipitation negatively affects the production levels of hydropower plants. Sustaining stream flows to supply dams in the event of reduced inflows presents the potential for conflicts over water access, especially for users in lower riparian areas. On the other hand, heavy rainfall leading to floods has a significant impact on electricity generation and transmission infrastructure (UNEP 2009). Increased rains increase runoff and consequent siltation thus increasing the costs of maintenance of dams. Above-normal rains also lead to downstream flooding due to overflow from dams. Temperature affects the hydrological cycle, which in turn affects water quantity (for hydropower) through regulation of evaporation and evapotranspiration. Temperatures also contribute to fluctuation of wind intensity and frequencies (UNEP 2009). This relationship is illustrated in Figure 8 based on Lake Victoria.

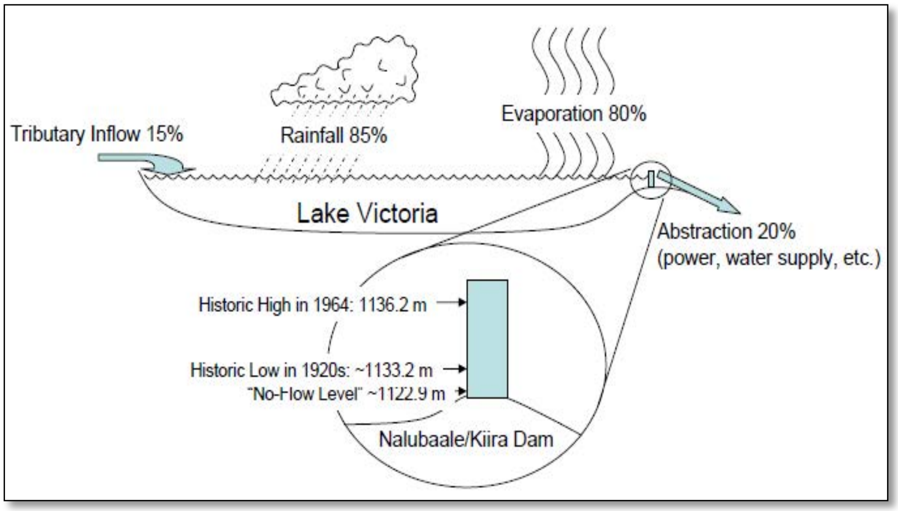

Figure 7: Effects of precipitation and temperature changes on the final impact of water flow for power generation

East Africa is prone to periodic extreme climatic events, including flooding and prolonged dry spells.

According to the Intergovernmental Panel on Climate Control (IPCC), warmer temperatures in East Africa may lead to a 5–20 percent increase in rainfall for December–February (wet months), and a 5–10 percent decrease in rainfall for June–August (dry months). Rainfall changes and variations are not expected to be constant, but rather more sporadic and unpredictable; resulting in periods of prolonged drought and periods of high rainfall leading to floods (IPCC 2007). This has been evident in the last 20 years with prolonged droughts in 1983/84, 1991/92, 1995/96, 2004/2005, and the La Niña–related drought of 1999/2001, all of which led to reduced water levels in the region. Similarly, El Niño–related floods were experienced in 1997/98.

- The 2011 drought affected hydropower generation in most East African countries.
- In **Burundi:** Mugere (5 MW) and Rwegura (18 MW) power stations were severely affected by droughts in 2012–2013.
- In **Uganda:** Several Mini-hydropower stations lie in the western region being served by rivers originating from glacier-covered Mount Rwenzori. The ice cap on the Rwenzori mountains is retreating, with climatic change a possible cause. The melting of the ice cap on tropical mountains has a negative effect on both water catchments downstream and eco-tourism, as well as on the overall economy.

Studies in recent years at both regional and national levels have examined the impacts of climate variability on the energy sector and consequently other economic sectors.

For example, the study "Future Hydropower Scenarios under the influence of climate change for the Riparian Countries of Lake Victoria Basin" in 2010 showed that the LVB suffers from electric power shortages despite its immense hydropower potential. The report concluded that hydropower generation is vulnerable to climate variability and change and that the increasing demand for water due to the rising population and economic growth will only exacerbate this vulnerability. Further:

- A World Bank report in 2006 pointed out that power rationing was causing huge losses in some sectors and put the cost to the economy at $1.7 million per day (World Bank 2006).

- Another study considered possible impacts on hydropower by 2030 under "moderate climate change" and "high climate change" scenarios projected losses of 0.7 percent and 1.7 percent of GDP due to decreased rainfall in the central region of Tanzania, where 95 percent of the country's hydropower installations are expected to be located by 2030 (EAC 2009).

Climate variability and change will severely affect energy infrastructure.

Tanzania's Initial National Communication identified flood damage to hydropower installations on the Rufiji River as a possible impact of climate change (URT 2003). While flooding has not damaged turbines in the past, it is an increasing problem. Smaller projects, such as Hale and Pangani, are filling rapidly due to sedimentation and may be completely full within 15 years. Once they are full, they will only run at 30–40 percent of capacity and will be not able to be used to meet peak demand.

- **Burundi**: Rwegura and Mugere rivers, which support the largest input of hydropower in Burundi, are prone to floods and landslides.
- **Rwanda:** Mapping by the Ministry of Disaster Management and Refugees (MIDIMAR 2012) showed that the southern, western, and northern provinces are prone to floods, siltation, and landslides.

Climate variability and change may cause a serious shortage of electricity and affect the entire economy.

Power rationing for makes an economy more vulnerable to climate change–related disasters and leads to inefficiency in service provision to the public. The following examples illustrate these effects:

- The 2011 drought affected hydropower generation in a majority of East African countries. In Kenya, the Kenya Power and Lighting Co. instituted power rationing for nearly three hours every evening due to generation shortfalls of 70–90 MW due to low dam water levels.[17]
- TANESCO made similar power cuts in Tanzania.[18] It was estimated that the water level at Mtera dam, the largest hydropower reservoir, was receding by almost 3 centimeters per day.[19]
- In Uganda, manufacturing bore the brunt of power cuts as Umeme Company rationed power to industries.[20] The decrease in Lake Victoria levels from 2004 to 2008 was reflected in the hydropower production and supply of the two hydropower plants, Nalubale (Owen Falls) and Kiira Dam (UNEP 2009).
- Mogaka et al. (2006) losses in hydropower generation and industrial production were estimated to cost about US$2 billion due to water shortage during the 1999/2000 drought, which severely affected the Tana River Basin.

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17 http://www.nation.co.ke/news/Blackouts-and-rising-bills-as-drought-bites---/-/1056/1207728/-/43fiow/-/index.html

18 http://www.bbc.com/news/world-africa-14192896

19 http://www.trust.org/item/?map=drought-worsens-power-crisis-in-tanzania

20 http://www.commoditiescontrol.com/eagritrader/common/newsdetail.php?type=MKN&itemid=158432&comid=7&cid1=7&varietyid=,26,&varid=0

Climate and variability may have economic impacts especially on the generation costs, tariffs and power purchase with impacts on the overall economy.

Due to traditional dependence on hydropower, drought years resulted in serious power supply shortages in the EAC Partner States. Most were forced to rely on expensive gas-powered generators and to consider thermal projects for future capacity increases.

- Due to the 2010 drought, the Government of Tanzania had to contract Emergency Power Producers and paid Tshs. 200 billion as part of the cost for the purchase of electric power generator with capacity of 60 MW for Mwanza region and 100 MW for Dar es Salaam region. The government also took emergency measures to reduce power rationing in the national grid by funding the purchase of fuel for running the Independent Power Tanzania Ltd. power plant at a cost of Tshs. 18.5 billion.
- In addition, expensive thermal power plants have significantly contributed to increased generation costs and escalated electricity tariffs in almost all countries. Figures 9 and 10 show tariff trends in Uganda and Rwanda. Figure 11 shows trends in purchase of power from different energy suppliers between 2006 and 2011.

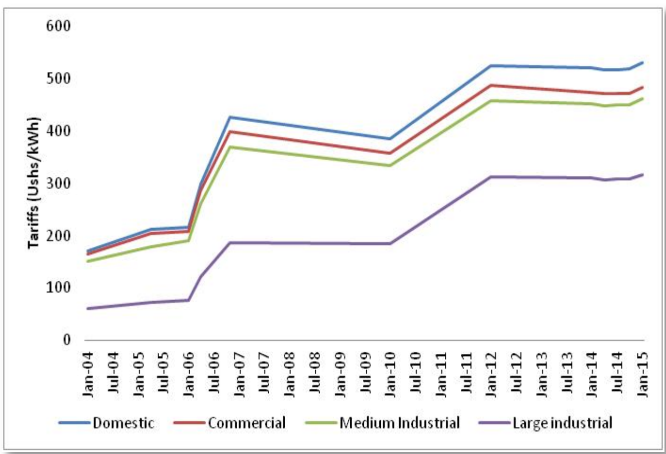

Figure 8: Electricity end-user tariffs (2004 – 2015) in Uganda (source: Uganda Regulatory Authority 2015)

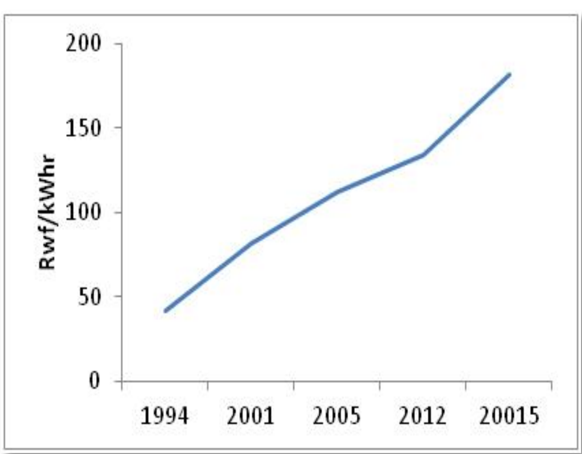

Figure 9: Tariff adjustment for domestic use (VAT exclusive) in Rwanda (source: Rwanda Utilities Regulatory Authority [RURA])

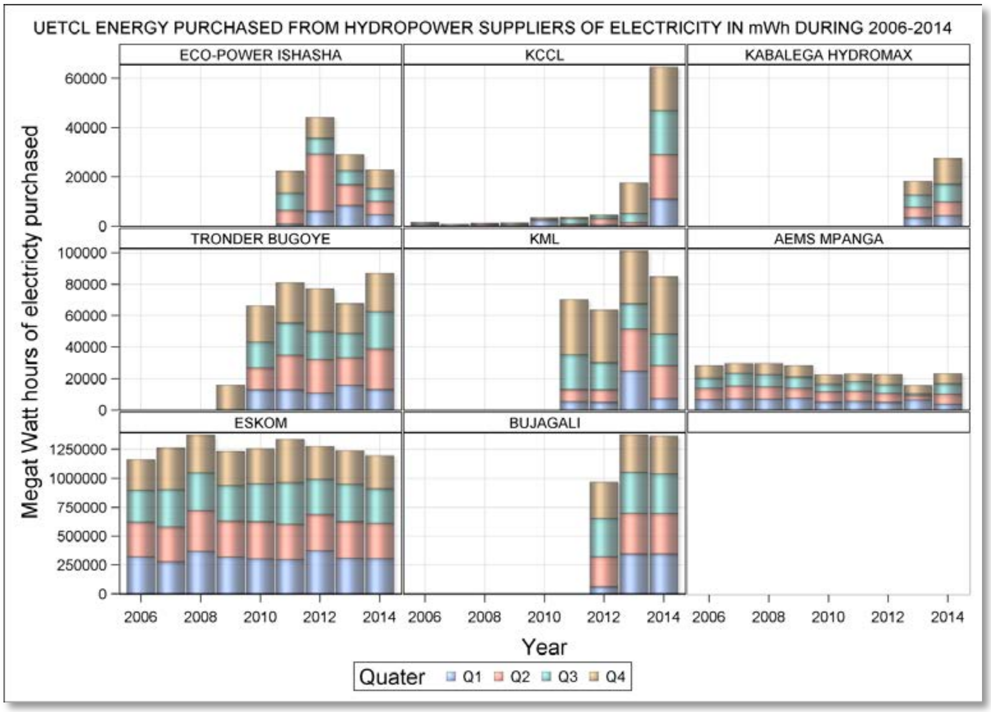

Figure 10: Variation of the quarterly energy purchased from hydropower suppliers from different companies between 2006 and 2014

Rainfall variability has the greatest impact on hydropower generation as trends in precipitation are correlated with trends in hydropower generation and transmission.

(a) Case Study—Tana River, Kenya

Climate variability and change could shift the timing and magnitude of river discharge, which could pose challenges to reservoir systems with limited management capacity. This relationship is illustrated by the Tana River trend analysis.

Figure 12 shows the trend for Tana River, which experienced significant water flow variability between 1981 and 2011. The trend mirrors the climate trend in the basin for the 20-year period with prolonged droughts in 1983/84, 1991/92, 1995/96, 2004/2005, and the La Niña–related drought of 1999/2001. Similarly, there were El Niño–related floods in 1997/98.

Water levels were below average in the drought years, especially 2001 and 2005, while the flows were high and far above the average in 1998 after the El Niño rains. A review of the statistics on power output from the power stations in the Tana River basin mirror this trend as well as trends in power bills due to supplementary electricity fed into the grid from diesel-powered generators whose fuel costs are pegged to the dollar exchange rate, hence resulting in a surge in power costs.

To illustrate how hydropower generation is regulated by climatic components, this study related monthly fluctuations in Tana River discharge (m^3/s) and hydropower generation (GWh) to monthly variation in rainfall. Lagged values (lags 0 to 6 months denoted by rain0 to rain6) and cumulative moving averages (spanning time windows of 2 to 6 months and denoted by mavrain2 to mavrain6) were computed for the total monthly rainfall. Each of the seven components of lagged rainfall and five components of cumulative past rainfall was related, in turn, to the river discharge and power generation at Masinga dam using linear, parametric, and non-parametric non-linear regression models.

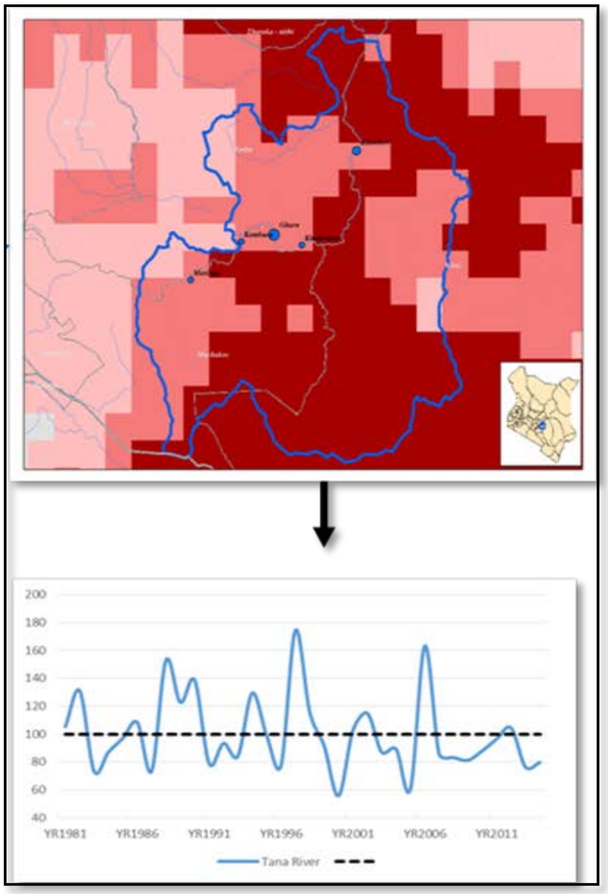

Figure 12: Flow variability – Tana River

The best statistical model relating rainfall with discharge can be expressed:

Discharge= *33.79575206 x exp(0.0068795815 xmavrain2)*

Whereas for hydropower generation the corresponding best model and rainfall component can be specified:

Hydropower generation=9.440610041+1.4237995098xlog(rain4+1).

Figure 13 shows the relationship between rainfall, and discharge at Masinga dam in Kenya. It shows a strong positive relationship using a two-month moving average that gives an almost linear relationship between the two variables. This implies that rainfall is significant in the overall discharge, and hence in hydropower generation. The orange band represents the 95 percent confidence band. Figure 14 shows the relationship between rainfall and power generation at Masinga dam in Kenya. The trend shows a linear relationship between rainfall and power generation at a lag of four months. This means that the instantaneous power being generated is related to the earlier four months rainfall within the basin. The green band is the 95 percent confidence band.

