REVIEW OF WOODFUEL BIOMASS PRODUCTION AND UTILIZATION IN AFRICA

A Desk Study

UN environment
United Nations Environment Programme

African Union
An Integrated, Prosperous and Peaceful Africa

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In 2015, the world committed to providing affordable, reliable, sustainable and modern energy for all in Sustainable Development Goal 7. As we work towards attaining this goal, billions of people are forced to use what energy sources they can, even if they are dangerous and unsustainable.

According to the "2019 TRACKING SDG7, THE ENERGY PROGRESS REPORT", in 2016 around 3 billion people distributed across both Asia and Africa continue to cook by burning biomass, like wood and charcoal. Access to clean cooking has increased from 57% in 2010 to 61% in 2017. To reach the target of universal access by 2030, the pace of recent progress would have to accelerate six-fold.

This study, undertaken by UN Environment in cooperation with the African Union Commission, and validated by experts from 35 African countries, presents the current status of biomass energy in Africa (woodfuel and charcoal) and explores ways to mitigate its negative impacts until a transition to cleaner energy sources takes place.

The study finds that woodfuel production and marketing systems are not organized. Wood from forests is considered a common resource, but forests are not being managed to provide it in a sustainable manner. As wood becomes scarce, women and children must walk farther to collect enough wood to survive. Meanwhile, town dwellers rely on supplies that come from more-distant locations.

Woodfuel and charcoal use brings many other problems. Indoor pollution from biomass cooking will soon kill more people than malaria and HIV/AIDS combined. Woodfuel and charcoal produce 2-7 per cent of global greenhouse gas emissions caused by human activity.

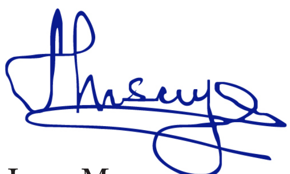
While renewable energy is advancing rapidly thanks to effort and investment, urgent action is required to address woodfuel use in the region. This is critical to meeting global energy goals by 2030, and ensuring the health of humans and forests in Africa.

This report looks at how to minimize this damage. It identifies opportunities for achieving a sustainable biomass energy production, marketing and consumption systems, and proposes detailed technical and policy options at all levels to address barriers.

We trust the findings will stimulate action on making woodfuel use more sustainable and healthier, and help pave the path to a future of clean energy for all.

Dr. Amani Abou-Zeid

Commissioner for Infrastructure and Energy
African Union Commission



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Acronyms

AfDB	African Development Bank
AFREA	Africa Renewable Energy Access
AFREC	African Energy Commission
AU	African Union
CAR	Central African Republic
CPA	Charcoal Producer Association
CVC	Charcoal Value Chain
DESA	Department of Economic and Social Affairs of the United Nations
DRC	Democratic Republic of the Congo
EIA	United State Energy Information Administration
ECE	Economic Commission for Europe
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GACC	Global Alliance for Clean Cookstoves
GCF	Green Climate Fund
GTF	Global Tracking Framework
ICRAF	International Council on Research in Agroforestry
ICS	Improved cookstoves
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LPG	Liquified petroleum gas
n.a.	Not available
n.d.	Not dated
n.s.	Not significant
NPP	Net Primary Productivity
REDD	Reducing Emissions from Deforestation and Forest Degradation
REEEP	Renewable Energy and Energy Efficiency Partnership
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SSA	Sub-Saharan Africa
TFEC	Total final energy consumption
TPES	Total primary energy supply
TWh	Terawatt hour
UN	United Nations
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UWET	Unified Wood Energy Terminology
USAID	United States Agency for International Development
WB	World Bank
WEC	World Energy Council
WFP	World Food Program
WHO	World Health Organization

Executive Summary

Context

In 2015, the United Nations Sustainable Development Goal 7 was adopted for 2030, "to ensure access to affordable, reliable, sustainable, and modern energy for all". The three pillars of sustainable energy are energy access, energy efficiency and renewable energy. Energy access involves access to electricity and to clean fuels and technologies for cooking, commonly referred to as 'clean cooking'. Wood used to generate energy, called woodfuel, is of significant value to African economies and is the single most important energy source for the majority of households. Thus, it is extremely important that woodfuel be managed in ways that exploit its advantages while limiting its negative impacts.

The Purpose of this Report

This report establishes the baseline data and information on woodfuel production and consumption, identifies opportunities for more sustainable use of woodfuel and presents the key challenges that must be addressed at all levels in the woodfuel and charcoal value chains. Ignoring this issue may result in massive degradation of forests and rangelands in Africa, and by the time the transition to other energy sources is realized, this extremely serious environmental problem may undermine the gains made on the energy front. Much effort and investment has been made and continues to be put into introducing modern renewable energy technologies, but little-to-nothing has been done to address the most-used energy source (woodfuel) in the region. The issue warrants urgent attention and the only prudent thing to do is to minimize its impact on society and the environment while making progress towards achieving the energy-related Sustainable Development Goals (SDGs).

This desk study establishes the current status of woodfuel use as an energy source in Africa. It also identifies opportunities for using wood energy more sustainably and outlines the key challenges to achieving a sustainable biomass energy production, marketing and consumption system (in the woodfuel and charcoal value chains). Finally, it proposes workable options to address these challenges. It is based on the premise that woodfuel production systems can be made sustainable and thus provide renewable energy sources and livelihood options for people in Africa in the coming decades. The report also provides a snapshot of the woodfuel situation in ten selected countries, namely, Benin, Cameroon, the Democratic Republic of the Congo, Ethiopia, Kenya, Malawi, Niger, Somalia, Tanzania and Zambia.

Key Findings

The key findings and recommendations of this REVIEW OF WOODFUEL PRODUCTION AND UTILIZATION IN AFRICA :A DESK STUDY is summarized below:

Status and trends

- In 2014, 3.04 billion people in the world — about nine times the population of the United States — had no access to clean cooking fuel; of these, about 800 million people were from sub-Saharan Africa (SSA, which excludes Northern Africa). More than any other region in the world, Africa relies predominantly on woodfuel (woodfuel and charcoal) for its energy requirements. This over-dependence on woodfuel is primarily due to the lack of access to modern energy sources, such as electricity, kerosene and liquefied petroleum gas (LPG).
- Biomass forms the fourth-largest energy source worldwide after coal, oil and natural gas. The main types of biomass include wood and agricultural products, such as crop waste, bagasse, solid waste, landfill gas and alcohol fuels. Traditional cookstoves consume much more energy than improved technologies and are more energy intensive and polluting than electricity or LPG. As a result, per capita residential energy consumption levels are higher in SSA than elsewhere in the world. Africa currently uses ten times as much energy to cook similar amounts of food than do other regions of the world that use modern technologies.
- About half the wood extracted from forests worldwide is used to produce energy, mostly for cooking and heating. Of all the wood used as fuel worldwide, about 17 per cent is converted to charcoal.
- Woodfuel production is most significant in Africa, where it accounted for 90 per cent of round- wood

production in 2016; of this, about 16 per cent is converted to charcoal.

- Global charcoal production is expected to continue increasing in the coming decades. The charcoal sector, which is largely informal, generates income for more than 40 million people, but a lack of regulation means that it is produced inefficiency and governments forgo billions of dollars in revenue.
- According to a World Bank estimate, SSA's charcoal sector alone employs an estimated 7 million people.
- According to FAO, in 2015 Africa had about 624 million hectares under forests and an estimated 400 million hectares under 'other wooded lands and other lands with trees'. About 16 million hectares were under forest plantations, which was modest compared to 129 million hectares of forest plantations in the Asia & Pacific region.

Driving forces

- The major drivers of woodfuel consumption include population growth, rapid urbanization, poverty and lack of income growth.

Impacts of woodfuel

Health

- Indoor pollution from biomass cooking — a task usually carried out by women — will soon kill more people than do malaria and HIV/AIDS combined.

Economic costs

- More than 40 million worker years are used each year on fuelwood gathering and slow biomass cooking. Cooking with traditional fuels and stoves represents a US$32 billion opportunity cost (3 per cent of SSA's GDP).

Forest loss

- According to FAO Forest Resources Assessment 2015, in Africa net annual forest change between 2010–2015 was 2.8 million hectares, however, there is no reliable estimate about how much was due to woodfuel productions.

Climate change

- An estimated 1–2.4 Gt of carbon dioxide equivalent (CO2e) in greenhouse gases are emitted annually in producing and using fuelwood and charcoal, which is 2-7 per cent of global anthropogenic emissions. These emissions are due largely to unsustainable forest management, and inefficient charcoal manufacture and woodfuel combustion. Solid-fuel cooking in SSA accounts for 6 per cent of global black carbon emissions and 1.2 per cent of carbon dioxide emissions.

Responses/Recommendations

The United Nation's projections show that the population in SSA will grow from 1.3 billion in 2017 to 2.5 billion by 2050. It is projected that by 2050, more than 1.8 billion people (65 per cent) in SSA will still rely on woodfuel for cooking. Rapid rural population expansion will hamper the transition to cleaner cooking.

One of the grand challenges for Africa is how to significantly increase the proportion of the population with primary reliance on clean fuels and technology

According to a World Bank study, SSA is already a large cooking market: US$20 billion was spent annually on cooking fuels in 2010, and US$300–400 million was spent on all types of stoves. By 2020, fuel spending is set to more than double to US$47 billion.

In this context, this report makes the following recommendations:

Accelerate economic growth

- Rapid economic growth is crucial. Three trends already in Africa's future — the young population, rapid urbanization and economic growth — auger well for the potential rapid progress of African economies, termed as 'lions on the move'.

Attract investment

- Despite the enormous potential for harnessing its untapped energy resources, the move to universal energy access will require policy advocacy, technology transfer, capacity building, sensitization and awareness creation, and large financial investments: by some estimates, US$43-55 billion per year are needed until 2030–2040, compared to current energy investments of about US $8–9.2 billion. Total financial commitments for residential clean cooking are estimated to average US$32 million over 2013–2014 for the world's 20 high-impact countries. Financing for clean cooking is so low that it will not close the cooking-access gap. Stronger efforts are needed to create 'big market' solutions rather than incremental ones.

Invest in innovation and R&D in biomass technologies

- Current efforts towards improving cooking stove technologies have not met expectations. There is a need for 'out of the box' thinking and innovation in cook-stove and charcoal making technologies. There is an urgent need for alternative sources of funding in Research and Development (R&D) to solve this ongoing problem, which will benefit billions of people across the globe. Social philanthropy organizations such as the Bill and Melinda Gates Foundation and others may be requested to support these areas.

- International Research Organizations like ICRAF should intensify their research in developing fast growing, low-water consuming and heat-tolerant trees for biomass production in the changing climate.

Encourage promising policies, incentives, research and capacity building to meet the growing demand for woodfuel

Develop energy and cooking fuel policies and strategies

- Countries should develop national cooking-fuel strategies as part and parcel of a country's National Energy Policy. National cooking-fuel strategies should contain a basket of cooking fuels, with accompanying supports. The aim should be to improve the efficiency of biomass production and consumption and the substitution of sources of fuel, such as firewood/chips, dung cake and charcoal, and by cleaner sources of energy like regulated LPG and electricity. This strategy will also have positive ripple effects on the country's public health, gender equity, livelihoods and environmental sustainability.

- Policies and strategies should encourage institutions like hospitals, hotels, schools, industry and government offices to transition from fuelwood and charcoal to electricity, ethanol, kerosene and LPG. It might not be practical to expect the poor to make the energy shift, due to poverty and cultural sensitivities, but this transition could be successfully navigated for larger institutions.

Institute Sustainable Forest Management

- Integrating biomass energy collection, distribution and use into national energy and forestry policies should be urgently considered. Countries should evaluate and adopt appropriate business models/strategies encompassing policy and regulatory measures, financial measures, capacity building and awareness-creation measures to increase woodfuel production through sustainable forest management and planting trees outside forest areas. Woodfuel can offer important ecological, economic and social benefits if forests are well managed, including the following:

  - Forest management guidelines be provided for the direct supply of woodfuel to ensure sustainable local supplies.

  - Protected areas and environmentally sensitive sites should be excluded from directives to remove wood for energy to mitigate potential adverse environmental impacts.

  - Adaptation of wood for energy Best Management Practices (BMPs) should be encouraged to protect soils, water quality and wildlife habitat.

Increase energy plantations and yield and improve woodstove efficiency

- The area under planted forest in Africa is about 16 million hectares, which is modest compared to the 129 million hectares planted in the Asia and Pacific region. There is a need to launch a massive afforestation and reforestation drive, using suitable fast-growing fuelwood species, to meet the growing needs of Africa's population. During the last two decades, several advances have been made in increasing fuelwood yield on a short-rotation period and in improving the conversion efficiencies of woodstoves and combustion furnaces/boilers to reduce wood consumption and to improve the environment. Modern biomass energy technologies, such as gasification, co-generation and pyrolysis, have been developed and commercialized to produce heat and power. Trees grown for energy can also help restore stability and fertility to the land, increase agricultural production and improve the quality of rural life. In fact, 'forests for energy' should now be a major part of any rural development program. Energy plantations may well provide a novel and exciting springboard for rural development.

Make policy and legislation more coherent

- A number of countries have passed legislations banning charcoal production, but they have not banned charcoal import and utilization. If there is any ban, it should be on charcoal utilization after identifying and disseminating alternatives. It is clear that the use of woody biomass (in the form of firewood or charcoal) will play an important role in the energy mix in Africa for a long time. To improve the sustainability of production and use of woody biomass, countries should consider introducing legislation that makes it mandatory for households to have their own fuel- wood plantations. Donor communities should be requested to support achieving compliance to such legislation.

Secure land tenure

- It is important to ensure that local populations have the rights of access and control of woodfuel plantations so they have a vested interest in protecting and developing such lands.

Promote trade and regional charcoal strategies

- The unregulated and illicit charcoal trade in Africa involves the loss of billions of US dollars annually to African economies. It has been observed that restricting charcoal in one country such as Somalia only shifts the charcoal problem to other areas unless a coordinated regional effort is made to curb illegal charcoal movements. Hence, a regional charcoal strategy backed up by strong enforcement mechanisms is needed. Strengthening and enforcing regulatory frameworks related to the charcoal trade is required.

Proposal for a harmonized regional charcoal strategy

Tier 1: Local Community Level:

Activities:

- Awareness
- Conservation
- Education
- Incentives
- Land tenure allocation

Tier II: National level:

Activities:

- Biomass Policy & Strategy formulation.
- Clear roles & responsibilities of various institutions
- Policies harmonization of different institutions
- Create synergy with international agreements such as:
- Forest (REDD+)
- Energy (Renewable)
- Agriculture (LULUCF)
- UNFCCC (Climate change)
- UNCCD (Combat Desertification)

Tier III: Regional level:

Develop:

- Regional joint mechanism (RJM) to regulate charcoal export
- RJM to implement sustainable production & management
- RJ funds to implement rule of law and enforcement
- Regional penalty system for illegal charcoal export
- Regional dispute resolution mechanism to resolve disputes

Tier IV: International level:

- AU, IGAD, UN resident Coordinator and UN agencies (UNEP, UNDP, FAO) can take the lead with regional countries.
- Formulation of International Charcoal Trade Regulatory Committee (ICTRC).
- This can serve as a forum to provide facilitation & dissemination of information to importing countries to curb illegal charcoal trade
- Update action to be taken

Green the charcoal value chain

- This has considerable potential for reducing greenhouse gas emissions on a global scale. It can be done at all stages of the value chain, especially in wood sourcing and carbonization, but also in transport, distribution and end-use efficiency.

Reconsider labelling and certification

- Due consideration should be given before embarking upon certification and labelling schemes, keeping costs and the beneficiary in mind, since biomass is the fuel of low-income earners and they are hard to implement.

Build capacity

- There is a need for training and capacity building across all the elements of the biomass energy value chain, including the following:
  - Capacity building for decision/policy makers
  - Capacity for harmonization and coordination of cross sectorial policies/strategies
  - Capacity building of researchers
  - Training on sustainable biomass supply (forestry, tree planting etc.)
  - Training in efficient kiln design, construction and use
  - Training entrepreneurs and small business owners on various aspects of biomass business management
  - Capacity building for production of Improved Cooking Stoves (ICS)
  - Capacity building on alternative technologies

Improve access to improved cook stoves and other clean fuels

- Reducing the disproportionate work burden on women (mostly cooking and fuelwood collection) by employing household energy interventions, such as improving access to cleaner fuels like LPG and more efficient cookstoves, should be implemented on a priority basis. This will reduce exposure to high levels of indoor air pollution and reduce the time spent on fuelwood collection.

Develop financing and entrepreneurship

- Governments should encourage and provide incentives to youth entrepreneurs to get involved in biomass-industry related businesses
- Align woodfuel planation with forestry programs, through sustainable woodfuel management
- Align national programs with international interventions
- Support and incentivize community involvement in the development and management of woodfuel plantations

Make use of agro-waste and biogas technology

- Exploit non-wood feed stocks as substitutes for wood biomass. Encourage the use of agro-industrial wastes through processes that transform them into pellets and briquettes as alternatives to woodfuel and charcoal and hence reduce dependence on woodfuel
- Encourage the production and use of micro-gasifier stoves that have recently been introduced through greater research and development for scaling up. This stove holds great potential as it uses agro-industrial wastes directly, thus reducing dependence on woodfuel. The residue is biochar, which has the potential to enrich soils and enhance sustainable agriculture
- Promote the greater application of biogas technology in an integrated approach where possible, using waste streams to further reduce pressure on natural forests and for cleaner and healthier sustainable energy for cooking, heating and power generation

Design houses to safely use biomass

- Current house designs and construction include kitchens with provisions for electricity or gas, but most households don't use them because they are unaffordable. There is need to develop guidelines on house design and construction to accommodate the efficient and safe use of biomass.

International Day for Clean Cooking Fuel: The United Nations designates specific days, weeks, years and decades as occasions to mark particular events or topics in order to promote the objectives of the organization through awareness and action. Usually, one or more Member States proposes these observances and the General Assembly establishes them with a resolution. The UNE may consider a proposal by Member States for an International Day for Clean Cooking Fuel to raise attention to this pressing issue.

As Africa's population continues to grow, the number of people who depend on traditional biomass as their main cooking fuel will also increase. Strong policies will thus be required to expand access to cleaner fuels and technologies. Because of poverty, cultural preferences or even lack of awareness, switching away from traditional biomass may not feasible for many households in the short-term, but there are opportunities to change the situation. First, more R&D should be invested in improved cookstoves and more people can be encouraged to use more efficient cookstoves, which would reduce the pressure on forests. Secondly, for those in the population that can do so, switching fuels would help protect the existing forest resource. Lastly, greater afforestation and reforestation efforts can help to restore degraded forests and increase the forest stock. This would bring about the double dividend of improving people's health and that of the environment.

Elizabeth Eunice cooks dinner for her family in Kisumu West, Kenya with her new rocket stove. It uses less firewood than her previous stove.

Chapter 1

Introduction

1.1 Biomass Energy: The Context

In 2015, the United Nations Sustainable Development Goal 7 was adopted for 2030, "to ensure access to affordable, reliable, sustainable, and modern energy for all". The three pillars of sustainable energy are energy access, energy efficiency and renewable energy. Energy access involves access to electricity and to clean fuels and technologies for cooking, which is commonly referred to as 'clean cooking'. Table 1-1 shows the trend in the proportion of the world's population with access to electricity and clean fuels.

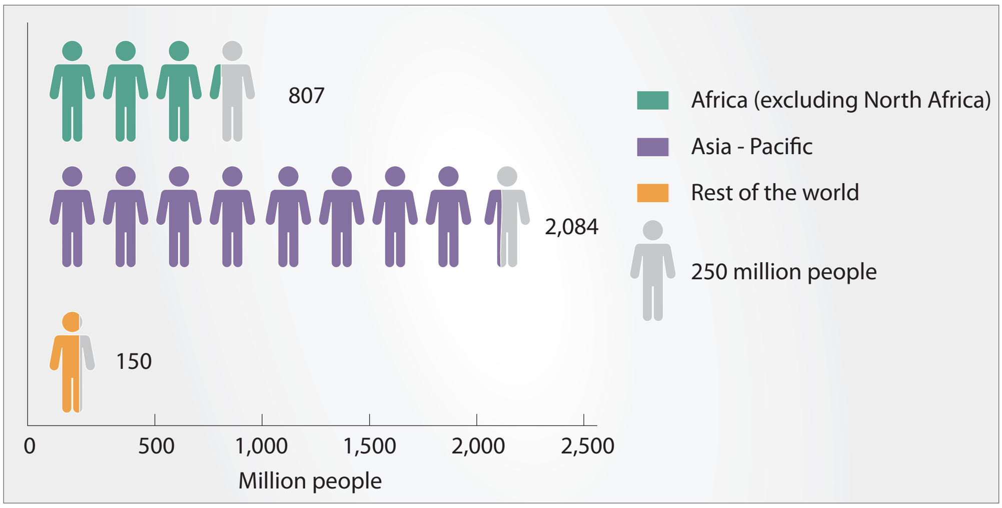
In 2014, 3.04 billion people — about nine times the population of the United States — had no access to clean cooking fuel, a slight increase in the deficit since 2012 (Figure 1-1). This increase is driven by Africa, where the population expands by 25 million annually while access to clean cooking increases by only 4 million, however significant gains have been made in the Asia-Pacific region (Figure 1-2), (World Bank, 2017).

Table 1-1: Access to electricity and clean cooking

Region	Access to electricity (% of population)							Access to clean fuels and technologies for cooking (% of population)			
	Total					Urban	Rural	Total			
	1990	2000	2010	2012	2014	2014	2014	2000	2010	2012	2014
World	73	78	84	85	85	96	73	50	56	56	57
Africa	38	38	43	45	47	76	27	25	25	25	25
North Africa	75	81	85	86	88	95	80	75	83	84	85
Rest of Africa	23	26	32	35	37	70	17	11	12	12	12

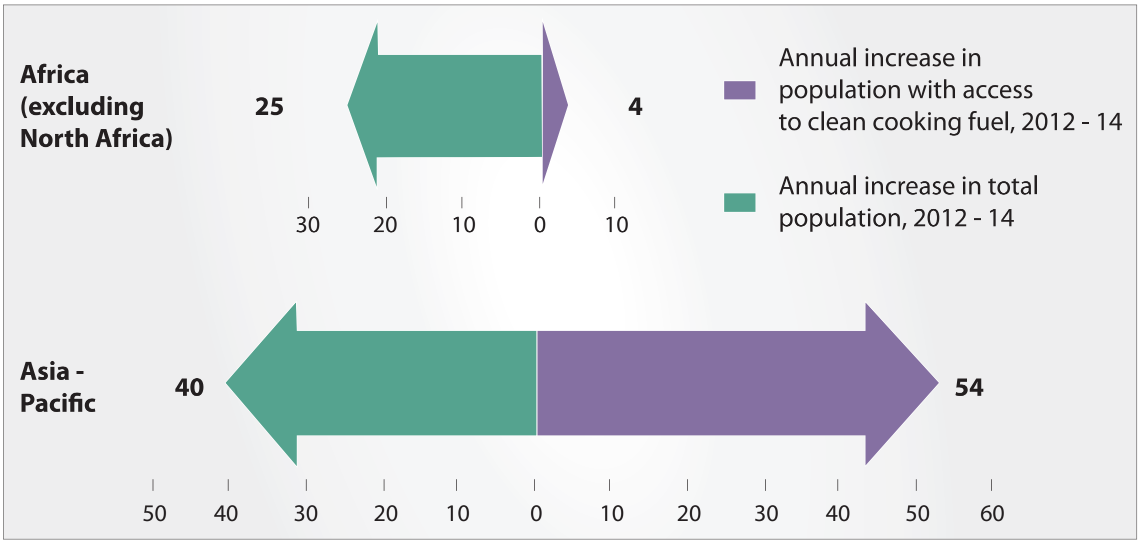
Source: (World Bank, 2017)

Figure 1-1: Location of the 3.04 billion people without access to clean cooking fuel, 2014



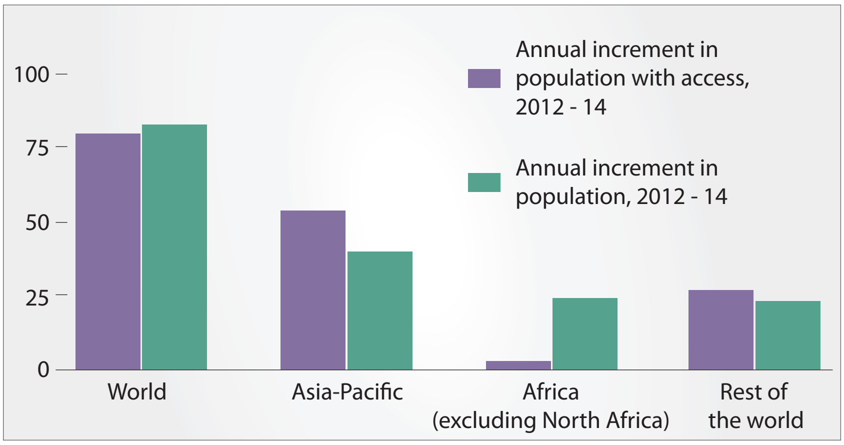
Source: (World Bank, 2017)

Figure 1-2: Demographic challenges for progress on access to clean cooking



Source: (World Bank, 2017)

Figure 1-3: Annual change in clean cooking and population growth, by region, 2012-14: The Asia–Pacific region faced the largest access deficit, yet made the most progress



Source: (World Bank, 2017)

Table 1-2: Africa (excluding North Africa) showed the lowest percentage increase in access to clean cooking, 2012-14

Attribute	Region		
	Africa	Asia-Pacific	Rest of the world
Access increase	5	63	32
Population increase	28	45	27

Source: (World Bank, 2017)

Outside of North Africa, the situation on the continent is serious: in 2012-14, the total population increased five times more than the population with access to clean cooking (Figure 1-3), such that in 2014, the region accounted for 28 per cent of the global population without access and only 5 per cent of the incremental clean cooking access in 2012-14 (Table 1-2). The use rate of clean cooking grew by a mere 0.07 percentage points each year between 2012-14 — a huge shortfall against the annual 4.6 percentage points to reach universal access by 2030 (World Bank, 2017).

Cooking on wood, Burkina Faso

1.2 Biomass—renewable energy from plants and animals

The term 'biomass' is shorthand for 'biological mass'. Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. Woodfuel, being derived from plants in the form of trees, is therefore one form of biomass. The importance of biomass as an energy source lies in the fact that it can be used to provide all the known modern energy services. In addition, it is renewable (fast growing trees can already be used in 10 years' time or less) and it is widely available across the globe. Under certain conditions, it is a sustainable source of energy.

Most-commonly used forms of woodfuels include firewood. Firewood represents the largest share in wood energy fuels production and consumption. Historically, firewood has been the most common source of bioenergy used by households. Fuelwood is a type of woodfuel where its original composition is preserved and is used solely for the purpose of energy generation. The quantity of fuelwood consumed or produced is commonly expressed in volumetric units (e.g. m^3) as mass and heating values change depending upon moisture content (FAO, UNECE, 2018).

Charcoal production is one of the oldest and most commonly used thermal treatments used to improve wood energy content and to reduce smoke. It is commonly used to enhance the energy density of firewood and to improve its rot resistance and hydrophobic characteristics. Charcoal is produced via partial pyrolysis as form of combustion in the absence of significant amounts of oxygen. The temperature employed in charcoal production varies; charcoal production itself begins at about 280^{O}C, but some species, such as oak, need higher temperatures ($\tilde{}$600^{O}C) to achieve maximum energy content. Earth-cover kiln is one of the oldest charcoal production methods. Much charcoal production takes place in brick or cement kilns that allow for better control and significantly faster production rates than earth-covered kilns. Production process consists of kiln filling, wood carbonization, extinguishing and cooling of kiln and then packing of charcoal. (FAO, UNECE, 2018)

In the developed world, woodfuel has traditionally been used in the form of logs burned in open fireplaces, log-burning stoves or furnaces. However, wood chips and pellets which can be burned in sophisticated, modern stoves and boilers - some of which have thermostatic controls and automated ignition and loading systems - are becomingly popular for their convenience and ease of handling (UK Forestry Commission, 2017).

Following are some of the benefits of woodfuel:

a) It's competitively priced or "free": Woodfuel can compete on fuel price with the fossil fuel alternatives, although the costs of installing woodfuel systems can be higher than fossil fuel systems. In developing countries, the bulk of firewood is collected free or sold at the nominal charges as it is only source of energy for cooking for majority of poor household. While woodfuel may be free to individual households, the hidden costs to society could be high in economic terms

b) It's carbon-lean: Woodfuel has a number of benefits, but the most significant one in the 21st Century is its potential role in helping to prevent dangerous climate change. That's because it can result in lower net emissions of greenhouse gases than those emitted by burning fossil fuels. Woodfuel produced in sustainably managed forests is 'replaced' by the next crop of growing trees, which reabsorbs the same amount of carbon that is emitted by the current crop being burned. The only net emissions are those caused by the harvesting, transport and processing of woodfuel. No such balanced carbon cycle exists for fossil fuels except, perhaps, one measured in millions of years. Their emissions are effectively all one-way traffic from the Earth's crust to the atmosphere.

c) It's renewable: Unlike fossil fuel reserves, sustainably managed woodland can produce an endlessly renewable source of energy.

d) It's good for the woodland environment: Sustainable management of woodlands for woodfuel is good for wildlife, biodiversity and woodland health and vigor, because the thinning, harvesting and coppicing of trees for woodfuel opens up the woodland floor to the sunlight. Sustainable management means the stewardship and use of woodlands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.

f) It's good for business and jobs: Woodfuel can generate new business and job opportunities, often in economically fragile rural areas and it can an extra source of income from trees.

g) It's good for fuel security: Woodfuel reduces our dependence on unsustainable and declining fossil fuel resources, and people who use locally produced woodfuel can be shielded from some of the vagaries and fluctuations of the international oil, gas and coal markets.

Table 1-3: Per cent global total primary energy supply by fuel, 1973-2015

Energy source	Year	
	1973	2015
Nuclear	0.9	4.9
Hydro	1.8	2.5
Biofuel/Waste	10.5	9.7
Coal (Includes Peat and Oil Shale)	24.5	28.1
Natural Gas	16.0	21.6
Oil	46.2	31.7
Other	0.1	1.5
Total Mtoe	**6 101**	**13 647**

Source: (IEA, 2017c)

h) It can relieve fuel poverty: Woodfuel can help to combat fuel poverty by providing an alternative source of energy in areas that are off the gas grid and too expensive for poor people to buy.

i) It's convenient and simple to use: Modern, wood-burning boilers and stoves can compete on ease of use, cleanliness, efficiency, convenience and maintenance with the fossil-fueled alternatives, especially if they burn chips or pellets (UK Forestry Commission, 2017).

Biomass energy in the global and regional context

Total primary energy supply worldwide in 2015 was 13,647 Mtoe, having more than doubled from 6,101 Mtoe in 1973 (IEA, 2017c). Biomass forms the fourth largest energy source worldwide after coal, oil and natural gas (Table 1-3). The main types of biomass include wood and agricultural products such as crop waste, solid waste, landfill gas and alcohol fuels such as biogas and ethanol.

Biomass fuels, especially fuelwood and charcoal are staples in many households, delivering lighting, heating and cooking energy needs. They are also used to

Table 1-4: Proportion of households cooking with woodfuel, by region and fuel type, 2011

Region	Share of households where wood is the main fuel used for cooking (%)			Estimated population using woodfuel for cooking ('000)		
	Fuelwood	Charcoal	Woodfuel	Fuelwood	Charcoal	Woodfuel
Africa	53	10	63	555 098	104 535	659 632
Asia and Oceania	37	1	38	1 571 223	59 034	1 630 257
Europe	3	0	3	19 001	156	19 157
North America	0	0	0	0	0	0
Latin America and the Caribbean	15	1	16	89 569	5 383	94 952
World	**32**	**2**	**34**	**2 234 890**	**169 108**	**2 403 998**

Source: (FAO, 2014); (FAO, 2017b)

Some key facts wood energy:

- About half the wood extracted worldwide from forests is used to produce energy, mostly for cooking and heating. Of all the wood used as fuel worldwide, about 17 per cent is converted to charcoal.
- Global charcoal production is expected to continue increasing in the coming decades. The charcoal sector, which is largely informal, generates income for more than 40 million people, but a lack of regulation means that it promotes inefficiency and governments forgo billions of dollars in revenue.
- An estimated 1–2.4 Gt CO_2e of greenhouse gases are emitted annually in the production and use of fuelwood and charcoal, which is 2–7 per cent of global anthropogenic emissions. These emissions are due largely to unsustainable forest management and inefficient charcoal manufacture and woodfuel combustion.
- The greening of the charcoal value chain has considerable potential for reducing greenhouse gas emissions on a global scale. It can be done at all stages of the value chain, especially in wood sourcing and carbonization but also in transport, distribution and end-use efficiency.

Source: (FAO, 2017c)

provide industrial energy needs at different scales, ranging from small-scale commercial ventures, such as brick making and bakeries, to larger agricultural industries, such as tea processing and tobacco curing. Table 1-4 highlights the use of various fuels for cooking in different regions of the world.

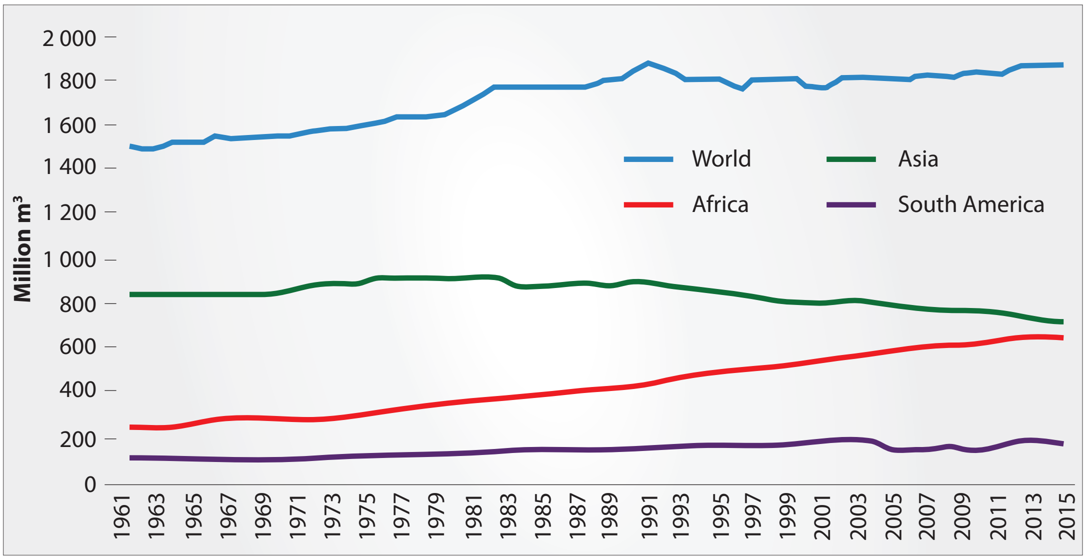
Biomass as a form of energy is important because of the number of people who depend on it for their heating and cooking needs. It is estimated that between 2000 and 2010 in sub-Saharan Africa (SSA), the average yearly growth rate for firewood was 1.01 per cent and 2.96 per cent for charcoal. Average population growth rate over the same period was 2.58 per cent. It is projected that the demand for charcoal will increase by 2.8 times and demand for firewood by 1.4 times between 2015 and 2050 (Iiyama, et al., 2014).

Woodfuels are often considered as polluting fuels because of their emissions, which have negative impacts on the 807 million people who use it for cooking in their homes in sub-Saharan Africa (World Bank, 2017). Other environmental impacts include unsustainable harvesting, which can deplete forest stocks or lead to deforestation and ultimately climate change (Bailis, Drigo, Ghilardi, & Masera, 2015). The combined

Trees cut into small pieces will be processed into charcoal in Zambia

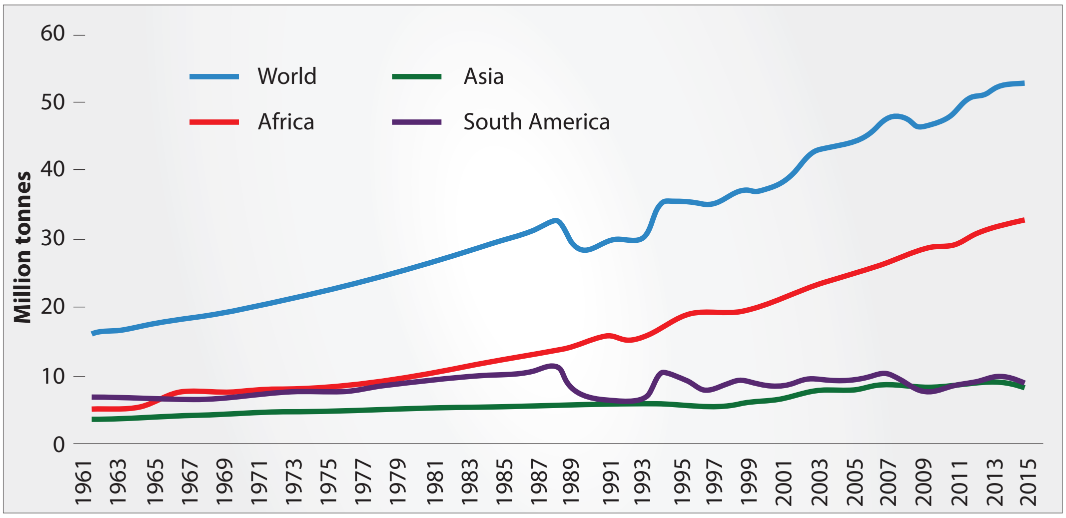
Mokhamad Edliadi/CIFOR

Figure 1-4: Woodfuel production (fuelwood and charcoal combined), worldwide and by region (Africa, Asia and South America), 1961-2015



Source: (FAO, 2016b); (FAO, 2017c)

Figure 1-5: World charcoal production worldwide and by region (Africa, Asia and South America), 1961-2015



Source: (FAO, 2016c); (FAO, 2017c)

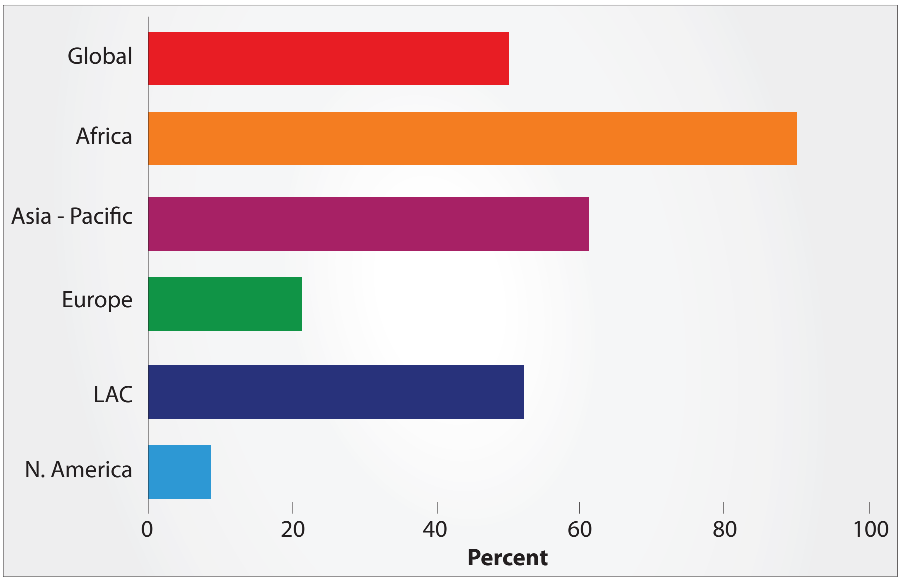
Table 1-5: Share (%) of biomass in final energy consumption, 2010

Region	Share of Biomass (%)	
	Traditional Biomass	Modern Biomass
Northern America		3.0
Europe	0.3	6.0
Eastern Europe	1.1	2.0
Caucasian and Central Asia	0.4	0.4
Western Asia		2.0
Eastern Asia	10.4	0.0
South Eastern Asia	23.4	6.0
Southern Asia	26.7	6.0
Oceania	4.3	5.0
Latin Americas and Caribbean	5.1	12.0
Northern Africa	2.5	1.0
Sub-Saharan Africa	65.3	9.0
World	**9.6**	**4.0**

Source: (WEC, 2016)

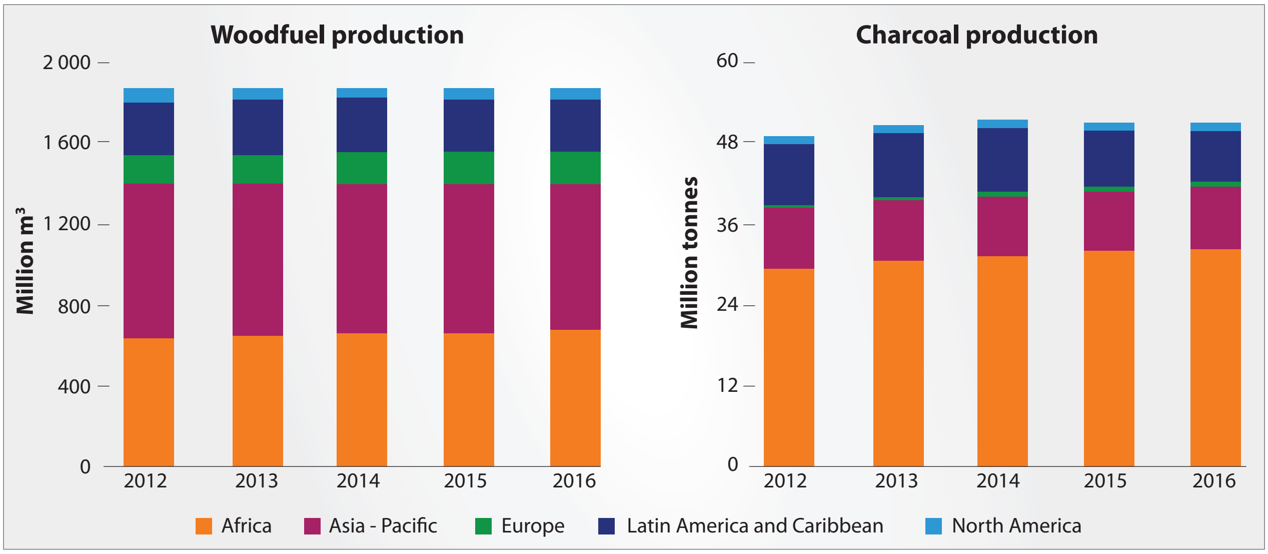
Traditional biomass includes fuelwood, charcoal, agricultural residues etc. used for cooking and heating. Modern biomass includes organic matter managed sustainably, the technology used to obtain the energy limits or mitigates emissions of flue gases and accounts for ash residue management and lastly, the efficiency of conversion to energy is higher leading than the use of traditional fuels (WEC, 2016).

