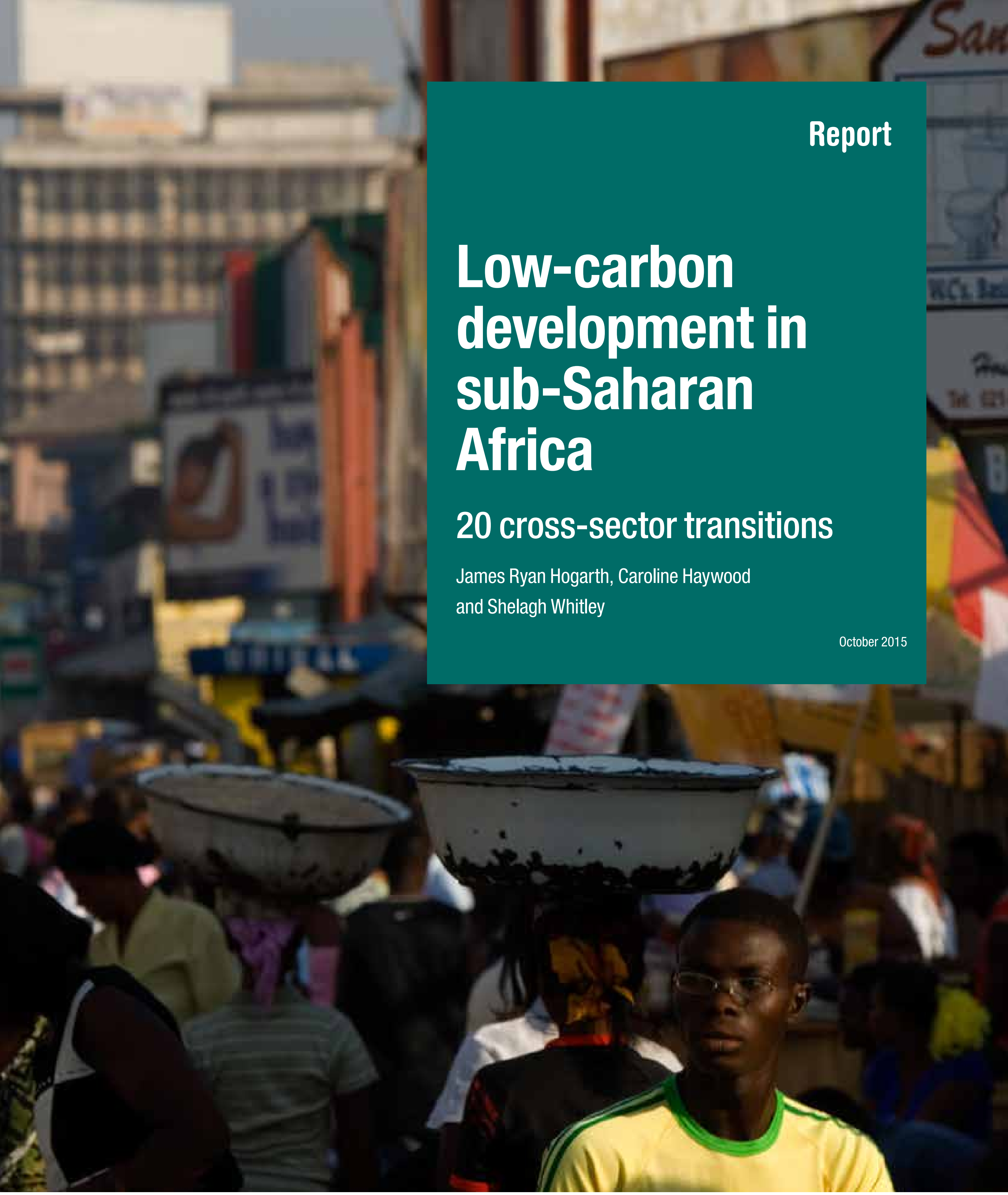

Report

Low-carbon development in sub-Saharan Africa

20 cross-sector transitions

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This report is an integral component of the Deep Decarbonization Pathways Project (DDPP), which is a key element of the research agenda of the Sustainable Development Solutions Network (SDSN) of the United Nations. In the context of DDPP, long-term quantitative projections of CO_2 emissions of the world's major economies are being prepared. The overall objective is to develop scenarios that are compatible with the globally agreed goal of staying below 2 degrees Celsius in terms of global warming.

With generous funding from the German Government (specifically from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety - BMUB), the German Development Institute is complementing this DDPP modeling exercise by a qualitative analysis and assessment of the transformation processes in Germany, China and South Africa. In addition, it was considered essential to undertake an exploratory study in terms of the challenges faced by low-income countries to build up low-carbon economic structures in a context of high donor dependency. In a competitive bidding process, ODI was selected to undertake this study specifically for the countries of sub-Saharan Africa (excluding the Republic of South Africa).

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Acronyms

AfDB African Development Bank
ARGeo African Rift Geothermal Facility
AU African Union
bcm billion cubic feet
BIP backward integration policy
BMUB Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
BREEAM Building Research Establishment Environmental Assessment Method
BRICS Brazil, Russia, India, China and South Africa
CAPP Central African Power Pool
CCECC China Civil Engineering Construction Corporation
CDCF Community Development Carbon Fund
CDM Clean Development Mechanism
CEEC Centre for Energy Efficiency and Conservation (of Kenya)
CER Certified Emission Reduction
CH_4 Methane
CNG Compressed natural gas
CO_2 Carbon dioxide
CO_2e Carbon dioxide equivalent
COMESA Common Market for East and Southern Africa
CSP Concentrated solar power
CTCN Climate Technology Centre and Network
CTF Clean Technology Fund
DIE Deutsche Institut für Entwicklungspolitik / German Development Institute
DRC Democratic Republic of Congo
EAC East African Community
EAPP Eastern African Power Pool
ECCAS Economic Community of Central African States
ECOWAS Economic Community of West African States
ERC Energy Regulatory Commission (of Kenya)
EU European Union
FAO Food and Agriculture Organization of the United Nations
FDI Foreign Direct Investment
FPCM Fat and protein corrected milk
FSC Forest Stewardship Council
GACC Global Alliance for Clean Cookstoves
GDP Gross Domestic Product
GE General Electric
GEF Global Environment Facility
GWh Gigawatt hours
ICE Internal combustion engine
IEA International Energy Agency
IMF International Monetary Fund
INDC Intended Nationally Determined Contribution
IPCC Intergovernmental Panel on Climate Change
IRENA International Renewable Energy Agency
ISO International Organization for Standardization
KAM Kenya Association of Manufacturers
KNCPC Kenya National Cleaner Production Centre
LAMATA Lagos Metropolitan Area Transport Authority
LDC Least Development Countries
LEED Leadership in Energy and Environmental Design
LIS Land Information Systems
LMIC Lower-Middle Income Country
LPG Liquid Petroleum Gas
MDB Multilateral Development Bank
MIC Middle Income Country
MMTPA Million metric tonnes per annum
MSME Micro, Small and Medium Enterprises
$MtCO_2e$ Megatonne of carbon dioxide equivalent
Mtoe Million Tonnes of Oil Equivalent
N_2O Nitrous Oxide
NACRDB Nigerian Agricultural, Cooperative and Rural Development Bank
NCE New Climate Economy
NDB New Development Bank
NEMA National Environment Management Authority (of Uganda)
NGO Non-Governmental organisation
NPK Nitrogen, phosphorus, and potassium
ODA Official Development Assistance
OECD Organisation for Economic Co-operation and Development
OOF Other Official Flows
OPEC Organisation of Petroleum Exporting Countries
OPIC Overseas Private Investment Corporation
PES Payment for Ecosystem Services
PIDA Program for Infrastructure Development in Africa
PPM parts per million
PV Photovoltaic
R&D Research and Development
RD&D Research, Development and Demonstration
REDD+ Reducing emissions from deforestation and forest degradation
RSA Republic of South Africa
SACCO Savings and credit cooperative
SADC Southern African Development Community
SAPP Southern Africa Power Pool
SBI Sustainable Budget Index
SDSN Sustainable Development Solutions Network

SSA Sub-Saharan Africa

T&D Transmission and Distribution

tCO_2e Tonne of carbon dioxide equivalent

TEC Technology Executive Committee

TFC Total final consumption (of electricity)

TNA Technology Needs Assessment

TWh Terrawatt hours

UN United Nations

UNDP United Nations Development Programme

UNEP United Nations Environment Programme

UNFCCC United Nations Framework Convention on Climate Change

WAPP West Africa Power Pool

WRI World Resources Institute

WTO World Trade Organisation

Executive Summary

Sub-Saharan African (SSA) nations (excluding South Africa for the purpose of this report) are at a critical point in their development. These countries are experiencing rapid population growth, particularly in urban areas, and a young and growing workforce. In addition, a number of SSA countries are experiencing high levels of economic growth. At the same time, the growing risk of catastrophic global climate change threatens to weaken food production systems; increase the intensity and frequency of droughts, floods, and fires; and undermine gains in development and poverty reduction.

Although SSA has the lowest per capita greenhouse gas (GHG) emission levels in the world, the region will need to join global efforts to address climate change, including through actions to avoid significant increases in emissions. Linked to projected increases in population and economic growth, GHG emissions in the region are expected to grow rapidly, through increased fossil fuel use, and agricultural expansion. Nonetheless, there are opportunities for SSA governments to facilitate the development of technologies and practices to avoid lock-in to resource- and emissions-intensive economies, and to navigate the difficult trade-offs necessary to achieve sustainable economic development in a carbon-constrained world.

Seven sectors are reviewed in detail in this report – agriculture, forestry, energy, transport, extractives, construction and manufacturing – based on their importance to the productive capacity of SSA and their contribution to current and future GHG emissions (see Table A). For each sector we identified 1) the 'assets and processes' (technologies, fuels, infrastructure, practices, land, etc.) that are critical for low-carbon development, and 2) the options of government interventions that can facilitate transitions towards low-carbon development across those assets and processes.

In addition, we found that certain sectors pose a high risk of creating technological, infrastructural and institutional lock-in to high-carbon development pathways, including energy (electricity), transport, extractives, construction, and manufacturing. Decisions on how to avoid lock-in in these sectors must be taken in the short-term.

Building on the in-depth sector analysis, we identified 20 more long-term cross-sector transitions that can be undertaken to promote low-carbon development in the region. While not part of the initial scope of work, we recognised that a focus on GHG emissions alone does not represent the full picture of low-carbon development. To capture this, we developed a preliminary methodology for scoring the transitions, to rank them according to set of four criteria: (1) the level of GHG emissions that they could avoid; (2) the risk of lock-in that they could avert; (3) their contribution to increased productivity; and (4) their contribution to poverty reduction. The results are displayed in Table A. Many assumptions were made in assigning scores under each category, as the data to support the scoring is not readily available. As such, the results should be considered as indicative only. Nonetheless, the exercise illustrates the decision-making processes and criteria, beyond GHG emissions, that governments should use to prioritise sectors, interventions, and transitions within low-carbon development plans.

The above analysis highlights that there are a series of transitions that can provide 'win-win-win' solutions: reducing GHG emissions, avoiding lock-in to high carbon development paths and supporting inclusive economic growth. These transitions include generating on-grid electricity from renewable sources (preventing lock-in of coal power) and implementing higher density multi-use urban plans, such as mass transportation systems, and integrating rural land-use planning. Governments should adopt policies in the near-term to accelerate these transitions.

Other transitions will require difficult trade-offs where reducing GHG emissions will have little or no impact on livelihoods of the poor, or on improving the productivity of the economy. These include: reducing emissions from construction materials, methods and building operations; reducing GHG emissions from livestock; improving the energy efficiency of manufacturing processes; and reducing the GHG emissions from automobile fleets. Governments will have to consider carefully their competing policy objectives when undertaking these transitions.

All of these transitions will require action by individual governments at the sector level. These will need to be supported through cross-sector collaboration on a national level and international support in the form of finance, technology transfer, and frameworks to promote low-carbon trade and productivity. This is particularly true for those transitions that currently involve significant trade-offs for SSA governments (see chapter 9), due to the absence of such support.

Developing the necessary policies to transform SSA's infrastructure, natural and human resources in the near term, will play a large role in shaping SSA nations' growth going forward. It is crucial that SSA governments, development partners, civil society and the private sector all seize this opportunity to shift the region's development along low-carbon pathways.

Table A: 20 cross-sector transitions scored according to their potential for supporting low-carbon economic development (high 15+, medium 10+, low 5+)

Cross-sector transitions	High GHG reduction potential	Avoids lock-in to GHG intensive activities	Increases productivity	Contributes to poverty reduction	TOTAL (out of 20)
1. Reduce demand for agricultural land by intensifying production and reducing post-harvest waste	5	2	5	4	16
2. Reduce emissions from livestock	5	2	2	1	10
3. Diffuse climate-smart agriculture practices	3	2	3	2	10
4. Integrate rural land-use planning	5	3	3	4	15
5. Capture the value of forests' ecosystems services	4	3	2	2	11
6. Formalise the charcoal industry, and promote efficient charcoal kilns and biomass cook-stoves, and fuel switching	2	2	2	4	10
7. Generate on-grid electricity from renewable sources and prevent lock-in of coal power	4	5	5	4	18
8. Promote electricity access from off-grid and mini-grid systems in rural areas	1	4	4	5	14
9. Remove fossil fuel subsidies for consumption	5	5	4	3	17
10. Shift to a low-carbon automobile fleet and fuels	4	4	3	1	12
11. Implement higher density multi-use urban plans	3	4	4	4	15
12. Promote mass transportation systems	3	5	4	4	16
13. Strengthen the use of energy efficient processes and technologies in the extractives sector	3	3	2	1	9
14. Switch to lower carbon fuel sources and renewable energy in the extractives sector	3	3	2	1	9
15. Remove and avoid subsidies for fossil fuel production	4	5	3	1	13
16. Reduce emissions from construction materials and methods	3	4	2	1	10
17. Reduce emissions from buildings operations	4	4	3	1	12
18. Increase use of energy efficient processes and technologies and clean energy in heavy manufacturing	4	5	4	1	14
19. Drive growth in light manufacturing	2	4	5	4	15
20. Develop low-carbon products	2	5	4	3	14

1. Introduction

Sub-Saharan African (SSA) nations are at a critical point in their development. These countries are experiencing rapid population growth, particularly in urban areas, and have a young and growing workforce. A number of SSA countries are also experiencing high levels of economic growth, however, this development and its benefits do not always reach the majority of citizens. At the same time, global climate change threatens to undermine food production systems; increase the intensity and frequency of droughts, floods, and fires; and reverse any gains in development and poverty reduction that the region has achieved or is expected to achieve in the coming years (IPCC, 2013). Despite the region's relatively low per capita levels of greenhouse gas (GHG) emissions, the growing risk of catastrophic global climate change means that all countries must move away from high-emission models of economic growth. Therefore, while the region works to overcome a well-documented range of development challenges – widespread poverty, scattered conflicts, and universally inadequate education, healthcare, and energy access – it must be part of a wider movement to develop globally in a manner that does not lead to large-scale increases in GHG emissions.

This report identifies the main transitions that must take place to build low-carbon productive capacity in SSA (excluding South Africa),[1] and the policy tools that can be used to facilitate each of those transitions. The report is part of a project funded by the German Government (BMUB) and has been commissioned by the German Development Institute (DIE) to complement further studies on low-carbon industrial transformation in China, Germany, and South Africa. The intended audience for this report includes decision-makers within SSA governments, development partners, international financial organisations, and other regional and international organisations.

This chapter outlines the current state of economic development and projected trends across SSA, along with the implications for the region's GHG emissions. The chapter concludes with a brief discussion of the policies available to induce low-carbon transitions and an outline of our research approach.

1.1 Key economic indicators for SSA

Between 1995 and 2012, the Gross Domestic Product (GDP) per capita of SSA grew on average 3% per year - a healthy growth rate by world standards but starting from a very low level (IEA, 2014; World Bank, 2015a). Growth can be attributed to improvements in political stability and macroeconomic management, expanded exports of

Table 1: Economic indicators for SSA (excl. RSA) at the sub-regional level (2014 data except where indicated otherwise)

	Population	Population density	GDP	FDI Inflows	GDP per capita	Poverty rate (2011)
	thousands	pop / km2	PPP valuation, US$million	US$ million	PPP valuation, US$	Percent below US$1.25
Central Africa	119,253	22	247,343	8,073	2,074	62.24
East Africa	272,210	52	567,319	6,262	2,084	36.9
Southern Africa (excl. RSA)	179,235	28	532,302	8,138	2,970	56.18
West Africa	338,507	55	1,428,349	14,177	4,220	50.18
SSA	909,207	39	2,775,314	38,663	3,052	50.77

Source: AfDB, OECD & UNDP, 2014; CIA, 2015; PovCal, 2014

1 Where possible, data given in this report is for sub-Saharan Africa as a whole, and excludes the Republic of South Africa. In some cases, regional data excluding South Africa was not possible to obtain. The text will explicitly state if South Africa is included with the abbreviation 'incl. RSA'.

2 Different international organisations use different groupings to define the sub-regions of sub-Saharan Africa. In this document, we use the IEA's groupings, as mapped in Figure 1.

Figure 1: Map of Africa and definition of sub-regions

Source: IEA, 2014, p. 21

primary resources as global commodity prices increased, growing domestic demand driven by a budding middle class, and population growth (IEA, 2014).

Despite this growth, the region's economies remain relatively small. The entire GDP of SSA, at $2.8 trillion, is of similar magnitude to the GDP of the United Kingdom ($2.6 trillion), despite the former having more than 14 times as many people (International Monetary Fund, 2014). Even though average incomes have increased, over half the population still lives in absolute poverty, on under $1.25 per day.