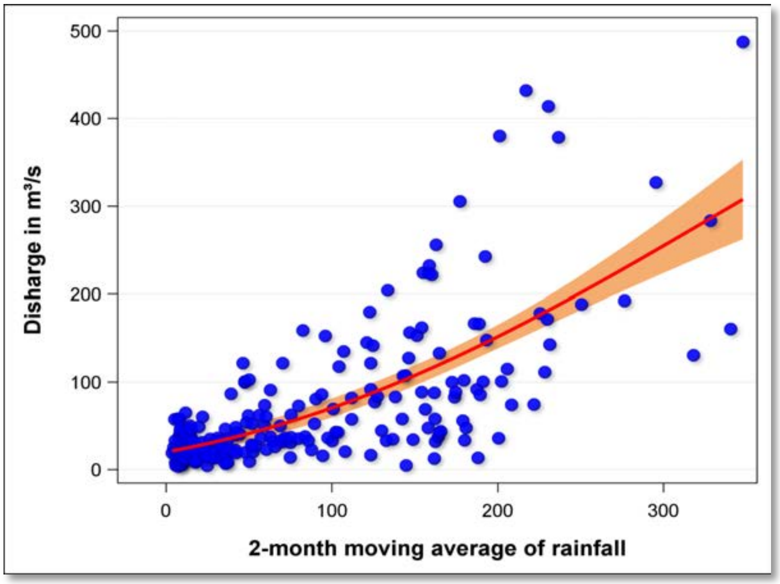

Figure 13: Relationship between rainfall, and discharge at Masinga dam in Kenya

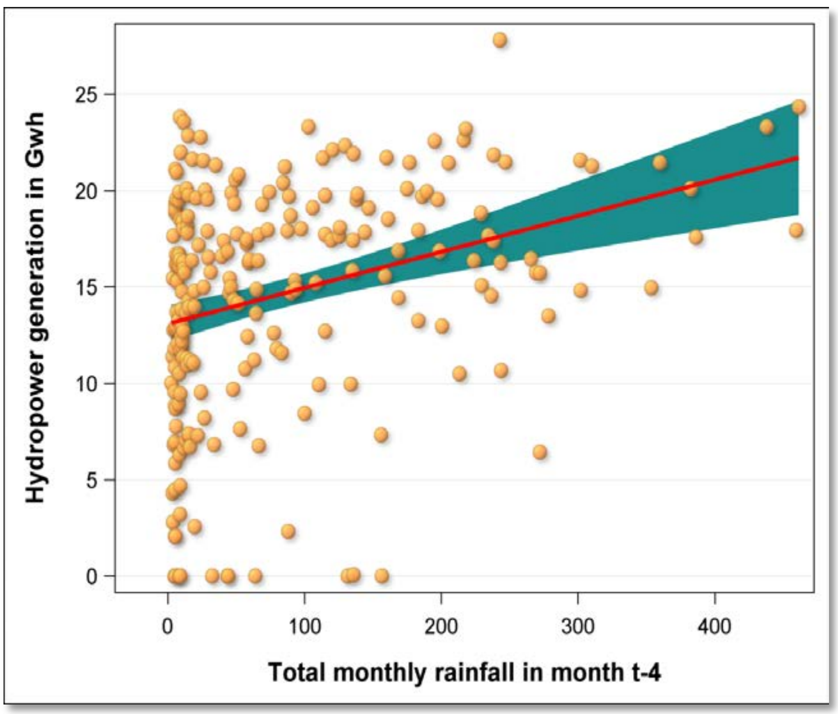

Figure 14: Relationship between rainfall and power generation at Masinga dam in Kenya

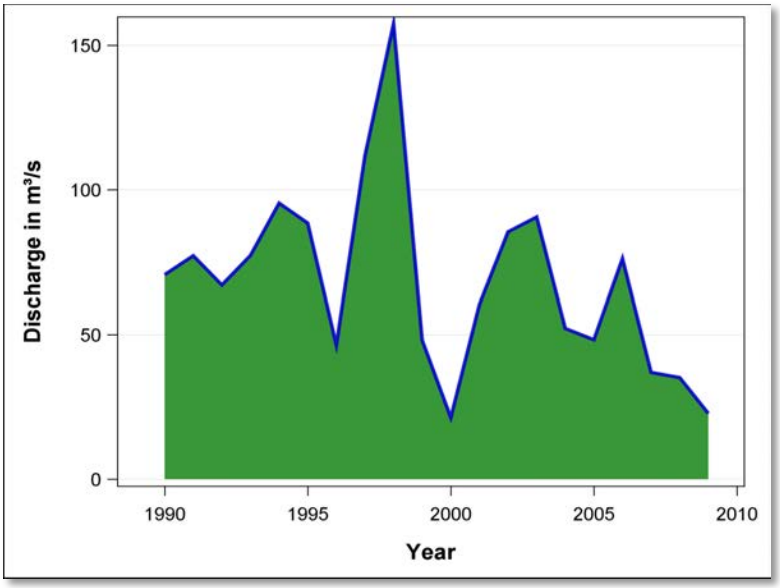

Figure 15: Annual variation of discharge at Masinga dam in Kenya between 1990 and 2000

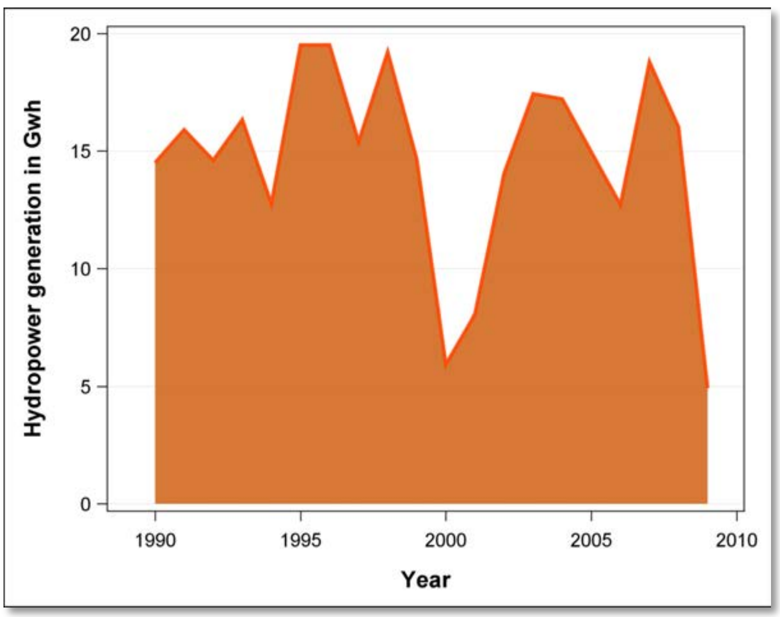

Figure 16: Annual variation of hydropower generation at Masinga dam in Kenya between 1990 and 2009

Similarly, Figure 15 shows the annual variation of discharge at Masinga dam in Kenya between 1990 and 2009. The trend depicts a major decline in the discharge around 1999–2000. This corresponds with the La Niña–related drought that hit the power sector causing huge economic losses.

Figure 16 gives the annual variation of hydropower generation at Masinga dam between 1990 and 2009.

These variations are like those seen for discharge. Low hydropower generation was evident during the 1999–2000 drought in which the production fell below 10 GWh that year.

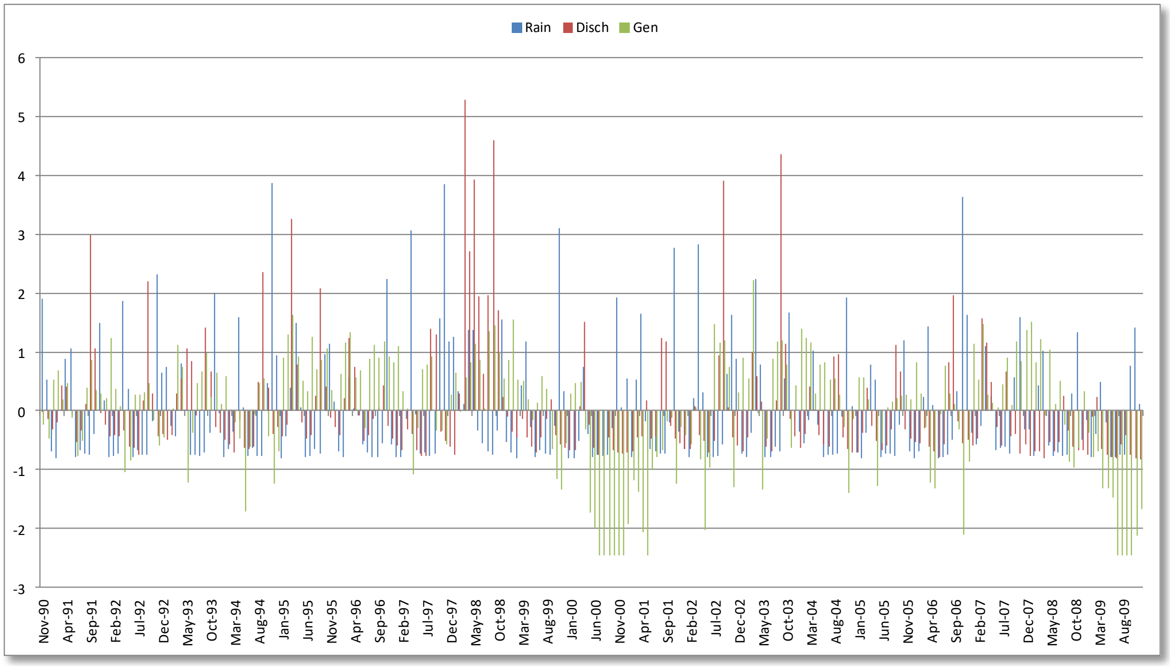

Figure 17: Rainfall, discharge, and power generation anomalies in the Seven Forks power station, Kenya, Note: Blue represents rainfall, red represents discharge, and green represents power generation.

Figure 17 shows the significant correlation between rainfall, discharge, and power generation at Masinga dam in Kenya. Changes in rainfall anomalies are directly related to changes in discharge and power generation. Negative anomalies in rainfall results in negative (reduced) discharge, and hence reduced power generation at Masinga dam. Most notable are the 2000 and the 2009 droughts that resulted in severe decline in power generation in Kenya.

(b) Case Study—Rwanda

Similar analysis was undertaken for Rwanda to illustrate the relationships between rainfall and power generation. Data from hydropower generation in Mukungwa, Ntaruka, and Rukarara hydropower dams between 1998 and 2014 was used in the analysis as well as Lake Burera. The results show significant correlation between the sector indicator trends and the climatic trends.

Figure 18 shows the relationship between rainfall and hydropower generation in the three dams while Figure 19 shows the variation of hydropower generation for the three hydropower dams between 1998 and 2014. Power generation was at its lowest in 2006. Figure 20 shows the variation in water levels for Lake Burera between 1996 and 2015. Water levels also declined significantly between 2001 and 2006, which could have been attributed to decrease in rainfall over the basin. Further, Figure 21 shows the relationship between rainfall and power generation at Mukunwa 1 and Ntaruka dams in Rwanda. The trends show strong linear relationship between rainfall and power generation at lag two. The orange band is the 95 percent confidence band.

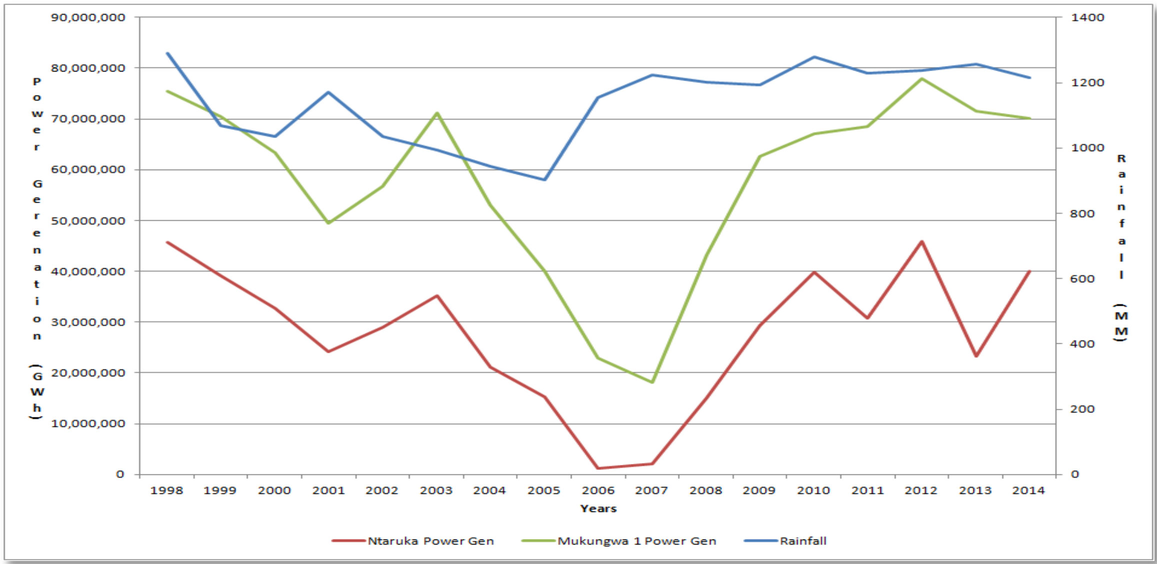

Figure 18: Relationship between rainfall and power generation between 1998 and 2014: Ntaruka (Red), Mukungwa (Green), and Rukarara (Blue)

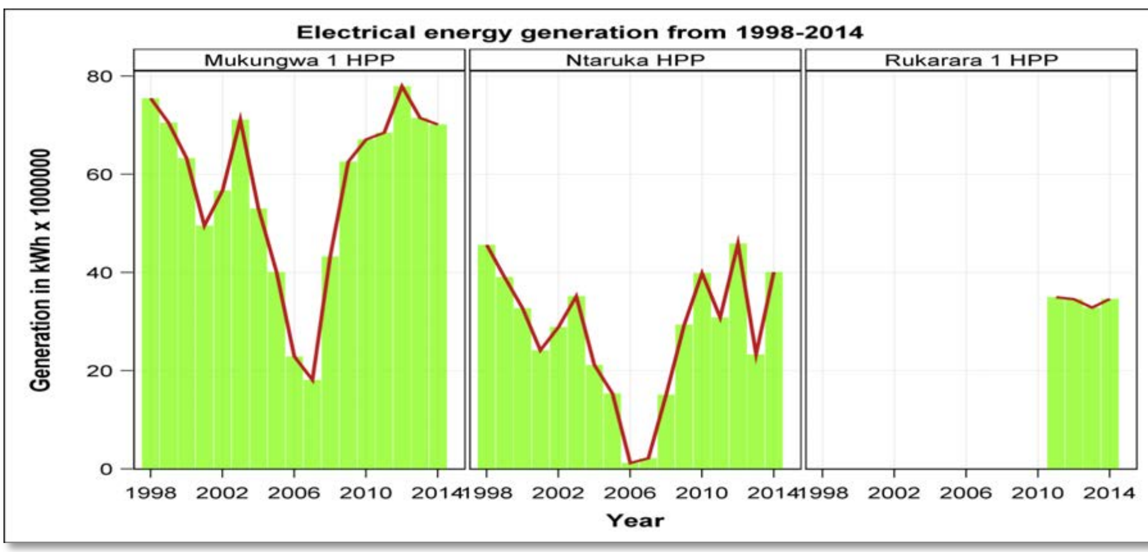

Figure 19: Variation of power generation in Mukungwa, Ntaruka, and Rukarara hydropower dams between 1998 and 2014

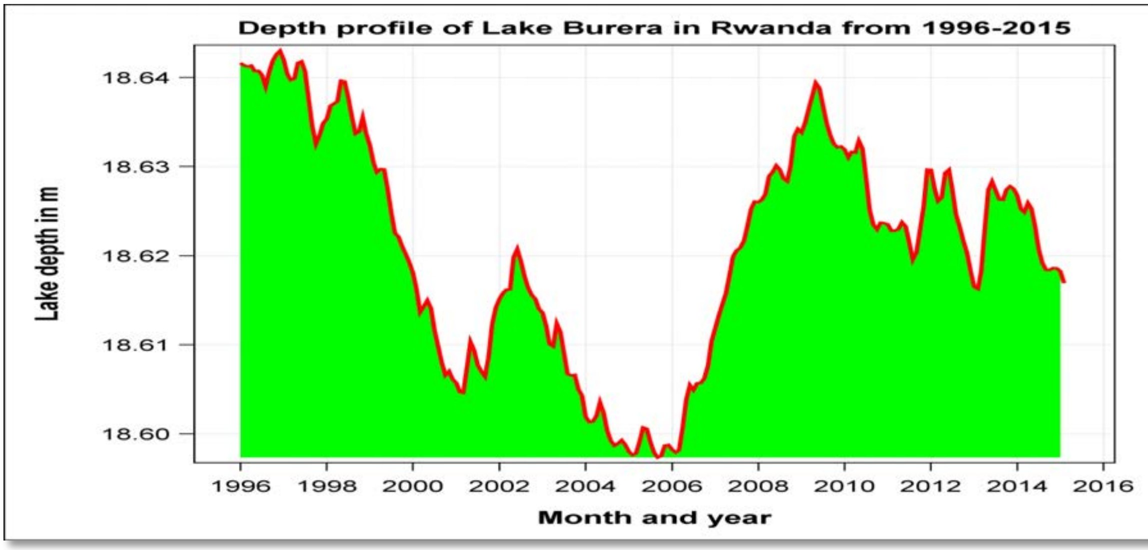

Figure 20: Variation of Lake Burera levels between 1996 and 2015

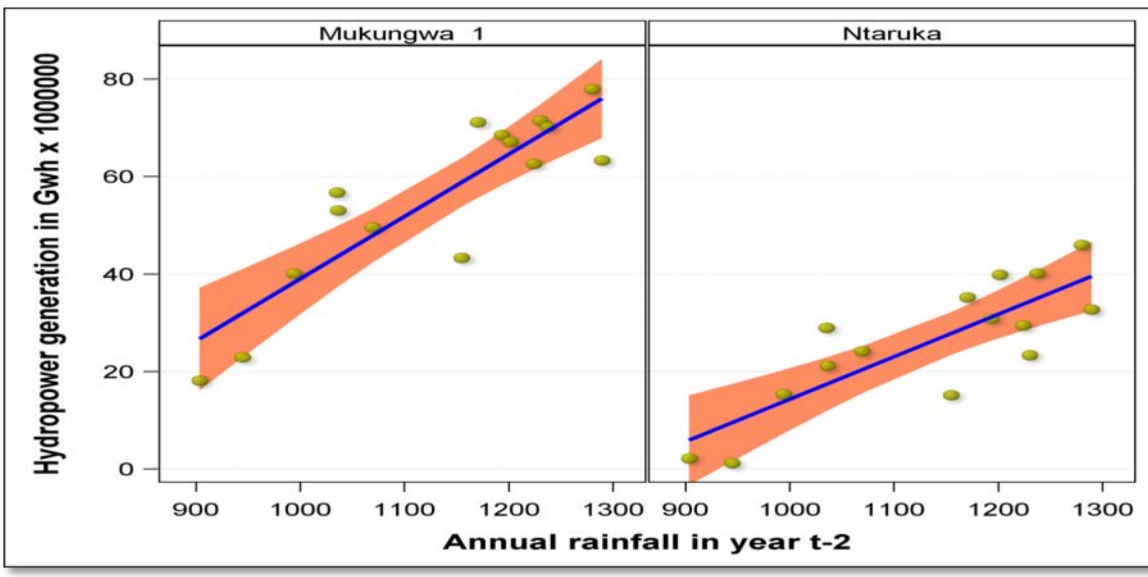

Figure 21: Relationship between annual rainfall, and power generation at Mukungwa 1 and Ntaruka dams

(c) Case Study—Tanzania

The water level at Mtera dam, the largest hydropower reservoir in Tanzania, was receding by almost 3 centimeters per day[21] following the 2011 drought. This study sought to establish the trends in the three major dams, Mtera, Kidatu, and Nyumba ya Mungu, to establish the effect of climate factors, especially climate variability. Figure 22 shows the relationship between rainfall and power generation at Kidatu and Mtera dams. A strong non-linear relationship increases then decreases with increasing rainfall at lag one.

[21] http://www.trust.org/item/?map=drought-worsens-power-crisis-in-tanzania

The purple band is the 95 percent confidence band. It is possible that rainfall of more than 1,100 millimeters has a negative effect on power generation, but further work in needed to determine the causal factors for that type of relationship. Figure 23 shows the relationship between rainfall and power generation at Nyumba ya Mungu dam. It shows a strong linear relationship that rises with increasing rainfall at lag three. The orange band is the 95 percent confidence band.

