STATE OF KNOWLEDGE
ENERGY ACCESS IN ZAMBIA

EPPSA TEAM

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KEY MESSAGES

1	ENERGY ACCESS	• Household electricity access is increasing; electricity access in urban areas (82%) is much greater than in rural areas (14%) • The Rural Electrification Authority (REA) is increasing electricity access in rural areas by expanding the grid and implementing off-grid solar projects • Biomass is the primary cooking fuel in most Zambian households in both urban (charcoal) and rural (fuelwood) areas • The Rural Electrification Act of 2003 created the Rural Electrification Authority, with ambition to increase electrification to 51% of rural households by 2030.
2	ENERGY SUPPLY	• >80% of Zambia's electricity is generated from hydropower; in the short term, the Government of Zambia is diversifying generation sources with coal (11% of power generation) • Zambia has immense potential for power generation through solar, wind, geothermal, coal and further hydropower development • Zambia is a net energy exporter through the Southern African Power Pool (SAPP); the magnitude of cross-border biomass trade is poorly documented
3	ENERGY DEMAND	• Charcoal use has increased over the past 30 years and is expected to continue to rise as Zambia rapidly urbanizes • Kerosene use has effectively stopped, with significant drop-off since 2010 • After residential use, the mining industry is the greatest consumer of energy • More data are needed to understand energy access and demand among schools and health care facilities
4	ENERGY POLICY	• Zambia has released three National Energy Policy documents (1994, 2008, and 2019); the Ministry of Energy released the Integrated Resource Plan in 2021 • The current energy agenda in Zambia is focused on diversifying the nation's energy sector and ensuring equitable access to clean and renewable energy sources for all populations in Zambia
5	ENERGY GOVERNANCE AND STAKEHOLDERS	• There are a wide range of stakeholders involved in the energy space in Zambia: government agencies and utilities, international aid organizations, NGOs, and private sector firms • In recent years, with the establishment of the Office for Promoting Private Power Investment, the Integrated Resource Plan, and Eighth National Development Plan, the government of Zambia has worked to integrate the efforts of all stakeholders towards their 2030 development goals in the energy sector
6	ENERGY, CLIMATE, ENVIRONMENT LINKAGES	• Hydropower, the main source of electricity generation in Zambia, is vulnerable to climate events (droughts, floods) that affect the reliability of water flowing through dam • Biomass reliance impacts deforestation and carbon stocks and biomass combustion contributes to greenhouse gas emissions • Zambia is addressing vulnerabilities to and impacts on climate change through the 2016 National Climate Change Policy
7	ENERGY DATA AND RESEARCH	• There are a range of data sources available on energy use and supply in Zambia including household surveys and spatial data sets • The average number of academic publications on energy in Zambia has increased rapidly over the past 5 years

ZAMBIA OVERVIEW

Zambia is a landlocked country in Southern Africa, bordered by Tanzania, Malawi, Mozambique, Zimbabwe, Botswana, Angola, and Democratic Republic of Congo. As of 2022, population of Zambia is 19 million people and is projected to nearly double to 37 million by 2050 (CSO 2016; United Nations 2022). Zambia's economy is highly dependent on natural resources, in particular its copper and cobalt (World Bank 2022a; CSO 2016). Zambia saw rapid economic growth until the mid-2010s when international copper prices began to fall, and hydroelectric power generation suffered due to insufficient rains (World Bank 2022b). The COVID-19 pandemic further damaged the Zambian economy with a historic contraction in 2020; but the outlook for growth through 2025 is optimistic (World Bank 2022a). In 2022, the government of the Republic of Zambia acknowledged their vulnerability to climate and economic shocks and rolled out their Eighth National Development Plan, which includes areas of focus on improving energy production and distribution, decreasing reliance on hydropower, promoting renewable and alternative energy, and increasing energy access for rural populations (MoF 2022).

A charcoal market in Lusaka. Charcoal is an important source of cooking fuel in Zambia.

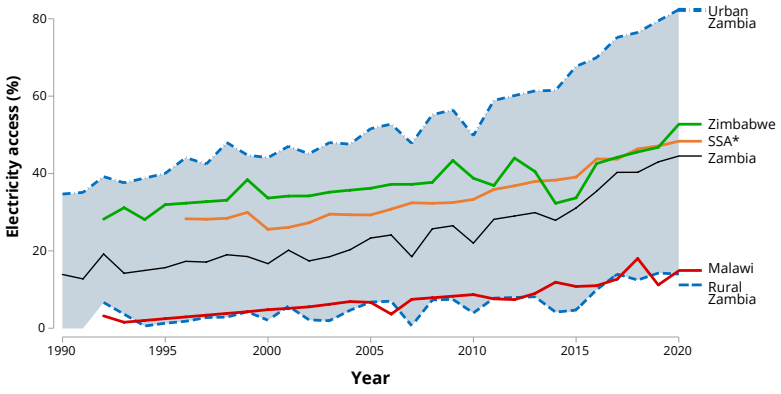
ENERGY TERMS

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

Access to electricity in Zambia grew from 13.9% in 1990 to 44.5% in 2020 (World Bank Data 2022). Electricity access is not distributed evenly across geography; urban populations have much higher electricity access rates compared to rural populations. Over the past 30 years, urban electricity access increased from 34.7% to 82.4%, while rural access increased from 0.6% to 14.0% access (World Bank Data 2022). **Figure 1** shows trends in electricity access over the time.

Figure 1: Trends in electricity access (Data: World Bank Data 2022)

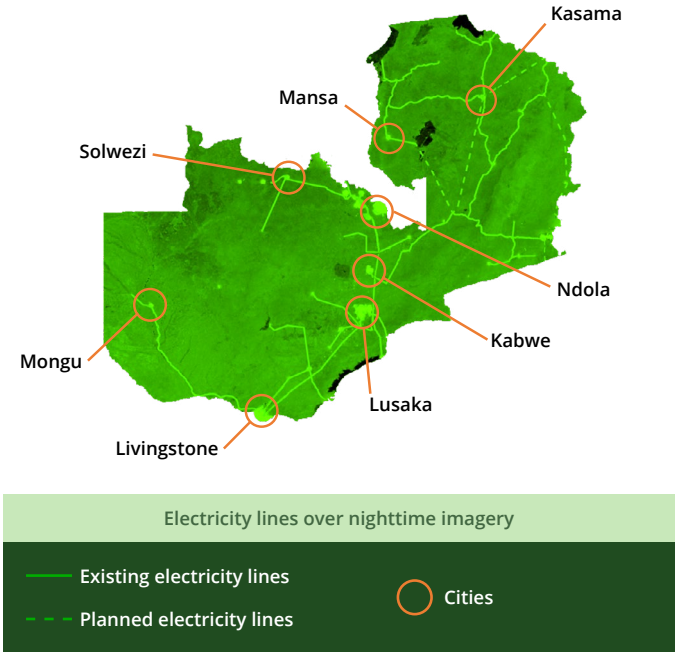


*Sub-Saharan Africa

Figure 2 shows the electricity gridlines in Zambia and nighttime light imagery highlighting nine urban centers. To improve rural energy access, the Zambian Government passed The Rural Electrification Act in 2003, which created the Rural Electrification Authority, with ambition to increase rural electrification to 51% of households by 2030.