Regional statistics conceal large variations within SSA (see Table 1 and Figure 1).[2] Of the sub-regions, West Africa, led by Nigeria, stands out as having the highest average GDP. However, despite having more than double the GDP per capita of East Africa, the poverty rate in West Africa is over 13 percentage points higher, highlighting the region's growing economic inequality.

The population of SSA has also increased rapidly from 626 million in 2000 to 909 million in 2014. This growth has been concentrated in West and East Africa, and split evenly between urban and rural areas. In contrast to global urbanisation trends, the vast majority of Africa's population still lives and works in rural areas (IEA, 2014).

Historically, economies have grown and developed at first through industrialisation – the structural shift from an agrarian society to one based on manufacturing – and subsequently by shifting to services (McMillan & Rodrick, 2011). Compared to the rest of the world, SSA countries are at a much earlier stage in this industrialisation process. Some studies show that between 1990 and 2005, SSA's labour actually moved against the grain of industrialisation and back to lower-productivity activities (Gelb, Meyer & Ramachandran, 2014; McMillan & Rodrick, 2011).

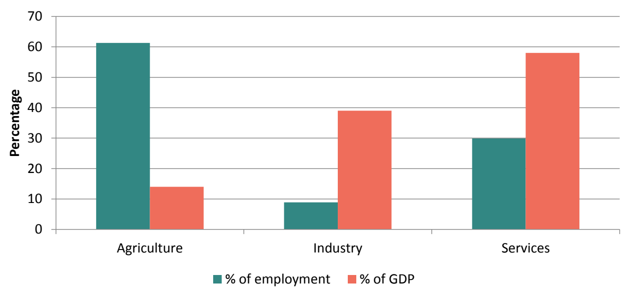
In 2013, agriculture employed more than 60% of the labour force, mostly as smallholder famers. However, it contributed only 14% of the region's GDP (see Figure 2.). Industry,[3] by contrast, employed nearly seven times fewer people, but contributed almost 40% of the regions GDP. Most industrial growth in SSA is driven by minerals[4] and hydrocarbons (led by Nigeria). Manufacturing operations are few at present (IEA, 2014). Services contributed the most economic output in the region in 2013, at 58%, and employed 30% of the labour force.

Primary commodities are the dominant exports of most SSA countries, and volumes of exports have increased significantly over the past decade. While the EU remains the region's largest trading partner, growth in trade over the last decade has been driven by China, whose trade with the sub-continent has increased from $6 billion in 2000 to $160 billion in 2013. Oil, gas, and natural resources account for 80% of China's imports from the continent. China is also the largest source of official development assistance (ODA) and a major source of foreign direct investment (FDI) in the region (see chapter 10).

1.2 Looking forward: population growth and urbanisation

Over the coming decades, SSA countries are projected to undergo extensive demographic change. In the United Nations' (2013) medium projection, the population of SSA will grow at more than twice the rate of the rest of the world. By 2050, the region's population will double to over two billion (IEA, 2014; UNDP, 2013). The projected growth is led by West Africa. Nigeria's population will double in size by 2040, making it the world's fourth most populous country.

Figure 2: Average employment percentage per sector versus average GDP percentage in SSA, 2013



Source: ILO, 2014; World Bank, 2015b

3 Industry refers here to the economic activities concerned with the extraction and processing of raw materials and the manufacture of goods.

4 Mining operations include those in Botswana, Democratic Republic of Congo, Ghana, Guinea, Liberia, Namibia, Sierra Leone, and Zambia.

The population is also very young. In Africa as a whole, 70% of people are currently under 30 years of age. Each year, an estimated 11 million people are expected to join the labour market – a workforce growth rate higher than any other region in the world (UNEP, 2015). Driven both by population growth and by rural dwellers moving to cities in search of employment, urban populations in SSA are projected to swell from 340 million in 2012, to 645 million in 2030 to 900 million by 2040 (IEA, 2014).

If managed effectively, urbanisation could be a catalyst for economic growth, providing centres for economic diversification, the development of a manufacturing base, agricultural processing, export-orientated trade, finance, and higher-level education. Governments and businesses can also deliver goods and services such as housing, electricity, healthcare, and primary education more efficiently in urban areas. Without proactive management, however, urban areas will develop in a reactive manner, with housing, water, sanitation, waste, electricity, and transport infrastructures failing to keep up with demand (NCE, 2015). There is also the risk that haphazard urbanisation will lock-in undesirable high carbon urban plans, as settled people and infrastructure become difficult to retrofit.

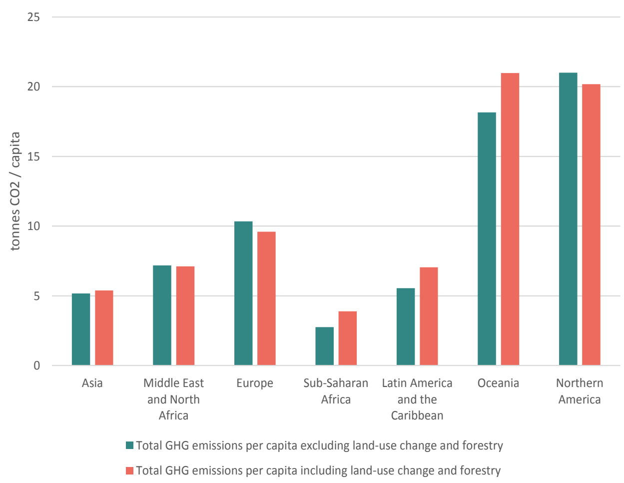
1.3 Greenhouse gas emissions in SSA

There is near consensus that to limit global warming to 2°C (the level necessary to avert catastrophic climate change), the atmospheric concentration of GHG must not exceed 450 ppm CO_2e[5] (IPCC, 2013).[6] To stay within this 'carbon budget' in a world projected to support 9.2 billion people by 2050, annual average per capita emissions will need to converge at 2.1 to 2.6 tonnes CO_2e by mid-century. SSA's current per capita emission levels, whilst the lowest in the world, are slightly above this level, at 2.7 or 3.9 tonnes CO_2e, depending on whether land-use change and forestry is taken into account (see Figure 3).

Of course, given their historic responsibility for climate change, industrialised nations have an obligation to bear most of the burden of reducing GHG emissions. Nonetheless, even dramatic cuts to industrialised countries' emissions will not be enough to meet the target. SSA's emissions can rise nominally in the short term, but they will need to decline to below current levels thereafter (King, 2012; King, Richards & Tyldesley, 2011). This climatological constraint conflicts with business-as-usual trends, which see the region's GHG emissions growing rapidly due to population growth, increased fossil fuel use and extraction, expansions in cattle production, and deforestation (FAO, 2015; IEA, 2014).

As a result of limited industrialisation in SSA, most emissions are not linked to fossil fuels; rather they are linked to agriculture and wider land-use change (see Figure 4). Nonetheless, as a result of projected population and economic growth, GHG emissions in the region are expected to grow rapidly due primarily to increased fossil fuel use and extraction, expansions in cattle production, and deforestation (FAO, 2015; IEA, 2014).

Figure 3: Average annual per capita GHG emissions by region, 2011



Source: Data from WRI, 2014b

The following chapters outline the current and projected GHG emissions for the seven sectors reviewed in this report: agriculture, forestry, energy, transport, extractives, construction and manufacturing.

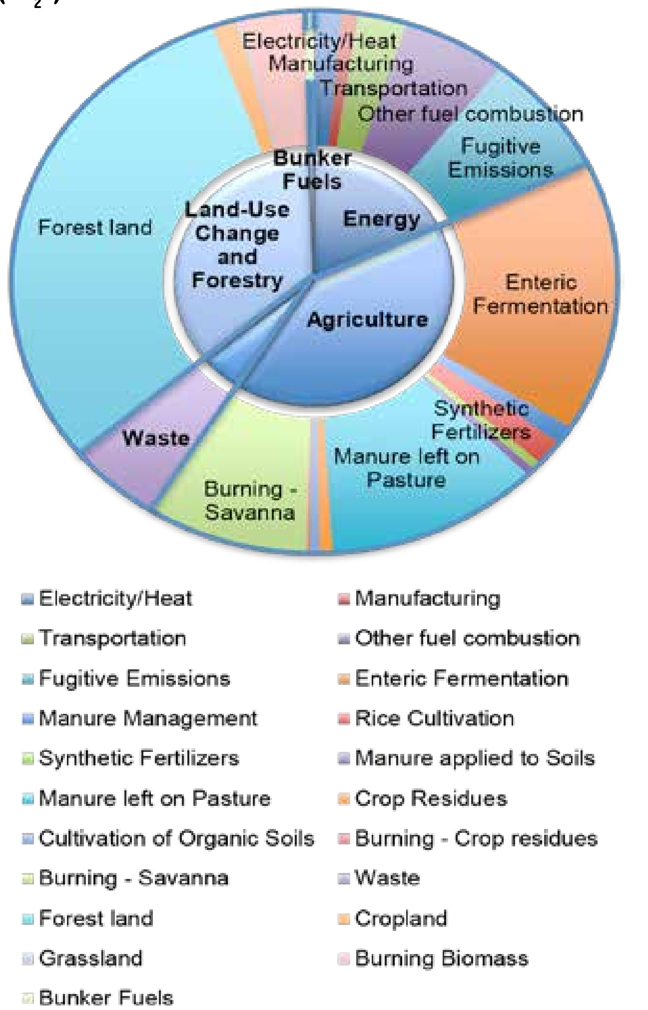
1.4 Policy tools to induce low-carbon transitions

Governments have a wide range of policy tools available to promote economic transitions, including those to low-carbon growth paths. The array of policy tools used by governments to promote specific industries and sectors that are considered economically beneficial is referred to as 'industrial policy' (UNCTAD, 1998; Whitley, 2013c). Elsewhere, the term 'industrial policy' has been used narrowly, referring specifically to government policy to encourage the development and growth of manufacturing. Historical examples of where industrial policy was used to induce structural economic transformations – for example, in the 'Asian Tigers' (Hong Kong, Singapore, Taiwan, and South Korea) in the latter half of the 20th Century – provide informative lessons for how governments can shape economic outcomes. Drawing from these lessons, we use the term 'industrial policy' to broadly refer to government interventions that support and shape the growth of any specific sector of the economy.

5 Parts per million by volume of carbon dioxide equivalent.

6 A number of Non-Governmental Organisations (NGOs) and scientists (Rockstrom, et al., 2009) have called for an even more ambitious target of 350 ppmv CO_2e, which equates to 1.5 °C, to stay within safe planetary boundaries and protect those most vulnerable.

Figure 4: GHG emission sources in SSA (excl. RSA), 2011 (CO_2e)



Source: FAO, 2015; WRI, 2014b

Note: The top six emissions sources, representing 80% of all emissions produced in the region, are as follows: (1) loss of carbon stock from forested land, 30.4%; (2) methane released during enteric fermentation of ruminant livestock, 16.1%; (3) nitrous oxide released from manure left on pasture during the microbial processes of nitrification and de-nitrification, 11.5%; (4) methane and nitrous oxide released during the burning of savannah, 8.6%; (5) fugitive emissions (CO_2, CH_4, N_2O) produced during the extraction and processing of fossil fuel, 7.3%; (6) other fuel combustion, which in the case of SSA includes mostly methane and nitrous oxide emissions produced by burning of biomass for fuel, 5.6%.*

** Burning of savannah and biomass also produces CO_2 but this is included in the land-use change and forestry category because theoretically, it can be offset through biomass growth (WRI, 2014a).*

The policy tools that governments have available to promote low-carbon transitions are not unlike those of conventional industrial policy. Industrial policy uses common regulatory, economic, and information instruments to guide investment and consumption behaviour (see Figure 5). These regulatory, economic and information instruments can be used to create new pathways, seeding the innovation of the technologies of the future by grants supporting research, development and demonstration (RD&D), concessionary lending, price subsidies, and public procurement schemes. They can also be used to disrupt old pathways or business as usual, which can include removing existing incentives through fiscal policy reform, and introducing new regulations for land-use planning and standards for buildings, technologies and vehicles.

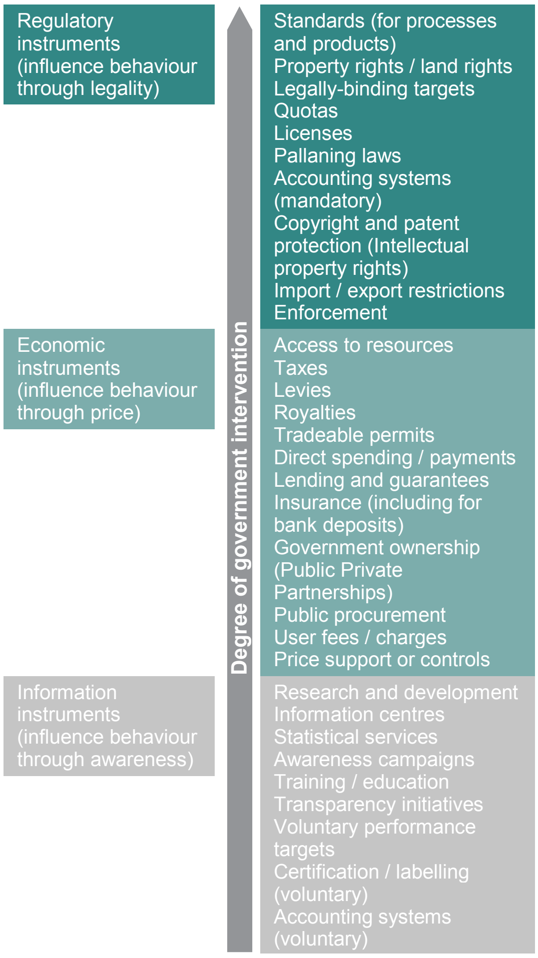
Such economic transitions require long-term planning horizons. In the case of a low-carbon transition, these are needed to effectively achieve the long-term end goal of global zero net emissions by the second half of this century (SDSN, 2014). Only by planning for this end goal, rather than short-term milestones, can governments make the choices needed to achieve a future of low-carbon production and avoid locking in high-carbon development patterns. Slow-changing assets, including transport, electricity, and buildings infrastructure, are particularly at risk of locking-in emissions intensive pathways (Fay, et al., 2015). Practically, avoiding lock-in requires SSA governments to set low-carbon development goals for 2050 and 2100, with incremental short- and mid-term actions and milestones developed always with the achievement of the end goal(s) in mind.

Beyond the tools and long-term planning that are common to all effective industrial policy, there is one element of low-carbon policy that sets it apart. The majority of our economic systems do not reflect the damage caused by emission-intensive activities, nor the benefits of low-carbon alternatives (Lütkenhorst, Altenburg, Pegels & Vidican, 2014, pp. 2-3). Failure to account for these so-called 'externalities' leads to more investment in emission-intensive activities than is optimal from a societal perspective and less investment in low-carbon technologies and practices (Stern, 2007).

The textbook solution to address negative externalities is for governments to increase the cost of activities that produce GHG emissions across the entire economy, either through a carbon tax or a cap-and-trade system. Carbon pricing in the least developed countries is a highly controversial topic, as it raises concerns that it would lead to inflation, reduce consumption and hinder the development of fledgling industries. A recent report entitled *Decarbonizing Development* by the World Bank argues that these concerns are overstated (Fay, et al. 2015). It argues that a carbon tax on energy consumption, in particular, can be progressive because (1) consumption of modern energy (fossil fuels and electricity) rises with income, and (2) it has the added benefit of raising revenues to support poverty reduction and development (Fay, et al. 2015). Emissions pricing will likely be a necessary component of shifting development pathways in SSA in the future.

Beyond emissions pricing, governments have a series of other regulatory, information, and fiscal instruments to trigger changes in investment patterns to promote low-carbon development in each sector of the economy. The sector specific chapters 2-8 discusses how the policy

Figure 5: Types of policy tools available to promote low-carbon transitions



Source: Whitley, 2013a

tools shown in Figure 5 can be used to induce a series of low-carbon transitions. Importantly, beyond these individual transitions, another opportunity to promote low-carbon development in SSA is for governments to focus support on sectors that produce few emissions relative to output – such as services and light manufacturing – over high-emitting ones like heavy manufacturing and the extractive industries.

1.5 Research approach

This report aims to address three overarching questions:

- What are the current development trends in terms of technologies and GHG emissions in SSA?
- How can development be shifted towards low-carbon trajectories?
- What would effective low-carbon policy look like?

For each sector reviewed, we identify the key transitions that must take place to build up low-carbon production policy on a sector-by-sector basis and the policy tools available to achieve each of those transitions.

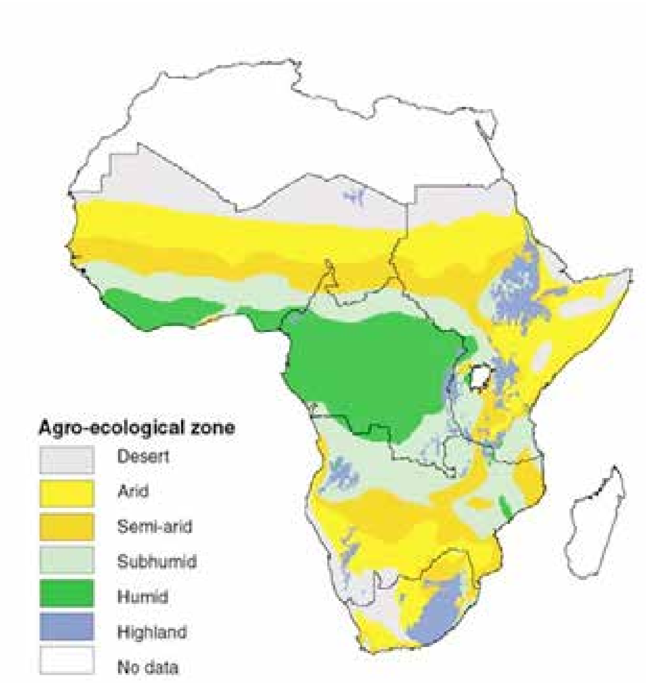
Each sector-focused chapter (chapters 2-8) begins with a discussion about the importance of the sector to the economy of SSA, followed by a review of its current and projected contribution to regional GHG emissions. Given the breadth of sectors covered, most of the information presented is regional, with specific country-level case studies detailing particularly successful policy measures. Based on an analysis of the value chain in each sector, the sub-sections then identify the most important 'assets and processes' in the sector to manage in order to promote low-carbon production. By 'assets and processes' we are referring to the different elements – technologies, fuels, infrastructure, land use, practices, etc. – that are fundamental to transitioning to low-carbon production. They are introduced in this paper to provide insights that are regionally relevant but which can be adapted to country-specific circumstances. Lastly, each sub-section presents an analysis of the transitions necessary to enhance low-carbon productivity in each sector and the policy tools and incentives available to induce and manage them. Each transition's implications for productivity and poverty reduction are discussed.