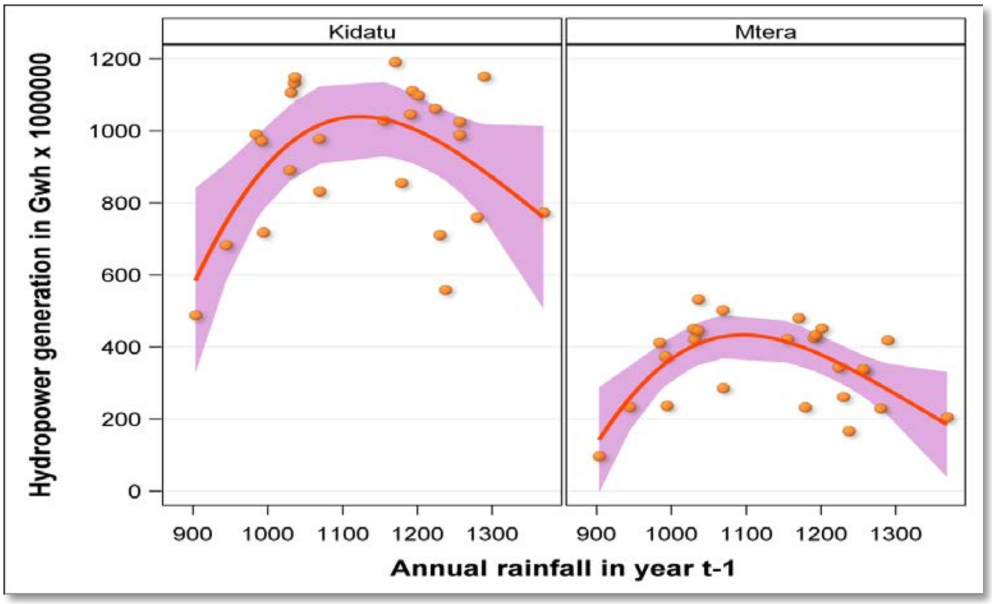

Figure 22: Relationship between annual rainfall and power generation at Kidatu and Mtera dams

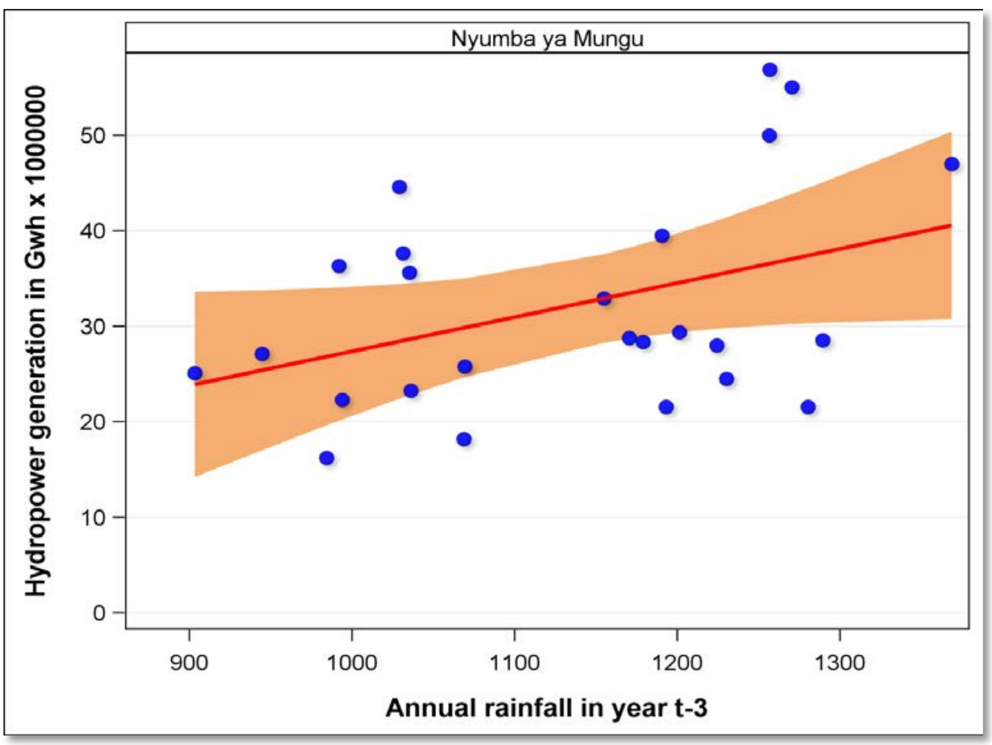

Figure 23: Relationship between annual rainfall, and power generation at Nyumba ya Mungu dam

Temperature rise may have a negative impact on hydropower generation.

Climate change projections show that temperatures in Burundi and Rwanda are projected to rise by 0.4ºC every 10 years, and an increase of 1.9ºC by the year 2050. In Tanzania, the National Adaptation Programme of Action (NAPA) indicates that mean annual temperatures are projected to rise by 2.2°C by 2100, with somewhat higher increases (2.6°C) over June, July, and August, and lower values (1.9°C) for December, January, and February. The Climate Change Master Plan for the EAC, 2011, indicates that Kenya is likely to experience an average annual temperature rise of 1°C by 2020s and 4°C by 2100. Climate projections for Uganda indicate an increase in temperature in the range of 0.7ºC to 1.5ºC by 2020 (EAC 2011b). Temperature affects the hydrological cycle, which affects water quantity (for hydropower) through regulation of evaporation and evapotranspiration. Temperatures also contribute to fluctuation of wind intensity and frequencies (UNEP 2009).

Box 1: Effect of evaporation on hydropower

Effect of evaporation on hydropower

The largest dam in Tanzania is Mtera, with surface capacity of 605 square kilometers at full supply level. An average of 5 percent of gross reservoir capacity is lost per year due to evaporation; for Mtera, total storage (live and dead) is 3700 Mm^3, which would be a loss of 185 mm^3.

Source: Postel et al. 1996.

In **Tanzania,** the relationship between annual temperature, and power generation at Mtera and Nyumba ya Mungu dams is shown in Figure 24.

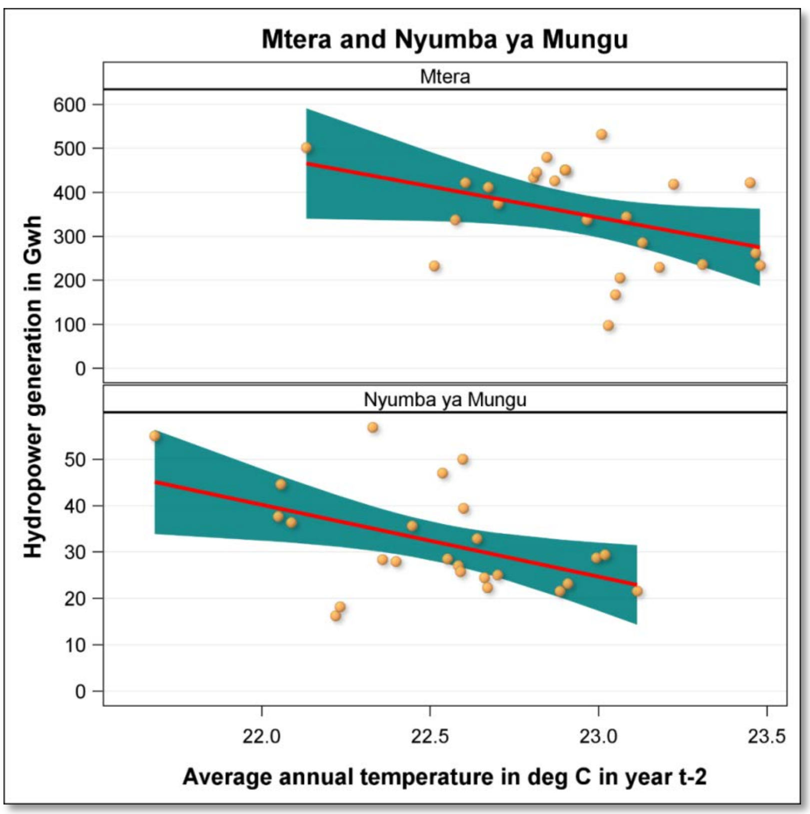

Figure 24: Relationship between annual temperature and power generation at Mtera and Nyumba ya Mungu

The analysis shows temperature varies inversely with power generation, implying that higher temperatures affect power generation negatively. This could be attributed to higher evaporation at higher temperatures causing water levels in the dam to fall. This relationship is significant at a two-year lag correlation as shown in the figure (year t-2).

In **Uganda,** the hydropower potential is estimated at 2,000 MW along the White Nile, the source of which is Lake Victoria. The existing installations include the Bujagali, Kiira, and Nalubaale hydropower plants. Water levels in Lake Victoria are key to their functioning. For example, the decrease in lake levels from 2004 to 2008 was reflected in a reduction in hydropower production of Nalubaale and Kiira hydropower plants (UNEP 2009).

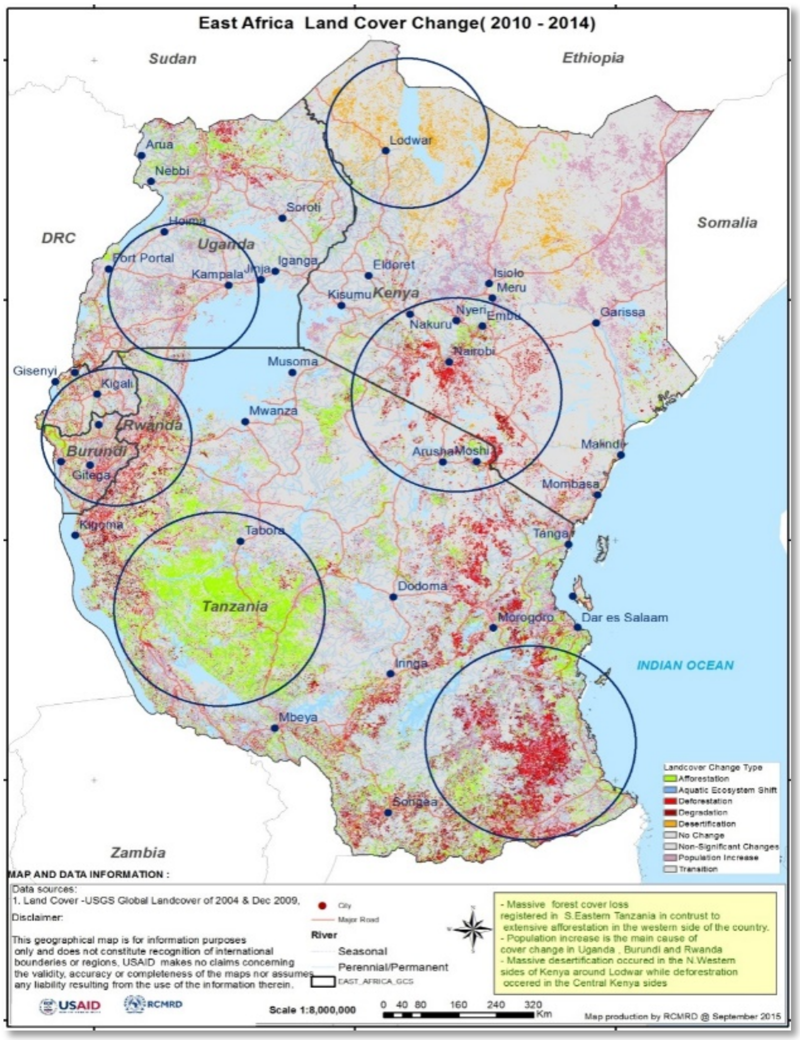

Figure 25: Spatial and temporal distribution of natural vegetation in the EAC based on 10 years (2001–2010) of collection of MODIS data

Climate change is a major cause of loss of vegetation and wood biomass, affecting energy access for local communities. Forests are the main sources of biomass and often water towers for the drainage basins, but they are vulnerable to climate variability and climate change. Rainfall enhances vegetation growth and biomass supply, but decrease in rainfall, coupled with increased temperature and wind, may trigger forest fires and hence adversely affect natural forests, water catchments, and their ecosystems (Kiiza et al. 2009). For example, forest fires have contributed to the reduction in forest cover and forest resources in parts of Tanzania. Among the areas where chronic bush fires have caused negative effects are Mounts Uluguru (Eastern Arc Mountain range) and Kilimanjaro. According to the Tanzania NAPA (2007), on Mount Kilimanjaro, Montane forest disappeared in year 2000 due to frequent occurrence of fires. The trends in forest cover in EAC Partner States for 1990–2010 is shown in Figure 25 and Table 9. While climate variability and change may not be the main driver of loss, it will compound other non-climatic factors and cause tipping points beyond which ecosystems, habitats, and forests may not recover.

Table 9: Trends in the extent of forest cover between 1990 and 2010

Country	Forest area (1,000 ha)						Annual change rate			
	1990	2000	2005	2010	1990-2000		2000-2005		2005-2010	
					1000ha/yr	%	1000ha/yr	%	1000ha/yr	%
Kenya	3,708	3,582	3,522	3,467	-13	-0.35	-12	-0.34	-11	-0.31
Uganda	4,751	3,869	3,429	2,988	-88	-2.03	-88	-2.39	-88	-2.72
Tanzania	41,495	37,462	35,445	33,428	-403	-1.02	-403	-1.10	-403	-1.16
Burundi	289	198	181	172	-9	3.71	-3	1.78	-2	-1.01
Rwanda	318	344	385	435	3	0.79	8	2.28	10	2.47

Source: FAO 2011.

Given these trends, studies have highlighted emerging hotspots for charcoal production that will require monitoring and restoration under a changing climate. Examples, by country, are as follows:

- **Burundi:** The Country Baseline Report for the EAC Strategy to Scale-up Access to Modern Energy Services (Hakizimana 2008) indicated that most of the charcoal consumed in Burundi comes from rangelands, government forests, and small farmlands. These include rangelands targeted for resettlement particularly in the Kibira Forest, Bururi Forest, Rububu National Park, and Kigwena and Rumonge Reserves. The degradation and deforestation of rangelands, particularly around urban areas such as Bujumbura, Gitega, and Ngozi, is attributed to charcoal production.

- **Kenya**: Drigo et al. (2015) identified counties that are most likely to experience fuelwood supply deficits due to unsustainable harvesting. The counties that are most heavily exploited, resulting in NRB values over the national average (listed by decreasing NRB values) are: Kajiado, Nakuru, Kiambu, Baringo, Kakamega, Taita Taveta, Bungoma, Nyeri, Uasin Gishu, Kisii, Kericho, Nyandarua, Migori, Embu, Trans Nzoia, Murang'a, Kisumu, Kirinyaga, Mombasa, Busia, Nyamira, and Vihiga. A similar study specifically for charcoal in 2013 showed that the highest levels of production occur in arid and semi-arid areas. The major charcoal producing counties identified included; Kajiado, Makueni, Kitui, Kwale, Baringo, Elgeyo Marakwet and Tana River, Kilifi, Garissa, Laikipia, Machakos, Marsabit, Meru, Narok, Tharaka, and Turkana. Based on the quantities of charcoal produced annually (estimated by the number of charcoal production and transportation permits issued by the Kenya Forest Service), the key charcoal hotspots were Baringo, Kajiado, Makueni, Keiyo-Marakwet, Kitui, Kwale, and Makueni. Mandera, Kisumu, Kajiado, and Kwale counties are linked with transboundary trade in charcoal.

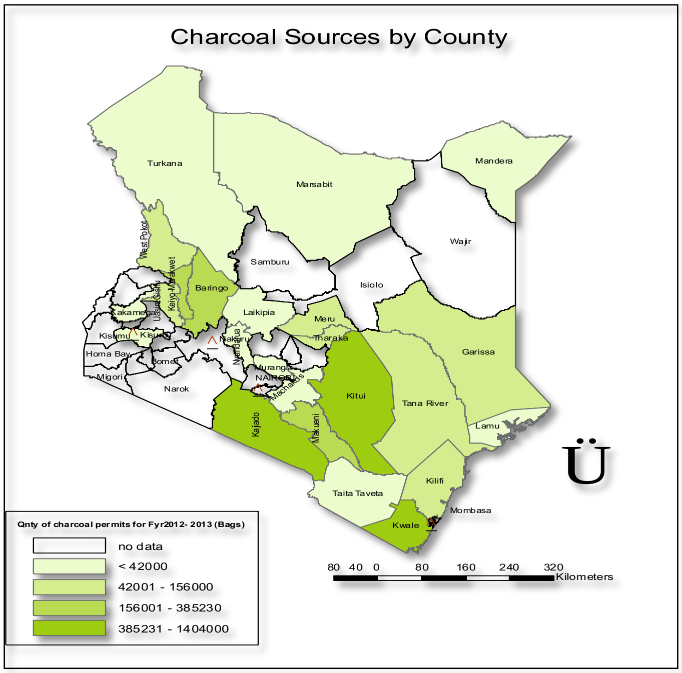

Figure 26: County map showing the charcoal hotspots in Kenya (source: KFS Charcoal Value Chain Analysis)

- **Tanzania:** Natural forests from southern, western, and coastal areas are under pressure to supply charcoal and commercial fuelwood to Dar es Salaam and other urban areas. According to Biomass Energy Strategy (BEST) (2014), charcoal production hotspots are Arusha, Mwanza, Njombe, Tanga, Coast, Lindi, Mtwara, and Morogoro.

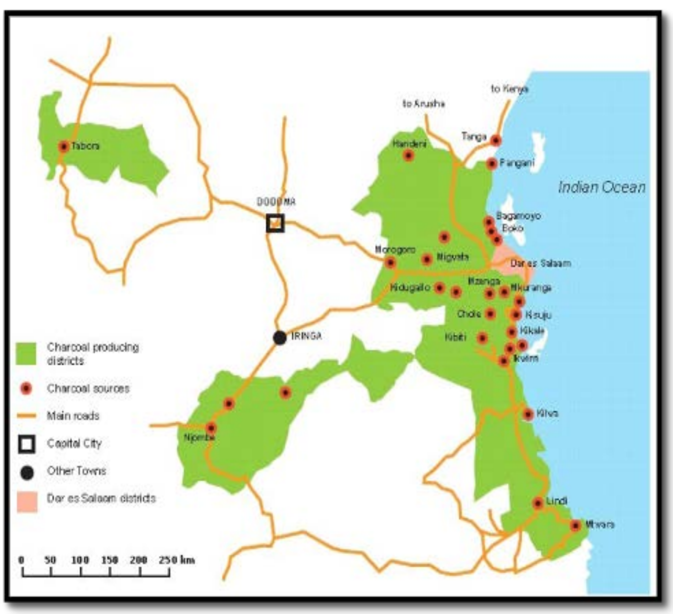

Figure 27: Tanzania Main charcoal sources (source: BEST 2014)

- **Rwanda:** Recommendations from WISDOM Rwanda (Drigo 2011) and a 2014 ICPAC report on hotspot mapping shows that most of Rwanda is a hotspot due to factors mentioned before. The

Eastern Province, where charcoal production is high, is a priority for efforts to regenerate biomass resources as it has become a new resettlement area and is prone to severe droughts and lacks biomass resources.

- **Uganda:** Charcoal consumption is concentrated in urban areas, and deforestation has been greatest in central Uganda's forest lands, which are near the cities. The Ministry of Energy and Mineral Development (MEMD) has identified Luwero, Nakasongola, Kiboga, Mpigi, and Masindi as the main charcoal producing districts (MEMD 2004). A UNDP/NAMA study on Sustainable Charcoal in Uganda identified the same districts as "Cone of Deforestation" because of unsustainable charcoal production (UNDP 2013).

Figure 28: Main charcoal producing districts in Uganda (source: MEMD 2014, UNDP 2013)

The vulnerability of the energy sector is worsened by climate change challenges. To address this, SDG No. 13 calls for urgent action to combat climate change and its impacts by:

- Strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries;
- Integrating climate change measures into national polices, strategies, and planning;
- Improving education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning.

2. TRANSPORT AND ASSOCIATED INFRASTRUCTURE

2.1 INTRODUCTION

"Transport is a driver of social and economic development, enabling citizens to access health care, education, and jobs, and unlocking growth potential for cities and countries."