In March 2021, the government of Zambia released the Integrated Resource Plan (IRP) which outlines a strategy for developing the nation's energy sector over the next 30 years, A major goal of the IRP is to achieve universal access to clean, reliable and affordable energy for all Zambians (MoE 2022). While the overall number of people with access to clean fuels and technologies for cooking in Zambia has increased in the past two decades, the percentage of people who rely on clean fuels is stagnant. In 2018, the share of households with access to clean cooking technology was 32.8%, with only 8% of households using electricity or liquified petroleum gas (LPG) as their primary cooking fuel (ZSA, MOH, & ICF 2019). In urban areas, the primary cooking fuel is charcoal (75.7%), and in rural areas it is fuelwood (81.4%) (ZSA, MOH, & ICF 2019).

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



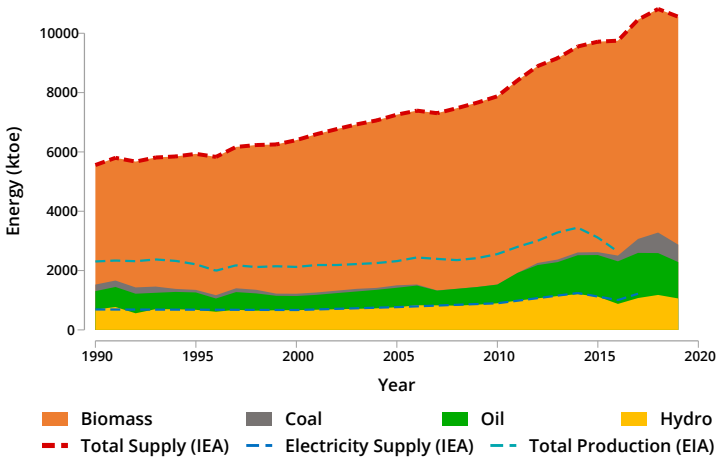
Burning biomass for cooking and space heating produces household air pollution (HAP), which is associated with several health problems, including cardiac and respiratory diseases (WHO 2022). The impacts of using biomass on household members are uneven; women and young children bear the majority of the exposure to HAP because women are traditionally the primary cooks and child caretakers in the household (WHO 2022). In Zambia, air pollution (from all sources) is the third highest risk factor driving deaths and disabilities in the population (IHME 2019). Energy access in Zambia has also been affected by both economic and environmental shocks, particularly in the past two decades.

In the mid-2010s, Zambia experienced an economic downturn because of falling international copper prices leading to an increase in the price of electricity (CSO 2016). The copper mining industry is the largest consumer of energy in Zambia, consuming approximately half of the country's electricity supply (Baruya & Kessels 2013; Bridle 2018). During this time, insufficient generation led to an increase in electricity prices along with frequent load shedding, leading to rolling blackouts of eight hours or more a day (World Bank 2015). At this time, the Zambian energy authority, ZESCO, asked companies to reduce electricity consumption due to short supply (Baruya & Kessels 2013). The World Bank reports that more people switched to cooking with charcoal or LPG (if available) as blackouts increased (World Bank 2015a).

ENERGY SUPPLY

The national energy supply in Zambia is accounted for in several forms: electricity (generated from hydropower, coal, oil, and solar), petroleum-based products which are imported into Zambia, and biomass (primarily used by households for cooking and heating). **Figure 3** shows the make-up of Zambia's energy supply from different sources beginning in 1990. While energy from oil, coal, and hydroelectric power have steadily increased over time, the greatest energy increase is contributed by biomass consumption. Because the Zambian population has yet to transition away from biomass fuels as a primary fuel for household energy needs, the increase in biomass consumption tracks with increase in population.

Figure 3: Total energy supply by type (ktoe) (Data: IEA 2022; EIA 2022)



Electricity Generation

Zambia has great potential for electricity generation from both renewable and non-renewable sources. While the majority of electricity supply in Zambia is generated by hydroelectric dams, the government of Zambia has sought to diversify the energy supply portfolio in recent years and into the future (Bridle 2018; World Bank 2019a; World Bank 2019b). In the 2010s, Zambia expanded its electricity generation capacity from hydropower

alone to increase generation using coal, oil and diesel (Bridle 2018). Currently, Zambia has an installed electricity generation capacity of 3,030 megawatts (MW) from hydro, coal, diesel, oil, and solar (USAID 2022a). For comparison, the United States has a current installed electricity generation capacity of over 1.1 million MW (EIA 2022). The majority of electricity generation and distribution is managed by the state-owned entity ZESCO. Zambia has vast wind, geothermal, and uranium power potential that it has not yet developed (MoE 2021).

Hydropower

Zambia relies heavily on its rivers to provide electricity to the country. Zambia's current hydroelectric power installed capacity is 2,704 MW, which is 81.5% of the nation's total installed electricity generation capacity (ERB 2022). It is estimated that between 82% and 95% of electricity consumed in Zambia is generated by hydropower, as electricity generation from diesel plants has been declining since 2015 (World Bank 2019a, page 14; ERB 2022; MoE 2022). There are thirteen hydroelectric power plants in the country (including on- and off-grid plants) with the largest, Kafue Gorge (990 MW), located on the Zambezi River at the Kariba Dam (MoE 2021). Though electricity supply from hydropower has steadily grown since the early 1990's, the installed capacity at hydropower plants alone is insufficient to meet demand as energy demand in Zambia has soared with a growing and urbanizing population (IEA 2022). Zambia is working to address this by increasing its installed hydro capacity through public-private partnerships in building new plants and increasing capacity of existing ones to reach its estimated hydroelectric power generation capacity of over 6,000 MW (MoE 2021).