Although a sector-focused approach is useful as it reflects the structure of the majority of governments, economic planning, and data collection, it is important to recognize the significant interactions and even overlaps that exist between sectors. For example, the main drivers of deforestation are agricultural expansion and the harvesting of biomass for energy. Similarly, energy consumption represents the largest source of emissions across a number of different sectors (transport, manufacturing etc.). As a result, many opportunities to reduce emissions from deforestation and energy generation involve actions outside of the forestry and energy sectors. It will be important to keep these cross-sector linkages in mind during the development of low-carbon policy. For example, mutually reinforcing steps to transition to less emitting fuel sources, and to adopt more energy-efficient technologies and practices, will be discussed in four of the seven sectors reviewed in this report: extractives, manufacturing, construction, and transport.

Following the sector-focused chapters, chapter 9 examines the potential for lock-in to high carbon paths for each sector; and chapter 10 examines the role of international finance, frameworks and institutions in supporting and guiding country-level transitions. Particular attention is paid to international climate agreements and frameworks, climate finance and carbon finance, international trade policy, and regional engagement policies. Chapter 11 concludes with further discussion of the cross-sector implications of the 20 low-carbon transitions identified. Finally, an indicative scoring exercise is used to rank the sectors across four categories: set of four criteria: (1) the level of GHG emissions that they could avoid; (2) the risk of lock-in that they could avert; (3) their contribution to increased productivity; and (4) their contribution to poverty reduction. The exercise illustrates the decision-making processes and criteria, beyond GHG emissions, that governments should use to prioritise sectors, interventions, and transitions within low-carbon development plans.

2. Agriculture

Figure 6: Agro-ecological zones in SSA



Source: FAO, n.d.-b.

Agriculture provides employment for the majority of the population in SSA. Smallholder farmers – those farming less than two hectares in area – represent 80% of all farms in the region (Livingston, Schonberger & Delaney, 2011). Continent-wide, these small farms provide 70% of the food supply (IAASTD, 2009).

The food produced by smallholders in SSA varies across agro-ecological zones (see Figure 6 and Table 2). As seen in the table, livestock are an important component of many economies and cultures in SSA. For farmers, livestock can represent prestige and a form of savings (Herrero, Thornton, Kruska & Reid, 2008).

Productivity of crops per unit of land is low in SSA. Over the last several decades, crop harvest and erosion has led to depleted nitrogen in the soils and declining grain yields, which is a contributing factor to the chronic malnutrition experienced by 250 million people in SSA, 30% of the region's population (Hickman, Havlikova, Kroeze & Palm, 2011). It is vital that crop yields increase to keep pace with the region's growing population and demand for food.

2.1 Agriculture sector GHG emissions and projections

Agriculture produces more GHG emissions than any other sector in SSA. The biggest sources of emissions in the sector are:

Table 2: Farming systems and products in SSA by agro-ecological zone

Agro-ecological zone	Farming systems	Land area (% of SSA)	Agricultural population	Agricultural products
Arid	Pastoral	14%	27 million (7%)	Cattle, camels, sheep, and goats
Semi-arid	Agro-pastoral	8%	33 million (8%)	Sorghum, millet, pulses, sesame, cattle, sheep, goats, and poultry
Sub-humid	Mixed cereal/ root-crop	13%	59 million (15%)	Maize, sorghum, millet, cassava, yams, legumes, and cattle
	Mixed maize	10%	60 million (15%)	Maize, tobacco, cotton, cattle, goats, and poultry
Humid	Root crops	11%	44 million (11%)	Yams, cassava, legumes, and cattle
	Tree crops	3%	25 million (7%)	Cocoa, coffee, oil, palm, rubber, yams, and maize
Highlands	Forest-based	11%	28 million (7%)	Cassava, maize, sorghum, beans, and cocoyams
	Highland perennial	1%	30 million (8%)	Banana, plantain, enset, coffee, cassava, sweet potato, beans, cereals, and cattle
	Highland	2%	28 million (7%)	Wheat, barley, peas, lentils, broad beans, rape, tef, potatoes, and cattle

Source: Livingston, et al., 2011.

- encroachment of pasture and cropland into forested areas;
- livestock manure and digestive processes;
- burning of savannah; and
- cropland management and cultivation practices.

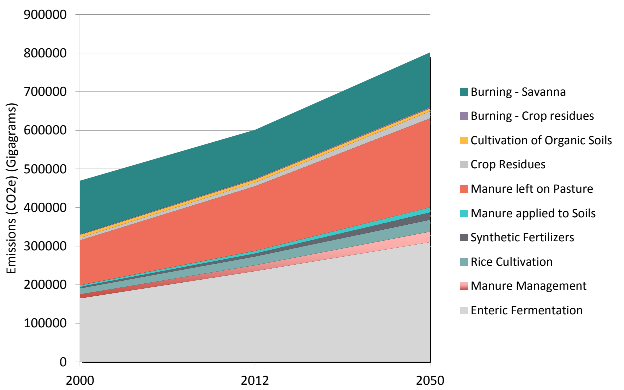
Due to conventional emissions-accounting techniques, the 'indirect emissions' caused by agriculture's expansion into forested areas fall into the category of land-use change, and are therefore considered in chapter 3 on the forestry sector.

Figure 7 illustrates the magnitude and growth trends of emissions that result directly from agricultural processes. The FAO (2015) projects that direct agricultural emissions in SSA will increase by a third between 2012 and 2050, from 600 million to 800 million tCO_2e – an amount double that of the European Union's agricultural emissions in 2012 (407 million tCO_2e) and almost as high as those of China (832 million tCO_2e), which in 2012 had the highest level of agricultural emissions of any country (WRI, 2015). The main source of projected growth is from livestock.

2.1.1 Encroachment of pasture and cropland into forested areas

Agricultural expansion, primarily of smallholder farms, accounted for approximately 70% of forest loss between 2000 and 2010 (African Progress Panel, 2015). Population growth in rural areas is an underlying central driver of the encroachment. Traditional shifting cultivation practices require significant land to enable regeneration, and therefore are only sustainable under conditions of low-population density. For this reason, regional differences in the rate of deforestation can largely be explained by differences in population density (Mayaux, et al., 2013, p. 7). With projected population growth, demand for land will continue to rise unless changes to agricultural practices can lead to increased yields through intensification, rather than extensification.

Figure 7: Projected agriculture emissions in SSA (excl. RSA), 2000-2050



Source: Data from FAO, 2015.

2.1.2 Livestock manure and digestive processes

Livestock produces the two largest sources of direct agricultural emissions. It releases methane during the digestive process of enteric fermentation and it produces nitrous oxide through manure left on pasture (FAO, 2015). Cattle alone represent 80% of all methane emission (Herrero et al., 2008).

In addition, Africa has a relatively high emission-intensity per unit of production of meat and milk compared to other regions of the world due largely to the livestock's poor diet and low productivity. For example, whereas the dairy industry in Europe and North America produce 1.6 and 1.9 tCO_2e per tonne of milk, the same ratio in SSA is the highest of any world region at 9 tCO_2e per tonne of milk (FAO, 2013a).

Continent-wide, Africa had an estimated 305 million cattle, 348 million goats, and 328 million sheep in 2013, up from 230 million, 237 million, and 247 million in 2000. Livestock ownership is projected to increase in the region, driven by a growing demand for meat and milk induced by population and income growth. In turn, livestock-related emissions are projected to increase, with most growth occurring in East and West Africa (see Figure 8) (Herrero et al., 2008).

2.1.3 Cropland management and cultivation practices

Aside from the conversion of forested land, crop production in SSA is relatively low-emitting compared to other regions of the world that rely on industrialised systems. The main cropland management technique that results in emissions is the burning of savannah, which is partly practiced to clear land for cropland and pasture, but is also used to control pests, and encourage re-growth of perennial grasses for forage. Burning of savannah produces methane, nitrous oxide and carbon dioxide (FAO, 2015).[7] As seen in Figure 7, emissions from savannah burning are projected to remain relatively stable through to 2050 (FAO, 2015).

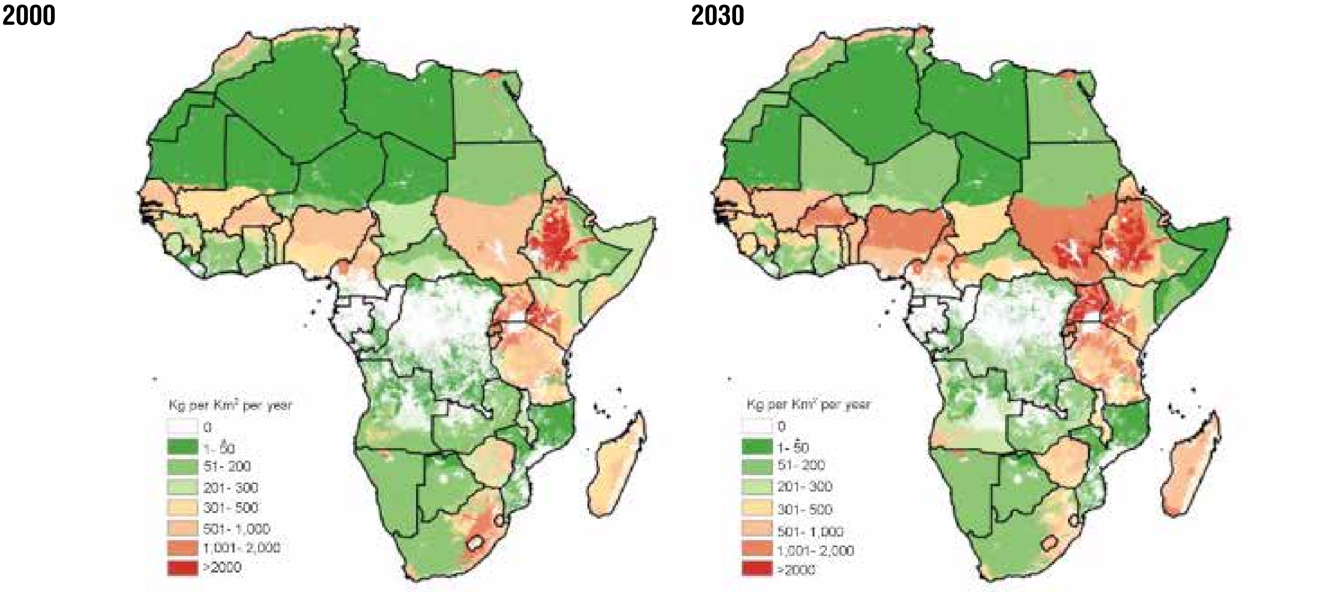
Part of the reason that crop production in SSA is relatively low-emitting is that the region represents only 3% of synthetic fertiliser consumption, which, as a whole, contributes 0.6% to 1.2% of global emissions (Bellarby, Foereid, Hastings & Smith, 2008). Moreover, mechanised tillage of the land, which can result in reductions in the stock of soil carbon in cropland, is not commonly practiced.

SSA emissions from use of inorganic fertiliser are likely to increase over the coming decades. Hickman et al. (2011) projects that nitrogen inputs (from inorganic fertiliser and manure) in 2050 will be up to six times the levels of the year 2000 and that as a result nitrous oxide emissions will roughly double. Indeed, in cases where

7 Carbon dioxide is also produced during the process. If the savannah is left to regenerate after a fire, then the proactive of burning is carbon neutral. Methane and nitrous oxide emissions, in contrast, remain in the atmosphere.

Figure 8: The projected spatial distribution of methane emissions from African ruminants in the year 2000 and 2030

2000 **2030**



Source: Herrero et al., 2008, p. 130.

organic manure is insufficient, an increase in nitrogen, phosphorus, and potassium (NPK) inputs through manure and/or synthetic fertiliser will be necessary to increase the intensity of crop production and thereby decrease pressures on forests (FAO, 2013a; IFAD and UNEP, 2013). However, excessive use of synthetic fertiliser without other important soil management techniques could lock-in their use by undermining the biological basis for agricultural production (Mancus, 2007).

2.2 Key assets and processes in the agriculture sector

In order to reduce emissions in the agricultural sector, the most important assets and processes to manage are (1) livestock and livestock diets; (2) crop production techniques and processes; and (3) post-harvest storage, transport, and processing facilities. This section outlines the opportunities to reduce emission across these assets and processes. While post-harvest processing is discussed below as a strategy to reduce wasted agricultural produce, strategies to promote agro-processing are covered in the manufacturing sector.

2.2.1 Livestock and livestock diets

A relatively low-cost option for reducing emissions from enteric fermentation and manure left on pasture is to reduce the overall headcount of cattle by, for example, shifting consumption and production from beef to pork or chicken (Government of Ethiopia, 2012). Given the importance of cattle to many African cultures, as well as the religious abstention from pork in some areas, such a shift would be likely to encounter social obstacles (Bass, Wang, Ferede & Fikreyesus, 2013).

The intensity of methane produced during enteric fermentation relative to beef and/milk production can also be reduced. These reductions can be achieved through changes to the diet of livestock; lowering the age of beef-cattle at slaughter; selection of livestock that produces fewer emissions, i.e. animal husbandry; and biotechnological solutions such as vaccinations or the introduction of microorganisms to the animals that reduce enteric fermentation (FAO, 2013a; Waghorn & Hegarty, 2011; Wright & Klieve, 2011).

Some of these emission-reducing practices can also enhance yields. Animal husbandry can select for genetically superior bulls that not only produce fewer methane emissions but also produce higher yields of meat and milk. Higher yields, in turn, could mean that less pasture is needed, reducing pressures on forests.

Likewise, improving the diet of cattle can increase yields. Most livestock in SSA graze openly (rather than in feed-lots). Therefore, changing their diets involves improving forage through grassland management practices. The introduction of practices, such as rotational grazing, can enhance grassland productivity by reducing grazing pressures (P. Smith et al., 2008). By providing animals with greener, more nutritious forage, enteric fermentation can be lowered relative to weight gain, reducing methane emissions (Rolfe, 2010). In Brazil, Gouvello (2010) estimated that a 20-year programme to promote both genetically superior bulls and improved forage could reduce annual emissions from beef-cattle farming by 12%.

2.2.2 Crop production techniques and processes

There are also opportunities to reduce GHG emissions by altering the way in which crops are grown. Land management practices themselves can be altered. For example, farmers can shift to 'prescribed burning' of savannah, early in the season, which produces less biodiversity loss and fewer emissions than late-season burning (FAO, n.d.-a).

Increasing the yield per hectare can alleviate the pressure that agricultural expansion places on Africa's forest carbon stocks. Irrigation in particular could improve the productivity, intensity, and resilience of crop production in the region. Despite the fact that irrigated systems are on average more than twice as productive as non-irrigated land, only 4% of agricultural land is under irrigation in SSA (World Bank, 2008a). Cropland is frequently left fallow during dry spells and that which is cultivated is vulnerable to drought.

Other methods of increasing yields include improved crop selection and soil nutrient management (FAO, 2013a, n.d.-c). Production could be increased through selection of crop varieties that are not only higher yielding, but also drought or pest resistant. Healthy and more productive soils can be maintained through optimal application of compost, manure, and fertiliser. As discussed above, increasing fertiliser use will result in increases in nitrous oxide. Therefore, rather than reducing overall emissions from fertiliser application, the goal should instead be to achieving optimal fertiliser application to nitrogen-depleted soils.

A host of agricultural methods – dubbed 'climate-smart agriculture' – offers additional climate benefits. As explained by Granoff et al. (2014, p. 34) 'climate smart agriculture involves increasing technical inputs that improve the efficiency of water and fertiliser inputs, conserve and improve the quality of the soil, and make better use of residues and post-harvest waste.' For example, recycling organic waste through composting not only returns nutrients to soil, increasing its fertility, it diverts waste from landfills and thereby reduces methane emissions (Adam-Bradford, 2011).

Other climate-smart agriculture techniques have been shown, in many contexts, to increase productivity while either reducing emissions or increasing the soil carbon stock. These include more precise application of fertiliser and manure, improved manure management, agro-forestry, direct planting, and the use of more nitrogen-efficient and nitrogen-fixing plants (such as comfrey) (Adam-Bradford, 2011; Pretty, et al., 2006).

The effectiveness and appropriate application of some climate-smart agricultural techniques have been shown to vary significantly across different climates and soil types. For example, direct planting (also known as conservation tillage, minimum tillage or no-till agriculture) has been shown to increase the quantity of organic matter and water in the soil, thereby sequestering an estimated average 500kg of soil carbon per hectare annually (Cerri, et al., 2009; Pinto, 2009).[8] However, in direct planting systems, the temperature and/or chemical composition of the soil will affect the optimal thickness of the layer of residue spread on the soil or left from the previous harvest. Despite the context-specific technical knowledge required, direct planting has the potential to operate on a very large scale. In Brazil, 23-26 million hectares, approximately 10% of the nation's cropland, is cultivated without tillage (Assunção, et al., 2013).