(Rachel Kyte, Former World Bank Vice President for Sustainable Development, now CEO of SEforALL)

Transport infrastructure connects people to jobs, education, and health services; it enables the supply of goods and services within the countries; and allows people to interact and generate the knowledge and solutions that foster long-term growth. However, the World Energy Council predicts that globally the transportation sector will face unprecedented challenges over the next forty years. It will come under increasing pressure due to demographics, urbanization, aging infrastructure, growing fuel demand, and pressure to minimize and dislocate emissions outside urban centers. "The biggest challenge," the World Energy Council say, "will be to provide sustainable transport for the seven to nine billion people with the minimum possible congestion, pollution, and noise generated by additional traffic and freight," (World Energy Council 2011).

2.2 CONTEXT

2.2.1 Global

According to the IEA (2010) and Word Bank (2011), the world's common means of transport are aviation, ship transport, and land transport, which includes rail, road, and off-road transport. Other modes include pipelines, cable transport, and space transport. Different regions employ different modes of travel. According to World Energy Council (2011), Organization for Economic Co-operation and Development (OECD) countries rely on passenger light-duty vehicles (cars, light trucks, and minibuses) much more than non-OECD countries, while non-OECD countries show higher shares for buses, rail, and vehicles with two or three wheels. Non-motorized travel is also common outside of the OECD. Also, people in non-OECD countries use less air travel per capita than those of OECD countries. Figure 29 compares passenger travel by mode (World Energy Council 2011; IEA 2010).

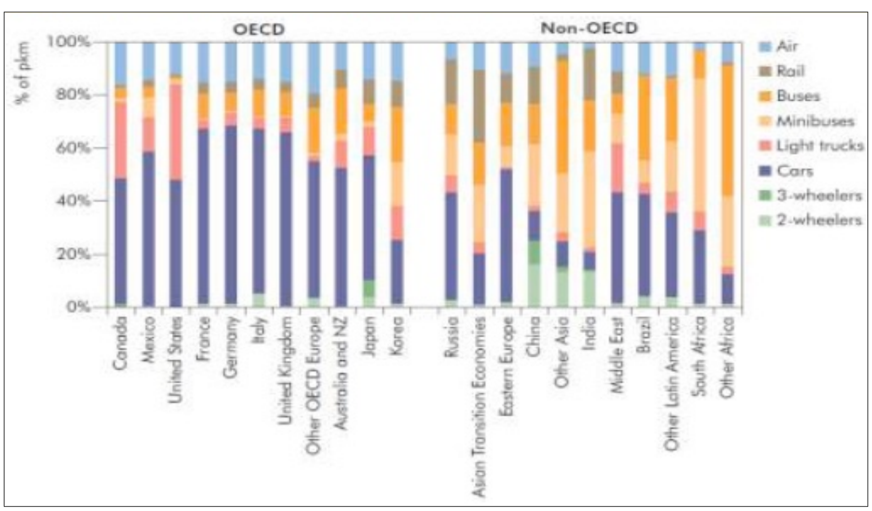

Figure 29: Motorized passenger travel by mode in 2007 (IEA 2010)

Although the sector is crucial to reducing poverty, boosting prosperity, and achieving the SDGs, transport will face several unprecedented challenges over the next four decades (2010 through 2050) (IEA 2010). Population projections indicate there will be 2.2 billion more people in the world, a total of 9.2 billion, and more than two-thirds will live in cities compared to about half the population of today. With burgeoning urban populations, the number of megacities will increase from 22 today to between 60 and 100 by 2050 (IEA 2010).

Driven by increases in all travel modes, some sources expect the energy consumption of the transport sector to increase as shown in Figure 30 (MTOE,[22] IEA 2010). Most of this demand will likely come from countries undergoing strong economic and population growth (China, India, Russia, Latin America, and the Middle East) (IEA 2010).

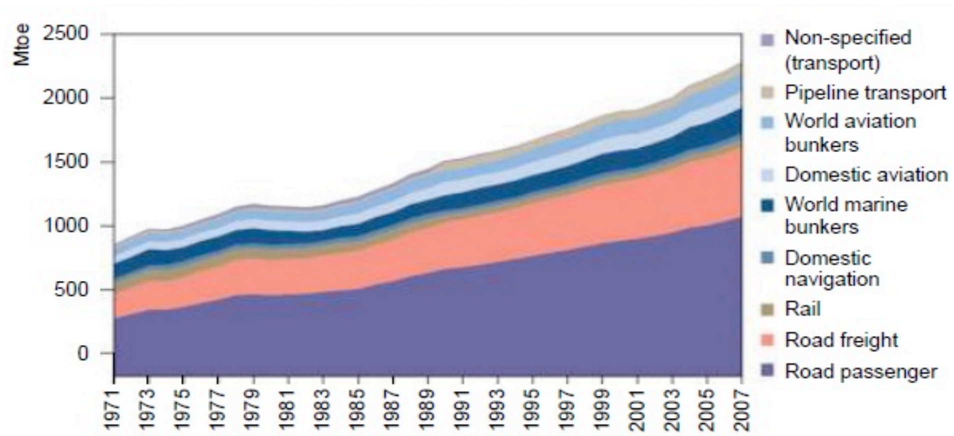

Figure 30: Global transport final energy use by mode (IEA 2010)

In addition, transport contributes about 15 percent of global greenhouse gas emissions. With motorization and population on the increase, that share is expected to grow dramatically (World Bank 2011). In light of these challenges and uncertainties, the World Bank's strategy in the transport sector (adopted in 2008) envisioned an opportunity to build **safer, cleaner,** and **more affordable** transport systems that reduce congestion, facilitate access to jobs and lower transport energy consumption.

2.2.2 Africa

Road transport. Roads dominate the transport sector in most African countries, carrying 80 to 90 percent of passenger and freight traffic. The size of the classified road network, including main roads and secondary network is estimated to be 1,052,000 kilometers. Together with an unclassified network of 492,000 kilometers and an urban road network of about 193,000 kilometers, this makes an estimated total network of 1,735,000 kilometers. Figure 31 shows major road networks. The condition of the road system is poor by international standards. Nevertheless, the fiscal burden of the road network per capita is relatively high—a consequence of the combination of low population density and low GDP per capita.

Four strategic roads that serve international transit corridors (Table 10). These corridors play are crucial to maintaining the economies of Africa's landlocked countries.

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[22] 1 tone = 6.5 to 7.9 boe depending on the type of oil.

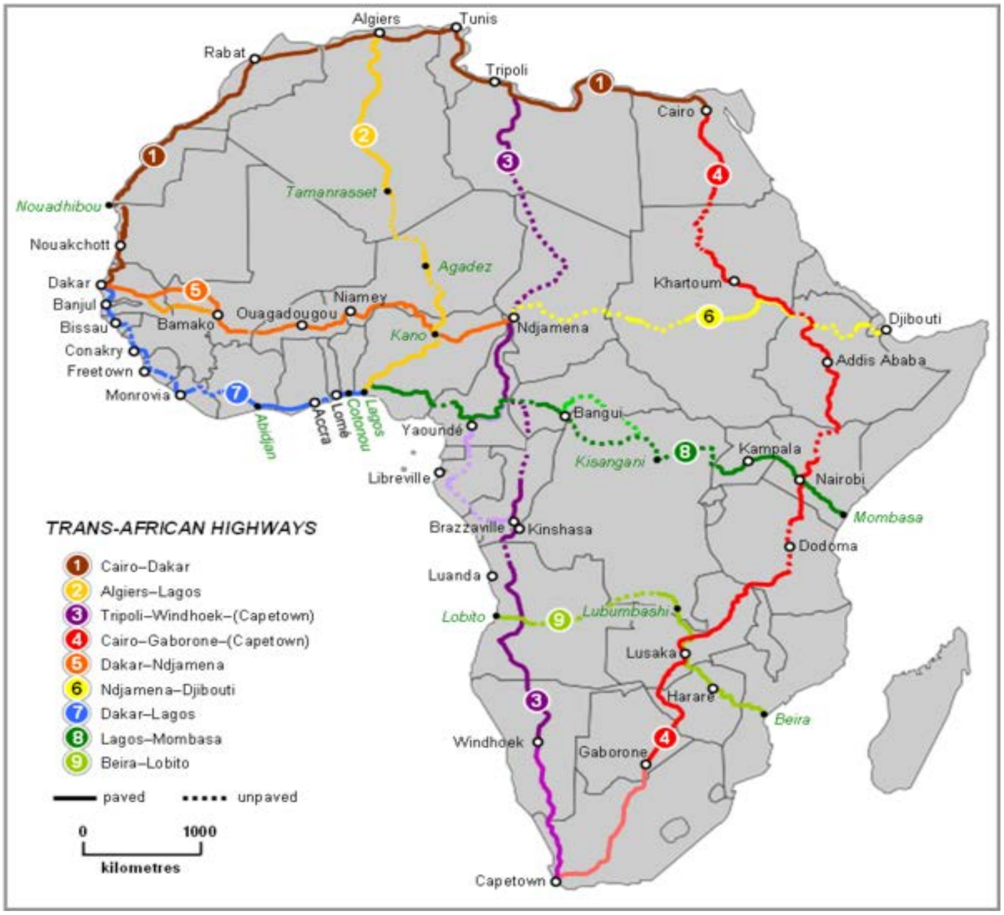


Figure 31: Trans-African Highways (source: https://en.wikipedia.org/wiki/Trans-African_Highway_network)

Table 10: Key transport corridors in Africa

Corridor	Length (km)	Roads in good condition (%)	Trade density (US$ million/km)	Implicit speed (km/hr)	Freight tariff (US$/ton-km)
Western	2,050	72	8.2	6.0	0.08
Central	3,280	49	4.2	6.1	0.13
Eastern	2,845	82	5.7	8.1	0.07
Southern	5,000	100	27.9	11.6	0.05

Source: Gwilliam 2011.

Rail transport. The most significant railway is the TAZARA line, which links Tanzania and Zambia. Other rail networks include the Trans-Gabonais, the extension of the Cameroon network from Yaoundé to Ngaoundere, and the northeastern extension of the Nigerian network from Kuru to Maiduguri. Other international networks are South Africa–Zimbabwe–Zambia, and the Democratic Republic of Congo. This pattern of railway development reflects the historically limited amount of intercountry trade in Africa, hence trade volumes between adjacent countries are remarkably small (Gwillian 2011).

Air transport. Africa has at least 2,900 airports, with major intercontinental hubs at Johannesburg, Nairobi, and Addis Ababa. Airports with higher traffic volumes generally have higher-quality infrastructure. Lower-quality infrastructure is much more prevalent among airports with low traffic volumes. The busiest airport in 2011 was OR Tambo (Johannesburg) followed by Cairo and Cape Town (Table 11).

Table 11: Busiest airports in Africa (by passenger traffic) in 2011

Airport	Country	Passengers/yr 2011	Percent change from 2010
OR Tambo International	South Africa	18,922,346	+2.9
Cairo International	Egypt	13,037,541	-19.3
Cape Town International	South Africa	8,436,562	+4.1
Mohammed V International	Morocco	7,290,314	+0.6
Murtala Muhammed International	Nigeria	6,748,290	+7.6
Hurghada International	Egypt	5,875,423	-25.9
Jomo Kenyatta International	Kenya	5,803,635	+5.8
Sharm el-Sheikh International	Egypt	5,476,388	-27.0
Bole International	Ethiopia	5,054,213	+25.0
King Shaka International	South Africa	5,038,231	+6.0
Houari Boumidienne Airport	Algeria	4,750,000	+6.02
Carthage Airport	Tunisia	3,994,705	-13.2
Sir Seewoosagur Ramgoolam International	Mauritius	2,587,526	+3.1
Djerba-Zarzis International	Tunisia	1,781,000	N.A.
Monastir International	Tunisia	1,000,007	-70.3

Source: http://www.africastrictlybusiness.com/lists/busiest-airports-passenger-traffic

Water transport. Africa has many ports, most of which are small by world standards. Few can accommodate the largest ships. In general, African ports are poorly equipped, have low productivity, and are unprepared for the rapidly unfolding changes in global trade and shipping patterns. Durban is by far the largest port in the region (Figure 32). Its container volume in 2005 was 1.9 million TEUs (20-foot equivalents), more than twice the volume of any other port. Conakry and Cape Town are the next largest, handling 753,827 and 690,895 TEUs in 2005, respectively. Abidjan comes in fourth with a container volume of 500,119 TEUs.

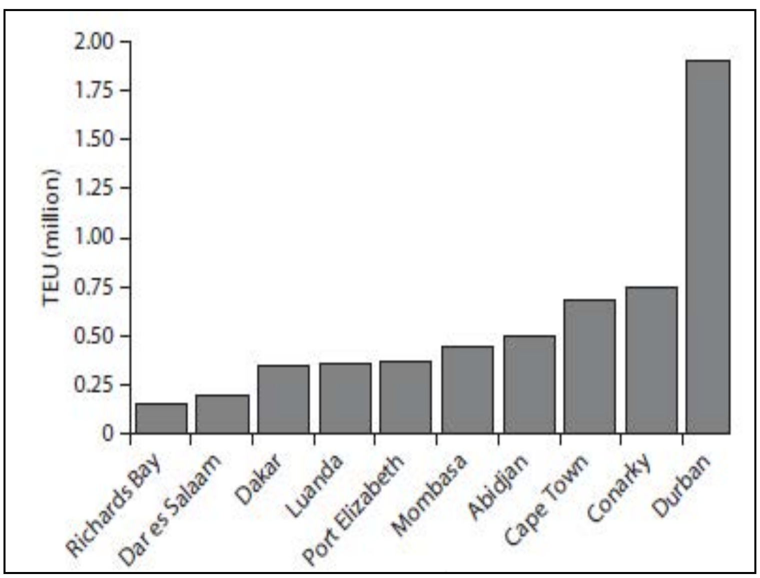


Figure 32: Top 10 sub-Saharan African Ports in 2005 (source: Mundy and Penfold 2009)

2.2.3 East Africa

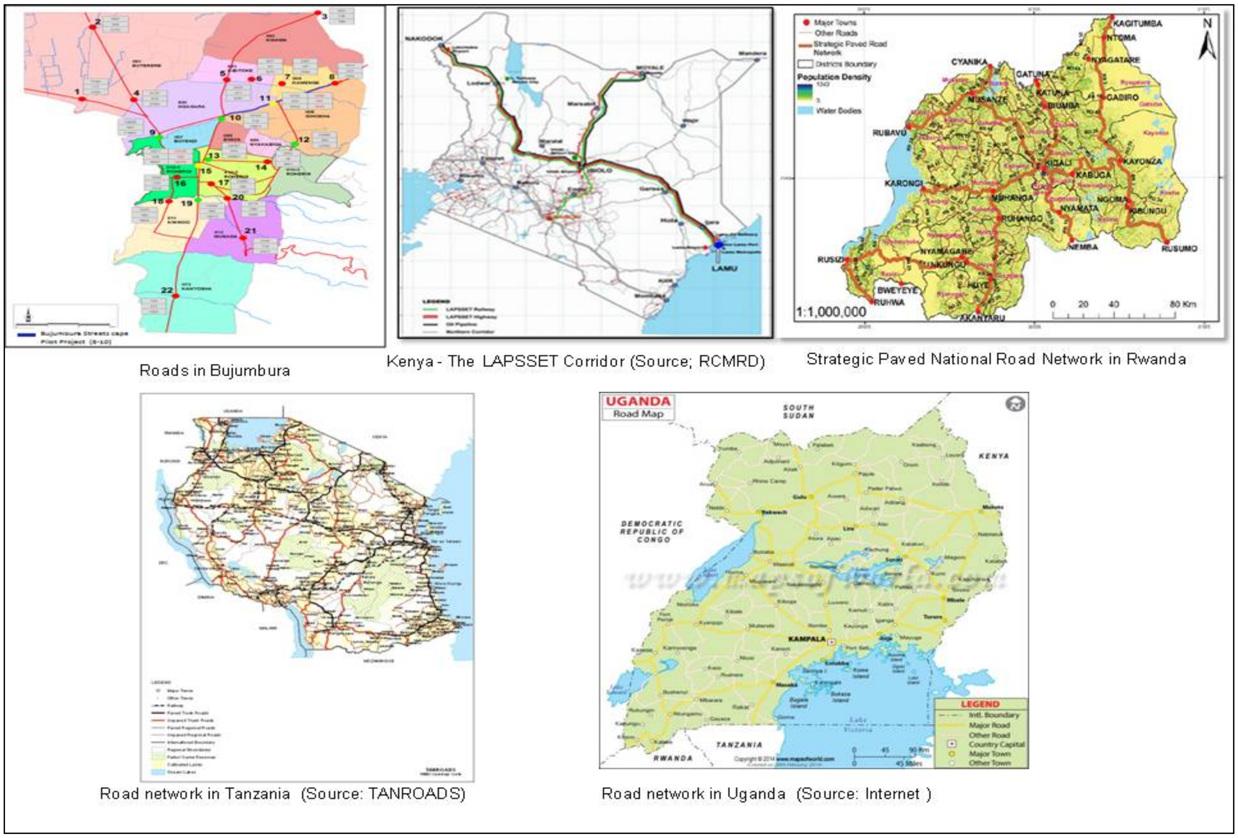
East Africa has all three broad categories of transport. The status of all three for the EAC Partner States is described in this section (Tables 12, 13, 14, 15, and Figure 33).

Surface Transport

Table12: Status of surface transport

	Burundi	Kenya	Rwanda	Tanzania	Uganda
Roads	Has a total of 12,480 km. In 2011, 1,438 km were paved, 5,621 km were unpaved, and the rest are classed as local roads or tracks.	A total of 61,945 km of roads are classified, the remaining 98,941 km are not classified. In 2014, 13,000 km were paved and 63,000 km were unpaved.	Has a total of 12,000 km of roads. In 2011, 1,217 km were paved, 1,639 km were unpaved.	Has 91,049 km of roads. In 2014, 8,793 km were paved, 78,871 km were unpaved.	The total national road network is categorized as National Roads (20,800 km), District Roads (17,500 km), Urban Roads (4,800 km) and Community Access Roads (35,000 km). In 2014, 3,795 km were paved, 17,202 km were unpaved.
Rail	Currently does not have railway infrastructure.	There is a total of 2,066 km of 1,000 mm gauge. Kenya Railways Corporation runs the main rail line to Uganda and its branches in Kenya.	Currently does not have railway infrastructure.	Has 3,689 km of rail; with 2,720 km of 1,000 mm gauge and 969 km of 1,067 mm gauge track.	Had 1,266 km of networks from Malaba the Kenya border to western Uganda in Kasese and Packwach; only 337 km are currently operational with an average annual volume of about 585,000 tons.
Pipeline	Currently does not have a pipeline.	The oil pipeline runs from the port of Mombasa to Nairobi (450 km) with extensions to Eldoret (325 km) and Kisumu (121 km).	Currently does not have a pipeline.	There are two functional long-distance pipelines. The TAZAMA pipeline transports crude from Dar es Salaam to Ndola refinery terminal in Zambia, a distance of 1,750 km. The pipeline that transports gas from Songo Songo Island to Dar es Salaam, a distance of 232 km.	Currently does not have a pipeline.

