STATE OF KNOWLEDGE
ENERGY ACCESS IN MALAWI

EPPSA TEAM

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KEY MESSAGES

1	ENERGY ACCESS	• Malawi has one of the lowest rates of household electrification in the world at 15% • 97% of households rely on solid fuels for cooking • Energy reliability is an issue due to interruptions in electricity supply; blackouts and brownouts are common
2	ENERGY SUPPLY	• 95% of Malawi's electricity generation comes from hydropower; there is a large deficit in supply relative to demand • Transmission capacity of Malawi's electrical grid exceeds installed capacity by 170% percent • The Government of Malawi is working to diversify the energy generation profile through investment in renewable energies including wind and solar
3	ENERGY DEMAND	• A rapidly growing and urbanizing population will dramatically increase energy demand in coming years • Health centers have reasonably good energy access; schools lag behind • Industrial needs are not met by current energy systems
4	ENERGY POLICY	• Electricity access is concentrated in urban areas; the Malawi Rural Electrification Program (MAREP) seeks to increase access in rural areas • The National Energy Policy aims to increase the affordability and reliability of energy nationwide by reaching 80% electricity access by 2035, in part through investment in solar and other renewable energy sources • Malawi's energy policy has strong linkages to related sectors including health, climate, forestry, and gender
5	ENERGY GOVERNANCE AND STAKEHOLDERS	• Malawi's energy department has not been decentralized in line with other government departments • Several major international donors play a key role in funding, implementation and technical support in the energy sector • Household energy is a major focus of many international and local NGO and private sector efforts
6	ENERGY, CLIMATE, ENVIRONMENT LINKAGES	• Hydropower, Malawi's main source of electricity generation, is highly vulnerable to climate events (droughts, floods) • Heavy reliance on biomass contributes to climate change with greenhouse gas emissions from burning woodfuels, and due to lost forest carbon stocks • Malawi's 2016 National Climate Change Management Policy directly addresses energy
7	ENERGY DATA AND RESEARCH	• Malawi's census and other population representative surveys have information on energy access; spatial datasets supplement what we know about household demand for energy • Research on the social science dimensions of energy in Malawi is increasing with a focus on cooking, health, and lighting

MALAWI OVERVIEW

Malawi is a landlocked country in Southeastern Africa, bordered by Tanzania, Mozambique, and Zambia. The current population of Malawi is 19 million people, and is projected to double to 38 million by 2050 (UN World Population Prospects, 2019). Malawi is one of the poorest countries in Africa; its economy is highly dependent on subsistence agriculture (World Bank, 2019a). In 2017, Malawi released its third medium term development strategy, the Growth and Development Strategy (MGDS III), which includes energy as a priority sector with objectives not only to increase access to modern energy systems, but also to improve reliability and affordability focusing on decentralized, off-grid, and private options for enhancing energy access (GoM, 2017). Malawi's National Energy Policy has a goal of achieving 80% electricity access by 2030, shifting from a centralized grid model towards mini-grids, private sector investment, and increased standards for energy technologies. Expanding energy access is likely to enhance overall economic development, but given current energy supply constraints in the context of a growing population, including limited infrastructure development, insufficient financial resources, and a limited policy landscape, the goal of sustainable energy for all in Malawi remains a challenge.

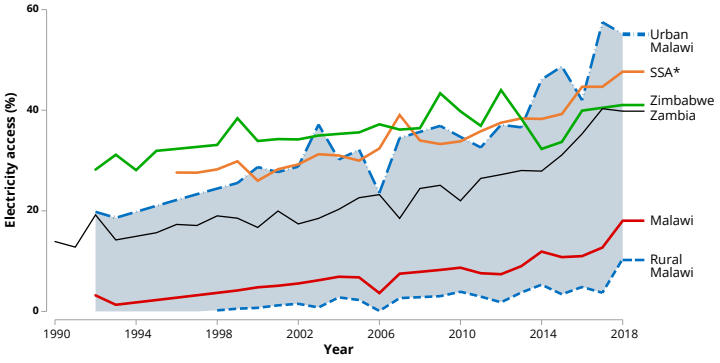
ENERGY TERMS

WATT	A **watt** is a unit for power that is equal to 1 Joule per second (energy in an amount of time) (1 megawatt (MW) = 1 million watts)
WATT-HOUR	A **watt-hour** is a unit of energy equal to one watt of output per hour (power in an amount of time). **Kilowatt-hours** (equal to 1,000 watt-hours) are a standard unit used to describe electrical power consumption and/or production.
TONNE OF ENERGY EQUIVALENT	A **tonne of energy equivalent** (toe) is a unit of energy used to describe the amount of energy released by burning one tonne (1000 Kilograms) of crude oil (**1 ktoe** = 1,000 toes)
TRANSMISSION CAPACITY	The **transmission capacity** of an electrical gridline is the amount of power (in watts) that can be sent over the transmission line.
INSTALLED CAPACITY	The **installed capacity** of a power plant refers to how much power a station can produce.
INDEPENDENT POWER PRODUCER	An **independent power producer (IPP)** is a non-public entity, which owns the facilities and infrastructure needed to generate electrical power for sale to public utilities and/or directly to users.