Coal Power

After hydropower, coal is the second largest source of electricity accounting for approximately 11% of national capacity (USAID 2022a). It is estimated that over 30 million tons of coal exist in Zambia, though the true total of coal reserves is not known with certainty (MoE 2021). Estimates of reserves range between 10 to 200 megatons (Mt) (Baruya & Kessels 2013). The majority of coal is mined from the Maamba Mine which opened in 2016 (MoE 2021). Over half of the coal consumed is by the mining industry, while 37% is consumed by the commerce industry and under 10% is consumed by government service sectors (Baruya & Kessels 2013; USAID 2022a). Zambia recognizes the impact coal can have on the supply of electricity and is conducting several feasibility studies to expand coal electricity generation infrastructure through several private partnerships (GoZ 2022).

Solar Power

Zambia has great potential for solar power through both photovoltaic and solar thermal generation, with over 3,000 sunshine hours annually (MoE 2021). The areas with the greatest potential for solar are Western Province, Luapula, and Northern Province (Mwanza et al. 2017). The greatest barriers to a widespread proliferation of solar technology are high upfront costs and a lack of solar expertise in Zambia (Bowa et al. 2017).

Despite this, there are several projects trying to expand solar in Zambia. The Rural Electrification Authority (REA) is the main agency supporting solar projects, as many of these projects are off-grid solar generator implementations in rural areas. International organizations like the World Bank are also partnered with the REA to expand solar energy access and usage in Zambia. Current installed solar electricity generation capacity is estimated at 91 MW including both grid-tied and off-grid generators, comprising approximately 3% of Zambia's total electricity generation capacity (MoE 2021; USAID 2022a).

Imports and Exports

Zambia imports and exports a variety of energy sources including electricity, petroleum/liquid fuels, and biomass. The main framework for electricity import and export is through the country's membership in the Southern African Power Pool, which facilitates electricity trading for countries in the Southern African Development Community (SADC). A major source of electricity produced in Zambia comes from the Kariba Dam on the Zambezi River, which also acts as the border between Zambia and Zimbabwe. The two countries share output of the dam managed by the Zambezi River Authority (ZRA), a parastatal company owned equally by Zambia and Zimbabwe (ZRA 2022). There are two powerhouses beneath the dam, the South Bank Power Station owned by Zimbabwe and the North Bank Power Station owned by Zambia. The total generation capacity of the dam is 1,830 MW, of which Zambia generates 1,080 MW (World Bank 2015b). Overall, Zambia was a net exporter of electricity over the last ten years (ERB 2022). From 2011–2018, Zambia exported more electricity than

Hydroelectric power accounts for over 80% of Zambian national electricity supply, the majority of which comes from the Kariba Dam at Victoria Falls.

imported except for 2011 and 2016 (ERB 2022), which could have been due to low hydro output from low water levels.
To date, no oil or gas reserves have been discovered in Zambia (Baruya & Kessels 2013). Imported fuels are brought to the North Eastern Region of Zambia where the country's one refinery is located (de la Fuente et al. 2017). Zambia produces LPG primarily through the Indeni petroleum refinery, though the majority of it is re-exported (World Bank 2015b). In the past, petroleum as brought into the country in the state-owned Tazama pipeline routed through Tanzania (de la Fuente et al. 2017). More recently, imported oil has been imported via trucks and represents approximately half of all of Zambia's fuel imports (de la Fuente et al. 2017). Currently, 7% of Zambia's installed electricity generation capacity is from diesel (122 MW) and heavy fuel oil (91 MW) (USAID 2022a). Over one third of oil imported is consumed by mining companies and other industrial entities (Baruya & Kessels 2013). Biomass imports and exports are an important trade in the region, and Zambia shares borders with several neighboring nations whose populations are heavily reliant on biomass for their primary household fuel. Charcoal trading between Zambia and the Democratic Republic of Congo, Zimbabwe, and Tanzania is occurring, despite commercial charcoal trading being illegal under current Zambian law (Sola et al. 2021). Because cross-border trade of charcoal and fuelwood without permits is illegal, it is difficult to study and quantify the magnitude of the trade and its value and impact on Zambian livelihoods. More research is needed to understand the informal biomass commercial sector (Moombe et al 2020; Sola et al. 2021).

ENERGY DEMAND

The main sources of energy consumed in Zambia are biomass, electricity, and imported oil/petroleum products. The residential sector (household cooking, heating, lighting, and electronics charging) accounts for 65.4% of the nation's consumed energy, mainly from biomass and some electricity (IEA 2022). Industry is the second largest energy consuming sector at 22.3%, mainly from electricity and oil, followed by transportation at 8.5%, mainly from oil-derived products, with all other sectors combined accounting for 3.8% (IEA 2022).

While biomass is consumed almost entirely by the residential sector, electricity consumption is split across several sectors. Demand for electricity in Zambia has more than doubled since 1990, largely due to a growing population and increased economic activities (IEA 2022). The mining sector has long represented the majority of the country's electricity consumption, consistently consuming half of electricity in Zambia on an annual basis (Baruya & Kessels 2013; Bridle 2018; ERB 2022). Approximately one-third of national electricity consumption is from the residential sector, while the remaining electricity consumption is from pubic services, agriculture, and other purposes (IEA 2022).