Figure 1-6: Amount of roundwood used as woodfuel in 2016



Source: (FAO, 2017a)

Figure 1-7: Woodfuel and Charcoal production, 2016



Source: (FAO, 2017a)

health, environmental and economic costs of solid fuels is estimated to be about US $123 billion per year (Putti, Tsan, Mehta, & Kammila, 2015). It is against this background that access to clean cooking fuels has become an important global issue and one of the elements that will enable the achievement of the Sustainable Development Goals (SDGs).

Figures 1-4 and 1-5 show how Africa compares with other regions in woodfuel and charcoal production. In both cases Africa shows highest increase over Asia and South America.

Similarly, Table 1-5 shows that Sub-Saharan Africa had the highest use of traditional biomass (fuelwood and charcoal) than the rest of the world in 2010.

Woodfuel production is most important in Africa, where it accounted for 90 percent of roundwood production in 2016 (Figures 1-6 and 1-7).

Charcoal production near Chiana, Kassena Nankana District - Ghana

Chapter 2

Status and Trends in Woodfuel Production and Consumption in Africa

2.1 The State of Woodfuel in Africa

Overview of Africa's energy sources

According to the International Energy Agency (IEA) (2017a), Africa's total primary energy supply (TPES) in 2015 was 787.62 Mtoe, up from 495.59 Mtoe in 2000. This accounted for 5.8 per cent of the world total. In 2015, total final energy consumption (TFEC) for Africa was 572,945 ktoe compared with 368,805 ktoe in 2000 (IEA, 2017a).

In 2015, biomass dominated the energy mix, contributing about 48 per cent of the total primary energy supply (Table 2 1) (IEA, 2017a). This was followed by crude oil at about 15 per cent, natural gas at 13.7 and coal at 13.69 per cent. However, these figures mask important regional differences. The share of traditional biomass in the total final energy consumption mix in North Africa in 2010 was only 2.5 per cent compared with 65.3 per cent for sub-Saharan Africa in the same year and coal is especially important in South Africa (WB and IEA, 2017). Natural gas and oil are particularly important in the North African countries where 99 per cent of the population has access to non-solid fuels in 2010 compared with 32 per cent in sub-Saharan Africa. The consumption of Liquefied Petroleum Gas (LPG) is popular in North Africa. On average, modern renewables such as wind, solar, hydro and geothermal account for 1.9 per cent of the total primary energy supply in Africa (IEA, 2017a).

According to the IEA (2017d), the proportion of traditional biomass in Africa's total primary energy supply decreased from 61 to 48 per cent between 1971 and 2015. This is thought to be due to some improvements in access to electricity and also developments in the fossil-fuel sector. Overall, African governments need to invest a lot more effort into energy development. In 2014, only 76 per cent of urban and 27 per cent of rural areas were electrified — the lowest of all regions worldwide. This, in combination with a poor, large and growing rural population, means that many people will continue to depend on biomass for their primary energy needs (Figure 2-1) (IEA, 2017d).

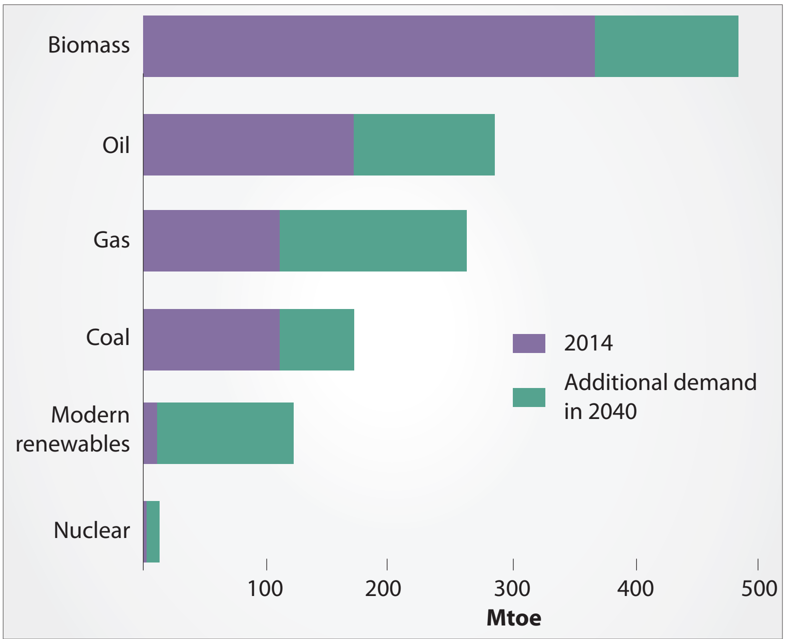
Table 2-1: Percentage of Africa's total primary energy supply by fuel, 1971 and 2015

Energy source	(%)	
	1971	2015
Biofuels/Waste	61	48
Coal (Includes Peat and Oil Shale)	19	14
Oil	18	22
Natural Gas	1	14
Hydro	1	1
Other	n.s.	1
Total (Mtoe)	**192**	**787**

Source: (IEA, 2017d)

In Africa, firewood and charcoal are the two main forms of biomass used as energy sources. Only a few countries account for most of the woodfuel harvested in sub-Saharan Africa: the Democratic Republic of the Congo (DRC), Ethiopia, Nigeria and Tanzania

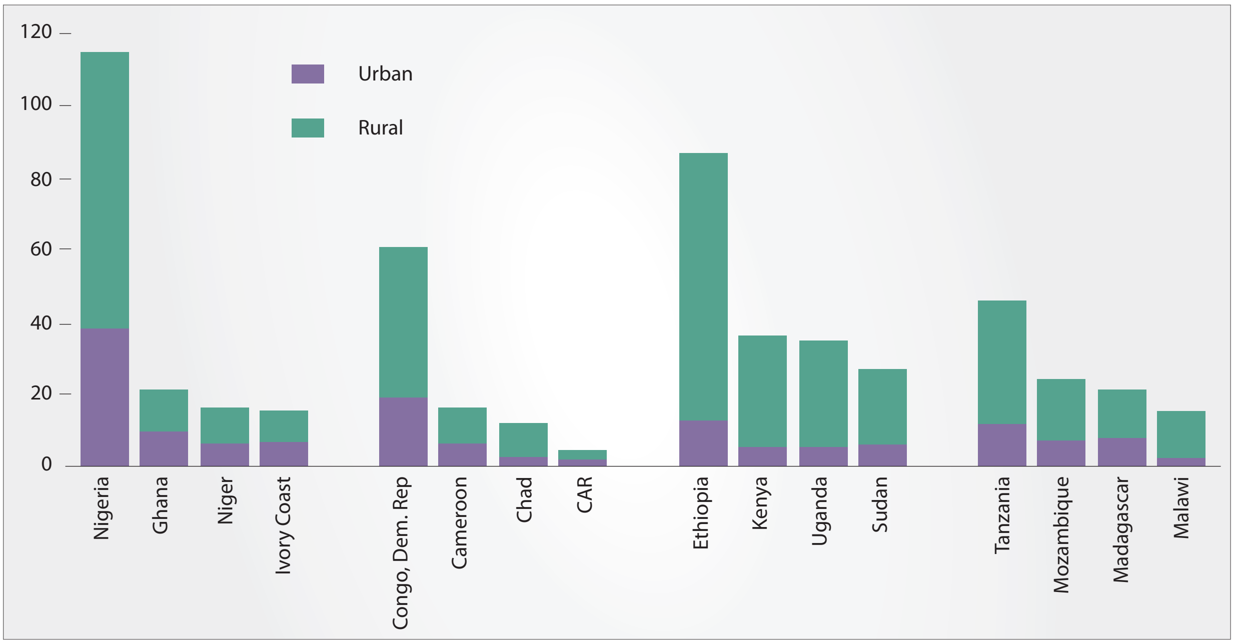
Figure 2-1: Projected total primary energy demand in Africa, 2014-2040



Source: (IEA, 2017d)

Opposite photo: CIFOR / CC BY-NC-ND 2.0

Figure 2-2: Annual estimated wood-fuel use (for firewood and charcoal) in selected countries, 2014



Source: (IEA, 2014)

(Figure 2-2). The fast-growing population implies an increasing demand for these sources, which is likely to put growing pressure on forests and other biomass sources.

Woodfuel is widely used in Africa. It's long history of use, cultural barriers, widespread poverty and daunting geographic conditions make other forms of fuel unpopular or unavailable (Mendum & Njenga, 2018). Estimates indicate that 1.8 billion people will still be dependent on traditional biomass resources in SSA in 2040 (IEA, 2014). As a result, it is important that governments put in place sustainable wood-fuel production systems and sustainable lifecycle systems for their use.

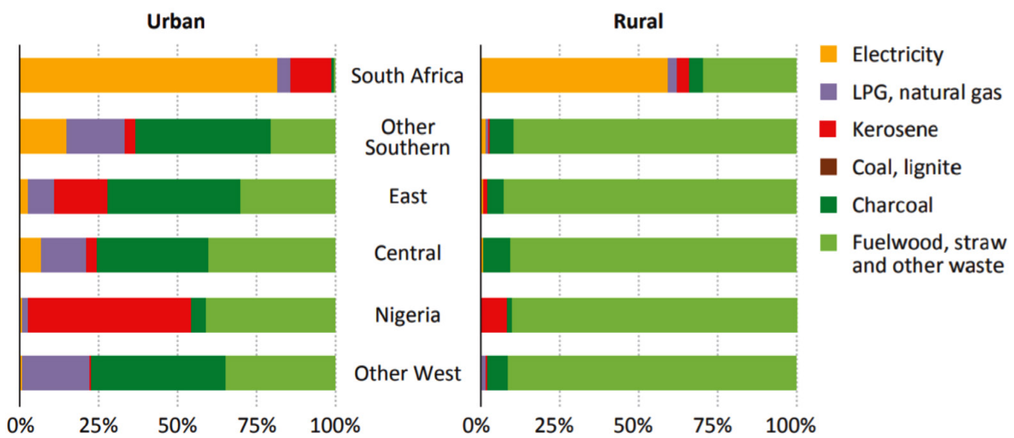
Fuel types used for cooking in Africa

According to the World Bank and the International Energy Agency, only 26 per cent of people in Africa cook with clean fuels or improved technologies (WB and IEA, 2017). When segregated by region, 85 per cent in North Africa and only 12 per cent in the rest of Africa cook with clean fuels. In 2014, in absolute terms, the regional share of the population with access to clean cooking fuels and technologies was 50 million people. Figure 2-3 highlights main fuel used for cooking by location.

As may be expected, North Africa and South Africa had the highest percentage of the population using non-solid fuels (Figure 2-4).

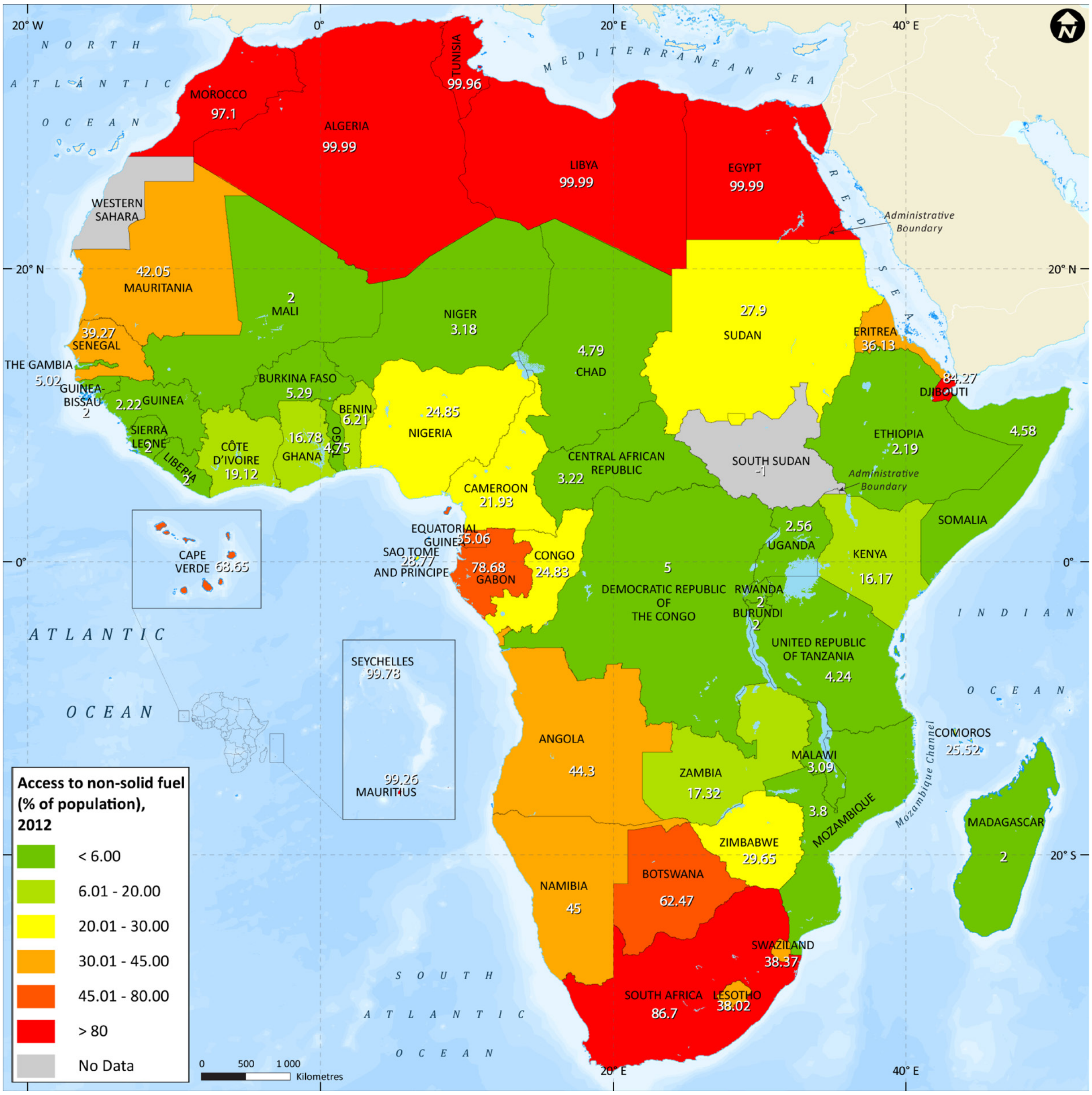
As with electricity access rates, the African region has the lowest rate of access to clean fuels and technologies for cooking among all of the regions. The share of the population cooking with clean fuels and technologies edged up only marginally, from 24.6 per cent in 2000 to 26.0 per cent in 2014, for an annual increase of 7.1 million users, equivalent to the population of Eritrea and Botswana combined (Figure 2-5). Yet the total population increased by 24.4 million a year during that period (World Bank, 2017).

Figure 2-3: Fuel types used for cooking



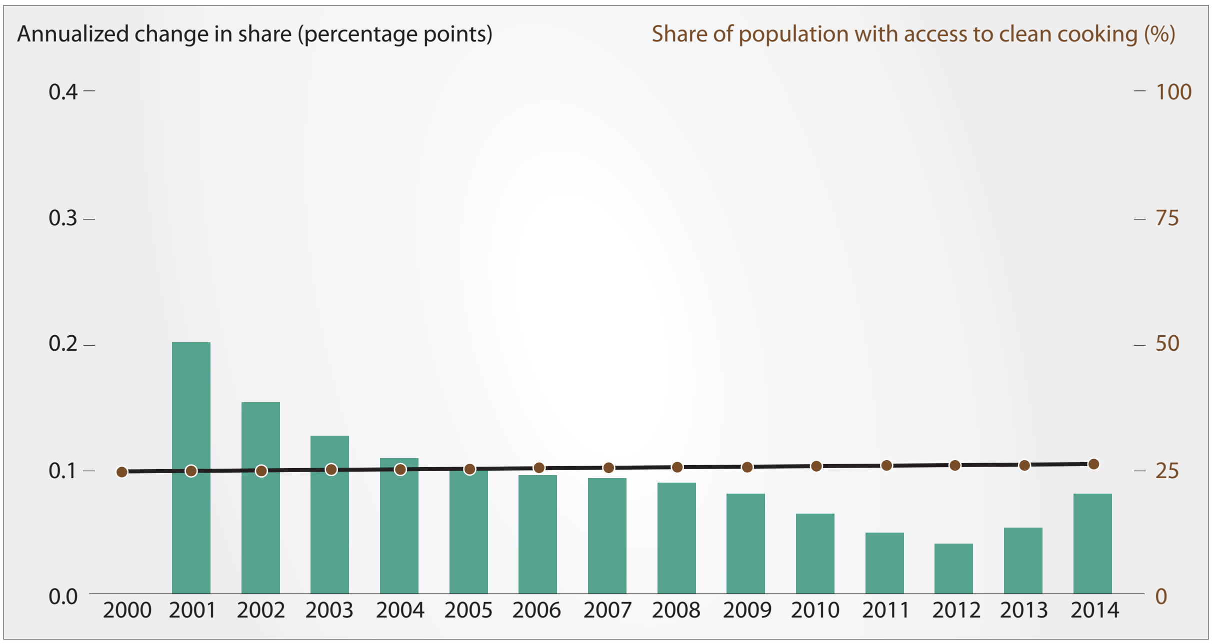
Source: (IEA, 2014)

Figure 2-4: Share of population with access to non-solid cooking fuels



Source: (UNEP, 2017a)

Figure 2-5: Africa struggled to improve access to clean cooking, leaving 850 million people relying on traditional, polluting cooking solutions in 2014



Source: (World Bank, 2017)

Table 2-2: Area of forest, other wooded land and other land with trees (1,000 ha), 2015

Country	Total Land Area	Forest	Other wooded land	Other land with trees	Total land with trees	Per cent (%) of total land area with trees	Tree planted land
Algeria	238 174	1 956	2 569	0	4 525	2	556
Angola	124 670	57 856	0	0	57 856	46	125
Benin	11 276	4 311	2 889	289	7 489	66	23
Botswana	56 673	10 840	34 791	0	45 631	81	0
Burkina Faso	27 360	5 350	4 795	6 094	16 239	59	239
Burundi	2 568	276	201	0	477	19	120
Cabo Verde	403	90	0	0	90	22	84
Cameroon	47 271	18 816	12 715	0	31 531	67	36
Central African Republic	62 298	22 170	32 731	978	55 879	90	2
Chad	125 920	4 875	19 563	0	24 438	19	18
Comoros	186.1	37	26	0	63	34	3
Congo	34 150	22 334	10 479	0	32 813	96	71
Côte d'Ivoire	31 800	10 401	2 554	493	13 448	42	427
Democratic Republic of the Congo	226 705	152 578	11 513	0	164 091	72	60
Djibouti	2 318	6	220	0	226	10	0
Egypt	99 545	73	20	0	93	0	73
Equatorial Guinea	2 805	1 568	9	0	1 577	56	0
Eritrea	10 100	1 510	7 132	0	8 642	86	39
Eswatini	1 720	586	496	0	1 082	63	135
Ethiopia	100 000	12 499	40 631	0	53 130	53	972
Gabon	25 767	23 000	0	0	23 000	89	30
Gambia	1 012	488	99	0	587	58	1
Ghana	22 754	9 337	0	0	9 337	41	325
Guinea	24 572	6 364	5 850	0	12 214	50	104
Guinea-Bissau	2 812	1 972	224	0	2 196	78	1
Kenya	56 914	4 413	9 365	0	13 778	24	220
Lesotho	3 036	49	96	0	145	5	17
Liberia	9 632	4 179	0	0	4 179	43	8
Libya	175 954	217	330	0	547	0	217
Madagascar	58 180	12 473	14 466	0	26 939	46	312
Malawi	9 428	3 147	0	0	3 147	33	419
Mali	122 019	4 715	19 406	0	24 121	20	135
Mauritania	103 070	225	3 040	10	3 275	3	27
Mauritius	203	39	12	0	51	25	18
Mayotte	37.4	6	1	0	7	19	0
Morocco	44 630	5 632	580	1 273	7 485	17	706
Mozambique	78 638	37 940	14 421	0	52 361	67	75
Namibia	82 329	6 919	8 107	0	15 026	18	0
Niger	126 670	1 142	3 140	8 000	12 282	10	150
Nigeria	91 077	6 993	2 681	270	9 944	11	420
Reunion	251	88	51	0	139	55	5
Rwanda	2 467	480	61	0	541	22	418

Country	Total Land Area	Forest	Other wooded land	Other land with trees	Total land with trees	Per cent (%) of total land area with trees	Tree planted land
Saint Helena Ascension and Tristan da Cunha	39	2	0	0	2	5	0
São Tomé and Príncipe	96	54	0	31	85	89	0
Senegal	19 253	8 273	5 250	1 230	14 753	77	561
Seychelles	46	41	0	0	41	89	5
Sierra Leone	7 218	3 044	200	15	3 259	45	16
Somalia	62 734	6 363	0	0	6 363	10	3
South Africa	121 309	9 241	32 592	30	41 863	35	1 763
South Sudan	64 430	7 147	35 582	0	42 729	66	0
Sudan	187 940	19 210	20 677	0	39 887	21	6 121
Togo	5 439	188	1 246	0	1 434	26	46
Tunisia	15 536	1 041	293	2 242	3 576	23	725
Uganda	20 052	2 077	2 879	4 174	9 130	46	60
United Republic of Tanzania	88 580	46 060	7 984	0	54 044	61	290
Western Sahara	26 600	707	0	0	707	3	0
Zambia	74 339	48 635	6 108	0	54 743	74	64
Zimbabwe	38 685	14 062	0	0	14 062	36	87
Total Africa	**2 979 690.5**	**624 095**	**378 075**	**25 129**	**1 027 299**	**34**	**16 332**

0=No data available

Source: (FAO, 2015)

The fuels and technologies households use for cooking have become a major global health issue. Inhaling carbon monoxide and particulate matter from traditional biomass cookstoves causes some 4 million premature deaths each year, primarily among women and children. Reducing exposure to these health risks calls for either switching to clean fuels, typically liquefied petroleum gas, or adopting advanced combustion cookstoves that burn biomass more cleanly and efficiently (World Bank, 2017).

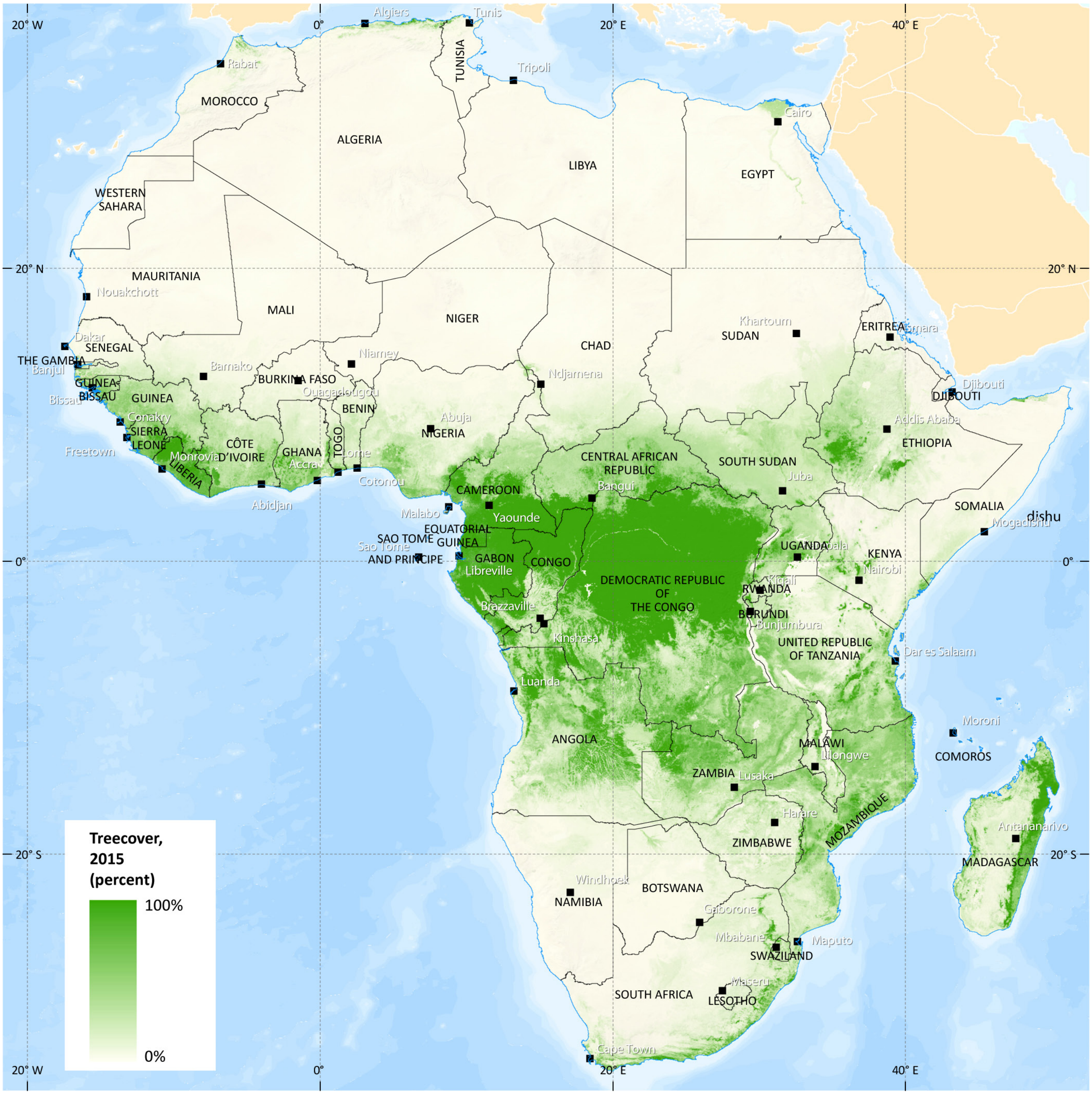
Biomass resources assessment

Biomass resources in Africa come from a variety of sources — forests and agriculture, and as by-products, residue or waste from the production of food, fibre or wood products (WEC, 2016). There are differences that manifest at national levels; for instance, although animal dung is insignificant in the energy mix at the continental level, it is important in a few countries including Ethiopia, Lesotho, Niger, Rwanda and Senegal.

It is estimated that 90 per cent (615 million m^3) of all wood removals from forests, woodlands, plantations and trees outside forests are the main sources of firewood and charcoal in Africa (Lundgren, 2014). As well, an estimated 82 per cent of Africa's household energy is derived from wood. Most of the firewood for people use comes from the small understory trees or shrubs within or outside forests and woodlands, or from plantations. Charcoal is made from trees harvested specifically for this purpose or as a result of agricultural land clearance. Most woodfuels are collected in the vicinity of villages outside actual forested areas.

According to the Food and Agriculture Organization (FAO), Africa's forested area is estimated at 624 million hectares with an additional 378 million hectares classified as 'other wooded land'. Over one third of the land area of the continent is under 'land with trees' (Table 2-2). However, forests in Africa are not evenly distributed and many countries have rather modest area under forest. Most of Africa's forests are found in the Congo Basin countries.

Figure 2-6: Tree cover distribution map of Africa derived from satellite

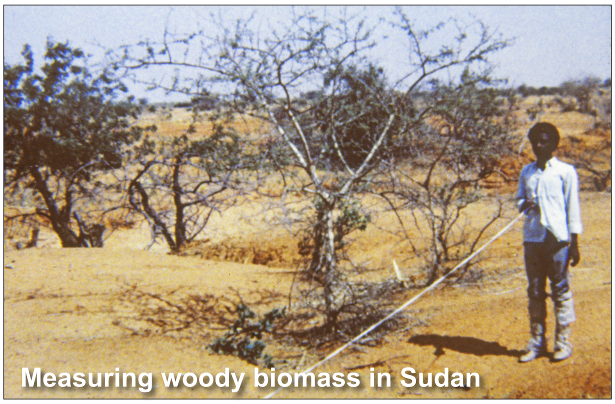


Source: (University of Maryland, USA)

Figure 2-6 shows the distribution of tree cover in Africa. Note the major forested areas are in west and central Africa.

The assessment of Africa's biomass resources is a research area that requires greater intervention. Most reports/studies for Africa are based on desk studies previously conducted. There has not been a comprehensive resource assessment in most countries for decades. Even national statistics for fuelwood/woodfuel use in the countries are old and outdated. Funds are not available to conduct national surveys.

Many developing countries lack reliable data on the production and consumption of woodfuel, largely because it is associated with subsistence activities; in fact, woodfuel is abundantly produced and traded at the local level by small-scale producing units, but this major component of production - and the labour associated with it - are not usually taken into account by national statistical systems. As a result, insufficient attention is paid to wood energy in national policies and strategies. Sound data are generally available for large-scale industrial production of woodfuel, however (Borlizzi, 2017).



Measuring woody biomass in Sudan

H. Gyde Lund

In addition, little empirical research into wood burning in sub-Saharan Africa has been conducted. As a result, policy makers have scant data to guide them in formulating best practices for sustainable biomass production and consumption (Mendum & Njenga, 2018) .

It is not possible to design development strategies, conservation plans or policies without the science to inform decisions. Reliable data is required on the growing stock and sustainable yield of woody biomass. There are a number of methods used to estimate biomass resources. These include using forest inventory data, estimates of biomass from field surveys and the use of remote sensing technologies. Forest inventories have tended to concentrate on commercial species in forested areas, ignoring other important sources of woodfuel in woodlands, farms and other cultivated areas, shrublands and savannahs. For the policy maker, it is important that biomass assessments are cognizant of all forms of biomass. This is because twigs, branches, dead wood and other marginal woody materials are major sources of biomass for household energy use.

It is important to explore funding internationally to undertake comprehensive resource assessment and mapping for Africa. This should include survey on fuelwood or biomass use in the cooking sector and the alternative fuels used.

Household energy use

More than any other region in the world, Africa relies predominantly on woodfuels (charcoal and firewood) for its energy requirements. This over-dependence on woodfuels is primarily due to the lack of access to modern energy sources, such as electricity, kerosene and liquefied petroleum gas (LPG). At the household level, most energy is required for lighting, cooking and space conditioning (cooling or heating), with most (between 90 and 100 per cent of energy consumption) going towards cooking. Cost and availability are among the factors that determine the amount and types of energy used at the household level.

Young boy cooking over open fire

H. Gyde Lund

Table 2-3: Traditional and modern use of solid biofuels, 2015

Region/Country	Solid biofuels (%)	
	Traditional use	Modern use
Algeria	0.1	0.1
Angola	45.2	1.1
Benin	42.1	8.6
Botswana	28.9	0
Burkina Faso	73.5	0.4
Burundi	97.2	1.1
Cabo Verde	22.9	0.3
Cameroon	64.5	6.6
Central African Republic	38.1	35.2
Chad	88.0	1.3
Comoros	45.3	0
Congo (Dem. Rep. of)	78.7	14.2
Congo (Rep. of)	59.8	0.8
Cote d'Ivoire	56.9	6.4
Djibouti	15.4	0
Egypt	1.7	1.8
Equatorial Guinea	5.7	0
Eritrea	75.8	3.9
Eswatini	15.3	45.7
Ethiopia	89.5	0.9
Gabon	22.0	58.6
Gambia	51.5	0
Ghana	27.9	7.9
Guinea	73.9	0.4
Guinea-Bissau	79.1	7.8
Kenya	68.9	0.1
Lesotho	47.7	0
Liberia	10.1	73.8
Libya	2.0	0
Madagascar	31.6	36.8
Malawi	36.4	38.9
Mali	57.2	1.6
Mauritania	31.1	0
Mauritius	0.7	9.2
Morocco	4.0	4.7
Mozambique	67.8	9.0
Namibia	6	1.7
Niger	78.9	0
Nigeria	80.5	5.8
Reunion	1.4	7.3
Rwanda	78.5	7.1
Sao Tome and Principe	40.0	0
Senegal	40.1	1.7
Seychelles	0.7	0
Sierra Leone	53.5	23.8
Somalia	60.5	33.8
South Africa	13.6	2.9
South Sudan	36.6	2.5
Sudan	36.9	19.1
Tanzania (United Rep. of)	70.0	19.1
Togo	58.6	9.5
Tunisia	11.3	0.2
Uganda	70.3	17.0
Zambia	56.7	19.6
Zimbabwe	72.8	5.5

Source: (World Bank, 2017)

Most biomass use in Africa comes from traditional sources (firewood, animal dung and agricultural waste (Table 2 3). They are mostly used within the household and the level of burning efficiency is low compared to modern uses of biomass. These involve using biomass to produce electricity, among others. Intermediate uses of biomass include the use of charcoal (IEA, 2006). Countries like Ethiopia, Burundi, Chad, Nigeria, and Rwanda had the highest percentage in traditional use and are largely depended on biomass based energy sources (hot spots) in SSA and interventions need to be priorities.

Two major types of households use charcoal — the urban charcoal-dependent poor and the middle-to-high income charcoal households (WB; AFREA; ESMAP, 2014). The general increase in both urbanization and incomes are resulting in shifts from firewood to charcoal use. Africa produces 62 per cent of global charcoal production, mostly in sub-Saharan Africa (SSA) (FAO, 2017c). In many developing countries, particularly in SSA, wood for charcoal production is sourced mainly from natural forests and woodlands, and only a small volume is produced sustainably. In most countries, the first step in developing a modern bioenergy sector is to better utilize the resources from wastes and residues (WEC, 2016).

2.2 Drivers of Woodfuel Consumption

Population growth

Rapid population growth is driving the increase in the production and consumption of woodfuels. In 1990, Africa's population was 635 million; by 2010, it had increased to 1,049 million and it is expected to grow to 1,703 million by 2030 (Table 2-4). The demand for woodfuels in all sectors is increasing in tandem with rapid population growth including an increase in number of homesteads, towns and industrial zones.

Table 2-4; Total and projected population and woodfuel production and consumption in Africa, 1990-2030

Year	Population (millions)	Wood Fuel (1,000 m^3)	
		Production	Consumption
1990	635	445,047	0
2000	818	542,363	542,361
2010	1,049	630,677	630,266
2015	1,194	665,568	664,904
2020	1,353		
2030	1,703		

0=No data available

Source: FAOSTAT

Increasing urbanization

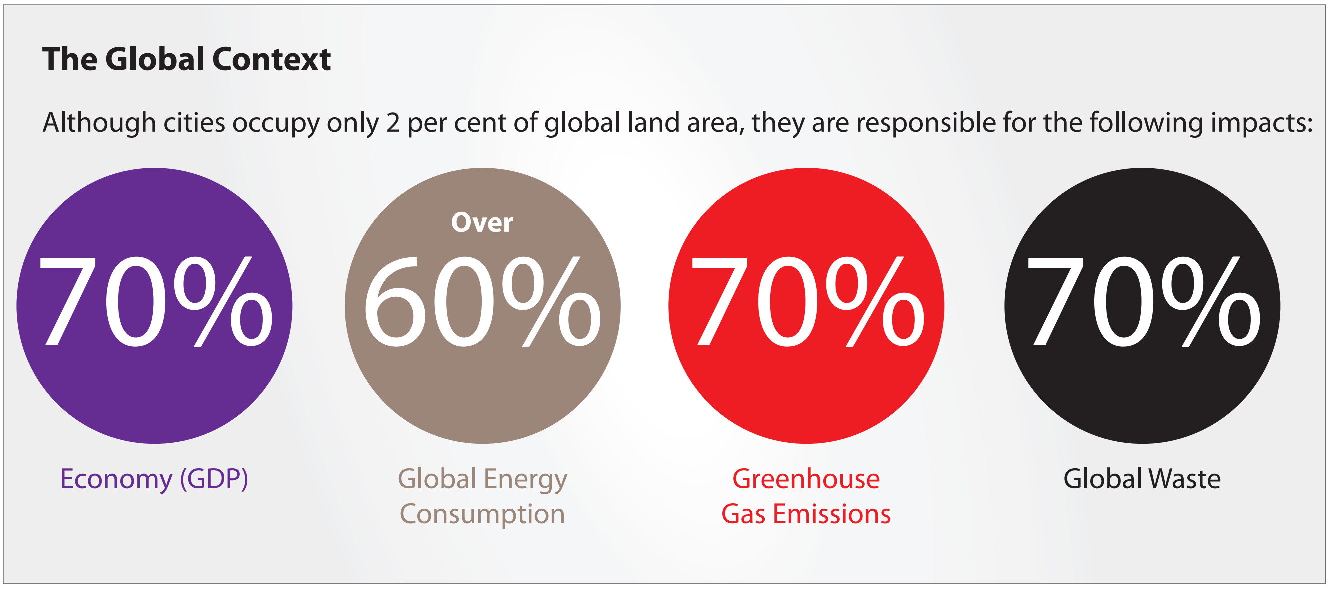
In 2015, just over half (54 per cent) of the world's population lived in cities and it is projected that by 2050, that proportion will have increased to 66 per cent. Although the geographic footprint of cities on the planet is relatively small — they only occupy about 2 per cent of the world's total land area — their impact is very significant (Figure 2-7).

Africa is the most rapidly urbanizing region worldwide, growing at rate of 3.44 per cent between 1995 and 2015 (UN-Habitat, 2016). The proportion of the continent that is urbanized rose from 15 per cent in 1960 to 40 per cent in 2010, and is projected to reach 60 per cent in 2050 (UN-DESA, 2014). In absolute numbers, the urban population is projected to grow from 400 million to 761 million urban dwellers between 2010 and 2030. Sub-Saharan Africa in particular is urbanizing faster than any other of the world's regions. Small and medium-sized cities with less than one million people are the fastest growing. These account for 62 per cent of Africa's urban population (UN-Habitat, 2016).

Countries with a predominantly rural population seem to have a greater share of biomass in their total energy mix. As well, although urbanization has been linked to the transition to cleaner fuels, the proximity of forests to urban centers seems to correlate with the greater use of woodfuels. Economic growth and development also seem to drive the energy transition from traditional to commercial or modern fuels. However, the total amount of traditional energy utilized in the economy varies in more complicated ways.

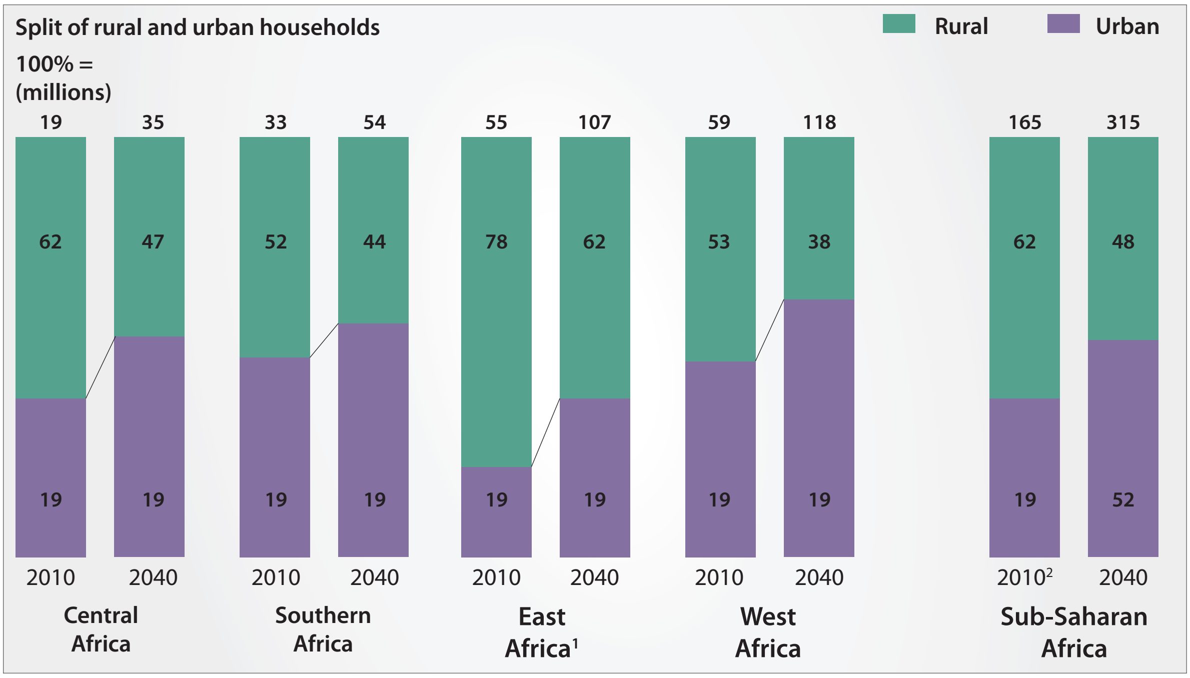
The growth in urban populations has been linked to increased demand for woodfuels. Charcoal is the predominant form of woodfuel mostly used in urban centres, while firewood is used mainly in rural areas (Ghilardi, Mwampamba, & Dutt, 2013); (Mendum & Njenga, 2018) A study in Tanzania estimated that a one per cent rise in urbanization has increased charcoal consumption by 14 per cent (World Bank, 2009). Data from Kenya indicates that between 2004 and 2013, the national charcoal consumption rate grew by 5 per cent a year, which was higher than the rate of urbanization (2.7 per cent) over the same

Figure 2-7: The footprint of urban



Source: (UNEP, 2017b)

Figure 2-8: Growth of urban households by Africa region



Source: (UNEP, 2017a)

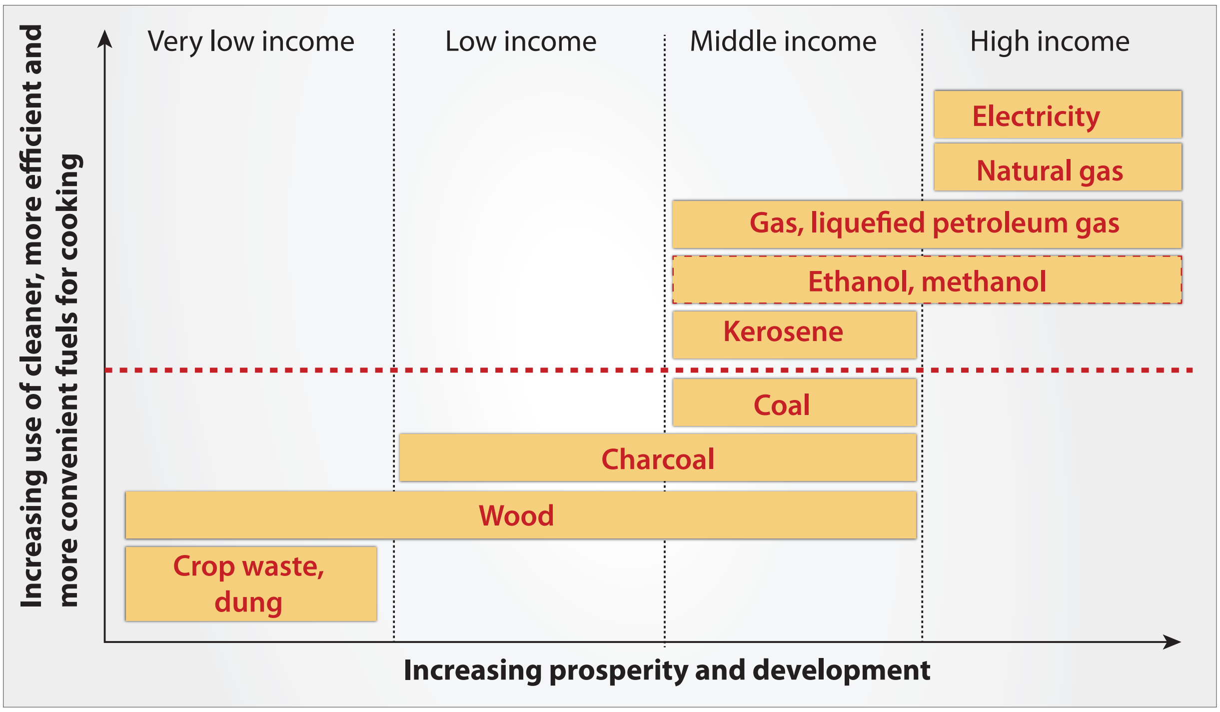
period (Iiyama, et al., 2014) (Iiyama, Petrokofsky, Kanowski, & Kuehl, 2013). In Uganda, there is a clear link between charcoal consumption and urban growth, with both increasing at roughly 6 per cent a year (Ekeh, Fangmeier, & Müller, 2014).