ENERGY ACCESS

Malawi has one of the lowest rates of household electricity access in the world, with only 15% of the total population having access to electricity; two-thirds of which comes from hydro powered grid electricity and the remainder from solar (World Development Indicators, 2018; National Statistical Office, 2019). This leaves over 15 million people in Malawi without access to electricity, and those with access regularly experience blackouts and brownouts due to insufficient capacity to meet the demand. As is true in many low-income countries, electricity access is disproportionately concentrated in urban areas with 55.2% of Malawi's urban population having access to electricity, compared to 10.4% of the rural population (World Development Indicators, 2018). Malawi has made considerable gains in energy access since 2000, when only 28.7% of urban households and 0.7% of rural households had access to electricity (World Development Indicators, 2018). (**Figure 1**). Notably, Malawi lags far behind other countries in the region. Increasing electrification rates, particularly in rural areas is an explicit goal of the Malawian government. The 2019 National Electrification Strategy and Action Plan aims to provide more lighting sources, specifically to rural areas relying on proliferation

Figure 1: Trends in electricity access (data from World Development Indicators, 2000–2018)

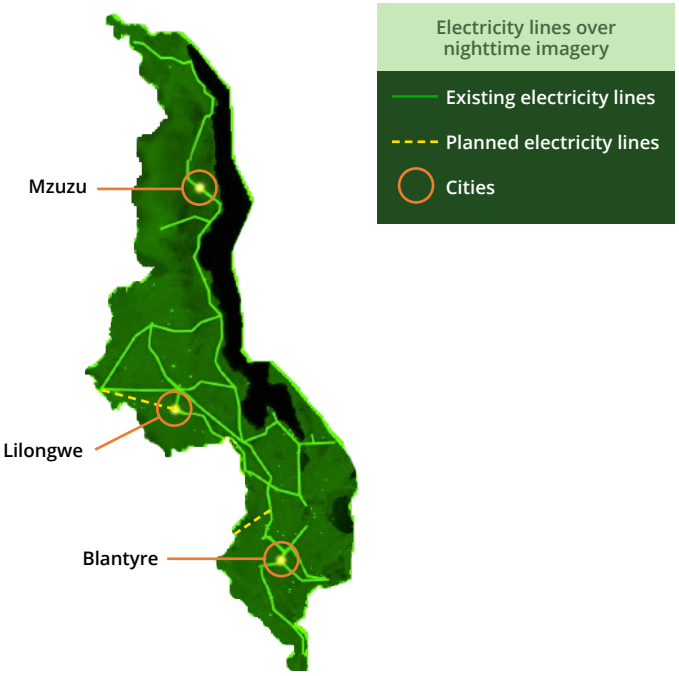


* Sub-Saharan Africa

of solar technology to households and the development of mini solar and hydro grids for electricity generation (GoM, 2019). In addition, increased investment in rural electrification through the Malawi Rural Electrification Program (MAREP) whose 9th phase commenced in October 2020 and runs through 2025.

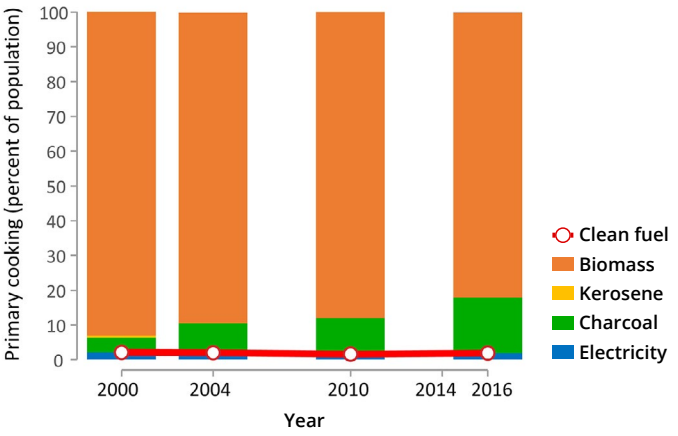
Figure 2 shows the electricity gridlines in Malawi and nightlight imagery highlighting the three urban centers. Improving electricity access is critical for large and small-scale industrial development, and for improving human well-being through the provision of lighting in homes.

Figure 2: Nighttime lights and major cities
(Data: Small & CIESIN 2020; AICD 2017)



Ninety-seven percent of Malawi's population (90.3% urban; 99.7% rural) rely on solid fuels (e.g., firewood, charcoal, crop residues) for cooking (Malawi Integrated Household Survey 2017) (**Figure 3**). Burning solid fuels for cooking and space heating produces household air pollution (HAP). Exposure to HAP can lead to a myriad of health problems, including cardiac and respiratory diseases (WHO, 2017)[1]. Air pollution is the most important environmental risk factor driving death and disability in Malawi, and is third overall after malnutrition and unsafe sex (IHME, 2019). Women and young children are particularly at risk since they spend the most time cooking. The Government of Malawi is continuing to explore and promote innovative interventions to increase access to and usage of clean cooking fuels and technologies (GoM, 2018), but use of liquefied petroleum gas and electricity for cooking remains extremely rare.

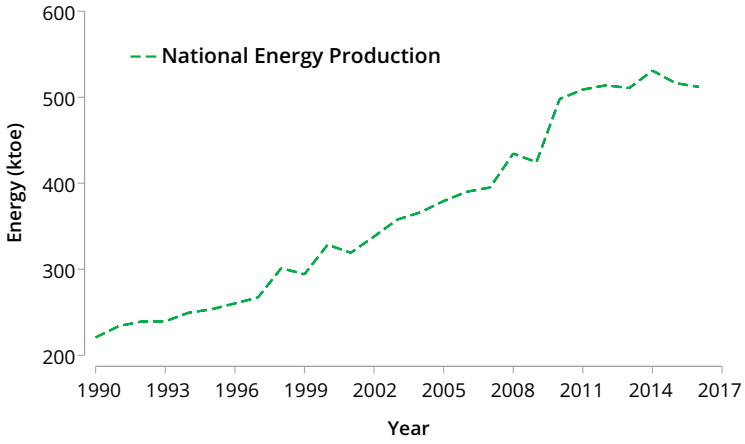
Figure 3: Primary cooking fuel in Malawian households over time
(Data: Demographic and Health Survey, 2000–2014; GoM, 2017)



ENERGY SUPPLY

The majority of Malawi's electricity supply comes from hydroelectric power plants. Renewable sources such as solar and geothermal, imported petroleum-based products, and biomass (e.g., predominately firewood and charcoal) also contribute to energy supply. Even for those connected to the electricity grid, high tariffs and cost of electricity appliances makes most households complement electricity with other energy sources. Total energy supply has increased over the past several decades, primarily due to external support and some private investment in the energy sector (**Figure 4**). Malawi has also made efforts to improve its governance structure on energy in the past decade by rewriting policies and unbundling its electricity utility company. Despite growth in electricity supply, Malawi relies on biomass for over 80% of its energy needs (GoM, 2018).