2.2.3 Post-harvest storage, transport, and processing facilities

Compared to other regions of the world, relatively little food is wasted by consumers in SSA. However, a significant portion of crops and milk is wasted before making it to market. A US Department of State (US DoS, 2013, p. 2) report found that in Ethiopia, post-harvest losses in some regions could be between 30% and 50%: 'The causes of post-harvest losses are multiple, however, the most significant losses are caused by pests (insects and rodents), by lack of appropriate storage facilities, by inappropriate packaging, and by inadequate means of transportation.' This loss could be reduced substantially through a variety of measures along the production chain, including improved drying equipment and packaging; warehousing facilities and fumigation services; and transport networks to open up access to markets (US DoS, 2013). Reducing post-harvest loss could reduce the amount of land required to feed the population, thereby reducing pressure on forests and abating losses in the carbon stock.

2.3 Enabling low-carbon transitions in the agriculture sector

One important step in reducing emissions from the encroachment of cropland and pasture into forested areas will be to manage the supply of land available for cultivation through integrated land-use planning (Transition 4). While supply-side land management policies are discussed in chapter 3, it is important that agricultural ministries, farmer's associations, and other agricultural stakeholders be involved in land-use planning processes to ensure that the effects on agricultural productivity, food prices and low-income households are taken into account. This section will focus on the policy instruments that can be used within in the agriculture sector specifically to induce transitions to low-carbon production capacity.

Transition 1: Reduce demand for agricultural land by intensifying production and reducing post-harvest waste

Beyond managing the supply of land, there are steps that can be taken within the agriculture sector to reduce its demand for land. Practices that enhance yields and reduce post-harvest waste – such as irrigation, cold storage, and

8 The quantity of carbon sequestration from no-till agriculture varies with practice, climate, and soil type.

the use of compost, manure, fertilisers, and high-yielding varieties of crops – are frequently cost-effective and can produce significant economic benefits, including among low-income farmers. However, their diffusion can be inhibited by farmer's lack of technical capacity and capital for upfront costs (FAO, 2013a). Therefore, information and economic policies and instruments will be necessary to promote their diffusion.

Where technical capacity is lacking, agricultural extension services will be necessary to train farmers in irrigation, composting, crop varieties, and the appropriate application of manure and fertiliser. Training is also important in the reduction of post-harvest waste: 'Even when reliable modern storage technologies are available for use, such as the case with the grain sector in Nigeria and Ghana, workers at these facilities may lack proper training. Significant post-harvest loss, up to 50%, has been attributed to the lack of adequate knowledge and implementation of sound grain storage management' (US DoS, 2013, p. 1).

Where financial capital is lacking, policies that enable farmers to secure affordable sources of credit can help intensify productivity by enabling them to purchase irrigation systems and yield-enhancing other inputs. Likewise, affordable credit could unlock farmers' access to post-harvest processing technologies and cold storage facilities (Salemi & Arawomo, 2013). Agricultural credit markets are particularly weak in SSA,[9] and may need to be strengthened through support for agricultural credit cooperatives and government provision of agricultural finance.[10] In many cases, land tenure formalization is necessary to unlock access to finance by enabling landowners to borrow against the land. Land tenure reform is discussed in more detail in chapter 3.3.

Farmers will only want to take on loans if they can be confident that they can access profitable and affordable output markets. Enabling farmers to get their product to market will also be key to reducing post-harvest waste. In some rural areas, building transportation infrastructure will be an important step to this end (see chapter 5).

Transition 2: Reduce emissions from livestock

Practices that reduce GHG emissions whilst improving the yield of livestock – for example, through measures to improved forage and genetic stocks – could have a positive impact on farmers' yields and incomes. Despite their cost-effectiveness, significant financial and technical barriers remain.

Low-income farms are frequently incapable of affording the upfront costs of the fencing and watering infrastructure needed for rotational grazing. The incentive to invest is also frequently undercut by poorly defined tenure. Policies to promote rotational grazing would include tenure reform, agricultural extension services, and tools to secure affordable credit.

Animal husbandry has particularly high technical threshold. As explained by Gouvello (2010, p. 63), public programmes or research funding to evaluate the genetic stock of bulls, and subsidies for the acquisition of tested animals of good lineage, could improve yields and reduce GHG emissions over the medium-term.[11]

Other options to reduce emissions from livestock, such as shifting consumption from beef to pork or poultry, would not necessarily provide adequate private returns. A great deal of projected increases in cattle production is to meet a rising demand for beef among the growing urban middle class. National governments may therefore need to provide support for such shifts through regulatory, economic and information instruments. In the case of Ethiopia, the Government of Ethiopia's Climate-Resilient and Green Economy Strategy aims to increase poultry's share of the nation's meat consumption from 15% to 30% by 2030. To achieve this target, the government plans to provide $10 million in subsidies for the establishment of feed processing plants, hatcheries, grandparent farms, and poultry slaughter and processing units, plus $1 million annually to run the programme. The government's efforts also include an extension programme to convince the population to produce and consume poultry (Government of Ethiopia, 2012). Bass et al. (2013) cautions that although the government's promotion of poultry over beef could yield major GHG reductions, it may also have negative social and cultural outcomes. Social impact assessments would be important to ensure that policies aimed at mitigating emissions from livestock are both green and inclusive (Bass et al., 2013).

Biotechnological solutions to reduce enteric fermentation – such as animal vaccinations or the introduction of microorganisms to livestock guts – are

9 A recent African Development Bank report found that despite agriculture contributing more than any other sector to GDP on the continent, commercial banks lent less than 10% of their portfolio to agriculture in five of the seven countries studied (Nigeria, Kenya, Lesotho, Egypt, Rwanda, with Mali and Sudan being the only exceptions) (Salemi & Arawomo, 2013). Other sources of agricultural credit in the region include informal moneylenders; microfinance institutions and savings and credit cooperatives (SACCOs); specialised public agricultural lending bodies such as the Nigerian Agricultural, Cooperative and Rural Development Bank (NACRDB); and out-grower schemes where large agri-business companies extend loans tied to their suppliers (often small-scale farmers) (IFAD, 2003; Salemi & Arawomo, 2013; IFAD, 2003; Salemi et al., 2013).

10 Subsidised credit could also be made contingent on borrowers demonstrating compliance with forestry regulations. For example, the Brazilian government's Low-Carbon Agriculture programme has used low-interest loans as an incentive to agricultural practices shown to improve the intensity of production (Assunção, Bragança, & Hemsley, 2013). Likewise, it had success in reducing deforestation rates in the Amazon by requiring borrowers to demonstrate proof of compliance with forestry regulations (Assunção, Gandour, & Rocha, 2012). In sub-Saharan Africa, subsidised credit could be instrumental in promoting agricultural intensification and reducing post-harvest waste linked to the protection of forest areas.

11 Note that Gouvello (2010) was referring to the Brazilian context.

Box 1: Uganda Municipal Waste Compost Programme

In Uganda, 80 percent of the waste sent to the landfill is organic, resulting in significant methane emissions. In 2010, the Uganda's Municipal Waste Compost Programme was set up as a countrywide CDM programme of activities to eliminate these methane emissions by recovering and composting the organic matter. The resulting compost is sold to farmers to enhance plant growth. Municipalities either set up and operate the composting facilities on their own, or contract the service out to the private sector. The implementing entity, the National Environment Management Authority (NEMA), provides financial and technical assistance during implementation of the composting facilities and then monitors their operation.

To finance the initial costs of the project, the Government of Uganda has taken a loan from the World Bank. The municipalities then transfer their Certified Emission Reduction (CER) rights to the NEMA in repayment for the initial investment. NEMA, in turn, sells the CERs directly to the Community Development Carbon Fund (CDCF) of the World Bank.

On average, each municipality handles 70 tonnes of waste per day (between 50 and 200 tonnes), and 25,550 tonnes per annum. The average yield of compost for each municipality is about 5000 tonnes, which at the predicted price of $13 per tonne, is worth $65 thousand. The predicted emission offset for the whole programme during the first seven-year crediting period is 8370 tonnes of CO_2e per year from 2010 to 2017 (UNFCCC CDM, 2011).

practices that show promise but have not yet been proven (FAO, 2013a). As there is little economic incentive for private farmers to develop these techniques, there is justification for public investment in experimenting with the practices and transferring proven technologies from other regions. Once proven, subsidies and agricultural extension services are likely to be necessary to further promote the practices.

Transition 3: Diffuse climate-smart agriculture policies

The cost-effectiveness of different climate-smart agriculture techniques is context specific, depends on the local climate and soil, and on whether that soil is nitrogen depleted. Nonetheless, in many areas, climate-smart approaches to agriculture have been shown to enhance yields, reduce input costs, and reduce risks compared to business-as-usual approaches. For example, Kaczan et al. (2013) found that in Zambia and Malawi farmers improved yields and profits by adopting conservation agriculture and agro-forestry systems with nitrogen-fixing trees. In such cases, climate-smart agriculture practices could have significantly positive impacts on poverty and economic growth.

Even when cost-effective, climate smart agricultural techniques often continue to face barriers to diffusion due to upfront costs, lack of coordination, insecure tenure and insufficient flows of information. Box 1 provides an example of how the Government of Uganda has overcome financial and coordination issues to promote composting at the municipal level and secured carbon revenues in the process.

Climate-smart agricultural techniques – composting, direct planting, agro-forestry, precision application of manure and fertiliser, the use of nitrogen-efficient and nitrogen-fixing plants – all require technical knowledge. Even within small areas, this knowledge does not lend itself to diffusion through the process of learning from one's neighbour, because practices must be adapted to local climate and soil conditions, which vary widely. Public research programmes or publically funded research can identify which techniques are most appropriate in local soil and climate types (Assunção, et al., 2013). Demonstration projects, farm tours and agriculture extension services (particularly mobile ones) can target barriers to knowledge diffusion directly and teach farmers about the benefits of new technologies, practices and species (Adam-Bradford, 2011; Assunção, et al., 2013). Box 2 discusses a success story in which knowledge enhancing policies were used to promote no-till agriculture in Ghana.

Box 2: No-till agriculture in Ghana

A successful example of knowledge diffusion to improve agricultural practices is offered in Ghana. In the 1990s, the Crop Research Institute of the Ghanaian government's Council for Scientific and Industrial Research collaborated with the international NGO Sasakawa-Global 2000 and the multinational corporation Monsanto, to conduct research on the potential for no-till agriculture with mulch, to replace increasingly unsustainable slash-and-burn practices in the Forest, Transition, and Guinea Savannah Zones. It funded the doctoral dissertation of a soil scientist who worked with a group of innovative farmers to pilot a weed and mulch management system that responded to their needs and then developed an extension programme to disseminate the package widely. By 2005, an estimated 300,000 small-scale farmers were using no-till (Ekboir, Boa & Dankyi, 2002).

3. Forestry

Although tropical rainforests cover only 13% of the African continent, they represent 90% of its terrestrial carbon stock. Rainforests are found in Central Africa, West Africa, and Madagascar. However, the Congo Rainforest in Central Africa accounts for 89% of the rainforest in the region and is the second largest contiguous forest zone in the world after the Amazon (Mayaux et al., 2013). Forests in East Africa and Southern Africa are primarily dry and make up less of these regions' carbon stock (FAO, n.d.-c; Pfeifer et al., 2012).

In addition to their role as a significant global carbon sink, forests are vital to economic productivity. Forests provide timber, food, fibre, medicine, and especially fuel – almost 80% of all energy consumed in SSA is produced through the combustion of solid biomass – largely from forests (see chapter 4.1). Rainforests alone support the livelihood of 60 million rural residents and 40 million urban residents (Mayaux et al., 2013; Nasi, Taber & van Vliet, 2011). Forests are also rich in biodiversity and provide refuge to endangered animals like gorillas and chimpanzees, which draw important tourism revenues. Furthermore, forests provide ecosystem services that are essential to agricultural and hydroelectric production, including nutrient cycling, watershed maintenance services, erosion prevention, and the hosting of pollinators. Local climate cycles often depend on forests to distribute precipitation inland through evapotranspiration (Sonwa, 2013).

3.1 Forestry sector GHG emissions and projections

The relationship between forestry and GHG emissions is two-way, i.e. the stock of forest carbon can be increased, through increases in biomass, and decreased, through the processes of deforestation and forest degradation.[12] On balance, losses in forest carbon significantly outweigh the gains across all regions and lost forest carbon stock is the single largest source of emissions in SSA. In 2012, it contributed an estimated 889 million tCO_2e, over 30% of the region's total (FAO, 2015).

Nonetheless, total emissions from deforestation in SSA are lower than in Southeast Asia and Latin America, owing to the relatively low deforestation rate in the Congo Basin compared with the other major rainforests of the world (Mayaux et al., 2013). Tropical deforestation rates are also declining in SSA. Over the previous two decades, net annual deforestation halved from 0.28% between 1990-2000 to 0.14% between 2000 and 2010.

Given the large size of the Congo rainforests, deforestation rates are three times higher in West Africa and nine times higher in Madagascar. This higher rate of deforestation places the rainforest in Madagascar especially at risk (Mayaux et al., 2013) (see Figure 9). In the last decade, forest cover also declined throughout East Africa (except Southern Sudan), with the most severe declines in the previously forest-rich countries Uganda and Rwanda (Pfeifer et al., 2012).

The principle drivers of deforestation and forest degradation in SSA are the expansion of small-holder agriculture and fuelwood collection (see chapters 2 and 4). As mentioned, agricultural expansion, primarily of smallholder farms, accounts for approximately 70% of forest loss (African Progress Panel, 2015). More than half of forest degradation, on the other hand, is caused by fuelwood collection and charcoal production (see chapter 4.1). Logging is responsible for approximately one-third of forest degradation (African Progress Panel, 2015).

These drivers contrast with other regions of the world, where large-scale agri-business and logging contribute to the majority of forest clearing (with the notable exception of a few oil palm and rubber plantations in West Africa). In the future, agri-business is likely to play a bigger role in driving deforestation, driven by increasing global demand for coffee, cocoa, rubber and/or palm oil.

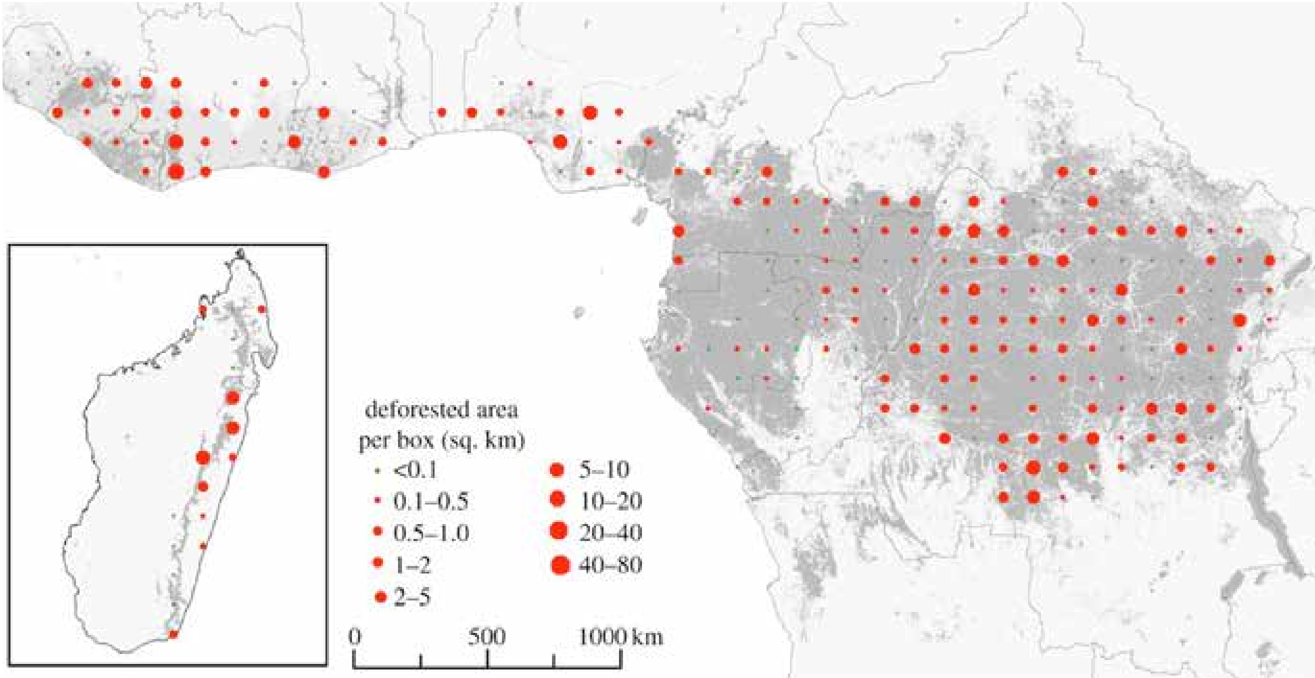
Underlying these direct causes is a series of driving factors. The first is population growth. As discussed in chapter 2, population growth in rural areas leads to deforestation as more land is cleared for farming (Mayaux et al., 2013, p. 7). Increased urban populations, in contrast, are associated with an increased demand for charcoal (the fuel of choice for urban households) (see chapter 4.1).

A further underlying driver is the expansion of road networks, which open up access to new forested lands: 'This is particularly evident in the Democratic Republic of Congo (DRC) where cropland mosaics match road networks established in the colonial period' (Mayaux et al., 2013, p. 3). Arguably, the construction of road networks locks-in a certain level of deforestation (see chapter 5).

These underlying factors are likely to cause deforestation rates to increase in the near future unless crop yields per hectare can increase significantly to feed

12 Forest degradation refers to a reduction in biomass stock or canopy cover and deforestation is the complete loss of forest cover (Chidumayo & Gumbo, 2013).

Figure 9: Spatial distribution of Africa's tropical rainforests and net deforestation, 1990-2000



Source: Mayaux et al., 2013, p. 7.
Note: The main illustration is a map of West and Central Africa, and the inset is a map of Madagascar. The spatial distribution of Africa's rainforests is illustrated in grey. The size of the red circles indicates the proportion of surface area affected by deforestation in each sample of 100 km².