On the whole, charcoal consumption within SSA is expected to continue increasing, driven by rising urbanization trends (WB; AFREA; ESMAP, 2014). Urban areas in Africa are expected to grow from 38 to 52 per cent between 2010 and 2040, respectively (Figure 2-8) (World Bank, 2017). Furthermore, projections indicate that demand for charcoal will also exceed fuelwood demand (FAO, 2017c).

Income growth

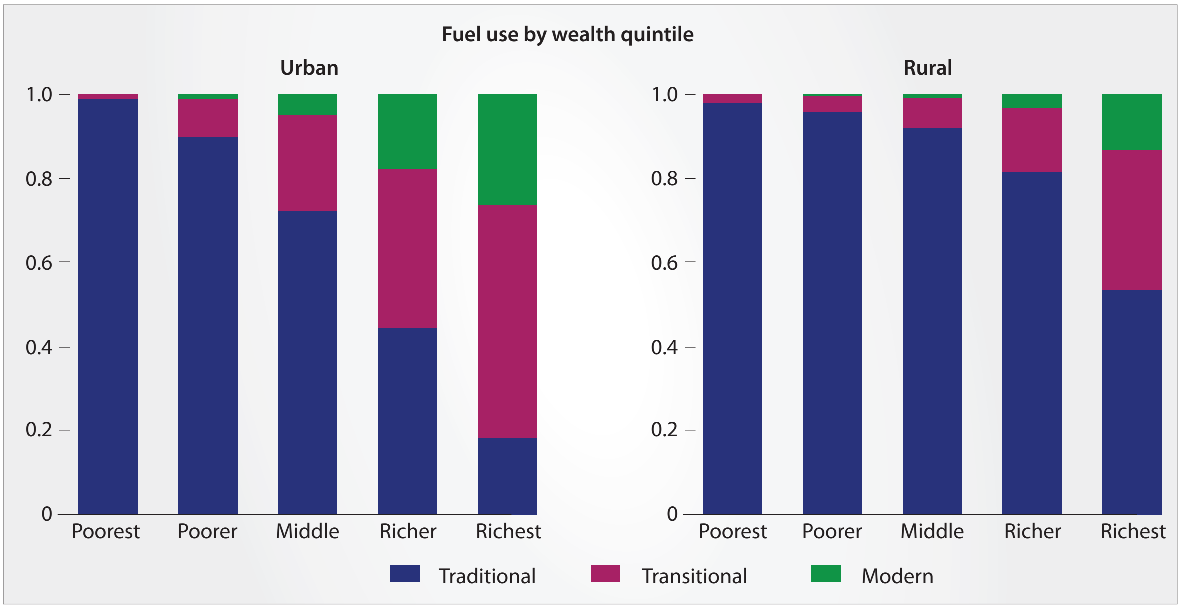
Much of the population in sub-Saharan countries live in extreme poverty with lack of livelihoods. Traditional biomass is the energy source for the poor since it is generally freely available or can be had at nominal prices. Traditional biomass energy has been majorly used by low income population due to ease of access

Figure 2-9: The Energy Ladder



Source: (Manyo-Plange, 2011)

Figure 2-10: Per cent of use of cooking fuel types by wealth quintiles



Source: (Toole, 2015)

and availability in smaller quantities in the market easily affordable by majority.

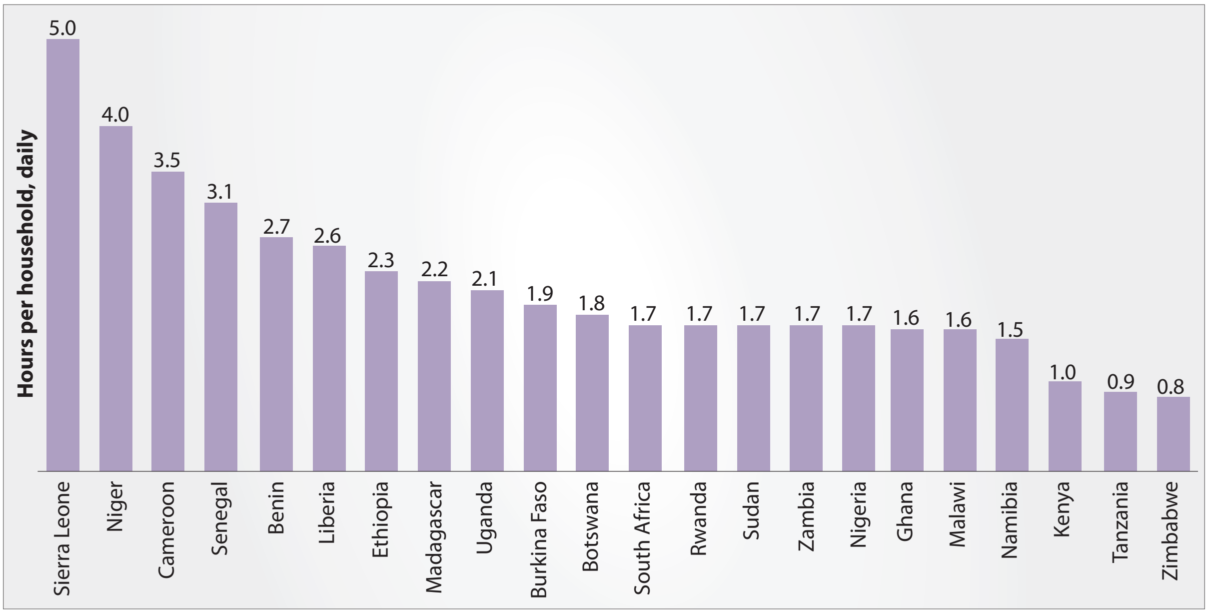
Most often, the poorer the country, the greater is the dependence on traditional biomass (Karekezi, Lata, & Coelho, 2014). As a country gets richer, the use of traditional biomass tends to decline while electricity use and per capita energy use also increase. At the household level, there is still a strong correlation between the share of fuelwood in total energy consumption and rising income. As income increases, the share of fuelwood in total household energy consumption declines.

Furthermore, as incomes increase, there tends to be a transition towards more modern forms of

Selling charcaol in Dakar

Susanne Jaros

Figure 2-11: Hours spent collecting fuelwood for cooking, heating and lighting in households across Africa



Source: (UNEP, 2017a)

energy, as shown in the energy ladder in Figure 2-9 (Toole, 2015). There are also variations in energy use depending on location in urban or rural areas, which are also influenced by income levels (Table 2-5 and Figure 2-10). Most people in rural areas tend to use traditional fuels, but this may be mainly due to the lack of knowledge, access to modern technology and financial resources.

Income is also one of the drivers behind the increasing demand for certain types of energy sources (Adam, Brew-Hammond, & Essandoh, 2013). Rising prices of fossil fuels and electricity make switching to alternatives an option that is only open to those within certain income brackets. Between 4–10 per cent of consumers in SSA switch from fuelwood to charcoal per year (Sepp, 2014). For example, in Côte d'Ivoire, a combination of increased urbanization and a decrease in subsidies for LPG have led to increased use of charcoal as a fuel (UNDP, 2014)

Education level

Studies show that more educated households are more likely to transition away from using fuels on the lower end of the energy ladder. The more education one has, the greater value is placed on time. Thus, for more educated individuals, there is a high opportunity cost in spending time collecting biomass fuel. The literature indicates that a good number of rural households in Africa spend more than 1.5 hours each day gathering fuelwood for cooking, heating and lighting purposes (Figure 2-11). This time could be put into alternative productive activities such as studying, maintaining the household and farming activities, among others. Education empowers individuals with knowledge about alternative fuels and their associated benefits, allowing them to make more informed fuel choices (Toole, 2015). What is striking in this chart is that Sierra Leone is in the tropical rain forest belt and therefore with a lot of biomass but spending the highest number of hours collecting fuelwood.

2.3 Production and Consumption Patterns of Fuelwood and Charcoal

Production of fuelwood and charcoal

Fuelwood and charcoal production in Africa has been steadily increasing over the years (FAO, 2016b). Africa produced a total of 665.6 million m^3 of woodfuel in 2015 (Table 2-5) (FAO, 2016b). Ethiopia was the largest producer of woodfuel, producing 108 million m^3 in 2015, followed by the DRC with 82.5 million m^3 and Nigeria with 65 million m^3 of woodfuel (Table 2-6) (FAO, 2016b). Other countries in the top-ten producers of woodfuel in Africa include Ghana, Uganda, Kenya, Tanzania, Egypt and Mozambique.

Total production of charcoal on the continent in 2015 was 31.8 million tonnes (Table 2-7) (FAO, 2016b). Nigeria and Ethiopia are the biggest producers of charcoal in Africa, producing 4.4 million and 4.3 million tonnes respectively in 2016. Other top-ten charcoal producers in Africa include the DRC, Ghana, Tanzania, Madagascar, Egypt and Somalia, producing between 2.4 and 1.2 million tonnes each (Table 2-8) (FAO, 2016b). Production also varies by sub-region, with Eastern Africa producing the biggest proportion (42 per cent) of charcoal. This is followed by Western Africa, Central Africa, Northern Africa and Southern Africa, with 32, 12.2, 9.8 and 3.4 per cent, respectively (FAO, 2016c).

Table 2-5: Regional woodfuel production, imports, exports and consumption (m^3), 2015

Region	Production	Import	Export	Consumption
Eastern Africa	287,864,257	463	6,785	287,857,935
Middle Africa	110,109,852	41	90	110,109,803
Northern Africa	52,785,337	21,017	5,342	52,801,012
Southern Africa	17,343,757	717,946	647,233	17,414,470
Western Africa	197,465,187	12,744	4,798	197,473,133
Total Africa	665,568,390	752,211	664,248	665,656,353
World	**1,862,443,915**	**6,102,038**	**9,556,840**	**1,858,989,113**

0=No data available

Source: FAOSTAT

Charcoal bags stacked beside a traditional charcoal factory in the Ivory Coast.

Reuters

Table 2-6: Country woodfuel production, imports, exports and consumption (m³), 2015

Country	Production	Import	Export	Consumption
Algeria	8,533,232	2	0	8,533,234
Angola	4,491,689	2	0	4,491,691
Benin	6,506,720	1	12	6,506,709
Botswana	699,139	230	0	699,369
Burkina Faso	13,713,710	1,855	14	13,715,551
Burundi	5,999,000	2	922	5,998,080
Cabo Verde	186,000	3	0	186,003
Cameroon	10,354,732	0	40	10,354,692
Central African Rep.	2,000,000	0	0	2,000,000
Chad	7,662,541	5	23	7,662,523
Comoros	301,967	0	0	301,967
Congo	1,445,562	0	0	1,445,562
Côte d'Ivoire	9,192,511	39	508	9,192,042
Djibouti	384,902	76	1,695	383,283
DRC	82,526,362	30	25	82,526,367
Egypt	17,740,286	98	4,318	17,736,066
Equatorial Guinea	447,000	2	0	447,002
Eritrea	1,000,536	29	0	1,000,565
Eswatini	1,141,303	248,000	436,000	953,303
Ethiopia	108,173,872	3	2,670	108,171,205
Gabon	1,070,000	0	2	1,069,998
Gambia	741,392	9,139	591	749,940
Ghana	44,018,427	508	351	44,018,584
Guinea	12,231,215	0	4	12,231,211
Guinea -Bissau	2,791,363	0	0	2,791,363
Kenya	26,400,000	73	51	26,400,022
Lesotho	2,131,497	290	0	2,131,787
Liberia	8,325,786	0	0	8,325,786
Libya	1,011,659	13	23	1,011,649
Madagascar	13,891,495	2	30	13,891,467
Malawi	5,730,655	53	196	5,730,512
Mali	5,630,995	0	2,705	5,628,290
Mauritania	2,051,160	191	0	2,051,351
Mauritius	1,800	5	4	1,809
Mayotte	26,500	0	0	26,500
Morocco	6,679,160	61	80	6,679,141
Mozambique	16,724,000	109	8	16,724,101
Namibia	1,342,754	426	27,031	1,316,149
Niger	11,009,539	14	82	11,009,471
Nigeria	65,287,615	919	407	65,288,127
Réunion	100,667	0	0	100,667
Rwanda	5,000,000	13	20	4,999,993
Sao Tome & Principe	111,966	2	0	111,968
Senegal	5,556,504	3	25	5,556,482
Seychelles	3,160	0	0	3,160

Country	Production	Import	Export	Consumption
Sierra Leone	5,798,250	72	57	5,798,265
Somalia	14,038,437	23	0	14,038,460
South Africa	12,029,064	469,000	184,202	12,313,862
South Sudan	4,621,000	0	813	4,620,187
Sudan	15,211,000	20,819	852	15,230,967
Togo	4,424,000	0	62	4,423,938
Tunisia	3,610,000	24	69	3,609,955
Uganda	42,438,054	4	111	42,437,947
United Rep. Tanzania	24,119,214	28	23	24,119,219
Zambia	9,799,612	23	222	9,799,413
Zimbabwe	9,109,386	20	20	9,109,386

0=No data available

Source: FAOSTAT

Total production of charcoal on the continent in 2015 was 31.8 million tonnes (Table 2-7) (FAO, 2016b). Nigeria and Ethiopia are the biggest producers of charcoal in Africa, producing 4.4 million and 4.3 million tonnes respectively in 2016. Other top-ten charcoal producers in Africa include the DRC, Ghana, Tanzania, Madagascar, Egypt and Somalia, producing between 2.4 and 1.2 million tonnes each (Table 2-8) (FAO, 2016b). Production also varies by sub-region, with Eastern Africa producing the biggest proportion (42 per cent) of charcoal. This is followed by Western Africa, Central Africa, Northern Africa and Southern Africa, with 32, 12.2, 9.8 and 3.4 per cent, respectively (FAO, 2016c).

Table 2-7: Regional wood charcoal production, imports, exports and consumption (tonnes), 2015

Region	Production	Import	Export	Consumption
Eastern Africa	13,724,533	2,087.03	52,612.1	13,674,007.93
Middle Africa	3,939,346	153	537	3,938,962
Northern Africa	3,169,414	2,323	80,567	3,091,170
Southern Africa	448,494	89,133	127,290	410,337
Western Africa	10,471,547	2,797.25	192,445	10,281,899.25
Total Africa	31,753,334	96,493.29	453,451.1	31,396,376.19
World	**50,873,234**	**2,513,752.29**	**2,387,889.1**	**50,999,097.19**

Source: FAOSTAT

Table 2-8: Country wood charcoal production, imports, exports and consumption (tonnes), 2015

Country	Production	Import	Export	Consumption
Algeria	730,029	261	140	730,150
Angola	347,630	15	19	347,626
Benin	49,050	73	375	48,748
Botswana	75,106	27	0	75,133
Burkina Faso	672,887	8	12,000	660,895
Burundi	264,000	3	5	263,998
Cabo Verde	921	16	0	937
Cameroon	477,188	1	258	476,931
Central African Rep.	210,471	5	8	210,468
Chad	456,942	3	0	456,945
Comoros	45,490	0	0	45,490
Congo	4,749	13	15	4,747
Côte d'Ivoire	517,398	12	2,704	514,706
Djibouti	51,988	520	49,312	3,196
DRC	2,400,342	45	214	2,400,173
Egypt	1,423,059	793	79,807	1,344,045
Equatorial Guinea	10,304	13	17	10,300
Eritrea	142,000	2	0	142,002
Eswatini	48,618	31	3,211	45,438
Ethiopia	4,219,572	173	32	4,219,713
Gabon	22,212	54	6	22,260
Gambia	65,622	2,339	61	67,900
Ghana	1,887,538	40	2,222	1,885,356
Guinea	388,320	8	811	387,517
Guinea -Bissau	72,011	0	97	71,914
Kenya	1,119,116	8	132	1,118,992
Lesotho	105,819	133	0	105,952
Liberia	281,654	8	391	281,271
Libya	110,891	539	15	111,415
Madagascar	1,560,024	0.03	79	1,559,945.03
Malawi	552,852	12	2	552,862
Mali	275,000	0.25	112	274,888.25
Mauritania	211,737	58	18	211,777
Mauritius	2	136	0.1	137.9
Mayotte	0	0	0	0
Morocco	113,435	535	291	113,679
Mozambique	263,000	45	218	262,827
Namibia	160,676	143	97,920	62,899
Niger	688,078	14	31	688,061
Nigeria	4,371,175	213	171,148	4,200,240
Réuinon	14,708	651	0	15,359
Rwanda	48,000	8	406	47,602
Sao Tome & Principe	9,508	4	0	9,512
Senegal	300,000	7	2,338	297,669
Seychelles	0	46	5	41

Country	Production	Import	Export	Consumption
Sierra Leone	432,032	3	88	431,947
Somalia	1,181,457	0	277	1,181,734
South Africa	58,275	88,799	26,159	120,915
South Sudan	272,000	0	0	272,000
Sudan	588,000	7	200	587,807
Togo	258,124	0	49	258,075
Tunisia	204,000	188	114	204,074
Uganda	1,065,731	8	6	1,065,733
United Rep. Tanzania	1,872,024	7	4	1,872,027
Zambia	1,041,000	9	212	1,040,797
Zimbabwe	11,569	461	1,932	10,098

0=No data available

Source: FAOSTAT

Trend in the regional share of firewood and charcoal production and use is given in Figures 3-2 to 3-5to).

Data shows that West Africa leads the continent in the producion on firewood (Figure 2-12) whereas East Africa leads in charcoal production (Figure 2-13) Households are the largest consumers of both firewood and charcoal

Figure 2-12: Regional shares of firewood production, 2000 and 2013

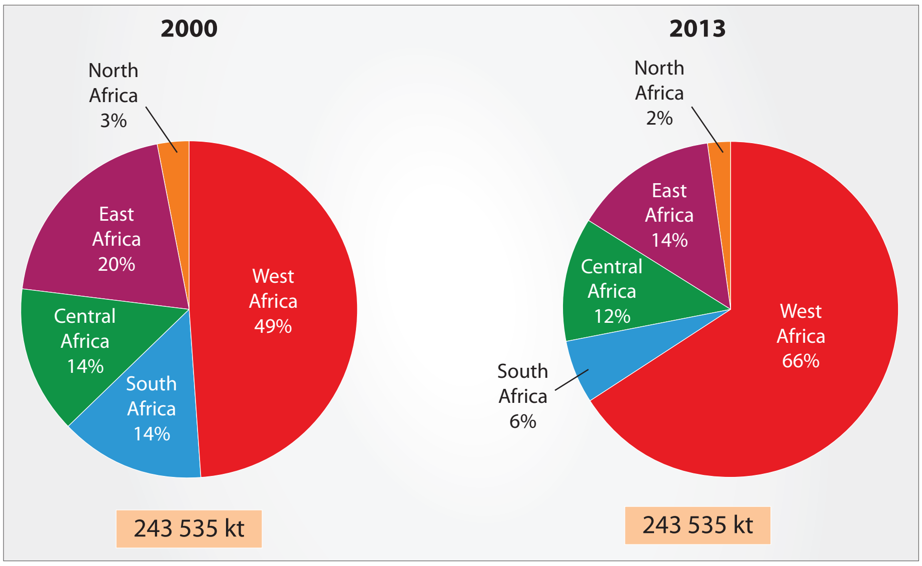


Figure 2-13: Shares of Africa's firewood consumption by user, 2000 and 2013

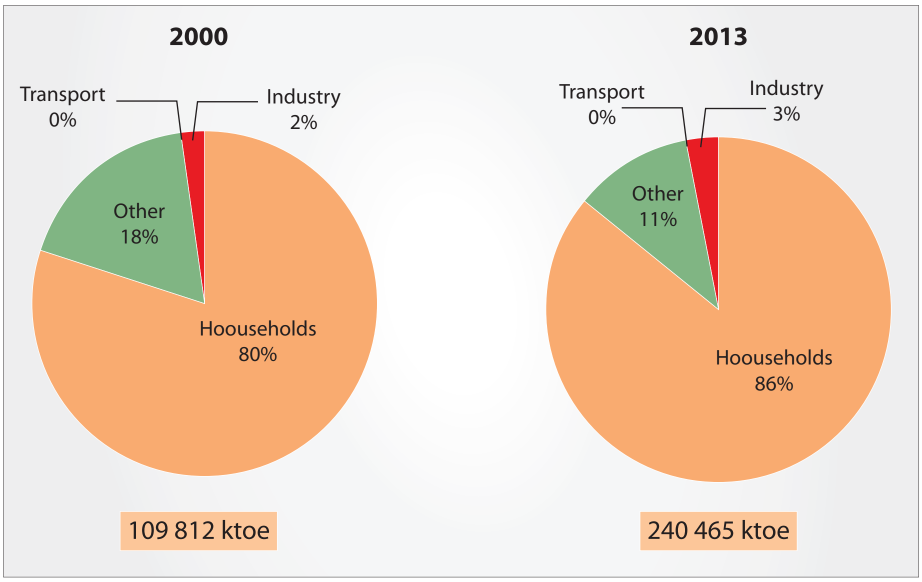


Figure 2-14: Regional shares of charcoal production, 2000 and 2013

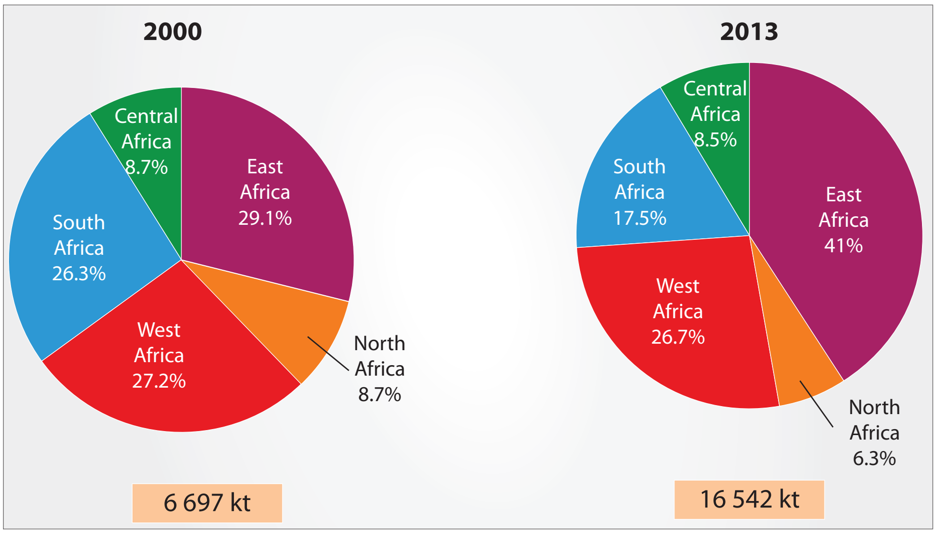
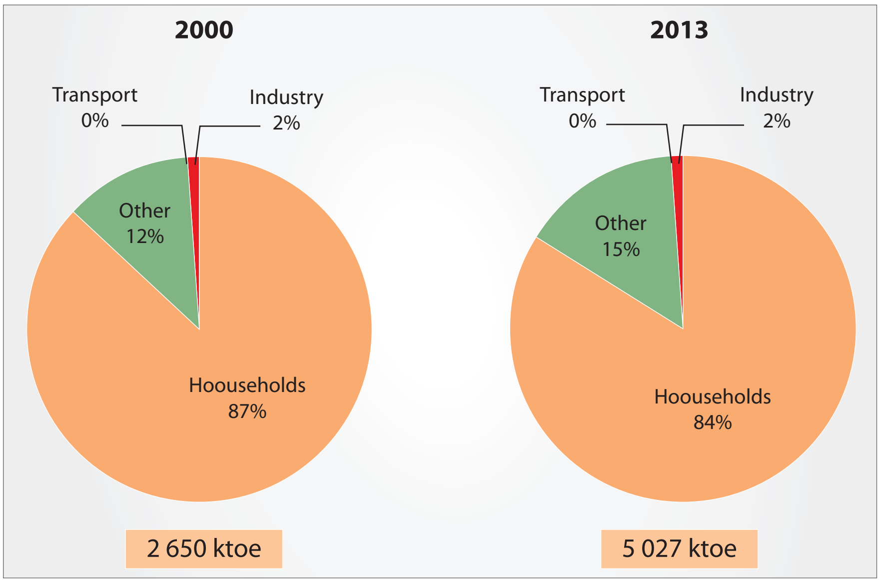


Figure 2-15: Shares of Africa charcoal consumption, 2000 and 2013



Source: (AFREC, 2015

Traditional and improved methods of charcoal production

An abundance of woody material, leaves, mud and a fire are all that are required to set up a traditional kiln to make charcoal. Charcoal is produced when wood is pyrolyzed (carbonized) by burning in a limited supply of oxygen. The heat generated by the wood already burning pyrolyzes the rest of the mound. The woody biomass is arranged in a conical pile, at the bottom of which is an opening to allow air through. A hole is left through the centre of the pile that acts as a channel or conduit for the smoke and waste gases. The entire pile is the covered with green leaves and mud. The leaves maintain the mud layer by preventing it from falling through. A fire is started at the bottom of the flue and it slowly spreads upwards and outwards. The energy efficiency of this traditional process varies and may result in a conversion rate of wood into charcoal of up to 35 per cent (Shikorire, 2015). The success of the operation depends upon the rate of combustion. Under average conditions, 100 parts of wood yield about 60 parts by volume, or 25 parts by weight, of charcoal. Small-scale production on the spot often yields only about 50 per cent, and large-scale production can be as efficient as about 90 per cent (Bukhari, 2015). The charcoal makers spend nights managing the process, which can take up to 2 weeks.

The charcoal produced this way varies in quality depending on the efficiency of the kiln. Charcoal production has improved over the years with the innovation of kilns that have increased the efficiency of burning and improved the quality of charcoal produced, as highlighted in (Table 2 9).

Table 2-9: Types of charcoal kilns

Kiln Type	Efficiency (%)	Remarks
Casamance Kiln (improved earth mound kiln)	30	-Requires capital investment for the chimney -Difficult to construct
Brick kilns	30	-Suitable for semi-industrial production -Carbonization of 13-14 days -Cost intensive and stationary
Steel kilns	27-35	-Carbonization after 16-24 days -Cost intensive -Promoted as community kilns in Kenya
Adam Retort	40	-Noxious emissions reduced by 70% -Carbonization within 24-30 hours -Cost intensive and suitable for semi-industrial use
Traditional kiln	8-15	-Simplest method with no cost -Labor intensive -Charcoal of inconsistent quality and at a very low yield- to-feedstock ratio

Source: (Shikorire, 2015)

2.4 Biomass Fuel at the Nexus

Charcoal-forest nexus

Contrary to commonly held beliefs, charcoal production does not have to lead to permanent loss of tree cover or forest degradation. As long as the area harvested is allowed to regenerate by protecting it from fire, cultivation and overgrazing, charcoal can be sustainably produced. Continued charcoal production requires the maintenance of a certain level of forest without which charcoal production will become unviable. There are many benefits from sustainable charcoal production. These include providing ecosystem services, generating revenues from forest products, maintaining biodiversity, sequestering carbon and safeguarding forest habitat. To achieve these, however, charcoal production must be formalized, especially when it occurs in the vicinity of concentrated urban markets (Doggart & Meshack, 2017). Table 2 10 highlights the trend between forest area, population and wood-fuel production for Africa. However, one should be cautioned that the data itself may not tell much of the relationship between changes in forest area and woodfuel production. It can be a high risk to conclude or imply that woodfuel production leads to reduction in forest areas. Between 1990 and 2015 the total wood production increased by 1.5 times whereas the charcoal production doubled over the same period.

Charcoal-agriculture nexus

Opening up land for agriculture is well known to cause land-use changes that result in the conversion of forest to cropland. This land-use change involves clearing forested areas that are then replaced with crops, leading to deforestation. In informal situations, the minor clearance of trees or bushes may simply lead to forest degradation (Doggart & Meshack, 2017). On the other hand, the prearranged clearing for agriculture, settlements or other needs involves deforestation. Land clearance for agriculture may result in some charcoal production from the trees and bushes cut down. For example, in Nyakweri Forest, Trans Mara, Kenya, charcoal was a by-product from the trees that were felled to clear land for the surrounding farms (Iiyama,

Table 2-10: Forest area and charcoal and fuelwood production for Africa as a whole, 1990-2015

Year	Forest Area (1 000 ha)	Wood Charcoal Production (1 000 tonnes)	Wood Fuel Production (m^3)		
			Coniferous Production	Non-coniferous Production	Total
1990	705,740	15,080,654	9,611,058	435,436,356	445,047,414
2000	670,372	20,400,275	13,287,968	529,075,038	542,363,006
2010	638,282	28,304,298	16,648,670	614,028,344	630,677,014
2015	624,103	31,753,334	17,907,160	647,661,230	665,568,390

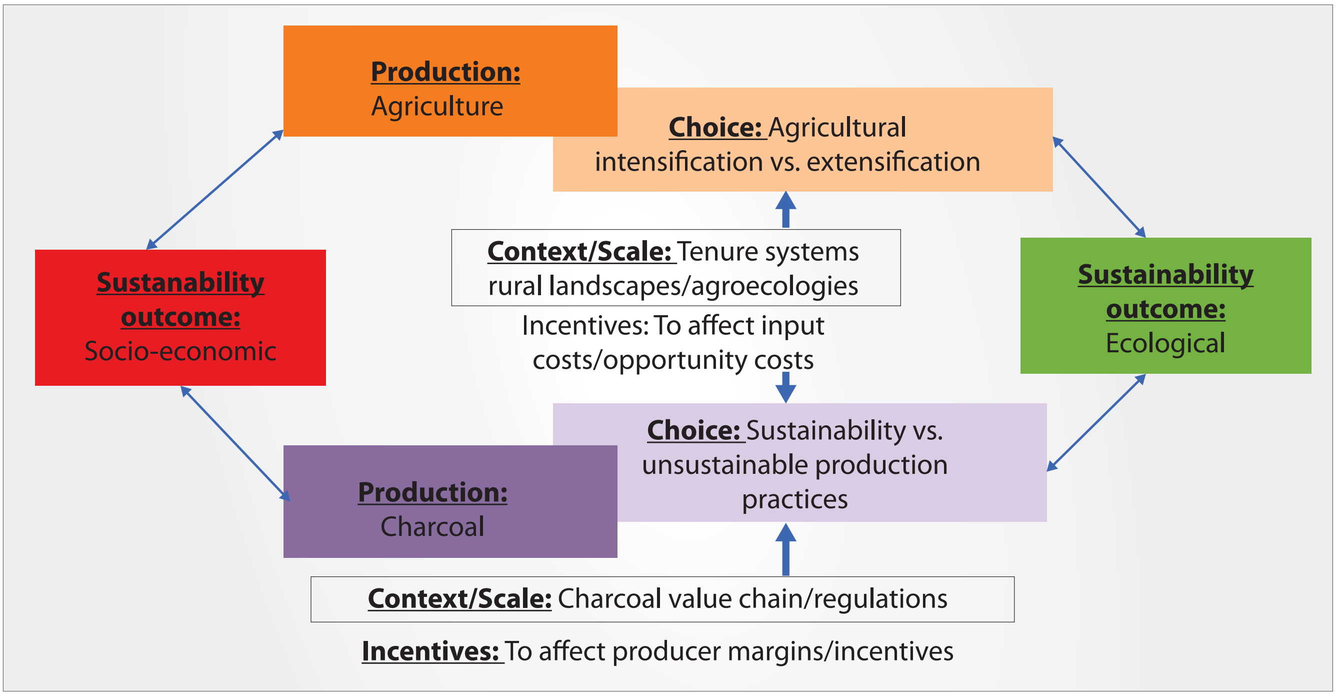
Source: http://www.fao.org/faostat/en/#data/FO


Firewood for sale. Sudan

UNEP


Charcoal storage South Sudan

Figure 2-16: The charcoal-agriculture production nexus



Source: (Iiyama, et al., 2017)

et al., 2017). In Rwanda, where land is scarce, charcoal production has become an integral part of sustainable agricultural intensification, providing additional revenues for farmers and employment for specialized labor (Iiyama, et al., 2017).

The gender-energy nexus

Energy roles tend to vary by gender. Women and children tend to be more involved in biomass collection. Women, more than men, are more likely to adopt new energy options and solutions, especially if convinced of their viability. However, women face a number of barriers that prevent them from benefiting from sustainable energy solutions. These may include the lack of access to land, natural resources, financial credit, information and decision making at all levels (AfDB, 2016b); because of these barriers, they tend to depend on men's choices for fuelwood. Research has shown that the education of women (as opposed to cost) is the most important determinant in fuel choice (Morrissey, 2017). So, the education of women may be a key in encouraging the greater use of clean cooking fuels that come with benefits, including better health, job generation and market opportunities. When gender issues are integrated into energy policy, they can be effective in raising awareness amongst all stakeholders (UNIDO, 2014).

Rural-urban energy nexus

There are significant interlinkages between urban and rural areas. While rural areas may benefit from income earned on goods and services provided to urban dwellers, the reverse is not always a beneficial relationship. Urban areas exert an ecological footprint on rural areas that includes increased pressure on rural agricultural land, over-exploitation of natural resources such as water and forests, impacts on micro-climate and loss of biodiversity, among others. Charcoal production by rural areas to meet the energy needs of urban dwellers has been found to be a major cause of forest degradation. For instance, forest degradation in Tete province has been linked to charcoal production to meet urban energy demands in Tete city, Mozambique (Sedano, et al., 2016).

Charcoal seller at Mokolo Market. The trade is a contributor to deforestation as people rely on charcoal and firewood for their cooking and energy needs Yaoundé, Cameroon.

Chapter 3

Woody Biomass: Value-Chain Analysis and Impacts

3.1 Introduction

Woodfuel (firewood and charcoal) production and sale is a fast-growing industry in Africa. The production, sale and export of charcoal is a multimillion-dollar industry (Table 3-1). Growth is driven by the fact that the majority of the population relies on woodfuel as their primary household energy source. This demand is expected to keep growing. Charcoal has become the preferred way to cook in African cities.

Growth in the woodfuel trade is also being driven by demand from international markets, including the European Union. Africa is now the second largest exporter of biomass fuel products to Europe after North America. South Africa and Egypt are the leading exporters of biomass to Europe. South Africa has the capacity to export 80,000 tonnes per year while in Egypt exports to Europe between 2009 and 2010 were in the range of 10,000 tonnes. Namibia also exports a unique product called Bushbloks, which are compressed wood logs made from vegetation, to the UK (GEMCO, 2011). Table 3 1 provides the quantity and value of Africa's woodfuel exports.

The value chain analyses in this chapter covers woodfuel production and consumption, from trees or biomass supply to fuelwood or charcoal consumption as a domestic fuel. Figure 3-1 provides an overview of the five cost steps in the wood-fuel value chain.

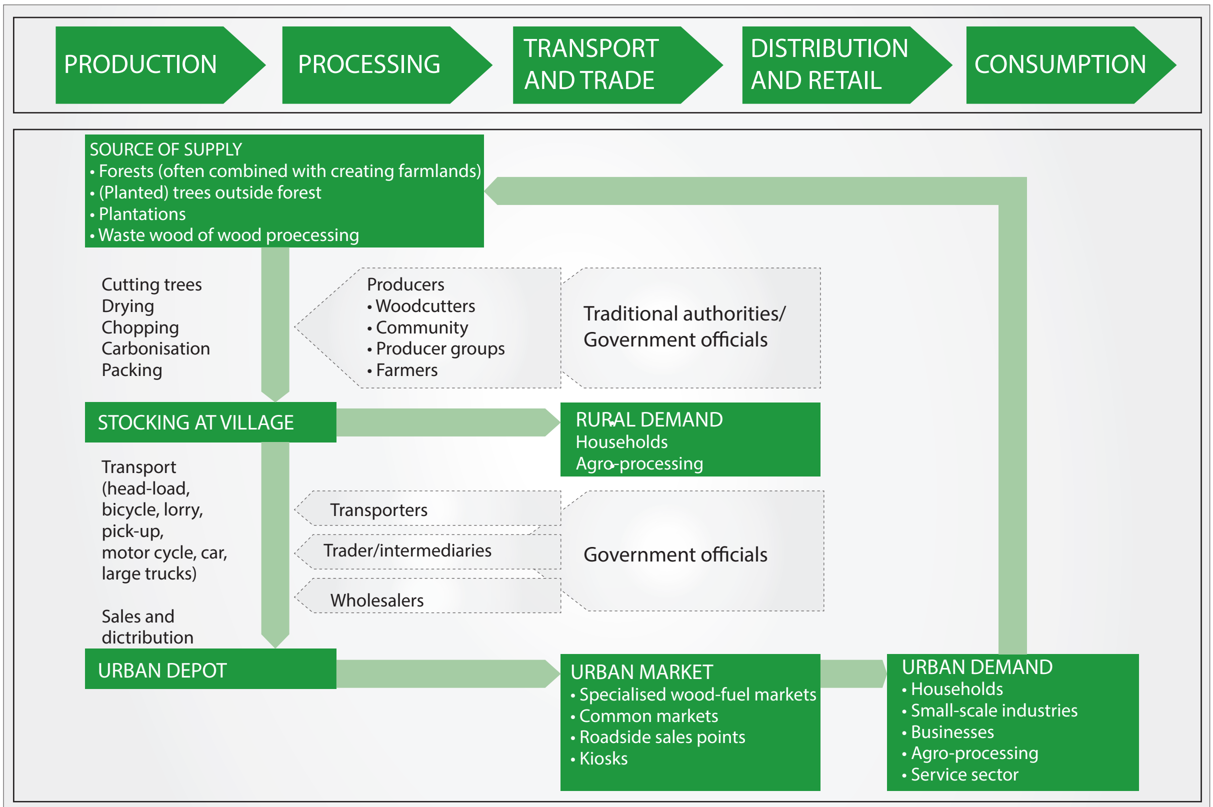
The chain starts with growing trees or woody biomass, which is then cut and dried. If it is to be processed into charcoal, it will undergo a carbonization

Table 3-1: Quantity and value of Africa's woodfuel (woodfuel and wood charcoal) exports, 2000-2015

Year	Wood fuel all species			Wood charcoal		
	m^3	1 000 US$	US$/$m^3$	Tonnes	1 000 US$	US$/tonne
2000	1 873	63	33.64	182 757	34 905	190.99
2005	10 038	881	87.77	329 063	73 483	223.31
2010	410 673	22 460	54.69	467 622	109 626	234.43
2015	664 248	23 092	34.76	453 451.1	106 102	233.99

Source: http://www.fao.org/faostat/en/#data/FO

Figure 3-1: Basic steps in a typical value chain



Source: (Schure, Dkamela, van der Goes, & McNally, 2014) process. The fuelwood or charcoal, as the case may be, is then packed and transported to market. The woodfuel is then consumed by industry or domestic users. Most of the processing happens in the rural countryside. The woodfuel gets to market either by direct sales to the consumer or through intermediary buyers who then sell it to the end users.

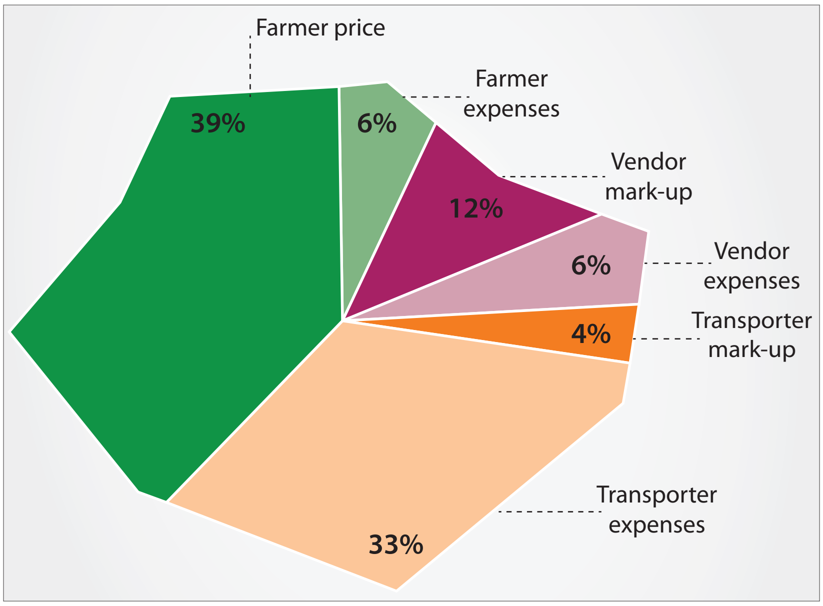
A lot of stakeholders are involved in the wood-fuel value chain, including producers, transporters, dealers (wholesalers and retailers), buyers and local authorities or other institutions (FAO, 2016a).

3.2 Steps in a Woodfuel Value Chain

Biomass supply

There are a number of sources for the biomass needed to process fuelwood and charcoal. These include natural and plantation forests, the growing stock of woody biomass, residues from forest harvesting, agroforestry and silvicultural thinning (Schure, Dkamela, van der Goes, & McNally, 2014). Although woodfuel is a renewable resource, it must be sustainably managed. There are studies indicating that productive forests are declining because of logging for charcoal and fires that prevent forest regeneration (Karisson, 2017). For instance, a study in the Lowveld savannas of South Africa indicated that at the current levels of fuelwood consumption (67 per cent of households use fuelwood exclusively, with a 2 per cent annual reduction); biomass in that area will be exhausted within thirteen years. The same study calculated that maintaining a sustainable consumption level would require a 15 per cent annual reduction in consumption for eight years to a level of 20 per cent of households using fuelwood (Wessels, et al., 2013).

Figure 3-2: Price share for actors per sack of charcoal in Kenya



Source: (Sepp, 2014)

Production and consumption of fuelwood and charcoal

This involves cutting down the trees, chopping the poles to the required size, drying and packing them ready for transport. This cost step in the wood-fuel value chain is most important in terms of creating livelihood opportunities. In the DRC, for example, some 290,000 people are involved in producing the woodfuel supply for Kinshasa (Schure, Dkamela, van der Goes, & McNally, 2014). In Malawi, the production sector was estimated to employ between 120,000 and 140,000 people in 2008 (Morrissey, 2017). Wood cutters, farmers, community people and formal and informal authorities are some of the stakeholders involved as producers.