Figure 4: Total energy production
(Source: Energy Information Administration, 1990–2017)



1 HAP exposure is also linked to stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD), lung cancer, low birth weight, tuberculosis, cataract, nasopharyngeal and laryngeal cancers (WHO, 2022).

Electricity generation

Malawi's electricity utility is divided into two arms: The Electricity Supply Corporation of Malawi, Ltd. (ESCOM), which manages the transmission and supply of electricity through the national grid; and the Electricity Generation Company (EGENCO), which oversees all nationalized electricity generation. This separation allows actors not connected with the Government of Malawi to access the transmission system. The current transmission capacity of the national grid is 1000 megawatts (MW), which far exceeds Malawi's current installed capacity for power generation (GoM, 2018).

As of 2017, Malawi's total installed capacity for electric power generation was at 370 MW/year, 350 MW from hydropower production and the other 20 MW from diesel generators. However, actual energy production from the hydropower plants averages 150 MW/year due to frequent infrastructure and equipment breakdowns and fluctuating river levels limiting water flow (GoM, 2020). In 2017, estimated energy demand was 380MW, which far outweighs current supply.

Hydropower

Malawi is heavily reliant on hydroelectric power with 95% of electricity generation coming from the country's four hydropower plants: Nkula power station, located on the Shire River (installed capacity of 123 MW); the Tedzani power station, also on the Shire River (capacity of 93 MW); the Kapichira power station located at Kapichira Falls (installed capacity of 130 MW); and the Wovwe power station on the Wovwe River (capacity of 4 MW) (ESCOM, 2020). Nkula, Tedzani and Kapichira power stations are connected to the national grid, providing electricity to households, agriculture, businesses, manufacturing, and mining. Currently, none of Malawi's hydropower plants have dams, which would allow for holding water reservoirs to ensure consistent power supply when water levels in the river are low. Diesel power plants (with capacity up to 20 MW) supplement hydropower plants during daily peak periods.

The government is currently exploring the potential for hydroelectric power generation on the South Rukuru and Bua Rivers to complement power generated on the Shire River. It is estimated that Malawi has unexploited hydropower potential of 1,478 gigawatts (GW) (Zalengera et al., 2014)[2].

Solar and wind energy

Increasing solar and wind energy capacity is an explicit goal of the Malawian government. Currently, the estimated installed capacity of solar and wind-generated energy is 10 MW, which is a significant increase from 0.2 MW in 2007 (Zalengera et al., 2020). Currently, the largest solar PV installation in Malawi is the 850 kW (kilowatt) solar farm at Kamuzu International Airport in Lilongwe (Zalengera et al., 2014).

Private investment and power sharing

Given that the transmission capacity of ESCOM currently exceeds the installed capacity generation by several hundred megawatts, there are opportunities for investment in the electricity sector.

There is no private investment in the electricity generation sector from independent power producers (IPPs), which could help to close the gap between electricity supply and demand by tapping into the transmission network. Additionally, there is an opportunity for Malawi to integrate into regional power sharing agreements such as the Southern Africa Power Pool (SAPP) and the East African Power Pool (EAPP). In 2019, the World Bank approved funding to link the power grids of Malawi and Mozambique, which will create Malawi's first regional connection (World Bank, 2019b). This will permit Malawi to join SAPP and trade power with Southern African Development Community (SADC) neighbors.

Rural electricity production

The government of Malawi launched a flagship rural electrification program in the early 1980s, the Malawi Rural Electrification Program (MAREP) with funding from the Africa Development Fund (ADF), Germany and Spain and ESCOM's internal resources. ESCOM is spearheading the implementation of the project to increase access to electricity for people in peri-urban and rural areas in order to reduce poverty, transform rural economies, and to improve productivity and the quality of social services. The approach of MAREP is to electrify trading centers and marketplaces in a phased manner. Currently MAREP is in its 9th phase, with completion expected in 2025. So far, the government under MAREP has electrified 1,074 trading centers across the country.

Liquid, gas, and coal energy sources

Petroleum products

Because Malawi has no known natural gas reserves, nor the ability to refine petroleum fuels, it must import all petroleum fuel sources (GoM, 2018). These include petrol (gasoline), diesel, paraffin (kerosene), and heavy fuel oil, which are used for a range of energy services from transportation, to running generators, to household lighting. The import process is managed through the National Oil Company of Malawi, which also maintains the country's fuel reserves. The transportation industry uses the largest share of petroleum products and relies on imported sources to meet 96% of demand. Two domestic companies produce bio-ethanol and bio-diesel from sugarcane and another from *Jatropha curcas* providing 4% of total transport energy (GoM, 2018).

2 Gigawatts are a unit of power. 1 gigawatt (GW) =1000 megawatts (MW)

Liquefied petroleum gas

Malawi imports liquefied petroleum gas (LPG), a cleaner alternative to biomass for household cooking and heating for domestic and industrial use. Currently, LPG usage in homes is extremely limited due to high costs, perceived lack of safety, and the absence of a distribution network. In 2018, the government committed to building a market and infrastructure for LPG proliferation (GoM, 2018). Taxs on LPG, including a 16.5% VAT and 5% levy are a major barrier to market expansion.

