TRANSITIONS PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES

Energy Access and Climate Change in Sub-Saharan Africa: linkages, synergies and conflicts

Project Coordinator: SPRU, Science Policy Research Unit, (UoS) University of Sussex

Work Package 4

Leader Organisation: SEI

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Preface

Both the models concerning the future climate evolution and its impacts, as well as the models assessing the costs and benefits associated with different mitigation pathways face a high degree of uncertainty. There is an urgent need to not only understand the costs and benefits associated with climate change but also the risks, uncertainties and co-effects related to different mitigation pathways as well as public acceptance (or lack of) of low-carbon (technology) options. The main aims and objectives of TRANSrisk therefore are to create a novel assessment framework for analysing costs and benefits of transition pathways that will integrate well-established approaches to modelling the costs of resilient, low-carbon pathways with a wider interdisciplinary approach including risk assessments. In addition TRANSrisk aims to design a decision support tool that should help policy makers to better understand uncertainties and risks and enable them to include risk assessments into more robust policy design.

PROJECT PARTNERS

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Executive Summary

Only 35% of the population in sub-Saharan Africa (SSA) has access to electricity and 80% rely significantly on traditional biomass in the form of fuelwood, charcoal, animal dung and agricultural residues. Modern energy services are also needed in transforming agriculture, creating productive enterprises and supporting income-generating activities. Access to reliable, affordable and sustainable energy is a prerequisite for achieving many of the Sustainable Development goals (SDGs) as it significantly affects health, climate, land use and other sectors.

Even as African countries struggle to expand energy access, their governments have committed to climate mitigation goals through the Nationally Determined Contributions (NDCs). At the same time, their populations are vulnerable to the impacts of climate change due to the high dependence on rain-fed small-scale agriculture, lack of industrial and transport infrastructure, and especially deep poverty that leaves them with low adaptive capacity.

Investments and measures that support all three aims—or at least those that improve in one or two without worsening the other—should receive special priority. This report provides a (non-exhaustive) synthesis and review on energy access issues in sub-Saharan Africa, focusing especially on the linkages, synergies and conflicts with climate mitigation and adaptation goals.

With the exception of South Africa and Nigeria, emissions from land use change in SSA are generally more significant than emissions from the energy sector. Land use emissions are correlated with areas of high dependence on traditional biomass and rain-fed small-scale agriculture. These same areas have rural populations that are highly vulnerable to climate impacts. Sustainable land use management, including agro-forestry and integrated approaches to food and energy systems, is thus critical to Africa’s climate and development goals.

Some African countries are promoting ambitious plans for low emissions development pathways even as they expand energy access. The cases of Ethiopia, Kenya and Rwanda are highlighted here, and they exemplify the pioneering efforts to create portfolios that combine investment in renewables, energy efficiency and land use productivity. Significant investment in hydropower in Ethiopia, geothermal in Kenya and biogas in Rwanda are among the major efforts underway.

High dependence on hydropower in some African countries contributes to power sector vulnerability to climate change: diversification is important although the intermittency of renewables presents reliability challenges. The non-intermittent renewables (geothermal and modern bioenergy) are less vulnerable although biomass productivity may be problematic in semi-arid and arid regions. The high cost of extending the grid has led to a surge of interest in decentralised energy, including mini-grids. African countries will need to develop carefully balanced energy portfolios that accommodate access, mitigation and adaptation goals. More importantly, the triple win for development, mitigation and adaptation requires major efforts for poverty reduction and rural development, with energy access as a significant side benefit.
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1 EC SUMMARY REQUIREMENTS

1.1 Changes with respect to the DoA

The aim of this deliverable (4.4.4) was to consider linkages between energy access goals and climate mitigation goals in developing countries, focusing especially on household energy, rural electrification and cross-sector effects. The approach was originally intended to be based on modelling results from tasks 4.2 and 4.3, which would be applied to selected developing countries/regions. The overall aim has been maintained here, but the approach is changed somewhat: the scope has been broadened thematically but narrowed somewhat geographically. Tasks 4.2 and 4.3 were not focused on energy access and thus could not be used as inputs. It was also determined that this sub-task is closely linked to Task 6.4 (Identifying Innovation Policy Options), which occurs later in the TRANSrisk timeline. Furthermore, it was noted that energy access is linked to adaptation goals as well as mitigation. Since adaptation is not yet well-reflected in TRANSrisk, we broadened the scope of this task to include adaptation. The geographical scope has been narrowed to sub-Saharan Africa where energy access problems are so acute, with a special emphasis on eastern Africa.

Consequently, this task has effectively been split into two parts. This report is the formal deliverable and encompasses Part 1, which includes a synthesis and review on the relation between energy access, mitigation and adaptation goals, and is closely related to the notion of climate-compatible development (Stringer et al., 2014; Suckall et al., 2015). In order to illustrate these issues in relation to national goals, we have highlighted three African countries (Ethiopia, Kenya and Rwanda) that are considered to be among the African leaders in promoting innovative approaches to renewable energy and climate-friendly development. In this way our synthesis and review prepares for Part 2, which is linked to Task 6.4 and thus needs to be carried out simultaneously with that task. In particular, within that task we will analyse innovative approaches for energy access that do not compromise climate goals, based on the aims as expressed in the DoA regarding household energy, rural electrification, and cross-sector effects.

1.2 Dissemination and uptake

This report will provide the basis for a continuing discussion with key stakeholders on how to reconcile energy access and climate goals. It also provides the background for the design of a more detailed analysis on specific innovation options, policy measures and transition pathways in which energy access goals receive equal priority. As the focus is in Africa, the aim is to choose dissemination activities focused on African audiences during 2017-2018 or international conferences where African participation is based (e.g. UNFCCC African Pavilion).
1.3 Short Summary of results (<250 words)

The vast majority of the population of sub-Saharan Africa lacks access to modern energy services. Only 35% have electricity access while 80% of the population relies significantly on traditional biomass. In spite of such challenges, African governments have recently pledged to reduce GHG emissions under the Paris Agreement. At the same time, African countries are expected to suffer some of the most serious impacts of climate change. Energy infrastructure in Africa faces risks from climate change due especially to low reliability and over-dependence on hydropower while a population dependent on rain-fed small-scale agriculture is directly vulnerable to climate impacts. Energy access, climate mitigation and climate adaptation thus constitute a development trilemma in the African context.

One way out of this trilemma is to promote new development pathways based on renewable energy and sustainable land management. Countries such as Ethiopia, Kenya and Rwanda have ambitious goals for both energy access and climate mitigation while also implementing a variety of measures to reduce their vulnerability to future climate change. Diversification of sources in African energy systems and reduced dependence on woodfuels will contribute to access, mitigation and adaptation aims. Integrated approaches such as agro-forestry can support the transformation to climate-friendly, multi-purpose and highly productive agricultural systems. A better alignment of energy and climate goals in the African context requires careful analysis on the complex transitions that are underway and deeper investigations of the linkages, synergies and conflicts between energy goals, mitigation options and adaptation measures.

1.4 Evidence of accomplishment

Submission of this report to the European Commission and posting to the TRANSrisk website provides evidence.
2 INTRODUCTION

Energy access is a fundamental development goal, as expressed in SDG number 7 and in major international platforms, particularly the Sustainable Energy for All platform (SE4All, 2017). An estimated 2.74 billion people rely on traditional biomass and lack reliable access to modern fuels, while 1.2 billion lack access to electricity. In sub-Saharan Africa (SSA) the problem is especially acute: the region is home to more than half of those who lack electricity access globally and nearly one-third of those who rely heavily of traditional biomass. Rapid population growth combined with dependence on local resources and increasing export of raw materials to urban areas has contributed to a vicious cycle of poverty and land degradation.

In spite of bearing almost no responsibility for climate change, African countries that depend so heavily on small-scale agriculture and the use of biomass as fuel may suffer some of its worst impacts in the form of drought, less predictable seasons and more extreme events. The lack of energy access leaves the most vulnerable persons with even greater constraints and fewer options in adapting to climate change (Sumiya, 2016). In addition to the benefits at household level, improvements in energy access can empower communities, improve adaptive capacity and build local resilience (Murphy and Corbyn, 2013).

At the same time, the climate challenge brings economic opportunities to African countries that are at an early stage of development and are investing in new energy infrastructure: green growth plans in many countries are shifting financing to more sustainable energy investments. Developing countries can seize on the opportunities afforded by international financing and the domestic advantages of renewable energy systems that can be brought online in smaller increments and with prospects for decreasing unit costs. The investment landscape for renewables in Africa has evolved considerably in recent years (Schwerhoff, 2016). Yet there are also significant governance challenges in insuring that the energy infrastructure now being installed across Africa is sustainable in social, economic and environmental terms (Johnson et al., 2017).

While either adaptation or mitigation can reduce climate change risk, harmonising both approaches can complement each other and the co-benefits can better minimise the risks (IPCC, 2014). Until now the energy sector has focused on mitigation, yet there is benefit in implementing strategies that accomplish both aims. Once established, these actions together can offer a more cost-effective and socially responsive way to respond to climate change in the energy sector while improving the ability of the energy sector to implement programs to respond to climate change (Morand et al., 2015). Combining these actions with energy access goals furthers the aim of climate-compatible development (Stringer et al., 2014).

Of special significance in the African context are the opportunities for improved land use management to stimulate transformations in agricultural and energy systems that could offer triple wins for
adaptation, mitigation and development (Suckall et al., 2015). Decentralised renewable energy options that have never been deployed significantly in developing countries have emerged in more cost-effective applications where they can also improve adaptive capacity in local communities (Venema and Rehman, 2007).

The identification and implementation of technical and institutional innovations in design and deployment of renewable energy and sustainable land use management are therefore critical in achieving climate and development goals in SSA. Vulnerable populations need energy access in order to adapt to climate change. At the same time, sustainable energy solutions to energy access will support global climate ambitions and reduce the longer-term impacts of climate change.

2.1 Objective and scope

This report provides a synthesis and review on the intersection of energy access, climate mitigation and climate adaptation in sub-Saharan Africa with special reference to three countries in eastern Africa (Ethiopia, Kenya, Rwanda). The current status of the energy and climate policies of these countries are used to illustrate some of the key trade-offs that occur. We also consider how energy access, mitigation and adaptation goals might be reconciled, so as to reduce risks to vulnerable populations while advancing transitions in energy and development pathways. As the issues are extremely broad, the report is selective and does not review them exhaustively. The synthesis and review in this report instead aims to identify key issues that can be explored in more depth and documented in a later report (as discussed in sections 1.1 and 2.3) using scenarios, quantitative modelling and qualitative comparisons across the three countries that are briefly profiled here.

2.2 Relation to WP4

WP4 is concerned with the inter-related policy goals and issues across different energy transition pathways in terms of linkages, synergies and conflicts. This sub-task does not have a direct relation in terms of inputs and outputs, but rather it is complementary to the other sub-tasks in 4.4; each sub-task within 4.4 considers different sectoral goals or perspectives in relation to climate goals, including health/pollution, land use, energy security, water resources and macro-economic effects (especially employment). By focusing on Africa, this report is also complementary to other tasks in WP4 in terms of geographical scope. Global energy-economic models, as used in other sub-tasks of task 4.4, generally do not capture the sub-Saharan context since it is quite small in economic terms (except for South Africa and Nigeria) but vast in its geography and diverse in its natural resource endowments and socio-economic characteristics. Thus this report focuses on Africa, whereas most sub-tasks in WP4 are global or emphasise the EU (D4.2) or other regions.
2.3 Relation to other WPs

This report is most directly related to task 6.4 in WP6. It provides the initial basis for the analysis to be undertaken within a sub-task of 6.4 that will focus especially on understanding the climate implications of innovative energy access interventions and cross-sector initiatives that support both energy access and climate aims. In that sub-task the focus will rest on the household energy transition itself in the African context, in terms of the long-term transformation from heavy dependence on non-renewable biomass to modern climate-compatible energy services.

2.4 Report organisation

In Chapter 3, we briefly discuss the significance of energy access in relation to economic development and human well-being and provide the common metrics and indicators. In Chapter 4, we provide an overview on the status of energy access, focusing especially on electrification rates and household biomass use. Chapter 5 shows the key mitigation options and the different policies and national strategies that have been developed and/or adopted. Chapter 6 considers energy sector options in the context of adaptation strategies and adaptive capacity. Chapter 7 looks at some of the cross-cutting issues that are especially valuable in conceptualising multi-objective approaches to reconcile energy access and climate aims. Three country cases (Ethiopia, Kenya and Rwanda) are used throughout the report to illustrate key issues and challenges.

2.5 Limitations

A few limitations must be noted. We have alluded previously to the limitations of addressing a broad topic through synthesis and descriptive analysis, which results in being somewhat selective. A related limitation arises due to geographical breadth, since SSA is a vast region with an incredible variety of physical and socio-economic conditions. The feasible and optimal solutions vary widely; thus we can only assess the current status in fairly general terms using three country examples while identifying some key linkages between energy access, mitigation and adaptation.