SSA's growing population, and new land made accessible through planned transport and extractives infrastructure development can be protected or sustainable extraction enforced. This section focusses on the forestry sector and land-use management specifically. Other chapters in this report discuss the role of other sectors in supporting the use of and access to forest resources in a manner that mitigates climate impacts.

3.2 Key assets and processes in the forestry sector

Within the forestry sector, the important assets and processes to manage to reduce emissions are (1) primary forests and (2) plantations.

3.2.1 Primary forests

The first option to reduce emissions from the forestry sector is to take steps to prevent the clearing or degradation of primary forests. The most important forest assets to protect are those that provide local ecosystem services that underpin local and regional water supply, agricultural productivity, and biodiversity. The most vital ecosystem services can be shored up through planned networks of parks and protected areas and forest buffer zones along streams.

3.2.2 Sustainable forestry management, tree plantations and agro-forestry

Beyond conserving primary forests, steps will need to be taken to maintain carbon stored in forests on private land and public land not in reserve through sustainable forestry management practices, afforestation/reforestation, and agroforestry. Managed harvesting of forests for lumber, pulp, or fuel should be carried out in a rotational manner and at a sustainable rate, leaving adequate time for regrowth so as not to deplete forest stocks. Conversion of forests to cropland, pasture, etc., should be managed so that the knock-on effects on ecosystem services are taken into account in decision-making.

Forest carbon stocks can be maintained or increased through tree planting. Reforestation can speed up the regeneration of harvested land reducing pressure to harvest virgin forest, while afforestation (the process of planting land that was previously unforested) can enhance the forest carbon stock and provide a regenerative supply of wood for fuel or timber. In each of these processes, it is important to choose appropriate tree species that provide economic and ecological benefits and that do not endanger local ecosystems.[13]

Agro-forestry, the practice of integrating trees into cropland or pasture, can also enhance the carbon stock. In smallholder agricultural systems in the tropics, the adoption of agro-forestry techniques has been found to triple carbon stocks over a 20 year period to 70 Mg per hectare (Montagnini & Nair, 2004; Watson et al., 2000).

Beyond carbon sequestration, agro-forestry systems can provide a diverse range of other ecosystem services including fuel, food, fodder, improved water quality and quantity, soil stability, and nutrient cycling. Potential benefits of these services can include increased agricultural yields and reduced pressure on forests (Montagnini & Nair, 2004; Verchot et al., 2007).

3.3 Enabling low-carbon transitions in the forestry sector

Many of the opportunities to reduce deforestation involve steps to reduce demand for land and fuel. These 'demand-side' opportunities are discussed in the agriculture and energy (biomass) sections. In this section we focus on the 'supply-side' opportunities, i.e. those that aim to manage and enhance forests themselves.

Transition 4: Integrate land-use planning, reform tenure systems, and improve forestry data and monitoring

The first step to managing forests is to establish a land-use management plan: 'If the changing demands and uses of land are not managed through a rigorous planning and zoning regulatory framework, impacts in real terms are escalated uncontrolled development, increased energy demand and emissions, inefficient transport systems, over-burdened water and sanitation systems leading to reduced livelihoods' (Warnest, 2011).

Given the economy-wide implications of land-use planning, it is important that planning be conducted in a cross-sectoral manner and on consultation of local populations and stakeholders. Integrated land-use planning takes into account all uses of land in a holistic and coordinated manner, as opposed to planning on a sector-by-sector basis. It emphasises the impacts that one sector may have on another to better understand where trade-offs exist and to minimise conflicts between user groups (UNEP, n.d.). Beyond forestry, integrated land-use planning would necessitate consultations between government representatives and stakeholders from the agriculture, energy, transport, extractives, water, and environment sectors. Plans should balance the need to protect ecosystem services (including water maintenance, carbon sequestration and biodiversity protection) with the need to produce food, hydroelectricity, woodfuel, charcoal, and mineral resources.

Watersheds and animal habitats frequently span multiple countries. Hence, land-use planning often must be coordinated at the regional level. For example, the 7,800 km2 Virunga National Park in northeastern DRC borders the Volcanoes National Park, Rwenzori Mountans National Park, Queen Elizabeth National Park in neighbouring Rwanda and Uganda, protecting vast swaths of habitat for chimpanzees and gorillas. Each country benefits from the resulting ecotourism revenues.

In many cases, a prerequisite for influencing land-use is tenure reform. In Africa, the ownership of more than 90% of rural land on the continent is undocumented. Women especially have been locked out of land ownership by customary laws, despite making up 70% of Africa's farmers (Byamugisha, 2013, p. XV). Unclear legal status of land creates risk of land grabbing and expropriation and acts as a significant disincentive to sustainable land management (Byamugisha, 2013). The appropriate policies will be highly context specific, depending on a location's existing institutions and capacity. Nevertheless, where poorly defined, land tenure reform can enable governments to implement and enforce land-use plans and collect taxes (Warnest, 2011). In some cases, land tenure formalisation can be boon to economic productivity and poverty reduction. It can unlock access to finance by enabling landowners to borrow against the land, and if carried out in a pro-poor manner, it can grant rural poor greater access to natural resources (UN-HABITAT, 2008). A further prerequisite to developing and executing integrated land-use plans is improved data collection. Ongoing and detailed data collection on changing forest composition and cover also allows governments to evaluate the effectiveness of forest management policies and target deforestation hotspots. Currently, the Observatory for Central African Forests, which was established by forest ministries across the region, provides biannual reports on the 'state of the forest of the Congo Basin.'[14] These reviews can be improved over time through access to more detailed satellite data and through the complementary use of ground surveys and multivariate analysis. Executing these steps will require strengthening regional forest departments and research centres, and training personnel in various information technology, particularly aerial and satellite imagery and electronic Land Information Systems (LIS) (Warnest, 2011).

Transition 5: Capture the value of forests' ecosystems services in public and private decision-making

The second transition necessary for sustainable forest management is to take steps to ensure that the value of forests' ecosystem services and carbon stock benefits are taken into account in decision-making. A degree of forest conservation is generally a worthwhile policy aim from a national and sub-national perspective, given the valuable ecosystem services that forests provide locally – particularly

13 In terms of plantation development, for example, in Rwanda it was found that Eucalyptus and Pinus, though fast growing, demand relatively large amounts of water and nutrients, leading to increased soil acidity, limited ground cover and higher levels of evaporation and evapotranspiration. In contrast, diversified woodlots with long-term, high calorific trees such as *Acacia polycantha*, *Acacia melanoxiolon*, and *Aacation menansii* are particularly useful for woodfuel production (Suazo, as cited in Dyszynski, 2011).

14 Support for this project is provided by the EU, Norway, USA, Germany, France, Canada and FAO.

those essential to agricultural and hydroelectric production. However, given that the benefits of carbon sequestration services are global, rather than local, it may be necessary for international mechanisms to encourage national and sub-national governments to conserve forests and reform practices that drive deforestation. For example, at the national level, the Government of India has recently announced that state governments' share of national fiscal revenues will partly be tied to their performance on conserving forests (Busch, 2015).

At the international level, more than $9.8 billion was pledged to support governments and projects in reducing emissions from deforestation and forest degradation (REDD+) between 2006 and December 2014. For example, since 2008, the Government of Norway has offered $3 billion in total to Indonesia, Guyana, Brazil and other governments to conserve their forest stock: 'Norwegian finance for REDD+ is often relatively small in the context of the economies that it targets, but large enough to get key actors within government to take it seriously, creating financial incentives for high-level policy-makers to continue to take actions that will help protect forests and promote national sustainable development objectives' (Norman & Nakhooda, 2015, p. 14).

International negotiations on REDD+ are ongoing as part of a wider international agreement on climate change. While REDD+ negotiations and pledges have slowed, they offer some promise that in the future, governments may be able to generate a steady income from maintaining standing forests as well as planting new ones (see chapter 10).

Once governments are incentivised to conserve forests, the policies designed to capture the value of the ecosystem services in private decision-making can take numerous different forms. Regulatory instruments such as protected areas can be used to simply ban private exploitation of public lands. Forests that provide vital ecosystem services such as watershed maintenance, especially, should be set aside as public parks or protected areas. In these forest areas, transport infrastructure should be carefully planned and monitoring and enforcement systems developed to limit access and minimise or ideally prevent illegal exploitation.

On public land designated for timber and woodfuel/charcoal production, different approaches can be used to ensure rotational harvesting and sustainable land-use management. The conventional approach is for the state to grant rotating concessions to forestry firms to harvest land in return for stumpage fees. Alternatively, management of forests can be devolved to local communities. In the Littoral province of Cameroon, for instance, a community-based forest management model has proven successful in curbing illegal logging while improving local socioeconomic conditions (Alemagi, 2010; Njebet, 2008). In both models, the state can mandate that land be reforested after harvesting (Alemagi, 2010).

Certification schemes promoting legal exploitation, such as the Forest Stewardship Council (FSC), can also reduce the market for illegally logged timber. Currently, demand for certified products is highest in European and North American markets. In Gabon, Cameroon, and Congo, certified forests increased from zero hectares in 1995 to 4.8 million in 2010 (Mayaux et al., 2013). Despite this progress, certification is expensive for smallholders and financial support would likely be required to afford the costs.

On private land, regulatory tools can also be used to achieve sustainable forest management. For example, buffer zones can prevent private landowners from harvesting forests along streams. Brazil's Forest Code goes as a far as mandating that private landowners in the Amazon keep 80% of their land as forest reserve (Arima, Barreto, Araúrjo & Soares-Filho, 2014).[15] Kenya's Vision 2030 similarly advocates a requirement of 10% forest cover in all farmlands by 2030.

Economic and information tools can also be used to promote sustainable management of private land. For example, agriculture extension services can promote cost-effective agricultural methods that enhance, rather than threaten forests. For example, Rwanda's National Land Use and Development Master Plan aims expand agro-forestry to 85% of farmland by 2020 through the promotion of multipurpose trees in all farming systems, the provision of improved seeds, and the introduction of innovative financing mechanisms including carbon crediting and payments-for-ecosystems-services (PES) (Dyszynski, 2011).

Likewise, policies promoting ecotourism can allow communities to benefit financially from standing forests and the biodiversity. In 2014, Africa's tourism and travel sector, as a whole, directly employed an estimated 8.7 million people (3.0% of total employment) and directly contributed $83.3 billion to the continent's GDP (3.4% of GDP), up from about $70 million in 2005 (World Travel & Tourism Council, 2015). Ecotourism is the fastest growing sector within the tourism industry (globally). Given Africa's wealth of biodiversity, ecotourism offers long-term and sustainable growth potential in the region (Dyszynski, 2011).

Finally, the value of ecosystem services and climate benefits from standing forests can be monetised directly. Payments for ecosystem services (PES) can include downstream users of water paying upstream landowners for conservation, or the receipt of international carbon credits for local afforestation and reforestation. Most PESs or carbon credit models require government endorsement and intervention through capacity building. For example, small volumes of support for forest carbon projects in

15 According to Viola (2013), this law marks the greatest interference into private property ever seen in any capitalist country in the world.

SSA have been developed through the voluntary carbon markets. For instance, the N'hambita Community Carbon Project in Mozambique, launched in 2007, provides cash payment to local farmers for carbon sequestered through afforestation, reforestation and agro-forestry. Emission reductions are certified and sold under the Plan Vivo Standard. As of July 2012, over $2 million had been paid to approximately 2,800 participants in the project (Plan Vivo Foundation, 2012). The total REDD+ Voluntary Carbon Market sales in 2014 amounted to $94 million, to mitigate approximately 22.6 million tonnes of CO_2e (Peters-Stanley & Gonzalez, 2014). While promising, these figures will need to be scaled up substantially, preferably through a compliance mechanism, for project-based REDD+ financing to have the necessary transformative impact.

4. Energy

Energy consumption is the largest source of emissions in a number of the other sectors reviewed in this report. As a result, many opportunities to reduce emissions from energy involve actions within other sectors to either switch to lower-emissions fuel sources or adopt more energy-efficient technologies and practices. These opportunities will be discussed within the extractives, manufacturing, construction, and transport sections of this report. The remainder of this energy section will be divided into two sub-sections on reducing the emissions intensity of (4.1) biomass energy, and (4.2) electricity generation.

4.1 Biomass energy

Almost 80% of the energy consumed in SSA is generated through the combustion of solid biomass. The majority of biomass consumed is used for household cooking. An estimated 80% of households in SSA lack access to modern cooking services and rely on only woodfuel or charcoal for cooking (IEA, 2014). Woodfuel is generally more common in rural areas because it can be gathered for free, while charcoal is more popular in urban areas because it has higher energy content per kilogram, making it more suitable for transport from rural areas. Biomass is also the largest source of energy for industry and services, which each use it to produce process heat (IEA, 2014).

As a result, woodfuel and charcoal industries provide an important source of employment for wood producers, charcoal producers, transporters, and vendors: 'In Rwanda, in 2007, the value of transactions at fuelwood and charcoal markets was estimated to be $122 million, amounting to 5% of GDP. 50% of these revenues stayed in the rural areas' (IEA, 2014). In Zambia, the sale of charcoal and other forest products represents 30-32% of rural household incomes (Gumbo et al., 2013). In 2012, the estimated market value of SSA's charcoal market was estimated to be $11 billion (IEA, 2014).

Despite representing an important source of income and employment, the vast majority of charcoal production and consumption occurs in the informal economy. For example, the World Bank (2009) estimates that over 80% of charcoal production and trade in Tanzania occurs in the informal sector. According to UNEP and INTERPOL (2014), the unregulated nature of the charcoal industry makes it a frequently lucrative source of income for militia, and a missed opportunity for securing government revenues. An estimated $1.9 billion in potential public revenue is lost to African governments each year due to the informal nature of the charcoal industry.

The consumption of woodfuel and charcoal using traditional cooking methods is a significant health hazard, particularly among low-income households. The World Health Organization (2014) estimated that indoor air pollution causes around 600 thousand premature deaths per year in Africa. In East, Central, and West Africa, indoor air pollution was the second highest risk factor contributing to the disease burden (measured in disability-adjusted life years) after low body weight among children (Lim et al., 2012). In general, women are more exposed to household air pollution than men given the greater amount of time that they spend in close proximity to stoves.

4.1.1 Biomass energy GHG emissions and projections

According to the IEA (2014), total consumption of woodfuel in SSA, including that consumed directly by households and that used to produce charcoal, amounted to 658 million tonnes in 2012, or 0.5% of the total available biomass stock of 130 gigatonnes.

It is difficult to estimate the overall level of GHG emissions produced by biomass burning. If harvested and consumed at a sustainable rate, biomass is a renewable resource and could have a net zero or even negative impact on GHG emissions. However, if harvested unsustainably, biomass consumption can contribute to climate change through deforestation and forest degradation (see chapter 3). Current levels of consumption are already depleting biomass stocks in some areas. Deforestation can also lead to local environmental impacts including erosion and reduced watershed maintenance (Chidumayo & Gumbo, 2013).

The FAO (2010) estimated that woodfuel collection accounts for over three-quarters of wood removal from forests in Africa. However, there is significant debate concerning the degree to which it leads to deforestation. Generally speaking, the wood gathered and used by rural residents for personal consumption comes predominantly from dead trees, whereas the wood converted to charcoal for use by urban households and industry comes from felled trees (Practical Action, 2014). Therefore, whereas unsustainable woodfuel collection tends to contribute to forest degradation, the charcoal industry can contribute to both forest degradation and deforestation.

Where charcoal is produced from felled trees, it is often associated with subsequent deforestation for agriculture and timber production. For example, Chidumayo et al. (2001) found that almost 70% of forest cleared for charcoal production in central Zambia was subsequently converted to farmland and settlement. Despite the difficulties in determining the driving forces of deforestation, charcoal production is estimated to have caused 14% of total deforestation in SSA in 2009 (Chidumayo & Gumbo, 2013). This figure ranged between countries, from only 0.33% in Zimbabwe to 33.16% in Tanzania, with most forest loss from charcoal production in Zambia, DR Congo, Nigeria and Tanzania.

During charcoal production, the oxygen-poor environment created by earth-mound kilns causes incomplete combustion of woodfuel, and, as a by-product, methane. As a result, charcoal production produces emissions with a greater global warming potential than emissions from the burning of charcoal or woodfuel (Kammen & Lew, 2005). Chidumayo & Gumbo (2013) estimated Africa produced 67.23 $MtCO_2e$ (gross) from charcoal production in 2009, of which approximately 30% was from methane. While some of the carbon dioxide produced during charcoal production is theoretically offset if the forest is regenerated, the methane emissions are not (Chidumayo & Gumbo, 2013)

In the IEA's New Policies Scenario projection,[16] it is estimated that biomass will remain the largest source of energy in SSA. Overall consumption will increase to 1,031 million tonnes in 2040. By this year, a projected increase in urban population in SSA of 560 million people will cause demand for charcoal to surpass that of woodfuel, creating concerns that future biomass demand will accelerate deforestation.

4.1.2 Key assets and processes in the biomass energy sector

GHG emissions (and other associated pollutants) can be reduced along the entirety of the woodfuel and charcoal value chains. The first asset to manage is the forest carbon stock itself, which is discussed in chapter 3. Other important assets and processes to manage are (1) charcoal production processes and (2) cooking technologies.

4.1.2.1 Charcoal production processes

After harvesting, the next important step along the biomass value chain is the process used to convert woodfuel to charcoal. The prevailing technology used for charcoal production in SSA is earth-mound kilns, which have a highly inefficient conversion efficiency of 8% to 12% (IEA, 2014). The quantity of wood used to produce charcoal and associated emissions can be reduced through the diffusion of more efficient kilns. Industrial kilns have a conversion efficiency of over 25% - two to three times that of traditional kilns. Industrial kilns are less popular due to their higher cost, which increases the unit costs of charcoal (IEA, 2014).