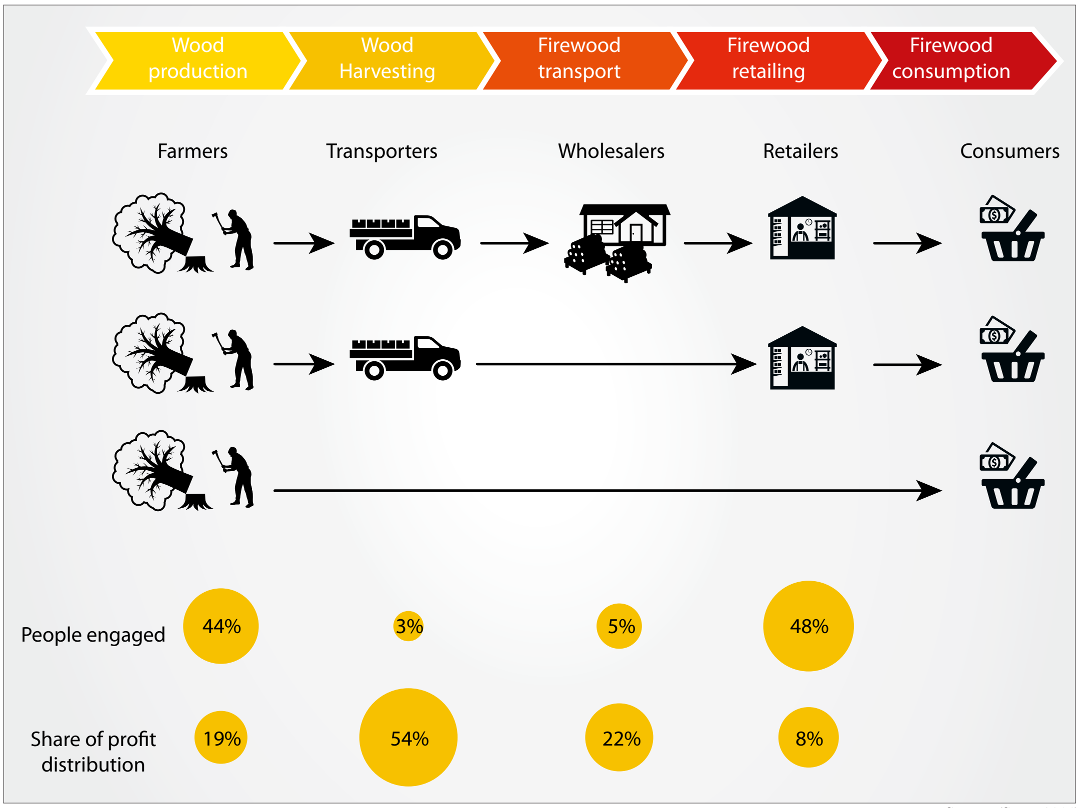
Transport

The mode of transport used to get woodfuels to market depends on the distance to be covered; it ranges from people walking with loads on their heads, to transport by bicycles, donkey carts or truck. The profit earned by a transporter in Kenya is about 4 per cent of the price of a sack of charcoal (Figure 3-2) (Sepp, 2014).

Distribution and sale

Selling woodfuel is an important job for many people in Africa. The supply chains are quite extensive to allow for a ready and reliable supply across the continent to meet demand (Morrissey, 2017). However, because of their informal (and sometime illegal) nature, they tend to be overlooked in policy research and national accounts. Woodfuel value chains are very lucrative and as a result support a huge number of livelihoods. The charcoal sector in Rwanda is valued at US $77 million per year while in Kenya it is about US $450 million a year. In Tanzania, charcoal contributes US $650 million a year to the economy (Morrissey, 2017).

Figure 3-3: Common structure of a firewood supply chain



Source: (Sepp, 2014)

3.3 Summary of the Fuelwood (Firewood) Value Chain

Most of fuelwood is not for sale and is collected directly by consumers. Biomass for fuelwood (firewood) is gathered and carried to a point of sale, usually the roadside. It is packed in bundles and transported to market. The firewood is then sold to transporters or traders who carry it to markets in urban areas. In some instances, big buyers hire wood cutters who go into the forested areas directly to harvest fuelwood. Figure 3-3 outlines the process. In some countries, a cutting permit prescribing a set harvest amount is required. However, the reality is that wood harvesting, transport and trade are very often unregulated. Where legislation exists, enforcement and compliance are weak and they are frequently ignored.

Previous attempts to upgrade the woodfuel value chains have been too narrow and have relied too strongly on technology and/or central state regulation and have not been able to control the sector under SSA conditions. In particular, relying on top-down prohibition, certification and central state control has disregarded the role of weak implementation capacities, local realities (informal community rules, power imbalances) and corruption in circumventing such measures. For future approaches to be successful, they need to target the multi-level nature of the wood energy sector and provide more comprehensive and location-specific interventions (Hoffmann, Brüntrup, & Dewes, 2016).

3.4 Summary of the Charcoal Value Chain

Charcoal has a number of advantages over firewood, which have led to its success as an energy source, especially for cooking in urban areas and particularly by restaurants and food kiosks.

- Charcoal has a higher calorific value per unit weight than firewood (about 31.8 MJ/kg of completely carbonized charcoal with about 5 per cent moisture content compared to firewood, which obtains about 16 MJ/ kg of firewood with about 15 per cent moisture content on a dry basis). It is therefore more economical to transport charcoal over longer distances compared to the weight of firewood needed for the same energy. Storing charcoal also takes less room than firewood;
- Charcoal is not liable to deterioration by the insects and fungi that attack firewood;
- Charcoal is almost smokeless and sulphur free, making it ideal fuel for use in densely populated towns and cities;
- In most cities, charcoal is cheaper than kerosene, LPG or electricity for use in homes, restaurants and kiosks; and
- The current prices of fuelwood and charcoal make charcoal the preferred cooking fuel for urban consumers. In fact, in terms of useful energy, the charcoal calorie is cheaper than a wood calorie. (Bauner, De Toni, Oulu, Sangal, & Thenya, 2016).

Charcoal production methods generally fall into three broad categories: Earth kilns, Masonry kilns and Metal kilns. Artisanal charcoal production using traditional earth kilns is the dominant process. There are several factors affecting a producer's choice of kiln: the cost of production, the ease of transport, flexibility in production size, operational cost and efficiency.

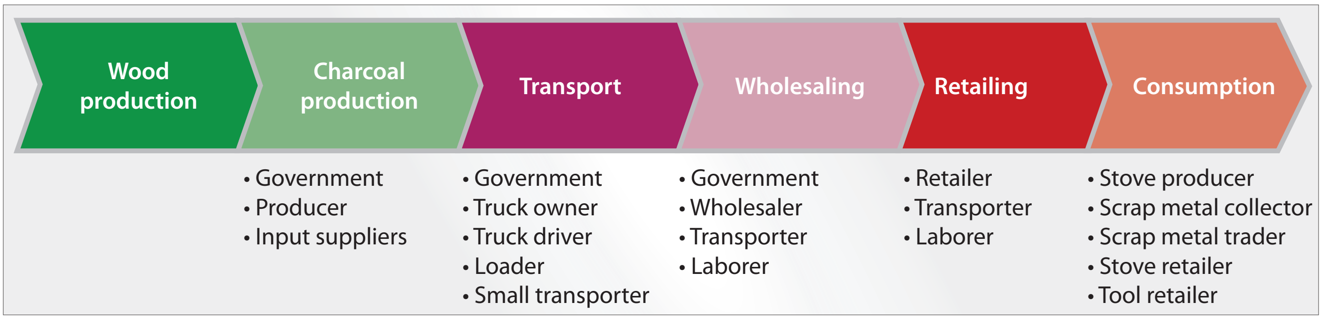
Charcoal is produced by carbonization. Carbonization is a thermal decomposition/breakdown of biomass material (wood) to drive off volatile materials in absence of free oxygen to produce charcoal (a black solid residue primarily carbon. The process typically involves the following steps:

- Preparation of the wood: once the wood has been cut and collected, it is often laid out in the open sun to dry by reducing the wood-moisture content.
- Preparation of the traditional earth pit or earth mound kiln: the most common methods used for the carbonization process are the traditional earth mound or pit kiln. For an earth pit kiln, the process involves digging a pit, stacking the dried wood inside the pit and covering the wood with a layer of soil and grass to prevent direct contact with the air, and lighting the wood at one end. An earth mound made of wood stacked in a polygonal shape is covered with grass and soil and is lit.
- Carbonization: the wood is allowed to burn slowly (carbonize) under controlled conditions (i.e., absence of free oxygen) allowing the wood to be converted to charcoal without getting burnt completely. This process can take 3-15 days (GIZ, 2014), depending on the moisture content of the wood and the evenness of the gas circulation (FAO, 1987). However, the use of traditional earth mounds gives efficiencies as low as 8-15 per cent (i.e., 85-92 per cent of the wood gets burned to ashes and volatile matters).
- Cooling Period: once the combustion is complete, the kilns are allowed to cool down naturally or are cooled down with water before the charcoal can be placed in bags for transportation (UNDP, 2016).

Charcoal business is executed through a variety of supply chains. Different supply chains have emerged determined by the amount of charcoal involved and the distance between production and consumption. For example, in Kenya there are five different supply chains from production to consumption, starting with the wood producer selling trees to the charcoal producer, as follows:

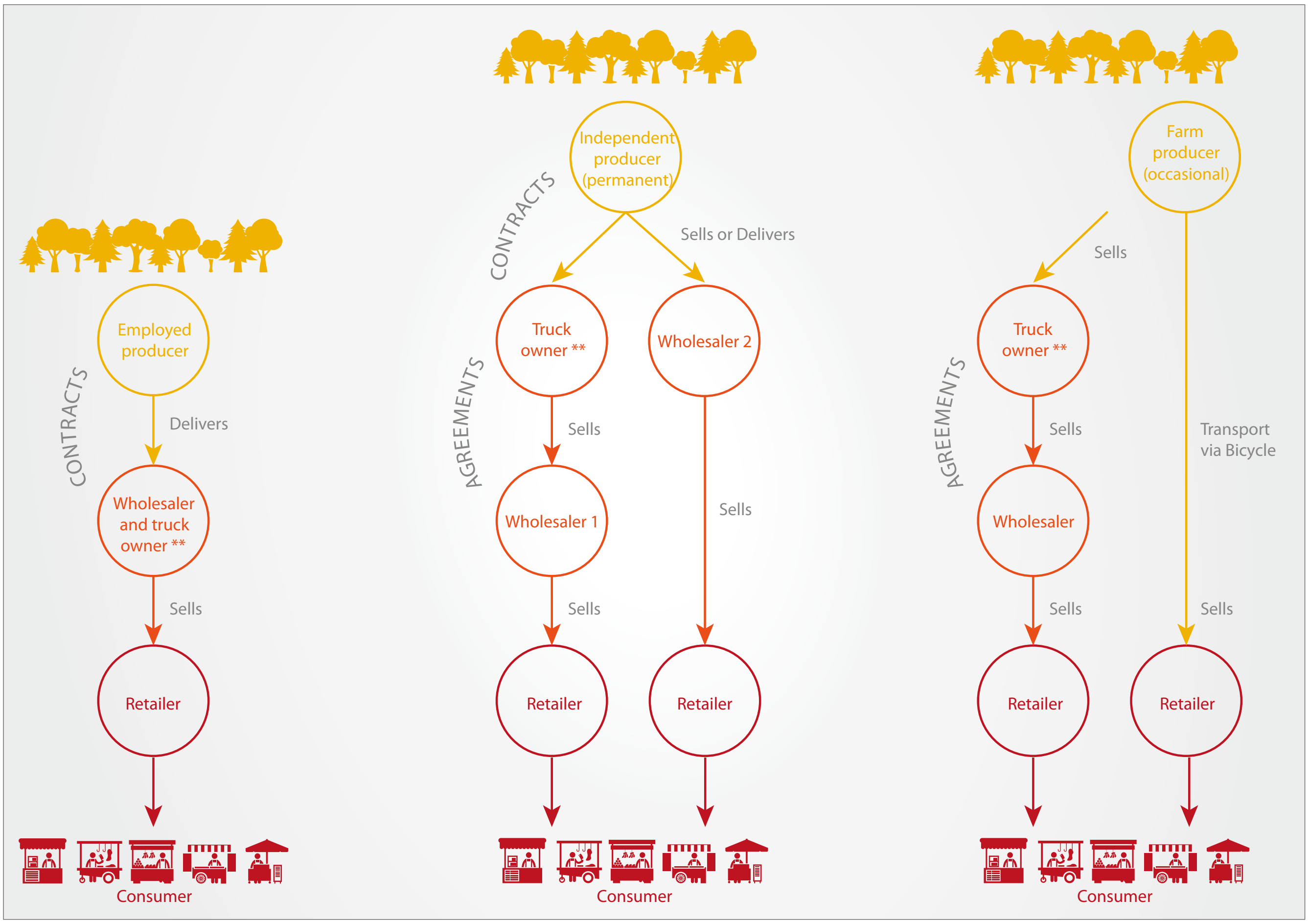
1. Wood producer to charcoal producer to transporter to retailer to consumer;
2. Wood producer to charcoal producer to transporter to wholesaler to retailer to consumer;
3. Wood producer to charcoal producer to broker to transporter to broker to wholesaler to retailer to consumer;
4. Wood producer to charcoal producer to consumer: usually a small-scale producer takes the charcoal directly to the consumer; and

Figure 3-4: Example of a charcoal value chain



Source: (MEAAI, 2010)

Figure 3-5: Structures of the charcoal supply chain



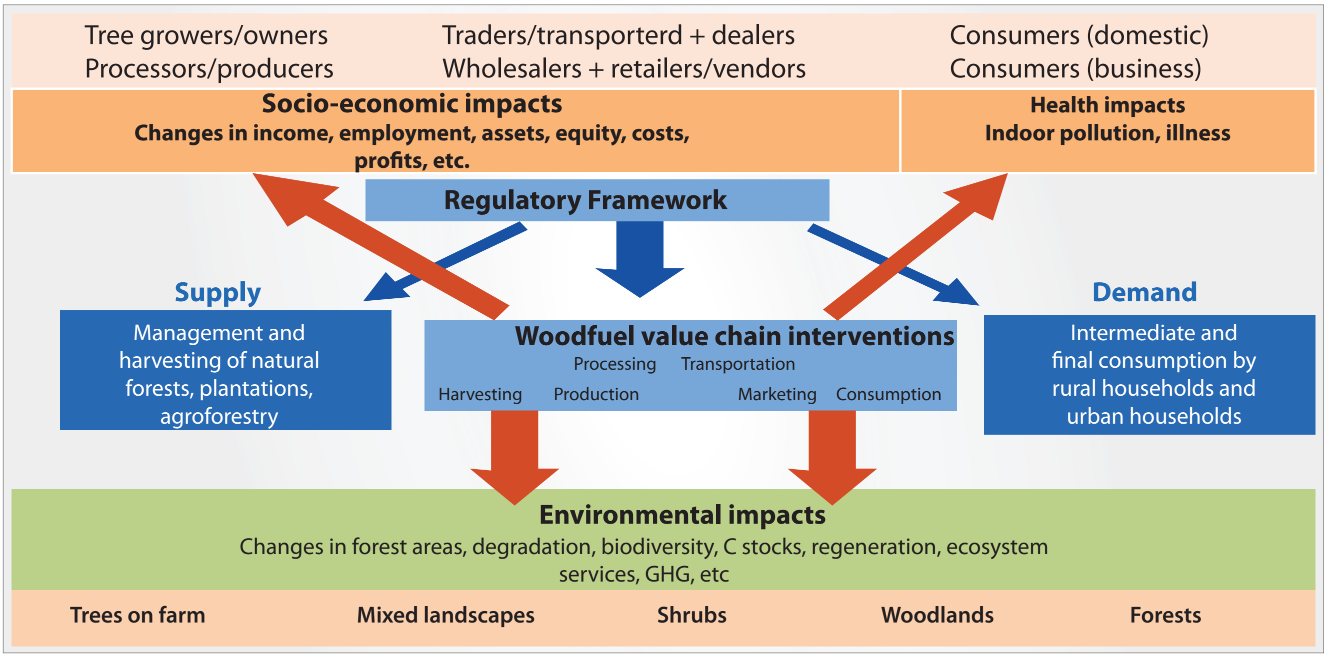
Source: (Sepp, 2014)

5. Wood producer to charcoal producer to retailer to consumer (Bauner, De Toni, Oulu, Sangal, & Thenya, 2016).

Two types of charcoal producers can be discerned: the one for whom this is a permanent business and who is employed on a monthly contract; and the occasional farm producer who sells his produce directly to a buyer (Sepp, 2014).Figures 3-4 and 3-5 illustrate the charcoal value and supply chain. There are whole range of players such as wood producer, charcoal producer, transporter, wholesaler, retailer, stove and tool manufactures & sellers are involved in the charcoal supply chain before the product is delivered to the consumer.

Wood for charcoal production is often harvested from coppice systems, where trees re-sprout after cutting. Coppicing is especially common among trees in dry environments where seasonal stress and animal grazing favour coppice strategies. While charcoal harvest and coppice management can be managed sustainably, coppice rates are dependent on a multitude of factors, including harvest rates, soil fertility, grazing and precipitation (Yale, 2014).

Figure 3-6: Conceptual framework



Source: (Sola, et al., The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: a systematic map, 2017)

3.5 Impacts of the Woodfuel Value Chain

All steps along the value chain may have some socioeconomic and environmental impacts affecting household and community health and livelihoods and the state of the local and global environment, including climate change. Some of these impacts can be tempered by various socioeconomic influences, such as the presence or not of wood-fuel policy frameworks, the economic status of the communities involved and the health of the environment in the area. It is the action of the stakeholders along the value chain that determines the extent of the impact (Sola, et al., The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: a systematic map, 2017). Sola et al. (2017) conducted an

Box 3-1: The environmental, socioeconomic, and health impacts of wood-fuel value chains in sub-Saharan Africa: a systematic map

A systematic mapping of the wood-fuel value chains in sub-Saharan Africa was undertaken to review the associated environmental, socioeconomic and health impacts. It involved a search of bibliographic databases and used the abstracts of articles as the main literature sources. The studies came from 26 of the 49 sub-Saharan African countries, and most were published within the last 10 years.

The context of the research is the relative importance of woodfuel in economic and livelihood activities in Africa, where more than 70 per cent of the population relies on it as their primary household energy source. Despite the importance of woodfuels, they are often viewed negatively due to their association with detrimental health and environmental impacts. Governments have been hampered in formulating and implementing sound policy interventions due to a lack of a reliable evidence base and a limited understanding of the role of contextual factors in influencing the various impacts of wood-fuel value chains.

The findings suggest that wood-fuel value chains have environmental, socioeconomic and health consequences, but that there are also frequent trade-offs. The reporting of contextual factors in the studies challenge the widespread perception of deforestation as being directly caused by bush fires, overgrazing and woodcutting. Instead, agricultural expansion (which often includes forest clearing) and pre-existing biophysical factors were the most frequently cited factors in shaping environmental outcomes.

Although this systematic map suggests that there are environmental, socioeconomic and health consequences associated with wood-fuel value chains in sub-Saharan Africa, there is mixed evidence to justify the claim. Against that background, there is an urgent need to undertake robust studies at appropriate scales that integrate environmental and socioeconomic issues to provide a reliable data foundation upon which policy formulation can be undertaken in SSA.

Source: (Sola, et al., The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: a systematic map, 2017)


Women carrying heavy loads of charcoal in Rwanda

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extensive review of the published academic literature on this matter and their findings are summarized in Figure 3-6 and Box 3-1).

Climate change, biomass energy and forests — the nexus

The International Panel on Climate Change (IPCC) decadal analyses of temperatures strongly point to an increased warming trend across the continent over the last 50 to 100 years. African ecosystems are already being affected by climate change, and future impacts are expected to be substantial. Climate change will amplify existing stress on water availability in Africa.

Key regional risks relating to shifts in biome distribution, loss of coral reefs, reduced crop productivity, adverse effects on livestock, vector- and water-borne diseases, undernutrition and migration reflect Africa's existing adaptation deficit (Niang, et al., 2014).

The over-dependence on biomass energy means that some countries may be impacted by the droughts, less predictable seasons and extreme events. For example, warmer weather in Kenya over the past two decades has led to prolonged droughts and some forests, such as the Mt. Kenya and Mau forests, have experienced forest fires with devastating impacts (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017). Forest fires burn the brush and other undergrowth that would otherwise be used by local communities as fuelwood. Lack of access to energy affects human wellbeing and increases vulnerability. The lack of access to woodfuels is likely to have impacts on food security and health as people may choose less nutritious foods simply because they take a shorter time to cook, requiring less fuel (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017).

Depending on how the climate changes, some trees no longer suited to the new climatic conditions will be replaced by more adaptable species. Also, increasing temperatures will make more land available in the higher latitudes and if this occurs, some plantation forests are likely to move from tropical to sub-tropical regions. Some forests will exhibit increased productivity and people will benefit through increased social and economic activity (Kirilenko & Sedjo, 2008). The increased availability of woodfuels would increase access to energy but might also increase carbon emissions, making the use of improved cookstoves very important (Morrissey, 2017). Changes in soil moisture content due to reduced rainfall may affect the overall productivity of forests, which may result in higher costs of woodfuels and biomass supply challenges (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017). Some of the negative impacts of declining forest productivity due to climate change could be offset by promoting agroforestry (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017). Table 3-2 shows some of the linkages between biomass energy and climate mitigation and adaptation strategies.

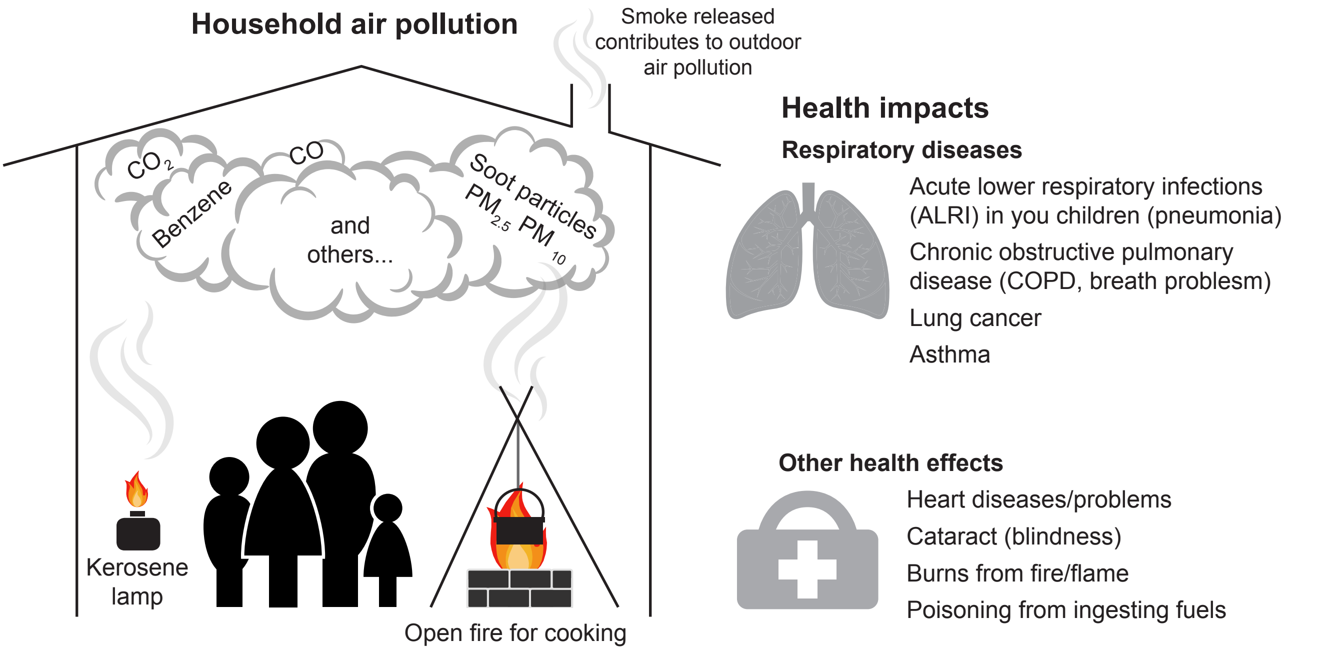
There will be opportunities presented by green growth plans as more African countries are increasingly shifting toward green energy options (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017). A good example is the greening of the charcoal value chain where each step presents the potential to reduce greenhouse gas (GHG) emissions.

Impacts on forests

Fuelwood consumption by rural households, in most locations, is seldom the cause of forest removal. Conversely, land clearing for agriculture, commercial and residential development and other permanent land-use changes are the main contributors. Harvesting fuelwood for energy most likely does not deplete wood stocks beyond what would be cleared as a result of the afore-mentioned activities. If fuelwood harvesting is the only objective for forest exploitation, the regeneration potential of the forest ecosystem can generally off-set the quantities extracted, thus, not causing a permanent decline in forest stocks (AFREA, 2011).

Fuelwood is usually collected from trees and dead wood and its impacts on forest stocks and climate change may not be significant.. Concerns remain about charcoal, however, as charcoal is produced from forest stock. Charcoal usually comes from live tree trunks or large limbs and requires cutting trees (Iiyama, Petrokofsky, Kanowski, & Kuehl, 2013). Charcoal has

Figure 3-7: The health impacts of cooking indoors with woodfuels and kerosene



Source: (UNEP, 2017a)

been identified as contributing to deforestation and driving carbon releases. However, the exact impact of charcoal collection on forest stocks is now contested, with numerous studies questioning the link between deforestation and charcoal production. Reviews of the literature looking at the impacts of charcoal production on deforestation have found that the impact is both relatively minor and reversible. This suggests that what is occurring can better be classified as degradation, especially when compared with other activities that result in widespread deforestation, such as clearance for agriculture or commercial tree cutting (Morrissey, 2017). In terms of scale, charcoal production is estimated to account for only 2–7 per cent of global deforestation (including cases of charcoal production for industrial use, as in Brazil).

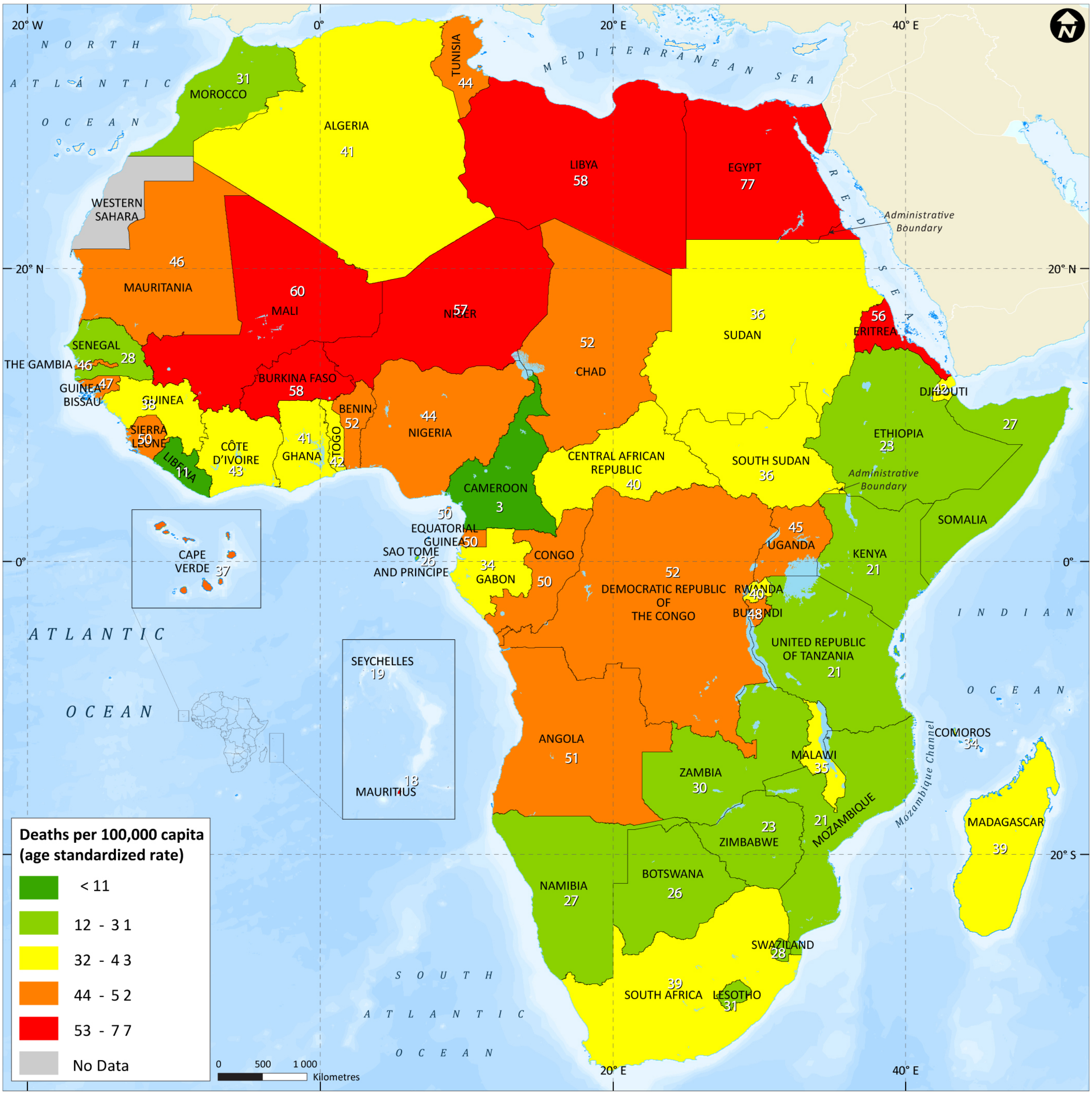
In general, firewood collection and trade is considered sustainable in most parts of SSA (Onishi, 2016). Much of the material gathered is already dead, and collection rates are usually below the regeneration rate. Less than 5 per cent of woodfuel in SSA comes from dedicated planted areas (Gazull & Gautier, 2015). Rwanda — where almost all wood for charcoal comes from woodlots in smallholder plots — is an exceptional case: it is claimed that virtually no illegal charcoal production activities affecting natural forests occur in the country (Drigo, Munyehirwe, Nzabanita, & Munyampundu, 2013). In SSA, the bulk of woodfuel is extracted from uncontrolled and unmanaged natural forests and woodlands (Gazull & Gautier, 2015) in which natural regeneration is the main source of recovery (Chidumayo & Gumbo, 2013).

Impacts on health

The key challenge facing Africa is not to increase energy consumption per se, but to ensure access to cleaner energy services through advances in energy efficiency, renewable energies and sustainable consumption. Emissions that arise from the incomplete combustion of woodfuels used for energy sources in domestic, educational, health and other institutional settings have varying impacts on people's health. Women are the most exposed since they are responsible for most of the chores associated with woodfuel collection and use. Within a domestic setting, young children are also exposed since they accompany their mothers within the household. The health impacts include respiratory problems, eye irritations, headaches and backaches. The health hazards can be reduced by using technology that decrease the amount of emissions, such

Cooking dinner on a three stone cook stove in Kisumu, Kenya.

Figure 3-8: Number of deaths in Africa attributable to ambient air pollution, per 100,000 people, 2012



Source: (UNEP, 2017a)

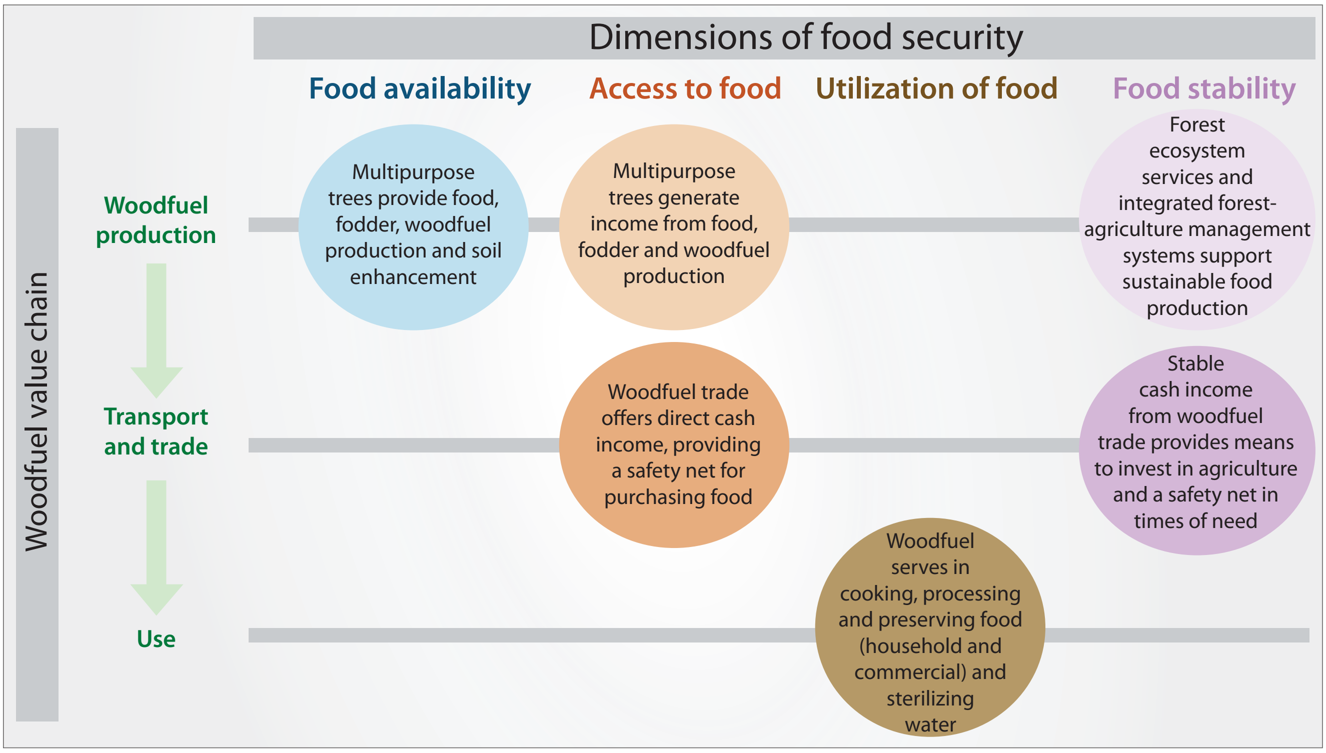
as improved cookstoves or alternative forms of fuel.

According to the World Health Organization, only 16 per cent of Africa's population uses clean cooking fuels compared to a global average of 57 per cent. This means that most of Africa's population is at risk from exposure to pollutants from traditional fuels. Particulate matter from the combustion of wood contains polycyclic aromatic hydrocarbons (PAHs), which are classified as a human carcinogen with mutagenic properties that can lead to heart disease, lung cancer and stroke (Figure 3-7). In 2012, the mortality rate attributed to household and ambient air pollution in Africa was 80.2 per 100,000 people compared to a global rate of 92.4 per 100,000 people (Figure 3-8) (WHO, 2017). Avoiding these health risks will involve switching to clean fuels such as LPG or adopting advanced cookstoves that burn biomass more cleanly and efficiently.

Impact on food security

There are four primary factors of hunger and undernourishment for the majority of SSA: economic growth, agricultural productivity growth, markets (including international trade) and social protection (FAO; IFAD; WFP, 2015). Although all of these factors are critical, it is important that energy availability for household use, specifically woodfuels, should be added

Figure 3-9: Links between the sustainable woodfuel value chain and food security



Source: (FAO, 2017b)

to the short list of essential drivers of food insecurity in SSA (Mendum & Njenga, 2018). Figure 3-9 illustrates the linkages between woodfuel and food security.

Impacts on livelihoods

Woodfuels provide a multitude of benefits to communities. These include employment opportunities directly related to the production and sale of woodfuels such as charcoal. For instance, data from Kenya indicates that the charcoal industry supports a total of 2.5 million people in transportation and marketing; in addition, about 700,000 charcoal producers are also involved, along with their families (Bauner, De Toni, Oulu, Sangal, & Thenya, 2016).

Indirect benefits accrue from the use of woodfuels in small-scale industries, such as in smoking and drying various products. Examples include drying tea and tobacco, fish smoking, beer brewing, lime making and brick making, among others. These industries provide employment to many people in a community. Those who benefit from woodfuels along the value chain face numerous challenges. Table 3-2 provides a summary of the steps on the value chain and some of the most pressing sustainability issues.

Much of the woodfuel in Africa is obtained from arid lands. These lands are frequently used by pastoralists. The few trees are often used as fodder. The removal of trees and charcoal burning reduces rangeland carrying capacity and increases biodiversity depletion, soil erosion, land degradation and gully formation. These actions, in turn, reduce grazing area thus jeopardizing the livelihoods of many pastoralists and creating rangeland resource conflicts (Bukhari, 2015); (Brown, 2018).

Minimizing economic losses and opportunity cost

For households that buy their fuels, the purchase of biomass fuels is also a major expense. The total annual spending on fuelwood and charcoal in SSA was about US $12 billion or 0.9 per cent of the region's GDP in 2010. Much time and effort are spent on fuelwood collection; time could be more usefully spent pursuing an education or other livelihood opportunities. Research (Table 3-3) shows that the economic losses associated with time wasted on fuel collection when using the higher performing biomass stoves is US $3.3 billion) and the amount varies depending on the type of cookstove being used (Lambe, 2016). In fact, due to the paucity of research in this field, rigorous analysis of the economic cost and benefits of woodfuels needs to be conducted. According to a World Bank study (2014) more than 40 million worker years are wasted each year on fuelwood gathering and slow biomass cooking. Cooking with traditional fuels and stoves represents a US$32 billion opportunity cost (3 per cent of SSA GDP).

Table 3-2: Main issues related to sustainable woodfuel supply

Step of value chain	Issues identified
Source of supply	• Pressure on the resource and deficit of sustainable supply • The large number of poor-income households involved in production • The lack of awareness and knowledge of sustainable management practices • The lack of (successful) woodfuel plantations • An overall lack of good resource governance • Tenure and access rights are not secured • Conflicting interests in use of trees and land for fuel and for other purposes • Producers encounter unequal distribution of benefits • The low energy efficiency of charcoal production • The kilns introduced are not locally appropriate
Transport and trade	• High costs for transport, due to increasing distances and bribes • Wood-fuel prices do not reflect their true economic value • The illegal wood-fuel trade • Additional regulations by the city regarding sales and insufficient capacity for control and corruption management • The role of transporters and traders has been insufficiently taken into account • Demand side pressure for specific tree species resulting in degradation of forested areas
Demand	• Energy security for the poor • A growing wood-fuel demand with growing pressure on wood resources • Fuel switching is hampered because of costs and lack of access • The low use of improved cooking stoves

Source: (Schure, Dkamela, van der Goes, & McNally, 2014)

Table 3-3: Annual economic losses and opportunity costs (Billion US$) associated with solid-fuel dependence in SSA, 2010

Activity	Low (Full adoption of higher-performing biomass stoves)	Mid (Tier 3–4 gasifier biomass stoves at the top of the range)	High (Intermediate Tier 2–3 rocket stoves at the bottom of the range)
Mortality from household air pollution	0.3	3.5	6.8
Morbidity from HAP	0.2	0.7	1.1
Other health conditions (burns, eye problems)	0.1	0.8	1.5
Total health	0.6	5.0	9.4
Spending on solid fuels	0.4	3.8	7.3
Time wastage (fuel collection)	0.6	6.5	12.4
Time wastage (cooking)	3.3	10.2	17.2
Total economic	4.2	20.6	36.9
GHG emissions (fuel consumption)	0.2	2.1	3.9
GHG emissions (charcoal production)	0.2	0.7	1.2
Deforestation	0.2	3.5	6.7
Total environment	**0.6**	**6.3**	**11.9**
Total all categories	**5.4**	**31.8**	**58.2**

Source: (Lambe, 2016)

A new gas cooking stove Tissina Bamako Mali.

Chapter 4

Biomass Energy and Sustainable Development: Policies and Strategies

4.1 Biomass Energy and the Sustainable Development Goals

The Sustainable Development Goals (SDGs) are a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity (Figure 4-1). The 17 Goals build on the successes of the Millennium Development Goals, while including new areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice, among other priorities. The goals are interconnected – often the key to success on one will involve tackling issues more commonly associated with another.

The goal of sustainable production and consumption is to produce and consume many of the resources we use, including energy, more efficiently, economically and sustainably. It is ultimately about improving quality of life. The Sustainable Development Goal (SDG) 7 is to 'Ensure access to affordable, reliable, sustainable and modern energy for all'. The target that specifically measures progress towards this goal focuses on household energy access for cooking and other everyday activities. Other important SDGs that support the energy goals include those on health, gender equality, sustainable consumption and production, climate change and addressing environmental conservation and degradation (WB

SUSTAINABLE DEVELOPMENT GOAL 7

Ensure access to affordable, reliable, sustainable and modern energy for all

Target 7.1

By 2030, ensure universal access to affordable, reliable and modern energy services

Indicators

7.1.1

Proportion of population with access to electricity

7.1.2

Proportion of population with primary reliance on clean fuels and technology

Figure 4-1: The Sustainable Development Goals

Opposite photo: Frank van der Vleuten / Flickr / CC BY-NC-ND 2.0

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and IEA, 2017). The central role that woodfuels play in both urban and rural African households means that improving access to energy will directly improve the quality of life of all, and most especially the poor (Goal 1). Furthermore, the consumption patterns of woodfuels will directly impact the achievement of the targets of Goal 3 (health and wellbeing), Goal 5 (gender equality), Goal 7 (energy), Goal 13 (climate change) and Goal 15 (protect, restore and sustainably use natural resources), further highlighting the importance of woodfuels on the SDG agenda.

It is important to recognize that any actions that reduce the emissions from cooking will decrease the burden of disease related to household air pollution and ultimately improve the wellbeing of women and children. Reducing emissions will also decrease global warming through the reduction of GHGs.

Gender roles in Africa are clearly defined and most women do unpaid labour on behalf of the household. Women are in charge of collecting the fuel to cook the day's meals. They sometimes have to travel long distances to collect heavy loads of firewood and as trees within their residential vicinity thin or get depleted, they may have to travel ever further afield, which can compromise their health and safety. Cooking for the family may present health hazards from exposure to smoke in poorly ventilated kitchens. Poor health may impede their role as the main caregivers in families. They are thus disproportionately affected by lack of access to clean and modern forms of energy or to improved technologies that would have better health outcomes. Given their role in the household's energy requirements, women should have a say in domestic energy decisions; policy makers need to recognize this.

Women are the main consumers of woodfuels and are negatively impacted from the inefficiencies of the energy and from the impacts of cooking. Encouraging energy efficiency reduces household energy costs, lessens pressure on forest and tree resources, improves health and frees up time to be used on more productive activities.