Household Demand

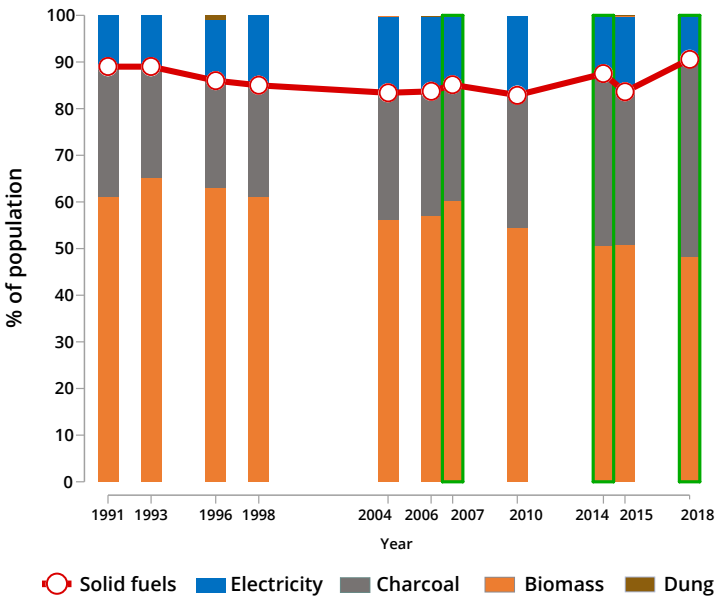
Household energy is split into two primary uses: cooking and lighting. At the household level, only 34% of the population has access to electricity (ZSA, MOH, & ICF 2019). In urban areas, 82.4% of households have access to electricity compared to 14.0% of rural households (World Bank Data 2022). Demand for charcoal, while produced in rural areas, is driven by energy needs in urban areas. The typical household in Zambia's capital Lusaka uses up to 1.3 tons of charcoal per year (Gumbo et al. 2013). There is some evidence that urban households prefer to use cleaner sources of energy but are inhibited by lack of reliable electricity, poverty, and limited affordability of other cleaner energy sources (Gumbo et al. 2013).

Household Cooking

Zambia relies heavily on biomass to meet its energy needs for household cooking with 91.8% of household cooking energy coming from solid fuels (ZSA, MOH, & ICF 2019). From the 2018 Demographic and Health Surveys report, rural households rely heavily on biomass with 81.4% of households using wood as their primary cooking fuel and 16.6% using charcoal, for a total of 98% of rural household reliant on biomass for cooking (ZSA, MOH, & ICF 2019). In urban households, reliance on biomass also high with charcoal being the dominant biomass fuel (75.7%) of households and 6.2% relying on wood (ZSA, MOH, & ICF 2019). Nearly one in five urban households use electricity as their primary cooking fuel, which is expected as a consequence of higher electricity access rates in urban areas (ZSA, MOH, & ICF 2019). **Figure 5** shows a breakdown of primary fuels used for cooking in households.

Since 1996, the share of households that use charcoal as their primary fuel has steadily increased (CSO 1997; CSO 1999; CSO 2004; CSO 2005; CSO 2011a; CSO 2011b; CSO 2016). Over the same period, fuelwood usage in urban households has dropped while the use of electricity has risen. There is some evidence that urban households turned to charcoal as reliability of electricity supply decreased from 2010 to 2015 (World Bank 2015a; CSO 2016). The highest reporting of electricity as a primary cooking fuel was in the

Figure 4: Primary cooking fuel in Zambian households over time. (Data: from DHS (bars with green outline) & CSO 1997–2016)



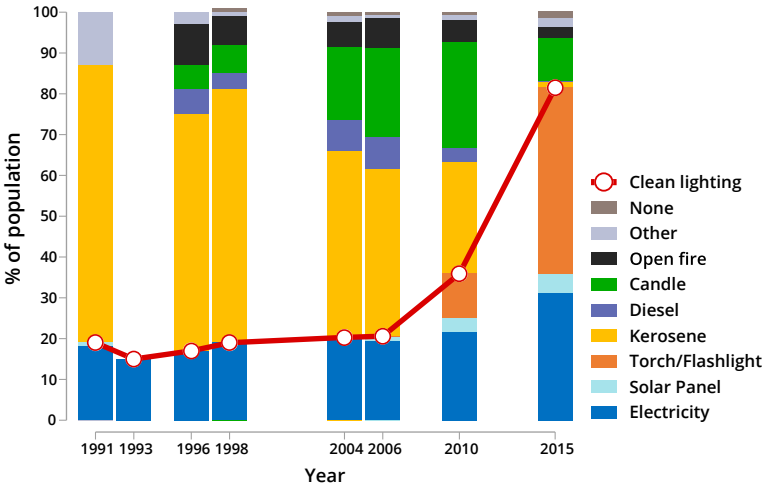
late 2000's before biomass usage increased again in the mid-2010's. Among rural households, there was a 4% increase in charcoal use as primary cooking fuel from 1996 to 2015 (CSO 1997; CSO 2016), and a concurrent decline in fuelwood use (CSO 2011b; CSO 2016).

Household Lighting

Two-thirds of households in urban areas use electricity as their primary lighting source (CSO 2016). **Figure 5** shows a breakdown of the primary lighting sources used by households throughout the country.

Historically, kerosene was the primary lighting source in both urban and rural households but was surpassed by electricity in urban areas by the early 2000s (CSO 1997; CSO 1999; CSO 2004; CSO 2005; CSO 2011a; CSO 2011b; CSO 2016). This is a striking transition that happened over the course of 10 years (**Figure 5**). Today

Figure 5: Primary lighting fuel in Zambian households over time (Data: CSO 1997-2016)



kerosene serves as the primary lighting source for less than 2% of households in Zambia (ZSA, MOH, & ICF 2019). In rural areas, where electricity access is low, torches (flashlights) are the primary source of lighting for the majority (70.6%) of households, followed by solar devices (7.4%) and candles (6.2%) (ZSA, MOH, & ICF 2019).

Institutional Demand

In addition to households, government- and privately-owned institutions rely on electricity and other energy sources to function. Health facilities and schools are two energy-dependent institutions that are critical for the health and future of Zambia and its people.

Health facilities

Electricity is required for health facilities to have lighting, operate and sterilize medical equipment, store temperature-sensitive medicines and vaccines, and other functions that enable critical services. Data from the 2015 Zambia Service Availability and Readiness Assessment (SARA) is the most recent, nationally representative data source of health care facilities' power resources that is publicly available. The 2015 SARA survey found that less than half of health facilities have access to reliable electricity, with no difference in electrification rates between urban and rural facilities at the national level (MoH 2015). Electricity access in health care facilities varies widely by province, ranging from 8% in North-Western Province to 87% in Northern Province (MoH 2015). Hospitals reported greater electricity access (69%) compared to lower-level facilities (40%) (MoH 2015). 51% of private facilities reported having reliable electricity access as opposed to 38% of public facilities (MoH 2015). More and up-to-date data are needed to understand the disparities in electricity access across health facilities in Zambia.