A second limitation arises in that we unfortunately cannot be precise in our use of the term “risk,” even though it is important within the TRANSrisk research programme. Because we consider energy access, mitigation and adaptation, the concept of risk might apply to different groups and at different levels. For example, it might be at systematic level in the case of infrastructure, at community level in terms of access and vulnerability or at national level in terms of risks associated with weak institutions or poor governance mechanisms. Risk is thus highly contextual in this report.
3 **ENERGY ACCESS MEASURES AND SIGNIFICANCE**

The impacts of climate change pose a significant threat to socio-economic development in SSA. The development priorities in the region are aimed at poverty reduction, economic growth and enhancement of human wellbeing. Economic development and human well-being require access to modern energy services, as outlined clearly in SDG-7 (UN, 2015). Energy access is also recognised to play a fundamental role in achieving other global imperatives such as gender equality, economic empowerment, improved health, and security (Practical Action, 2016). Energy access should be discussed in relation to *energy services*, especially basic services such as cooking, heating and lighting. Energy access is not necessarily concerned with specific fuels or applications although electricity access has special status since it provides high quality energy services for which electricity is the unique supplier.

In the African context, energy access is also closely linked to food security since the high dependence on traditional biomass for cooking contributes to negative health impacts, poor land use management, malnutrition and low productivity (Sola et al., 2016). Improvements in household energy access for cooking have direct impact on health, while household electricity access often has further direct effects on education and well-being. However, access to energy is important not only at household level but also for communities, industry and small-scale enterprises. Energy access for productive uses and for businesses and communities has direct impacts on economic growth and development. Energy access for mobility, i.e. motorised transport, can also have significant growth and development implications, although it is also dependent on infrastructure (roads) and is not addressed here as the focus is on stationary energy infrastructure and associated energy services.

3.1 **Definitions and measurement of energy access**

While there is no single definition, it is widely accepted that basic energy access includes:

1) access to a minimum level of electricity;
2) access to safer and more sustainable cooking and heating fuels and stoves (i.e. minimal harmful effects on health and environment as possible);
3) Access to modern energy that enables productive economic activity (e.g. mechanical power for agriculture, textile and other industries; and
4) Access to modern energy for public services, e.g. electricity for health facilities, schools and street lighting (IEA, 2016c).

Items 1 and 2 are within the household element of the three components or “locales” identified by ESMAP (2015), whereas items 3 and 4 relate to the other two components—productive engagements.
and community services, respectively. This inclusive approach recognises that merely counting the number of people connected to the grid doesn’t reflect the diversity of energy needs and services for household and commercial sectors. The Multi-Tier Framework, which shows how access is achieved at different levels and uses, was developed based on the different energy service requirements of the various users. The framework supports measurement, investment prioritisation, and tracking progress (ESMAP, 2015). It shows multiple modes of delivering energy access, includes the range of cooking fuels and can also help to reflect the contributions of various programs, agencies, and national governments towards achieving the energy access goals.

The Poor Peoples Energy Outlook, first published in 2012, defined Total Energy Access (TEA) based on key energy services (Practical Action, 2016). TEA is defined at the point of use in terms of energy services: lighting, cooking, water heating, space heating, cooling, and information and communications technologies. TEA minimum standards distinguish between household TEA, energy for enterprises, and energy for community services, to better understand these differing, but sometimes overlapping needs. The related Energy Supply Index (ESI) sets qualitative levels for the main supply dimensions: household fuels, electricity, and mechanical power (Figure 1).

Measuring and monitoring energy access levels supports national level energy planning. The seventh UN Sustainable Development Goal (SDG-7) identifies four dimensions in ensuring energy access: affordability, reliability, sustainability and modernity (UN, 2015). Those who lack energy access are
often among the poorest members of society and thus the same population is the target of SDG-1 that aims at eradicating poverty.

### 3.2 Global and African perspectives

Some countries and regions have made considerable progress on household energy access in recent years, particularly in Latin America where the electrification rate has reached 95%. A number of Asian countries have also made significant progress, particularly China where nearly all households now have electricity access. More than half of the world’s population lacking electricity access is located in SSA, where reliance on traditional biomass is above 80% (Table 1).

<table>
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<th>Population without electricity (millions)</th>
<th>Electrification rate (%)</th>
<th>Urban electrification rate (%)</th>
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<th>Population relying on traditional biomass (millions)</th>
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<td>2,742</td>
<td>38%</td>
</tr>
</tbody>
</table>

Due to population growth, the absolute numbers lacking energy access in Africa will increase under the business-as-usual case (IEA, 2016c). The low level of energy access in SSA poses fundamental challenges to sustainable development goals and constrains general growth and development objectives in some areas. At the same time, African countries are often highly exposed to climate impacts and consequently the most vulnerable populations are faced with multiple burdens that require comprehensive responses (Chevallier, 2006).

### 3.3 Household energy transitions

Heavy reliance on traditional biomass (firewood, charcoal, dung and agricultural residues) has been associated with serious socio-economic, health and environmental impacts. An estimated 4.3 million premature deaths occurred globally in 2012 due to exposure to household cooking fuels (WHO, 2014). Unsustainable harvesting of biomass, referred to as non-renewable biomass, is concentrated in
hotspots such as East Africa where population growth and lack of energy access are contributing to land degradation and deforestation (Bailis et al., 2015). Biomass combustion from cooking and land clearing for charcoal production contribute to GHG emissions and short-lived climate pollutants, particularly black carbon (UNEP/WMO, 2011). Consequently, low emissions development pathways are difficult with high traditional biomass dependence, even as populations and material demands are increasing. Furthermore, the significant health and social impacts of traditional biomass illustrate the opportunities for valuable synergies between climate and development goals as energy access is improved. At the same time, fuelwood and charcoal account for millions of livelihoods across Africa, creating strong economic interests (Openshaw, 2010).

The transition in household energy use has been conceptualised as an “energy ladder” (Figure 2) based on the principle that as households (and small industries to some extent) in developing countries increase their income or wealth, they switch from traditional biomass to modern fuels and electricity (Leach, 1992; Barnes and Floor, 1996). With successive rungs of the ladder, higher quality energy services are provided and negative social, health and environmental impacts of traditional biomass use are reduced or eliminated. Crop residues and fuelwood are the lowest quality; charcoal and kerosene are often seen as transitional fuels adopted by urban consumers aiming at more efficient fuels and health benefits; and gas and electricity are the cleanest fuels from a household perspective. Bioethanol has been promoted as a portable and clean cooking fuel that fills market gaps and provides significant climate and consumer benefits (Takama et al., 2012).

![Figure 2: Energy Ladder theory for household energy transitions](image-url)
Although the energy ladder may describe the long-term changes reasonably well, it does not accurately describe the transition process itself at household level, which is more likely to be characterised as “fuel stacking” (Masera et al., 2000). Households normally rely on multiple fuels and stoves in order to accommodate the needs of larger households and/or to reduce costs as fuel and stove prices or availability change over time. Projects, programmes and strategies that aim to accelerate the shift away from traditional biomass need to recognise the complex nature of the shifts and the marginal changes that occur. A number of countries have developed “Biomass Energy Strategies (BEST)” aimed specifically at shifting away from unsustainable biomass use (Government of Malawi, 2009; Government of Mozambique, 2012). Such strategies aim not only at increasing efficiency and commercial access but also coordination of local government policies with national policies for forest management and land use planning.

3.4 Energy access for productive engagements

Energy access often emphasises households, since business and industry face primarily economic and infrastructure barriers, whereas household energy shifts have more direct impacts on well-being. However, another dimension of energy access relates to productive uses and income-generating activities that generally take place in small enterprises, which can also include household-based enterprises (TERI, 2011). Furthermore, the definition of “productive” use should be broadened to include education, health and gender; improved energy access in schools, health clinics and community settings plays an invaluable development role (Cabral et al., 2005). Although not covered in this report, due to the emphasis on vulnerable populations, it must be noted that such productive uses deserve further scrutiny.

Energy access for productive uses in the agricultural sector has direct impacts on food security, adaptive capacity and other dimensions highly relevant for vulnerable populations. Increased agricultural productivity in SSA is essential for reducing poverty and improving adaptive capacity of marginalised regions. For small farmers, modern energy services can increase incomes at each step of the agricultural value chain from production, post-harvest processing and storage to marketing (Figure 3). Small farmers are also part of the wider group of micro and small-scale enterprises (MSEs), which are often run by those lacking energy access.

3.5 Electricity access

Improving electricity access requires addressing the problems of high cost of connections, grid unreliability, accessibility to infrastructure and high household tariffs. When considering total access concepts, measurement is based on technology-neutral multi-tiered standards where successive
thresholds for supply attributes allows increased use of electric appliances. The key attributes relevant for household electricity multi-tier standards are: (i) capacity, (ii) duration (including daily supply and evening supply), (iii) reliability, (iv) quality, (v) affordability, (vi) legality, and (vii) health and safety (ESMAP, 2015).

![Diagram of the agricultural value chain]

Figure 3: Energy inputs across the agricultural value chain (Source: Practical Action, 2016)

In regions with low population densities, the cost of connections per household increases and there are also greater distribution losses. Costs are linked to the demand side, since low per capita consumption in developing countries limits the payback on projects with large upfront investment costs. Many countries have developed long-term strategies for cost-effective electric power sectors (GoK, 2011; GoR, 2015).

However, the pace of new connections has not kept up in SSA, and many rural areas are unlikely to obtain grid access for many years to come due to costs, financing and weak institutions. Consequently, decentralised electricity systems, are seen as a more effective solution. Off-grid systems and mini-grids that focus on industry and businesses are more likely to reach a critical mass of customers and cover their fixed costs than those that focus only on households. Developers of smaller mini-grids (those under 1MW, especially under 100kW) often must market to customers by promoting productive, income generating uses for electricity. Larger mini-grids (those over 1MW) may sell their electricity through a power purchase agreement (PPA) to an anchor client such as a government entity or small industrial operation such as a telecom tower or flower farm. These larger mini-grids are likely to have more predictable cash flow and construction and expansion may be easier to finance than mini-grids targeting smaller customers, (AfDB, 2016). Off-grid options are discussed further in section 4.2 below.
4 Energy Access in the African Context

Lack of access to modern energy services provided by electricity and modern fuels is more widespread in sub-Saharan Africa (SSA) than in any other major world region. Outside of South Africa, the overwhelming majority of rural areas and even many urban areas lack reliable access to electricity. The availability and/or affordability of modern fuels such as LPG are also greatly constrained. At the same time, climate change and energy security goals are influencing the nature and direction of energy investment, as many African nations place additional emphasis on developing domestic resources and/or renewable energy options. This chapter provides a brief overview of energy access and energy sector plans in the African context, with some additional profile and comparison for three countries in eastern Africa: Ethiopia, Kenya and Rwanda.

4.1 Electricity access

The electric power sector remains underdeveloped and underutilised in SSA yet it is vital for its future growth and development (Schwerhoff, 2016). The lack of access to modern energy services in SSA stands in contrast to its huge energy potential (IEA, 2016b). Energy affordability remains a critical issue because of low disposable income, inefficiency of energy supply and high electricity prices (Sambo, 2016). Even for those with some electricity access in Sub-Saharan Africa (SSA), supplies are often unreliable, with frequent cases of power shortages and interruptions that hamper economic growth and development (Welsch et al., 2013).

The estimated SSA population without access to electricity as of 2016 was 632 million people (Table 2). More than half of that total is concentrated in just six countries: DRC, Ethiopia, Kenya, Nigeria, Tanzania and Uganda.

Table 2: Electricity Access in Sub-Saharan Africa

<table>
<thead>
<tr>
<th>Region</th>
<th>Population without electricity (Millions)</th>
<th>National Electrification rate (%)</th>
<th>Urban Electrification rate (%)</th>
<th>Rural electrification rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>634</td>
<td>45</td>
<td>71</td>
<td>28</td>
</tr>
<tr>
<td>Sub-Saharan Africa (SSA)</td>
<td>632</td>
<td>35</td>
<td>63</td>
<td>19</td>
</tr>
<tr>
<td>Kenya</td>
<td>36</td>
<td>20</td>
<td>60</td>
<td>7</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>73</td>
<td>25</td>
<td>85</td>
<td>10</td>
</tr>
<tr>
<td>Rwanda</td>
<td>8</td>
<td>27</td>
<td>72</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: IEA (2016a)
In SSA, the overall electrification rate is estimated to be 35%, with an urban electrification rate of 63% and rural electrification rate of 19% (IEA, 2016a). By contrast, electrification rates in Northern African countries are nearly 100%. Among Eastern African nations, Rwanda has been able to increase its national electrification rate to 27%, due in part to its smaller size but also due to considerable government efforts in recent years. Ethiopia has been able to achieve a high urban electrification rate of 85%, but because of its large rural population (80% of the population), progress at national level lags behind. Kenya has achieved an urban electrification rate of 60% but its rural electrification rate remains stubbornly low at 7%. The Brighter Africa report promotes a goal of 70% grid connection in SSA by 2040 (Brighter Africa, 2015).