The energy resources on which the majority of Africa depends are derived from forests, woodlands, shrubs or other land-based resources. Unstainable use of these resources leads to degraded forests or deforestation. This can lead to soil erosion, food insecurity and losses in biodiversity.

Since the adoption of the United Nations' Sustainable Development Goals (SDGs) in 2015, the UN annually convenes the High-Level Political Forum (HLPF). Ahead of the HLPF in July 2017, the UN Secretary-General released a report on Progress towards the Sustainable Development Goals (SDGs) in which he highlighted some of the interlinkages, as discussed below.

Good health and well-being (SDG 3)

"Indoor and ambient air pollution is the greatest environmental health risk," according to the Secretary General's progress report. Approximately 1.3 million more people die from household air pollution-related causes than they do from traffic and industrial air pollution, making the case to focus on combatting household air pollution to improve health.

Gender equality (SDG 5)

Women and girls' empowerment is inherently tied to the time they spend on unpaid domestic and care work, much of which — up to five hours each week — is devoted to collecting cooking fuels and cooking itself. The UN, member states, and civil society increasingly recognize that time poverty prevents women from pursuing professional opportunities and girls from attending school. According to the progress report, women spend more than triple their time on unpaid duties than do men.

There is a need for conducting more research on the complex issues that connect the use of women's time, environmental degradation and competition for agricultural nutrients. There are a host of other factors surrounding wood-fuel energy use in sub-Saharan Africa that remain poorly understood (Mendum & Njenga, 2018).

Affordable and clean energy (SDG 7)

Goal 7 on energy access is an underlying and essential factor to making sustainable, inclusive gains. According to the progress report, clean cooking is lagging in rural populations. Only 22 per cent of rural communities, on average, have access to clean cooking. Cooking solutions will only scale up to meet the needs of the millions when resources are mobilized and innovative tools created that all players in the cooking sector can access: "Meaningful improvements will require higher levels of financing and bolder policy commitments, together with the willingness of countries to embrace new technologies on a much wider scale."

4. 2 Challenges and Opportunities

The Grand Challenge

It is projected that by 2050, more than 1.8 billion people (65 per cent) in SSA will still rely on woodfuels for cooking. The transition to cleaner cooking will be hampered by rapid rural population expansion. The United Nations Projections show that the population in sub-Saharan Africa will grow to 2.5 billion in by 2050, from 1.3 billion in 2017. Many of these people are likely to remain relatively poor and rural, due to both limited per capita economic growth and a strong dispersion of that growth. This makes it more difficult to expand access to cleaner cooking fuels as biomass is almost free and often widely available, while more modern technologies require both infrastructure and a recurring cost for cooking fuels (Smeets, Tryggestad, Casteleyn, & Hooghiemstra, 2017).

Cooking makes up about 80 per cent of domestic energy demand in sub-Saharan Africa. Most of the cooking is done using traditional biomass and inefficient technologies. These unimproved cookstoves consume double the energy compared to improved technologies and are more energy intensive and polluting than electricity or LPG. As a result, per capita residential energy consumption levels are higher in SSA than elsewhere in the world. Compared to modern technologies elsewhere in the world, Africa currently uses ten times as much energy to cook similar amounts of food (Smeets, Tryggestad, Casteleyn, & Hooghiemstra, 2017). This results in high energy-intensity figures for the continent. The slow pace in increasing the adoption of improved cooking technologies also has impacts on the environment, in some cases resulting in forest degradation, biodiversity decline and soil erosion.

> One of the grand challenges for Africa is how to significantly increase "the proportion of population with primary reliance on clean fuels and technology"

The main drivers of this dependence on biomass energy are population growth, income levels, increasing urbanization and lack of education. The majority of the population in Africa resides in rural areas where incomes are low. Biomass is perceived as a fuel of the poor. It is easily available and 'free' to collect. However, if woodfuel is to continue to play a meaningful part in Africa's economy its status needs to be elevated and integrated into the national energy policy framework. However, at a higher-level, opportunities could arise due to accelerating economic growth, attracting investments and innovation in this sector.

General recommendations for creating opportunities

Accelerating economic growth

Economic growth is the most powerful tool for reducing poverty and improving the quality of life in developing countries. Africa — largely bypassed by previous industrial revolutions — stands in a unique position to reap the benefits of these changes. Its young and growing population, vast resources and largely untapped markets could provide the foundations for a continent-wide renewal, powered by technological innovations. In 2010, the McKinsey Global Institute (MGI) described the potential and progress of African economies as 'lions on the move' and identified three trends for Africa's future: the young population, urban growth and rapid economic growth.

First, the young population, which is potentially a growing labour force, is already a highly valued asset in an ageing world. By 2034, Africa is expected to have the world's largest working-age population of 1.1 billion. Secondly, Africa is expected to reap much of the economic benefits of urbanization in the coming future as the continent is still urbanizing. Productivity in cities is three times as high as in rural areas. This urban expansion is contributing to rapid growth in consumption by households and businesses. It is projected that Africa's consumers will spend US $2 trillion by 2025. Lastly, African economies are also well positioned to benefit from rapidly accelerating technological change that can unlock growth and leapfrog the limitations and costs of physical infrastructure in important areas of economic life (Leke & Barton, 2016). Rapid economic growth will be a major driver in making the shift to modern cooking fuels.

Attracting investment

Despite the enormous potential for harnessing its untapped energy resources, the move to universal energy access will require off-grid and technology solutions, capacity building and large financial investments: by some estimates, US $43-55 billion per year are needed until 2030-2040, compared to current energy investments of about US $8-9.2 billion (UNEP, 2017a).

According to a recent report, total financial commitments for residential clean cooking were estimated to average US $32 million over 2013-14 for the world's 20 high-impact countries. Finance for clean cooking is so low that it will not close the cooking access gap. By one estimate, global annual clean cooking investment needs are at least US $4.4 billion per year. Finance for clean cooking in high-impact countries comes to under US $1 per capita per year. This compares to the cost of providing an improved cookstove for one 5-person household of around US $8 for an advanced biomass cookstove or US $40 for an alcohol stove — in both cases excluding fuel costs. Source (SE4ALL, 2017)

Stronger efforts are needed to create 'big market' rather than incremental solutions. Given the urgency and scale of the clean cooking access and finance gap, governments, financiers and other decision-makers should immediately prioritize efforts and financing to scale up and accelerate clean cooking solutions that address the needs of all consumers in rural and urban areas. Transitioning to cleaner fuels — including ethanol, LPG and natural gas — will require long-term 'industry-building' initiatives, which must begin immediately to meet 2030 clean cooking goals. These efforts will also require significant consumer awareness efforts about the opportunities and benefits of clean cooking (SE4ALL, 2017).

According to a World Bank study SSA is already a large cooking market: US$20 billion was spent annually on cooking fuels in 2010, and US$300–400 million was spent on all types of stoves. By 2020, fuel spending is set to more than double to US$47 billion.

There are opportunities for significantly higher levels of investment through the National Determined Contributions (NDC) under the United Nations Framework Convention for Climate Change (UNFCCC) and funding instruments like the Green Climate Fund (GFC), among others. In fact, the African Development Bank group strategy for the new deal on energy for Africa 2016-2025 envisions providing 'Access to clean cooking energy for around 150 million households by 2025' (AfDB, 2016a).

Encouraging innovation and R&D in biomass technologies

In recent years, a lot of emphasis has been put on use of Improved Cookstoves (ICS). But the introduction of ICS in developing countries has been fraught with problems, including their cultural unacceptability and low uptake by consumers who find them difficult to use and fix.

Recent studies have demonstrated that improved biomass-burning stoves typically only incrementally improve air quality and yield modest or minimal health benefits. Likewise, their contributions to climate change mitigation and other SDGs may be limited. Evidence indicates that cleaner fuels, such as liquefied petroleum gas (LPG), ethanol and biogas, offer greater potential benefits not only to health, but also greater progress towards climate goals and other relevant SDGs (Rosenthal, Quinn, Grieshop, Pillarisetti, & Glass, 2018)

There is a need for 'out of the box' thinking and innovation in cookstove and charcoal making technologies. Social entrepreneurs should invest heavily in Research and Development (R&D) to solve this ongoing problem, which will benefit billions of people across the globe. The main goal is to ensure a higher efficiency in the combustion process as emissions arise from inefficient combustion processes.

There is also a need for creating financial policy to support wood-burning systems and developing agroforestry to ease the burden on wood gatherers. In rural areas, encourage the planting of trees and then pruning them to use the branches for firewood (Mendum & Njenga, 2018).

4.3 Policies and strategies for increasing production and reducing demand of woodfuels

Wood energy must be recognized as an inter-sectoral issue, connected to forestry, energy, agriculture and land (Hoffmann, Brüntrup, & Dewes, 2016). Future policies and strategies should include three critical elements for cooking fuels: increased supply of biomass through sustainable production; reduced demand of biomass through sustainable utilization; and the accelerated transition to a diversified portfolio of modern cooking fuels.

Sustainable production of woodfuel

Africa has made steady progress towards sustainable forest management in the past decade (UNECA, 2015). The net loss of forest area has slowed down, and the areas of forest designated for the conservation of biological diversity and included in protected areas have slightly increased. One of the challenges is to ensure biomass continues to be sustainably produced to meet the needs of the growing population.

The literature on the linkage between harvesting of woodfuels, forest degradation and deforestation has mixed findings. Agricultural expansion and illegal logging are well known to contribute to deforestation (Ogunbunmi & Mwando, 2014) with charcoal production a by-product of these activities. East Africa has been identified as a hotspot for unsustainable woodfuel harvesting, where the volume of woodfuel that is harvested exceeds the incremental growth by over 50 per cent. The harvested wood is thus known as non-renewable biomass (Bailis, Drigo, Ghilardi, & Masera, 2015). Tree cutting also occurs outside protected forests. Indeed, in Kenya, 87 per cent of charcoal is obtained from private or communal land in arid areas (Mutimba & Barasa, 2005). In searching for fuelwood, people generally harvest dead branches and twigs, rendering it a sustainable practice. However, with increasing demand for woodfuel and declining supply, this practice is changing as people start cutting down live trees to meet their energy needs. Indeed, there have been reports of woodfuel deficits in some part of Kenya and Zambia (Kalenda, Ngatia, Ng'oriareng, Simanto, & Oduor, n.d.); (Luwaya, 2015).

Engaging in the sustainable management of forests and afforestation and reforestation to expand forest cover is critical for the future supply of biomass resources. A combination of the following business models could be promoted to increase the supply of biomass resources:

Model-1: Community based forest management

Model-2: Private sector-based forest management

Model-3: Public sector forest management

Model-4: Agroforestry management

Countries have their own forest policies and legislations. So, every country needs to assess, and adopt and/or amend if necessary, specific business models based on their unique situation and within the umbrella of existing national policies and legislations.

Agroforestry

The practice of agroforestry, or the interplanting of trees with farmland, pasture or lawns, has many benefits. It is a source of woodfuels (for domestic use or sale) and it provides ecosystem services, improves soil fertility and ameliorates the micro-climate. Agroforestry trees can also be a source of food, such as fruits or seeds, and they may reduce human pressures on protected forests by providing the required wood supply. There is also an opportunity to diversify the energy from trees. For example, oilseeds and leaf residues can be used to produce liquid biofuels, such as biodiesel and biogas (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017). Coppice management, staggered planting and rotational harvesting are opportunities that could be employed on communally owned or private land, as the yields are reasonable. For instance, even in drylands where productivity is known to be low, a native stand of Acacia drepanolobium can yield up to 18 tonnes of wood suitable for charcoal production in about 14 years (Okello, O'Connor, & Young, 2001).

For agroforestry to be successful, tree species selection, individual or community involvement and seedling aftercare, among other strategies, need to be carefully thought through. Native trees have a good success rate because of their natural adaptation ability and the fact that they provide the best habitat for local biodiversity. However, this must be balanced against other desirable factors that interest tree growers, such as the attributes of fast growth and the straightness of the tree bole (Loo, Souvannavong, & Dawson, 2014). Successful agroforestry would also need to be combined with other technological innovations such as improved kilns and stoves for it to deliver the desired decline in wood harvest pressures on forests (Iiyama, et al., 2014). Within the context of climate change adaptation and mitigation the Table 4-1 summarizes the pros and cons of agroforestry:

Research in fast growing trees

One possible means of reducing deforestation from biomass production is the development of fast growing trees, including developing new species that withstand climate change and water shortages.


Agroforestry Mali

Jean-Marie De Bruyn GCCA

Table 4-1: Adaptation and mitigation relationships with respect to agroforestry

		Mitigation	
		Positive	Negative
Adaptation	Positive	• Soil carbon sequestration • Improved water use and efficiency • Commercial products diversification • Reduced nitrogen fertilizer and fertilizer substitution with manure • Fire management • Improved micro climate • Providing multiple food & energy sources	• Dependence on biomass energy • Overuse of ecosystem services • Increased use of mineral fertilizers • Poor management of nitrogen and manure • Emphasis on non-timber products
	Negative	• Integral protection of forest reserves • Forest Plantation excluding harvest • Large-scale biofuels export through international carbon finance	• Use of forest fires for pastoral management • Tree exclusion in farming lands • Increasing reliance on urban charcoal use without land tenure for rural production

Source: (Johnson, Mayaka, Ogeya, Wanjiru, & Ngare, 2017)

Generally, all species of wood can be carbonized to produce charcoal. However, the quality of charcoal depends on the species and also depends on the method of carbonization. Characteristics of such species include (Hines & Eckman, 1993):

- Rapid growth;
- Yield a high volume of wood quickly;
- Require minimum management time;
- Coppice or sprout well from shoots;
- Have dense wood with a low moisture content;
- Produce little and nontoxic smoke;
- Produce wood that splits easily and can easily be transported;
- Yield other products or services that are demanded by the household;
- Produce wood that does not spit or spark when burning; and
- Have nitrogen-fixing ability, enabling them to grow satisfactorily in nitrogen-deficient soils.

Recommendations:

- **Appropriate business models/strategies encompassing policy and regulatory measures, financial measures, capacity building and awareness creation measures should be adopted to increase biomass production through sustainable forest management and planting trees outside forest areas.**
- **Area under planted forest in Africa is about 16 million hectare which is modest in comparison to 129 million hectares planted in the Asia& Pacific region. A massive afforestation and reforestation drive, using suitable fast growing fuelwood species, should be launched to meet the growing need of population.**
- **International Research Organizations like ICRAF should intensify their research in developing fast growing, low water consuming and heat tolerant trees for biomass production in a changing climate.**

Sustainable utilization of woodfuel

To be effective, any innovations in biomass fuels consumption will have to go hand-in-hand with developments in the cookstove arena, among others. There should also be improvements in the conversion of raw biomass into more superior fuels such as charcoal and briquettes. Cookstove extension programs are found all over Africa, although some are better established than others.

It is generally recognized that the cookstoves in programs using biomass are inefficient. A program to improve the efficiency of biomass cookstoves is of vital importance.

Improved cookstoves (ICS)

Improved cookstoves (ICS) is the key technology available for improving the efficiency of consumption of firewood and charcoal. Such stoves have been modified to use less fuel, cook faster and reduce smoke. For example, a traditional metal charcoal stove can be improved by adding clay as insulating material, which helps conserve heat and save fuel while cooking. ICS have been developed for use with either firewood or charcoal, or even biomass briquettes.

The cookstoves vary depending on how they were produced, the fuels they are designed to use, the materials used to make them and their form, among other factors (Putti, Tsan, Mehta, & Kammila, 2015). For instance, the 'Mirt'cookstoves in Ethiopia were designed for baking injera, the national staple. They result in fuelwood savings of about 40 per cent compared to the traditional three-stone fire, translating into total annual savings of 1.28 tonnes of fuelwood per household (Dresen, De Vries, Herold, Verchot, & Müller, 2014). Figure 4-2 highlights some of the cookstove models and their key elements.

Market-based clean cooking solutions have not evolved due to poor receiving environments. For example, the type of cookstove with natural draft has poor emission specifications, while the type with forced draft is often not acceptable to the consumers due to poor design and non-availability of biomass pellets. Despite the large market potential, there are a limited number of manufacturers of clean cookstoves in the market (many lack design/testing/standard protocols) and none of them have received scale and profitability. Issues of Research and Development (R&D), fiscal support to manufacturing and after sales services deter expansion of the market. The problem of maintenance of clean cookstoves (biogas or improved) should be addressed in rural areas, so as to maximize adoption. In addition, improving ventilation in the cooking areas can reduce exposure to the harmful emissions from biomass energy usage. Some practical methods may include enlarging windows, installing chimneys or using smoke hoods to extract the smoke.

A policy and legal framework that streamlines the improved cookstove sector is necessary to support their development and dissemination. For instance, in Kenya, the Energy (Improved Biomass Cookstoves) Regulations, 2013 provide guidelines for the licensing of manufacturers, importers, distributors and contractors to ensure that specifications for thermal efficiency, emissions, safety and durability are met. Furthermore, these household cookstoves are required to meet certain performance requirements as specified under Kenya Standards KS 1814-1. Other countries that have specified national standards for cookstoves include Uganda (US 761:2007) and Zimbabwe (Ref. 05/03/2012 S. Control No. 354594).

Inynenyeri Biomass pallet for cookstoves in Rwanda

Inynenyeri

Figure 4-2: Overview of improved and clean cooking technologies

	Improved Solutions		Clean Cooking Solutions		
	Legacy and Basic ICS	**Intermediate ICS**	**Advanced ICS**	**Modern Fuel Stoves**	**Renewable Fuel Stoves**
Key Features	Small functional improvements in fuel efficiency over baseline technologies; typically, artisan produced	Rocket style designs with highly improved fuel efficiency and moderate gains in combustion efficiency; some with high-end materials	Fan jet or natural draft biomass gasifiers with very high fuel and combustion efficiencies; may require pellet/briquette fuel	Rely on fossil fuels or electricity, have a high fuel efficiency, and very low particulate emissions	Derive energy from renewable non-wood fuel energy sources; some are supplementary rather than primary cookstoves
What is Included	• Legacy biomass and coal chimney[a] • Basic efficient charcoal • Basic efficient wood	• Portable rocket stoves • Fixed rocket chimney • Highly improved (low CO_2) charcoal stoves	• Natural draft gasifier (TLUD or side-loading) • Fan gasifier/fan jet • TChar Stoves	• LPG and DME • Electric and Induction • Natural Gas • Kerosene[b]	• Biogas • Methanol • Solar ovens • Retained heat cookers
Potential Impact	Moderate				High

Sources; World Bank; Global Alliance for Clean Cookstoves; Task Team analysis.

a. Although legacy stoves are categorized as "improved" within the typology, the actual performance of many legacy stoves likely tells below provisional ISO/IWA standards.

b. Controlled tests of good quality kerosene pressure stoves show low emissions, but field data suggest that many kerosene stoves are actually highly polluting.

c. "Potential Impact" defined as potential positive impact on health and environment outcomes vis-à-vis traditional cooking solutions.

Source: (Putti, Tsan, Mehta, & Kammila, 2015)

Governments need to implement measures to encourage the greater adoption of improved cookstoves. Removing trade and tax barriers can be employed to aide this process. As an example, in the 2016-2017 budget, Kenya reduced the import tax on cookstove technologies from 25 to 10 per cent. Now that the tax for biomass cookstoves is at par with similar gas and electric stoves, it is likely that this will translate into lower costs for the cookstoves and is expected to transform the market and lead to higher adoption of improved stoves. Greater cookstove adoption will bring economic benefits for manufacturers and consumers and as traditional stoves are phased out, environmental and health outcomes will improve.

The data on how to shift to cleaner cooking fuels is growing and can be used to guide the process at national levels.

Green charcoal

As described earlier in this report, the charcoal value chain involves the collection or cutting of wood at source (such as forests, woodlands, shrublands, agroforestry systems and woodlots, and from wood processing operations), the carbonization of wood in kilns, the transportation, trade and distribution of charcoal and consumption by households or enterprises. Charcoal production technologies currently in use are still very wasteful, with efficiencies ranging between 8 to 40 per cent (Shikorire, 2015); (Jones, 2015). However, work is being done to improve their efficiency and to reduce the amount of emissions and wood waste.

The green charcoal value chain is the efficient and sustainable sourcing, production, transport, distribution and use of charcoal. It is low-carbon, resource-efficient, produced from sustainably sourced wood and socially inclusive.

Charcoal production is lucrative, providing incomes and jobs for people. The charcoal industry in sub-Saharan Africa was worth more than US $8 billion in 2007 (FAO, 2017c), while in Kenya the charcoal production industry is estimated to employ between

Box 4-1: Actions needed to green the charcoal value chain

The following are five actions needed to green the charcoal value chain:

1. Simultaneously initiate multiple interventions to reduce greenhouse gas emissions, targeting the entire charcoal value chain.
2. Increase the financial viability of a green charcoal value chain by reforming tenure, increasing legal access to land and resources, providing evidence-based evaluations of the benefits of the charcoal sector for national economies, putting a fair price on wood resources, incentivizing sustainable practices, and attracting investment for a transition to a green charcoal chain.
3. Develop comprehensive national policy frameworks to sustainably manage the charcoal value chain and integrate charcoal into wider efforts across sectors to mitigate climate change, including by making the charcoal value chain a specific component of nationally determined contributions.
4. Support national governments and other stakeholders in their efforts to green their charcoal value chains through research and providing reliable data.
5. Disseminate the lessons learned from pilot projects, success stories and research that take into account the entire charcoal value chain.

Source: (FAO, 2017c)

Table 4-2: Technical interventions for cleaner and more efficient charcoal production and use

Stage of charcoal value chain	Intervention	
Sourcing of wood/ charcoal	1	Sustainably manage source (e.g. natural forests, planted forests and community forests)
	2	Switch to alternative sources, such as agricultural waste, wood residues and wood outside forests, including agroforestry
	3	Process charcoal dust into briquettes
Carbonization	4	Better manage traditional kilns to increase efficiency and use improved kilns with higher efficiencies
	5	Cogenerate charcoal and electricity (in the case of industrial-scale production)
Transportation and distribution	6	Reduce fossil-fuel consumption in transportation
End use	7	Use improved cookstoves

Source: (FAO, 2017c)

200,000-300,000 people earning annual revenues of KSh 52 billion (approximately US $520 million) (Kalenda, Ngatia, Ng'oriareng, Simanto, & Oduor, n.d.). Despite this, the uptake of improved kilns is slow and many farmers abandon the new technology over time. A good example is the Casamance kiln that has been promoted in Africa without much success for the last 20 years (ESMAP, 2012). This is primarily because investing in the technology is expensive and does not pay for itself as long as wood remains a free resource. Secondly, maintaining private woodlots is uncompetitive for the same reason (ESMAP, 2012). For instance, it has been estimated that subsidies of US $300 per hectare are required to encourage farmers in Madagascar to maintain their own woodlots (ESMAP, 2012).

Another challenge is the impacts of charcoal kilns on the environment. The high temperatures generated during the charcoal production process have been found to permanently damage soils. Also, despite being small, recovery of forests around kiln sites tends to be incomplete with regrowth limited to shrubs in the medium term (Morrissey, 2017).

There are opportunities to integrate sustainability issues into the entire charcoal value chain as shown in Table 4-2.

Certification and eco labelling

The use of standards, certification and labeling has been growing in a number of areas as consumers demand more information about the products they

Box 4-2: Briquette technology

Fuel briquetting technology converts organic byproducts into briquettes, which are then used as fuel. Briquettes are made from any locally available biomass material such as charcoal dust, wheat or barley straw, coffee husks, maize cobs, coconut shells or rice husks, depending on material that is available. The biomass may be combined with soil or clay, paper, or sugarcane bagasse that acts as a binder. Finely crushed biomass is then compressed into small blocks using a press. The blocks are solar dried before being put on the market.

By improving combustion performance and efficiency, briquettes reduce demand for fuel wood and thus improve access and use of cleaner fuels. The briquetting technology can also support micro-enterprise opportunities, including production, packaging, transporting and selling of equipment and products (briquettes).

Biomass briquettes are more economical than other fuels because they have low moisture and low ash content and have a high density. Briquettes are also more cost effective than fuelwood; they are cheaper to make and use than charcoal and depending on the raw materials used, they burn longer, cleaner and more evenly. In order to improve efficiency and reduce production costs, investment in improving the technology is needed.

Sources: (SEI, 2015); (Njenga, Karanja, Jamnadass, Kithinji, & Jirjis, 2013)

use. Certification has become a popular tool in environmental policy and is widely seen as a method to influence purchasing behavior, and through the power of markets, reputation and branding, the environmental behavior of suppliers. A number of countries in Africa have embarked upon a simple yet robust nationwide certification and labelling scheme for all charcoal sourced from local biomass and produced (carbonized), transported, traded and consumed ((Bauner, De Toni, Oulu, Sangal, & Thenya, 2016). The basic assumption is that certification will also create more business opportunities as more people enter the regulated and streamlined charcoal sector. For example, large supermarkets will be more willing to stock certified, labelled and properly packed charcoal, while financial institutions and SMEs will be encouraged to lend to and tailor financial products to those involved in the streamlined charcoal sector.

The choice of scheme depends on a variety of factors, including ease of application of procedures, knowledge and implementation capacity of the biomass producers, availability of qualified certifiers and inspectors and the cost implications. Certification can also be costly, so producers must carefully weigh the pros and cons of acquiring a label. Since biomass energy primarily thrives in rural informal markets, the impact of such schemes on the price of final products should be carefully evaluated.

Recommendation:

Since woodfuel is the fuel of the poor, due consideration should be given before embarking upon certification and labeling schemes, keeping costs and the beneficiary in mind.

Training and capacity building

There is need for training and capacity building across all the elements of the value chain of biomass energy, including the following:

- Training on sustainable biomass supply (forestry, tree planting etc.);
- Training in efficient kiln design, construction and use;
- Capacity building for implementing agencies and charcoal stakeholders on the certification scheme;
- Training for producers of ecolabels and packaging; and
- Training of entrepreneurs and small business owners on various aspects of business management.

There are environmental, socioeconomic and health consequences associated with woodfuel value chains in Sub-Saharan Africa. However, the literature also shows a weak and geographically limited evidence base to justify the above claims. Policy formulation processes targeting woodfuels in SSA require more solid, coherent and broad body of knowledge, especially for such a vital sector in rural economies. Thus, there is an urgent need to design and undertake research using robust methodologies, at appropriate scales that further takes into account the interrelationships between environmental and socio-economic outcomes in order to generate substantial and reliable evidence for informed policy formulation (Sola, et al., The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: a systematic map, 2017).

4.4 Improving the woodfuels Policy Framework

The policy framework within Africa for woodfuels tends to be weak or non-existent for a number of reasons. For example, policy is not always grounded on firm scientific evidence. While there is some consensus that uncontrolled woodfuel exploitation is a problem, the accuracy of data on forest resources and on charcoal production, trade and consumption could be improved. As well, other drivers of deforestation and forest degradation, such as poverty, agricultural expansion, overgrazing, mining and bush fires, need to be taken into consideration (Arevalo, 2016). Other barriers to strong policy development include lack of awareness of available technologies, limited financing, lack of political support and the fact that the importance of wood energy to Africa's population tends to be overlooked by international development partners (ESMAP, 2012); (Johnson, et al., 2014). The capacity of the entire sector also needs to be built, including public and private research, national planning capacity and the required institutional and funding frameworks (Johnson, et al., 2014).

Woodfuel in national energy policies

Governmental energy policies guide the growth of the energy sector. These policies usually address energy issues from its production and distribution to use. There is usually a wide policy framework that may include action plans, guidelines, strategies, regulations and laws. They detail specific aspects outlining how the policy will be implemented.

Biomass energy plays a central role in Africa and will continue to do so for the foreseeable future. The expectation, therefore, is that biomass energy issues should also command a central role in a country's national energy policy. However, this is not the case. In a number of cases, biomass energy is viewed as promoting poverty and degrading the environment, so many governments' energy strategies focus instead on fossil fuels and electricity, which are thought to be more modern and able to support economic growth and poverty reduction (Owen, van der Plas, & Sepp, 2013) (Van Leeuwen, Evans, & Hyseni, 2017). While the use of electricity and fossil fuels are convenient, the reality is that they are expensive and with the projected population growth, biomass energy use is expected to increase in the future. Any change in the use of biomass energy is likely to have far reaching impacts on livelihoods and the economy. For instance, in 1984, the Ethiopian government instituted a policy to limit the use of fuelwood in the city, successfully reducing its use from 70 to 13 per cent. However, this resulted in the loss of livelihoods for about 38,500 transporters who were supplying fuelwood (Morrissey, 2017).

Recommendation:

Biomass energy collection, distribution and use must be integrated into the energy policies of each and every country based on sustainability criteria.

Biomass in national energy legislation

Africa's countries have established National Energy Laws and many have undergone reforms in recent years. Many of these laws are modern and include

Members of the Atiriri Bururi ma Chuka community group during a recent meeting in Tharaka Nithi County in the central part of Kenya, to lobby against illegal logging.

David Njagi/ Mongabay

Table 4-3: Overview of policies and measures implemented in sub-Saharan Africa to support sustainable wood-fuel value chains

Policy approach	Characteristics	Examples
Bans on woodfuel production or transportation	• Difficult to enforce • Encourage corruption • Create a risk that consumers turn to lower quality fuels	• Attempted in many countries, including Cameroon, Chad, Ethiopia, Kenya, Malawi and the United Republic of Tanzania
Land-tenure and forest management reforms	• Important to ensure rights of access and control for woodfuel producers, as well as the right to exclude others from exploiting a given resource • Typically implemented as broader strategies, not necessarily linked to woodfuel value chains • Common to all examples of successful woodfuel value-chain development, but insufficient on their own to ensure success	• Tenure and forest management reforms, with some successful woodfuel value-chain development – Burkina Faso, Chad, the Gambia, Madagascar, the Niger (limited to specific projects), Senegal and the United Republic of Tanzania and those without significant value-chain development – Democratic Republic of the Congo (private and community forestry), Ethiopia (participatory forest management), Kenya (community forest associations) and Uganda (district-level management)
Licenses, quotas and permits	• Established as means to formalize, monitor and control resource flows • Under private or community forest management, licenses and permits can channel revenue to individuals or communities • Often require forest management plans, which individuals and small communities can find difficult to develop and implement Licenses and permits are more effective when the application process is simple and decentralized Complicated or costly permit systems can act as de facto bans, resulting in the same negative outcomes	• Use is widespread, with varied results: Burkina Faso, the Niger, Senegal – some degree of compliance with the permit/ licensing system in Congo, Democratic Republic of the Congo, United Republic of Tanzania – permit systems are in place but obtained by only a small fraction of producers • Mali – permits are costly and often ignored Kenya, Malawi – permits are required through a highly centralized application process; few permits are issued, leading to de facto ban Zambia – permits are required; adherence to regulations varies with location
Subsidies and taxes	• Subsidies – common for electricity, kerosene and cooking gas but rarely applied to woodfuels • Taxes – frequently built into license and permit fees and may be levied on extraction and transportation • Frequently circumvented, leading to lost tax revenue • Differential taxation – can encourage woodfuel production from community or privately managed resources	• Many countries in sub-Saharan Africa have some woodfuel taxation system in place, but the systems vary greatly in detail and coverage Differential taxation has been implemented with some success in Chad and the Niger and with less success in Mali and Senegal
Cooperatives and producer associations	• Can provide officials with means to monitor who produces woodfuels and create clear pathways for communication and revenue flows • Allow members to pool resources and increase bargaining power in some market conditions	• Woodfuel producer cooperatives are common in Senegal, the Niger and Mali • In Kenya, charcoal producers are required to form associations in order to obtain production permits. Many associations are registered but few permits, if any, are issued • The Sudan has had some success with producer cooperatives

Source: (FAO, 2017b)

elements of biomass energy (Table 4-3). For instance, the Renewable Energy Act 2013 (Cap 32.05) of the Gambia specifically talks about developing biomass energy as part of hybrid energy systems. The Mauritius Cane Industry Authority has been mandated by the Sugar Industry Efficiency (Amendment) Act 2016 Act No. 34 of 2016 to develop and monitor a framework to be known as the Renewable Sugar Cane Industry Based Biomass Framework to promote production of energy from biomass, including sugar cane and other biomass waste generated by the industry. Although some policies and laws are progressive, implementation is sometimes hindered by lack of resources and political will to implement them (Ogunbunmi & Mwando, 2014).

Box 4-3: Key recommendations for the sustainable sourcing of woodfuels in sub-Saharan Africa

- Multiple measures involving structural changes, such as the devolution of forest management rights, combined with targeted regulatory measures have the most profound and lasting impacts.
- Secure tenure over communally held woodland resources or individually held private land (depending on the context) is particularly important.
- Permit systems must be simple and easy to enforce, with quotas based on simple management plans developed with local participation. Systems under local management, with permits issued by communities or local authorities, function better than centralized systems, but communities must have recognized, enforceable rights over forest resources.
- A successful targeted financial measure is differential taxation to reward harvesting from sustainably managed sources.
- When taxes or permits are implemented, a substantial fraction of the revenue must reach rural communities to incentivize their participation and compliance.
- Transformations take time and can easily be undone by shifts in policy. Efforts to bring about sustainable woodfuel sourcing need to be maintained for long periods and must not be undermined by contradictory policies.

Although there are efforts to regulate the charcoal trade in Africa (Table 4-4), there are still a number of countries where charcoal legislation or policy is absent. The profitability of the charcoal trade has allowed for the development of unregulated markets and illegal taxation of charcoal. In 2012, about 30.6 million tonnes of charcoal produced a value estimated at between US $9.2 and 24.5 billion per year (Nellemann, Henriksen, Raxter, Ash, & Mrema, 2014). Revenue losses attributed to the unregulated trade in charcoal average US $1.9 billion for countries in Africa. Net profits from dealing and taxing illegal charcoal in Central, East and West Africa is estimated at US 2.4-9 billion (Nellemann, Henriksen, Raxter, Ash, & Mrema, 2014).

4.5 Regulating the Charcoal Trade

Criminal gangs and militia groups across Africa use the illegal taxes on charcoal to finance their operations. These may amount up to 30 per cent of the value and is thus very lucrative. It is also likely to continue as current growth trends in population and urbanization are expected to continue driving up demand for charcoal. In the Democratic Republic of the Congo (DRC), illegal road taxes earn the militias between US $14-15 million per year. The illegal export of charcoal in Somalia is estimated at US $340-384 million and at one roadblock point in Badhadhe district, a Somali militia is thought to raise between US $8-18 million a year. This has implications for other countries that have on-going conflicts such as Central African Republic, DRC, Mali, Somalia and Sudan, among others (Nellemann, Henriksen, Raxter, Ash, & Mrema, 2014).

Recommendation:

- Strengthen regulatory framework to enforce the charcoal trade.
- It would be appropriate to: 1) identify gaps in the policies, laws and institutions (at national and regional levels) that are relevant to charcoal production, transportation and trade; 2) propose to address the gaps in the national, regional and international legal and institutional framework.

Women and children are key elements in the collection of fuelwood. Women in particular walk up to 10 km to collect wood and then walk back with the heavy load. The impacts on health include injuries to the head, neck and spine and there is the threat of attack from wild animals, violence or rape, which are well documented (Njenga & Schenk, n.d). In addition, the time spent collecting woodfuel could be used for other more productive economic activities, such as farming or the pursuit of education (in the case of children) (Njenga & Schenk, n.d).

Thus, women have a major role to play in developing entrepreneurial ventures to make up for the loss of productive time. The productive time gained presents an opportunity to empower women within communities to be more efficient in their domestic chores, pursue educational opportunities, enter the workforce or start a business (O'Dell, Peters, & Wharton, 2015). In East Africa, because of their role in cooking, women have taken a central role in the cookstoves business. Women (more than men) make good marketers, especially

Table 4-4: Summary of efforts to regulate charcoal production from selected sub-Saharan countries

Country	Commercial utilization rights	Legislated Licensing Scale	CBFM commercial rights	Notes
Cote d'Ivoire	• There are clear use rights for different forest types. • Commercial charcoal production permits are issued for wood from natural and plantation wood. • Taxes: A fee is paid for each permit and an additional annual fee for company, enterprises and associations at twice the rate for individuals. • Forest owners often require an additional tax per bag of coal produced	National, municipality, local.	Individual and through associations	• For plantations, detailed guidelines allow charcoal production by individuals and companies and from own or others' wood with contract or agreement with the third party. • For natural forests, any licensee must reforest a compensation hectare of land per permit, and a certificate of reforestation is issues locally (municipality). • A contract is needed with owner/forest-right holder for natural forests. • Exploitation zones are defined as a minimum of 25,000 ha of forest. • Promotes formalization of the charcoal sector and improvement of charcoal production efficiency yields. • Provides reductions in import duties and value added tax for investments in energy production, protection of the environment and the forestry sector. • Promotes charcoal production from waste wood. • Charcoal NAMA proposes a Charcoal Unit, a Charcoal Fund to partially fund it, and an Inter-ministerial Steering Committee for discussion and coherent coordination for improvement of the charcoal value chain.
Ghana	• A Bulk Charcoal Production License for producers of 100+ tonnes per year • A Bulk Charcoal Transportation License for license holders to transport charcoal • Charcoal Wholesale Storage License (for storage by license holders) • Charcoal Export License for each consignment through online application	National, district	Through registered associations	• Proposed charcoal licensing is through pre-purchased black (through registered association, non-sustainable) and green (sustainably produced) bags. Illegal charcoal has neither bag. • A proposed charcoal Fund to partly finance Charcoal Unit. • An Interdisciplinary Committee discusses and advises on issues of charcoal. • Expanded eco-labeling for charcoal (black and green bags for charcoal, quality and type), efficient cookstoves, efficient kilns and promotes a registered association. • A private non-profit agency, the Energy Foundation promotes energy efficiency and renewable energy mainly in urban areas. • A Renewable Energy Fund and a strategy seek to reduce woodfuel demand. • Growing of bamboos to reduce deforestation and provide an alternative for woodfuel production. • A Forest Plantation Development Fund provides financial assistance for development of private commercial plantations. • Improved carbonization and cookstoves technologies
Kenya	• Licenses (harvesting, production, transportation) based on sustainable harvesting (reforestation/ conservation plan)	National (Kenya Forest Service), Provincial/ local administration	Must be member of charcoal association	• Pilot charcoal rules were introduced in 2008 in 5 districts Charcoal is to be sold in designated areas • Has designated areas for harvesting • Also protects endangered species, encourages use of invasive species and agriculture waste for charcoal, briquettes from charcoal dust • Inspections, record keeping are required, with fines ~$150 and prison sentence for breach • Include transportation rules • ENERGY Kenya funds forestry to plant trees for energy and catchment areas.

since they have hands-on experience with the product. Word-of-mouth plays a big role in marketing cookstoves to remote areas where the normal distribution and marketing is absent. In Kenya, women have been found outsell men on cookstoves by 3:1 (Mukulu, 2017). In addition, women who bought from other women were more likely to exhibit correct cookstove use than those who bought from men (Mukulu, 2017).

Table 4-4 (cont.): Summary of efforts to regulate charcoal production from selected sub-Saharan countries

Country	Commercial utilization rights	Legislated Licensing Scale	CBFM commercial rights	Notes
Mozambique	• Licenses, concessions. • Transportation fee to transporters per bag and 15% restocking fee	Provincial	None	• License fees supposed to go into Agrarian Development Fund to promote small-scale rural development/ economic activities, e.g., reforestation. • Use checkpoints on main roads into cities to collect fees. • They are testing taxing of producers, not only transporters.
Rwanda	• Licenses, concessions (industrial production) • Licensed/regulated transportation. • Regulated retail sales	National/Local government	Large private concessions to achieve the scale of production required by the market (and an economy of scale in production). Private concession/ producers linked to outgrower schemes, employment and other benefits	• Developed a Supply Master Plan for Firewood and Charcoal. • Most of wood stock is (bought) from large industrial plantations (eucalyptus, with mean wood age 6-8 years), and conversion in large efficient kilns. • In 2013, wood producers had highest profit in Charcoal Value Chain (CVC) (22%), then dealers/retailers (13%), transporters (10%), charcoal makers (7%), taxes and other costs (48%). • There has been an increase in adoption of improved charcoal kilns (e.g., Casamance) • Government trains charcoal producers on best carbonization practices; provides fast growing tree seedlings (eucalyptus); enforces laws and regulations; links small-scale producers to industrial producers, and to microfinance institutions • Cooperatives buy charcoal from member producers and sells to wholesalers & retailers
Senegal	• Licenses (wood cutting, transportation, storage), concessions, professional permits, quotas/ management plans	Region, Rural Councils	Have licensing rights (licenses, permits, concessions) Keep 70% of fines, sales	• Govt. forestry taxes go to govt. controlled National Forestry Fund meant to help forest rehabilitation. • Quotas based on forest inventory and management plan. • Commercialization banned in non-managed areas. • Urban elites monopolize contracts in collusion with forestry officials, rarely follow conditions of permit.
Sudan	• Concessions, tender to charcoal association, taxes for traders	National	None. Villagers can grow crops for few years in harvested forests	• Government-run, plantations based production of wood for charcoal production • Producers organized into Sudan Charcoal Association • Separate Sudan National Corporation regulates charcoal production and trading
Tanzania	Licenses and permits on harvesting and transportation	Rural Councils (village groups), Central Government	Communities have licensing rights (licenses, permits)	• Has long history of decentralized village governance. • Has requirements for sustainable feedstock, forest/ reforestation plans. • Has designated areas for harvesting. • Also protects endangered species, encourages use of invasive species and agriculture waste for charcoal, briquettes from charcoal dust. • Inspections, record keeping are required, with fines ~$150 and prison sentence or breach. • Include transportation rules (e.g., only during day). • Some studies show success in sustaining wood supply and benefits in community-controlled charcoal production.
Uganda	Licenses	District, sub-district councils	Licenses, permits	• Commercialization is banned from Central Forest Reserves (all forests 100 hectares or more), allowed in buffer zones. • Very little forest land for local management.
Zambia	Licenses and permits Charcoal conveyance fee (US$0.10/bag)	National, district, village	Have licensing rights (licenses, permits)	• Has charcoal cooperatives. • Use checkpoints on main roads into cities to collect fees.

Source: (MNREM, 2017)

4.6 Women, Youth and Entrepreneurship Development

The launch of the Africa Women Energy Entrepreneurs Framework (AWEEF) is an opportunity to operationalize the Libreville Outcome Statement from the workshop on **Women Entrepreneurs and Sustainable Energy in Africa** held in June 2017 and the Africa Environment Ministerial Declaration titled **Innovative Environmental Solution to implement the Sustainable Development Goals (SDGs) and African Union (AU) Agenda 2063**. The Libreville Outcome Statement includes a raft of policy recommendations to support women's inclusion in the energy value chain through expanded economic opportunities, such as greater access to finance and markets, and also by enhancing their technical and business skills. Political leadership, appropriate priorities and policies, and the massive scaling up of programs are also needed to enhance opportunities for investment (Legros, Havet, Bruce, & Bonjour, 2009).