Source: EAC Facts and Figures 2015.



Roads in Bujumbura

Kenya - The LAPSSET Corridor (Source; RCMRD)

Strategic Paved National Road Network in Rwanda

Road network in Tanzania (Source: TANROADS)

Road network in Uganda (Source: Internet)

Figure 33: Maps of showing Road Networks in EAC Countries

Table 13 shows performance of railway transport in the EAC Partner States for the period 2006–2014.

Table 13: Trend on access to rail transport facilities/services

Indicator	Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
Stations (number)	Tanzania	216	216	216	216	216	216	216	216	216
	Kenya	172	172	172	172	172	172	172	172	172
Passengers ('000)	Tanzania	1,484	1,635	1,506	1,540	1,057	1,306	1,298	1,027	1,130
	Kenya	4,348	4,500	3,226	8,861	3,411	6,004	4,077	4,016	3,845
Cargo volume ('000 tons)	Tanzania	1,376	1.084	1.033	836	779	631	1,383	1,196	1,128
	Uganda	645	624	585	460	645	680	536	473	
	Kenya	1,891	2,304	1,628	1,532	1,572	1,596	1,394	1,214	1,509

Source: EAC Facts and Figures 2015.

Water Transport

East Africa has three major lakes that have transboundary transport potential: Lake Victoria (Kenya, Uganda, and Tanzania), Lake Tanganyika (Tanzania and Burundi), and Lake Kivu (Rwanda). Ultimately, each of the five EAC Partner States has some form of marine transport. These lakes are important for national as well as regional trade and communication between the EAC countries.

Table 14: Status of Water Transport

Main Ports and Routes				
Burundi	Kenya	Rwanda	Tanzania	Uganda

Victoria	-	Port: Kisumu <u>Routes:</u> Kisumu – Bukoba Kisumu – Mwanza Kisumu – Port Bell	-	<u>Ports:</u> Mwanza, Bukoba, Musoma <u>Routes:</u> Mwanza – Port Bell Mwanza - Jinja Bukoba – Jinja Mwanza – Bukoba, Mwanza – Musoma Bukoba – Kisumu Mwanza – Kisumu	<u>Ports</u>: Jinja, Port Bell <u>Routes:</u> Jinja – Port Bell Port Bell – Mwanza Jinja – Bukoba Jinja – Mwanza Port Bell – Kisumu
Tanganyika	<u>Ports:</u> Rumonge, Kabonga <u>Routes:</u> Rumonge – Kigoma Rumonge – Kigoma Rumonge – DRC Kabonga – Kigoma Kabonga – Kigoma Kabonga – DRC	-	-	<u>Ports:</u> Kigoma <u>Routes:</u> Kigoma – Rumonge Kigoma – Kabonga Kigoma – DRC	-
Kivu	-	-	Lake Kivu is shared with the DRC. There are occasional boat services between the major ports of Cyangugu, Kibuye, and Gisenyi.		-

DRC = Democratic Republic of Congo

Air Transport

Table 15: Status of Air Transport

Burundi	Burundi has eight airports, one of which has paved runways with a length exceeding 3,047 meters. Bujumbura International Airport is the primary airport and the only one with a paved runway. There are also several helicopter landing strips. Kigali is the city with the most daily departures. In 2014, a total of 241,000 international passengers were recorded.
Kenya	Jomo Kenyatta International Airport in Nairobi, is the largest airport and serves the most destinations. Some international flights go to Moi International Airport in Mombasa. Kisumu Airport was upgraded to an international airport in 2011 and a second phase of expansion is under way. In 2012, a new tarmac runway was built at Wajir Airport that can take heavy aircraft. The number of passengers at the main airport grew from 5.521 million in 2004 to 10.187 million in 2013.
Rwanda	Rwanda's air gateway is Kigali International Airport, located in Kanombe, a suburb about 10 km (6 mi) from Kigali city center. A new airport is planned at Nyamata in Bugesera district, approximately 40 km (25 mi) from Kigali. That airport will be much bigger and could act as a hub for the entire region. The other airport in the country with passenger service is Kamembe Airport in the city of Cyangugu. Service between Kigali and Kamembe serves southwestern Rwanda and Bukavu in the Democratic Republic of Congo. Aircraft movements, commercial passenger numbers, and cargo volumes doubled between 2008 and 2014.
Tanzania	Air travel is regulated by the Tanzania Civil Aviation Authority. The Tanzania Airports Authority operates 56 airports and aerodromes on the Tanzania mainland, while airport in the semi-autonomous Zanzibar Archipelago are under the jurisdiction of the Zanzibar Airports Authority. International airports in the mainland are Julius Nyerere, Kilimanjaro, and Songwe/Mbeya. Fifteen airports offer the airport of entry service. Number of passengers recorded in 2014 was 5,276 million, an increase of 13 percent from 2012. The increased might be contributed by the launch of Fastjet Airline, a low-cost carrier.
Uganda	Uganda has one international airport, Entebbe, but has started a program to upgrade Kasese, Gulu, and Arua airfields to international standards. About 18 international airlines are operational with potential for growth. Upgrading of Kasese Airport to international standards is under way with designs completed. Entebbe Airport experienced an annual increase of passengers of 9.1 percent, in 2013, 1.464 million passengers were recorded.

2.2.4 Lake Victoria Basin

Transportation in the LVB includes ports, railways, roads, ships, and airports. The main modes are shown in Figure 34.

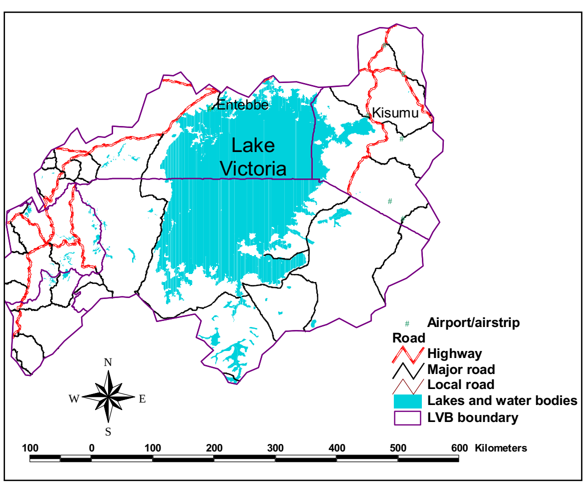


Figure 34: Mode of transport in the LVB (source: GEOCLim 2016)

Surface transport (roads and rail). The basin has a total road network of 36,208 km of which 2,850 km is tarmac and the rest is earth. Five major transport corridors transact directly with the LVB. These are:

1. Mombasa – Malaba – Kigali – Bujumbura
2. Dar es Salaam – Rusumo, with branches to Kigali, Bujumbura, and Masaka
3. Biharamulo – Sirari – Lodwar – Lokichogio
4. Nyakanazi – Kasulu – Tunduma, with a branch to Bujumbura
5. Tunduma – Dodoma – Namanga – Isiolo – Moyale.

The Kenya–Uganda Railway operates within the LVB. Construction of a regional railway line that will connect Mombasa-Nairobi-Kampala-Kigali-Bujumbura has been proposed.

Water Transport. A significant number of vessels operate commercially on Lake Victoria for transportation of passengers and cargo for Kenya, Tanzania, and Uganda. The main international transport routes include Mwanza – Port Bell/Jinja, Mwanza – Bukoba, Mwanza – Musoma, Port Bell/Jinja – Bukoba, and Kisumu – Bukoba. The main ports include Kisumu in Kenya, Mwanza, Bukoba and Musoma in Tanzania as well as Jinja and Port Bell in Uganda. Transport on Lake Victoria is constrained at present with only one ferry operational and with the infrastructure of most ferry stations in poor condition or non-operational.

Transport on Lake Victoria has steadily declined as transport is increasingly conducted by road. However, transport of passengers and bulk/low-value cargoes still make lake transport a viable and cost-effective option for the three East African countries.

Air Transport. Six airports serve the LVB: Bujumbura, Kigali, Entebbe, Mwanza, Kisumu, and Homabay. These airports serve both domestic and regional markets. The major regional routes are Kigali–Mwanza, Kigali – Entebbe, and Kigali – Bujumbura. Entebbe is the largest airport in the LVB followed by Kigali and Mwanza. Table 16 shows trend of volume of passengers for some of the airports in the LVB.

Table 16: Trends of passengers for selected airports within the LVB (2009–2012)

	Passengers/airports		
Year	**Kisumu**	**Mwanza**	**Entebbe**
2009	264,698	224,207	996,395
2010	199,828	227,479	1,110,876
2011	243,636	319,749	1,166,996
2012	280,840	439,128	1,342,112

2.3 Analysis of Transport Sector and Associated Infrastructure in the East Africa Partner States

2.3.1 Surface Transport

(a) Road

East Africa has a well-structured road network (Figure 35), but the condition of most rural roads makes it difficult to travel or move goods within the EAC, particularly during the wet season.

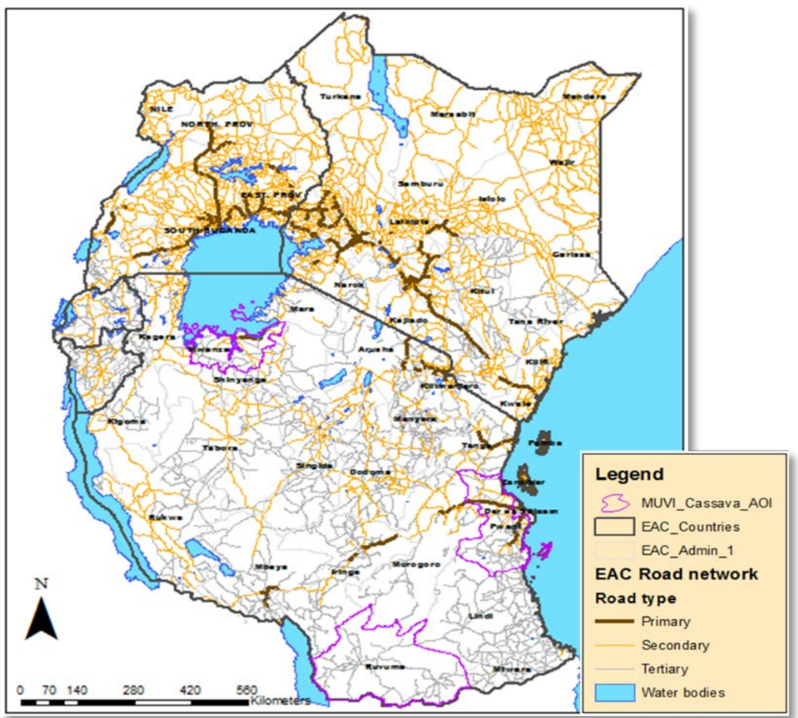


Figure 35: EAC major roads network (source: RCMRD Database 2015)

East African Transport Corridors

The East African Transport Strategy established the concept of transport corridors as an organizing principle for transport in the region. It defines surface transport routes forming the scaffold to which smaller, more localized access links are attached and aggregates the load from these feeder links. The corridors are not just transport arterials, but also routes for development that can attract complementary industrial and utility investments. The major corridors linking the EAC to the rest of the continent are the Dar es Salaam (TAZARA) Corridor, which links to the larger North-South Corridor and the Moyale-Addis Ababa Corridor. Two established east-west corridors within the EAC (Northern and Central) as well as lower-trafficked north-south corridors (along Lake Tanganyika via Sumbawanga and along the eastern shore of Lake Victoria via Sirari to Lokichoggio).

The Northern Corridor starts at Mombasa, Kenya, a port that serves Uganda, Rwanda, and Burundi, and ends in Bujumbura. This corridor has a budget of $1.87 billion to make it fully functional. The Central Corridor includes Dar es Salaam, a major port serving Rwanda, Burundi, and the eastern part of the Democratic Republic of Congo. The Central Corridor has a budget of US$1.67 billion to revamp the infrastructure and make it fully functional.

Ten transport corridors in the region cover a total of 14,460 kilometers (Table 17 and Figure 36).

Table 17: Details for the 10 East African transport corridors (as of November 2015)

Corridor	Description	Distance (km)
Northern Corridor	Mombasa–Voi–Bigiri–Kamala–Masaka–Kigali–Kibuye–Kayanza–Bujumbura	2,080
Central Corridor	Dar es Salaam–Morogoro–Dodoma–Singida–Nzega–Nyakanazi–Kigali–Gisenyi	2,170
Dar (Tazara) Corridor	Morogoro–Iringa–Mbeya–Tunduma	1,100
Namanga Corridor	Iringa–Dodoma–Kalema–Arusha–Nairobi–Thika–Muranga–Embu–Nyeri–Nanyuki–Isiolo–Marsabit–Moyale	1,800
Sumbawanga Corridor	Tundum a–Sumbawanga–Kasulu–Makamba–Nyansa Lac–Rumonge–Bujumbura	1,260
Sirari Corridor	Lockichokio–Lodwar–Kitale–Bungoma–Kisumu–Kisii–Mwanza–Biharam uro	1,500
Coastal Corridor	Mingoyo–Dar es Salaam–Chalinze–Vanga–Mombasa–Malini–Matondoni	1,500
Mtwara Corridor	Mtwara–Mingoyo–Masasi–Tunduru–Songea–Mbamba Bay	800
Tanga Corridor	Tanga–Moshi–Arusa–Musoma	1,650
Gulu Corridor	Sudan/Uganda Border–Bibia–Bulu–Lira–Soroti–Mbale–Tororo	600
	Total	**14,460**

Figure 36: The East African Transport Corridors (**source: RCMRD**)

(b) Rail

Although Burundi and Rwanda do not have railway infrastructure, proposals have been made to connect these countries to neighbors via railway. One option is a Chinese-funded railway project connecting Isaka with the existing Tanzanian railway network and running via Kigali through Rwanda to Burundi. Another potential project would link Burundi and Rwanda to the Democratic Republic of Congo and Zambia and therefore to the rest of Southern Africa. A new railway has also been proposed from the Ugandan western railhead at Kasese into the Democratic Republic of Congo.

The governments of Kenya and Uganda signed a memorandum of understanding in October 2009 to construct a standard gauge railway from Mombasa to Kampala. An agreement to fast-track development was signed by Kenya, Uganda, and Rwanda in August 2013.

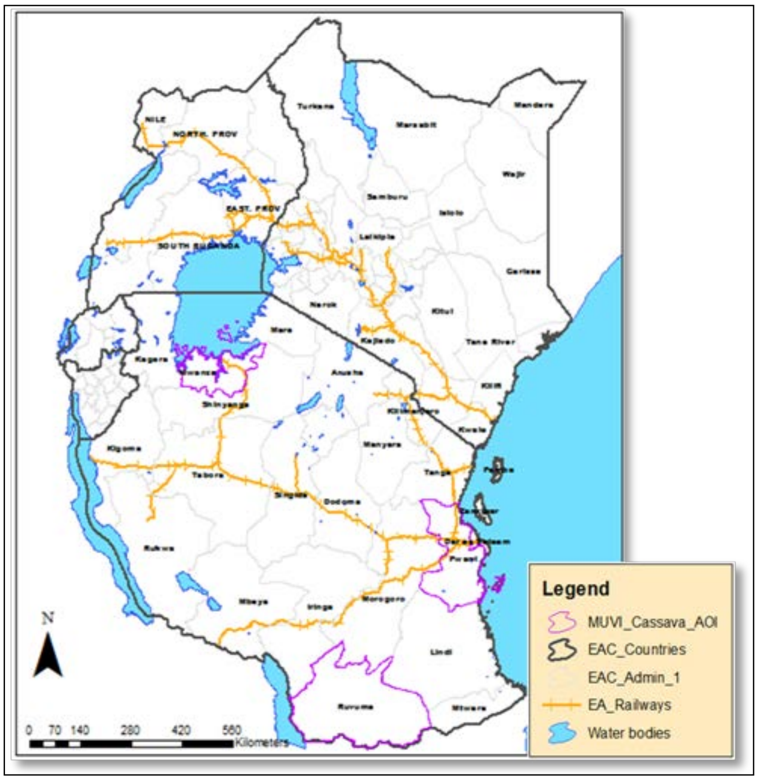


Figure 37: EAC Railway Plan (source: RCMRD Database 2015)

In addition, the East African Railway Master Plan proposes rejuvenating existing railways serving Tanzania, Kenya, and Uganda, and extending them to Rwanda and Burundi and eventually to South Sudan, Ethiopia, and beyond (Figure 37). According to the Master Plan, the current network system (RVR, TAZARA, and TRL) has the potential to increase from 3.7 million tons in 2007 to 16 million tons by 2030 with a growth rate of 6.7 percent. However, the projected future growth of rail traffic, based on anticipated GDP growth of member countries, especially from mining, fuel, cement, and other products is anticipated to range from a low of 13 million to a high of 20 million tons by 2030.

The region uses several gauges, which has been a challenge. The following gauges are in use by existing railways in the EAC:

- 3 ft 6 in (1,067 mm) gauge in Tanzania (south), Zambia, Mozambique, South Sudan, Sudan
- 1,000 mm (3 ft 3 ⅜ in) gauge in Tanzania (north), Kenya, Uganda, Ethiopia

- 950 mm (3 ft 1 ⅜ in) gauge in Eritrea
- 1,435 mm (4 ft 8 ½ in) standard gauge in various new and rebuilt lines.

The first of the proposed regional lines, the Mombasa-Nairobi-Kampala-Kigali-Bujumbura Railway would use standard gauge tracking.

(c) Pipelines

Transport of hydrocarbons (oil and natural gas) is expected to increase in East African following recent discoveries of deposits. Commercial hydrocarbon deposits were discovered in 2006 in the Albertine Rift basin that straddles the Uganda–Democratic Republic of Congo; more recently, viable quantities of natural gas have been found in the area. Kenya announced two oil finds in the Tertiary Rift Basin and several multinational oil exploration companies will soon begin bidding for five or more new offshore oil and gas exploration sites. The East African coastline shares the same geological formation as some of the gas-rich areas in Tanzania and Mozambique, so finds are likely there.

Currently, major oil pipelines include the Kenya pipeline from Mombasa to Nairobi, which extends to the Kisumu and Eldoret depots (in Kenya) and the Tanzania-Zambia Mafuta (TAZAMA) pipeline, which runs from Dar es Salaam to Ndola in Zambia (Figure 38). The governments of Uganda, Kenya, and South Sudan have agreed to produce preliminary designs for an pipeline to transport crude oil from Hoima via Lokichar to Lamu Port.

Figure 38: Proposed and existing oil products pipeline network in the East African Region

2.3.2 Water Transport

A significant number of vessels operate commercially on the East African lakes (Victoria, Kivu, and Tanganyika) for transportation of passengers and cargo.

Lake Victoria. The huge expanse of this lake is important for regional trade and communication and for inland water transport. It is served with ports and piers with docking facilities and service providers. With increased economic integration in the EAC, lake transport is expected to handle higher volumes of cargo and passengers. The EAC Development Strategy 2006–2010 outlines one of its strategic interventions as that of undertaking capacity building of Lake Victoria Transport Commission to enable it manage transport in the lake, as facilities will have to be updated and in some cases, rehabilitated.