Power Africa is an innovative development model initiated in 2013 aimed at facilitating electricity access across the continent and based on three pillars: generation, connection and unlocking (Power Africa, 2016a). It includes on-grid and off-grid power with the aim to double electric power access by 2030 and increase generation capacity to nearly 30 GW by 2030. To track the targeted connections, Power Africa has developed an online tool, the Power Africa Tracking Tool (PATT).

### 4.2 An emerging role for off-grid solutions

The low rate of rural electrification has led to various alternative approaches, especially mini-grids or standalone systems. By 2040, it is projected that 70% of the new rural electricity connections in SSA will be provided by mini-grids and stand-alone systems, with 40% of the investment needed to achieve universal access to energy achievable through deployment of mini-grids (IEA, 2014). Rwanda, with support from the Africa Development Bank, is reaching out to 145,000 rural homes with mini-grids and aims to boost off-grid access from the current 5% to 22% by 2018.

In the countries of the Southern African Development Community (SADC), installation of mini-grids reached 728 MW by the end of 2014 (Johnson and Muhoza, 2016). Approximately 400 MW of this total were renewable-based mini-grids, with a variety of configurations (see Table 3). Low oil prices in recent years along with widespread availability have contributed to the popularity of diesel-based mini-grid systems. Yet the cost per unit of electricity rises further in remote and/or land-locked areas, due to the high road transportation costs and logistical costs.

However, development of mini-grids comes with challenges too like gaps in regulatory and policy sector, weak business models lack of market data and linkages, inadequate access to finance and lack of capacity among the key stakeholders. Another key challenge in scaling up mini-grids is that solutions must be tailored to the local economic and social context (Johnson and Muhoza, 2016). Nevertheless, improved matching of multiple complementary sources of supply to meet local needs is an enabling characteristic of mini-grids that creates an important role in the African context.
Other off-grid solutions have emerged through technological advancements coupled with new business models, particularly in the solar industry where households and communities are gaining access. Solar home systems have been operating for two decades in South Africa, and have enabled access in remote areas even after significant grid expansion (Lemaire, 2011). Pay-as-you-go solar companies (e.g. M-Kopa, Off-Grid Electric, d.Light, Bboxx, Nova Lumos, Mobisol) have been growing considerably in East and West Africa, selling through kiosks and other means and serving over 700,000 customers, which is nevertheless a small fraction of the potential market (FS-UNEP, 2017).

Table 3: status of known mini-grids in southern Africa (in MW, 2015; Source: Johnson and Muhoza, 2016)

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>Biomass (and biomass hybrids)</th>
<th>mini-hydro (1-9 MW)</th>
<th>other hydro (&lt; 1 MW)</th>
<th>Solar PV</th>
<th>Wind</th>
<th>Other (including other hybrids)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
<td>139,0</td>
<td>21,3</td>
<td>0,1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>160,4</td>
</tr>
<tr>
<td>Botswana</td>
<td></td>
<td></td>
<td>1,3</td>
<td>0,1</td>
<td></td>
<td></td>
<td></td>
<td>1,4</td>
</tr>
<tr>
<td>DRC</td>
<td>39,0</td>
<td></td>
<td>0,1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39,1</td>
</tr>
<tr>
<td>Lesotho</td>
<td></td>
<td></td>
<td>0,7</td>
<td>0,1</td>
<td></td>
<td></td>
<td></td>
<td>0,8</td>
</tr>
<tr>
<td>Madagascar</td>
<td>10,0</td>
<td>2,0</td>
<td>3,0</td>
<td>0,2</td>
<td></td>
<td></td>
<td></td>
<td>15,2</td>
</tr>
<tr>
<td>Malawi</td>
<td>1,1</td>
<td>5,9</td>
<td>1,0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8,0</td>
</tr>
<tr>
<td>Mauritius</td>
<td>19,0</td>
<td></td>
<td>18,0</td>
<td>1,3</td>
<td>1,2</td>
<td></td>
<td></td>
<td>39,5</td>
</tr>
<tr>
<td>Mozambique</td>
<td>1,9</td>
<td>0,5</td>
<td>1,2</td>
<td>0,3</td>
<td></td>
<td></td>
<td></td>
<td>3,9</td>
</tr>
<tr>
<td>Namibia</td>
<td>1,1</td>
<td></td>
<td>4,5</td>
<td>0,3</td>
<td>0,2</td>
<td></td>
<td></td>
<td>6,1</td>
</tr>
<tr>
<td>Seychelles</td>
<td>84,0</td>
<td></td>
<td>0,9</td>
<td>6,0</td>
<td></td>
<td></td>
<td></td>
<td>90,9</td>
</tr>
<tr>
<td>South Africa</td>
<td>4,4</td>
<td>195,3</td>
<td>1,9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>201,6</td>
</tr>
<tr>
<td>Swaziland</td>
<td>7,7</td>
<td></td>
<td>0,1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7,8</td>
</tr>
<tr>
<td>Tanzania</td>
<td>53,0</td>
<td>11,5</td>
<td>15,0</td>
<td>2,0</td>
<td>11,0</td>
<td>7,5</td>
<td></td>
<td>100,0</td>
</tr>
<tr>
<td>Zambia</td>
<td>11,3</td>
<td>3,0</td>
<td>25,5</td>
<td>2,0</td>
<td></td>
<td></td>
<td></td>
<td>41,8</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>0,5</td>
<td>6,1</td>
<td>0,4</td>
<td>5,0</td>
<td></td>
<td></td>
<td></td>
<td>12,0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>328,5</strong></td>
<td><strong>19,4</strong></td>
<td><strong>307,7</strong></td>
<td><strong>7,5</strong></td>
<td><strong>48,3</strong></td>
<td><strong>8,0</strong></td>
<td><strong>9,0</strong></td>
<td><strong>728,3</strong></td>
</tr>
</tbody>
</table>

4.3 Biomass use and access to modern fuels

The use of traditional biomass resources as a household fuel in Sub-Saharan Africa continues to increase despite efforts to search for alternatives. The high environmental and health burden of such dependence on traditional biomass is a significant barrier to development goals (Masera et al., 2015). Outside of South Africa, in rural areas of SSA, household dependence on biomass often approaches 100%. The number of people relying on traditional biomass in SSA is estimated as 792 million, which is nearly 90% of the population. In Eastern Africa, dependence remains stubbornly high due to the
“free” nature of woody biomass, reaching 98% in Rwanda, 95% in Ethiopia and 85% in Kenya (Table 4). In reality of course, it is not free, since many of these areas experience land degradation as a result. A few African countries with large populations (DRC, Ethiopia, Nigeria, and Tanzania) account for a majority of the woodfuel extraction in SSA (Figure 4). Due to significant population growth, it is estimated that 1.8 billion people will still be dependent on traditional biomass resources in SSA in 2040 (IEA, 2014).

![Figure 4: Annual estimated woodfuel use (for firewood and charcoal) in selected countries (IEA, 2014)](image)

There are nevertheless a variety of improved stoves, fuels and applications that allow biomass to be used much more efficiently as well as delivering better energy services (Smeets et al., 2012). Such alternatives are important since fuel-switching is costly and biomass will remain the major source of energy for low income households across SSA for many years to come.

Table 4: Reliance of traditional biomass resources in SSA (Source: IEA, 2016c)

<table>
<thead>
<tr>
<th>Region</th>
<th>Population relying on traditional use of biomass (Millions)</th>
<th>Percentage of population relying on traditional use of biomass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>793</td>
<td>69</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>792</td>
<td>89</td>
</tr>
<tr>
<td>Rwanda</td>
<td>11</td>
<td>98</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>92</td>
<td>95</td>
</tr>
<tr>
<td>Kenya</td>
<td>38</td>
<td>85</td>
</tr>
</tbody>
</table>

Eastern Africa has been identified as a hotspot for unsustainable woodfuel harvesting and thus a significant carbon footprint (Bailis et al., 2015). Population growth and growing urban demand for...
charcoal has contributed to deforestation and degradation as biomass becomes scarce; biomass deficits translate into unsustainable harvesting and imports from other countries. Land use conversion to agriculture or pasture after unsustainable harvesting may lower overall productivity further. In the case of Kenya, biomass deficits are expected to grow further (Githomi and Oduor, 2012). The overall deficit in tonnes/year is expected to increase by 70% during 2000-2020 (Table 5).

Table 5: Historical and Projected Biomass Consumption/Supply in Kenya (GoK, 2013)

<table>
<thead>
<tr>
<th>Years</th>
<th>Yr. 2000</th>
<th>Yr. 2005</th>
<th>Yr. 2010</th>
<th>Yr. 2015</th>
<th>Yr. 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>28.7</td>
<td>32.7</td>
<td>36.8</td>
<td>40.2</td>
<td>45.0</td>
</tr>
<tr>
<td>Consumption, million tonnes/yr</td>
<td>35.1</td>
<td>39.9</td>
<td>44.6</td>
<td>49.2</td>
<td>53.4</td>
</tr>
<tr>
<td>Sustainable supply, million tonnes/yr</td>
<td>15.0</td>
<td>15.5</td>
<td>16.6</td>
<td>18.0</td>
<td>19.6</td>
</tr>
<tr>
<td>Deficit, million tonnes/yr</td>
<td>20.0</td>
<td>24.4</td>
<td>28.0</td>
<td>31.0</td>
<td>33.9</td>
</tr>
<tr>
<td>Deficit (%)</td>
<td>57.2</td>
<td>61.2</td>
<td>62.7</td>
<td>63.4</td>
<td>63.4</td>
</tr>
<tr>
<td>Deficit(tonnes/person)</td>
<td>0.70</td>
<td>0.75</td>
<td>0.76</td>
<td>0.76</td>
<td>0.75</td>
</tr>
</tbody>
</table>

### 4.4 African renewable energy targets

Investment in renewables in SSA has increased considerably in recent years, led by South Africa. Although infrastructure is poor compared to Europe, decreasing costs and a favourable investment climate aimed at diversifying the power sector has supported sustained growth in renewables in South Africa, which is poised to exceed its previous goal of 3.7 GW of renewables by 2020 (JCRA, 2017). Investment in the Sub-Saharan renewable energy sector overall has more than doubled during the past 15 years or so (FS-UNEP, 2017). The Africa-EU Energy Partnership (AEEP) status report of 2016, show installed capacity of renewable energy between 2010 and 2015 an AEEP targets by 2020 (Figure 5). A key development is the diversification away from hydro among renewable options; although still in its infancy, the high potential in the region has opened up new opportunities as generation costs have fallen on the global market. The shifts are also closely linked to the commitments made under the Paris Agreement in African nations’ NDCs, and have benefitted from an improved international investment climate for renewables.

Ethiopia, Kenya and Rwanda are among those countries that have linked their overall development goals to renewable energy targets, as a way to grow their economies more sustainably and improve energy access without compromising climate goals. Consequently they have encouraged both domestic and foreign investment in renewable energy in recent years. In addition to the power sector, SSA countries have also invested in biofuels in the transport sector so as to also address energy security concerns (Sekoai and Yoro, 2016). Those SSA countries that that are oil importers and/or landlocked...
such as Malawi and Zimbabwe in fact already started investing in biofuels in the 1980s (Johnson and Matsika, 2006). Other opportunities foreseen for biofuels in SSA include: household energy access in rural settings, community use for small-scale electricity generation and powering farm machinery and irrigation equipment.

Figure 5: Renewables and AEEP target by 2030 (AEEP, 2016)

4.5 Energy status in Eastern Africa

Eastern Africa faces energy deficits as supply has not kept pace with increasing demand. Investments in renewables are aimed at lowering the energy deficit both in urban and rural settings, and are often facilitated by the associated GHG reduction benefits (Salahuddin et al., 2015). The EAC Renewable Energy and Efficiency report of 2016 indicates that rapid urbanisation and population growth have
magnified the energy challenges. Brief energy access case studies are provided here for Kenya (Box 1), Rwanda (Box 2) and Ethiopia (Box 3).
# Energy Sector Overview for Kenya


## Energy sector overview

Kenya has established a long-term development plan, Vision 2030, which aims to transform the country into a middle-income economy by 2030. The Ministry of Energy and Petroleum (MoEP) report of 2016 on Sustainable Energy for All (SE4All) towards Kenya Investment Prospectus (KIP) indicates that the demand for energy in Kenya will double in the next 10 years. Power demand grew steadily in Kenya, adding 1512MW by 2014 compared to 899MW in 2004/2005. Kenya has rolled out its Least Cost Power Development Plan (LCPDP) that will run for twenty years. The plan will be updated every two years from 2013-2033.