Recommendations:

- Reduce the disproportionate work burden on women (mostly cooking and fuelwood collection) by employing household energy interventions such as improving access to cleaner fuels and more efficient cookstoves. This will reduce exposure to high levels of air pollution and reduce the time spent on fuelwood collection since it will burn efficiently.
- Encourage and provide incentives to youth entrepreneurs to get involved in biomass industry related businesses.

Business Model

Clean cooking is a vast market with its economic spin-offs, which should be tapped. The culture and context for clean cooking in urban areas needs to be strengthened, including a mass market for cookstoves; the availability of electric cooking appliances and bottled LPG in various refill sizes; the setting up of fuel distributorships across the country; and the strengthening of city gas networks. The creation of a database-driven intervention strategy, which includes sales records, a consumer database that projects the benefits accrued in terms of reduced emissions is essential for designing future interventions. Promotion of an enterprise-based model for operating biogas plants in rural areas would increase usability and provide co-benefits of employment and livelihood opportunities. Waste-to-energy generation facilitates the deployment of appropriate technology to tap energy from other available wastes including organic garbage and sewerage from urban areas.

Kettle on wood stove

Pixabay.com/CC0 Public Domain

4.7 Accelerating the Transition to a Diversified Cooking Fuel Portfolio

Table 4-5 illustrates trade-offs between the various fuels and restrains one must consider.

Although many government policies encourage a shift towards clean or modern fuels, this may not be practicable. Traditional fuels include dung, agricultural residues and fuelwood; intermediate fuels include charcoal and kerosene; while clean or modern fuels include LPG, biogas, ethanol gel and electricity, among others. However, given that most biomass use is highest amongst the rural poor, most of these clean fuel options will be unavailable or unaffordable to these people. For instance, the costs involved in extending grid electricity to many rural areas may be economically unviable. A majority of LPG-deprived households cite their inability to pay as a barrier to their adopting LPG. Thus, decision makers need to look at practical fuel solutions such as charcoal and briquettes and frame policies accordingly. Universal access to electricity and LPG has been the most preferred-model fuel technologies for economically growing areas.

Table 4-5: Trade-offs between different cooking fuels and technologies in a developing country context

Fuel	Stove cost	Fuel cost	Reliability	Health impact	Gender inequality	Environmental impact	Fuel availability
Biomass (traditional)	Advantage	Advantage	Advantage	Disadvantage	Disadvantage	Advantage, Neutral	Advantage, Neutral
Coal	Neutral	Neutral	Advantage	Disadvantage	Advantage	Neutral	Neutral
Kerosene	Neutral	Neutral	Advantage	Disadvantage	Advantage	Neutral	Neutral
Biomass (improved/ advanced)	Neutral	Advantage	Advantage	Neutral	Advantage, Neutral	Advantage, Neutral	Advantage, Neutral
LPG	Disadvantage	Neutral	Neutral	Advantage	Advantage	Advantage	Neutral, Disadvantage
Electricity	Neutral	Disadvantage	Disadvantage	Advantage	Advantage	Advantage	Neutral, Disadvantage
Biogas, solar cookers	Disadvantage	Advantage	Disadvantage	Advantage	Advantage	Advantage	Disadvantage

● Advantage ● Neutral ● Disadvantage

Source: Modified from (IEA, 2017b)

Recommendations:

- National cooking fuel strategies as part and parcel of a country's National Energy policy should be developed. A basket of cooking fuels should comprise the national cooking fuel strategy, with accompanying supports. The aim should be improving efficiency of biomass production and consumption and fuel substitution of sources of energy such as firewood/chips, dung cake and charcoal to cleaner sources of energy like LPG and electricity. This strategy will also have positive ripple effects on the country's public health, gender, livelihoods and environment.
- Governments should make every effort to encourage the transfer from fuelwood and charcoal in institutions like hospitals, hotels, schools, industry and government offices to electricity, kerosene and LPG. It might not be practicable to encourage underprivileged people to make the energy shift due to poverty and cultural sensitivities, but this transition could be successfully navigated for larger institutions.

4.8 Conclusion

Biomass energy is of significant economic value to African economies and is the single most important energy source for the majority of households. This importance thus requires that biomass fuel be managed in ways that exploit its advantages while limiting its negative impacts. The main advantage with woodfuels is the energy security they provide to both urban and rural dwellers. They are locally available and when well managed the resources are renewable. Poor people can more readily afford charcoal and woodfuel compared to other fuels such as kerosene, LPG or electricity. However, in many areas, even biomass is being bought, and it is no longer accessible for free everywhere. Expenditures incurred (wage opportunities lost) in collecting/buying biomass is higher than the cost of clean fuels. Hence, there is an appetite to pay for the latter. With rapid growth in urban populations, the demand for modern cooking fuels will keep on rising.

The continent currently has abundant wood stocks, but they are shrinking (FAO, 2015). Forests are renewable resources only if the rate of harvesting is lower than the regeneration rate of the trees. When trees are over-harvested, it may cause forest degradation and ultimately deforestation. The upshot of this is global warming, loss in soil quality and biodiversity degradation. The majority of deforestation results from land conversion for agriculture and illegal logging. In both cases charcoal production may be a byproduct of those activities. The use of fuelwood and charcoal is not without its problems. Their use results in greenhouse gas emissions and household air pollution with negative impacts on the environment and human health.

As Africa's population continues to grow, the number of people depending on traditional biomass as their main cooking fuel will also increase. Strong policies will thus be required to expand access to cleaner fuels and technologies. Although switching away from traditional biomass may not feasible for many households in the short-term, since they may be hindered by poverty, cultural preferences or even lack of awareness, there are opportunities to change the situation. First, people can be encouraged to use more efficient cookstoves, which would reduce the pressure on forests. Secondly, for the population segment that can do so, switching fuels would help protect the existing forest resource. Lastly, greater afforestation and reforestation efforts can help to restore degraded forest and increase the forest stock. This would bring about the double dividend of improving people's health and that of the environment.

Going forward, it is important that governments implement strategies that will create economic and livelihood growth opportunities as these will result in the increases in income so necessary to support the purchases of improved cookstoves or a switch to alternative fuels. They will also need to give much attention and investment to improving the national energy infrastructure so that people have access to alternative sources of energy such as electricity and LPG when forests are protected.

As indicated throughout this report, the main challenge on the continent is not to increase energy consumption as such, but to expand access to clean energy and it services. Awareness-raising activities are key to educating people and allowing them to make informed decisions on energy efficiency, renewable energy options and sustainable consumption. This is especially necessary in rural areas where literacy levels are low. The educational programs will need to be supported by adequate capacity building, research and development activities at institutional levels.

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Glossary (From FAO, EIA and other sources)

Biofuels: Organic primary and secondary fuels derived from biomass which can be used for the generation of thermal energy by combustion or some other technology.

Biomass: Organic material that comes from plants and animals, and it is a renewable source of energy. It contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels. Examples of biomass and their uses for energy are: Wood and wood processing wastes—burned to heat buildings, to produce process heat in industry, and to generate electricity. Agricultural crops and waste materials—burned as a fuel or converted to liquid biofuels, Food, yard, and wood waste in garbage—burned to generate electricity in power plants or converted to biogas in landfills and Animal manure and human sewage—converted to biogas, which can be burned as a fuel. Solid biomass, such as wood and garbage, can be burned directly to produce heat. Biomass can also be converted into a gas called biogas or into liquid biofuels such as ethanol and biodiesel. These fuels can then be burned for energy. Biogas forms when paper, food scraps, and yard waste decompose in landfills, and it can be produced by processing sewage and animal manure in special vessels called digesters. Ethanol is made from crops such as corn and sugar cane that are fermented to produce fuel ethanol for use in vehicles. Biodiesel is produced from vegetable oils and animal fats and can be used in vehicles and as heating oil.

The phrase "**traditional biomass energy use**" refers to the direct combustion (often in very inefficient devices) of wood, charcoal, leaves, agricultural residue, animal/human waste and urban waste, for cooking, drying and charcoal production. "**Improved traditional biomass energy technologies (IBTs)**" refers to improved and efficient technologies for direct combustion of biomass e.g. improved cookstoves, improved kilns, etc. "**Modern biomass energy use**" refers to the conversion of biomass energy to advanced fuels namely liquid fuels, gas and electricity

Black liquor: is the alkaline-spent liquor obtained from the digesters in the production of sulphate or soda pulp during the process of paper production, in which the energy content is mainly derived from the content of lignin removed from the wood in the pulping process.

Charcoal briquettes: Product made from wood-based charcoal which, after crushing and drying, is moulded (often under high pressure); generally with the admixture of binders to form artefacts of even shape.

Charcoal, Wood: Energy item that is derived from fuelwood and used to satisfying final sectorial energy demand or for electricity generation where relevant. Wood carbonised by partial combustion or the application of heat from external sources. It includes charcoal used as a fuel or for other uses, e.g. as a reduction agent in metallurgy or as an absorption or filtration medium. It is reported in metric tonnes.

Charcoal: A solid residue derived from the carbonization, distillation, pyrolysis and torrefaction of wood (from the trunks and branches of trees) and wood by-products, using continuous or batch systems (pit, brick and metal kilns). It also includes charcoal briquettes.

Chips: Wood in the rough that has been deliberately reduced to small pieces, or residues suitable for energy purposes.

Consumption, Woodfuel: Production + Imports – Exports =Total Primary Energy Supply (TPES) → (Losses) and Conversions →Total Final Consumption.

Fuelwood (or firewood): Includes "wood in the rough" in small pieces (fuelwood), chips, pellets and/or powder derived from forests and isolated trees, as well as wood by-products from the wood products industry and from recovered woody products. They preserve essentially the original structure of wood and can be used either directly or after some conversion to another woodfuel, as charcoal. When needed, fuelwood can be prepared (without major chemical-physical transformations) into more convenient products, such as chips and pellets. Fuelwood or firewood (in log, brushwood, pellet or chip form) obtained from natural or managed forests or isolated trees. Also included are wood residues used as fuel and in which the original composition of wood is retained. Remark: Charcoal and black liquor are excluded.

Production, Woodfuel: The solid volume or weight of products that may immediately be consumed in the production of another product (e.g. wood pulp, which may immediately be converted into paper as part of a continuous process).

Pyrolysis: Decomposition brought about by high temperatures.

Roundwood: Wood in its natural state as felled, with or without bark. It may be round, split, roughly squared or in other forms.

Torrefaction: A thermal process to convert biomass into a coal-like material, which has better fuel characteristics than the original biomass. Torrefied biomass is more brittle, making grinding easier and less energy intensive

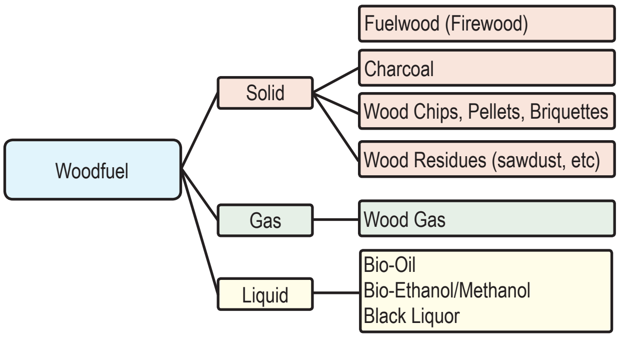
Wood energy: The energy generated from wood or wood-derived products – usually through combustion processes – and used for cooking, heating or electricity generation. The term "wood energy" is also used to refer to wood and wood-derived materials used for energy purposes ("woodfuel"), which may be in solid, liquid or gaseous form.

Woodfuel (Including Wood for Charcoal): Coniferous or Non-Coniferous Roundwood that will be used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that will be used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets and other agglomerates. The volume of pyrolysis used in charcoal production is estimated by using a factor of 6.0 to convert from the weight (mt) of charcoal produced to the solid volume (m^3) of pyrolysis used in production. It also includes wood chips to be used for fuel that are made directly (i.e. in the forest) from pyrolysis. It excludes wood charcoal, pellets and other agglomerates. It is reported in cubic metres solid volume underbark (i.e. excluding bark)

Wood pellets: A fuel derived from the self-compaction of woody material from the combined application of heat and high pressure in an extrusion machine

Woodfuels: Include all types of biofuels derived directly and indirectly from trees and shrubs grown in forest and non-forest lands. Woodfuels also include biomass derived from silvicultural activities (thinning, pruning etc.) and harvesting and logging (tops, roots, branches, etc.), as well as industrial by-products derived from primary and secondary forest industries which are used as fuel. They also include woodfuels derived from ad hoc forest energy plantations. Woodfuel includes all categories of primary or converted wood used for energy: Fuelwood, Charcoal and Black liquor.

Common types of woodfuel (FAO, 2018)



Woodfuels, Direct: Wood directly removed from Forests (natural forests and plantations; land with tree crown cover of more than 10% and area of more than 0.5 ha); Other Wooded Lands (land either with a tree crown cover of 5-10% of trees able to reach a height of at least 5 m at maturity in situ; or crown cover of more than 10% of trees not able to reach a height of 5 m at maturity in situ, and shrub or bush cover); and Other Lands to supply energy demands and includes both inventoried (recorded in official statistics) and non-inventoried woodfuels. Direct woodfuels can be directly burned or are converted into another fuel, such as charcoal, pyrolysis gases, pellets, ethanol, methanol, etc.

Woodfuels, Indirect: Usually consists of industrial by-products, derived from primary (sawmills, particle boards, pulp and paper mills) and secondary (joinery, carpentry) wood industries, such as: sawmill rejects, slabs, edging and trimmings, sawdust, shavings and chips bark, black liquor, etc.. Indirect woodfuels can be directly burned or are converted into another fuel, such as charcoal, pyrolysis gases, pellets, ethanol, methanol, etc.

Woodfuels, Other: includes a broad range of liquid and gaseous fuels derived from fuelwood and charcoal basically by pyrolysis or enzymatic processes, such as pyrolysis gases, ethanol, methanol, products of growing interest but to date not as important as energy commodities (FAO, 2001).

Woodfuels, Recovered (or Recycled): Woody biomass derived from all economic and social activities outside the forest sector, usually wastes from construction sites, demolition of buildings, pallets, wooden containers and boxes, etc., burned as they are or transformed into chips, pellets, briquettes, powder, etc.

Woodfuels, Solid: Includes fuelwood (also called firewood), charcoal and wood pellets (briquettes, chips) produced from wood or wood residues. Fuelwood comprises unprocessed woody biomass harvested from the stems, branches or other parts of trees, and it sometimes is also taken to include wood residues (such as sawdust and wood shavings) derived from timber harvesting or wood-processing industries used for energy production.

Annex

Selected Country Case Studies

Demostration of biomass stove

Scott Chacon / Flickr / CC BY 2.0

A fuel-effiecient rocket stove

Inhabitat / Flickr / CC BY-NC-ND 2.0

Benin

Heavy reliance on biomass energy

Benin, officially Republic of Benin, is a narrow wedge of territory in west Africa extending northward for about 675 km from the Gulf of Guinea in the Atlantic Ocean, on which it has a 12` km seacoast, to the Niger River, which forms part of Benin's northern border with Niger. Benin is bordered to the northwest by Burkina Faso, to the east by Nigeria, and to the west by Togo (Ronen, Adotevi, & Law, 2017). The original rain forest, which covered most of the southern part of the country, has now largely been cleared, except near the rivers. In its place, many oil palms and rônier palms have been planted and food crops are cultivated. North of Abomey the vegetation is an intermixture of forest and savanna (grassy parkland), giving way farther north to savanna. Apart from the oil and rônier palms, trees include coconut palms, kapok, mahogany, and ebony. The few stretches of tropical forest that remain in Benin, mostly in the southwest and central areas, contain mahogany, iroko, teak, samba, and other tropical hardwoods (Ronen, Adotevi, & Law, 2017).

In Benin, around 2009 access to modern fuels for cooking was rather insignificant and it seems not much has progress has been made in recent years.

In 2015 biomass energy fuels were estimated to provide 99 per cent of Benin's total national energy supply (AFREC, 2014). As Benin's population increases, the forest area decreases (Table 2). The production of

Table 1: Fuels used for cooking and access to modern fuels in Benin (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0	3.7	1.9	21.2	72.2	93.4	-	-	1	5.6
Rural	0	0.2	0.9	6.5	91.7	98.2	-	-	0.7	1.1
Urban	0.1	9	3.2	43	43.3	86.3	-	-	1.4	12.3

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2: Benin's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m³)
2000	6,865.951	5,061	183	5,910
2010	9,199.259	4,561	242	6,275
2015	10,575.952	4,311	49	6,507

Note the production of woodfuel has been steadily increasing whereas charcoal production has been erratic.

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Benin, 1990-2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m³)	
	Household	Total	Household	Total
1990	134	134	1,873	5,676
2000	184	184	3,935	4,725
2010	351	421	5,623	6,754
2015	446	535	5,211	6,307

Source: (UNDATA, 2018)

Table 4: Benin's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Woodfuel	161.00
Urban Per Capita Consumption of Woodfuel @ 10% of Total Consumption	322.60
Rural Per Capita Consumption of Woodfuel @90% of Total Consumption	29.20
National Per Capita Consumption of Charcoal Fuel	59.00
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	117.80
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	10.70

Source: (AFREC, 2014)

woodfuel increased while the production of charcoal decreased in 2015.

Consumption of both charcoal and fuelwood has been increasing with households being the major users (Table 3).

As with many countries in Sub-Saharan Africa, Benin's energy sector is dominated by the use of biomass-based energy sources. Traditional fuels such as woodfuel and charcoal are the most frequently used. Around 97 per cent of rural households rely on woodfuel for cooking.

The potential of wood energy includes contributions generated through National Reforestation Campaigns, as well as allocations of the National Wood Resources Office. The objective of the dedicated firewood project is to increase the supply of wood energy by enlarging plantations in the south of Benin. Besides traditional wood energy, a substantial potential of about 5 million tonnes is identified from agricultural residues. There are currently only a few production capacities for ethanol. For example, the Benin sugar plant, operated by Sucrerie Complant du Bènin (SUCOBE), produces 40,000 tonnes of sugar and 4,200 m^3 of ethanol per year. The YUEKEN Benin International plant has an output of 3,000 m^3 of ethanol per year, derived from cassava. Due to the missing distribution infrastructure this production is not used for energy or transport purposes. Various oils like pourghère, castor, palm, cotton, soy and peanut oils could be used for the production of biodiesel. In Benin there are few plants that can process vegetable oil to transport fuels. Two installations with a combined capacity of 210,000 tonnes are located in Bohicon. Furthermore, there is a palm oil plant in Hinvi. The capacities of these plants are not fully exploited, with currently only 30 per cent being used. The utilization of ethanol at an admixture rate of 15 per cent will create a market for roughly 33 million litres per annum. A recent survey identified a potential of 116 million litres in 2015 and 229 million litres in 2020. If the market of the European Union is considered, these figures are even higher (AFREC, 2014).

The area of biomass energy is governed at the level of use of wood resources for various purposes, including woodfuel, by the forestry legislation and Bill No.98030 of February 12, 1999 relating to the Framework Bill on the Environment. The government is working on a bill on renewable energies and energy control in Benin. (Gouhizoun, 2018).

Wooded savanna being cleared for agriculture

Gray Tappan / USGS

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Cameroon

Tropical deforestation due to commercial plantations and wood extraction

Cameroon lies at the junction of western and central Africa. Its ethnically diverse population is among the most urban in western Africa. The capital is Yaoundé, located in the south-central part of the country. The hot and humid south supports dense rainforests where evergreen trees may grow to more than 60 metres tall. Mangroves grow along the coasts and at the mouths of rivers. The rainforest gives way to the semi-deciduous forest of the central region, where a number of tree species shed their leaves during the dry season. North of the semi-deciduous forest, the vegetation is composed of wooded savanna with scattered trees 3 to 18 metres high. The density of trees decreases toward the Chad basin, where they are sparse and mainly of Acacia species. About half of the country is forested, but only about one-third of the available hardwood forest resources are exploited. Nevertheless, the export of sawn wood, which provides more than one-tenth of Cameroon's export earnings, is one of the country's most important sources of trade income. Forestry is largely limited to the most accessible areas along the Douala-Yaoundé railway and the main roads, but

Table 1: Fuels used for cooking and access to modern fuels in Cameroon (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0.1	16.1	5.2	1.7	73.5	75.2	-	-	3.4	21.4
Rural	0	1.4	1.2	1	93.9	94	-	-	2.5	2.6
Urban	0.2	30.6	9.1	2.4	53.2	55.6	-	-	4.5	39.9

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Cameroon's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m³)
1990	11,715	24,316	216	7,648
2000	15,274	22,116	21	9,111
2010	19,971	19,916	429	9,906
2015	22,835	18,816	477	10,355

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Cameroon, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m³)	
	Household	Total	Household	Total
1990	216	216	10,077	12,836
2000	99	99	13,536	17,069
2010	195	214	16,699	18,439
2015	220	243	18,916	20,887

Source: (UNDATA, 2018)

Table 4: Cameroon's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	99
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	171
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	21
National Per Capita Consumption of Charcoal Fuel	25
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	43
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	5

Source: (AFREC, 2014)

expansion into new areas is occurring rapidly (Benneh & DeLancey, 2017).

Approximately 18 per cent of the households rely on clean cooking fuels (WHO, 2016). A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

Cameroon's energy balance shows a clear predominance of renewable energy (RE) sources particularly biomass. Cameroon also has the third largest biomass potential in sub-Saharan Africa. Primary uses for biomass in the country include heating and light for the majority of the rural population. Utilization of palm oil for biodiesel is also a viable prospect for the country (AFREC, 2014).

Modern bioenergy remains largely untapped due to a lack of availability of biomass data and gaps in existing policies. Environmentally benign residues amount to 1.11 million bone dry tonnes per year in Cameroon. This has the potential to yield 0.12–0.32 billion liters of ethanol annually to displace 18–48 per cent of the national consumption of gasoline. Alternatively, the residues could provide 0.08–0.22 billion liters of biomass to Fischer Tropsch diesel annually to offset 17–45 per cent of diesel fuel use. For the generation of bioelectricity, the residues could supply 0.76–2.02 TW h, which is the equivalent of 15–38 per cent of Cameroon's current electricity consumption. This could help spread electricity throughout the country, especially in farming communities where the residues are plentiful. The residues could, however, offset only 3 per cent of the national consumption of traditional biomass (woodfuel and charcoal (Ackom, Alemagi, Ackom, & Tchoundjeu, 2013). Production of charcoal and woodfuels has been increasing along with the country's population (Table 3). At the same time forest land has been decreasing.

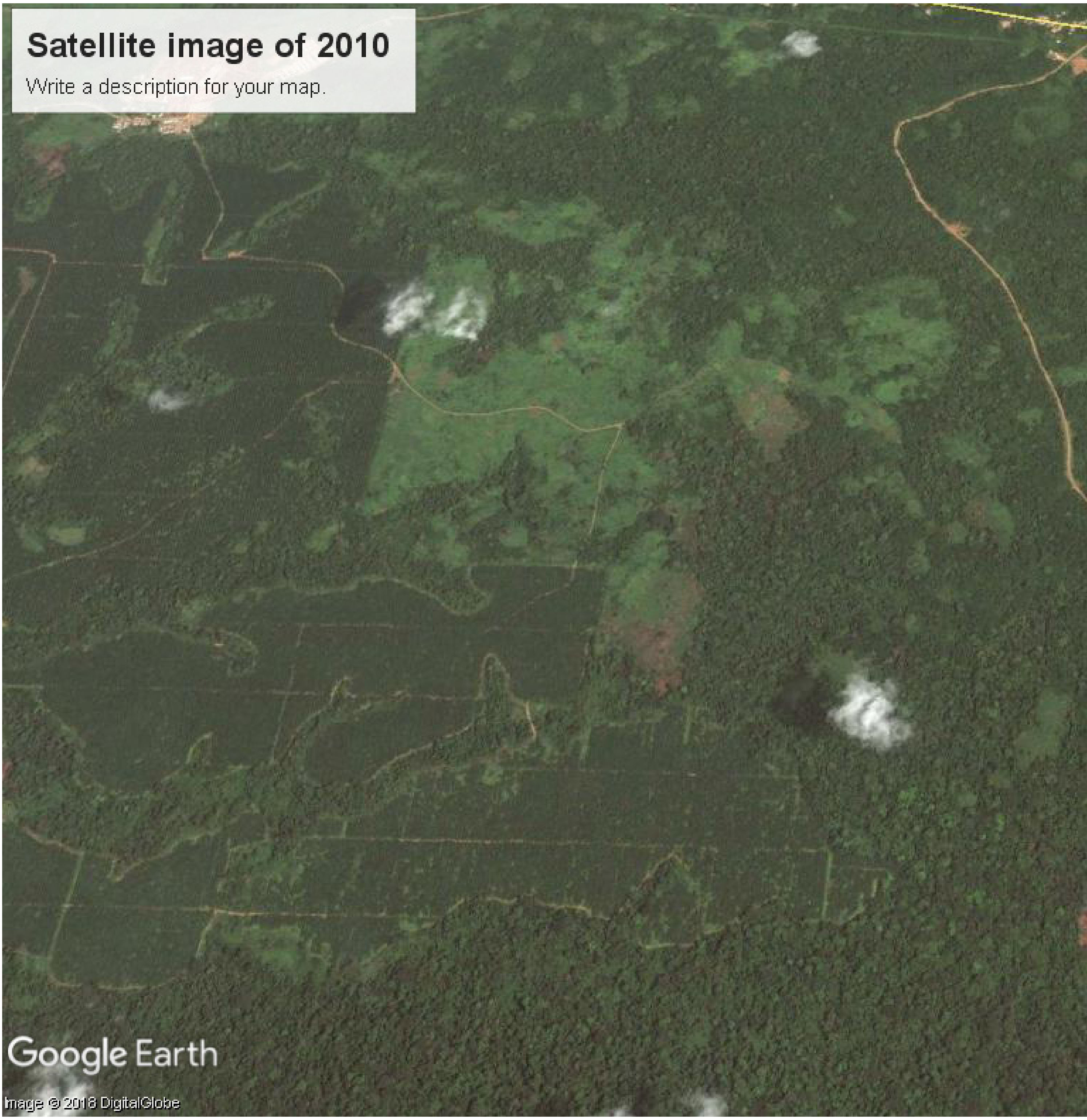
Biomass energy fuels provided an estimated 26 per cent of Cameroon's total national energy supply in 2015 (AFREC, 2014), Table 4 shows a per capita breakdown of woodfuel and charcoal fuel consumption.

One study estimates a total consumption of 2.2 million metric tonnes for woodfuel and 356,530 metric tonnes for charcoal in urban areas of Cameroon. Firewood and charcoal contribute to the GDP for an estimated amount of US$ 304 million representing 1.3 per cent of the GDP of Cameroon. In addition, the sub-sector provides about 90,000 equivalent full-time jobs while 80 per cent of the people in Cameroon depend entirely on wood-energy for household energy supply.

The fuelwood sub-sector represents a turnover estimated at over Euro € 287.1 million per annum and an added value of over 232 million per annum making it the largest sub-sector in the forest-wildlife sector after the timber sub-sector (industrial and artisanal). Moreover, the value of self-consumption of fuelwood is estimated at nearly €119 million per annum. On the social front, the fuelwood sub-sector is certainly more important than the timber sub-sector not only going by the number of full-time equivalent jobs it provides (here estimated at 90,000), but also because it plays a crucial role in food security given that about 80 per cent of the people of Cameroon (16 million) depend on it to cook their food. Source: (Atyi, Poufoun, Awono, Manjeli, & Kankeu, 2016)

From 2011-2014 Cameroon established production facilities for charcoal from sawmill waste and strengthened local cooperatives. A total of 29 t charcoal produced — 96 t sold—640 tCO_2 emission reduction (van Dam, 2017).

Resources are considerable and fuelwood remains in many cases a by-product of agriculture or the logging of timber or poles. On the contrary, the sector suffers from a lack of organization both with regard to public services and private actors. The legislation is inadequate and institutional framework inappropriate. These organizational, legal and institutional shortfalls may in



turn aggravate the situation in the Far North and North Regions by promoting the destruction of resources in addition to promoting illegality and depriving the State of needed resources. Fuelwood energy will continue to play an important role in the next 15–20 years and its demand will definitely increase over the next 5–10 years (Atyi, Poufoun, Awono, Manjeli, & Kankeu, 2016).

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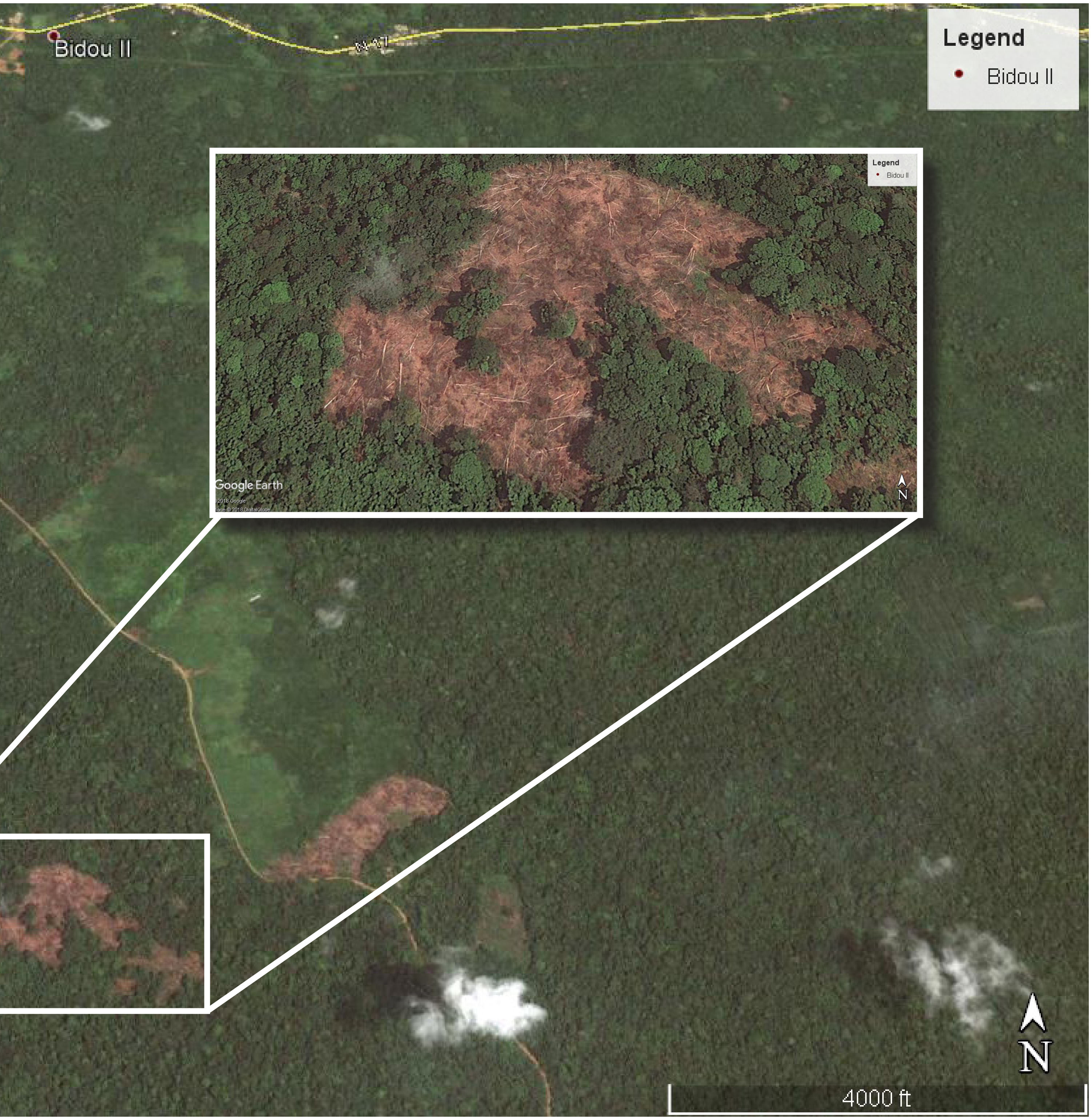

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Democratic Republic of the Congo

Deforestation along road networks

The Democratic Republic of the Congo, (DRC) has a 25- 40-km coastline on the Atlantic Ocean but is otherwise landlocked. It is the second largest country on the continent; Plant life is lush and varies between climate zones. Grasslands and woodlands are characteristic of the tropical climate zone, while stands of mangrove dominate the coastal swamps and the mouth of the Congo. The eastern plateaus are covered by grasslands, and mountain forest, bamboo thickets, and Afro-Alpine vegetation occur on the highest mountain (Wiese, Lemarchand, & Cordell, 2017). Approximately 68 per cent of DRC's surface area (154,446,400 ha) is covered by Africa's greatest extent of rainforests, and the world's second-largest. About 45 per cent of the country's territory is covered by primary forest, among the most species-rich habitats

Table 1: Fuels used for cooking and access to modern fuels in DRC (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	4.6	-	0.1	28.9	66.2	95.2	-	-	0.2	4.7
Rural	0	-	0	11.4	88.5	99.9	-	-	0.1	0
Urban	10.8	-	0.2	52.2	36.6	89	-	-	0.2	11

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:DRC's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m³)
1990	34,615	160,363	791	44,183
2000	47,076	157,249	1,431	64,903
2010	64,523	154,135	2,025	76,602
2015	76,197	152,578	2,400	82,526

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for DRC, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m³)	
	Household	Total	Household	Total
1990	0	0	37,812	37,812
2000	1,431	1,431	64,903	64,903
2010	728	728	60,941	78,081
2015	3,936	3,936	63,909	77,944

Source: (UNDATA, 2018)

Table 4: DRC's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	621
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	564
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	95
National Per Capita Consumption of Charcoal Fuel	57
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	51
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	9

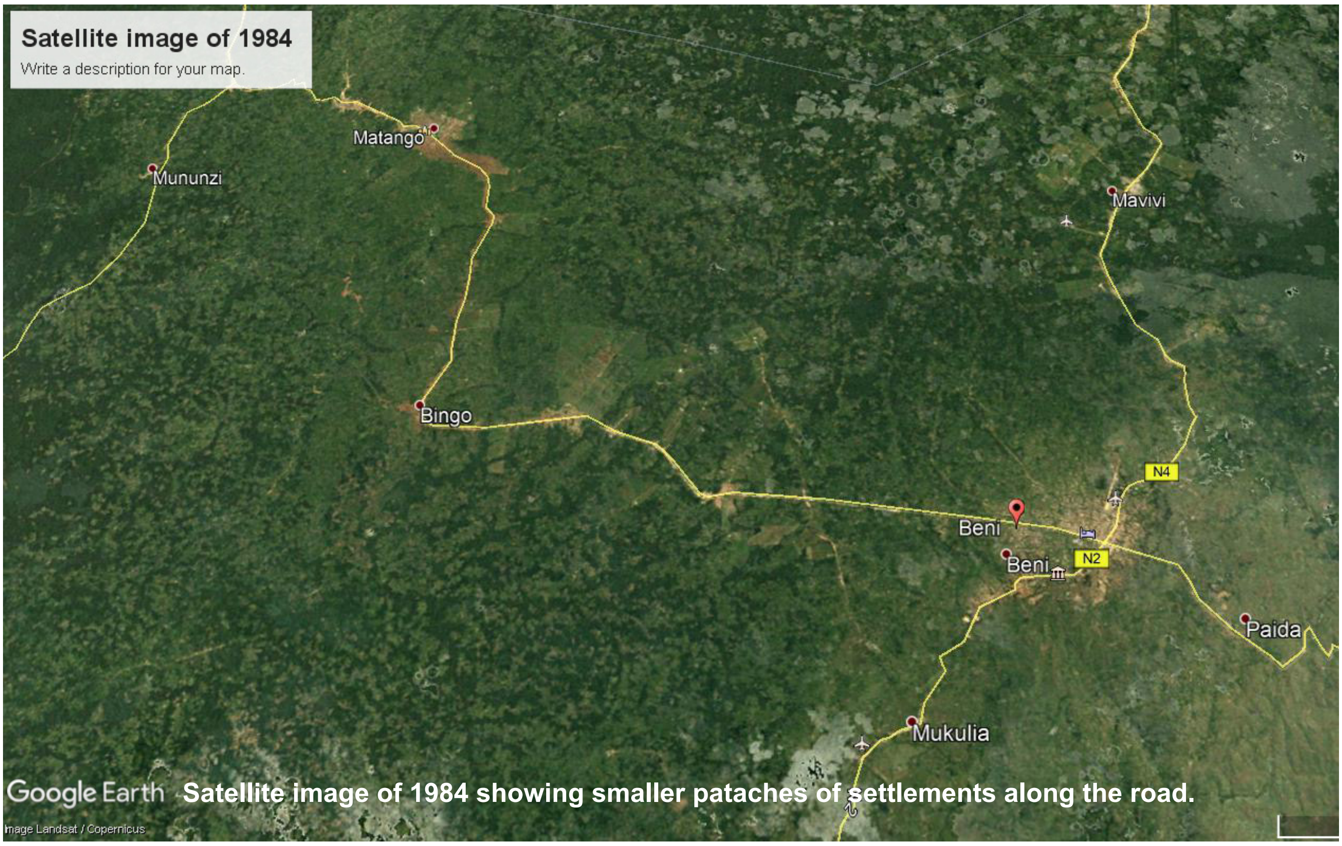
Source: (AFREC, 2014)

on earth (Picton-Tubervill & Derrick, 2017). The wood potential is 12.5 billion m^3 i.e., 100 m^3 of wood per hectare, and annual production is 2 m^3/ha (AFREC, 2014).

Currently about 94 per cent of the DRC's population relies on traditional uses of biomass, mainly wood in rural areas and charcoal in urban areas (WHO, 2016). A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

It is estimated that 490,000 tonnes of charcoal is used every year in Kinshasa alone. Apart from fuelwood, the country's potential includes agriculture and animal wastes. It is estimated, for instance, that in 2005, bagasse resulting from sugar production amounted to 195,600 tonnes, enough to power a 100 MW biomass power plant with 24 hours' production per day (Picton-Tubervill & Derrick, 2017).However, the lack of infrastructure in the country, and the dispersed form of waste production, is not encouraging for viable biomass projects. Moreover, despite its enormous potential, the biomass energy sector remains unregulated and informal (Picton-Tubervill & Derrick, 2017).


Charcoal burning

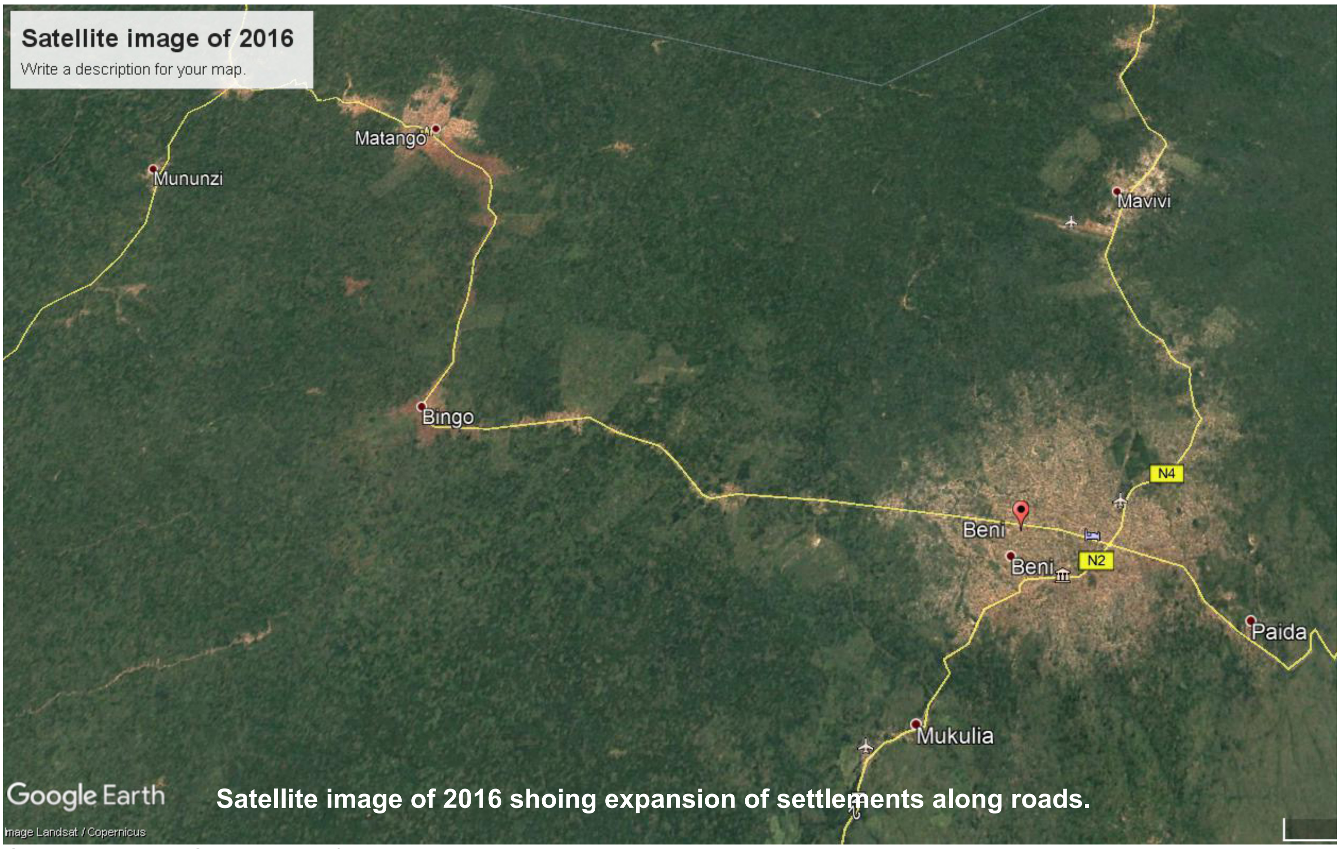


Green: Vegetation; Grey : Bare surfaces and settlements

Much of the biomass is from shifting cultivation plots and secondary forest fragments. Wood for charcoal production is often harvested from coppice systems, where trees re-sprout after cutting; coppicing is especially common among trees in dry environments where seasonal stress and animal grazing favor coppice strategies. Even in Africa, where woodfuel harvest is most common, deforestation caused by wood collection is estimated at only 5-20 per cent. While charcoal harvest and coppice management can be managed sustainably, coppice rates are dependent on a multitude of factors including harvest rates, soil fertility, grazing, and precipitation (Yale, 2014). Production of charcoal and fuelwood has been increasing over the years, but at the same time the forest area has been decreasing (Table 2).

A pattern of deforestation concentrated along the major road N4 near the city of Beni can be seen clearly in the 2018 satellite image as loops of light green through the otherwise dense rain forest. Most of this deforestation is the result of agricultural expansion, fuelwood collection, and settlement.Even though deforestation is occurring there may also be some gains in tree cover due to natural regeneration, afforestation and reforestation illustrating that forests are renewable. In 2009-2013 techniques for sustainable resource management, village management and community plantations were introduced. Accomplishments include:

- More than 1,700 ha of village tree plantations planted (100 villages, 800 nurseries)
- Reforestation with 60,000 trees
- 20,000 ha of managed forest lands (FAO, 2017).