Lake Tanganyika. The four Lake Tanganyika riparian countries—Burundi, Democratic Republic of Congo, Tanzania, and Zambia—started in the 1990s to establish a cooperative and collaborative approach to the sustainable development and management of the natural resources of Lake Tanganyika and its basin. Working with supporting partners, the four countries established the Lake Tanganyika Authority (LTA) and gave it oversight of implementing a regional integrated management program based on the provisions of the Convention on Sustainable Management of Lake Tanganyika that was signed on June 12, 2003. Transport services on Lake Tanganyika are mainly provided by Democratic Republic of Congo and Burundi. Tanzania also provides services, but on smaller scale. Zambia's inland waterway activities on the lake are low and limited to domestic operations.

Lake Kivu. On the Rwanda side, inland coastal shipping represented the bulk of transport activities on Lake Kivu. The main localities served were Gisenyi (the passenger port, the loading dock of the "fishing" project, the Kitraco berthing space, the Bralirwa loading dock), Kibuye, and Cyangugu.

2.3.3 Air Transport

Domestic air transport markets in East Africa are most important to Kenya and Tanzania, and they are emerging in Rwanda. Regional integration is low in East Africa. Total interstate traffic is only about 766,000 passengers, which is less than the total intrastate traffic of Kenya and Tanzania. The two major regional (interstate) routes are Nairobi–Entebbe and Nairobi–Dar es Salaam with traffic in the 250,000–300,000 range, followed by Nairobi–Kigali and Nairobi–Zanzibar, with volumes in the 60,000–75,000 range. All other routes have modest volumes below 30,000 passengers. Ranked by order of decreasing volume, Nairobi is first, followed by Entebbe and Dar es Salaam.

Other airports have experienced sizable growth, mainly due to business traffic (Entebbe and Dar es Salaam) and tourism (Mombasa, Zanzibar, and Kilimanjaro). Kenya and Tanzania have ambitious plans to expand their airport infrastructure to keep up with traffic growth and increased customer expectations for service quality. Funding these plans is a challenge for most Airport Authorities because total volume in the region is only about 5 million passengers per year, which keeps the revenue base low (Table 18).

Table 18: Access to air transport, number of passengers ('000)

Indicator	Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
International	**Burundi**	138	152	165	183	195	228	261	258	241
	Tanzania	1,081	1,233	1,288	1,262	1,385	1,617	1,761	1,860	1,976
	Uganda	643	789	936	929	1,023	1,086	1,239	1,344	1,332
	Kenya	4,634	5,165	4,575	5,086	5,553	5,889	5,850	5,183	5,744
	Rwanda	196	217	226	242	279	324	397	444	446

Indicator	Country	2006	2007	2008	2009	2010	2011	2012	2013	2014
	East Africa	6,693	7,556	7,190	7,702	8,436	9,144	9,507	9,089	9,739
Domestic	**Burundi**	—	—	—	—	—	—	—	—	—
	Tanzania	1,389	1,548	1,622	1,492	1,729	1,989	2,297	2,764	2,898
	Uganda	33	26	23	18	12	10	14	25	23
	Kenya	2,822	3,233	2,784	2,183	2,325	2,833	2,734	2,604	3,138
	Rwanda	3	4	6	6	9	21	28	26	21
	East Africa	—	—	—	—	—	—	—		
Transit	**Burundi**	—	—	—	—	—	—	—	—	—
	Tanzania	316	371	327	227	261	320	373	399	402
	Uganda	36	36	39	49	76	72	90	95	95
	Kenya	1,041	1,077	1,103	1,160	1,272	1,479	1,457	1,368	1,305
	Rwanda	5	17	22	20	26	32	63	91	103
	East Africa	—	—	—	—	—	—	—		

Source: EAC Facts and Figures 2015.

2.4 IMPACTS OF CLIMATE VARIABILITY AND CHANGE ON THE TRANSPORT SECTOR AND ASSOCIATED INFRASTRUCTURE

This section assesses transport sector vulnerability to climate change using the approaches and guidelines described in the GIZ *Vulnerability Sourcebook: Concept and guidelines for standardized vulnerability assessments* (Fritzche et al. 2014). It covers exposure to climate variability and change factors and identifies sensitivity aspects arising from natural and societal environmental factors with subsequent respective potential impacts and adaptive capacity. Analyses of the spatial and temporal trends in rainfall, maximum and minimum temperatures (exposure factors) have been discussed under the climate change section. The GIS data for identified indicators for **sensitivity** and **adaptive capacity** for the transport sector were obtained from the Regional Centre for Mapping of Resources for Development (RCMRD).

2.4.1 Exposure

Table 19: Exposure—parameters and indicators used in vulnerability mapping

Parameter	Data for VIA mapping	Remarks/impacts
Precipitation	❖ Average precipitation (1981–2013) ❖ Precipitation trends (1981–2013) ❖ Variability (1981–2013)	❖ Decreasing average precipitation leads to more system exposure ❖ Decreasing trend, more exposure ❖ Higher variability, more exposure ❖ Average but increased frequency, more exposure
Temperature	❖ Annual average temperature (1981–2013)	❖ Increasing temperature, more exposure ❖ Average but increased frequency, more exposure
Flood risk	❖ Major flooding events over 10 years (1997–2007)	❖ Increasing in flood-prone areas based on events, more exposure

2.4.2 Sensitivity

Table 20: Sensitivity—parameters and indicators used in vulnerability mapping

Parameter	Data for VIA mapping	Remarks/impacts
Land use	Road and urban outlay maps	❖ The land use/land cover maps are based on 30 years—1985, 1995, 2005, and 2014 for LVB and 2004, 2010 for EAC ❖ Road access is a key factor in biomass exploitation ❖ Heavy density is key factor to road wear and tear when exposed
Topography	Slope gradient (in %), DEMs SRTM 3 sec (30 m)	❖ Slope and elevation are key factors in the design of land and air transportation and power transmission infrastructure. A threshold of 30° was used for transportation ❖ Slope and elevation also influence accessibility of biomass for energy
Locational geo-references	Water bodies (rivers) road network	❖ Water bodies affect bridge maintenance
Floods	Flood risk maps	❖ Increased flooding improves power generation but destroys surface transportation
Geology	Soil type	❖ Soil type/particle size affects stability, drainability, erodibility and hence suitability of road/dam construction, harbors, airports, etc.
Drainage and river basins	Rivers	❖ Every hydropower station is associated with a drainage basin ❖ Presence of rivers increases potential for flooding, bridge construction, maintenance, etc.
Economic development	Poverty index	❖ Higher poverty levels lead to more biomass energy demand and hence degradation of land cover ❖ Reduces tax revenues for transport infrastructure repairs
Population	Population density	❖ Higher population leads to more biomass energy and transport demand and hence degradation of land cover ❖ Higher population strains transport infrastructure leading to wear and tear

2.4.3 Adaptive Capacity

Table 21: Adaptive capacity—parameters and indicators used in vulnerability mapping

Parameter	Data for VIA mapping	Remarks/impacts
Water discharge and recharge	Water recharge	Higher water discharge may imply high transport maintenance costs
Access	Market access	Long travel time to urban centers significantly reduces the adaptive capacity

2.4.4 Vulnerability

Table 22 shows key indicators and thresholds[23] for analysis of vulnerability in the transport sector. The selection of indicators and thresholds for analysis is limited by availability of data and not all indicators have equal magnitude in terms of impact.

Table 22: Sample of transport sector thresholds

Indicator and threshold	Mode	Purpose
Annual, seasonal, and monthly precipitation Annual, seasonal, and monthly average minimum, maximum, and mean temperature	Multi Airports	Pavement design Runway design
Daily high temperature: mean, 50%, 95%, and warmest day in the year during each 30-year period	Rail	AREMA rail design/ buildings
Seasonal and annual number of days and maximum consecutive days of high temperatures at or above 95°F, 100°F, 105°F, and 110°F	Civil/ Geotech/ Pavement	Comparing high temp days' duration to existing design standards
Mean, 5%, 25%, 50%, 75%, 95%, and largest occurrences for the average minimum air temperature over four consecutive days in winter, and the average maximum temperature over four consecutive days in summer	Bridge/Rail	Comparisons
Mean, 50%, 90%, 95%, and 99% occurrence of the coldest day of the year during each 30-year period	Multi	Pavement design
Maximum 7-day average air temperature per year with the percent probability of occurrence during each 30-year period (mean, 50%, 90%, 95%, 99% occurrence)	Multi	Pavement design (asphalt)
Exceedance probability precipitation for 24-hour period with a 0.2%, 1%, 2%, 5%, 10%, 20%, and 50% exceedance precipitation events (e.g., 500-year, 100-year, 50-year)	Multi	Drainage/liquid storage
24-hour exceedance probabilities based on today's 0.2%, 1%, 2%, 5%, 10%, 20%, and 50% exceedance precipitation events	Multi	Drainage
Exceedance probability precipitation across four consecutive days: 0.2%, 1%, 2%, 5%, 10%, 20%, 50%, mean; exceedance probability of precipitation across two consecutive days: 0.2%, 1%, 2%, 5%, 10%, 20%, 50%, mean	Pipeline	Historical analysis of inundation
Largest 3-day total of precipitation each season	Multi	Change in storm events

Figure 39 shows the overall vulnerability of the transport sector. As for the energy sector, there is a very close correlation between the existing road networks in EAC with areas identified as being less vulnerable. Areas with high to very high vulnerability have limited coverage of the infrastructure. This map is best on the historical trends.

[23] Climate Variables Used in the Gulf Coast Phase 2 Study (The US Federal Highway Administration's Climate Change and Extreme Weather Vulnerability Assessment Framework) December 2012 p.15 (51 pages) (https://www.fhwa.dot.gov/environment/climate_change/adaptation/publications/vulnerability_assessment_framework/fhwahep13005.pdf)

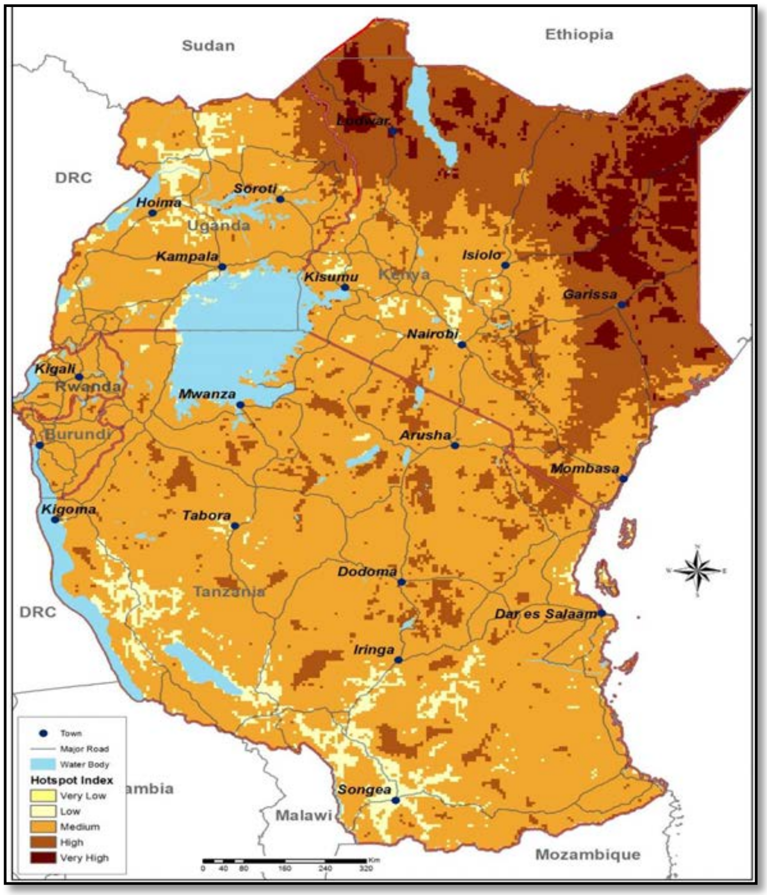


Figure 39: EAC Vulnerability Hotspot Map – Transportation Sector

2.4.5 Impacts of Climate Variability and Change on the Transport Sector and Associated Infrastructure

The potential impacts are summarized in Table 23.

Table 23: Potential impacts of climate variability and change on the transport sector and associated infrastructure

Climate effects	Thresholds and indicators	Impacts of infrastructure
Increase in temperature	❖ Hot days ❖ Heat waves ❖ Increased frequency ❖ Increased range ❖ Increased ultraviolet (UV) radiation	❖ Increased thermal expansion at joints for railways leading to speed limits and even derailments ❖ Increased melting of bitumen for tarmac roads ❖ Increased rate of degradation from UV light ❖ Increased wear and tear reducing durability ❖ More frequent maintenance of roads due to asphalt migration ❖ Stress on bridges – joints, coats, sealants, steel ❖ Frequent fires ❖ Use of solar services for road signs and power supply (positive impact) **Services:** ❖ Increased cost of construction

Climate effects	Thresholds and indicators	Impacts of infrastructure
		❖ More nighttime work
Increase in rainfall	❖ Annual rainfall ❖ Seasonality ❖ Frequency ❖ Duration ❖ Mist ❖ Storms ❖ Flooding	❖ Destruction of roads, breaks and erosion of materials, or washouts ❖ Blockage of drains due heavy silt loads ❖ Increase in flooded roads, tunnels, railways ❖ More frequent maintenance and replacement due to slow failures ❖ Structural integrity of roads, bridges, tunnels affected due to increased soil moisture and stagnant water ❖ Increased landslides ❖ Overhaul and upgrade required for roads and bridges due to rising stream levels and peak flows **Services:** ❖ Increase in weather-related delays, disruptions, diversions ❖ Increase in maintenance, upgrade, or replacement costs ❖ Increase congestion, disruptions, diversions and delays
Extreme events	❖ Storm surges range and frequency ❖ Flooding intensity and frequency ❖ Mist intensity and frequency ❖ Wind intensity and frequency	❖ Safety of Life at Sea (SOLAS) is compromised ❖ Increased frequency of emergency services and repairs ❖ Debris and soil, blow-over, and destruction of critical assets ❖ High-intensity primary and secondary damage from flooding ❖ Erosion of road byways and rail road byways ❖ Damage to road and rail foundations ❖ Destruction of shipping vessels ❖ Reduced visibility in aviation, maritime, roads at escarpments, railways (non-ITS) ❖ Risk for landing and take off at airports ❖ Increased wind intensity leading to aviation disasters, unstable cars on roads, increased loss of fines on gravel roads, maritime disasters ❖ Low wind intensity loaded aircrafts unable to take off due to insufficient lift ❖ Average but increased frequency of wind events lead to wear and tear reducing durability of assets **Services:** ❖ Severe disruptions ❖ Loss of lives ❖ Loss of critical assets ❖ Heavy economic losses ❖ Heavy costs for repair and replacement
Sensitivity	❖ Loss of vegetation and land use change ❖ Soil type ❖ Slope	❖ Increased erosion and increased soil load in drainages ❖ Soil types affect temperature and reflection increasing surface temperature

Climate effects	Thresholds and indicators	Impacts of infrastructure
	❖ Settlements ❖ Population growth versus asset criticality ❖ Watershed catchment size, roughness, index, shape, and slope ❖ Age of asset ❖ Frequency of use	❖ Steep slopes predisposed to landslides while low slopes lead to floodwater retention in water basins ❖ Unplanned settlements overload infrastructure and poor planning affects efficient planning of infrastructure increasing vulnerability ❖ High populations increase demand and wear and tear of infrastructure and assets ❖ Built up infrastructure increases in strength during the first few decades then deteriorate and weaken ❖ Frequency of use increases wear and tear
Adaptive capacity	❖ Economic capacity ❖ Robust infrastructure network ❖ Modal transport options (road versus air versus maritime versus rail) ❖ Cost of repair/extent of damage ❖ Institutional and technical capacity ❖ Policy framework	❖ Economic assets in community provide options and alternatives ❖ National GDP enables quick response and preparedness at technical and financial level ❖ Alternatives are only available if there is a network ❖ Modal transport options provide alternatives, especially if affordable ❖ Cost of repairs affects ability for response ❖ Disaster and risk preparedness framework present or absent

(a) Surface Transport

The impacts due to climate variability and change will vary in scale, intensity, duration, and space for different forms of transportation and transport infrastructure. Some examples are described in this section.

Impacts of climate change on the transport sector have negative impacts on other sectors of the economy. East Africa has a well-structured roadway, but the condition of most rural roads makes it difficult to travel or move goods, particularly during the wet season. The state of infrastructure and the ability to bounce back also directly affects other sectors driving the economy of EAC Partner States. For instance, Kenya's National Climate Change Action Plan 2013/2017 notes that the trade, industry, agriculture, health, transport, energy, and education sectors, among others, depend on infrastructure to function optimally (GoK MEWNR 2013). The East African Climate Change Master Plan (2011) acknowledges that the infrastructure in the Partner States is generally "poor and underdeveloped" and hence unable to cope, adjust, or bounce back in the face of climate extremes. As a result, disaster risk is increased, resulting in adverse effects on the economy (East African Climate Change Master Plan, 2011). For example, Burundi, Rwanda, and Uganda depend on rail and road transport for imports and exports. This has put substantial pressure on trunk roads, which also serve neighboring countries. Climate-related extreme events, especially on the roads to the Indian Ocean ports have in the past seriously affected the export/import subsector.

A critical function of road infrastructure is connectivity and access, especially in rural areas where such infrastructure essential for social welfare and economic growth (Limi et al. 2015). In Uganda, the poor state of infrastructure results in high transport costs and increasing transaction costs. For many commodities, the cost of transportation already equals or exceeds their farm gate value. The impacts of climate variability and change will exacerbate the deterioration of transport infrastructure and increase the cost of moving people and goods from farm to market. High transport costs make use of purchased inputs the low use of which reduces productivity and thereby sustains poverty (USAID 2014). The impacts of climate change on transport infrastructure will therefore further penalize farmers who are already vulnerable to the vagaries of climate variability and change.

In **Uganda**, during the 1997/1998 El Niño, considerable transport infrastructure, especially bridges, were destroyed and lives lost. Estimates of damage of road infrastructure varied from US$300 million to US$500 million. The El Niño that followed (2001/2002) was of comparable magnitude, yet not as many bridges were washed away. The difference was that the Ministry of Works and Transport used weather and climate information to clear drainage and prepare adequately before the onset of the El Niño (Kaggwa, Hogan, and Hall 2009).

Bujumbura City is in the Imbo lowlands area, which the NAPA identifies as vulnerable. This region is subject to torrents flowing from the Congo-Nile watershed and Mumirwa. This has regularly caused disastrous erosion, characterized by landslip and deposits of alluvia and colluviums in the lowlands. This situation is likely to be accentuated by increased precipitation due to climate change and variability. This type of erosion affects urban zones, in particular Bujumbura, which is crossed by four such torrents. Heavy rains in 1937, 1941, 1950, 1960, 1961–1964, 1983, 1986, 1989, and 1991 caused regular cuts of roads, landslides, and damage to infrastructure and the population in Bujumbura (Figure 40).