Coal

Malawi has four coal fields, three in the Northern region and one in the Southern region. Two are active, but the capacity is not sufficient to meet industrial demand; coal is imported from Mozambique (Gamula et al., 2012). Construction is currently underway to build the Kam'mwamba coal-fired power plant, which will have a production capacity of 300MW and will be managed by EGENCO.

Biomass energy

Biomass is the source of approximately 80% of Malawi's total energy supply (GoM, 2018). Biomass energy includes firewood and charcoal harvested from forests and woodlands, agricultural residues, dung, municipal waste, and energy crops (Taulo et al., 2015). For over 97% of households in Malawi, fuelwood (firewood and charcoal) is the main source of energy for cooking and heating (**Figure 3**) (GoM, 2017). Government owned forest reserves supply approximately 75% of the biomass used in Malawi (Jumbe and Angelsen, 2011). Other sources include private plantations and community managed forests. Approximately 276 million tons of total available biomass energy come from 3.2 million hectares of forests, which cover about 36% of the total land area of Malawi (Kambewa and Chiwaula, 2010).

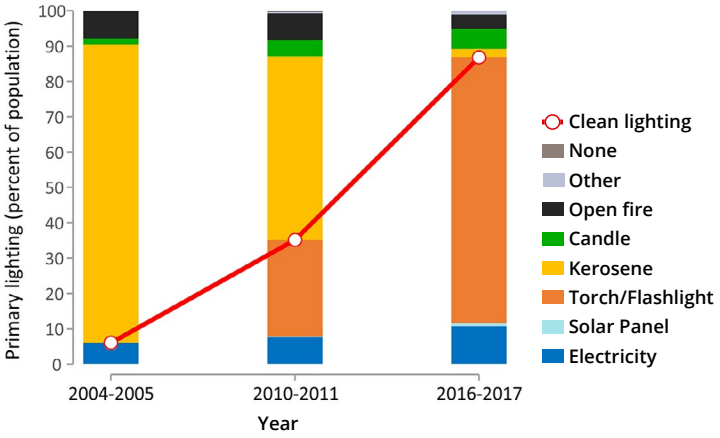
ENERGY DEMAND

As Malawi's population continues to grow and urbanize, energy demand will continue to exceed supply. This has implications for household energy access, as well as institutional and industrial energy access.

Household energy demand

Household energy demand is driven by cooking and lighting needs. The vast majority of households rely on biomass for cooking, with alternatives very limited in urban areas, and non-existent in rural areas. Access to clean sources of energy for lighting have increased significantly in the past two decades as households shift away from kerosene use towards battery or solar powered torches (flashlights), and small, but growing amounts of electricity from the national grid or home solar systems (**Figure 5**). Urbanization will play a large role in increasing demand for household energy in Malawi. It is predicted that internal migration from rural to urban areas will increase by five percentage points between 2010 and 2030. This would mean that, on average, the size of the urban population would be growing at a rate of 21.2% by 2030

Figure 5: Primary lighting fuel in Malawian households over time (Data: DHS, 2004–2017)



(World Bank, 2017). This increase in urban population will affect the already high, unmet demand for energy. On average, annual electricity demand is projected to grow 5% percent per year over the next decade, which will only increase the gap between energy demand and supply (World Bank, 2019a). With heating, water, and cooking as primary uses of electricity in Malawi, larger home solar systems could offset some of the demand for grid electricity and/or biomass fuels. However, at present, solar technology cannot supply sufficient energy for cooking. An increasingly urban population will also alter the portfolio of biomass fuels used for household energy purposes, increasing the country's reliance on charcoal, more commonly used than fuelwood in urban settings. Total woodfuel energy demand was projected to be 13,551,000 metric tons or 15,749,273 MW in 2020 (Schuenemann et al., 2018). At the same time, charcoal prices are increasing due to its scarcity and unpredictable electricity supply making LPG a more attractive to urban, middle to high-income groups (GOM, 2017).

Institutional demand

Many government institutions, industries and private businesses that rely on electricity and other energy sources to function. Health facilities and schools are two energy-dependent predominantly public sector institutions critical for the health and future of Malawi and its people.

Health care facilities

Sufficient, reliable energy is fundamental for safe and effective patient care in healthcare facilities (HCFs) (WHO and World Bank, 2015). Electricity enables many functions essential to healthcare services, among them, lighting, refrigeration, sterilization and powering medical devices (Ouedraogo and Schimanski, 2018). According to data from Malawi's most recent (2013/2014) Service Provision Assessment (a USAID funded health facility census), 69% of health facilities were connected to the electrical grid as their primary energy source, 22% relied on off-grid sources of energy such as solar systems or diesel-powered generators, and 9% had no energy source at all. Of the 69% connected to the grid, 80% of facilities reported interruptions in their electricity

supply (MoH and ICF, 2014). A more recent study evaluated 44 health care facilities indicated that 82% of HCFs depended on the electrical grid as their primary source of energy, however less than half of the health care facilities received a consistent, uninterrupted supply (Reuland et al., 2019). The GOM and donor organizations are increasing investment in solar electrification of health care facilities to support refrigeration and lighting. Solar backup systems a promising option to provide reliable energy at health care facilities throughout the country.

Schools

Electricity access also plays an important role in school settings by improving the educational services offered, improving administrative processes, and extending the possibility for new services such as evening classes or computer courses (Lenz et al., 2017). According to the United Nations Educational, Scientific, and Cultural Organization (UNESCO), in 2012 only 10% of primary schools and 52% of lower secondary schools in Malawi had access to electricity (GoM, 2017).