4.1.2.2 Cooking technologies

The quantity of charcoal and woodfuel consumed can be reduced through the use of more efficient biomass stoves or through fuel switching to electricity, biogas, or LPG. If rates of harvesting in the area are unsustainable, fuel switching may also decrease GHG emissions.

Generally, the least expensive method of cooking besides open fires using 'free' woodfuel is efficient charcoal cookstoves. Given their affordability, woodfuel and charcoal are likely to remain in use by poor households in Africa for some time in the future (Sanga & Jannuzzi, 2005, p. 13). Even after households adopt modern cooking technologies, they will often engage in 'fuel stacking' (the use of multiple fuels) as a result of both cultural preferences for biomass cooking (people say they prefer the taste of food cooked with wood or charcoal) and as a way to address the unreliable electricity, LPG and kerosene supply (Elias & Victor, 2005).

However, other non-price-based factors play a role in cooking choices, including the desire to free up time spent on collecting woodfuel and reducing the adverse health effects of indoor air pollution (Chakrabarti & Chakrabarti, 2002). When health benefits and time savings are monetized, Jeuland & Pattanayak (2012) argue that kerosene and LPG become the most attractive options. Further evidence suggests that between LPG and kerosene, LPG poses lower health costs[17] (Eberhard & Van Horen, 1995; Lam, Smith, Gauthier & Bates, 2012; Peck et al., 2008).

While electricity can be used for cooking, empirical evidence suggests that in Africa, it rarely is, even in grid-connected areas (World Bank, 2008b). This is primarily due to economic factors – the high connection fees and tariffs and the high cost of electric stoves, which range from $100 to $500. Households that can afford to switch to modern fuels are more likely to shift from open fires and traditional charcoal stoves to other modern methods of cooking, such as advanced biomass cookstoves, LPG or kerosene stoves, or biogas stoves (IEA, 2011; Sanga & Jannuzzi, 2005). Innovations in electric cooking technology, including the development of low-cost induction stoves, may alter this pattern (Smith, 2014). However, the diffusion of electric cookers must be accompanied by an increase in the reliability of supply and preferably low-carbon generation.

16 The IEA offers multiple scenarios describing the future development of energy markets. The New Policies Scenario is the only one that is based on existing policies, supply, demand, and investment trends. In the 2014 New Policies Scenario the sub-Saharan African economy quadruples by 2040, increasing nearly US$8 trillion in size. Despite this growth, the region's GDP per capita will remain less than one-quarter of the world average. We use projections from the New Policies Scenario, but caution the reader that it is not a forecast. As with any multi-decade projection, it is beset with substantial uncertainty due to unforeseeable political, technological and market developments.

17 Kerosene's risks include toxic emissions, burn risks and ingestion risks, particular among children.

4.1.3 Enabling low-carbon transitions for biomass energy

Transition 6: Formalise the charcoal industry and promote efficient charcoal kilns and biomass cookstoves, and fuel switching

To promote sustainable biomass energy systems, governments should take steps to formalise the biomass energy industry. Formalisation could enable government to more effectively manage resource use and production processes, and could unlock a significant source of public revenue. A number of governments in SSA, including those of Ethiopia, Sudan, Mozambique and Sierra Leone, are already in the process of developing national strategies to formalise and manage biomass energy industries (Chidumayo & Gumbo, 2013; IEA, 2014).

It will be important to co-ordinate biomass energy strategies with integrated land-use planning (see chapter 3). Land management policies including tenure systems, protected areas, rotational harvesting, tree plantations and agro-forestry will have important implications further down the value chain, including in biomass consumption for heat and cooking. Most woodfuel is harvested for direct consumption or for charcoal production without any payments being made for the resources used beyond the cost of labour. As a result, the cost paid by consumers does not reflect the real value and alternative fuels or sustainably produced charcoal and fuelwood (including the costs of planting, land-use, and efficient kilns) are put at a competitive disadvantage. Policies that capture in charcoal prices the real cost of harvesting would incentivise charcoal producers to invest in more efficient kilns. Likewise, households and enterprises would be incentivised to invest in efficient biomass stoves or to switch fuels (World Bank, 2009). Nonetheless, such policies could negatively impact on poor households and must not be implemented prior to a social impact assessment.

Supply-side policies should be complemented by efforts to reduce demand for woodfuel and charcoal by promoting high-quality fuel-efficient kilns and biomass stoves. Policies to unlock consumer finance can help promote diffusion of these technologies where consumers' purchasing power is a barrier. Considering that health concerns are an additional driver of shifts in cooking technologies, public information campaigns can increase awareness of the health risks of traditional uses of open fires and inefficient cooking indoors. Ultimately, if deforestation rates are high, subsidies may be necessary to promote shifts to alternative fuels for cooking, such as LPG, biofuels, and electricity.

Technical assistance and funding will be needed to support entrepreneurial manufacturers and distributors of advanced biomass cookstoves and other cooking technologies, as well as manufacturers and users of kilns for charcoal production. A number of efficient cookstove programmes have been financed partially through carbon credits sold through voluntary carbon markets and the Clean Development Mechanism. The Global Alliance for Clean Cookstoves (GACC), a public-private partnership, has developed a $1 million Capacity Building Facility to support clean cooking enterprises. Similarly, the U.S. Overseas Private Investment Corporation (OPIC) and General Electric (GE) have committed $4 million in finance to Burn Manufacturing for a clean cookstove manufacturing facility in Kenya and satellite assembly plants in Rwanda, Tanzania, and Uganda. Collectively, these plants aim to sell 3.6 million clean cookstoves in the region by 2020 (OPIC, 2013).

Given the health hazard associated with traditional methods of cooking, a transition to cleaner burning stoves or fuels could have significant benefits for low-income households. In addition, reducing household consumption of woodfuel could indirectly increase economic productivity by improving health outcomes and enabling individuals to more productively budget their time. The IEA (2014) estimated that households using woodfuel for cooking spend between one and five hours every day collecting it, a task disproportionately borne by women. Improved access to modern fuels could lead to a healthier workforce with more time allocated to productive activities (Elias & Victor, 2005).

4.2 Electricity generation

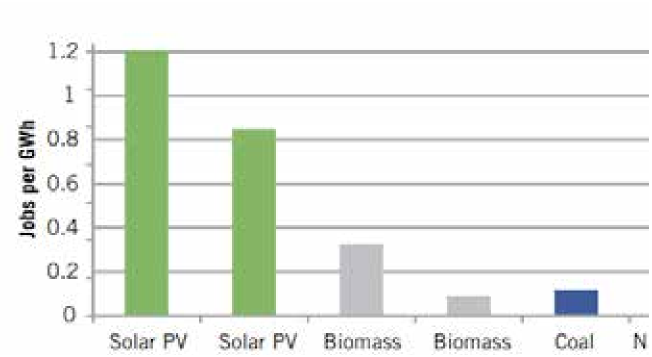
In 2012, electricity accounted for only 7% of all energy consumed in SSA. Electricity consumption was dominated by productive uses (as opposed to residential consumption). Industry accounted for half of electricity consumption and the services sector another fifth. Consumption of electricity in the agriculture sector was negligible (IEA, 2014).

Electricity access and supply are widely considered to be important factors driving economic development and poverty reduction. Statistically, household access to electricity has been associated with improved incomes, health, and educational outcomes, while firms with access to electricity tend to have higher productivity than firms without. The causal direction of each of these relationships is difficult to establish (Pachauri, Scott, Scott & Shepherd, 2013; Scott, Darko, Lemma & Rud, 2014; World Bank, 2008).

In SSA, around 620 million people – more than two-thirds of the population – lack access to electricity (IEA, 2014). Furthermore, almost 50% of firms identify inadequate access to electricity and poor quality of supply as serious constraints to production. Electricity grids in the region typically experience over eight power outages per month, each lasting an average of 5.3 hours. Power surges and blackouts can damage equipment and halt production (Scott et al., 2014).

Beyond increasing the productivity of other sectors, the production and distribution of electricity itself can be a source of growth and employment. As discussed in the following section, infrastructure to generate, transmit and distribute electricity is projected to expand rapidly in SSA over the coming decades resulting in substantial job creation during construction. The number of jobs created per GWh through decentralised electricity systems using renewable technologies tends to be significantly higher than centralised fossil-fuelled power production (Practical Action, 2014) (see Figure 10). Potential jobs in the home solar system industry include marketing, sales, financing, installation and maintenance. Locally produced technologies and fuels, such as mini-grids and biomass, also offer potential job creation throughout the value chain. Considering that most households in SSA would be served most cost-effectively through decentralised systems, renewable electricity industries could be an important source of low-carbon growth.

Figure 10: Estimated jobs created per GWh



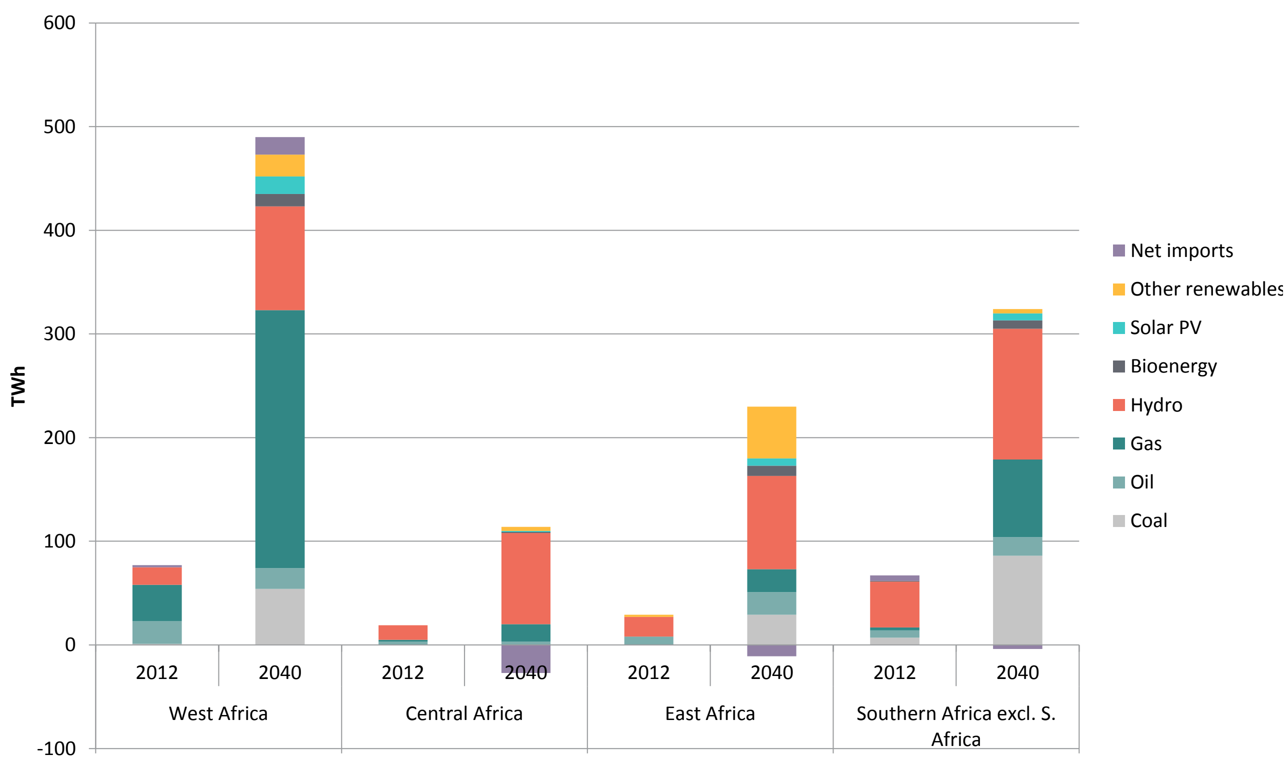
Source: Practical Action, 2014, p. 31.

Table 3: Total installed capacity and key indicators for SSA power pools

	CAPP 2009	EAPP 2008	WAPP 2010	SAPP 2010
Installed capacity (GW)	6.07	28.37	14.09	49.88
Hydropower share	86%	24%	30%	17%
Fossil fuel share	14%	73%	70%	83%
kW/1000 habitants	49	74	54	311

Source: Mandelli, Barbieri, Mattarolo & Colombo, 2014, p. 662.

Figure 11: Electricity generation and trade across different regions in Africa in the New Policies Scenario, 2012 and 2040



Source: Data from IEA, 2014, pp. 197-222.

4.2.1 Electricity generation GHG emissions and projections

In 2012, electricity generation in SSA (excl. RSA) accounted for approximately 63 million tCO_2e, only 2% of the region's total GHG emission, and of similar magnitude to the quantity of emissions produced from electricity generation in France or the Czech Republic (IEA, 2014; WRI, 2014b).

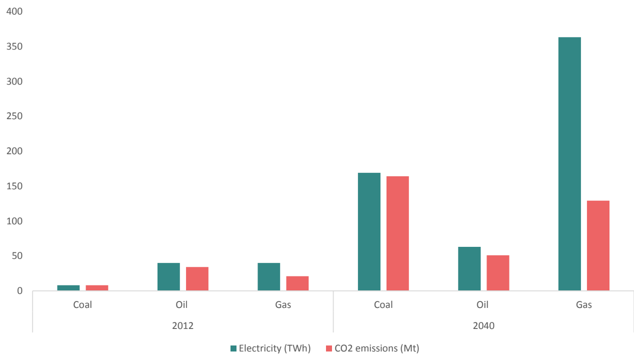
Emissions from electricity are produced primarily where fossil fuels are used for generation. Table 3 gives an idea of the regional breakdown of thermal electricity generation. It breaks down installed capacity into four regional power pools that provide the potential for transboundary transmission: the Central African Power Pool (CAPP), the Eastern Africa Power Pool (EAPP), the West Africa Power Pool (WAPP), and the Southern Africa Power Pool (SAPP). Although little transboundary trade occurs, the power pools offer a useful unit for regional analysis. As seen, hydropower is the largest source of power in the CAPP, while fossil fuels contribute a greater share in the remaining power pools. Note that the SAPP includes South Africa, which represents nearly 80% of Southern Africa's generating capacity, and the vast majority of SSA coal-fired power production.

In the IEA's New Policies Scenario, electricity generation in SSA is projected to grow more than six-fold between 2012 and 2040, and emissions are projected to grow more than seven-fold (see Figure 11). Hydropower and natural gas are currently responsible for most electricity generation in the region and are projected to continue to make up the majority of production in the future. Most of the increase in gas-powered electricity will occur in West Africa and, to a lesser extent, in Southern Africa, while moderate increases in hydropower will occur throughout the sub-continent.

Including hydropower, renewables are projected to contribute 48% of all electricity in SSA, a higher share than that found in India, China or the US (IEA, 2014, p. 104). However, wind, solar PV, bioenergy, and geothermal collectively contribute only 2% to current electricity generation. This figure is projected to grow to 12% by 2040, mostly due to increased geothermal power. In the IEA's (2014) New Policy Scenario, at least, the contribution of wind, bioenergy, and solar is projected to remain low. As discussed in section 4.2.2.2, a recent study by McKinsey & Co. (2015) paints a substantially different picture, projecting solar power will contribute about one-third of SSA's capacity additions after 2030 and produce almost half as much power as hydro sources by 2040.

Coal-fired power is projected to grow significantly in Southern African nations and emerge as a source of power in both West and East Africa. This expansion is concerning.

Figure 12: Electricity generated versus emissions produced by coal, oil and gas-fired power plants in SSA (excl. RSA), 2012 and 2040



Source: Data from IEA, 2014.

Coal is the most polluting and least efficient of the fossil fuels. In the IEA's New Policies Scenario, coal is projected to contribute only half as much electricity as natural gas in 2040, but produce over 25% more GHG emissions (see Figure 12).

4.2.2 Key assets and processes for electricity generation

As electricity access and generation are expanded in SSA, it will be important to ensure that emission levels remain low. The main assets and processes to manage are (1) fossil fuel-fired power plants; (2) renewable power plants; and (3) transmission and distribution (T&D) infrastructure.

4.2.2.1 Fossil fuel-fired power plants

As the source of GHG emissions, the first assets to manage in promoting low-carbon electricity generation are fossil fuel-fired power plants. The high cost and longevity of power plants make the power sector particularly at risk of lock-in (chapter 9). The sunk costs associated with construction of a fossil fuel-fired power plant can lock-in consumption of its feedstock for decades, regardless of innovation in and falling costs of alternatives. While lock-in should be a consideration in the construction of all fossil-fuelled power plants, it should be of particular concern in the projected expansion of coal-fired electricity generating capacity in West, East and Southern Africa.

Beyond producing fewer emissions than coal, natural gas is also more 'dispatchable', meaning it can be turned off and on according to demand.[18] Dispatchable energy sources, like natural gas and hydropower, are better complements to electricity grids that have a high proportion of intermittent energy sources, such as wind and solar, which are unable to supply constant electricity due to uncontrollable natural factors. Natural gas, therefore, could present an opportunity to 'bridge' away

18 Coal is much less combustible than gas, which is why coal power plants take much longer to start up.

19 The CDM defines large hydropower projects as those greater than or equal to 10 MW.

from coal to renewable energy sources. However, the switch to natural gas must be a temporary one, with a time limit on its use, in favour of a long-term transition to renewable energy sources (Granoff, et al., 2015).