## Energy mix

- The total installed electric power capacity in Kenya as of November 2014 was 2295 MW. Sources include hydropower (821MW), Geothermal (598MW), wind (25.5), fossil/thermal (827MW) and cogeneration from bagasse (26MW).
- 20% of power generation is produced by Independent Power Producers (IPPs), including Iberafriaca Power, Westmont Power, Orpower 4 and Tsavo Power Company.

## Energy demand

- Energy demand in Kenya outstrips supply. Major energy sources in Kenya are biomass (69%), electricity (22%) and petroleum (9%).
- Domestic demand according to Kenyan economic survey (2016) was 3652 KWh.
- Only 20% of population has access to electricity (60% urban and 8% rural areas); biomass in the form of fuelwood and charcoal meets basic energy needs of rural areas and urban poor.

## Energy development plans

- SREP Investment Plan - this plan is in line with Least Cost Power Development Plan (LCPDP) that aims scaling up renewable energy anchored to Vision 2030.
- Power Generation and Transmission Master Plan (2015-2030) - this plan aims to turn Kenya into a secure, reliable and cost effective as per power generation and transmission in its load centre.
- Kenya, being part of Eastern Africa Power Pool project, is expected to start importing electricity from Ethiopia when phase 1 of the project is complete, as an addition to its energy mix.

## Energy challenges

- Electricity tariffs are higher compared to other countries in Africa. The cost of a kWh in Kenya is 0.15 USD with a fixed charge of 1.4 USD. In Ethiopia the cost per kWh is 0.09 USD and Rwanda is 0.22 USD
- Limited capacity during peak demand hours
- Rural electrification cost still high for the poor because majority live below 1 USD per day and they opt for biomass (charcoal and wood) that is easily accessible.
- The distribution capacity is limited.
- There is low investment from private investors to the power sector.
- Complexities within transmission agencies and power generation agencies
Box 2: Energy Sector Overview for Rwanda (GoR, 2015)

### Energy sector overview

The Government of Rwanda (GoR) through its current Economic Development and Poverty Reduction Strategy envisions to achieve middle income country status by 2020, including a goal of 100% electricity access. Rwanda has considerable potential energy resources including solar, hydro, peat and natural gas. Rwanda energy sector is dominated by biomass which accounts to 85% for domestic use (households). Rwanda has the lowest electricity consumption per capita in Eastern Africa.

### Energy mix

Rwanda has an estimated 112MW installed electricity capacity. The energy mix for the national grid includes hydropower (59%), thermal generation (40%) that consists of heavy oil fuels and diesel, and natural gas (1%).

Rwanda aims to increase generation from hydro (333MW), Natural gas (300), Geothermal (310), Peat (200) and Solar PV (20MW).

### Energy demand

Energy demand deficit, due to technology adoption, population increase, urbanisation and economic development. Energy Strategic Plan aims to increase power access and affordability by phasing out indiscriminate electricity subsidies.

### Energy development plans

Rwanda Development Board has established targets for energy access and power generation, some of which are anchored to 2020.

- a) Government aims to reduce biomass dependency from current level of 86% to 50% by 2020.
- b) All public institutions to have 100% connection by 2018.
- c) Increase its electricity generation capacity to 563MW from 186MW by 2018.
- d) National electricity access to up by 70% by 2017/18.

Through these energy planning targets, Rwanda has established the following strategies:

- a) Involving private sector in energy generation that will include Independent Power Producers (IPPs) and Private Public Partnerships (PPPs).
- b) Rwanda has emphasised energy diversification.
- c) Setting up agreements. In January 2015, the Government approved two Power Purchase Agreements (PPAs) and Concession Agreements for development of Green Fields micro hydro projects, including Nyundo (4 MW) and Rwaza-Muko site of (2.6 MW).

### Energy challenges

- a) Biomass remains the dominant source of energy, which is mainly used in households.
- b) Rwanda requires more funding to boost its energy sector. It has been a challenge for the country to obtain grants internationally. Foreign financial support is needed to expand its power sector.
- c) Low consumption of commercial energy as majority of the population relies on woodfuel.
- d) Low generation capacity to meet national energy demand.
- e) Insufficient institutional and legal frameworks.
- f) Higher importation costs on power generation inputs. e.g. oil products.
Box 3: Energy Sector Overview for Ethiopia (CRGE, 2012; MWE, 2012; Climate Action Tracker, 2017)

**Energy sector overview**

Ethiopia is a major economic actor in Eastern African economy. Annually Ethiopia’s GDP grows by nearly 10.7 percent. By 2020, the Ethiopian government aims to become a middle income country with the strongest economy across the East African region. Energy sector expansion is a critical driver for growth and development.

<table>
<thead>
<tr>
<th>Energy mix</th>
<th>Energy demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia transmission covers 10,869 kilometres with transmission lines of 400kV, 230kV and 132kV capacity of National Load Dispatch Centre. Ethiopia power mix comprises of 88% hydro, geothermal (1%) and the remainder mainly fossil thermal. Ethiopia has high renewable energy potential, including hydro (45000 MW), geothermal (7000MW), and wind (10000MW). As of end 2014, woodfuel dominates the energy sector with 1120 million tons (50%) with natural gas 113 million tons and coal 300 million tons respectively.</td>
<td>Ethiopian demand is currently expected to grow more than 32% per year. The current installed generating capacity of approximately 2,300Mw is far from meeting the rising demand. Nearly 81% of Ethiopian households depend on biomass (firewood) and about 11.5% rely on dung and various other residues for cooking.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy development Plans</th>
<th>Energy challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>The government of Ethiopia to meet its energy demand has installed various projects.</td>
<td>a) Increasing population that surpasses the current energy generation.</td>
</tr>
<tr>
<td>a) Gibe 3 hydro with installed capacity of 1870MW expected to produce 6240GWh/yr.</td>
<td>b) The ongoing projects still lack adequate funding to be completed.</td>
</tr>
<tr>
<td>b) Grand Renaissance hydro - 6000MW expected to produce 15700GWh/yr.</td>
<td>c) The power grid infrastructure still remains a major challenge.</td>
</tr>
<tr>
<td>c) Wind farms with grand total of 8397MW with expected annual average of 23,514GWh/yr.</td>
<td>d) Hydro energy has been a prioritised sector compared to other sectors like geothermal, gas, wind and solar.</td>
</tr>
</tbody>
</table>

Ethiopia pledged to spend 20 billion dollars between 2015 and 2020 on the power development programme in the second phase of the Growth & Transformation Plan (GTP-II).
These brief country summaries are of course not intended to be exhaustive, but they do reveal certain commonalities that have emerged in the past decade or so between energy access goals and the broader energy and climate landscape in these countries. Whereas energy access was previously associated primarily with infrastructure investment aimed at widening the provision of modern fuels and electricity, energy access is now more integrated into energy, climate and natural resource planning so as to facilitate synergies with greener economic growth and sustainable development.

The diversification away from large-scale hydro among renewables in the power sector in all three countries is one clear manifestation of this shift in policy and planning. At the same time, the significant cost reductions in small and medium-scale renewable energy options during the past two decades has opened up the opportunities for such shifts. By investing in energy projects of a more manageable size and lower initial capital investment, the “new” renewables (i.e. excluding large-scale hydro) are more tailored towards local needs while also hedging the supply and demand-side risks that are associated with large investments.

There is a somewhat analogous diversification in the approach to the high dependence on traditional biomass. In past years, there was a common expectation that more efficient cookstoves in combination with rapid increase in electricity connections would solve the biomass issue. It is now widely accepted that other complementary approaches are needed that combine natural resource management with more effective and efficient alternatives that are tailored to local needs, including biogas, electricity mini-grids, agro-forestry and other smaller-scale decentralised options for energy and resource management.
5 RELATION TO MITIGATION GOALS

Africa is facing severe climate change impacts even though it bears almost no responsibility for it, as some 96% of world GHG emissions are attributable to developed countries along with Asia (Nakhooda, et al; 2011). Collier et al. (2008) narrates how Africa is likely to suffer severe consequences of climate change mainly as a result of over-dependency on rain-fed agriculture and limited adaptive capacity. The parties to the UNFCCC agreed to hold the increase in the global average temperature below 2°C, above pre-industrial levels, as indicated in the Paris Agreement of 2015. Governments sought voluntary cooperation through Nationally Determined Contributions (NDCs) to allow for higher ambition in local mitigation and adaptation actions taken by 2030 (Marcu, 2016). Leading the way, the EU climate and energy framework set up ambitious targets of 40% cuts in GHG emission below 1990 levels by 2030. Several African countries also have ambitious and well-articulated low carbon development goals.

In the African context, climate change mitigation options should not be seen as the primary objectives but should rather be viewed within the overall energy and development context. In this chapter, we use especially the lens of energy access in discussing climate mitigation goals and measures. We briefly provide an overview of climate change emission in SSA and in selected Eastern African countries (Kenya, Ethiopia and Rwanda) and explore mitigation options as described in the Nationally Determined Contributions (NDCs). We then compare and discuss some key linkages and conflicts or synergies between energy access priorities and the respective NDCs.

5.1 Brief economic overview

The SSA region had a population of roughly one billion people in 2016 (Africa Economic Outlook, 2016) and with an average population growth rate of 2.8%. About 62% of the total population lives in rural areas, however there is an increasing urban influx from the rural areas. By 2014, about 35% of the total population had access to electricity with 63% of the urban population and 19% of the rural population connected to the grid (IEA, 2016c).

The capacity (as well as the responsibility under UNFCCC) to engage in climate change mitigation is closely related to the level of wealth and economic development. The majority of countries in SSA are low income or lower middle-income according to World Bank definitions, with GDP per capita less than 4035 USD per year, while only two (Botswana and South Africa) are high-income (Figure 6). The low income countries are largely dependent on rain-fed agriculture along with some small industries, although in some cases they are also major commodity exporters for non-petroleum products. The major petroleum exporters (Angola and Nigeria) fall in the higher middle-income group. The more
developed economy of South Africa exhibits much higher overall economic diversification, with the exception of its power sector that is still based overwhelmingly on coal.

![Figure 6: GDP per capita for SSA countries with population over 2 Million (Africa Economic Outlook, 2016)](image)

Agriculture is the backbone of the African economy, contributing 14% of the GDP (Berendregt et al., 2015). From the World Bank statistics, total agricultural land is estimated at 10.2 million km$^2$ covering about 42% of total land area. From 1961 to 2014, agricultural land grew by 8%. However, arable land in hectares per person has decreased substantially due to population growth, from 0.57 ha/capita in 1961 to 0.22 ha/capita in 2014 (World Bank Data, 2017).

The forest sector and associated products are nearly as important as agriculture to African economies, especially those without mineral resources. Future sustainability is threatened in some areas with forest cover declining from 1990 levels of 29.5% of total land area to 25.7% in 2014. The 3.8% forest cover reduction can be attributed to population growth, the need for more agricultural land and the high dependence on trees for timber and fuel. Woodfuel for firewood and charcoal accounts for 90% of total harvested biomass in the region. As shown in Figure 7, a significant share of land cover in the region spans semi-arid and arid regions or agro-ecological zones (Berendregt et al., 2015). Climate change variability poses an even greater threat in such regions, affecting the livelihoods and survival of millions of people in SSA dependent on agriculture and livestock. The implementation of Sustainable Land Management (SLM) practices is thus crucial in both climate and energy terms (Liniger et al., 2011).
5.2 GHG emissions in SSA

GHG emissions in SSA have experienced an average growth rate of 4%, with the rate of increase outside of South Africa slightly surpassing that of South Africa itself (Figure 8). Due to its heavy reliance on coal and much larger economy, South Africa nevertheless still accounts for more than half of GHG emissions in SSA. Excluding South Africa, the emissions profile in SSA is quite different from the global profile in which energy, transport, wastes and industry accounts for roughly 75% of total GHG emissions, while agriculture, forestry and land use (AFOLU) accounts for 25%. The situation is reversed in the SSA context where AFOLU constitutes the major sources of emissions, accounting for more than 80% of the total in some countries. Municipal solid waste contributes 1-4% of total anthropogenic GHG emissions; however this share has been increasing in developing nations (Sunil-Kumar et al., 2004; IPCC, 2010).
5.2.1 Emissions associated with land use

Land use, land use change and forestry (LULUCF) is an important segment of AFOLU in the African context as it is the largest or the second largest source of GHG emissions (after agriculture) in many SSA countries. Land degradation results from slash and burn agriculture, uncontrolled fires, and unsustainable harvesting of wood for timber, firewood and charcoal. Fuelwood and charcoal provide more than 80% of African household energy needs in SSA (excluding South Africa) and contribute to 90% of wood harvested (Africa Economic Outlook, 2016). Unsustainable harvesting of trees for firewood and charcoal threatens forest health and biodiversity and contributes to land degradation and desertification. Past land use emissions estimates have tended to count emissions from deforestation but not degradation: according to Pearson et al. (2017), emissions from land degradation amount to more than one-third of emissions from deforestation. In the African context these emissions are associated fairly evenly with timber extraction, woodfuel use and fires.