Schools

Schools need electricity for lighting and information and communication technologies. According to a 2018 survey, 54% of schools in Zambia lack any power source, and only 32% of schools are connected to the national grid (PMRC 2020). Other power sources include diesel generators (3.5%), solar (10.1%), or mini-hydro grids (0.5%) (PMRC 2020). As with hospitals, more data are needed to understand electricity access among schools in Zambia.

Industrial Demand

Extractive industries are the largest in Zambia, and the main consumers of electricity. The copper mining industry alone consumes 47% Zambia's electricity supply (ERB 2022). ZESCO and the Copperbelt Energy Corporation provide the majority of electricity consumed by the mining industry (MoE 2021). The copper industry consumes over half of all coal-produced energy in the country and imports coal from Zimbabwe (Baruya & Kessels 2013). In 2021, 57.9% all diesel consumed in Zambia was from industrial sectors: 33.5% from mining and 24.4% from all other industries (ERB 2022). The other 42.1% of diesel was purchased and used by consumers from filling stations (ERB 2022). Very little petroleum is consumed by the industrial sector (1.7%), and nearly all other petroleum is for residential and consumer use (ERB 2022).

Urbanization

Zambia stands out as one of the most rapidly urbanizing nations in sub-Saharan Africa, with 50% of its population expected to be urban-dwelling by 2030 (MLGH 2015). The high rates of urbanization are due to historical impacts of mining industry and development of urban centers. In addition to natural population growth, cities receive an influx from rural areas looking for work (MLGH 2015). As urban areas grow and become more electrified, so will demand on the country's electricity supply. Additionally, because urban areas are drivers for charcoal demand, rapid urbanization has the potential to increase forest degradation (Gumbo et al. 2013).

ENERGY POLICY

The Government of the Republic of Zambia wrote its first National Energy Policy in 1994, then developed its first revision of the policy in 2008 acknowledging that the energy sector drives economic growth and reduces poverty (MoE 2008). The 2008 revision focuses

on the relationship between health, education, transport, and commerce in the energy sector. A major goal of the 2008 policy was to reduce household wood fuel reliance and to increase national electricity generation, with a focus on generation from renewable sources, by 2030. The third and latest version of the Zambian National Energy Policy was published in 2019 (MoE 2019).
The 2019 National Energy Policy focuses on enabling energy supply in Zambia to support Zambia becoming a middle-income nation by 2030. It emphasizes climate change mitigation and ensuring access to clean energy for all populations in Zambia.

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

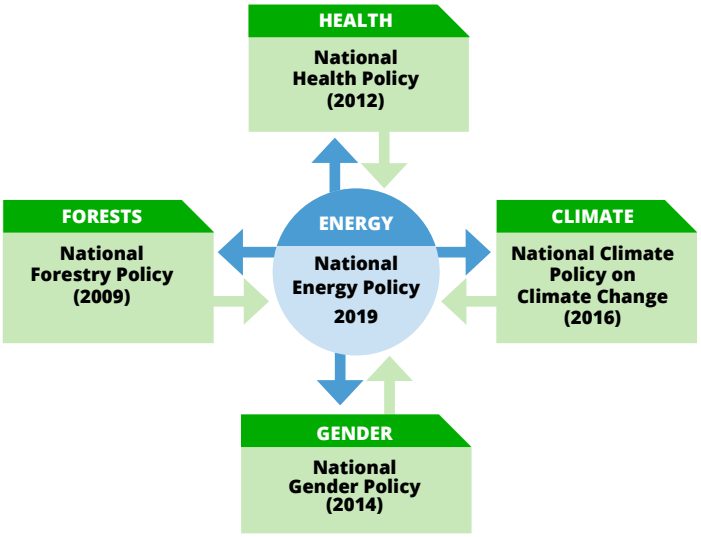


Figure 6 shows how the National Energy Policy is connected with other policy sectors in Zambia, specifically forestry, health, climate, and gender. The National Energy Policy of 2019 explicitly talks about the links between energy, forestry, climate, health, and gender. Additionally, each of Zambia's national policies on forestry, climate change, health, and gender each integrate energy and energy sector development as integral to advancing these policies. The Government of Zambia's Eighth National Development Plan recognizes that energy is a key to development (MoF 2022). In the short term, Zambia seeks to secure its national electricity supply through diversification of electricity generation sources and a shift away from overreliance on hydropower (MoE 2022). The Ministry of Energy launched the Integrated Resource Plan (IRP) in March 2021, to evaluate energy supply and demand in Zambia and implement development of a diverse and climate resilient energy infrastructure over the next 30 years (MoE 2022). Specifically, the IRP outlines a strategy for moving towards a diverse electricity supply portfolio, as between 82% and 95% of Zambia's current electricity supply is from hydroelectric power, which has become increasingly vulnerable to changes in rainfall patterns (MoE 2022; World Bank 2019).

ENERGY SECTOR GOVERNANCE AND STAKEHOLDERS

The Eighth National Development Plan of Zambia includes areas of focus to diversify electricity generation sources, promote renewable and alternative energy, and improve electricity access to rural and peri-urban populations (MoF 2022). Through the work of various government stakeholders, non-governmental organizations, the private sector, and international partners, Zambia is working to accomplish its energy sector development goals.

Government

The government of Zambia takes the lead in developing energy infrastructure. The government operates, installs, and monitors energy infrastructure across the country. There are two main government owned utilities: ZESCO and the Zambezi River Authority. The Energy Regulation Board (ERB) was established in 2003 and has the responsibility of monitoring and evaluating the energy sector in Zambia, though it does not have the legal authority to enact changes to protect consumers (MoE 2019; ERB 2022).

Government Agencies

At the national level, the Ministry of Energy oversees the development and management of the Zambian energy sector (MoE 2019). The Ministry of Energy works in conjunction with many other ministries for development of the energy sector; namely, the Ministries of Water Development, Sanitation and Environmental Protection, Lands and Natural Resources are key for coordination of hydropower permits, as well as the Ministry of Transport and Communication which is responsible for the importation and regulation of petroleum (MoE 2019).

The Rural Electrification Authority (REA) was created in 2003 to implement the country's rural electrification program. As a statutory agency without regulatory or licensing power, their goal is to increase electricity access in rural areas to improve productivity and quality of life. In 2021, the REA facilitated the implementation of 11 grid extension projects and 7 solar power plant projects to increase rural electrification (ERB 2022). Under the National Decentralization Policy, districts and local governments have little responsibility for energy development.