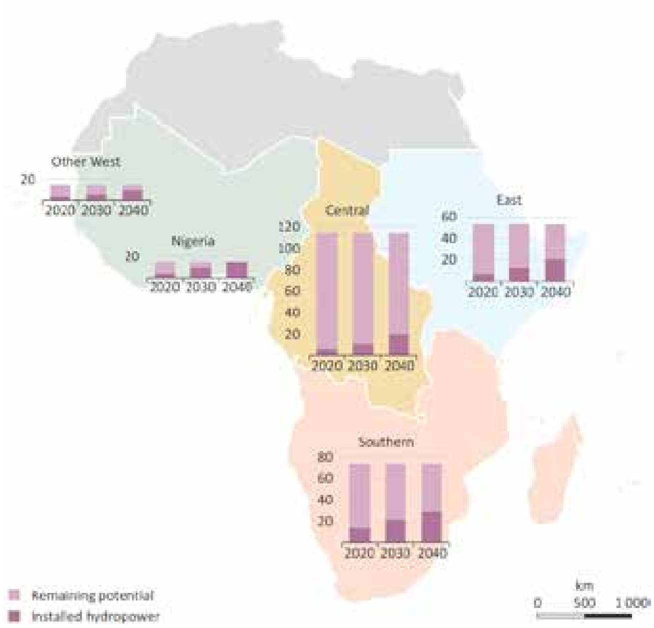
4.2.2.2 Renewable power plants

Renewables are projected to contribute a relatively large share of total electricity generation in SSA compared with other regions of the world. Nonetheless, the projected growth in renewable electricity falls well short of potential capacity. A recent African Development Bank (AfDB) report argued, 'Africa's reserves of renewable energy resources are the highest in the world, and the continent has enough renewable energy potential to meet its future energy needs' (Mukasa, Mutambatsere, Arvanitis & Triki, 2013, p. 1). Mandelli et al. (2014, p. 666) further posited that wind, solar, hydropower and sustainable biomass resources are so abundant in Africa that each could supply the entire continent's electricity demand (see Table 4). Interestingly, each sub-region has at least one renewable resource in abundance (Mandelli et al., 2014, p. 665).

Hydropower

The greatest hydropower potential is in Central, East and Southern Africa (see Figure 13). Of particular note is the planned 4.8 GW Inga III project in DR Congo and the widely discussed ~44 GW Grand Inga project. Barriers to construction of the Grand Inga plant included complexities surrounding upfront cost and the lack of a market in Central Africa that is capable of absorbing the levels of electricity produced (IEA, 2014, pp. 56-57).

Figure 13: Sub-Saharan hydropower capacity and remaining potential in the New Policies Scenario



Source: IEA, 2014, p. 108.

Growing evidence suggests that hydropower dams, which create a reservoir of stagnate and oxygen-starved water, may release significantly higher microbial-produced methane emissions than previously thought, bringing into question their climate-friendly credentials (Magil, 2014). Large hydropower projects[19] can also cause downstream ecological damages and lead to displacement of people, while

Table 4: Sub-Saharan Africa's renewable electricity generation potential in TWh/year and in relation to current total final consumption of electricity (%TFC)

	Middle		Eastern		Western		Southern	
	TWh/year	% TFC	TWh/year	% TFC	TWh/year	% TFC	TWh/year	% TFC
Wind	120	688	1443	3240	394	1096	852	416
Solar	915	5245	3953	8875	1265	3520	3128	1527
Hydropower	1057	6059	578	1298	105	292	26	13
Biomass	1572	9011	642	1441	64	178	96	47
Geothermal	0	0	88	198	0	0	0	0

Source: Data from Mandelli, et al., 2014, pp. 665-666.
Note: Mandelli et al.'s (2014) sub-regions vary from that of the IEA. The country groupings are defined as follows: Middle Africa – Angola, Cameroon, Congo, Congo DR, Gabon; Eastern Africa – Eritrea, Ethiopia, Kenya, Mozambique, Tanzania, Zambia, Zimbabwe; Western Africa – Benin, Cote d'Ivoire, Ghana, Nigeria, Senegal, Togo; Southern Africa – Botswana, Namibia, South Africa.

19 The CDM defines large hydropower projects as those greater than or equal to 10 MW.

20 Though generally associated with small-scale hydropower, the largest application of run-of-the-river technology is the 11.2 GW Belo Monte hydropower plant in Brazil. It is the largest hydropower project currently under construction and will be the third largest in the world once completed (The Economist, 2013). Even so, Belo Monte will still submerge 478 km^2 of the Amazon Rainforest in 28 mini reservoirs (Watts, 2014).

reservoirs are often linked to negative health impacts from insects and parasites that thrive in stagnant water (Hancock, 2015, p. 4). There remains significant debate about the negative social and environmental impacts of large hydropower projects. A potential solution is 'run-of-the-river' hydropower technology. In these hydropower plants, rather than creating a large reservoir, the water needed to drive the turbines is channelled through a man-made canal. Run-of-the-river hydropower plants have historically been small-scale, making them well suited to mini-grids to supply rural communities. However, a new generation of run-of-the-river hydropower can be large-scale, as demonstrated by the Belo Monte hydropower project in Brazil.[20] Albeit an improvement, these large-scale run-of-the-river hydropower plants do still require a reservoir.

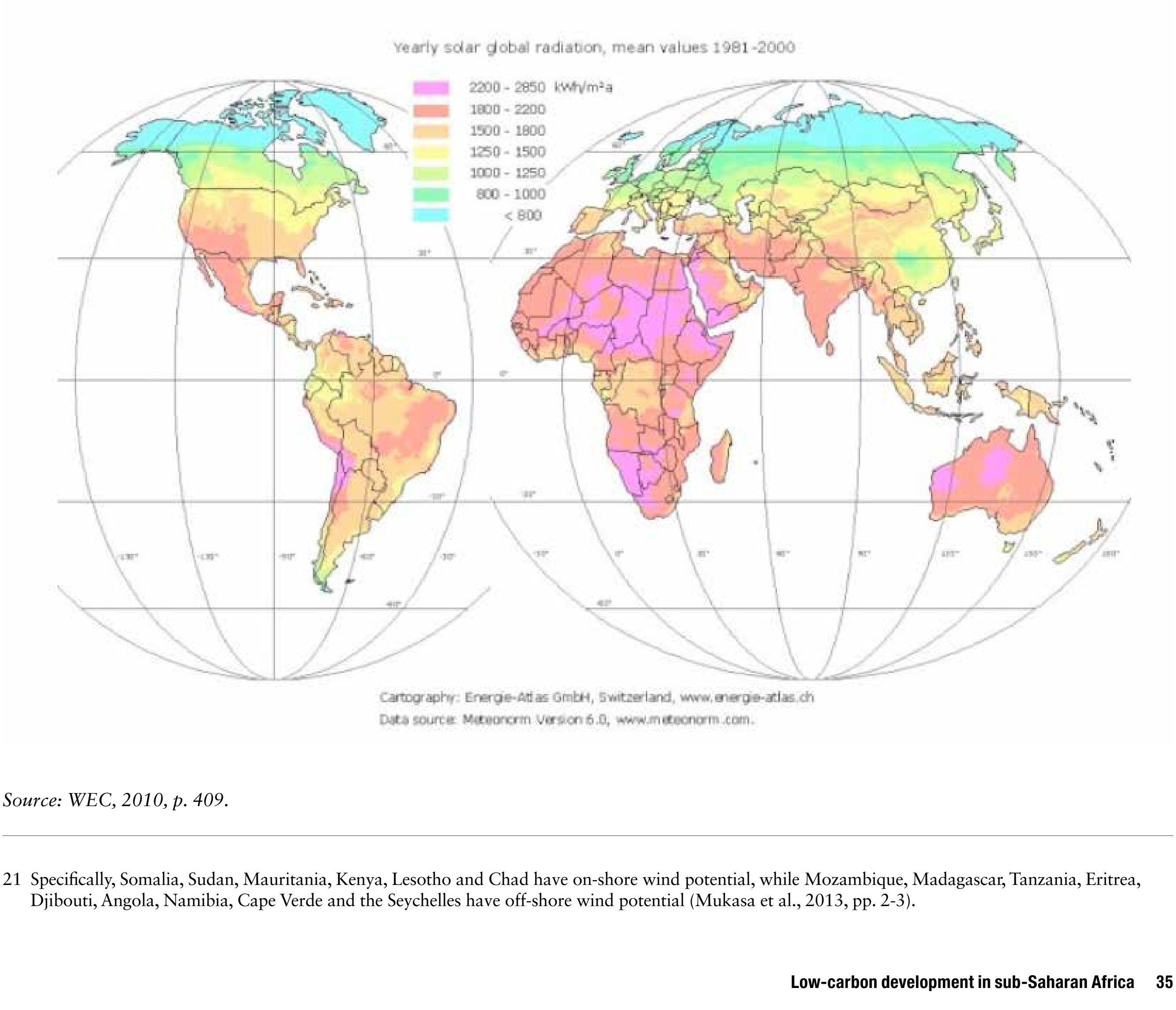
Solar

Although not as developed as hydropower, Africa is also endowed with the highest level of solar radiation of any continent (see Figure 14). Most of Africa experiences more than 320 days per year of sunshine and twice the solar radiation levels of Germany, which currently has the highest level of solar power production in the world (Belward et al., 2011). The highest levels of solar radiation in SSA are in Southern and Eastern Africa.

Despite the abundance of solar energy, solar PV contributed less than 1% of electricity generated in the SSA in 2012. Historically, the primary barrier to solar electricity generation is its high cost relative to other on-grid technologies. As a result, solar PV's primary contribution has been to provide electricity access in numerous rural areas, where it is more cost-competitive compared with off-grid alternatives and where high loads of electricity are not required.

Nonetheless, the cost of solar PV has declined dramatically in recent years, and is expected to continue to fall (see Figure 15). According to McKinsey & Co. (2015, p. 18): 'solar levelized costs are projected to decline by more than 20 percent from 2020 to 2040… By 2030, solar would be the cheapest or second-cheapest domestic energy source in more than half of SSA countries.' Ghana is currently constructing a 155 MW on-grid solar PV Nzema plant and other on-grid plants of 100 MW or more are under consideration in Mozambique, Sudan, Nigeria and Ethiopia (IEA, 2014, p. 58). Moreover, the costs of concentrated solar

Figure 14: Average yearly solar radiation, mean values 1981-2000



Source: WEC, 2010, p. 409.

21 Specifically, Somalia, Sudan, Mauritania, Kenya, Lesotho and Chad have on-shore wind potential, while Mozambique, Madagascar, Tanzania, Eritrea, Djibouti, Angola, Namibia, Cape Verde and the Seychelles have off-shore wind potential (Mukasa et al., 2013, pp. 2-3).

power (CSP), which offers advantages over PV in terms of storage capacity and dispachability, are also falling. In the IEA's New Policies Scenario, deployment of CSP in SSA is expected to begin in the mid-2020s (IEA, 2014, p. 109).

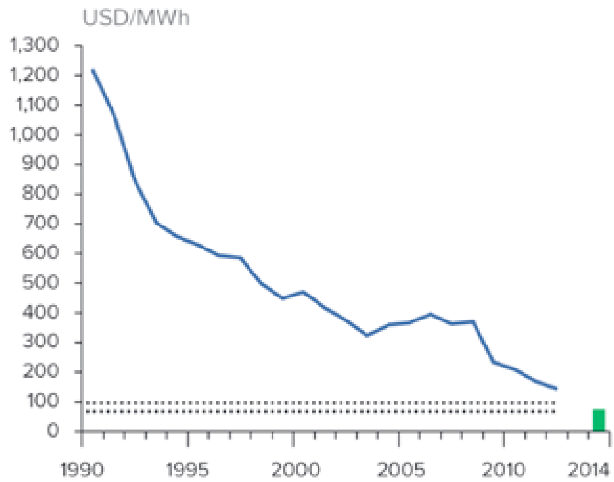
Given the rapid rate of innovation in the solar industry, it is difficult to predict the rates of solar power diffusion going forward. The IEA's (2014) New Policies Scenario projected that solar power would contribute less than 3% of SSA's power production in 2040. However, as illustrated by McKinsey's & Co (2015) contradictory findings, it is entirely plausible that with the right policy support solar could contribute a much higher share of the electricity mix.

Wind

Globally, wind power is characterised by rapid innovation and growth (Mukasa et al., 2015, pp. 90-91). Until recently, however, wind power has lagged behind in SSA, despite significant potential and prevalence in North Africa. It currently plays only a limited role in SSA's electricity mix, with installations in Cape Verde, the Gambia, Namibia, Mauritius, Mozambique, Kenya, Ethiopia and Eritrea (Mukasa et al, 2015, p. 94).

Recent developments suggest that wind power may be on the rise. In May 2015, Ethiopia opened its third wind farm, Adama II. The largest in SSA at 153 MW capacity, this brought the country's installed wind capacity to 324 MW. In Kenya, construction has begun on first 50-90 MW of the Lake Turkana Wind Power Station. When complete, it will also have a capacity of 300 MW (AFP, 2015; Davis Jr., 2015).

Figure 15: Indicative levelised costs of solar PV electricity over time, and estimated lowest utility-scale



Source: NCE, 2014, p. 39.

If wind is sufficiently strong and regular, wind power can be a cost-competitive source of electricity, in both on- and off-grid contexts. Mandelli et al. (2014, p. 665) estimated the total electricity generating potential of wind to be over 2800 TWh per year, mostly concentrated in East and Southern Africa.[21] However, the greatest potential for wind power generation often exists in rural areas where the necessary transmission and distribution infrastructure to reach end-users has not yet been developed. In many rural areas, small-scale wind power offers a cost-effective option to expand household electricity access and power rural industries (IEA, 2014, p. 59).

Geothermal

Geothermal is also a cost-competitive source of electricity, where resources are available. Unlike wind and solar, geothermal can provide a constant supply similar to hydropower. In Africa, geothermal resources are concentrated in the East African Rift Valley, mostly in Ethiopia and Kenya.[22] Total potential capacity is estimated to be 10 to 15 GW (IEA, 2014, p. 15).

Bioenergy

Currently, bioenergy's contribution to the electricity mix is negligible in SSA and is mostly concentrated in Mauritius at 500 MW (Mandelli et al., 2014, p. 665). As seen in Table 4, the technical potential of bioenergy for electricity production in SSA is massive, particularly in Central Africa. However, as discussed, the net contribution of bioenergy to GHG emissions depends on the sustainability of the harvested feedstock. Ackom et al (2013) estimated that in Cameroon, sustainably harvested residues from agriculture and forestry could be used to generate 15- 38% of the nation's electricity demand.

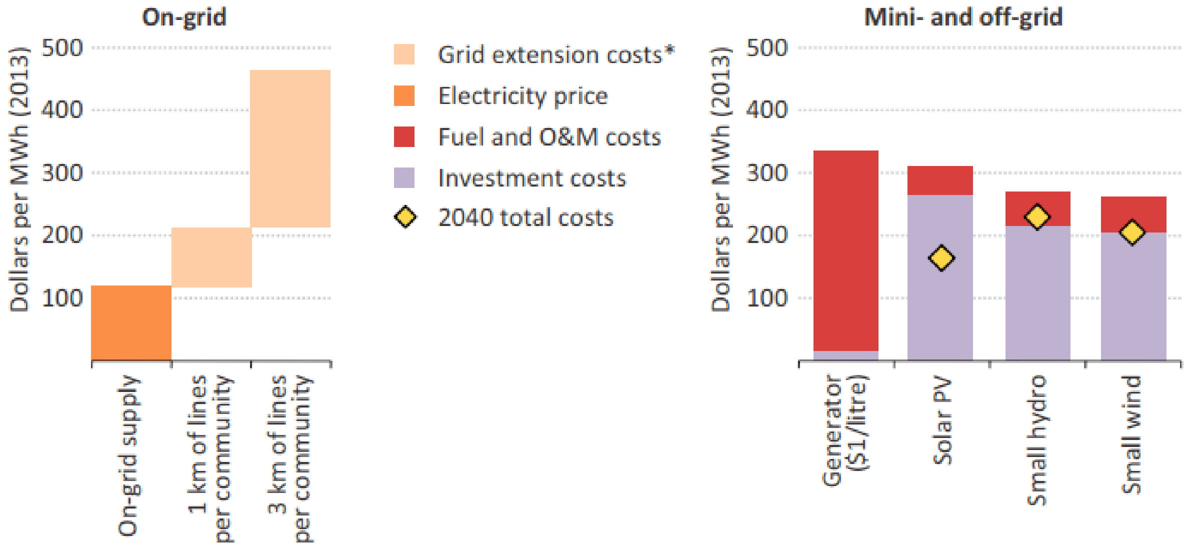
4.2.2.3 Transmission and distribution (T&D) infrastructure

T&D infrastructure is important for low-carbon productivity for four reasons. First, 10.8% of electricity generated in SSA is lost due to T&D inefficiencies and failures (compared to 6.8% in high-income countries) (Scott et al., 2014). Improved maintenance of T&D infrastructure can therefore reduce these losses and, in turn, reduce the quantity of electricity generation necessary to achieve the same outcomes.

Second, as discussed previously, many potential sources of renewable electricity in the region (particularly hydropower and wind power) are far from markets capable of absorbing the electricity produced, necessitating large-scale interregional transmission. For example, in order for the massive Grand Inga project in DR Congo to be realised, transmission infrastructure between Central Africa and the larger markets in West Africa and Southern

22 Kenya has developed 250 MW of geothermal generating capacity and aims to develop 5 GW by 2030. Ethiopia aims to develop one additional GW over the next decade, while Zambia, Tanzania, Rwanda, Eritrea and Uganda are at earlier stages of geothermal exploration and development.

Figure 16: Indicative levelised costs of electricity for on-grid, mini-grid and off-grid technologies in SSA, 2012



Source: IEA, 2014, p. 128.

**Costs of grid extension are calculated as the average cost of extending the medium-voltage grid a certain distance (e.g. 1 km to each community on a levelised cost basis.*

Notes: Costs are indicative and could vary significantly depending on local conditions such as electricity tariffs, population density and the delivered cost of diesel. The quality of service for the different technologies also varies: additional investment in batteries or back-up power may be needed to compensate for the variability of renewables or intermittent grid supply.