Livestock is also a major source of agricultural GHG emissions in SSA; measures such as intensification, agro-forestry, soil sequestration and multiple use systems have been promoted to reduce emissions. Climate mitigation measures in the livestock sector that address soil and vegetation responses yield significantly higher reductions that soil sequestration measures alone (Brown et al., 2012). Livestock grazing, depending on land use practices, can give rise to significant GHG emissions even as overall productivity may be low: food production in Sub-Saharan Africa could be tripled by widespread

Figure 8: Total emission trends in SSA (World Bank Data, 2017)
adoption of site-specific best management practices that result in sustainable intensification and lower emissions (Gerssen-Gondelach et al., 2017).

5.2.2 Emissions from fuel combustion

![CO2 Emission from Fuel Combustion in 2014](image)

**Figure 9: Emissions from fuel combustion in Africa (IEA, 2014)**

As shown in Figure 9 and Figure 10, electricity and heat production dominate energy-related emissions in Africa at 45% with South Africa contributing to 83% of total power sector emission. The industrial and transport sectors follow at 12% and 22% respectively. The only sector where South Africa does not dominate is transport, which is mainly due to high energy use in freight transport due to the long distances across SSA, the poor road conditions and the lack of other modes or alternatives such as rail. Considering that the power sector in SSA outside of South Africa is expected to be largely based on renewables in the future, the non-power sectors may offer a different mix of least-cost mitigation efforts compared to the historical record in developed countries that coincided with falling renewable power costs.

The low consumption in residential sector is due to high biomass use in SSA, with most of the emissions being attributable to land use change or forestry rather than energy or fuel use. Non-biomass residential use of energy for cooking would be with fairly efficient alternatives, mainly LPG along with kerosene and electricity.
5.2.3 Emissions from Other sectors

Among the other key sectors for GHG mitigation effort in SSA is that of municipal waste management, which is a major health and environment challenge in most urban cities in Africa and an increasing source of potent emissions due to methane leaking from landfills. Many African cities have unmanaged landfills, illegal dumps and uncollected wastes (Couth and Trois, 2011). Besides being an environmental hazard, waste management in developing countries is also a major financial expenditure. Scarlat et, al (2015) reports that between 20%-50% of municipal budgets in many African cities were spent on waste management, of which 80%-90% was used for collection even with more than 50% of residences not served. Couth and Trois (2011) further describe the wastes in SSA as having biogenic content of around 56%, which is approximately 40% higher than developed countries and hence leads to higher methane emission. The rampant open burns have contributed to increased pollution, causing illness and premature deaths as well as GHG emissions.

5.3 GHG mitigation in selected East African countries

A brief profile of GHG emissions in Kenya, Rwanda and Ethiopia is provided here. As shown in Figure 11, AFOLU sectors form the overwhelming part of GHG emissions in all three cases, contributing to 71%, 84% and 93% of GHG emissions in Kenya, Ethiopia and Rwanda, respectively. The power sector
has a substantial contribution to GHG emission in Ethiopia and Kenya due to thermal power plants. However, the significant investment in renewables in the two countries suggests that the power sector is unlikely to be a significant source in the future. Waste is currently a small share of emissions, however with urbanisation in all three countries, emissions associated with municipal solid waste are likely to increase (Scarlat et al. 2015).

![Figure 11: GHG emission contribution by source in Ethiopia, Kenya and Rwanda](image)

*Source: UNFCCC, 2017; Stiebert, 2013*

A comparison of emissions for the different GHGs in each country, with and without land use impacts, is shown in Figure 12. A number of issues are noteworthy from this comparison. First, the role of agricultural-based non-CO₂ gases (CH₄, N₂O) is significant in all three countries; considering the low productivity of agriculture in many regions of the three countries, ample opportunities for climate-smart agriculture can be identified (FAO, 2016). In Rwanda, N₂O accounts for an estimated 57% of total GHG emissions while methane emissions from livestock are also significant (Stiebert, 2013). Second, Rwanda is currently a net carbon sink due to its forest cover, though maintaining this sink will require a shift away from biomass use as it ramps up climate and development ambitions. Third, LULUCF in Ethiopia, associated especially with deforestation and land degradation, is a major component of their GHG profile and is the country’s most fundamental climate-development challenge, since it also imperils food security (Hamza and Iyela, (2012)).
The significance of the land use component of GHG emissions is common throughout SSA. Deforestation and land degradation associated with land use emissions also frees up land and effectively allows further expansion of small-scale agriculture that has low productivity. Those dependent on small-scale agriculture and biomass are often the same vulnerable populations that have access only to degraded or marginal lands. These vulnerable populations are in turn more exposed to the impacts of climate change as they have low adaptive capacity (Smit and Wandel, 2006). Consequently, better integration between mitigation and adaptation actions in agriculture, forestry and land use management could offer a greater impact in achieving both NDCs and the overall development agenda in the region.

### 5.3.1 Mitigation options for Kenya

Kenya’s climate change mitigation plans under their Nationally Determined Contribution (NDC) include a variety of options and measures: expansion in geothermal and other renewable energy options, enhancement of resource efficiency, ensuring 10% tree cover of total national land area, reduced reliance on woodfuel, efficient transport, climate-smart agriculture and sustainable waste management. The national climate change action plan projects a reference scenario in which emissions from electricity grow from 2.2Mt CO$_2$ equivalent in 2010 to 18.5Mt CO$_2$eq by 2030. The agriculture and forestry sector, which contributes 71% of GHG emission in 2010, is estimated to reduce to 65% in 2030 as emissions from other sectors grow significantly.
Figure 13: Kenya Climate Change Action Plan roadmap, including power sector supply additions (upper graph) and demand-side reductions (lower graph); Source: GoK, 2013
Kenya's energy access goals under Vision 2030 include 100% grid connectivity and reduced energy costs for all citizens. Such goals contribute to a steep growth trend in energy-related emissions according to the National Climate Change action plan, since the baseline trajectory considers rapid development and fluctuating hydropower that triggers growth in diesel power plants. In policy scenarios, the expansion of geothermal is considered a key enabler for climate-friendly development in the power sector. Geothermal development is critical for Kenya achievement of its NDC, and its abatement potential is estimated as 14MtCO$_2$eq per year. Other power generation options such as wind, solar, landfill gas and clean coal shall contribute abatement of between 0.5-1.4MtCO$_2$eq per year (GoK, 2013).

On the demand side, nine mitigation options were analysed. Replacing and or improving biomass energy as a source of cooking fuel is considered to have high mitigation potential. Improved cookstoves are estimated to have a potential to mitigate 5.6MtCO$_2$eq by 2030. Standards and labelling for energy-efficient appliances in Kenya are also expected to yield emissions benefits.

Other options at household level include fuel-switching by replacing kerosene lamps with solar lanterns and using LPG instead of charcoal and fuelwood for cooking. In other sectors, the cogeneration of heat and power in the agriculture sector using residues and agro-energy options has significant abatement potential as illustrated in Figure 13.

In the transport sector, seven options were analysed including, bus rapid transport (BRT) corridors complemented by light rail transit (LRT). These have an abatement potential of 2.8 MtCO$_2$eq annually. Introduction of bio-diesel (B10) in the transport fuel has a potential of approximately 1.2 MtCO$_2$eq in 2030.

### 5.3.2 Mitigation options for Rwanda

Although agriculture is currently by far the largest source of GHG emissions in Rwanda (Stiebert, 2013) in the future, emissions from other sectors will need to grow in order to meet development and energy access goals. Being a small country with low electricity use and many renewable sources, current energy supply from thermal power plants only contributed 69 ktonnes CO$_2$eq. Biomass energy demand for cooking and heating contributed to an estimated 23% of total national emission and is projected to increase significantly in 2030 (Figure 14).

According to GoR (2015), priority implementation in the energy sector includes:

- a) Establishment of new grid connected renewable electricity generation in the form of large hydropower plants and solar photovoltaic systems;
- b) Installation of solar PV mini-grids in rural areas targeting 100 mini-grids;
- c) Increase energy efficiency through demand-side measures including bulk procurement and distribution of CFLs;
d) Environmentally sustainable use of biomass including 100% adoption of improved cook stoves by 2030, installation of 35,000 biogas plants, efficient charcoal production and increased adoption of LPG;

e) In order to reduce fossil fuel imports the country will develop efficient transport networks, including Bus Rapid Transit (BRT) in Kigali;

f) Enhancement of industrial energy consumption by promoting efficient equipment and energy management.

Figure 14: Rwanda GHG emission from all sectors (GoR, 2015)

5.3.3 Mitigation options for Ethiopia

Ethiopia ratified the Paris Agreement in January 2017 and its NDC, if fully implemented, will lead to an estimated 64% emission reduction below the BAU by 2030 (Irish Aid, 2016). The full implementation is, however, dependent on availability of finance, technology transfer and capacity building, as highlighted by Ethiopia Climate Resilient Green Economy plans (CRGE, 2012). The BAU estimation projects an increase in emission from 150MT CO$_2$eq to 400MT CO$_2$eq by 2030, with the key emission sources being agriculture, industry and forestry (Climate Action Tracker, 2017; Irish Aid, 2016). One of its major projects is the 6000 MW grand Ethiopia Renaissance hydropower station that will not only serve the country but will be a major source of power export to Eastern African countries.

The climate action tracker (Figure 15) rates the implementation of mitigation implementation options as sufficient to achieve its NDCs. Although not obligated to reduce its GHG emissions, Ethiopia has invested unilaterally (Ministry of Environment and Forestry, 2015). Ethiopia is considered one of the most significant countries in Africa in terms of its vast potential of renewable energy that can transform many sectors of the economy, particularly its 45 GW of hydro potential and 7 GW of geothermal potential.
Figure 15: Ethiopia Emission projections (CRGE, 2012)

The current renewable energy contribution of 93% is projected to increase to over 99% in 2030 (Ministry of Water and Energy, 2012). The renewable energy potential and plans in Ethiopia thus justify prioritising emission reductions in the household sector, due to heavy dependence on firewood and charcoal for cooking (88%) and kerosene for lighting (71%), according to the Ministry of Water and Energy (2012). Figure 16 highlights key mitigation options.

Figure 16: Emissions in Ethiopian BAU case by sector and mitigation options (CRGE, 2012)
Reduced demand for fuelwood is expected to be achieved through four main actions including: rapid adoption of improved cookstoves, switching to electric stoves (mainly in urban areas), switching to LPG stoves and enhanced adoption of biogas (CRGE, 2012). Other REDD+ activities that contribute to an improved land use emissions profile include afforestation and reforestation, improved forest management, agricultural intensification on existing land and reclamation of new agricultural land through irrigation. Ethiopia has also pursued significant investments to reduce industrial and transport emissions including: Intra-Urban electric rail system, use of biofuels, promoting mass transport and non-motorised transport systems.

5.4 Comparative overview

A variety of energy investments that are in line with climate and development strategies are in the pipeline in the three countries. The table below provides a snapshot and sample across some of these investments and comments on how they relate to energy access goals.