Public Utility Companies

ZESCO is the largest publicly owned utility company and is responsible for generating, transmitting, and distributing electricity across the country (MoE 2019; MoE 2021). ZESCO has over 2,300 MW in generation capacity across all of its 11 power generation facilities (MoE 2019; MoE 2021). They produce and distribute the majority of the electricity produced in Zambia and are also responsible for electricity imports and exports, being part of the Southern African Power Pool (SAPP) (MoE 2019). Private companies in Zambia purchase power generated by ZESCO and distribute it through privately managed transmission infrastructure (MoE 2021).

Zambia and Zimbabwe jointly own the Zambezi River Authority (ZRA 2022). Nearly 60% of the power generated from the Kariba Dam goes to Zambia through the ZRA (World Bank 2015b).

Non-Governmental Actors

Bilateral and multilateral aid organizations

Zambia has multiple multilateral aid organizations that provide funding and implement projects related to energy, in particular, related to increasing the capacity of the grid and electrifying rural communities. The role of international donors in relation to Sustainable Development Goal 7 is to support programs addressing accessibility within Zambia. These donors provide resources and guidance on access to clean and renewable energy. They also provide quantitative and qualitative data for scaling up projects and reporting back to home nations. The European Union, World Bank, UNDP, and USAID are particularly active in the donor space in Zambia. Below, we highlight recent projects that have developed as a result of these partnerships.

The European Union partnered with Zambia for the IAEREP (Increased Access to Electricity and Renewable Energy Production Project) which works to improve renewable energy policies, laws, and regulations and increase the capacity for renewable energy in Zambia (ERB 2022). As a result of this partnership, the ERB released finalized mini-grid regulatory guidelines for Zambia in 2019 (ERB 2022). Additionally, the EU funded the development of a national Power Development Framework, which was published in 2021 (MoE 2021).

The World Bank completed a Renewable Energy Resource Mapping Project mapping solar and wind resource potential around the country (World Bank 2020). The Electricity Services Access Program (ESMAP) aims to increase electricity access in rural areas through increasing grid and off-grid connections through the World Bank. ESMAP has implemented a grid expansion project and found potential for wind energy near Lusaka.

Power Africa is a U.S. program to develop more than 208 megawatts of clean electricity generation facilities in Zambia (USAID 2022a). Specifically, USAID has been working through the Power Africa program with Zambia to improve the grid system. They have helped develop a Multi-Year Tariff Framework with the Energy Regulation Board and placed Senior Advisors in the Ministry of Finance and at ZESCO (USAID 2022a). USAID has also given money to support the International Finance Corporations Scaling Solar Program in Zambia, adding up to 100 MW of solar power to the grid. USAID has also worked with the United States Trade and Development Agency on feasibility studies for geothermal generation, wind generation, and micro-grids.

Charcoal is a major part of the economy, making up nearly 3% of the country's GDP (Gumbo et al. 2013). The value chain of charcoal includes wood collection, charcoal production, transport, retail, and charcoal consumption. The Forestry Department notes that engagement with charcoal producers is vital in this chain to ensure sustainable forest (Moombe et al. 2020). The Forest and Farm Facility Program (FFF), led by FAO with other partners, aims to make the charcoal value chain greener by working with producers to improve livelihoods, create multisector stakeholder platforms, disseminate information, and connect local producers to global knowledge. The FFF worked with the Government of Zambia to propose revisions to charcoal regulations and licensing agreements in 2017, with the specific goal of supporting the charcoal value chain (FAO 2017).

Bilateral donors are supporting private sector initiatives in cleaner renewable energy. USAID has implemented the $25M US Alternatives to Charcoal (A2C) project (USAID 2022b). The aims of the program are to decrease charcoal consumption by 25% and reduce deforestation associated with charcoal production by 6.7% by 2026. A2C is using a market-sector driven approach to expand alternative fuel use to over 80,000 new households over the course of the program.

Non-Governmental Organizations and Private Sector Firms

The Office for Promoting Private Power Investment (OPPPI) is a unit in the Ministry of Energy established to be a link between the private sector and the Zambian government. The OPPPI conducts feasibility studies and facilitates the implementation of new energy development projects (MoE 2021). The list of private sector firms working in the energy space in Zambia is very long. Notably, the Copperbelt Energy Corporation is one of the largest electricity distribution firms which purchases its electricity from ZESCO and maintains transmission lines throughout the Copperbelt (MoE 2021). There are several commercial firms that sell solar systems to businesses, industry, schools, and health facilities. Other firms focus on household energy with a focus on the sale of improved cookstoves (charcoal and pellet stoves) and solar home systems.

There are also a number of smaller, in country non-governmental organizations (NGOs) and private sector firms working in the energy space. NGOs have the opportunity to work on small- and large-scale projects addressing a wide range of issues in the energy sector. In Zambia, the most active NGOs all focus on market generation for renewable energy, with an emphasis on creating a biogas and solar market in peri-urban and rural communities.

ENERGY, CLIMATE, ENVIRONMENT LINKAGES

The Government of Zambia wrote the National Climate Change Policy in 2016. The vision was for Zambia to have "a prosperous and climate resilient economy." The creation of the policy was a response to an increase in the frequency of climate related shocks including droughts, flash floods, and extreme temperatures. The policy links climate change issues with forests, health, energy, and gender sectors. In Objective 3.6, the policy focuses on energy with the aim of developing more renewable energy resources in the country (MLNREP 2016).

Climate change has directly affected the energy sector in Zambia. In 2015, 2016, and 2019, during periods of severe drought, electricity output decreased by 7%, 13%, and 7% from the previous year respectively (ERB 2016; ERB 2017; ERB 2020; Bayliss & Pollen 2021), motivating many people to switch from cooking with electricity to cooking with charcoal or LPG (World Bank 2015a). Forest degradation and deforestation rose as load shedding increased in the country (World Bank 2015). The government of Zambia recognizes these challenges and has considered them in their national policy plans.

Hydropower

Impact

Hydropower, the largest electricity source in the county, is associated with several negative environmental impacts. Hydro projects are linked to a decrease in fish populations, destruction of wetlands, and wildlife displacement (Cowx et al. 2018). Additionally, hydropower systems cause changes in water temperatures, and are associated with water pollution from agriculture and urban development near hydropower centers (Winton et al. 2021). Hydropower projects also affect livelihoods dependent on fisheries and tourism (Cowx et al. 2018). Entities wishing to construct hydropower plants and facilities must obtain a license from the Ministry of Green Economy and Environment (MoE 2021).