Green: Vegetation; Grey : Bare surfaces and settlements

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Ethiopia

Charcoal production unabated

Ethiopia is on the Horn of Africa. The country lies completely within the tropical latitudes and is relatively compact, with similar north-south and east-west dimensions. Ethiopia's natural vegetation is influenced by four biomes. The first is savanna, which, in wetter portions of the Western highlands, consists of montane tropical vegetation with dense, luxuriant forests and rich undergrowth. Drier sections of savanna found at lower elevations of the Western and Eastern Highlands contain tropical dry forests mixed with grassland. The second biome is mountain vegetation; it comprises montane and temperate grasslands and covers the higher altitudes of the Western and Eastern highlands.

The third biome, tropical thickets and wooded steppe, is found in the Rift Valley and Eastern Lowlands. The fourth biome is desert steppe vegetation, which covers portions of the Denakil Plain (Mehretu, Crummey, & Marcus, 2017).

Ethiopia's energy sector is highly dependent on biomass, such as woodfuel, charcoal, crop residues and animal dung. The country has a huge biomass energy potential with estimates putting the national woody biomass stock at 1,149 million tonnes with annual yields of 50 million tonnes in the year 2000. Biomass energy accounted for 89 per cent of total national energy consumption in 2010 (AFREC, 2014)

Table 1: Fuels used for cooking and access to modern fuels in Ethiopia (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0.2	0.1	3.9	2.8	85	92	7.4	-	0.6	4.2
Rural	0	0	0.2	0.2	91.1	91.5	8.3	-	0.2	0.2
Urban	1	1.2	25.9	18.1	48.7	94.9	2.1	-	3	28.1

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Ethiopia's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m³)
2000	66,537	13,705	2,908	87,471
2010	87,703	12,296	3,734	101,274
2015	99,873	12,499	4,220	108,174

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Ethiopia, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m³)	
	Household	Total	Household	Total
2000	2,850	2,908	70,020	70,020
2010	3,621	3,734	77,944	78,869
2015	4,095	4,220	81,760	82,853

Source: (UNDATA, 2018)

Table 4: Ethiopia's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	73
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	4,960
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	113
National Per Capita Consumption of Charcoal Fuel	73
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	386
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	9

Source: (AFREC, 2014)

Biomass distribution across the country is uneven, with the northern highlands and eastern lowlands having low biomass cover. Population growth is putting pressure on these resources. Agro-processing industries, such as processing sugar-cane bagasse, cotton stalk, coffee hull and oil- seed shells, present an opportunity for biomass energy. But currently, there are no grid-connected biomass power plants. Municipal waste and biofuels have been underutilized, although the current Growth and Transformation Plan seeks to address this by stepping up the dissemination of domestic biogas plants, vegetable oil stoves and improved stoves (UNEP, 2017).

A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

Currently, less than 5 per cent of Ethiopia's population has access to clean cooking fuels (WHO, 2016). In 2015, and estimated 97 per cent of the country's total national energy supply came from biomass energy fuels (AFREC, 2014). Charcoal and fuelwood production have been steadily increasing over the years (Table 2).

Charcoal production and marketing is generally informally organized and implemented by the private sector. Prior to 1993 the state-owned Construction and Fuelwood Production and Marketing Enterprise (CFPME) had in theory the monopoly for charcoal production and marketing. In practice a great proportion of charcoal was produced and marketed "illegally" outside the State monopoly. After 1993 CFPME wound down its operations and was finally


Cooking stoves, Tigray

Rod Waddington / CC BY-SA 2.0 / Flickr


Charcoal distribution

Carsten ten Brink / CC BY-NC-ND 2.0 / Flickr


Selling charcoal at market

Carsten ten Brink / CC BY-NC-ND 2.0 / Flickr disbanded (Geissler, Hagauer, Horst, Krause, & Sutcliffe, 2013).

In August 1997 check points for charcoal were removed. It was intended that charcoal production could be better controlled by communities themselves. It was also envisaged that charcoal producers would be licensed and that Bureaus of Agriculture would be able to develop and enforce sustainable forest practices. In practice there have been delays in developing and implementing sustainable charcoal production practices at the field level and instituting a system of licensing and currently there is no nationally implemented charcoal strategy. However, increasingly regions are taking their own initiatives.

In Amhara region charcoal production and sales are permitted only if Eucalyptus or other exotic species are used. This has been occasioned by the opening up of the timber and charcoal markets in Sudan with the construction of the new road through Metema to Sudan.

In the Afar region in some of the large irrigation farms, charcoal burners are being invited to remove and use the invasive and disturbing tree Prosopis for the production of charcoal. Prosopis was introduced to partly reduce soil erosion, partly to produce biomass for feed and as life fence.

Currently, little or no official technical support is given to charcoal production and marketing, which is a legacy of the negative official view on charcoal production as being responsible for deforestation. There is no linkage of woodland and forest management to the production of charcoal, through e.g. 20-30 years rotational harvesting of woodland for charcoal production linked to woodland communities' supervision and licencing (Geissler, Hagauer, Horst, Krause, & Sutcliffe, 2013).

Active local-level institutions increase household dependency on open access forests, while land security reduces open access forest dependence. However, local level institutions are found to reduce the role of private fuelwood, while tenure security has not, at least yet, had any impact on private fuelwood collection activities. There is a need to bring more open access forests under the management of the community and increase the quality of community forestry management in order to realize improvements in forest conservation (Beyene & Koch, 2013).

In Ethiopia, households switching from a traditional three-stone open fire to an improved model saved between 20 per cent and 56 per cent of woodfuel (Mendum & Njenga, 2018)

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Kenya

Charcoal production and market

Biomass contribution to Kenya's final energy demand is 70 per cent and provides for more than 90 per cent of rural household energy needs. The main sources of biomass for Kenya include charcoal, wood-fuel and agricultural waste. The Government has identified the existence of a substantial potential for power generation using forestry and agro-industry residues including bagasse. It is estimated that 80 per cent of urban households' wood-fuel demand is met by charcoal (AFREC, 2014). The Kenya charcoal sub-sector employs about 200,000 charcoalers from impoverished rural areas of semi-arid districts like Kitui, Narok and Kajiando. There are also around 2,700 transporters, based mostly in the urban areas, and almost 500,000 charcoal vendors. The employees then support about 2.5 million people in terms of basic commodities like food, clothing and education (Ndegwa, Breuer, & Hamhaber, 2011).

Biomass, in the form of woodfuel and charcoal, is used extensively in rural areas, mostly by poor households for cooking and heating. It is estimated that 83 per cent of the population relies on biomass, though accurate figures are near-impossible to obtain since biomass exists mainly in the informal sector. Kenya's over reliance on biomass as a source of energy is perpetuated by poor rural electrification (Mukkam-

Table 1: Fuels used for cooking and access to modern fuels in Kenya (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0.6	3.5	13.2	13.3	68.7	99.3	-	-	0.7	17.3
Rural	0.2	0.7	2.7	7.7	88.2	99.5	-	-	0.5	3.6
Urban	1.8	12	44.6	30.2	10.3	98.9	-	-	1.1	58.4

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Kenya's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m³)
1990	23,403	4,724	463	16,793
2000	31,451	3,557	641	19,658
2010	41,350	4,230	937	26,400
2015	47,236	4,413	1,119	26,400

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Kenya 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m³)	
	Household	Total	Household	Total
1990	840	870	33,232	33,232
2000	640	640	19,658	19,658
2010	5,891	5,891	11,607	11,607
2015	6,485	6,485	8,807	8,807

Source: (UNDATA, 2018)

Table 4: Kenya's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	88
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	1,662
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	58
National Per Capita Consumption of Charcoal Fuel	88
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	331
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	12

Source: (AFREC, 2014)

Owuor & Kageni, 2018).There has been a recent push towards the use of ethanol, biogas and solar energy as alternative sources of energy due to greater awareness of the adverse impact which using biomass has on the environment, such as deforestation and pollution (Mukkam-Owuor & Kageni, 2018).

Kenya's forest resource is estimated at 3 million hectares of land. This comprises of 1.64 million hectares of canopy forest, 851,000 hectares of rain forest, 610,000 hectares of plantain forest and 211,000 hectares of dry zone forest (MEWNR, 2013). These forests are located in the following water towers: Mt Kenya, the Mau complex, Cherangani Hills, Aberdare range and Mt Elgon. Others are located along rivers such as Yala, Tana, Ewaso Nyiro, Athi, Nyando, Sondu, Turrkwel and Chania.

Only about 6 per cent of Kenya's households have used clean cooking fuels (WHO, 2016). A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

Current wood deficit is projected to increase from 10 million m^3 to at least 15 million m^3 per year by 2030 (MENR, 2016). An estimated 97 per cent of Kenya's total national energy supply comes from biomass energy fuels (AFREC, 2014).

While the production of charcoal has steadily increased over the years, the production of fuelwood has appeared to stabilized (Table 2).

In 2015, Kenya was the largest charcoal consumer in Africa (Table 3) (UNDATA, 2018).

Charcoal production and consumption pattern - Charcoal production heavily relies on wood obtained from forests. Production is achieved in three main ways; one, as a by-product after timber production, two, forest being specifically targeted for charcoal production, and three, when forests and other vegetation cover are being cleared or burnt to make land arable/agriculturally productive.

Although the Energy and Forestry Policies and Acts have recently legalized sustainable charcoal production, numerous challenges still affect the industry, while its true value is not adequately captured in national economic statistics. Increased charcoal consumption and the use of traditional kilns have resulted in increased destruction and depletion of national tree resources. For example, every tonne of charcoal produced through a traditional kiln depletes approximately 0.1 hectare of woodland. An efficient kiln would require only 0.05 hectares for every tonne of charcoal produced, a 50 per cent saving. This calls for tree growing aimed at sustainable on-farm / community level charcoal production and widespread adoption of efficient wood conversion technologies (Oduor, Ngugi, & wa Gathul, 2012).

To convert wood into charcoal, most producers generally use traditional kilns, with efficiencies of 10-22 per cent (FAO, 2017), which are illegal and informal because they are both labour and energy intensives. Therefore, producers have to construct them where the wood is being harvested to cut on transportation costs. However, there are other alternative kilns ranging from Improved Kilns, Semi-industrial Kilns to Industrial kilns with efficiencies of 12-18 per cent, 18-24 per cent, above 24 per cent respectively. Due to the high installation costs such efficient kilns are in most cases used for production where the producers have formed an association.

Charcoal production varies with seasons. However, the average production per producer is 30 bags per month. The number of producers, producing in Charcoal Producer Associations (CPAs), in Kenya is estimated to 28, 201, which if added to unregistered producers, sums up to 253, 808 (MEWNR, 2013).

Woodfuel production and consumption pattern - Woodfuel supplied approximately 89 per cent of the rural energy where it is used not only for domestic purposes but also in the cottage industries; such as tea industry, kiosks, restaurant, brick making and tobacco, and in institutions such as hospital, colleges and school. Some industries including sugar and brick-making rely on bagasse. According to AFREC, woodfuel production is estimated at 33.2 million tonnes. Consumption is lower, at 18.4 million tonnes, as shown in the table 2 above.

Demand for Biomass - The demand for biomass varies depending on the source, the affordability of alternative sources and the targeted end consumer. While the demand for woodfuel is higher in rural households, urban households heavily rely on charcoal, making its demand higher in such areas.

The affordability and availability of alternative sources, normally affects the demand for charcoal. Back in 2005 the demand of charcoal was high which in turn dropped because of the availability of alternative sources of energy such as LPG and paraffin. Most urban households shifted to the use of these alternative sources and only relied on charcoal when they wanted to cook food that took longer hours to prepare such as beans. However, the demand of charcoal in Kenya has shown a rising trend especially due to the increase in price of the aforementioned alternative sources. A sack which cost Kshs 500 in 2005 now costs approximately Kshs 950. Kenya requires around 87- 1,712 hectares of forests to meet the annual charcoal demand of 2.5 Mt (Iiyama, Petrokofsky, Kanowski, & Kuehl, 2013); (FAO, 2017) .

Marketing system and Pricing - The price of biomass products, charcoal and woodfuel depends on seasons and proximity to urban areas. Biomass produced in small-scale will often be sold at the producer premises. Some producers market their products on a door to door basis using bicycles or motorbikes, or directly delivering an order that had been placed earlier by the customer. Such markets can be reached by foot or any other form of public transport, and the producer, in most cases is not required to satisfy the requirements of Kenya Bureau of Standards (KEBS). Large scale producers and wholesalers use trucks transporter to deliver their resource to the market or to buy, in bulk, the produce from small scale and farm producers. Unlike the small-scale producer, most of large scale producer adhere to the requirement to cooperate with a permit.

With the briquettes, they are sometimes supplied to supermarkets for retailing and unlike the small-scale charcoal production they must meet the requirement of KEBS. They are also sold in bulk due to the diversified market base and financial capability. In advertising their products, some producer gives samples for free and even demonstrate their effectiveness to the customer. In most cases they empty the sack to another to ensure that the sizes remain constant and of satisfactory nature.

Charcoal had an extensive market in urban areas because it is presumed to be cheap, therefore affordable. In the urban areas, charcoal cost about Ksh 12,000 per household per year contrasted with electricity, Ksh 59,200. In small quantities, a 2 kg container of charcoal cost Ksh 30-50 while a 90 kg sack goes for around Kshs 1950 (retail). These costs do not reflect the real value of charcoal because most producers do not pay for the price of raw material. This has made it impossible for the government to enforce levies and licensing regulation hence loss of revenue.

Charcoal hotspots in Kenya - Production is always dominant in arid and semiarid areas, where production is unsustainable due to the use of inefficient technologies. This is because charcoal producing species such as Acacia and Prosopis juliflora survive in hot dry lands areas.

Hotspots in Kenya include, Makueni, Kajiado, Elgeyo Marakwet, Tana River, Kwale, Baringo, Kitui, Kilifi, Garisa, Laikipia, Turkana and Meru. In Kajiado County, the main hotspot is Bisil area, near Namanga, where the dominant specie is acacia and the kilns used being traditional earth kilns. 90 per cent of the produced charcoal is transported to Nairobi for sale (MEWNR, 2013).

In Baringo, the sites include Salabani, IIinarwa, Loboi and IIchamus locations. Half of the charcoal produced is transported to Nakuru, 40 per cent and 10 per cent being delivered to Nairobi and other areas respectively (MEWNR, 2013).

Makindu, Kibwezi and Makueni are the dominant hotspots in Makueni County. In Kwale County the dominant sites include Lunga Lunga and Mwereni ranches which produce almost 90 per cent of the county. Mombasa provides the market, with a small quantity being transported to Nairobi (MEWNR, 2013).

Kenya could lose about 65.6 per cent of its forest cover to charcoal production and use by 2030. Taking measures to propagate the most preferred Acacia species and ensuring massive tree planting exercise especially in order to protect arid areas of the country is important. Legislations on charcoal, reforestation/afforestation should be reinforced nation-wide if Kenya hopes to transition to a green economy within its vision 2030 agenda (Onekon & Kipchirchir, 2016). The traditional three-stone stove is the most common technology in the rural areas, with the Ministry of Energy reporting that it is used by about 96 per cent of the rural population. The energy policy (2004), and the Vision 2030 for Kenya, sector plan for Energy (2008) set the goal of increasing the national adoption rate of efficient wood stoves to 30 per cent by 2020, and efficient charcoal stoves to 100 per cent in urban areas and 60 per cent in the rural areas by 2020. The government also targets to improve the efficiency of the charcoal stoves from the current 30–35 per cent to 45–50 per cent by 2020 through investment in research and development (Ndegwa, Breuer, & Hamhaber, 2011).

While the existing energy sector reforms develop newly discovered energy sources, they should go a step further and institute an investment framework that encourages the diversification of energy sources and promotes renewable sources by making them competitive in the energy matrix. The legislature also ought to streamline all the laws which govern the various aspects of energy in the country,to avoid inconsistency and promote certainty (Mukkam-Owuor & Kageni, 2018).

In the meantime, given the popularity of biomass as a source of energy, the government ought to ensure sustainable use of biomass either through reforestation or reducing/changing consumption patterns. While demand for biomass is estimated at 40.5 million tonnes,Kenya's resources are currently only able to supply 16 million tonnes. Steps should be taken to address this mismatch between demand and supply (Mukkam-Owuor & Kageni, 2018).

Despite charcoal being an important energy source, its production and transportation is still artisanal and most of it is not regulated. The Energy Act and Policy, the Forest Act and Forest Policy recognize charcoal as an important source of energy and make provisions for its sustainable production, commercialization and utilization. In addition, the Ministry of Forestry and Wildlife has introduced subsidiary charcoal legislation to ensure these policies are implemented (Picton-Tubervill & Derrick, 2017).Forest in Kenya faces a myriad of challenges. Among them is illegal logging and unsustainable utilization of the forest products. Also, increase in population has led to human encroaching into forest reserves to establish settlement. These problems have reduced the extent of forest cover leading to a reduction in the available forest product.

Given the popularity of biomass as an energy source, the government should ensure sustainable use of biomass either through reforestation or reducing/changing consumption patterns. While the demand for biomass is estimated at 40.5 million tonnes, Kenya's resources are currently only able to supply 16 million tonnes. Steps should be taken to address this mismatch (Mukkam-Owuor & Kageni, 2018).

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Malawi

Making efforts to address deforestation problem

Malawi is a landlocked country in southeastern Africa. A country endowed with spectacular highlands and extensive lakes, it occupies a narrow, curving strip of land along the East African Rift Valley. The natural vegetation pattern reflects the country's diversity in relief, soils, and climate. Savanna (grassy parkland) occurs in the dry lowland areas. Miombo woodlands—sparse, open deciduous woodland characteristic of dry parts of eastern Africa—are an important habitat, particularly for the country's large mammal populations. Woodlands with species of acacia trees cover isolated, more fertile plateau sites and river margins. Grass-covered broad depressions, called madambo (singular: dambo), dot the plateaus. Grasslands and evergreen forests are found in conjunction on the highlands and on the Mulanje and Zomba massifs (Kadzamira, Phiri, Ingham, Kalinga, & Mitchell, 2017).

Malawi's energy balance is dominated by biomass (wood fuel, charcoal, agricultural and industrial wastes), which accounts for 97 per cent of the total primary energy supply. Household sector consumes about 92 per cent of biomass energy and the rest is distributed among other sectors. About 76 per cent of wood fuel is used for cooking, 21.5 per cent for heating

Table 1: Fuels used for cooking and access to modern fuels in Malawi (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	1.2	0	0	7.2	91.4	99.8	0	0	0.2	1.2
Rural	0.2	0	0	1.3	98.3	99.8	0	0	0.2	0.2
Urban	7.2	0.1	0	41.4	51.2	99.9	0	0	0.1	7.3

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Malawi's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m^3)
1990	12,171	3,896	344	5,164
2000	16,441	3,567	392	4,964
2010	23,369	3,237	490	5,405
2015	27,859	3,147	553	5,731

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Malawi, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m^3)	
	Household	Total	Household	Total
1990	0	344	3,101	3,101
2000	0	392	2,614	2,614
2010	0	490	2,465	2,465
2015	0	553	2,413	2,413

Source: (UNDATA, 2018)

Table 4: Malawi's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	266
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	1,529
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	32
National Per Capita Consumption of Charcoal Fuel	37
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	211
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	4

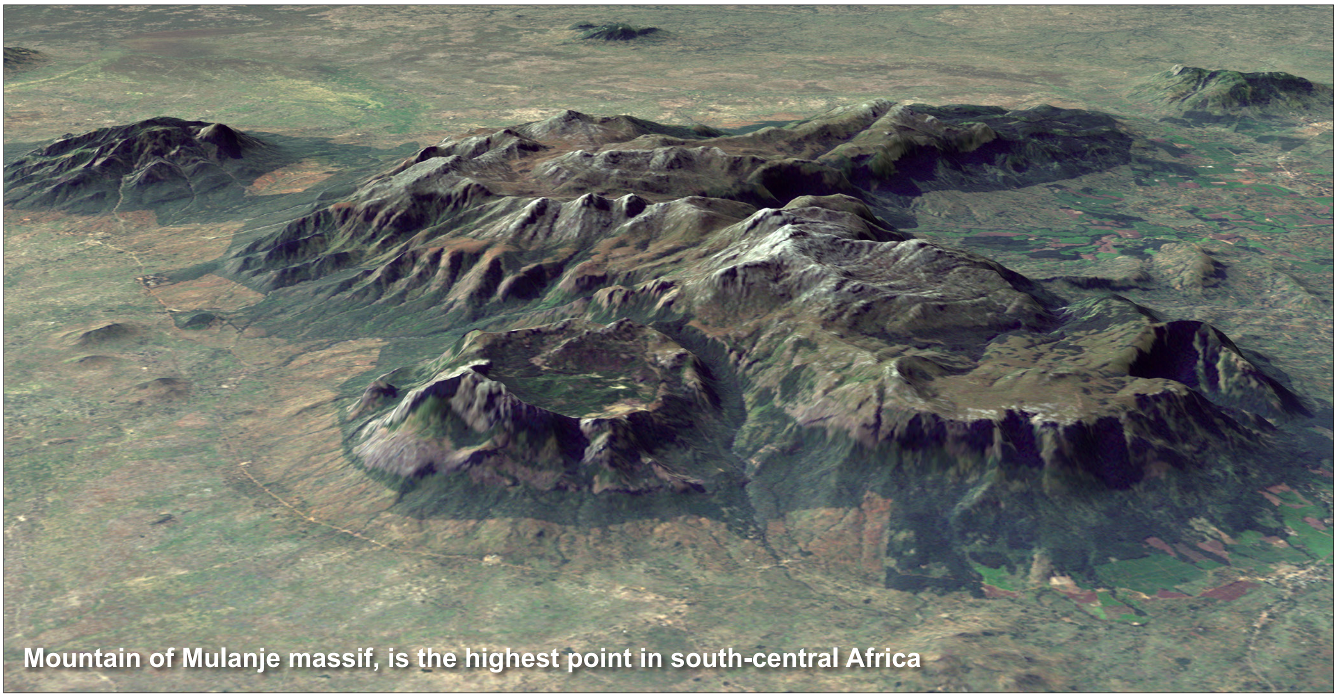
Source: (AFREC, 2014)

water, 2 per cent for space heating and the remainder for other uses. Nine out of 10 people use some form of biomass as a source of energy, and this translates to about 88.5 per cent of the total energy needs. In urban and rural areas, 43.4 and 41.8 per cent of people use charcoal and wood fuel for cooking, respectively (AFREC, 2014); (UNEP, 2017).

Demand for woodfuel exceeds the available sustainable supply and the deficit is increasing every year. Malawi is heavily dependent on biomass fuels yet the national energy policy has little information on biomass energy supply. The high usage of biomass by the growing population is a major driver behind loss in forest cover. Analysis of the sector reveals that wood resource base is diminishing mainly because woodlands and trees in agricultural areas are being cleared up to start new farming lands. Statistics show that between 1991 and 2008 about 669,000 hectares of woodlands were converted to farmlands. Diminishing standing stock is leading into gradual reduction of biomass that can be harvested (AFREC, 2014).

Government programs to improve efficiency in the sector are on-going. These include technologies options such as improved cook-stoves and the use of substitute fuels implemented by various government initiatives such as the National Sustainable and Renewable Energy Programme (NSREP) (UNEP, 2017).Much of the original woodland has been cleared, and, at the same time, forests of softwoods have been planted in the highland areas. Beginning in the early 1970s, the government sponsored the development of several large timber and pulpwood plantations aimed at making the country self-sufficient in construction grades of timber; pine and eucalyptus have also been


Tree nursery


Mountain of Mulanje massif, is the highest point in south-central Africa


Mulanje Massif
smoke
forest
farmland
Satellite image of forests in Mulanje 26 May 2002
N
5 km

planted extensively in the northern Viphya Mountains to supply a large pulp and paper project in the region. In spite of this, forest plantations account for only a fraction of the total Malawian forest cover (Kadzamira, Phiri, Ingham, Kalinga, & Mitchell, 2017).

The rapid rate at which wooded areas have been disappearing in Malawi, such as that in the Mulanje Mountain Forest Reserve, is a source of grave concern.

In southern Malawi, near the border with Mozambique, the land rises sharply into a multi-lobed plateau that towers about 1,400 meters (4,600 feet) above the landscape. The feature, an inselberg known as Mulanje massif, is the highest point in south-central Africa. While the lowlands get most of their rain during the wet season, the plateau sees rain year-round. Vegetation type varies with elevation. Mulanje's lower slopes are mainly miombo woodlands. The mid-elevation and upper slopes, as well as many of the ravines, are home to afromontane forests, which have a darker green color. Large outcrops of exposed rock appear gray.

Mulanje's forests, satellite observations show that deforestation has chewed away at the perimeter of many of them over the last decade. The lowlands surrounding Mulanje are densely populated, and people regularly harvest wood for cooking and heating. A wildfire is visible on the plateau in the Landsat image. (Source: NASA Earth Observatory image)

An estimated 91 per cent of Malawi's total national energy supply was from biomass energy fuels (AFREC, 2014). Currently less than 5 per cent of the population has access to clean cooking fuel (WHO, 2016). The use of wood as fuel is one major factor in the depletion of the country's woodlands. In rural areas, wood has always been used to provide fuel for cooking, and, as the population grows, more of it is used; in the urban areas, charcoal is the main source of energy, adding more pressure on woodlands. A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

Policy measures aimed at increasing cooking efficiency are not enough to decrease demand for cooking energy due to high population growth. Supply side interventions like agroforestry on the other hand will not only increase sustainable supply, but can also enhance food security and protect the environment. (Schuenemann, Msangi, & Zeller, 2018).

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According to the National Charcoal Strategy (2017-2027) nearly every Malawian household (97%) relies on firewood or charcoal as their primary source of cooking and heating fuel. With alternative fuel sources underdeveloped, firewood and charcoal will continue to form a significant part of Malawi's energy mix for the next few decades. Firewood remains the most used cooking fuel (88% of households), but charcoal now predominates in urban areas (54%). Between 1998 and 2014, the percentage of the population that relied on biomass energy actually increased from 94% to more than 97%. Over this same period, reliance on charcoal nationally increased five-fold (from 2% in 1998, to 11.3% in 2014), and charcoal surpassed firewood as the largest source of urban household cooking fuel (54.4% in 2014).

The charcoal value chain (CVC) in Malawi is complex. It includes the full process and the diverse set of actors involved from charcoal production to charcoal consumption. Main groups of interacting social actors in the CVC are: producers; rural and urban intermediaries (including charcoal packers, transporters by bicycle, headload, and trucks, and wholesalers); predominantly urban retailers (including women); and mostly household consumer

The production of charcoal in Malawi has been steadily increasing where as that of fuelwood has been fluctuating (Table 2). In any case the area of forest land has been decreasing.

The heavily dominant tobacco industry has resulted in further denudation of forests, as trees have been regularly felled both as timber for the construction of sheds to dry or cure the crop and to fuel the curing process itself. Another source of the problem is brick making, which relies heavily on wood fuel to fire the kilns. The reduction of casual labour and the number of civil service positions at the behest of the International Monetary Fund (IMF) and the World Bank has meant forest reserves no longer have personnel to guard them from abuse (Kadzamira, Phiri, Ingham, Kalinga, & Mitchell, 2017).

It is estimated that the annual sustainable supply of all biomass is some 2.7 times the demand. However, the seemingly surplus biomass energy is not accessible to all parts of the country because of spatial distribution of biomass resources. There are large surpluses in northern Malawi, but these are neither economically nor physically accessible to the bulk of the population living in the centre and the south because of high


Impounded vehicle carrying charcoal


Tree nursery for replanting degraded areas

transportation costs. Therefore, any efforts to improve production of biomass as a source of energy in the country should concentrate in the central and southern Malawi where there is more pressure than in the northern region. At the same time, programmes addressing biomass energy in the northern region should concentrate on sustainable use of the existing resources (Kambewa & Chiwaula, 2010).

In 2017, Malawi released two important strategies the National Forest Landscape Restoration Strategy and the National Charcoal Strategy (NCS) 2017-2027. The NCS is organized around seven inter-related pillars:

Pillar 1: Promote Alternative Household Cooking Fuels, focusing on:

- Electricity
- Liquefied petroleum gas (LPG)
- Briquettes and pellets
- Biogas

Pillar 2: Promote Adoption of Fuel-Efficient Cookstove Technologies

Pillar 3: Promote Sustainable Wood Production Pillar

4: Strengthen Law Enforcement

Pillar 5: Regulate Sustainable Charcoal Production

Pillar 6: Enhance Livelihoods

Pillar 7: Promote Information, Awareness and Behavior-Change Communications.

Malawi's National Forest Landscape Restoration Strategy and National Charcoal Strategy represent a huge step forward in articulating the drivers of the problems and the range of solutions available. They provide specific, actionable targets for curbing deforestation and restoring trees to the landscape by addressing both supply and demand (Reytar, 2017).

Malawi has banned the production, transport and sale of charcoal unless it is sustainably sourced. But the illegal trade is booming, serviced by rural residents who scrape a living turning timber into charcoal in a highly inefficient process which wastes enormous amounts of wood. According to the National Cook Stove Steering Committee, a coordinating body for officials, NGOs and other groups working on clean cook stoves in Malawi, 500,000 "clean and efficient" cook stoves are now in use. It hopes 2m Malawian homes, around 65 per cent of all households, will adopt the device by 2020 (Gercama & Bertrams, 2017).

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Niger

Increase in tree cover in farm lands of Southern Niger

Niger, officially Republic of Niger, French République du Niger, is a landlocked western African country. It is bounded on the northwest by Algeria, on the northeast by Libya, on the east by Chad, on the south by Nigeria and Benin, and on the west by Burkina Faso and Mali. The extreme southwest is a savanna region where baobabs, kapok trees, and tamarind trees occur. The exploitation of plant resources has long been practiced but on a small scale. The doum palm and the palmyra palm provide wood for construction, while the palms of the Manga oasis produce dates. Small amounts of kapok (a silky down from the kapok tree, used for insulation, life jackets, and so forth) and of gum from the acacia gum tree are exported (Fuglestad & Laya, 2017).

The energy sector is dominated by the high consumption of the residential sub-sector, which is mainly based on wood resources (wood and biomass remnants). Household biomass use is amongst the highest in Africa, with the vast majority relying on fuelwood for heating, lighting and domestic task. Approximately 75 per cent of Niger' total national energy supply comes from biomass fuels (AFREC, 2014).

As with several Sub-Saharan countries, less 5 per cent of the people in Niger use clean cooking fuels (WHO, 2016). A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

Table 1: Fuels used for cooking and access to modern fuels in Niger (per cent of national population), 2006/2007

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0.2	0.7	-	2.8	94.2	97	2	-	0.1	0.8
Rural	0.1	0.1	-	1.2	96.1	97.3	2.3	-	0.2	0.2
Urban	0.6	3.4	-	10.4	84.9	95.3	0.5	-	0.2	4

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Niger's population, forest area, woodfuel and wood charcoal production, 1990-2015

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m³)
1990	8,013	1,945	280	5,674
2000	11,353	1,328	424	7,805
2010	16,426	1,204	588	9,876
2015	19,897	1,142	688	11,010

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Niger, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m³)	
	Household	Total	Household	Total
1990	23	23	4,650	4,650
2000	28	28	7,805	7,805
2010	40	40	5,524	5,524
2015	51	51	6,535	6,535

Source: (UNDATA, 2018)

Table 4: Niger's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	266
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	1,529
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	32
National Per Capita Consumption of Charcoal Fuel	37
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	211
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	4

Source: (AFREC, 2014)

As its Niger's population increases, so does the production of charcoal and fuelwood. Unfortunately the forest area has decreased (Table 2).

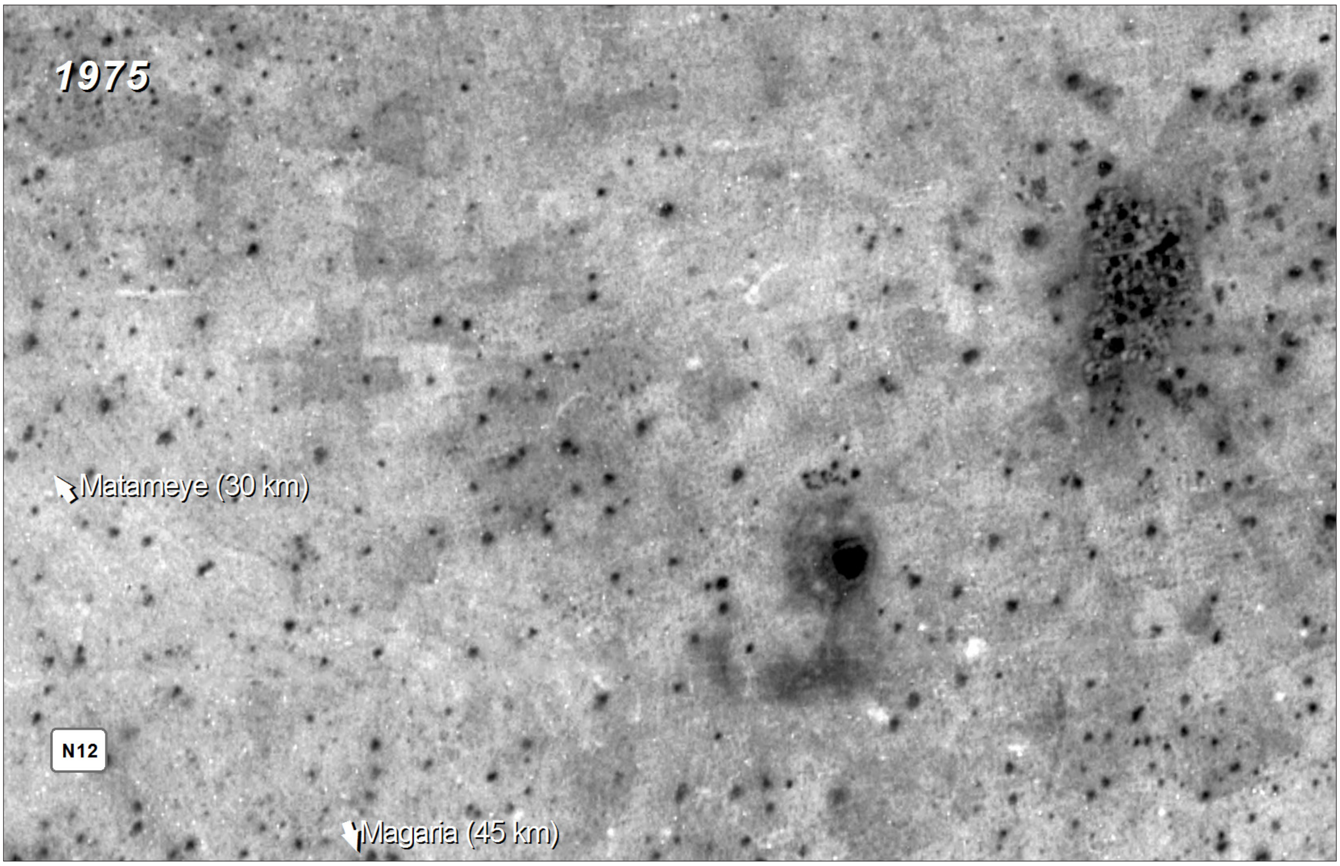
Deforestation has long been a problem for Niger, due to the dominant use of traditional biomass resources by the majority of the population. Nearly all households (96.4 per cent) use wood/charcoal as the main cooking fuel. This, and the expansion of croplands, contributes to the increasing deforestation. Inadequate infrastructure could generate high congestion losses, leading to low productivity (AFREC, 2014).

The limited infrastructure development in the energy sector has made it difficult to satisfy an increasing potential demand. The dependence on traditional biomass resources has also led to gender inequality in education and employment, as women are traditionally responsible for gathering fuelwood on a daily basis (AFREC, 2014).

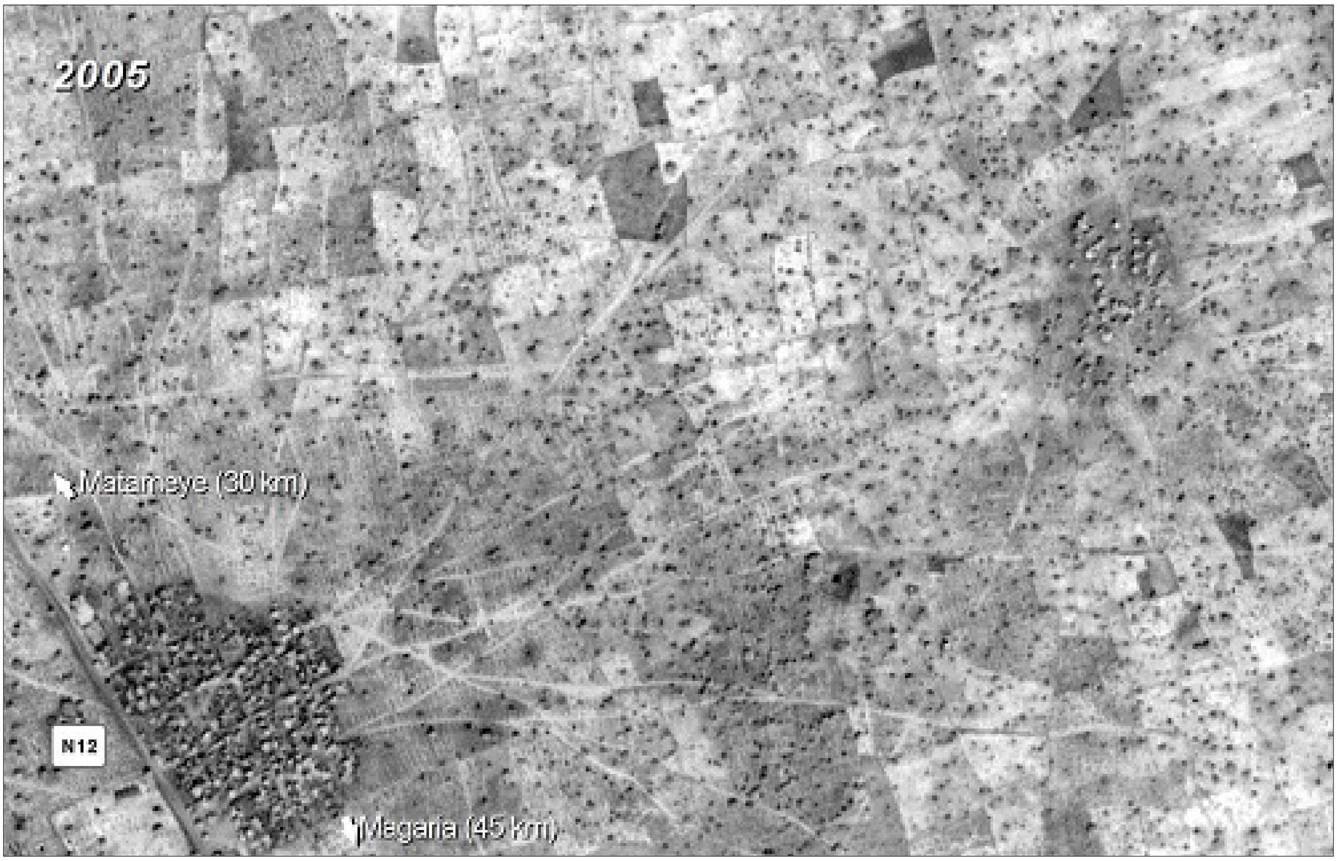
Regardless, there is huge potential for harnessing energy from biomass in this country. It is estimated that the current forest stock stands at about 9.9 million ha with a further 59 Mt of animal and agricultural wastes (AFREC, 2014). Biogas is only at the experimental stage (UNEP, 2017).

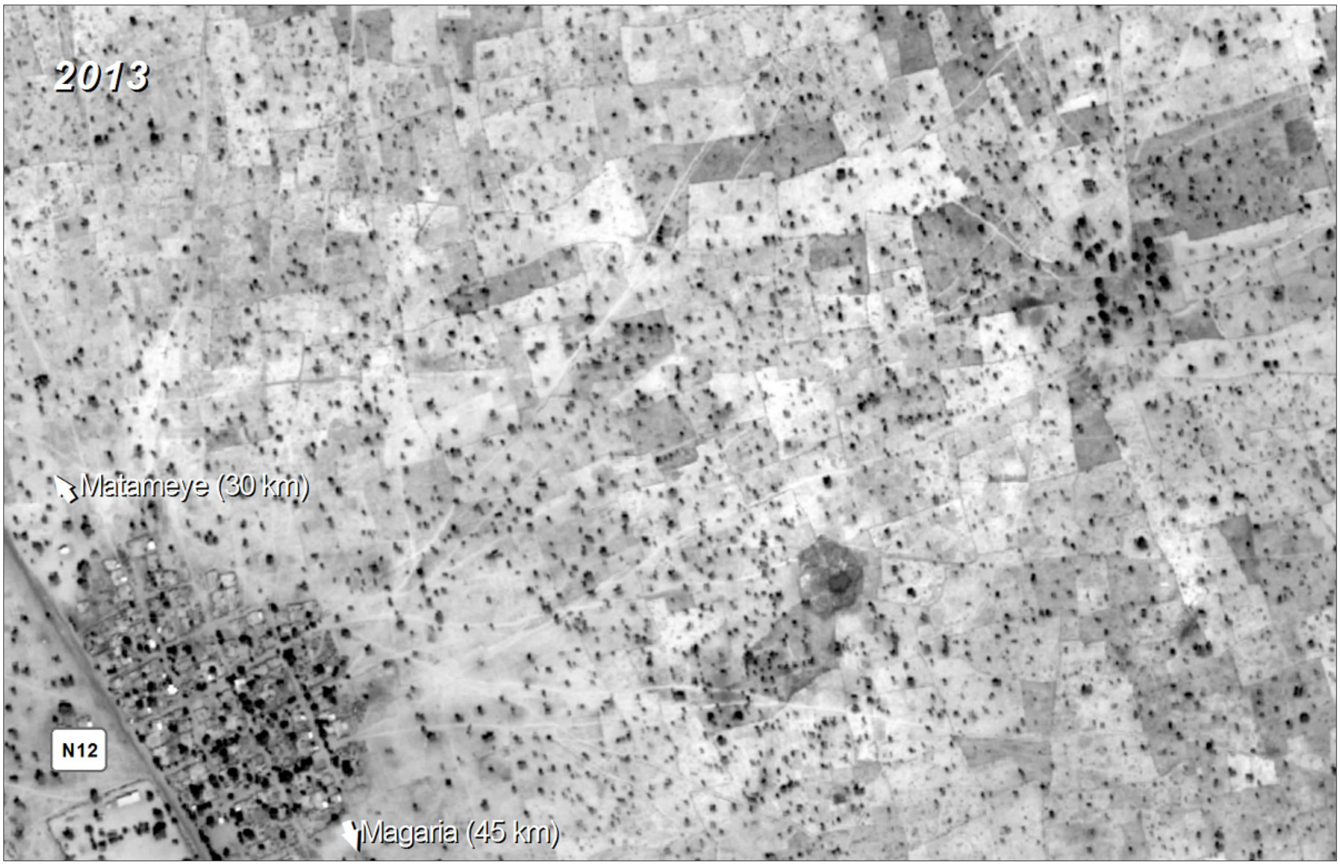
The forestry policy developed in Niger from the early 1930s until 1990 was marked by the preeminent role played by the colonial government, and subsequently by the government of independent Niger. In 1990, following the Maradi Conference in 1984, the importance of bringing local populations in on the process of forest management, after almost 70 years of being excluded, was finally accepted. In 1989, Niger adopted the Household Energy Strategy (HES) as a major axis of its forestry policy, choosing to prioritize the issue of woodfuel supplies for urban centers through community forest management. This


Tree cover in Niger



Satellite images show increase in tree cover in and around farm lands





policy, enacted by "decree 92-037" almost 20 years ago now, authorizes the creation of rural wood markets and allows rural communities to levy taxes at source, thus taking real ownership of their resources. After such a long period of exclusion, however, there is still some way to go in implementing this initiative. The hoped-for changes cannot be made to happen just by snapping ones' fingers, and this new power accorded to local populations has met with considerable reserve and much opposition. From 2007 to 2011, the rural district of Torodi introduced a major innovation in the implementation of the HES, improving the forestry control of woodfuel flows by setting up a communal monitoring unit, fully funded by the municipality. The HES is now in a position to consolidate its long-term viability and ultimately to improve the well-being of these populations (Montagne & Amadou, 2012).