Table 6: Energy access, climate mitigation goals and supply and demand measures

<table>
<thead>
<tr>
<th>Energy Access Priorities</th>
<th>Major projects</th>
<th>Mitigation goals</th>
<th>Conflict or synergy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Power Supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>350MW electricity</td>
<td>Landfill gas (KE)</td>
<td>Synergy with waste management</td>
</tr>
<tr>
<td>Peat</td>
<td>200MW electricity (RW)</td>
<td></td>
<td>Conflict with NDC</td>
</tr>
<tr>
<td>Geothermal</td>
<td>3000MW (KE); 450MW (ET)</td>
<td>Geothermal Expansion (ALL)</td>
<td>Synergy</td>
</tr>
<tr>
<td>Wind</td>
<td>300MW (KE); 760MW (ET)</td>
<td>Wind expansion</td>
<td>Synergy</td>
</tr>
<tr>
<td>Hydro power</td>
<td>Ethiopia GMRD, 6 GW</td>
<td>Large Hydro expansion (ALL)</td>
<td>Synergy</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.3M³ Natural gas (ET)</td>
<td></td>
<td>Depends on baseline</td>
</tr>
<tr>
<td>Coal</td>
<td>1050 MW (KEN)</td>
<td>Clean coal (KEN)</td>
<td>Conflict with NDC</td>
</tr>
<tr>
<td>Decentralised and/or Demand-side Solutions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved Cook stoves (ICS)</td>
<td>5 Million HH - ICS (KE)</td>
<td>Improved cook stoves (ALL)</td>
<td>Depends on charcoal supply chain</td>
</tr>
<tr>
<td>Off-grid Solar Home Systems</td>
<td></td>
<td>Renewable lighting</td>
<td>Synergy</td>
</tr>
<tr>
<td>LPG</td>
<td>LPG substitution (ALL)</td>
<td></td>
<td>Depends on original fuel</td>
</tr>
<tr>
<td></td>
<td>Cogeneration in Agriculture (KE)</td>
<td></td>
<td>Depends on biomass source</td>
</tr>
<tr>
<td></td>
<td>Energy efficient appliances and lighting (RW, KE)</td>
<td></td>
<td>Synergy</td>
</tr>
<tr>
<td>Biogas</td>
<td>35,000 plants (RW)</td>
<td>Biogas technology (ET, RW)</td>
<td>Synergy</td>
</tr>
<tr>
<td>Sustainable Biomass*</td>
<td></td>
<td></td>
<td>Depends on implementation</td>
</tr>
</tbody>
</table>

* Sustainable biomass here refers to on-farm trees (agro-forestry) for cooking fuel with strict regulations

**NOTE: KE: Kenya; RW: Rwanda; ET: Ethiopia; ALL: all three countries**

Sources: MoEP, 2015; IRENA, 2015; Ministry of Foreign Affairs, the Netherlands, 2014
5.5 Common approaches in SSA

African countries that are seen as leaders in renewable energy and/or green development strategies—such as Ethiopia, Kenya and Rwanda—also share common climate and development challenges with many other SSA countries. These commonalities are due to the widespread characteristics of high dependence on rain-fed agriculture, rapidly increasing population, low levels of electrification, high dependence on traditional biomass and insufficient infrastructure (outside of South Africa). Although the current contribution of SSA to global GHG emissions is barely 3%, baseline trends will lead to significantly increased energy demand and emissions in the coming years. There are some broad GHG emission reduction approaches that are widely applicable across SSA and also generally have synergies with energy access and other sustainable development goals:

a) **Reduced dependence on traditional biomass:** the current baseline with high dependence on traditional biomass has significant health and social impacts as well as contributing to GHG emissions on supply side (through unsustainable harvesting) and on the demand side (incomplete combustion and inefficient stoves). The mitigation approach requires incentivising fuel-switching to LPG, biogas and bioethanol along with improved cookstoves (ICS). The quality of energy services will be increased dramatically.

b) **Increasing Renewable energy share of grid:** The diversification of renewables beyond large hydro has offered different development paths and responds to the issues of availability and seasonality so as to improve reliability and reduce the upfront cost of investments through smaller capacity additions, thereby reaching new customers faster.

c) **Small-scale and decentralised power:** Until fairly recently, small-scale decentralised power in Africa often translated into diesel generators. Thanks to cost reductions and increased availability of financing, a diverse array of renewable energy options are available that can be better matched to local demand and supply.

d) **Industrial Energy Efficiency:** Economic incentives should promote energy efficiency and emissions reduction in industry. Since infrastructure is lacking across the continent, investment in industrial efficiency can be made for new equipment being installed for the first time, which is much less costly than retrofitting or refurbishing.

The extent to which higher demand translates into significant emissions increases depends especially on whether renewable energy investment can keep pace and whether the diversification of energy sources can be managed over the long-term. It also depends on whether the shift away from traditional biomass can be accelerated. Land use management and land use change will need to be a major component in almost any successful African strategy. As land use touches more on basic development issues rather than energy, land use and integrated approaches are discussed further in sections 6 and 7.
6 RELATION TO ADAPTATION

Climate change presents a dual challenge for regions such as SSA that lack energy access. At a stage of economic development where its population needs to increase energy use and utilise modern energy services, global climate goals ask them to decarbonise even as they must also adapt to the physical effects of a changing climate. Rising temperatures, increasing water constraints, and more frequent and severe extreme weather events are already threatening energy security around the world. The climate impacts cut across the energy value chain from extraction to transformation to energy end-use (Perera et al., 2015). Various studies (Fay, 2009; Murphy and Corbyn, 2013; Sumiya, 2016) suggest that the energy sector will be vulnerable due to its close association with climatic conditions, including seasonal variations, rainfall variability, and extreme events such as droughts, floods and heat waves. These changes affect production, transmission capacity, and distribution networks as well as affecting seasonal energy demand.

The sub-Saharan Africa energy system is vulnerable to climate change mainly due to its less developed infrastructure and its dependence on hydropower. At the same time, the lack of electricity access and the high dependence on biomass leaves millions of households vulnerable (Jarvie & Nicholson, 2013; Avila et al., 2017). The risks posed to the energy sector from climate change and the need to improve adaptive capacity are increasingly recognised, but achieving climate resilience will require sustained efforts over the long-term (Combat Climate Change, 2010; IEA, 2014). The energy sector needs to expand to improve energy access, thereby contributing to GHG emissions but at the same time it is impacted by climate change. This chapter provides an overview on linkages between energy access and climate change adaptation, with special reference to SSA and Eastern Africa. The focus is especially on the most vulnerable that lack energy access in terms of the relation to coping mechanisms (section 6.3) and adaptive capacity (section 6.4). The general context is also briefly discussed in terms of physical infrastructure (section 6.1) and socio-economics (section 6.2). A final section considers indicators of climate resilience in the context of energy systems and access (section 6.5).

6.1 Physical context

Climate change is increasingly placing additional pressures on the already strained energy sector in SSA. It has direct effects on energy resources, infrastructure, transportation and distribution. According to the IPCC (2014), changes in climate could affect the production and supply of energy, impact transmission capacity, disrupt oil and gas production, and impact the integrity of transmission pipelines and power distribution networks. Extreme weather events can affect areas that depend on water supply for hydro power and can also change the conditions for biomass, wind or solar energy production. A broad overview of climate impacts on the energy system is given in Table 7.
Table 7: Energy Access and Vulnerability to Climate Change (Source: authors’ elaboration)

<table>
<thead>
<tr>
<th>Energy system</th>
<th>Climate indicators</th>
<th>Impacts on the energy sector</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydro-power</td>
<td>Repeated and intensifying droughts</td>
<td>Less water available for power generation, particularly in dry season, decrease in generation</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Decrease in mean annual precipitation</td>
<td>Demand and supply challenges from hydro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unpredictable precipitation during short and long rains</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seasonal flows, high and low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar</td>
<td>Atmospheric transmissivity</td>
<td>Reduced solar cell efficiency</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Water vapour content</td>
<td>Decreased generation potential</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cloud cover</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ambient temperatures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>Changes in wind density, average speed and variability</td>
<td>Change in the amount of wind powered electricity available</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Changing wind regimes</td>
<td>Decrease in generation capacity of wind turbines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precipitation change may impact on soil stability and drainage</td>
<td>Stability of wind towers</td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td>Soil moisture content</td>
<td>Cost of biomass/biofuels</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Reduced rainfall</td>
<td>Biomass supply challenges</td>
<td></td>
</tr>
<tr>
<td>Geothermal</td>
<td>Cooling water availability</td>
<td>Generation cycle efficiency</td>
<td>Low</td>
</tr>
</tbody>
</table>

Studies from Eastern Africa demonstrate energy system limitations due to physical factors related to climate variability. Major forests like the Mau and Mt. Kenya forests have experienced forest fires in the past 20 years due to warmer temperatures and prolonged droughts, wreaking phenomenal economic damage (Mutimba et al., 2010). Examples from the hydropower sector in Kenya are found in the Masinga and Kiambere hydro plants. In 2009 Kenya Power was compelled to sanction power rationing due to a tremendous drop in the volumes of water in these dams. Prolonged droughts led to the drop in water volume, which directly affected performance of the power plant. In addition, a deepening drought cycle now threatens to spread Kenya’s energy crisis. During the 2009 dry spell, dams along the Tana River were affected which lead to power rationing in some sections of the city (Bunyasi, 2012).

A majority of those living in rural communities in eastern Africa rely on biomass to meet energy needs, which is impacted by changes in rainfall patterns. Changes in climate not only affect the overall productivity of biomass but also the local balance of biomass supply and demand (Muok et al., 2010). Other aspects related to biomass scarcity have arisen, such as impact on nutrition and health. For instance, change in diet or selection of foods that require less cooking time have been observed in connection with fuelwood scarcity (Sola et al., 2016). Such changes might include cooking beans and other fuel-consuming foods less often or choice of one-pot dishes with shorter cooking times (Reddy et al., 2000).
6.2 Socio-economic context

Energy is critical to global prosperity, as it fuels economic growth, social development and poverty reduction (IEA, 2014). Climate change not only impacts the operation of the energy sector and its actors, but also society at large in terms of the delivery of energy services. These services are important across all sectors of economic activity, including manufacturing, service sector, hospitals, schools and all the individual households that rely on them. Modern societies depend crucially on reliable and secure energy supplies for economic growth and community prosperity (Byrne & Taminiau, 2016).

In Eastern Africa, drought regularly results in losses of power production, with significant knock-on effects. In Kenya in 1999-2002, 2009 and 2010, power supply to businesses was regularly cut when generating capacity was curtailed. Hydro power capacity was reduced by 25%. Kenya receives more than 60% of its power from a string of dams along the Tana River. Some businesses were without power for 30% of the time. Temporary energy solutions, such as diesel generators, are polluting and very costly and the cost of production is highly sensitive to international fluctuations in the price of liquid fuels, which must be imported (Karekezi, 2012). In Ethiopia, power shortages have led to shutdowns in some small industries and curtailment of communications services in government offices (EthioNL, 2009).

A reliable supply of energy creates new livelihood options and income generation opportunities, such as stove manufacturing, energy crops and new supply chains for energy technologies. Even in the traditional biomass sector, the socio-economic multipliers are significant. The energy sector is a vital source of employment for millions of poor people living in the developing world (Practical Action, 2016). The production of fuelwood and charcoal continues to be an important source of income for poor people with significant rural value chains. Ochieng et al. (2015) argue that charcoal production is a livelihood measure particularly for communities living in dry lands and if sustainably managed can increase the adaptive capacity of these communities while also addressing the challenge of energy access.

Small-scale renewable energy, especially in the form of solar home systems and solar kiosks, has emerged in areas lacking grid access as a key enabler of economic development and household welfare improvements (FS-UNEP, 2017). The locally available electricity or charging stations facilitates extended working hours and enables productive activities to be done in the evening. Solar-powered lighting has enabled many businesses such as restaurants, shops and other small businesses to run for longer hours (Lemaire, 2011). Off-grid hybrid energy systems are also generally less likely to be disrupted by climate impacts.
6.3 Coping Mechanisms

Climate change coping mechanisms at the level of industries or sectors depend on availability of natural and economic resources, technological access, information access, proper infrastructures and suitable institutions (Troccoli, 2009). In the context of energy access at the level of small businesses and households, coping mechanisms relate especially to the ability of vulnerable areas to obtain sustainable and modern energy services and use these services productively and effectively. A number of mechanisms are briefly described below, emphasising those that offer cost-effective means to adapt or adjust to changing physical and economic circumstances.

**Diversification of energy options:** Over-reliance on a single source of energy can render a country vulnerable in case of severe climate change impacts. Alternative sources to produce energy can reduce the risk. Dependency on one source has serious implications not only to the energy sector but also to the entire economy (IEA, 2016c). Karekezi et al. (2005) noted the effects of the heavy reliance on hydropower in East Africa, with a combination of severe droughts and shorter rainy seasons significantly affecting power generation. Kenya has suffered less from weather or climate impacts due to the diversification of its electricity supply (away from hydro into geothermal and biomass) in comparison to the neighbouring countries of Uganda and Ethiopia (Karekezi et al., 2009; Chapman and Whande, 2013).

**Insurance:** Insurance products targeting weather impacts are emerging as a crucial tool for risk sharing, maintaining economic stability and motivating resilience-building and risk-preventive behaviour. The insurance industry has a shared interest in limiting the damage caused by a changing climate. Weather coverage is an emerging insurance product, with pay-outs based on measurable weather events and not on individual loss assessments (IEA, 2015). For instance, Munich Re’s Solar Shortfall insurance covers non-physical damage such as lower-than-normal solar radiation. Other products cover physical damages from weather events (such as floods and hail) suffered during the construction and operation of energy projects (OECD/EIA, 2016). Weather-index-based insurance schemes have been piloted in Ethiopia, among other countries, by the World Food Programme. Although the initial focus is on agriculture and food security, a platform for weather-indexed insurance is widely applicable in the energy sector. However, they are not yet easily accessible for rural poor who suffer most from energy inaccessibility.