Industrial demand

The industrial sector in Malawi, which is largely comprised of agricultural and manufacturing companies, is very energy intensive with demand for heating, motive power, and lighting. In the past, industry has relied exclusively on electricity from the national grid, but in the past decade, coal has provided just over half of total industrial demand for energy (Taulo et al., 2015; GoM, 2018). A number of industrial enterprises have installed diesel generators to serve as a backup for the energy services that are reliant on the national grid for electricity (Gamula et al., 2012). In addition, many small business owners have purchased portable diesel generators as back-up for grid electricity, or as a standalone power source.

ENERGY POLICY

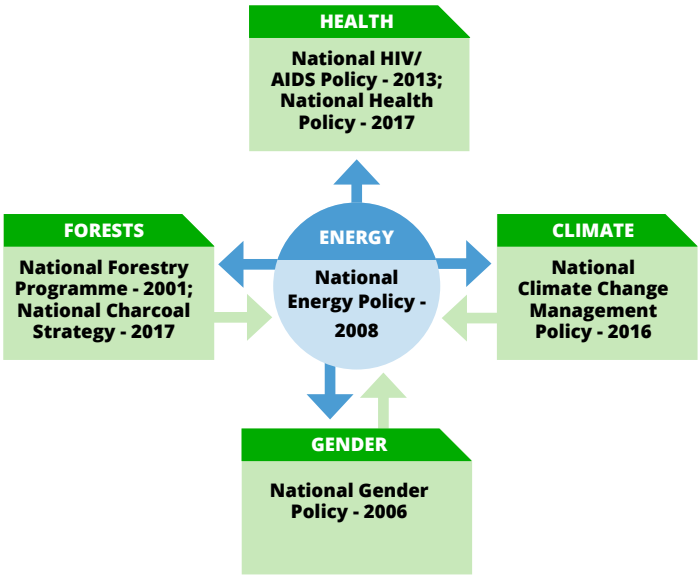
The Government of Malawi updated their National Energy Policy in 2018 with the following goals to: 1) improve efficiency and effectiveness of commercial energy supply industries; 2) improve the security and reliability of energy supply systems; 3) increase access to affordable and modern energy services; and 4) stimulate economic development and rural transformation (GoM, 2018). This policy aligns with Sustainable Development Goal 7 that aims to ensure access to affordable, reliable, sustainable, and modern energy for all (UN, 2018). Specific energy-related targets within the policy include reaching 80% national electricity access by 2035; increasing the share of renewable energy by 2030 by building 50 renewable mini-grids; and promoting solar home systems through financial incentives to businesses and households and enforcing international standards of solar products (GoM, 2018; Zalengera et al., 2020).

Since the policy was updated in 2018, the government has taken several steps to achieve their targets. Through the Malawi Rural Electrification Programme (MAREP), they have extended the national grid to 435 new locations (mostly small business areas, trading centers, health facilities, schools, etc.). They have conducted feasibility studies for multiple new hydropower projects and there are also rehabilitation efforts at existing power stations (GoM, 2020).

In 2016, the GoM passed the National Climate Change Management Policy (NCCMP). In addition to including capacity building, education, training and public awareness about climate change, this policy specifically incorporates mitigation and adaptation in energy measures (GoM, 2016). The Ministry of Forestry and Natural Resources coordinates the implementation, setting and enforcement of relevant and acceptable standards for energy development. Specifically, this policy aims at reducing reliance on biomass to reduce greenhouse gas emissions. One of the steps to achieve this goal is for the government to promote energy saving technologies. Public-private relationships are imperative for achieving these goals as the private sector has the potential to impact innovation and economic growth. By including the private sector in the national policy, Malawi participates in carbon emissions trading which in turn funds renewable energy investments (GoM, 2016). The policy guides stakeholders on best practices for adapting energy initiatives to correspond to climate change.

Figure 6 shows how the National Energy Policy is connected with other policy sectors, specifically forestry, health, climate, and gender. Arrows represent specific linkages between the energy and other policies, and if there is no arrow, for example from health to energy, then there is no specific mention of energy in the given policy.

Figure 6: Policy linkages between the National Energy Policy and Forestry, Climate, Health, and Gender policies



ENERGY SECTOR GOVERNANCE AND STAKEHOLDERS

Malawi is committed to achieving "sustainable energy for all" in accordance with the UN's Sustainable Development Goal 7. The GoM depends on multilateral and bilateral donors for funding development of the energy sector investments.

The Ministry of Forestry and Natural Resources (MFNR) through the Department of Energy Affairs (DoEA) and Malawi Energy Regulatory Authority (MERA) oversees all policies and regulations within the energy sector.

Government

In 1998, Malawi passed a decentralization policy, which devolved the management of its ministries and departments to administrative sub-units called districts. There are 28 total districts in Malawi. Despite this, prior to 2018, the Department of Energy Affairs was the only department in the central government that did not have officers at the district level. Because it has taken so long to implement decentralization of the energy administration in Malawi, the majority of the work continues to be managed centrally.

Central Level

At the central level, the Department of Energy Affairs, within the Ministry of Forestry and Natural Resources, oversees implementation of energy policies and programs. The Malawi Energy Regulatory Authority regulates energy supply and the import process.

▸ ***Ministry of Forestry and Natural Resources (MFNR)***

MFNR provides policy direction and guidance on the sustainable development and utilization of energy resources in Malawi (GoM, 2018). MFNR's mandate is to ensure sustainable development, management, and utilization of natural resources for the socioeconomic growth and development. MFNR oversees the Department of Energy Affairs, which is in charge of energy supply. Its mandate is, "to fully stratify public need for quality modern energy services by effectively governing and facilitating the development of a robust, sustainable and efficient private sector-driven energy industry," (Dept of Energy Affairs, n.d.).