Vulnerability

Dependency on hydropower leaves Zambia's energy supply vulnerable to droughts, which the Government of Zambia acknowledges and is working to address (MoF 2022). In the mid 2010's, Zambia experienced a major drought and subsequent reduction in electricity output throughout the country (ERB 2016; ERB 2017; ERB 2020). Studies have found that deforestation and forest degradation are positively associated with increases in load shedding (World Bank 2015a).

In addition to household vulnerability to hydropower supply shocks, industrial productivity is highly sensitive to an unstable electricity supply. For the copper industry, the droughts of 2015 and 2016 lead to decreased productivity, and electricity prices rose as the supply was limited and demand was high (World Bank 2015). These second order effects of reliance on hydropower demonstrate the nation's vulnerability in electricity supply and need to diversify sources to ensure a more resilient energy sector.

Biomass

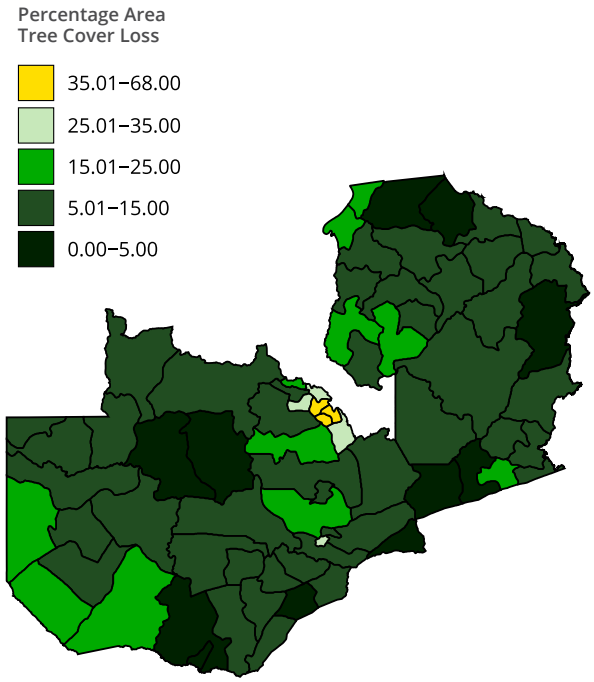
Impact

Over 70% of the energy consumed in Zambia is from biomass (IEA 2022). The climate impacts from biomass consumption in Zambia are from both consumption (greenhouse gas emissions from combustion of charcoal and fuelwood) and supply (reduced carbon stocks due to deforestation and forest degradation). Burning wood and charcoal releases several pollutants and greenhouse gases, including carbon dioxide, black and organic carbon, and methane. Harvesting wood for cooking and heating can also lead to localized forest degradation in some cases, particularly when wood is harvested unsustainably (Bailis et al. 2015; Jagger et al. 2019). In some districts, up to 20% of land has been deforested in the past 20 years (**Figure 7**). In Zambia, charcoal production and fuelwood collection have been a source of concern for several decades. It has been estimated that up to 25% of deforestation in Zambia is due to charcoal production, though more research is needed to quantify the true impact (Vinya et al. 2011; Gumbo et al. 2013).

Vulnerability

As Zambia's population grows, pressure for fuel and food production is expected to increase, leading to greater pressure on forests for energy and agricultural production (Ngoma et al. 2021). Continued instability of electricity supply may lead households to turn to biomass for their primary fuel use, which puts additional pressure on the forests (World Bank 2015a). Though research on biomass regeneration for sustainable fuel use has been conducted in specific contexts (Gumbo et al. 2013; Moombe et al. 2020), sustainable management of biomass at national scale is necessary for managing Zambia's energy sector until a transition to alternative fuel sources is achieved.

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



ENERGY DATA AND RESEARCH

Population data are used to evaluate energy consumption in Zambia. Since 1969, the Zambian census has been conducted every ten years. Data sources including WorldPop, Landscan, Global Human Settlement Layer - Population, Global Rural Urban Mapping Project, and Gridded Population of the World Version 4 are used to estimate population between census counts.

While census data and population grids are important for understanding population change, and therefore energy demand over time, there are also nationally representative studies of household behaviors and economics to understand household fuel choices and energy consumption. The Demographic and Health Surveys (DHS) are nationally representative surveys administrated to selected households with an emphasis on maternal and child health indicators; a module on household characteristics includes questions about fuel choices and electricity access. DHS surveys for Zambia are publicly available for the 1992, 1996, 2001, 2007, and 2013. The Multi-Tier Framework Survey for Measuring Energy Access (MTF) was administered

to 3,600 households in Zambia from 2017–2018. The World Bank and Energy Sector Management Assistance Program designed and administered the MTF to measure energy access and household cooking practices with nuance and depth.

In addition to demand-side data available, there exist some data on energy infrastructure. The African Development Bank maintains a dataset of power plant locations in Zambia. Data on electricity grid infrastructure is very limited; vector data of the main electricity transmission network is based on data from the World Bank, the Africa Infrastructure Country Diagnostic study, and OpenStreetMap data (Zambia ETN); alternatively, the KTH Division of Energy Systems Analysis has maintained a dataset of transmission lines greater than 69 kilovolts (Zambia TN). A Facebook-produced prediction map models medium-voltage grid distribution with about 70% accuracy (Medium-Voltage Distribution (Predictive)).

See a complete list of data sources on Zambia'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

- MICS. UNICEF.
- World Bank. "Multi-Tier Framework Survey for Measuring Energy Access 2017-2018." 2019.
- Zambia Statistics Agency, Ministry of Health (MOH) Zambia, and ICF. 2019. Zambia Demographic and Health Survey 2018. Lusaka, Zambia, and Rockville, Maryland, USA: Zambia Statistics Agency, Ministry of Health, and ICF.

ENERGY SUPPLY & SPATIAL DATA

- Medium-Voltage Distribution (Predictive). ENERGYDATA.INFO.
- Zambia ETN. ENERGYDATA.INFO.
- Zambia TN. ENERGYDATA.INFO.
- Zambia – Power Plants. ENERGYDATA.INFO.

A coal fired plant in Lusaka. The Zambian government has sought to diversify its electricity generation sources away from complete reliance on hydroelectric power. Coal accounts for 11% of electricity power generation today.