**Energy efficiency and demand-side management:** According to Fay (2009) the large technical and commercial losses in the distribution system could be reduced and demand-side management could be improved through, for example, improved bill collection and establishment of cost-recovery tariffs. Improved demand-side management and energy efficiency can lead to greater responsiveness to changes in both demand and supply (including those caused by climate change), and to reduced water demand. More efficient power plants use less water for cooling, while demand-side energy efficiency offsets the need for electricity capacity additions. In turn, additional water is then available is available to the agricultural sector for irrigation.
Decentralised energy systems: Renewables integrated into the main electricity grid pose intermittency problems that could be exacerbated by climate change. However, locally available renewable energy sources can also contribute to a more decentralised energy structure in a region where reliable transmission networks are not yet widespread outside of South Africa. Decentralised power can reduce large-scale outages when main grids/centralised power systems are compromised. The added flexibility can improve capacity to cope with increasing climate variability and unpredictability in the energy system (GoK, 2013). Renewable energy sources (except large hydro) are generally at much smaller scale and are more amenable to distributed generation, which can help to localise and buffer disruptions (Sumiyu, 2016). Mini-grids can have some useful characteristics in this regard (section 4.2).

Sustainable biomass: Competing and growing demand for biomass across multiple needs (food, feed, fuel) has contributed to land use change and greater pressure on forests. Non-renewable biomass has contributed significantly to emissions in Eastern Africa (Bailis et al., 2015). At the same time, the low productivity of African agriculture and woody biomass use results in extensive expansion. Greater productivity in agriculture through breeding of genotypes tolerant to higher temperatures, humidity, droughts, and pests will benefit crops use for both food and energy and improve overall land use management. Managing forests for multiple uses and products and planting trees on farms (Section 7.2) improves sustainable woody biomass supply.

6.4 Adaptive capacity

According to Adger et al. (2007), adaptive capacity is “the ability or potential of a system to respond successfully to climate variability and change.” It reflects fundamental conditions that enable people to anticipate, plan for and respond to longer-term changes. Adaptive capacity is context-and location-specific, varying from country to country, from community to community, among social groups and individuals as well as over time. It varies not only in terms of its value but also according to its nature. The scales of adaptive capacity are not independent or separate. For instance, the capacity of a household to cope with climate risks depends to some degree on the enabling environment of the community, and the adaptive capacity of the community is reflective of the resources and processes of the region (Smit & Wandel, 2006). Some adaptive capacities are highlighted below.

Risk assessment, auditing and reporting: Implementation risks within the energy supply chain cover all areas concerning the energy sector, including demand, exploration, site selection, infrastructure development, operations, maintenance, and delivery. These risks originate across all energy sector contexts from almost every aspect of hydrology, weather, and climate. Experience has shown that climate change has potentially serious consequences for stability and reliability of energy supplies, with many downstream impacts on society, commerce, and development. Energy investors need to conduct climate impact risk assessments to anticipate and
plan for the risks posed by a changing climate. Governments could catalyse such assessments by requiring them as part of permitting processes for new infrastructure projects and major retrofits (OECD/IEA, 2016).

**Emergency preparedness and response:** Emergency preparedness and response measures enable organised and coordinated reactions to disasters, including disruptions in energy supplies. Emergency preparedness ensures that a robust early warning system is in place, enabling advanced preparation as early as possible, as well as prepositioning crews, equipment and backup generation. Such responses following emergency events often facilitate restoration of damaged energy systems and ensure recovery (Ebinger and Vergara 2011).

**Capacity building:** In this context capacity building is understood as the strengthening of the abilities of organisations/individuals to make effective and efficient use of resources, through training or any other capacity building activity to address the shortfall of expertise. Lack of human professional capacity to manage the energy sector can lead to significant project delays (African Development Bank, 2014). Thus Governments should support the sector through policy and regulatory oversight, technology development and providing information about expected future climate developments (IEA, 2014). Policy, institutional and fiscal responses will be necessary to facilitate these processes (IEA, 2015).

**Adaptation strategies and plans:** Governments could provide overall guidance to the energy sector on how to enhance its resilience to climate change impacts, increase energy security and create synergies between mitigation and adaptation. Governments should also foster regional cooperation and inter-sectoral management plans as well as identify energy resilience and preparedness policies that are being used by governments and appropriate platforms for disseminating this information to stakeholders (Fay, 2009). Government role is critical in facilitating national frameworks and developing institutions covering the regulation of energy infrastructure and markets under national and regional market legislation.

**Institutional co-ordination and partnerships:** Integrating adaptation considerations across policies and management approaches requires coordination across sectors and policy domains (e.g. water, transportation, energy) and levels of government (e.g. between central and local governments), engagement of non-governmental organisations and the private sector, and mobilisation of scientific knowledge. New institutional and informational links should be incorporated into established processes of decision-making and management (IEA, 2015).

**Improving/building scientific knowledge:** Generating data and knowledge in organised and accessible frameworks is a necessary condition for effective climate action. Wilbanks et al. (2008) emphasises the need to expand knowledge on the effects of climate change and variability on energy production and use, including:
• higher resolution models for local and smaller regional impact evaluation where most energy facility decisions operate;
• reducing electrical peak load demand;
• expected impacts on regional energy supply, institutions, and consumers;
• effects of changing climate conditions on new energy systems market penetration; and
• associated impacts on regional energy balances and economies.

These components will contribute to strategies to improve the technological potential of energy supply systems (OECD/IEA, 2016).

6.5 Climate resilience indicators

Resilience of the energy sector refers to the capacity of the energy system or its components to cope with a hazardous event or trend, responding in ways that maintain their essential function (Perera et al., 2015). The resilience “value chain” integrates robustness, resourcefulness and recovery. Greater resilience to climate change impacts will be essential to the technical viability of the energy sector and its ability to cost-effectively meet the rising energy demands driven by global economic and population growth (IEA, 2015). Resilience is a popular and fluid concept that is used to frame and explore how societies continue to thrive and develop under shocks and stresses (Ellis, 2014).

This section draws on the DFID resilience framework to assess the evidence that links resilience, climate adaptation and energy access. The framework is built on four key elements; context, disturbance, capacity and reaction (Brooks et al., 2014). Perera et al. (2015) pinpoint several indicators of resilience: access to services, adaptive capacity, income and food access, social safety nets, livelihood viability, natural context, personal circumstances, institutional and governance contexts and assets. The evidence has been framed in line with Brooks’ proposed set of comprehensive dimensions that can be used to identify important features of resilience. Table 8 presents different indicators together with other issues highlighted in various literatures.

The relationships cross over many different aspects of well-being and illustrate the crucial role of energy access in reducing poverty and vulnerability. The vulnerable situation of the poor, particularly the rural poor, is exacerbated by the uncertainties of climate change in combination with the lack of modern energy services. In conclusion, there is strong conceptualisation of the potential linkages of energy access and aspects of adaptation to climate change. A better understanding of the link between improved access to energy and climate change adaptation offers the opportunity to maximise the co-benefits.
Table 8: Climate resilience indicators

<table>
<thead>
<tr>
<th>Resilience indicator</th>
<th>Energy and adaptation linkage</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to services</td>
<td>Services such as Water, early warning systems, reliable, affordable and resilient types of energy services</td>
<td>(UNDP, 2013)</td>
</tr>
<tr>
<td>Income and food access</td>
<td>Irrigation processes that improve food security, cheaper fuel options thus saving, new income and employment, new enterprises</td>
<td>Perera et al. (2015)</td>
</tr>
<tr>
<td>Social safety nets</td>
<td>Social support system and networks that connect government and support agency, disaster response aid recovery from shocks</td>
<td>Byrne &amp; Taminiau, (2016)</td>
</tr>
<tr>
<td>Livelihood viability</td>
<td>Improving access to energy in food production, diversifying livelihoods, income generating opportunities.</td>
<td>Ochieng et al. (2015)</td>
</tr>
<tr>
<td>Natural context</td>
<td>Reducing dependence forest resources and pressures on ecosystems, and improving soil fertility</td>
<td>Ebinger and Vergara (2011)</td>
</tr>
<tr>
<td>Personal circumstances</td>
<td>Female empowerment, social development and wellbeing, improved health and access to health services, particularly beneficial for women and children, improved socio-economic status by access to better education, time savings to improve productively</td>
<td>Jarvie and Nicholson (2015)</td>
</tr>
<tr>
<td>Institutional and governance contexts</td>
<td>Policies driving the synergies between energy access and adaptation and building resilience to climate change</td>
<td>Murphy and Corbyn (2013)</td>
</tr>
</tbody>
</table>
7 INTEGRATIVE APPROACHES

Integrative approaches offer mechanisms to protect vulnerable populations while promoting more productive land use and modern service provision. One class of systems of particular importance in the African context are Integrated Food-Energy systems, which can offer useful synergies or complementarities (Bogdanski, 2012). The water-energy-food nexus is similarly important in capturing the connection between adaptation, mitigation and access goals. Landscape integration includes a variety of approaches, especially including agro-forestry, under which farming practices are adapted to incorporate multi-functional use of inputs and soils to support tree growth on farms. A landscape perspective creates opportunities for different production models that can exploit synergies between food, fibre and fuel production (Dale et al., 2013). This section briefly discusses two important integrative approaches - the nexus approach and agro-forestry, along with a more general discussion on cross-sector impacts.

7.1 Energy-water-food nexus

Energy, water and food systems are closely linked, forming a nexus that is essential for human well-being and sustainability (Rasul, 2016). The demand intensifies with increase in population, rapid economic growth, declining agricultural lands and changing consumption patterns. The demand for water, food and energy is anticipated to increase by 30% - 50% in the coming two decades (KIRDI et al., 2012). The nexus point of view describes the interlinkage among the three sectors, such as the use of energy for food production and improved water supply, use of water in energy and food production and bioenergy for food and energy production (World Economic Forum, 2011). An integrated effort for exploiting the synergies and reducing the risks of trade-offs in the energy-water and food nexus is therefore important.

Energy and food interconnection: Energy is directly used in food production such as for irrigation, water pumping, mechanised agriculture, powering tractors, postharvest processing and distribution (Ferroukhi et al., 2015). At the same time some food crops such as maize and sugarcane are used for bioenergy production. However, these two may compete for land and water that may eventually lead to energy-food trade-offs.

Water and energy interconnection: Water is used at essentially all steps of energy supply chain right from production, supply and extraction. The most significant direct use is of course hydropower but also biofuel production has significant water intensity. Also, energy is required at all stages of water supply including extraction, water pumping, water treatment and purification, distribution as well as heating and cooling (Guta et al., 2015).

Water and food interconnection: Water has great relevance to food production however its availability is further constrained by climate variability (FAO, 2016; Rasul and Sharma, 2015).
Smallholder farmers in ASALs who depend on rain-fed agriculture are the most vulnerable to water shortage, which in most cases leads to low food production. Water is used for irrigation and food processing. Another example of the interlinkage is poor agricultural practices on the upstream that negatively affect water quality and availability downstream (Rasul, 2014). The interconnectedness among the three sectors is illustrated in Figure 18.

Figure 17: Dynamic interlinkage among water, food and energy nexus

![Dynamic interlinkage among water, food and energy nexus](image)

Adapted from Endo et al. (2015)

The available natural resources that the nexus draws upon are increasingly degraded and in scarce supply. The challenge is prominent in the Nile Basin in Eastern Africa. For instance the case of Ethiopia’s plans to intensify agriculture, develop large scale hydro-power, disseminate energy efficient technologies and reforestation have great implications on water, energy and food (Endo et al., 2015). In the Kenyan context, management of rainwater contributes to food security. Due to rains failing, Kenyan pastoralists, agro-pastoralists and marginal farm households are food, water and energy insecure, often leading to recurring conflict. Food security is closely related to water and energy security. Food growing and processing need water and energy; water supply and circulation requires energy and likewise some energy production processes require water. The agricultural sector also supplies biomass for renewable energy production (KIRDI et al., 2012).

There can also be some positive synergies for economic development goals. For instance, sugar plants in Ethiopia were developed downstream of hydropower dams, using the regulated water supply to irrigate the sugar fields and lowering overall water intensity. With expansions in hydropower generation, there will be more opportunities to open up new sugar plants, which could in turn also supply the raw material for additional bioenergy production in the form of bioethanol and cogenerated electricity (Power Africa, 2016). The impacts on upstream users must be
evaluated in relation to such benefits. Nexus linkages to different energy technologies are summarised briefly in Table 9.