▸ ***Malawi Energy Regulatory Authority (MERA)***

MERA was created in 2007 as an independent regulator for energy services including electricity with its mandate from the Energy Regulation Act of 2004. MERA's roles include: 1) reviewing tariff applications from ESCOM (Electricity Supply Corporation of Malawi Ltd.); 2) recommending tariff changes; 3) granting licenses for distribution operators; and 4) arbitrating commercial disputes (World Bank, 2019c). MERA also regulates utilization of energy resources (GoM, 2018).

National Energy Utility

The Electricity Supply Corporation of Malawi Ltd. (ESCOM) is a publicly owned company and the only electrical power supplier. Until 2017, ESCOM oversaw all electricity generation and transmission activities in Malawi. However, in January 2017, the company was unbundled to include the Electricity Generation Company Malawi Ltd. (EGENCO). Currently, ESCOM is responsible for all power generation activities in the country while EGENCO manages the transmission and distribution of electricity. This allows IPPs to operate and provide private and/or off-grid energy options. The unbundling of ESCOM has led to increases in installed generation capacity through the development of a range of new energy production projects (Zalengera et al., 2020).

District and Local Levels

The devolution of energy administration to the district and local levels officially began in 2018 and has not progressed in a significant way. While there seems to be a willingness to engage local and district government stakeholders, there remains a lack of local capacity, specifically related to the technical qualifications required to manage energy systems. Malawi's continued reliance on the central government for energy provision makes it difficult for the energy sector to expand beyond its focus on the centralized grid managed by ESCOM. If district and local governments got involved in the energy sector, it could open up opportunities for off-grid and privatized grid options that could expand energy access nationwide (Zalengera et al., 2020).

Non-governmental actors

Bilateral and multilateral aid organizations

Malawi has multiple multilateral aid organizations that provide funding to support the government to implement projects to increase energy access. The role of international donors in relation to SDG 7 is to support programs addressing energy access including providing resources and technical assistance on access to clean and renewable energy.

The United Kingdom's Department for International Development (DFID), United States Agency for International Development (USAID), the World Bank, GTZ, and IrishAid are particularly active in Malawi's energy sector. They fund large-scale projects to improve the amount and the quality of the energy supplied throughout the country, often with a focus on renewable energy sources and grid extension. Notably, in 2019, the World Bank approved funding for Malawi's first regional grid connection with Mozambique, which will allow them to join in the Southern Africa Power Pool (SAPP) (World Bank, 2019b).

In 2020, the Government of Malawi and development partners USAID and DFID launched a US$1.1 million clean cooking fund to promote fuel-efficient cooking technologies and alternative cooking energy in the country.

Non-governmental organizations and private sector firms

A range of non-governmental organizations (NGOs) and private sector firms engage in Malawi's energy sector. Large multi-national NGOs (e.g., United Purpose) and smaller local NGOs (e.g., Maeve Project) are implementing programs to improve household energy access. NGOs including the Mulanje Mountain Conservation Trust (MMCT), which runs the hydroelectric micro-grids in rural areas of Southern Malawi, Renew'N'Able, which coordinates stakeholders and lobbies for funding of renewable energy projects; and Community Energy Malawi (CEM), which fundraises for investment in renewable energy technologies are working on innovative solutions for transforming the sector.

The list of private sector firms working in the energy sector in Malawi is long. The types of companies range from those marketing solar home systems and fuel saving stoves, to those operating at larger scales on the development of a wind energy, marketing and distributing clean cooking technologies, and more.

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ENERGY, CLIMATE, ENVIRONMENT LINKAGES

Hydropower

Impact

The government requires a socioeconomic and environmental impact assessment (ESIA) prior to the development of large hydropower schemes, but smaller schemes are not held to the same standard (GoM, 2018). Large-scale hydropower projects (those that generate more than 1 MW) lead to carbon emissions from converted land, ecological changes in the river areas, and loss of livelihoods for people displaced from areas where energy infrastructure is established (de Faria et al., 2017; Rasanen et al., 2018). In Malawi, there is evidence of environmental degradation upstream along the rivers where plants are built (GoM, 2020; Gamula et al., 2012). Erosion from land cleared for hydropower infrastructure deposits excess soil into rivers, causing problems for the functionality of power stations (Gamula et al., 2012).

Vulnerability

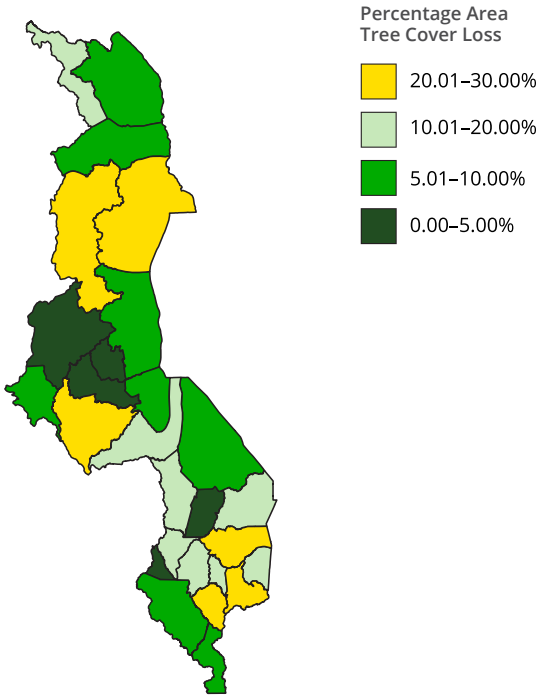
Malawi's dependence on hydropower makes it especially vulnerable to climate related weather events, which have increased in frequency, intensity, and magnitude over the last two decades in Malawi. These include prolonged dry spells, seasonal droughts, intense rainfall, riverine floods, and flash floods (GoM, 2016). Droughts and dry spells limit water supply passing through the hydropower system, which in turn limits electricity generation; and flash floods and other periods of heavy, inconsistent rainfall lead to too much water passing through power plants. In both cases, extreme weather patterns affect Malawi's primary source of electricity generation. As these events become more frequent, Malawi will be forced to increase load shedding and blackouts unless they are able to diversify their electricity generation profile.