Vendor in Lusaka selling mbaulas: typical metal braziers used for cooking.

Private enterprise firm in Zambia produces pellets from sawdust to sell directly to households for cooking. Pellets may be a greener alternative to other biomass cooking fuels.

Research on energy access in sub-Saharan Africa has grown exponentially in recent years (**Figures 8** and **9**) 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, 53 peer reviewed publications on various dimensions of energy have been published about Zambia.

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

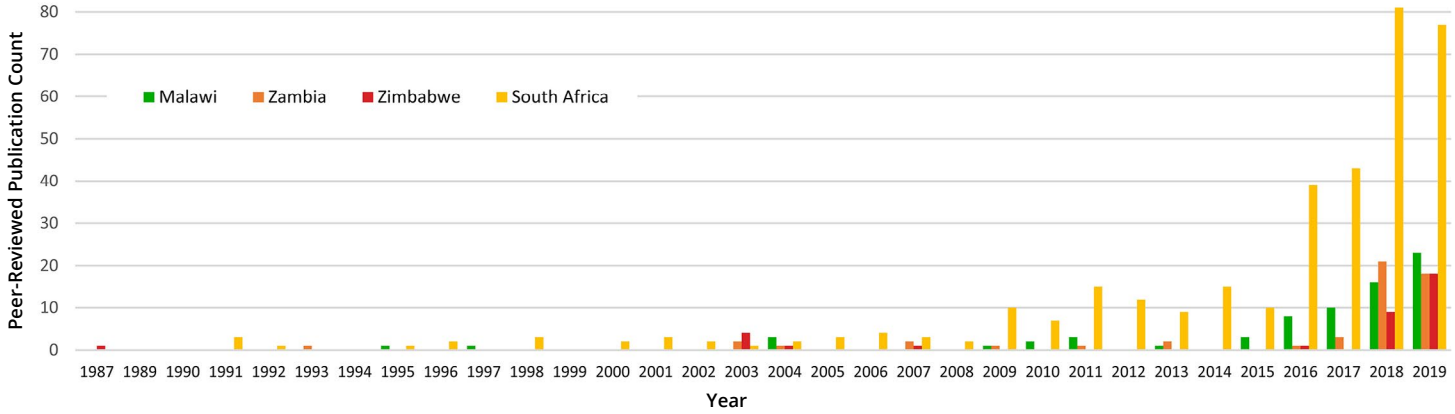
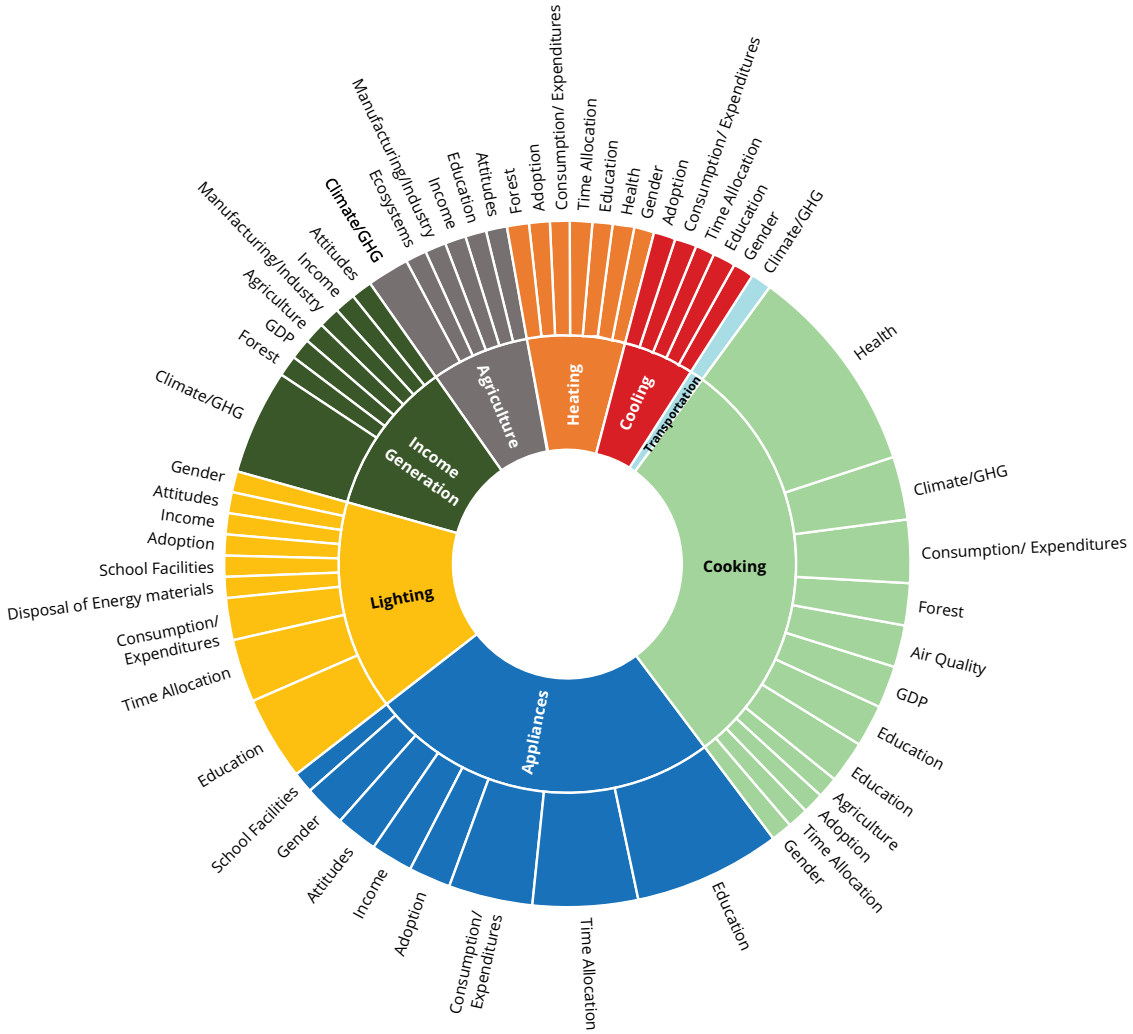


Figure 9: Energy topics and impacts of quantitative peer-reviewed publications based in Zambia from 1987–2019. (Data: Jeuland et al. 2021)



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