Figure 40: In April 2009, floodwaters had reached areas that were previously unaffected, "even moving down a road leading to Bujumbura International Airport"

In **Kenya**, a section of the Mai Mahiu–Narok road was washed away by flash floods in May 2012. The storm water was from the eastern slopes of Mau Hills. Due to the depth of the water and incessant rains, the road remained closed for one week. Traffic was diverted to other roads leading to delays and extra costs. The same road had been closed the previous week for a day due to floods near Suswa market. In this case part of the problem was attributable to terrain and change in land use.[24] Further, on May 11, 2015, Nairobi was submerged in floods after a downpour of slightly over two hours resulting in death and destruction. The delays in traffic exceeded 6 hours. Part of the problem in this case was attributable to old drainage systems. In both cases, however, the volume of the floods exceeded predictions and was in part due to climate change.[25]

A 2006 flood severely affect the Dadaab refugee camps and destroyed more than 2,000 homes in the Ifo camp. The flooding also cut the sole access road to the camp and town, effectively cutting off essential

[24] http://www.capitalfm.co.ke/news/2012/05/mai-mahiu-narok-road-stays-closed/

[25] http://www.capitalfm.co.ke/news/2015/05/1960s-drainages-bring-misery-to-nairobians/

supplies. This forced the relocation of more than 10,000 refugees. A new camp, Ifo II, was constructed on higher ground in 2007.

In **Rwanda**, floods and landslides frequently affect some areas of the country (MIDIMAR 2012). Most of the vulnerable areas are in the northwest (Figure 41): Nyabihu, Rubavu, and Musanze, Burera, Gakenke, Ngororero, and many others (Nsengeyumva 2012). Several areas of the country have experienced floods following above-normal rains, which resulted in landslides in localized areas where characterized by steep slopes and mountain valleys (Meteorological Services 2012). Rural communities in Rubavu District, in 2010 within three cells of Rubavu Sector, are among those most affected by landslides. Infrastructure is frequently destroyed, including small access roads connecting communities.

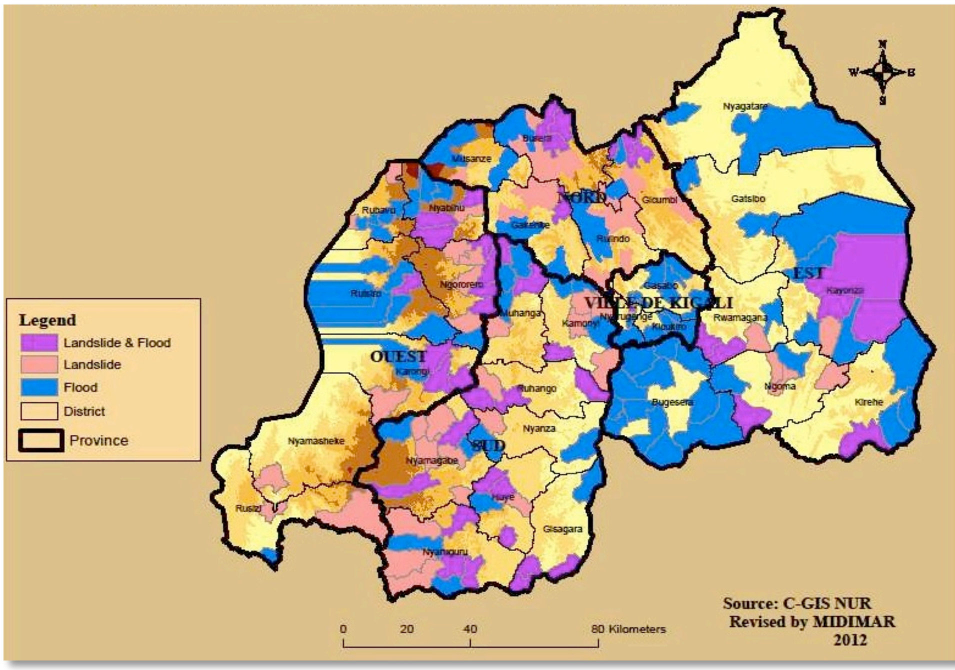


Figure 41: Flood and Landslide Map of Rwanda (source: Nsengeyumva 2012)

(b) Rail Transport

While rail transport is not directly affected as much as roads, landslides and mudslides, flooding, and rusting that due to weather variability have serious impacts. Bridges and embankments are weakened during intense rains and consequent rapid runoff flows that are associated with flooding. This increases the probability of accidents and derailments and huge losses are incurred especially for freight.

A wash away is a kind of landslide that can affect transport structures such as cuttings, embankments, and bridges in railways and roads. In ITS systems, an electrical signal that is normally green can be switched to red if a contact is opened by a slump of the earth beneath. However, in human-operated mechanical signaling systems, early warning signs do not exist. On January 30, 1993, 114 people perished in a passenger train that plunged into Ngai Ndethya River in Kenya after floods washed away the small bridge. This was due to a flash flood arising from multiple causes—change in land use, heavy rains, and poor visibility from mist. A new, larger and higher bridge was built to replace the small one that washed away.

Kenya Railways Corporation (KRC) says it loses an average of Sh500 million annually due to accidents along its tracks. Train derailments mostly occur during the daytime and when temperatures are very high.

Misalignment due to track buckling forces the wheels of the rolling stock to fly off and if the train was traveling at a high speed, it may tip over. With increasing incidents of high temperatures, the number of derailments can be expected to increase with attendant increase in costs of repair and insurance. KRC intends to install extra line restraints at curves along its single-lane tracks to curtail derailments arising from the effects of high temperatures.

Figure 42: Derailed train at Kibera, Nairobi (December 2013)

Water Transport

Fishing is an important economic activity in the LVB with an estimated annual fish catch of 500,000 tons, generating more than US$400 million (more than US$1 million per day) at the landing sites. Fishing products from the lake contribute US$250 million in export earnings. Primary fishing activity is undertaken by about 200,000 fishermen using a fleet of nearly 70,000 small crafts. In addition to the fishing fleet, a significant number of larger vessels operate commercially on the lake for transportation of passengers and cargo. Total trade transacted across the lake was US$830 million in 2007 (exports $650, imports $180 million). Climate variability and change leads to increased storm intensities (both wind and rain) and wave actions in water bodies used for transport. These directly affect vessels for transport and related infrastructure. Marine activities are usually affected by heavy rainstorms, wind gusts/hurricanes, silt, and seaweed.

Air Transport

In the LVB, all aviation activities are affected by weather and climate with major impacts on air transport. Weather and climate information are used for designing airports/fields, planning routes, and operating flights. No flights take off or land without weather forecasts due to safety implications. (Kaggwa, Hogan, and Hall 2009).

Weather is the cause of approximately 70 percent of aviation delays and 23 percent of accidents and incidents. Convective weather causes thunderstorms with severe turbulence, intense updrafts and downdrafts, lightning, hail, heavy precipitation, icing, wind shear, microbursts, strong low-level winds, and tornadoes. A single aviation accident looked at individually may not demonstrate a pattern or trend. However, considering the improved quality of aircraft, equipment, infrastructure, including digital navigation and communication systems and more educated and trained pilots, the increase in weather-related accidents and incidents can only be attributed to climate change.

Eldoret International Airport operates cargo flights out of a region associated with low temperatures. However, it has been experiencing high temperatures over prolonged periods. This phenomenon delays loaded aircraft from taking off until temperatures are low and winds are sufficient for liftoff.

In **Tanzania**, the Babati district, south of Lake Victoria and west of Mwanza, is a flooding hotspot. Floods occurred in Babati at Manyara in 1998, 1990, 1980s, 1970s, and 1964 (Government of Tanzania 2007). Flooding has severe impacts on the economy due to bridge washouts, road destruction, and airport flooding that leads to cancelled flights that paralyze the transport sector.

Figure 43: Mwanza airfield flooding (http://richard-mwaikenda.blogspot.com/2011/11/uwanja-wa-ndege-wa-mwanza-wageuka.html)

The impacts of climate change on transport infrastructure are varied depending on the asset type and criticality. The scale and nature of impact is determined by age of assets, current and historical performance and condition, level of use, structural design, materials used, design lifetime and stage of life, and replacement cost. Sensitivity is further determined by geographic location, elevation above sea level, Light Detection and Ranging (LIDAR) remote sensing data, maps, topography, and availability of risk maps, vegetation and soil survey maps. Further adaptive capacity is determined by jurisdiction (national, subnational), geographic location (floodplain or not) and history of vulnerability.

Surface transport assets include road pavements, bridges and tunnels, culverts and storm water drainage systems, bicycle lanes and pedestrian footpaths, evacuation routes, railway lines, railway yards, railway stations, bridges, viaducts and tunnels, pipelines, signage and other road furniture, and roadside landscaping and vegetation. Aviation transport assets include airports, runways, radar facilities, and control towers while maritime assets include ports, harbors, and quays.

3. POLICY FRAMEWORK AND SECTOR PREPAREDNESS TO CLIMATE CHANGE

3.1 ENERGY SECTOR

The economic, social, and political development of the EAC Partner States is supported by their respective strategic visions (Table 24). Through these visions, elaborate plans and policies have been launched to address issues relevant to the energy sector, transport infrastructure development, and climate change. Although the Partner States' visions and strategies were prepared independently, they are in line with the objectives of the EAC, which develops policies and programs aimed at widening and deepening cooperation for the mutual benefit of the Partner States.

Table 24: EAC Partner States Strategic Visions

Partner State	Time frame	Strategic vision	Priority areas
Burundi	Vision 2025	Sustainable peace and stability and achievement of global development commitments in line with the MDGS	Poverty reduction, reconstruction, and institutional development
Kenya	Visio 2030	Globally competitive and prosperous Kenya with a high quality of life	To achieve sectoral objectives including meeting regional and global commitments
Rwanda	Vision 2020	Become a middle-income country by 2020	Reconstruction, human capital development and integration with the regional and global economy
Tanzania	Vision 2025	High quality of life anchored in peace, stability, unity, and good governance, rule of law, resilient economy and competitiveness	Inculcate hard work, investment, and savings culture; knowledge-based economy; infrastructure development; and private sector development
Uganda	Vision 2035	Transform from a peasant society to a modern prosperous country	Transform from a peasant society to a modern prosperous country
EAC		Attain a prosperous, competitive, secure and politically united East Africa	Widen and deepen economic, political, social, and cultural integration at regional and global levels

Source: Adapted from the 4th EAC Development Strategy (2011/12–2015/16): Deepening and Accelerating Integration.

3.1.1 Regional Policies

Through sector support programs and resource mobilization plans, the EAC has policies and strategies that aim to develop and strengthen the energy sector while addressing climate change for the mutual benefit of all Partner States.

Both the EAC Climate Change Strategy (2011) and the Master Plan (2011–2031) recognize energy as a priority for regional development while acknowledging that the sector is vulnerable to climate variability and change. These strategic documents consequently call for climate change mitigation measures by EAC Partner States to increase availability and accessibility of sustainable, reliable, and affordable renewable energy resources.

The focus of the energy sector has been on electricity generation and transmission. The East Africa Power Master Plan, launched in 2003, is the key regional policy document. It aims to address technical requirements and economic viability for interconnection of the power systems of the Partner States as demand grows. The EAC also works closely with regional organizations, such as the Nile Basin Initiative (NBI) and the Economic Cooperation of the Great Lakes Countries (CEPGL), to promote regional projects and programs. Examples of such programs include the Nile Equatorial Lakes Subsidiary Action Plan (NELSAP) and Regional Power Trade Project of the NBI. In its efforts to increase access in a cost-effective manner, the EAC has developed a cross-border electrification program that enables border centers to access electricity from the nearest grid.

The EAPP, established in 2005 by the signing of an inter-governmental memorandum of understanding by Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda and Sudan, is a milestone. In a further development, EAPP was adopted as a specialized institution to foster power system interconnectivity by the heads of states of the COMESA region. Tanzania, Libya, and Uganda joined EAPP in March 2010, February 2011, and December 2012 respectively. The EAC, jointly with the EAPP is developing a Regional Power Master Plan and Interconnection Code (2013–2038). This is an expansion of the existing East African Power Master Plan (2003–2024) that includes Rwanda and Burundi, which joined the EAC after the Master Plan had been developed.

In addition, the Regional Strategy on Scaling-up Access to Modern Energy Services is another EAC initiative to supporting access to energy as part of achieving the Millennium Development Goals. However, these policy initiatives have not given adequate attention to potential future climate change impacts.

3.1.2 National Policies

Individual countries also have national policies relevant to climate change and the energy sector. However, the effectiveness of these policies is compromised by inadequate funding, lack of harmonization/conflict between policies touching on the same resources, lack of awareness among stakeholders, inadequate strategies for implementation, and bias toward electricity and petroleum-based fuels.

Burundi's Environment Act of 2000 is operational but needs review to harmonize it with the Forestry Code and the Land Code. Burundi's Energy Sector Strategy, 2011, on the other hand recognizes lack of coordination of various entities involved in the energy sector and recommends the overall coordination of entities by the Ministry of Energy and Mines (MEM), clear definition of roles assigned to each entity, and improvement of the legal and regulatory framework. The Sector Strategy May 2013 under "*Le Ministère de l'Eau, de l'Environnement, de l'Amenagement du Territoire et de l'Urbanisme (MEEATU),"* whose objective is the promotion of coordinated environment management including land and infrastructure, forests, water, and air quality, similarly recognizes the lack of harmonization of different codes, lack of population participation in the implementation of environment programs, and absence of public awareness on international conventions as impediments to successful implementation.

Kenya's policy is yet to be fully enacted. The latest version (Energy Policy, 2014), while recognizing the role of renewable energy in the country's energy mix, does not have robust strategies on biomass development, for example. The Energy Act, 2006, the primary legislation on energy in Kenya, is currently undergoing review to align it with both the 2010 Constitution and the country's Vision 2030. It similarly emphasizes petroleum and electricity at the expense of renewable energy. Kenya has a Rural Electrification Master Plan that was created to accelerate the pace of rural electrification, but it is inadequately funded. Skewed population distribution makes some regions uneconomical to connect. Furthermore, the high connection fees discourage application from the target population. The Least Cost Power Development Plan (2011–2031) is aligned to the Vision 2030 medium-term plan and aims at enhancing national power generation and supply by identifying new generation and supply sources to ensure that the national electric power supply exceeds 3,000 MW by 2018. Although has an elaborate implementation plan, it suffers from inadequate funding. Attempts have been made to promote bioenergy in the country. For example, the Bioenergy Policy and Strategy, 2011, provides a policy framework to promote and harmonize the development of sustainable bioenergy in Kenya, but it similarly suffers from inadequate funding and follow-up. Some policies and strategies also transcend the energy-climate-environment boundaries. The National Climate Change Response Strategy (2010) was the first national policy document to acknowledge the reality of climate change in Kenya. It advocates the use of renewable and clean energy as a mitigation and adaptation option. Like other strategies, it suffers from inadequate funding and its implementation through the National Climate Change Action Plan is highly dependent on donor funding. The Forests Act, 2005, and its subsidiary legislation the Forests (Charcoal) Regulations, 2009, both promote forest conservation, sustainable forest management, and renewable energy, but they are hobbled by ambiguities, need alignment with other strategies as well as the 2010 Constitution, and introduce bureaucratic requirements for issuance of licenses and the provisions on private forest ownership that discourage private investment in forestry development.

Rwanda has six notable laws and strategies on energy and environment. The Green Growth and Climate Change Resilience Strategy of 2012 encompasses all development sectors including energy and transport with strategies to address climate change impacts. However, it has not yet been formally adopted. Law 04/2005 of 2005, on the other hand, provides for establishment of modalities of protection, conservation, and promotion of environment in Rwanda. Its major weakness is that it only emphasizes environmental assessment and has little focus on climate change. This is a similar weakness with Law 16/2006 of 2006, which established the Rwanda Environmental Management Authority (REMA) to coordinate and integrate environmental management functions in relation to cross-cutting issues (monitoring, evaluation of environmental policy, implementation of legislation). In the energy sector, the National Energy Policy of March 2015 aims to advance Rwanda's targets by insuring sufficient, reliable, affordable, and sustainable energy services to all residents with promotion of environment conservation and climate change concerns into energy planning and development. The much earlier Electricity Act of 2011 specifically governs electricity power licensing for production, transmission, distribution, and trading within and outside of the territory of Rwanda. However, more efforts are needed to improve the legal and regulatory framework to attract investment for off-grid solutions. As a country that is heavily reliant on biomass, Rwanda also has a BEST (2009) whose objective is to integrate biomass resources into the economic development of the country with actions to be done, appropriate costs and benefits for a sustainable use. However, a new taxation system needs to be elaborated to avoid bureaucratic practices. Limited financial resources also affect successful implementation.

Tanzania's Energy Policy 2015 (draft) aims to ensure availability of sufficient, reliable, and affordable modern energy supplies and their use in a rational and sustainable manner. It recognizes that one of challenges in developing hydro systems is vulnerability to hydrology and climate change. It is meant to be a replacement of the Energy Policy of 2003 which, although it seeks to promote renewable energy to minimize threats on climate change, does not mention anticipated impacts of climate change and subsequent measures. In 2012, the National Climate Change Strategy was launched. The strategy seeks to address climate change and improve energy availability, reduce deforestation, and improve energy diversification and efficiency. The strategy is a major enhancement of the Environment Management Act, 2004, which stresses environmental impact assessments but does not mention anticipated impacts of climate change and subsequent measures. Furthermore, its implementation is limited by earlier acts. The Rural Energy Act (2005) promotes access to modern energy services in rural areas. It also provides for grants and subsidies to developers of rural energy projects. However, it does not mention the anticipated impacts of climate change or measures to address them. In 2007, Tanzania developed the NAPA, which recognized that biomass and hydropower are vulnerable due to declining rainfall and increasing mean temperatures and recommended the exploration and investment in alternative clean energy sources.

However, it suffered from ineffective implementation of proposed activities that address urgent and immediate needs for adapting to the adverse impacts of climate change and therefore has only seen limited adoption. The Electricity Act (2008) facilitates and regulates the generation, transmission, transformation, distribution, supply, and use of electric energy to provide for cross-border trade in electricity and planning and regulation of rural electrification and to provide for related matters, but it does not mention the impacts of climate change or measures to address them. Even the more recent Energy, Water, and Utilities Regulatory Authority Act of 2012, which regulates electricity, petroleum, and natural gas, and water sectors, and the and Power Sector Master Plan, also of 2012, have no mention of climate change. The BEST of 2014 identifies the means of ensuring a more sustainable supply of biomass energy to raise the efficiency with which biomass energy is used in Tanzania, and promotes access to alternative energy sources where appropriate and affordable. However, BEST has not critically assessed the impact of climate change on the future availability of biomass.