Biomass

Impact

The climate impacts of biomass use include greenhouse gas emissions associated with combustion of woodfuels, and the impact on degraded forest resources, which perform an important function as carbon sinks. The combustion process of woodfuel releases several harmful pollutants like CO2, black and organic carbon, methane, and others into the atmosphere. Harvesting wood for cooking and heating can also lead to localized forest degradation, and in some cases, deforestation, particularly where population densities are high and woodfuels are harvested unsustainably (Bailis et al., 2017; Jagger et al., 2019). **Figure 7** shows percent forest loss by district between 2000 and 2019.

Figure 7: Tree loss by district from 2000–2021 as a percentage of tree cover area in 2000. (Data: Potapov et al. 2022)



Vulnerability

Malawi's reliance on biomass for energy increases its vulnerability to climate change (GoM, 2018). Burning biomass as a cooking fuel leads to high household air pollution burden (Bruce, 2000), which contributes to climate change through the emissions of incomplete combustion of carbon dioxide, methane, nitrous oxide, carbon monoxide, non-methane volatile organic contaminants, and black carbon (Goldemberg, 2018). Black carbon in particular has implications for regional climate change. With Malawi's population growth trajectory putting the population at 40 million in 2040, climate change will add more pressure to the increased demand for energy (GoM, 2018). **Figure 7** show the forest loss by district in Malawi since 2000.

ENERGY DATA AND RESEARCH

Population data are used to estimate energy consumption in Malawi; there are two main sources of publicly available population data. The 2018 Population and Housing Census, conducted roughly every 10 years in Malawi has the most detailed population counts at the Traditional Authority level (the smallest administrative unit in Malawi) (National Statistical Office, 2019). To estimate population between census counts, there are a number of spatial gridded population data products that use demographic projections and density measures to disaggregate population estimates to sub-administrative unit levels at 1- or 5-year intervals. Products include WorldPop, Landscan, Global Human Settlement Layer - Population, Global Rural Urban Mapping Project, and Gridded Population of the World Version.

While census data and population grids are important for understanding population change, and therefore energy demand, nationally representative studies of household behaviors and economics are an important source of data for understanding household fuel choices and energy consumption. The Living Standards Measurement Study (LSMS) is a nationally representative survey that provides in-depth information about household dynamics (World Bank, 2017). The LSMS has a module on household energy to ask questions about fuel choices and sources, fuel stacking, stove types, cooking practices, and access to electricity. Five waves of the Malawi LSMS Integrated Household Survey were enumerated in 2004, 2010, 2013, 2016 and 2019; since 2010, a panel of some households has been maintained which is useful for evaluating change in household fuel practices over time.

The Demographic and Health Surveys (DHS) are nationally representative surveys administrated to selected households that include a module on household characteristics with questions about fuel choices and electricity access. DHS surveys for Malawi are publicly available for the years 1992, 2000, 2004, 2010, 2012, 2013, 2015, and 2017 (DHS, 2017). The Multiple Indicator Cluster Survey (MICS), administered by UNICEF, includes questions about fuelwood collection, cooking practices, stove type, household fuel choice, household labor and assets which are all relevant to understanding household fuel use (UNICEF, 2013). MICS for Malawi are available for the years 2006 and 2013.

The World Bank Multi-Tier Framework (MTF) survey collects household-level data on energy access, cooking, and electrification. An MTF survey is tentatively planned for Malawi with data collection to begin in 2021.

In addition to demand-side data available through population datasets, there is limited information for Malawi about energy sources. Publicly available data on electricity grid infrastructure is scarce; vector data of the main gridline is based on a digitized PDF map (AICD, 2017). A Facebook-produced prediction map models medium-voltage grid distribution with about 70% accuracy (Facebook, 2019). Beyond these products, there are limited data sources of geocoded energy infrastructure.

See a complete list of data sources on Malawi's population, energy use, and energy supply below:

POPULATION

- Global Human Settlement Layer. JRC.
- Global Rural-Urban Mapping Project (GRUMP), v1. CIESIN. 2020.
- Gridded Population of the World, v4. CIESIN. 2020.
- Oak Ridge National Laboratory. "Landscan." 2020.
- WorldPop. 2020.

HOUSEHOLD SURVEYS

- Demographic and Health Survey Program
- Malawi Living Standards Measurement Study
- Multiple Indicator Cluster Surveys. UNICEF.

ENERGY SUPPLY & SPATIAL DATA

- Malawi Electricity Transmission Network. 2017.
- Medium-Voltage Distribution (Predictive). 2017.