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Somalia

Ban on charcoal export

Somalia is the easternmost country of Africa. It extends from just south of the Equator northward to the Gulf of Aden and occupies ai geopolitical position between sub-Saharan Africa and the countries of Arabia and southwestern Asia. The climate is mainly dry and hot, with landscapes of thornbush savanna and semi desert. In accordance with rainfall distribution, southern and northwestern Somalia have a relatively dense thornbush savanna, with various succulents and species of acacia. By contrast, the high plateaus of northern Somalia have wide, grassy plains, with mainly low formations of thorny shrubs and scattered grass tussocks in the remainder of the region. Owing to inappropriate land use, the original vegetation cover, especially in northern Somalia, has been heavily degraded and in various places even entirely destroyed. The acacia species of the thorny savanna in southern Somalia supply good timber and are the major source of charcoal, but charcoal production has long exceeded ecologically acceptable limits. More efficient and careful handling of frankincense, myrrh, and other resin-exuding trees could increase yields of aromatic gums (Jansen & Lewis, 2018).

Biomass is the main and, indeed traditional source of energy for the Somali population. Charcoal is the

Table 1: Fuels used for cooking and access to modern fuels in Somalia (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0.1	0	0.2	33.1	66.5	99.6			0.1	0.3
Rural	0	0	0.1	8	91.8	99.8			0.1	0.1
Urban	0.2	0.2	0.3	79.1	20.1	99.2			0.2	0.6

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Somalia's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m^3)
1990	7,397	8,282	400	6,264
2000	9,011	7,515	651	9,228
2010	12,053	6,747	1,132	13,501
2015	13,908	6,363	1,181	14,038

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Somalia, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m^3)	
	Household	Total	Household	Total
1990	0	400	3,864	3,864
2000	0	591	5,322	5,322
2010	0	911	6,707	6,707
2015	0	1,182	6,949	6,949

Source: (UNDATA, 2018)

Table 4: Somalia's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	130
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	1,129
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	76
National Per Capita Consumption of Charcoal Fuel	130
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	311
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	21

Source: (AFREC, 2014)

principal source of energy in urban households (Table 1) and institutions for cooking and heating whereas wood fuel is commonly used in rural settlements. This energy is generated from Acacia trees that mostly grow in plateau zones. The natural regeneration of these trees is very slow. As demand generally exceeds regeneration, deforestation becomes a serious problem. Trees have many environmental, socio-cultural and economic benefits, apart from being essential for the control of soil erosion and land degradation (Bukhari, 2015).

A study by the African Development Bank in 2015 notes that Somalia's dependence on biomass fuel-wood and charcoal remains the highest in the world with between 80-90 per cent of households meeting energy needs through charcoal and wood. The Food and Agriculture Organization estimates 8.2 million trees were felled in Somalia between 2001 and 2017 for charcoal translating to one tree for every 30 seconds in the seven-year period. This has led to increasing land degradation, food insecurity and vulnerability to flooding and drought. Over 80 per cent of charcoal produced in Somalia is exported to Gulf States and neighbouring countries (Roble, 2018).

As with most of the other African countries, an increase in population leads to an increase production of woodfuel and a decrease of forest land (Table 2).

Somalia has the lowest consumption of modern forms of energy in Sub-Saharan Africa. Approximately 100 per cent of its total national energy supply came from biomass energy fuels.

Somalia has long relied on fuel wood and charcoal, and imported petroleum to meet its energy needs. In 1985, wooded areas in Somalia were estimated to be about 39 million hectares - roughly 60 per cent of Somalia's land area. Due to overexploitation these figures have reduced significantly. In 2001, statistics indicate that the forest cover may have been as low as 10 per cent. Solid and liquid biomass options in Somalia still hold a significant potential, however, primarily in the form of crop and animal wastes, and marine biomass. Sustainable charcoal production methods could also be used to great effect in the country, as current charcoal production is causing significant environmental impacts (AFREC, 2014).

Wood fuels serve as an income source of livelihood for most rural people and for the large number of urban dwellers engaged in the charcoal and fuel wood trade. Rural livelihoods are intricately linked to the natural environment and this makes the charcoal problem a delicate one to solve (Bukhari, 2015). Charcoal making and its export from Somalia have been in practice since pre-colonial times to meet local and regional energy requirements and provide livelihoods opportunities for Charcoal Value Chain Beneficiaries (CVCBs). However, the unscrupulous plunder of forest and range resources for charcoal production has been witnessed during the last two decades. The breakdown of state institutions in 1991, protracted conflict, weakening of traditional systems of decision-making, vague tenures or resource ownership, illegal imports of huge quantities of Somali charcoal by neighbouring countries of the region, absence of alternative sources of energy and limited livelihoods options for a large "warring & marginalised" population has led to unsustainable production, trade and use of charcoal. In recent years, charcoal became the most sought-after commodity to fuel the war economy with militia groups generating revenue in excess of USD15 million per annum from illegal exports. As such, a multitude of complex issues surround the production of charcoal in Somalia leading to triple threats - in the forms of irreversible environmental degradation, perpetual conflicts and dependence on short-term income from an unsustainable livelihood option. Realisation of these multifaceted issues resulted in imposition of a ban on the import of Charcoal from Somalia by the UN Security Council in February 2012 (UNDP, 2016).

Land Degradation

Two main direct causes of land degradation in Somaliland are overuse of vegetation and agricultural intensification. Over exploitation of vegetation occurs mainly through gathering wood for fuel, fencing and construction materials, over grazing of livestock and charcoal production. This is an un-controlled activity which selectively clears trees cover (especially Acacia bussei). Its effects are further complicated by the diminishing natural resilience of the vegetation occasioned by frequent and prolonged drought in the last few years (Bukhari, 2015).

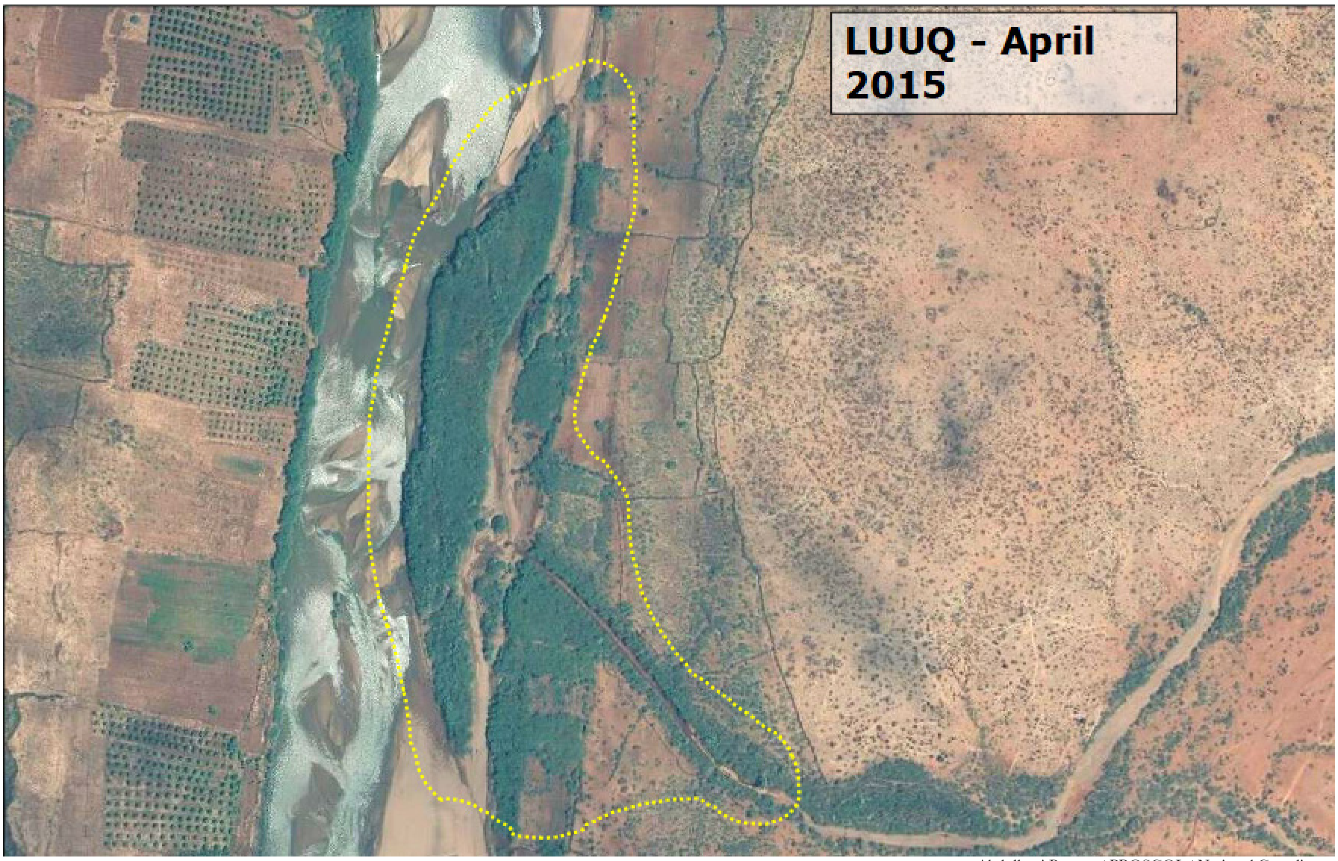
Its production triggers deforestation and has led to environmental degradation. For instance, the loss of the protective tree layer has the direct consequence of increasing the underlying soil's vulnerability to erosion by exposing it to agents such as desiccating winds and heavy rains. Charcoal production accelerates the process of desertification, decreasing the amount of land useable for agriculture or grazing and pushing locals out of areas as they become uninhabitable after charcoal producers clear all the trees. This deforestation also decreases bio-diversity as species that relied on the tree groves are unable to survive without them. Degraded rangelands due to tree felling to meet the increasing charcoal demand are a common sight across Somalia (FAO, 2017). With deforestation and lack of replanting, the Acacia bussei was placed on the International Union for the Conservation of Nature's Red List of threatened species. For years, this evergreen, drought-tolerant indigenous tree has provided feedstock to pastoralists and helped them stay resilient to droughts. But with increased demands for charcoal, the Acacia bussei is becoming an impractical source of fodder for livestock (Brown, 2018).

Charcoal production

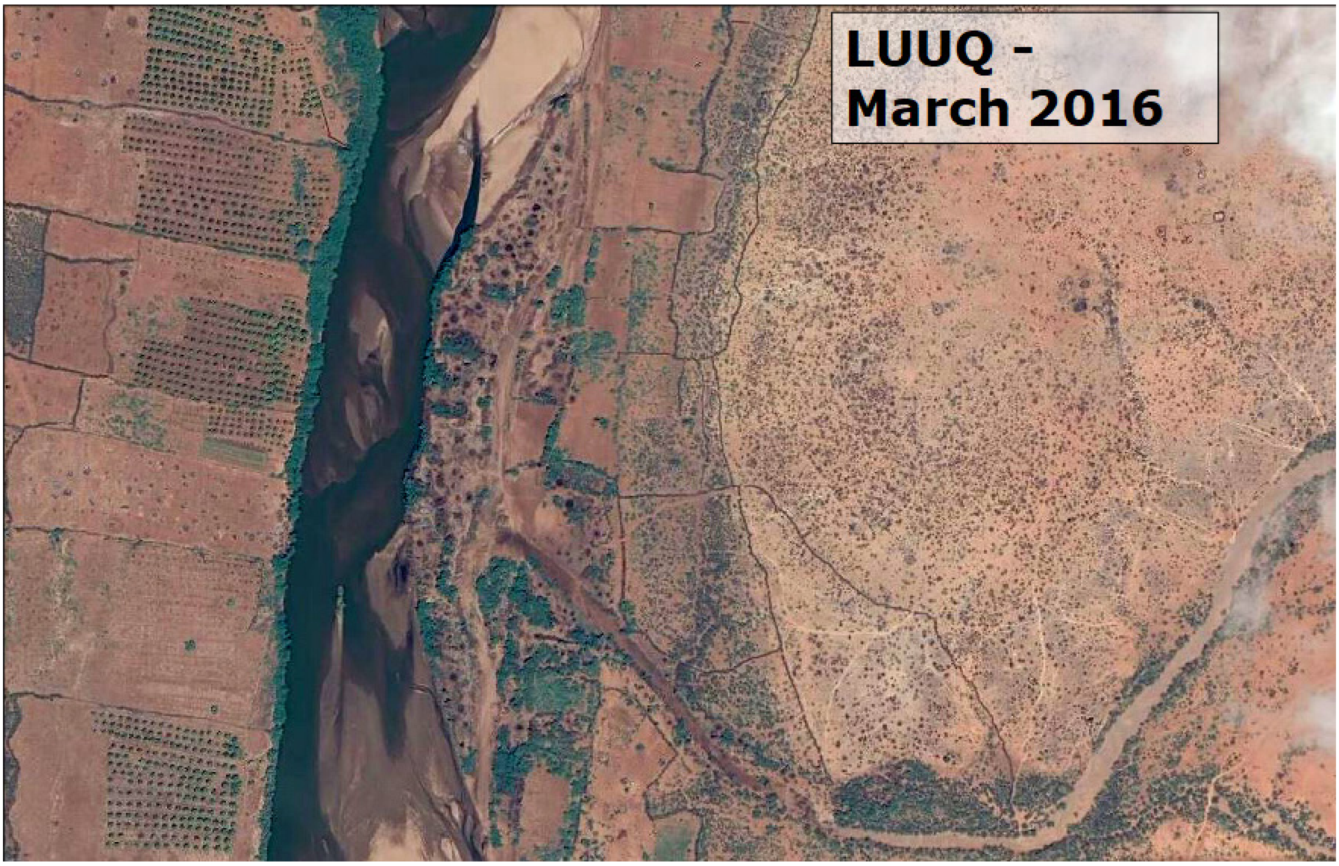
Charcoal is a major fuel for domestic use and revenue from its trade are the primary source of income for al-Shabaab, the Islamist terrorist group in Somalia. The charcoal industry is considered one of the most lucrative in the region earning traders as much as $120 million in exports (Waweru, 2018). Larger and consequently denser trees are selected for charcoal production. Therefore, the main and preferred timber species is Acacia bussei. A recent study by FAO Somalia Water And Land Information Management (SWALIM) for Puntland estimated a 5 per cent loss of this tree species annually. This estimate can be applied across Somalia. Large scale charcoal production concentrates first in areas where tree density is higher and distance from main roads, agriculture areas, and settlements is low, but also, as tree cover diminishes, new access roads are built to exploit areas further away. Tracks/access paths are a common feature at/around charcoal producing regions. In some cases, the trees are felled at a different

Stacks of charcoal on the roadside

AMISON / CC0 1.0 / Flickr



Abdulkani Barrow / PROSCOL / National Coordinator



site and transported to another one where the kiln is made for charcoal production (FAO, 2017).

According to an ongoing study under Program For Sustainable Charcoal Reduction and Alternative Livelihoods *Somalia* (PROSCAL) of Charcoal sites in Southern Somalis 2011/2017 using very high resolution satellite data, following observations were derived:

Sites: 194,826

Production (ton): 387, 033

Bags: 14,332,468

Trees: 7,166,234

ALMOST 1 TREE every 30 seconds

Some of the reasons why Charcoal business expanded from year 2000 onwards are given below:

- Ban on livestock exports due to outbreak of Rift Valley Fever
- Weak or non-existing enforcement institutions
- High demand from the gulf countries and well-connected individuals managing the illegal trade
- Weakening of traditional decision-making systems
- Repeated natural disasters and prolonged conflicts
- Lack of alternative source of energy to meet the basic needs

There is clear evidence that the war economy fuelled by the conflict is rapidly depleting the country s natural resources, especially the woody biomass. Wood charcoal production is one of the most relevant businesses supporting war regimes such as the extreme Islamist group Al Shabaab, which has ruled in Southern Somalia from 2006 to 2012. This conflict seriously affected tree cover. Within the lower Juba region of Southern Somalia there was an estimated tree loss rate above 7 per cent over the 5 years. The results are crucial for understanding the exact dimension and effects of the loss of woody biomass and for planning conservation and recovery interventions in the concerned area (Rembold, Oduori, Gadain, & Toselli, 2013). Between 2011 and 2013 the area lost 520,520 trees over the 2 years period. The results help to better understand the dimension and impact of charcoal production in Southern Somalia and are a first step towards the development of a charcoal production monitoring system (Bolognesi, Vrieling, Rembold, & Gadain, 2015).

Bans on Charcoal Exports

Charcoal is a source of conflict and strife (Waweru, 2018). For decades, the country struggled to implement the 1969 ban on charcoal and wood fuel exports. The gradual erosion of state institutions, which resulted in complete lawlessness and an outbreak of a full-fledged

civil war in 1991, only further undermined the initiative. With the protracted conflict, weak law and order, vague rules over resource ownership, and a lack of alternative sources of energy and livelihoods, the last few decades have seen an increase in unsustainable charcoal production (Brown, 2018). People will not stop using charcoal as a source of energy unless the government develops and enforces a policy which bans charcoal production throughout the country (Bukhari, 2015). In 2012 UN Security Council put a ban on importing Somalia's charcoal. The trade has continued apace: the market value of the exported commodity was estimated to be more than $250 million dollars over the two years following the ban (Brown, 2018).

The Somali political situation, characterized by a lack of central government, the absence of the rule of law, and the prevalence of local militias engaged in commercial activities, has created a situation that has allowed different actors to over-exploit forests, leading to deforestation and other environmental degradation. But what makes this industry so profitable (but ultimately unsustainable) is the huge increase in demand from Saudi Arabia and other Gulf States. This combination of external actors and a lack of any national authority or effective regulation make the charcoal industry extremely harmful to the Somalia's long-term environmental situation (Baxter, 2007).

On a positive note, destructive charcoal exports to the Arabian Peninsula have fallen by one third from the average annual level of $31 million during 2011–14. This decline coincides with the enforcement by the federal and state governments of the export bans they adopted in 2012. (Some illegal exports still take place, however, through informal channels and misclassification of shipments.) (World Bank, 2018).

A recent report of the United Nations Monitoring Group (www.un.org S/2018/1002 November 2018) aptly sums up the problem, to quote: -

"the charcoal exports from Somalia have declined by one quarter, from approximately 4 million to 3 million bags per year. The charcoal trade continues to be a significant source of revenue for Al-Shabaab, generating at least $7.5 million from checkpoint taxation in Middle Juba and Lower Juba regions. The systematic taxation of charcoal exports at the ports of Buur Gaabo and Kismayo also continues to generate significant illicit revenue for the Jubbaland administration. Using false certificates of origin to import Somali charcoal into foreign markets, criminal networks based in Dubai, United Arab Emirates, and Kismayo continue to generate substantial profits. In export markets, such as the United Arab Emirates, the estimated total wholesale value of illicit Somali charcoal is $150 million per year. During the current mandate, confirmed receiving ports

included: Hamriyah port, United Arab Emirates; Duqm port and Shinas port, Oman; and the Kish free zone and Qeshm free zone, Islamic Republic of Iran. The last two ports were used for the transshipment of Somali charcoal through the Islamic Republic of Iran to the United Arab Emirates. Overall, the implementation of the Somali charcoal export ban by Member States has improved. The confiscation of cargoes by Oman and the United Arab Emirates has built upon efforts made by Member States during previous mandates towards deterring the illicit trade. However, the implementation would have been more consistent if Oman and the United Arab Emirates had taken more timely action in response to correspondence from the Monitoring Group. The Islamic Republic of Iran, which did not reply to correspondence from the Group until one week before the submission of the present report, has been a weak link in implementation. Finally, within Somalia, AMISOM and the Jubbaland administration continue not to implement the charcoal export ban".

What to do?

Understanding the peculiar context of charcoal problems in Somalia is as important as coming up with a response strategy to address these problems. The major problems can be grouped into five main areas that broadly provide the basis to contextualise the enormity of charcoal challenges in Somalia. These are:

- Environmental un-sustainability challenge;
- Volatile political situation, insecurity, enforcement and institutional decay challenge;
- Outstripping regional demand challenge;
- Rampant Poverty and lack of livelihoods challenge; and
- Skewed energy mix and outstripping local charcoal demand challenge (UNDP, 2016).'

Within this context one has consider following ground realities:

- Unsustainable Charcoal production and trade is major contributor to instability & conflict.
- Environmental destruction, increased incidence of poverty, shrinking livelihoods opportunities for Somali men and women.
- Frequent recurrence of severe humanitarian crisis (droughts, floods) and internal displacements.
- 250,000 MT (9-10 million sacks of charcoal exported during 2011)
- 62,500 MT used in Somalia

So programmatic focus should be to:

1) Enhance regional cooperation and capacity building for monitoring and enforcement.
2) Focus on enhancing energy efficiency in charcoal production/use and introduce alternative sources of energy to reduce local demand.
3) Provide alternative sources of livelihoods for the charcoal value chain beneficiaries, particularly, vulnerable groups, Internally Displaced People (IDPs), women & youth.
4) Accelerate reforestation and afforestation throughout the country.

The government is looking for alternative sources of energy to replace charcoal as well as adopt and implement regulation of the product (Waweru, 2018). Somalia has an opportunity to diversify its energy sources through reduction of reliance on charcoal and firewood in favour of alternatives like wind, solar, liquefied petroleum gas, biogas, hydro and high-efficiency thermal generation and distribution systems (Brown, 2018). However, few of these alternatives are currently affordable and accessible to the public (Bukhari, 2015). One alternative is to implement reforestation and restorative environmental programs (Waweru, 2018).

The most promising avenue for changing the calculation of people engaged in the charcoal business is to solve the "problem of the commons." Local elites need to enforce property rights over acacia forests. Conservation grants will enable them to take a long-term view on resource management, rather than taking a fistful of dollars to acquiesce in the destruction of their ancient woodlands (Shortland, 2014).Proper utilisation of trees and natural resources will enhance and ensure a sustainable environment and natural resources conservation. Appropriate natural resources management is required to at least reduce the adverse impact on the environment (Bukhari, 2015). Further actions may include: -

- Developing and enforcing a policy which bans charcoal production for the protection of the environment
- Promote community awareness of energy alternatives for introducing biogas, solar, wind, new kerosene stoves and also LPG, and promote cost reduction.
- International NGOs, World Bank and UN agencies and others to play their part in financing development projects for introduction of alternative energies and reduction poverty.

- Research and development projects are needed to develop the best alternatives that have the lowest price for low income households while minimizing adverse environment impacts.
- In order to attract private sector, the government should take actions like exempting taxes, so all alternative energy appliances could be easily deployed in the market.
- Community leaders should engage themselves to get involved in these interventions.
- Government media should make efforts to reach out to everyone in the country.

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Tanzania

Challenges in Sustainable Charcoal Production

Tanzania is an East African country situated just south of the Equator. Tanzania's native forests are primarily composed of hardwoods, but softwood production is increasing. A large pulp and paper mill at Mufindi is supplied by the extensive softwood forest nearby at Sao Hill. (Ingham, Mascarenhas, Chiteji, & Bryceson, 2017).

Less than 5 per cent of Tanzania's households rely on clean cooking fuels (WHO, 2016). Biomass is the major source of energy in and is used domestically, in the form of charcoal and woodfuel. See table 1. However, other forms of biomass that are being used in Tanzania include agricultural wastes (sisal, rice and sugarcane husks) and wood chips (Picton-Tubervill & Derrick, 2017).

In recent years biomass energy activities mainly, woodfuel and wood charcoal have increased dramatically (Table 2).

Biomass energy fuels provided about 83 per cent of the total national energy supply in 2015 (Table 3).

There is significant household preference to miombo woodlands as source of woodfuel. Factors important in influencing choice of fuel are: location of household, residence ownership, dwelling category, household income, and education level of household head

Table 1: Fuels used for cooking and access to modern fuels in Tanzania (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	0.3	0.2	2.3	19	77.6	99.4	-	-	0.5	2.8
Rural	0.1	0	0.3	5.7	93.6	99.7	-	-	0.3	0.4
Urban	0.9	0.8	8.5	59.6	29.2	99	-	-	1.1	10.2

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Tanzania's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m^3)
1990	25,459.6	55,920	821	18,567
2000	34,178	51,920	1,165	20,787
2010	46,098.6	47,920	1,609	22,836
2015	53,880	46,060	1,872	24,119

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Tanzania, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m^3)	
	Household	Total	Household	Total
1990	459	459	24,835	28,526
2000	950	950	30,581	37,664
2010	1,695	1,695	38,232	53,419
2015	1,999	1,999	45,493	65,094

Source: (UNDATA, 2018)

Table 4: Tanzania's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	43
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	155
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	6.30
National Per Capita Consumption of Charcoal Fuel	43
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	145.70
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	5.90

Source: (AFREC, 2014)

(Lusambo, 2016). Households are heavily dependent on natural forests for household energy provision and that the choice to obtain fuelwood from the forest, farm or market depends on the availability of preferred fuelwood tree species at these sources. Acacia tortilis, Brachystegia spp. and Faidherbia albida are the significantly preferred tree species and hence affect the decision of where to obtain fuelwood. This revelation highlights the pressure applied to surrounding forests as well as to the aforementioned tree species which require immediate management interventions. The gender of the household head and whether the household lives in peri-urban or rural areas also influence choice of fuelwood source. Promotion of tree planting and on-farm management of tree species similar to preferred species found in natural forests is recommended (Kegode, et al., 2017).

The rapid population growth of both urban and rural areas, however, has placed severe strain on the biomass resources, which has led to desertification and deforestation of some areas (Felix & Gheewala, 2011). To produce one tonne of charcoal in Tanzania, 10 - 12 tonnes of wood are used in the traditional kiln. In 2009, wood from 342.5 ha of forest was required daily. This area increased to 583 ha in 2012 and the wood is in most cases harvested illegally (Ishengoma, 2015). It has been estimated that in Tanzania, charcoal consumption is responsible for anything between 20 and 60 per cent of the annual deforestation rate. (Farah & Luukkanen, 2015).

Despite being the largest energy source, biomass is produced in unsustainable ways (Ishengoma, 2015); (Picton-Tubervill & Derrick, 2017). Biomass has been used for the generation of power on a small-scale, and predominantly in rural areas. Some Small Power Purchase agreements (SPPAs) have resulted in supplying power to Tanzania Electric Supply Company Limited (TANESCO) (Sondo, Kidiffu, & Sondo, 2018).

Small-scale uses of biomass for energy generation in rural areas are taking off. Under the Small Power Projects (SPP) programme, two biomass power plants are supplying power to TA NESCO, which are: TPC in Kilimanjaro Region with an SPPA with a capacity for 9 MW; and TANWAT in Njombe Region with an SPPA with a capacity of 1.5 MW. A third SPPA for 1MW,at Ngombeni project, on Mana Island, was commissioned in February 2014 to supply power to TA NESCO's isolated grid in Mana Island. TANESCO has signed SPPAs for three additional biomass projects with a total capacity of 9.6 MW (Sondo, Kidiffu, & Sondo, 2018).

Household dependency on woodfuel is overwhelming and is likely to remain so for the foreseeable future. One way of economizing on woodfuel and charcoal use is to improve their production methods and the use of energy efficient stoves and improved charcoal making kilns. In addition, electrification, the use of alternative energy sources such as liquefied petroleum gas (LPG) and biogas reduces the frequent use of woodfuel and charcoal and consequently the burden on the forest resources (Felix & Gheewala, 2011); (Lusambo, 2016). In 2006 A complete ban was imposed on cutting of trees, harvesting timber and the production and transport of charcoal. Production, trade and consumption of charcoal continued illegally. The price of charcoal doubled (FAO, 2017),

Sustainable charcoal production from natural woodlands has been marginalized as a policy option in all sectors in Tanzania. The marginalization of sustainable charcoal production in the energy and forest sectors is exacerbated by the land policy in providing no explicit recognition of sustainable woodland management as a recognized land use, and by the agricultural policy in promoting the expansion of agricultural land. If woodlands do not generate income for their owners, including communities, the economic rationale to convert woodland to agricultural land is strengthened. Assuming that sustainable charcoal production can incentivize sustainable woodland management, an opportunity is therefore being missed to embed a sustainable financing mechanism into participatory woodland management. Widespread conversion of woodland to agriculture inevitably undermines the

Part of a re-forestation program by the Tanzanian government; all of the trees are in rows.

Charcoal bardges

ecosystem services generated by those woodlands, with corresponding risks to those sectors that depend on those ecosystem services, particularly agriculture. The marginalization of sustainable charcoal production from national policy is, therefore, a missed opportunity given the potential for it to contribute to more climate-resilient rural livelihoods, urban energy security, and sustainable management of woodlands with their inherent ecosystem services including climate change mitigation (Doggart & Meshack, 2017).

Policy objectives and statements supporting sustainable charcoal should be included in the energy and forest sector policies whilst revising policies on water, agriculture, and land should include objectives and statements that promote sustainable natural forest management and reduce agriculture-driven deforestation. Create a charcoal market supplying charcoal from sustainably managed, community- and privately-owned woodlands to urban households. Retain tax revenues at village and district level in order to incentivize and finance sustainable management of natural woodlands. The professionalism and organization of charcoal producers would increase with concomitant environmental benefits in terms of compliance with efficiency and sustainability guidelines, as well as improved livelihoods for producers, and other rural development gains (Doggart & Meshack, 2017).

The benefits of sustainable charcoal production become evident when viewed from the perspectives of multiple sectors. A nexus approach is for policy makers to consider the inter-sectoral implications of charcoal production and to develop more robust mechanisms to value ecosystem services when making trade-offs in the allocation of land and natural resources. Investigate the need for change throughout the policy cycle, including generating a stronger knowledge base, and valuing the needs and interests of more marginalized stakeholders, including woodland-owning communities and charcoal producers (Doggart & Meshack, 2017).

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Zambia

Charcoal trap

Zambia, a landlocked country, is situated on a high plateau in south-central Africa and takes its name from the Zambezi River. On the plateau, miombo woodland is characteristic: a semi-continuous tree cover dominated by small leguminous trees of the Brachystegia and Julbernardia genera but with significant grassy undergrowth. Burning of the grasses in the dry season causes the trees to develop a corky, fire-resistant bark. Mopane woodland, in which Colophospermum mopane dominates but in which the baobab is distinctive, occurs in the drier and hotter valleys of the Zambezi in the south and in the Luangwa valley. Zambezi teak (Baikiea plurijuga) occurs in the southern fringe of the area covered by the Kalahari Sands. Mukwa (Pterocarpus angolensis), a good furniture timber, is found in the Lake Bangweulu area. More than one-tenth of the country has been set aside as forest reserve or protected forest areas; in all, some two-fifths of the country's land is under protection. Some 67,300 km^2 of Zambia are classified as forest reserves, although the greater part of the country is wooded but not protected in this way. The main commercial timber areas are on the Copperbelt, where there have been plantings of exotic softwoods to supply the needs of the mining industry, and in the southwest, where there are extensive areas of

Table 1: Fuels used for cooking and access to modern fuels in Zambia (per cent of national population), 2006

Population	Fuels used for cooking									Access to modern fuels
	Electricity	Gas	Kerosene	Charcoal	Wood	Biomass	Dung	Coal	Other	
All	15.8	0	0	24.5	59.5	99.8	0.1	0.2	0	15.8
Rural	1.8	0	-	10	88.2	98.2	0.1	0	0	1.8
Urban	41.2	0	0	50.7	7.5	99.4	0.1	0	0	1.8

Source: (Legros, Havet, Bruce, & Bonjour, 2009)

Table 2:Zambia's population, forest area, woodfuel and wood charcoal production, 1990-2015.

Year	Population (1,000 persons)	Forest Area (1,000 persons)	Wood Charcoal (1,000 tonnes)	Wood Fuel (1,000 m^3)
1990	8,027	52,800	924	6,443
2000	10,531	51,134	1,041	7,828
2010	13,850	49,468	1,041	9,119
2015	16,101	48,635	1,041	9,800

Source: FAOSTAT

Table 3: Charcoal and Fuelwood Household and Total Consumption for Zambia, 2015

Year	Charcoal Consumption (1,000 mt)		Fuelwood Consumption (1,000 m^3)	
	Household	Total	Household	Total
1990	577	600	7,169	9,210
2000	762	793	9,090	11,669
2010	923	987	10,282	15,735
2015	1,025	1,108	12,796	19,857

Source: (UNDATA, 2018)

Table 4: Zambia's per capita distribution of woodfuel and charcoal consumption, 2015

Item	Estimation in 2015 (kg)
National Per Capita Consumption of Wood Fuel	1,019
Urban Per Capita Consumption of Wood Fuel @ 10% of Total Consumption	2,343
Rural Per Capita Consumption of Wood Fuel @90% of Total Consumption	168
National Per Capita Consumption of Charcoal Fuel	81
Urban Per Capita Consumption of Charcoal Fuel @ 90% of Total Consumption	185
Rural Per Capita Consumption of Charcoal Fuel @ 10% of Total Consumption	13

Source: (AFREC, 2014)

Zambezi teak. A mill at Mulobezi, which supplies timber products, is linked to Livingstone by a light railway (Williams, Hobson, & Robers, 2017).

It is estimated that 95 per cent of energy used by Zambian households in the countryside is derived from woody biomass and charcoal. Charcoal production in 2010 was 742 ktoe increasing to 842 ktoe in 2015. Although forest cover is vast (about 66 per cent of Zambia's total land area), it is being lost due to demand for energy from the growing population. This pressure on the forest resource is one of the drivers behind investing in alternative fuels such as biogas and biofuels. Possible feedstocks for biofuels in Zambia include Jatropha, cottonseed, soy seed and sunflower. The country has set up the legal framework for the biofuels sector including the development of standards for biodiesel and bioethanol; and a code of conduct for blending of biofuels. The National Energy Policy is promoting gel fuel made from sugar molasses as an alternative energy to woodfuel use. Initially, ethanol is made and then it is mixed with the gel to obtain the alternative fuel, but the limitation is in accessing the ethanol (UNEP, 2017).

The amount of biomass energy fuels in Zambia's total national energy supply is about 85 per cent (AFREC, 2014). Currently, only about 16 per cent of the households rely on clean cooking fuels (WHO, 2016). A breakdown of different fuels used for cooking by rural and urban population is given in the Table 1.

Fuelwood constitutes between 76 per cent and 90 per cent of the energy budgets among households (Clamini, Moombe, Syampugani, & Samboko, 2016).

Load shedding (the deliberate shutdown of electric power in a part or parts of a power-distribution system, generally to prevent the failure of the entire system when the demand strains the capacity of the system) is undoubtedly one of the primary drivers of increased production, trade, and demand for charcoal among Zambian households between 2013 and 2015. The number of charcoal kilns produced per person has increased, with incomes of charcoal producers increasing by over 53.2 per cent between 2013 and 2015. The income of charcoal traders has doubled to ZMW 978 per month, while charcoal prices have increased by ZMW 15 per 25 Kg bag. Prolonged load shedding in Zambia is likely to lead to more clearing of forests and woodlands. Unlike clearing land for agriculture, this is expected to lead to loss of forest resources, and associated ecosystem services. Ultimately, the high demand for charcoal arising from load shedding, guarantees economic sustainability of charcoal production. However, ecological sustainability may not be attainable given that the standing stock in the natural forests and woodlands is declining. Further, if unabated this would worsen climate change impacts (Clamini, Moombe, Syampugani, & Samboko, 2016)

The protection of miombo woodlands has to account for the energy demands of the population. The production at national level converts into 10 - 15 GWh y-1 of energy in the charcoal. A shift in energy supply from charcoal to electricity would reduce the pressure of forests but requires high investments into grid and power generation. Since Zambia currently cannot generate this money by itself, the country will remain locked in a charcoal trap - the fact that this energy supply has to be substituted when woodlands are protected. The question arises whether and how money and technology transfer to increase regenerative electrical power generation should become part of the Paris Climate Agreement. Furthermore, better inventory data are urgently required to improve knowledge about the current state of the woodland usage and recovery. Net greenhouse gas emissions could be reduced substantially by improving the post-harvest management, charcoal production technology and/or providing alternative energy supply (Kutsch, et al., 2011).

A major concern is forest destruction due to demands for charcoal; in the towns, charcoal is the most popular cooking fuel. See table 2.

According to an unpublished report, most markets exist, in cluster, along roadsides where producers exhibit few bags at a time while the rest is concealed elsewhere. Also, some markets exist adjacent to trading centers where only a sample of what exists is displayed. Most producers in such markets pack charcoal in 50kg bag but the actual weight of the commodity is estimated at 33kg. Charcoal sold in such markets is predominantly sourced in the villages at a low price of ZMK 13 per 50kg bag. At the roadside, such a bag is retailed at ZMK 20. Where retailers resort to small quantities packages of 1-5 kg, the price will vary from ZMK 1000-5000.Since most of the roadside retailers do not have licenses, charcoal is transported during the night using trucks, bicycles and ox-carts; to avoid the FD. For long distances, small scale traders use buses which charge up to ZMK 3000 per 50kg bag. Trucks charge ZMK 4000 per bag and cart owners ZMK 1000. (MLNR, 2017)

Summary of demand for wood products (MLNR, 2017)

- The national demand for wood products in 2010, including charcoal, fuelwood, construction material and timber is estimated to be 13 million tonnes dry matter (DM) (= 20. 7 million m^3), 82 per cent of which as fuelwood and charcoal in the residential sector.
- The total consumption of charcoal is estimated at 1.15 million tonnes, corresponds to 5 million tonnes of wood (DM), 67 per cent of which is consumed by urban households. The total consumption of fuelwood is estimated at 6.48 million tonnes DM, 94.8 per cent of which by rural households.
- Around half of the national demand for wood products (47 per cent) is concentrated in a relatively small area along the central axis of the country and the main markets are (North to South) Chingola, Kitwe, Ndola, Kabwe and Lusaka. In this analysis it is assumed that most of the commercial harvesting feeding these market sites takes place within 16 hours of transport time. The accessible resources along such axis are those under highest harvesting pressure and thus under higher risk of degradation. Summary of supply potential
- The total stock of woody biomass 35 is estimated at slightly over 2 billion tonnes DM. This could be estimated with good confidence thanks to the field inventory data and land cover mapping
- The balance analysis indicate that 61 per cent of the total demand (7.9 million tonnes DM) is satisfied by local resources (within a radius of 5 km), while 39 per cent (5.1 million tonnes DM) depend on the supply from distant areas, through commercial production systems. Comparing this last value (i.e. the gap to be filled) with the commercial surplus, 23.9 million tonnes DM, it's evident that the Country has great abundance of wood resources.
- Except Lusaka, all provinces show surplus conditions. Out of 74 districts, deficit conditions are found only for 12, represented mainly by small urban districts. This tells that the resources of the Country are not only abundant, they are also evenly distributed.
- An analysis shows that the theoretical minimum sustainable woodshed of the 5 major market sites (Chingola, Kitwe, Ndola, Kabwe and Lusaka), as well as the one of Chipata and surrounding deficit sites are well separated and relatively small (all necessary resources are within 150 -200 km distance from market sites), as shown in Figure (i). This indicates that the sustainable production of fuelwood, charcoal and industrial roundwood not only is feasible, it has a great potential in Zambia.
- While SFM should be implemented in all forest areas, these woodsheds clearly define the primary target of forest production and protection measures, wood energy planning and landscape management. Expected commercial harvesting sustainability and degradation rates
- Considering current sub -optimal resource management and harvesting practices, rather than optimal practices, the degradation due to excessive exploitation of wood resource is expected to occur primarily in the harvesting zones that feed the major market sites, along the central axis of the Country.
- Assuming a 16 -hours transportation threshold as the limit within which commercial harvesting concentrates, the expected annual degradation in all land cover classes in the central commercial harvesting zone is estimated to range between 224 and 629 thousand tonnes DM, assuming full -use and no -use of deforestation by -products, respectively. Considering forests only, the expected annual degradation is estimated to range between 134 and 391 thousand tonnes DM.
- Degradation of minor entity due to un -regulated harvesting and charcoal making is expected to occur in other areas of the Country where pressure is high, as in the territory around Chipata, for instance. In most areas, however, fuelwood, charcoal and timber are by -products of deforestation processes and thus direct harvesting (without land use change) are limited

and abundantly surpassed by natural re -growth capacities (MLNR, 2017).

The Government has adopted a landscape approach in the National Strategy to reduce Deforestation and forest Degradation in order to integrally and holistically address the challenges of deforestation and forest degradation at the watershed level. The landscape approach seeks to achieve multiple objectives - social, economic and environmental - through stakeholder engagement and adaptive management tools in areas where different sectoral interests (i.e. Agriculture, mining, etc.) linked to environmental conservation objectives. In Zambia, the approach aims to address the drivers of deforestation and forest degradation while supporting actions aimed at improving the livelihoods of local communities. This holistic and integrated approach will help avoid duplication, consider cumulative impacts of development, scattering of resources and conflicts among resource managers, which include local communities. The landscape approach will ensure that different aspects are dealt with simultaneously in a manner that coordinates sectoral investments and maximizes output s and benefits (MLNR, 2017)

With ample forest coverage, and dedicated support from the government, an integrated household-level biogas program is a possibility in the country (AFREC, 2014). Three actions might help to significantly reduce charcoal use in Zambia: introducing more efficient cookstoves; promoting simple and inexpensive solar water heating devices to reduce charcoal demand for water heating; and electricity price restructuring to lower tariffs for the poor (Atteridge, Heneen, & Senyagwa, 2013); (Williams, Hobson, & Robers, 2017).

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