Finally, **Uganda** has a raft of policies, laws, and regulations to govern the energy sector and address climate change. The main weakness for Uganda is the lack of harmony between the various legislations, inadequate funding, and insufficient treatment of climate change. The National Development Plan (2010), for example, while it acknowledges that forest cover has declined over the years and has even set targets to reverse the trend, does not adequately address climate change. The Disaster Preparedness and Management Policy (2010), in contrast, calls for proactive efforts to reduce the causes and the negative impacts of climate change but does not provide specific strategies for undertaking the activities. On a positive note the Climate Change Policy (2012), which sought to remedy this recognizes the need to act upon a number of sector-specific priorities to increase the resilience of the country's development path to the impacts of climate change and to contribute to the reduction of atmospheric greenhouse gas emissions. However, its effectiveness is limited by other related policies that are seen to be weak. For example, the more recent BEST of 2013, which recognizes overdependence and unsustainable use of tree biomass as key deterrents to sustainable development does not include an analysis of future scenarios for biomass supply and does not mention the anticipated impacts of climate change or measures to address them. Not surprisingly, none of the earlier policies and strategies address climate change either. These include the Renewable Energy Policy, 2007; the National Adaptation Programme, 2007; the National Forestry and Tree Planting Act of 2003; the Energy Policy, 2002; the Forest Policy, 2001; the National water policy, 1997; and the Environment policy of 1995.

3.1.3 Institutional Frameworks

Table 25: National institutional frameworks

Country	Function	Institution
Burundi	**Coordination**	Ministry of Energy and Mines; Ministry of Water, Environment, Land and Urban Planning
	Regulation, development, and maintenance	National Environmental Management Authority, Electricity Regulatory Board, Directorate General of Hydraulics and Rural Energies, Directorate General of Water and Energy (DGEE), Forest Department, Institut Geographique du Burundi (IGEBU)
	Execution /financing	Commercial banks, REGIDESO, Alternatives Energies Burundian Centre (CEBEA), Burundian Agency for Rural Electrification), IPPs, Burundi Renewable Energy Association, SINELAC (Société Internationale d'Electricité des Grands Lacs)
Kenya	**Coordination**	Ministry of Energy and Petroleum; Ministry of Environment, Water, and Natural Resources

Country	Function	Institution
	Regulation, development, and maintenance	National Environmental Management Authority, Rural Electrification Agency, Kenya Forest Service, Energy Regulatory Commission, Kenya Meteorological Department (KMD)
	Execution/financing	Commercial banks, Kenya National Federation of Agricultural Producers, Geothermal Development Company, Kenya Generation Company Ltd (KenGen), Kenya Power and Lighting Company (KPLC), Kenya Transmission Company (KETRACO)
Rwanda	**Coordination**	Ministry of Infrastructure (MININFRA), Ministry of Natural Resources (MINIRENA)
	Regulation, development, and maintenance	Environmental Management Authority (REMA) Rwanda Development Board, Rwanda Energy Group, Rwanda Natural Resources Authority for forestry resources management), Rwanda Meteorological Service (Meteo Rwanda)
	Execution/financing	Rwanda Energy Group with subsidiaries of Energy Utility Cooperation Limited and Energy Development Cooperation Limited, government through Ministry of Finance and Economic Planning (MINECOFIN), development partners (World Bank, AfDB, Nordic Fund, EADB, GIZ, EXIMBANK, public-private partnerships, and others), commercial banks, Rwanda Renewable Energy Association, SINELAC
Tanzania	**Coordination**	Ministry of Energy and Minerals, Vice President's Office–Division of Environment, Ministry of Natural Resources and Tourism, Ministry of Water
	Regulation, development, and maintenance	Rural Energy Agency, Energy and Water Regulatory Authorities, Tanzania Forest Service, National Environmental Management Council, Water Basins (Ruvu/Wami, Rufiji, Pangani, and others), Tanzania Meteorological Agency
	Execution/financing	Commercial banks, TANESCO, Tanzania Geothermal Development Company, IPPs, Tanzania Renewable Energy Association
Uganda	**Coordination**	Ministry of Energy and Mineral Development, Ministry of Water and Environment
	Regulation, development, and maintenance	National Environmental Management Authority, Electricity Regulation Authority, National Forestry Authority, Water Basins, Uganda Meteo
	Execution/financing	Bujagali Energy Limited (BEL), ESKOM and Uganda Electricity Generation Company Limited, Uganda Electricity Transmission Company Limited, Umeme and Uganda Electricity Distribution Company Limited (UEDCL), IPPs, Uganda Renewable Energy Association

Table 26: Regional Framework Institutions Function

Function	Institution
Coordination of policies, program development, financing under EAC Ministerial Conference	EAC Secretariat
Fostering interconnectivity of regional network for electricity trade	EAPP, including Burundi, Kenya, Rwanda, Tanzania, Uganda, Democratic Republic of Congo, Ethiopia, Eritrea, Egypt, Sudan, South Sudan, and Libya
Coordination of sustainable development of the agenda of Lake Victoria Basin	Lake Victoria Basin Commission (LVBC)

3.1.4 Policy Suggestions

1. Diversify sources of energy to include:
    - ❖ Alternative (renewable) sources, such as hydro, natural gas, geothermal, solar PV and thermal solar energy, and wind.
    - ❖ Hybridization (combining different energy sources in one power plant) to ensure a reliable and sustainable supply of electricity to residential, commercial, and industrial users.
2. Introduce a large-scale energy efficiency program with the adoption of modern technologies. This would include household energy efficiency, including cooking technologies such as improved cookstoves and solar cookers, solar water heaters, inverters in commercial buildings, domestic and industrial biogas, and cogeneration. All of which should be supported by an intensive public awareness campaign and political decision makers who will the model adoption of these technologies.
3. Reforest catchment areas of hydropower plants to retain underground water, mitigate erosion and landslides, and reduce siltation that can damage equipment in hydropower plants.
4. Improve regional interconnectivity of electrical networks through regional power pools and tariff harmonization.
5. Strengthen the institutional framework and capacity for planning and managing in the energy sector.
6. Review standards and specifications to cope with extreme events of climate change on national and regional levels.
7. Train technicians in design and development of energy infrastructure that is resilient to the impacts of climate change (district, province, government, regional).
8. Develop curricula for and training of specialists in climate change prediction to ensure the availability of reliable information for use in decision making (district, province, government, regional).

3.2 Transport Sector and Associated Infrastructure

The transport sector was responsible for approximately 23 percent of total energy-related carbon dioxide emissions in 2010, of which 72 percent was attributed to road transport and 10 percent to domestic and international aviation. The final energy consumption for transport reached 28 percent of total end-use of energy in 2010, 40 percent of which was used in urban transport.[26] Sustainable low-carbon transport could save governments and companies up to an estimated US$70 trillion.[27]

Transport is affected by climate change both positively and negatively. Adapting transport systems to the effects of climate change can both complement and counteract mitigation efforts.[28] The Paris Agreement on Climate Change (2015) affirmed the goal of keeping global temperature increases to 2°C and set an aspiration goal of a 1.5°C scenario. However, transformational change of the transport sector is not likely to happen purely based on climate change goals, and is more likely to be driven by sustainable development concerns such as co-benefits of reducing air pollution, reducing congestion, improving safety and health, enhancing energy security, economic growth, and mass transit. As such, synergies with the post-2015 SDGs provide a robust framework for translating mitigation and adaptation ambition into implementation. Cost-effective mitigation and adaptation action in the transport sector with economic, social, and environmental co-benefits can help to close the emission gap. These can result in policy choices that lead to cost saving, poverty reduction, food security, job creation, energy security, improved public health, reduction of pollutants and associated health risks, reduction in adaptation needs, and biodiversity benefits.

3.2.1 Regional Policies

The relevant regional policy document is the Transport and Communications Strategy and Priority Investment Plan, which was developed in 2010 by ESA States, represented by EAC, COMESA, Inter-Governmental Authority on Development (IGAD), the Indian Ocean Commission, and the Southern African Development Community as an observer. At the East African level, the EAC policy on Transport has largely been encapsulated in the EAC Treaty, which covers all modes of transport except pipelines. The treaty aims at harmonization of policies, standards, rules, and practices, and coordination of implementation programs of regional interest. The transport functions in EAC are under the Deputy Secretary General for Planning and Infrastructure. The Roads and Road Transport Unit in the Transport and Works Department is primarily responsible for land transport affairs. The Unit for Maritime Transport and Ports including Inland Waterways Transport has been a focus for strengthening. Within the EAC, transport-specific organizations function either under the auspices of the EAC Secretariat or as the result of a tripartite or multilateral agreement. The following organizations have significant functions relevant to regional road and maritime transport:

- Northern Corridor Transit Transport Coordination Authority (NCTTCA)
- Central Corridor Transit Transport Facilitation Agency (CCTTFA)
- Joint Technical Committee under the Tripartite Agreement on Road Transport
- The Joint Committee on Inland Waterways
- The EAC Lake Victoria Basin Commission to the extent that its responsibilities affect transport infrastructure development and services as well as navigational safety and maritime security
- Various technical committees established by the EAC Secretariat, such as the Technical Committee on Axle Load Limits Implementation.

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[26] IPCC 2014. Transport. In Climate Change 2014. Mitigation of Climate Change. Page 605.

[27] United Nations Climate Change Secretariat. 2015. Climate Action Now. Summary for Policy Makers. Page 9

[28] IPCC 2014. Climate Change feedback and interaction with adaptation. In Climate Change 2014. Mitigation of Climate Change, Page 622.

The Ports and Maritime Sector in EAC is established under articles 94 and 95 of the EAC Treaty. The Maritime and Ports Authorities in the Partner States meet regularly under the auspices of the EAC Secretariat to review and develop regional projects and programs in the sector. In the context of Lake Victoria, a joint undertaking is maritime search and rescue coordination center for the lake, a weather forecasting system, as well as quality management systems for the ports. The EAC Development Strategy 2006–2010 has two key strategic interventions: implement the Inland Waterways Transport Agreement and build the capacity of Lake Victoria Transport Commission to enable it manage transport on the lake.

Climate-proofing and adaptation in the transport sector requires substantial financial inputs and infrastructural investments. For example, resurfacing roads with more durable materials to withstand extreme events and serve higher volumes of traffic to meet the needs of a growing population increase project costs significantly. Given the economic cost and impact of the transport sector, policy interventions are critical not only in supporting efficiency but also in providing regulatory frameworks, governance structures, and institutional capacity. The EAC has put in place very good regional policy frameworks and their effective implementation will go a long way in enhancing the robustness of these sectors under a changing climate.

The East African Climate Change Master Plan[29] identifies good transport and communication infrastructure as vital for regional economic growth. From a national perspective, each of the East African governments has developed internal policies and strategies, most of which preceded the regional policies and strategies. The Master Plan builds the case for investment for climate-proofing infrastructure and recommends the following adaptation options:

i. Factor in climate change to building codes and practice
ii. Adopt designs and materials that can withstand extreme weather events
iii. Factor in potential impacts of any future climate change mitigation actions on infrastructural service in the design stage.

With respect to transport, there is a stronger focus in mitigation with clear guidance as outlines below:

i. Invest in low-carbon, low-cost transport modes such as bus rapid transit and mass transport
ii. Invest in efficient rail transport
iii. Impose strict vehicular emission standards with measures to phase old and inefficient motor vehicles while encouraging importation of efficient ones
iv. Proper urban and transport planning
v. Favor Public Transport
vi. Provide incentives for car-pooling and use of punitive incentives, such as a carbon tax, to encourage change.

Priority actions and policy guidance at the regional level for the transport sector is elaborated further by the EAC Climate Change Policy.[30] Aspects related the transport sector are addressed under both adaptation and mitigation as well as disaster risk reduction. This policy provides guidance for EAC Partner States to develop appropriate policy, institutional, and priority programs and projects at the national and subnational levels.

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[29] EAC 2011. The East African Community Climate Change Master Plan 2011-2031. www.eac.int

[30] EAC 2010. The East African Community Climate Change Policy, 35 pages. www.eac.int

Priority actions for disaster reduction and risk management (DRRM) include supporting development and implementation of climate-related DRRM as an adaptation tool as well as vulnerability and risk mapping on all sectors, including social and economic impacts of climate change. In tandem with this is the effort to improve early warning systems and preparedness to avert or minimize the adverse impacts of climate change.

Under the infrastructure component, the policy emphasizes the central role of transport in East Africa as the engine for economic growth and elaborates the need to reduce the stress on existing infrastructure in relation to extreme weather events due to climate change. Possible adaptation measures recommended include revision of structural/building codes and standards considering climate variability and change. In addition, integration of climate change in the design of most of the infrastructure as well as development of meteorological infrastructure to provide weather and climate data and information for robust infrastructure planning and design are advocated. The purpose is to support development of infrastructure that can withstand extreme weather conditions.

Policy guidance includes promotion of climate change integration in all planning and design of infrastructure, building awareness of architects and engineers to take account of climate change and revision/harmonization of structural/building codes taking account of climate change.

The policy notes the increase in use of motorized transport, traffic congestion in urban settings, and pollution of greenhouse gases that are compounded by poor infrastructure and inefficient transport systems. Development of efficient transport systems is seen as a challenge and the policy objective is to promote such systems and mitigate greenhouse gas emissions. As a result, the policy guidance stipulates the development of plans and strategies to improve efficiency in public transport and associated infrastructure, especially in cities and major towns, promote investment in common public transportation, and develop transport infrastructure suitable for all users.

While the national transport policies may not elaborate climate change and adaptation priorities, the national climate change frameworks, such as the NAPAs for Burundi, Rwanda, Tanzania, and Uganda and the National Climate Strategy and Action Plans provide appropriate frameworks and action at the national level. Further each country has defined the Intended Nationally Defined Contributions (INDCs), which for all the five EAC Partner States have a large component of transport (Table 27).

Table 27: Committed Mitigation and Adaptation Actions

	Mitigation	Adaptation
Kenya INDC[31]	❖ Enhancement of energy and resource efficiency across different sectors ❖ Low-carbon and efficient transportation systems	❖ Climate-proofing of infrastructure (energy, transport, buildings, ICT)
Uganda INDC[32]	❖ Development and implementation of long-term transport policy accounting for climate mitigation concerns ❖ Fuel efficiency initiative NAMA	❖ Updating transport codes and regulations and implementing measures to ensure compliance ❖ Updating risk assessment guidelines ❖ Improving water catchment protection
Tanzania INDC[33]	❖ Promoting low-emission transport system through deployment of Mass Rapid Transport System and investment in air, rail, marine, and road infrastructure	❖ Construction and rehabilitation of drainage systems in response to frequent and high-intensity floods
Rwanda INDC[34]	❖ Efficient resilient transport system (promotion of public transport, improvement of transport infrastructure, setting vehicle emission standards and regulations, and integrated national transportation planning)	❖ Conduct risk assessment and vulnerability mapping
Burundi INDC[35]	❖ Urban transit with low greenhouse gas emissions	❖

3.2.2 National Policies and Strategies

From a national perspective, each of the East African governments has developed internal policies and strategies, most of which preceded the regional policies and strategies (Table 28). These may not fully match the regional policies and strategies and may therefore need harmonization.

31 http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx Kenya's Intended Nationally Determined Contributions. Ministry of Environment and Natural Resources. 23rd July 2015

32 http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx Uganda's Intended Nationally Determined Contributions. Ministry of Water and Environment.

33 http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx United Republic of Tanzania Intended Nationally Determined Contributions.

34 http://www4.unfccc.int/submissions/INDC/Published%20Documents/Rwanda/1/INDC_Rwanda_Nov.2015.pdf Republic of Rwanda Intended Nationally Determined Contributions.

35 http://www4.unfccc.int/submissions/INDC/Published%20Documents/Burundi/1/Burundi_INDC-english%20version.pdf Republic of Burundi Intended Nationally Determined Contributions.

Table 28: National policies on transport

Burundi	❖ Decree No. 100/117 of October 37, 2001, on Statutes of the National Roads Fund ❖ Law No 1/06 of 10/09/2002 on Financial Resources of the National Roads Fund ❖ Ministry of Transport, Public Works, and Equipment resulting from Act No.1/04 of February 2009 (LOI No 1/04) ❖ Ordinance Ministérielle No 720/70 of Act No.1/04 of February 2009 (LOI No 1/04)
Kenya	❖ Integrated National Transport Policy 2010, the Road Traffic Act 1975, Cap 403 ❖ Transport Licensing Act, 1979, Cap 404 ❖ Ministry of Transport and Infrastructure ❖ Road Maintenance Levy Fund, 1994 ❖ Kenya Roads Board Act, 2000 ❖ Kenya Roads Act, 2007 ❖ Merchant Shipping Act 2009 ❖ Directorate of Roads ❖ Kenya Maritime Authority ❖ Public Road Toll Act, 407 ❖ Public Procurement and Disposal (PPP) Act.
Rwanda	❖ Law 39/2001 which created Rwanda Utilities Regulatory Agency (RURA) ❖ Road Maintenance Fund (Law no. 52 of 2006) ❖ Rwanda Roads Act, 2009 ❖ Law No 55/2011 of 14 Dec 2011 of Gazette No 04 of 23 January 2012 ❖ Ministry of Infrastructure ❖ Presidential Decree no 85/01 (Traffic Police and Road Traffic).
Tanzania	❖ Road Traffic Act, 1973 ❖ Surface and Marine Transport Regulatory Authority Act, 2001 ❖ Ports Act 2004 ❖ Civil Aviation Act no. 10 of 2003 ❖ Transport Licensing Act, 1973 ❖ Executive Agencies Act, 1997 ❖ Tanzania-Zambia Railway Act, 1995 ❖ Railways Act 2002 ❖ Road and Fuels Tolls Act (Cap 220), revised 2006 ❖ Roads Act, 2007 ❖ Regulations for Weights, 2001 ❖ PPP Act, 2010 ❖ Road Traffic & Safety Bill (2010 Draft)
Uganda	❖ Roads Act 1949 (Cap 358) ❖ Traffic and Road Safety Act No. 15, of 1998 ❖ Uganda National Roads Authority Act 2007 ❖ Uganda Road Fund Act 2008 ❖ Ministry of Works and Transport – Transport Directorate ❖ Ministry of Lands, Housing, and Urban Development

3.2.3 Policy Suggestions

1. **Policies:** Update national and subnational transport policies to take climate change into consideration, especially the introduction of adaptation measures in line with the Paris Agreement, the EAC Climate Change Master Plan and Policy, and other relevant policies.

2. **Planning:** Prioritize national projects and programs in response to climate change impacts as well as mitigation and adaptation measures for financing.

3. **Mainstreaming:** Domesticate the various agreements and protocols on road transport in the region, including through strengthening the implementation and monitoring mechanisms with respect to transport agreements.

4. **Institutional capacity:** Strengthen the institutional framework and capacity of transport institutions and stakeholders in risk-based approaches for identifying, analyzing, planning, and implementing transport projects.

5. **Financing:** Provide budgetary allocation for climate adaptation activities, including climate vulnerability assessments; climate resilience transportation planning, design, and construction; as well as projects to protect, upgrade, or overhaul assets based on criticality.

6. **Risk management and planning:** Develop risk-based asset management plans and allocate resources to secure critical assets and review disaster preparedness and emergency planning in light of vulnerability to climate change as well as early warning systems.

7. **Data and information:** Develop tools, guidelines, and protocols for pilot projects for national and subnational adaptation in the transport sector working in synergy with other relevant sectors to enhance co-benefits, enhance sustainability, and support economic development and poverty reduction.

8. **Capacity building of actors:** Enhance long-range transportation planning and land use with climate change as an influencing factor and enhance awareness of climate change among all actors (strategic and effective communication).

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