Table 9: Nexus linkages for different energy technologies (Source: authors’ elaboration)

<table>
<thead>
<tr>
<th>Energy technology</th>
<th>Discussion of the nexus linkages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biomass digesters</strong></td>
<td><strong>Water</strong>&lt;br&gt;-Reduce the contamination caused by the chemical elements&lt;br&gt;-Reduce the drinking water pollution caused by discarded pig dung and discharge of sewage&lt;br&gt;<strong>Food</strong>&lt;br&gt;-Use anaerobic digestion effluent and residue as a high quality fertilizer to improve food production&lt;br&gt;-Free the households from biomass collection for food production</td>
</tr>
<tr>
<td><strong>Improved cook stoves</strong></td>
<td><strong>Water</strong>&lt;br&gt;-Reduction of deforestation and therefore enhancement of water regulation&lt;br&gt;<strong>Food</strong>&lt;br&gt;-Better conditions for food preparation&lt;br&gt;-Initiation of healthy practices such as consumption of boiled water&lt;br&gt;<strong>Energy</strong>&lt;br&gt;-Less wood consumption, more productive use of resources</td>
</tr>
<tr>
<td><strong>Biomass for Heat and Power, including Agro-energy</strong></td>
<td><strong>Water</strong>&lt;br&gt;-Reduced land degradation, soil erosion (for some crops, e.g. jatropha), leading to improved water retention&lt;br&gt;-Cheap power gives possibility to draw drinking water from greater depths with lesser chances of contaminated drinking water&lt;br&gt;<strong>Food</strong>&lt;br&gt;-Savings associated with supply chains used for food AND the residues used for energy&lt;br&gt;-Cheap power supports more competitive agro-processing&lt;br&gt;-Cultivation of Energy crops in barren land fixes nitrogen and improves productivity of land&lt;br&gt;<strong>Energy</strong>&lt;br&gt;-Energy substitution for traditional biomass and fossil fuels&lt;br&gt;-Heat for industrial uses and development&lt;br&gt;-Plant residue can be used for making charcoal briquettes for cooking&lt;br&gt;-Reduced pollution and GHG emissions</td>
</tr>
<tr>
<td><strong>Hydro-power plants</strong></td>
<td><strong>Energy</strong>&lt;br&gt;-Cleaner source of electricity&lt;br&gt;<strong>Food</strong>&lt;br&gt;-Substitution of traditional agricultural mills with modern one&lt;br&gt;<strong>Water</strong>&lt;br&gt;-No direct impact (possibility of water pumping via electricity for both drinking and irrigation)</td>
</tr>
</tbody>
</table>

### 7.2 Agro-forestry

The use of biomass for energy in SSA will continue to play a critical role in the future and thus sustainability strategies involving integrated uses are highly valuable (Iiyama et al., 2014). However, woodfuel harvesting in some areas is already exceeding sustainable yields (FAO, 2010). At the same time, forest management and expansion is constrained by development pressures. Agro-forestry practices may provide an alternative and more sustainable source and many other benefits for small holders as it offers compelling synergies between adaptation and mitigation.
According to (Mbow et al., 2014), agroforestry is a source of income from carbon and wood fuels, it improves soil fertility and creates micro-climates and it provides ecosystem services and reduces the intensity of human impacts on natural forests. In general, agroforestry improves the economic and resource sustainability of agriculture while sequestering greenhouse gases. It provides a particular set of innovative practices that are designed to enhance productivity in a way that often contributes to climate change mitigation through enhanced carbon sequestration, and that can also strengthen the system’s ability to cope with adverse impacts of changing climate conditions (Torquebiau, 2013). Agroforestry builds opportunities for diversification that build resilience and generate additional income. Trees can provide various forms of bioenergy, for instance wood can be used as firewood and charcoal, Oilseeds can be used for production of liquid biofuels like biodiesel and residues like leaves and oilseed can be used for biogas production (Sharma et al., 2016).

<table>
<thead>
<tr>
<th>Mitigation</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
</table>
| Adaptation | • Soil carbon sequestration  
• Improved water use and efficiency  
• Commercial products diversification  
• Reduced nitrogen fertiliser and fertiliser 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 fertilisers  
• Poor management of nitrogen and manure  
• Emphasis on non-timber products |
| Positive   | • 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 |
| Negative   | |

Figure 18: Adaptation and Mitigation relationships with respect to agroforestry

Source: adapted from (Mbow et al., 2014; Rizvi et al., 2015)

The emphasis is on using improved crop and pasture land management alongside intercropping with trees, with an aim of better management of forest goods and services (Rizvi et al., 2015). From the energy point of view, agroforestry reduces pressure on harvesting wood from natural tree covers through increasing wood supply on farm (Iiyama et al., 2014). In order to optimise agroforestry for climate change adaptation and mitigation, there is a need for more integrated management to increase benefits and reduce negative impacts. Figure 18 highlights the positive and negative synergies between mitigation and adaptation for different uses of woody biomass.

The table shows how agroforestry systems readily bundle both mitigation and adaptation strategies and provide several pathways to securing food and energy security for poor households, while contributing to climate change mitigation. These options or pathways suggest that the efforts put in place to provide energy access to all communities in SSA may mean little without acceptance
of the reality on ground of continued/prominent use of wood energy and thus it should be considered in sector reforms for efficiency and sustainability.

7.3 Cross-sector issues

The energy-water-food nexus and agro-forestry are related to the more general notion that sustainability requires breaking down the barriers across different sectors, which are often managed separately through different government agencies, different markets and/or different actors and stakeholders. A cross-sector approach in relation to land and resource use is especially relevant in the African context: the way landscapes are managed varies tremendously across the continent and departs significantly from the division between agricultural and forest areas that is common in temperate climates and developed countries. The issues are especially relevant for biomass resources due to the fact that significantly more land and water is required (except for wastes and residues) but they are also relevant for all renewables, which generally require more land and/or water than their fossil fuel counterparts (Fthenakis and Kim, 2009).

The shift away from traditional biomass towards modern bioenergy and other sources benefits from a cross-sector or integrated landscape approach. Competition for land with forests and food production has emerged as a major concern for bioenergy expansion. Since first generation liquid biofuels are sourced from agricultural lands, there has been particular concern over the potential competition between food and fuel (Rosillo-Calle and Johnson, 2010). There can also be competition for water, nutrients and other resources or inputs. At the same time, traditional biomass use in the form of fuelwood and charcoal can have significant land use impacts, yet it generally provides low economic return to land owners and therefore offers little incentive for sustainable forest management (Zulu and Richardson, 2013). The shift away from traditional biomass can achieve the triple win for energy access, mitigation and adaptation.

Land competition can also have positive climate implications in that more efficient land use will improve resilience (Harvey and Pilgrim, 2011). Furthermore, bioenergy systems normally include multiple co-products and thus the effective land use intensity comparable to other energy sources is adjusted downward based on these products. In some developing countries, surplus agricultural wastes and residues offer significant energy potential and can thereby avoid competition with food. (Akom et al., 2013).

A landscape perspective (or ecosystems services perspective) creates opportunities for different production models that can exploit synergies between food, fibre and fuel production (Dale et al., 2013). In a landscape perspective, integrated uses are identified to preserve ecosystem integrity while also maintaining or increasing economic productivity. Agro-forestry in combination with improved stove, end-use and charcoal efficiency reduces pressure on forests and puts woodfuel consumption on a sustainable path (Iiyama et al., 2014). Agricultural or “on-farm” residues seem
to outperform forest-based biomass to bioenergy projects in terms of broader sustainable development benefits, based on the experience in Clean Development Mechanism (CDM) projects (Lee and Lazarus, 2013). There are significant numbers of livelihoods generated in the agricultural sector whereas bioenergy projects in the forest sector can be combined with conservation efforts that require minimal labour and may require only a small off-take of timber or logging residues using mechanised systems.

Combining conservation efforts with income-generating activities can reduce the extension of slash and burn agriculture and facilitate “land sharing” rather than “land sparing” although the choice between the two strategies (or even some mixture) is context-specific and depends on land tenure and related issues (Phalan et al., 2011). Alternatives that address both agricultural and energy productivity should be considered instead, such as using agricultural residues for both energy production and fertilisation, which creates useful synergies in the value chain (Akom et al., 2013). African soils are the most badly depleted of nutrients in the world and chemical fertilisers are too costly for all but the largest farmers; biological fertilisation through agro-forestry offers a more cost-effective approach (Sanchez, 2002).

The transition to sustainability in land use and energy is thus a cross-sectoral and cross-landscape issue where synergies and conflicts across agriculture, forestry and bioenergy resources must be addressed (Johnson and Jumbe, 2013). Integrating multiple objectives across different sectors facilitates useful synergies that can lower costs as well as increase the number of health, development and environmental co-benefits, as shown in Table 10. The purpose here is to compare aims across these key sectors and policy issues so as to facilitate exploitation of synergies in the policy making process, identify areas that require cross institutional support and highlight emerging business opportunities and challenges.

### Table 10: Integrating multiple objectives across different sectors (Source: authors’ elaboration)

<table>
<thead>
<tr>
<th>Sector/objective</th>
<th>Energy Access</th>
<th>Climate</th>
<th>Ecology and Biodiversity</th>
<th>Socio-economic</th>
<th>Food Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Land Use</td>
<td>• Integrated food-energy systems</td>
<td>• Incentives to use degraded or marginal land</td>
<td>• Enforcement measures for exclusion zones of high biodiversity</td>
<td>• Land reform included in strategy</td>
<td>• Food security assessments when land is set aside for energy crops</td>
</tr>
<tr>
<td></td>
<td>• Integrated provision of fibre and energy</td>
<td>• Agro-forestry</td>
<td></td>
<td>• Employment creation strategy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Use residues/wastes</td>
<td>• Perennial crops</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Water                            | • Bioenergy use for water pumping | • Adaptation schemes for reduced water availability | • Protection for wetlands and for watersheds | • Develop system to ensure water access for small farmers | • Availability of water for food crops evaluated
|                                  | • Encourage water-efficient energy crops |                                           | • Effluent capture methods promoted      |                                          | • Advanced irrigation methods               |
| Soils and nutrients              | • Guidelines for removal of agricultural residues | • Low tillage practices encouraged | • Support for conservation agriculture | • Support to small farmers for agrochemical use and fertiliser application | • Capacity-building for soil nutrient impact assessments |
|                                  | • Measures to safeguard high carbon areas |                                           | • Nutrient recovery systems              |                                          |                                            |
| Forests                          | • Identify sustainable harvest levels | • Protection for ecologically sensitive forests | • Organising wood, charcoal markets | • more efficient woody biomass use to avoid biomass scarcity |                                            |
|                                  | • Incentives for Fuel-switching |                                           | • Community forest management            |                                          |                                            |

The transition to sustainability in land use and energy is thus a cross-sectoral and cross-landscape issue where synergies and conflicts across agriculture, forestry and bioenergy resources must be addressed (Johnson and Jumbe, 2013). Integrating multiple objectives across different sectors facilitates useful synergies that can lower costs as well as increase the number of health, development and environmental co-benefits, as shown in Table 10. The purpose here is to compare aims across these key sectors and policy issues so as to facilitate exploitation of synergies in the policy making process, identify areas that require cross institutional support and highlight emerging business opportunities and challenges.
Access to affordable, reliable and sustainable energy is a fundamental development challenge in sub-Saharan Africa, more so than any other major world region. Two-thirds of the population lacks electricity access while 80% rely significantly on traditional biomass. The transition away from traditional biomass to modern fuels and electricity is critical not only for the sake of obtaining modern energy services but also to reduce the negative impacts of heavy reliance on traditional biomass. These negative impacts include the health effects of indoor air pollution, reduced socioeconomic welfare associated with heavy reliance on woodfuels and the climate impacts due to inefficient cookstoves and unsustainable harvesting of biomass. Lack of energy access also negatively impacts economic productivity and income-earning opportunities for small enterprises, while also increasing the risks for business investors and financiers.

At the same time that African countries are struggling to improve energy access, they must also face the challenge of adapting to climate change and contributing to global mitigation efforts, both of which are particularly daunting in light of the heavy dependence across the region on rain-fed small-scale farming. Nevertheless, many African countries embraced the Paris Agreement and are pursuing Nationally Determined Contributions (NDCs) that include significant climate mitigation measures in the energy, land use and transport sectors. African countries thus face a climate and development challenge that differs from their developed country counterparts: they must expand access to energy, and thus the supply of energy, at the same time that they must reduce emissions and adapt to a changing climate.

Fortunately, there are a wide range of renewable energy options and land use management approaches available to African countries at competitive costs. Some African countries are emerging as pioneers in the search for low emissions development pathways that also aim for universal energy access: a brief profile is provided in the report for Ethiopia, Kenya and Rwanda. Each has ambitious plans for scaling up renewable energy: Ethiopia has a special focus on hydropower, Kenya has strong development platforms for geothermal and wind and Rwanda aims for a rather diverse portfolio. All countries aim for a transition away from traditional biomass to LPG, biogas and other options. As with most African countries, high dependence on woodfuels presents a significant climate and development challenge.

The high dependence on rain-fed small-scale agriculture in combination with the high dependence on traditional biomass presents an energy access-mitigation-adaptation trilemma across the continent that calls for a special focus on integrated approaches to land management. Agro-forestry, sustainable charcoal supply chains, and due consideration for the energy-water nexus are among the critical approaches that can support the achievement of triple wins for energy, climate and development objectives across sub-Saharan Africa. Such triple wins are often characterised by complexity and diverse social contexts: more analysis and research is needed on the energy-mitigation-adaptation trilemma in the African context.
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