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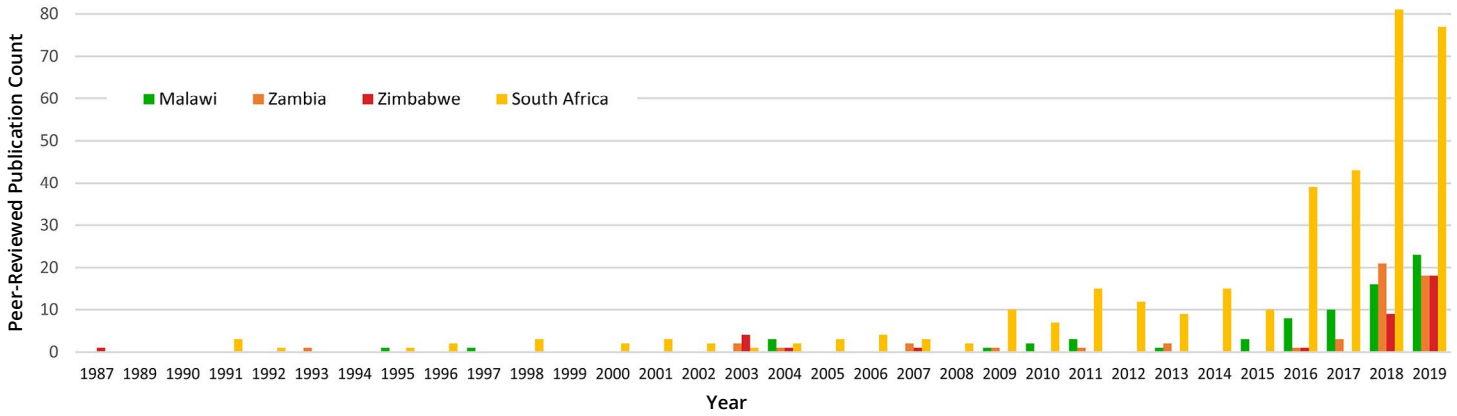
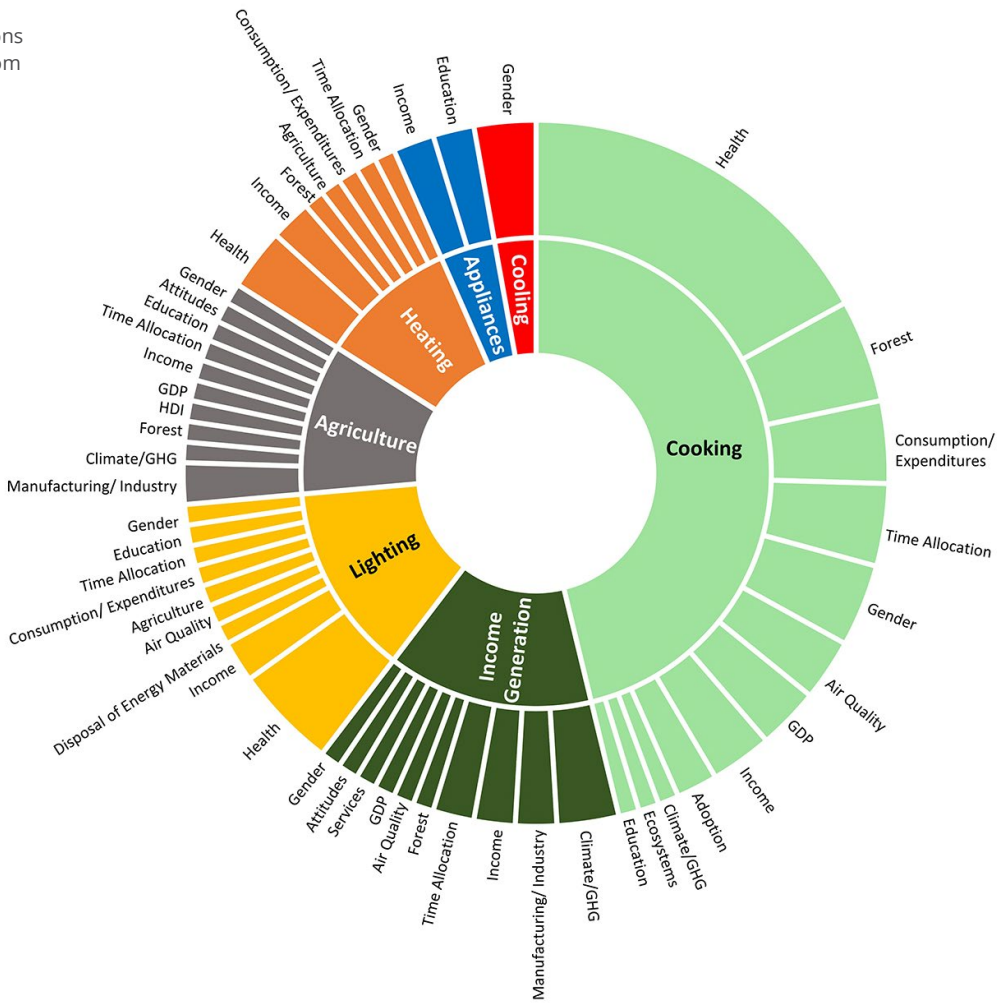
Figure 8: Count of peer-reviewed publications on energy over time. (Data: Jeuland et al. 2021)



Research on energy access in sub-Saharan Africa has grown exponentially in recent years (Figure 8) with major growth in the number of peer- reviewed publications coinciding with the announcement of SDG7 in 2015, and shortly after the advent of several global initiatives focused on energy access (e.g., Sustainable Energy for All, the World Bank's ESMAP program, and the Clean Cooking Alliance). Between 1987 and 2019, 78 peer reviewed publications on various dimensions of energy have been published in the social science literature offering guidance to Malawi's agenda on energy access (Figure 8). Figure 9 shows a breakdown of energy topics (inner circle) and impacts (outer circle) that are the focus of quantitative studies published since 1987.

Figure 9: Energy topics and impacts of quantitative peer-reviewed publications based in Malawi from 1987–2019. (Data: Jeuland et al. 2021)



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