O&M = operation and maintenance.

Africa must be expanded and improved to facilitate electricity export (IEA, 2014, pp. 56-57).[23] As seen previously in Table 3, despite the existence of four regional power pools, total trade in electricity is low. In 2009, trade as a portion of electricity generated ranged from 0.2% in CAPP to 7.5% in SAPP (Kambanda, 2013).

Third, as mentioned above, wind and solar are both intermittent energy sources, in that individual installations are unable to supply constant electricity due to the uncontrollability of the weather. Older electricity grids with a large proportion of intermittent energy sources can face problems with unstable supply. Higher levels of penetration by such sources over time can be accommodated through a number of measures. These include interconnecting geographically dispersed intermittent sources with smart-grid technology to smooth out supply, complemented by dispachable energy sources such as run-of-the-river hydropower, geothermal, and natural gas and improved energy storage (Delucchi & Jacobson, 2010).

Finally, the costs of T&D frequently determine the most economically efficient technology to provide electricity in a given context. For much of SSA, the high costs of expanding the grid make off-grid solar PV, micro-hydro and small-wind cheaper options than grid connections for providing electricity to rural areas. However, once the grid is extended, the sunk costs shift the balance in favour of grid connections and centralised generation (see Figure 16).

A 2011 report by the European Commission Joint Research Council developed a spatial model to determine the lowest cost option of providing electricity to different regions of Africa (see Figure 17). The study found that given the high cost of T&D, only 39% of the population would be served best economically through grid extension. The remaining 61% would be best served by off-grid/mini-grid systems (Szabó, Bodis, Huld & Moner-Girona, 2011). Mini-hydro was found to be the most cost-effective option for most areas in SSA. However, it is likely that since the study was completed, solar PV has become a more cost-effective option in many areas, given the rapid decline in cost of solar modules (shown previously in Figure 15).

4.2.3 Enabling low-carbon transitions for electricity generation

As electricity systems in SSA expand, growth in emissions can be mitigated by promoting energy efficient technologies and practices. Options to reduce energy demand are discussed in subsequent chapters. This section will focus on opportunities to reduce emissions from electricity generation.

23 Note again that new evidence suggests that large hydropower plants that create large reservoir of stagnant water may actually produce significant methane emissions.

Transition 7: Generate on-grid electricity from renewable sources and prevent lock-in of coal power

The first step in promoting low-carbon electricity generation will be to increase generation of on-grid renewable electricity. Given that a number of renewable electricity technologies are already cost-competitive with fossil fuels (hydro, wind, and geothermal), increasing their share of the electricity mix would also have significant benefits for both economic productivity and poverty reduction.

Despite their cost-effectiveness, utilities in Africa (like elsewhere in the world) tend to favour large-scale fossil-fuelled electricity generation over renewables, with the exception of hydropower. This is primarily because these technologies are less well-known than thermal power plants and developing countries frequently lack human capital with the expertise to build and operate them. Furthermore, while operating costs are lower, the upfront costs are frequently higher than thermal power plants, requiring access to more capital upfront.

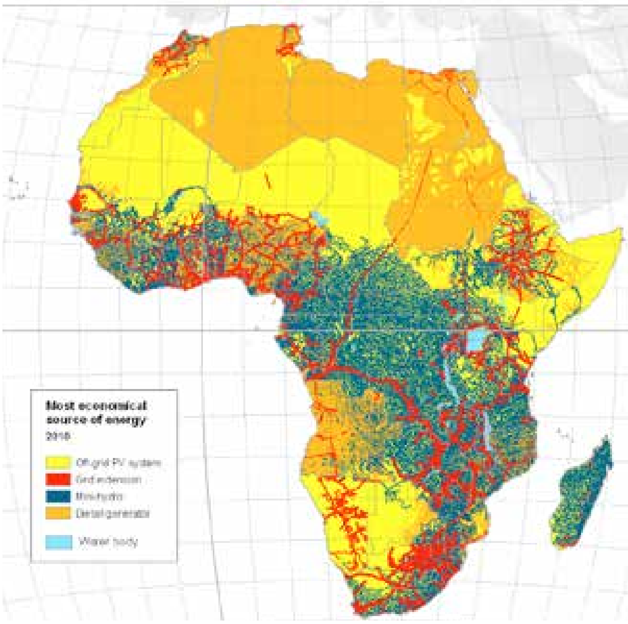
In addition, the ability to generate electricity from renewable sources does not always align geographically with electricity markets. As explained by the IEA (2014, pp. 180-181), 'The lack of regional scale is a particular constraint on the development of Africa's hydropower: the domestic markets of the countries with large hydropower potential (DR Congo, Ethiopia, Ghana, Guinea, Cameroon) are not of sufficient size to justify major project development. Without the regional market dimension, countries can be locked into less efficient – and more expensive – generation options.'

A number of steps can be taken to overcome these obstacles. Planning of increased on-grid renewable energy generation capacity and grid expansion should be long-term and transparent. To clear the way for increased electricity trade, planning should also be carried out at the regional level, as is occurring, for example, with the ongoing construction of the West African Power Transmission Corridor and plans to develop an 'Africa Clean Energy Corridor' from Egypt to South Africa.

Long-term targets for contributions of renewable technologies at the regional level can also send appropriate market signals to investors and can create the framework within which governments can jointly implement the necessary policies for regional integration of generation and distribution. For example, the Economic Community of West African States (ECOWAS) has a target of meeting 12% of electricity demand by 2030 from non-hydro renewables (IEA, 2014, p. 83).

Long-term decision-making should be based on the currently available technologies and their relative prices but also designed to foster innovation of the technologies that will generate electricity in the future, particularly wind, solar PV and CSP. For example, public procurement schemes, such as attractive feed-in tariffs, can secure a market for innovative technologies while a technical skill base is developed and innovation drives reductions in costs. Public investment and guarantees for demonstration projects can help build a track record for newer technologies, widening the skills base and increasing investor confidence. An excellent example of this use of linking policies and finance to support on-grid renewable generation is offered by Kenya's promotion of geothermal energy (see Box 3).

Figure 17: Most economical source of energy in Africa by area



Source: Szabó, Bodis, Huld, Pinedo et al., 2011.

It is also vital for long-term plans for expansion of electricity generation to take into account the risk of infrastructure investments that will lock-in emission-intensive pathways, such as coal-fired power generation. Governments considering the development of coal-fired power should complete cost-benefit analyses factoring in a shadow price on emissions, any subsidies to fossil fuels, up-to-date renewable energy prices and the risk of high-emissions infrastructure needing to be retrofitted or decommissioned in future due to regional or international climate change commitments. The removal of subsidies for coal production and consumption in Southern Africa could further shift the economic balance in favour of low-carbon alternatives. Where renewable or natural gas options are cost-effective, regulatory mechanisms such as emissions standards for power plants could effectively cease the construction of new coal power plants. To prevent lock-in to coal power, development partners may need to use climate finance and other forms of support to incentivise governments to implement alternative forms of power production.

Box 3: The Kenyan Geothermal Industry

Kenya currently generates 202 MW of electricity, or 17% of its total installed generating capacity, from geothermal energy (Kisero, 2010). Estimates of the total potential to produce geothermal electricity in Kenya range from 2,000 to over 3,000 MW (WEC, 2010).

The development of the geothermal industry encountered many of the barriers outlined above: high upfront costs and risk associated with exploration and drilling; a lack of technical capacity in the country; insufficient information on the competitiveness of geothermal relative to other sources of energy; a scarcity of finance; and a lack of creditworthiness, collateral and equity amongst potential project developers (Mwangi, 2010). Successful development was contingent on the long-term support of the Government of Kenya and international organisations, spanning three decades, which served to build the confidence of private investors and developers (Karekezi, Kithyoma & Muzee, 2007).

Drilling of deep exploratory wells began in 1973 with funds from the United Nations Development Programme (UNDP). However, even after the resource was proven, capital constraints impeded resource development until 1981, when KenGen, a state-owned power generation utility, installed the 15 MW plant Olkaria I (Karekezi et al., 2007). Since then, KenGen has continued to develop the resource with co-financing from the World Bank, the European Investment Bank, and KfW of Germany, bringing its total generating capacity to 150 MW (African Energy Policy Research Network, 2008).

With the increase in production, the Government of Kenya fully integrated geothermal targets into its national power master plan and its main planning documents: Vision 2030 and the Medium Term Plan 2008-2012. It also invested considerably in developing a local technical skill base, specialised in undertaking geothermal resource assessment and development (African Energy Policy Research Network, 2008; Karekezi, et al., 2007). The government's motivation lay in the potential for geothermal as a secure source of domestic energy not susceptible to global price fluctuations, anticipation that future innovation and successful exploration will drive the price down further, and its expectation of continued external financial support.

Over the last decade, interest in geothermal development from the private sector has increased. In 2000, construction began on the first and only private geothermal electricity plant in the country – the 52 MW Olkaria III, owned and operated by the company Orpower4 (Kisero, 2010; WEC, 2010). In 2006, the government offered 30% of its shareholding in KenGen through an initial public offering. Private Chinese companies, financed by Chinese banks, have come to dominate geothermal exploration to such an extent that in 2009 the Government of Kenya established the state-owned Geothermal Development Company to bring down the cost of drilling and ensure jobs are created for Kenyan nationals (Kisero, 2010).

With increased interest from the private sector in Kenya, the United Nations Environment Programme, Global Environment Facility (GEF) and World Bank have sought to extend the lessons from Kenya by establishing an $18 million African Rift Geothermal Facility (ARGeo) to develop a regional network of geothermal experts to exchange information, a capacity building programme, and a programme to promote regulatory frameworks supportive of geothermal development (Mwangi, 2010).

** Interestingly, geothermal experts from Kenya are now providing technical assistance to neighbouring countries in the African Rift Valley through a short training course and professional work placements.*

Transition 8: Promote electricity access from off-grid and mini-grid systems in rural areas

As discussed, off-grid and mini-grid systems powered by renewable electricity technologies are frequently the most cost-effective option to provide electricity access in rural areas. Efforts to promote the diffusion of these technologies could have profound effects on productivity and poverty reduction.

Often the primary barrier for diffusion of these technologies is the ability of households and small firms to afford the upfront cost. Government subsidised loans could help consumers afford these upfront-costs (Hogarth, 2012). Public investments can be made in training a workforce of renewable electricity engineers and business incubators for companies installing and constructing solar home systems and mini-grids powered by run-of-the-river hydropower and wind power (Miller, 2009). Finally, it is important that electricity planning is carried out in a transparent manner to link the planning of off-grid and mini-grids with the wider development of national and regional grids. This will enable communities to make upfront investments in local generation with a clear understanding of when they might be linked to a wider grid (for both supply and use) (IEA, 2014).

5. Transport

In urban and rural areas of SSA, transport infrastructure is underdeveloped and poorly maintained (Carey, 2011b). As little rail infrastructure exists and only 5% of global airline traffic originates from or goes to Africa, most transport in the region is by road (Boeing, 2013; IEA, 2014). However, despite the reliance on roads, infrastructure is sparse: 'Road density is extremely low, at 89 km per 1000 km2, it is less than a third the world average. In addition, less than 20% of African roads are paved (compared with almost 55% in Middle East, for example), while around 60% of the rural population (400 million people) live more than 2 km from an all-season road' (IEA, 2014, p. 45).

The underdeveloped and poor quality of transport infrastructure causes the costs of transporting goods in SSA to be among the highest in the world (IEA, 2014). According to the Program for Infrastructure Development in Africa (PIDA, 2010, p. 2), 'East Asian firms save close to 70% in transportation costs relative to their African counterparts, while Latin American and South Asian firms save approximately 50%.' Any growth-orientated development policy will therefore need to address the deficit of transportation infrastructure on the continent. This section discusses how the deficit can be addressed in a low-carbon manner.

5.1 Transport sector GHG emissions and projections

Transportation emissions in SSA are produced primarily by vehicles powered by oil fuelled internal combustion engines (ICEs).[24] Between 2000 and 2012, transport fuel consumption increased 82% from 17 Mtoe (Million Tonnes of Oil Equivalent) to 31 Mtoe. Associated transport emissions increased 88% from 49 million tCO_2e to 92 million tCO_2e. Despite the increase, these emissions remain lower than the transport emissions of the UK (113 million tCO_2e) or Italy (102 million tCO_2e) (WRI, 2014b). Vehicle ownership remains low, owing to the region's low average income and poor road infrastructure. Overall, only 2% of SSAs own a passenger car (compared to 70% of US citizens) (IEA, 2014). Motorbike ownership has increased rapidly over the last two decades, due to their affordability and suitability for dirt roads, but figures are difficult to find (Kumar, 2011).[25]

The Programme for Infrastructure Development in Africa (PIDA, 2010) – launched in 2010 and funded by African governments, international banks and development partners – aims to expand massively the continent's road networks by 2040. The plan would develop the existing 10,000 km network of major roads to between 60,000 and 100,000 km. It would also build or upgrade 250,000 km of small roads connecting small cities, plus an additional 70,000 km of rural roads (Coghlan, 2014).

Given SSA's vast territory and low rates of urbanisation, the IEA (2014) concluded that there is a high latent demand for transport in the region and that car ownership, fuel consumption and emissions will all continue to increase as road infrastructure improves. In the IEA's New Policies Scenario, the number of light duty passenger vehicles in SSA is expected to triple to over 50 million by 2040 (see Figure 18). However, this number is skewed towards South Africa, where vehicle ownership rates will increase to 20% relative to a regional average of only 3%. Outside South Africa, most growth is expected to occur in Nigeria, where per capita income is projected to exceed $5,000 before 2030 – a level at which vehicle ownership rates have been observed to accelerate rapidly in other countries (Chamon, Mauro & Okawa, 2008). In the IEA New Policies Scenario, Nigeria's car ownership rate increases to 5% in 2040. The numbers of commercial vehicles and buses in SSA also increases, from 8 million in 2012 to 25 million in 2040. Again, this figure is skewed towards South Africa, although the growth rate in East Africa, at 5% per year, is particularly high (IEA, 2014).

In the IEA New Policies Scenario, automobiles in SSA are expected to continue to run almost entirely on oil despite the development of alternatives elsewhere in the world. Both demand for oil and associated emissions are projected to increase by approximately 160% between 2012 and 2040: oil consumption is projected to grow from 31 Mtoe to 81 Mtoe; and transport emissions are expected to grow from 92 tCO_2e to 239 tCO_2e.

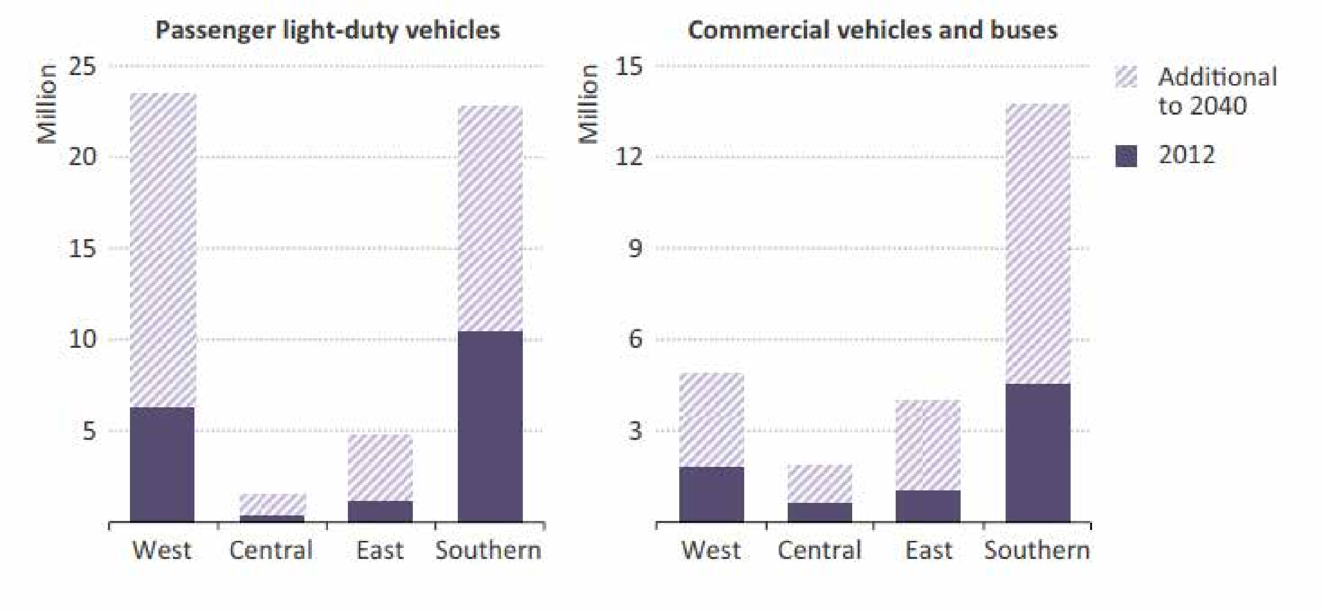
5.2 Key assets and processes in the transport sector

The three most important assets and processes to manage in reducing fuel from transport are (1) roads; (2) vehicle fleet and fuels; (3) urban design; and (4) mass transit systems.

24 Primarily diesel, but some gasoline concentrated in Nigeria (IEA, 2014)

25 In Kampala, traffic surveys revealed that motorcycles represent between 20 and 42% of all motorised trips (Kumar, 2011).

Figure 18: Vehicle stock in SSA by type in the New Policies Scenario



Source: IEA, 2014, p.90.

5.2.1 Roads

GHG emissions from transportation are intrinsically tied to road infrastructure. On the positive side, improved rural roads could reduce post-harvest waste by opening up farmers' access to markets. This effect may reduce the amount of land necessary to fulfil demand for food (see chapter 2). However, the expansion of road networks frequently opens up access to forested areas for exploitation leading to GHG emissions from deforestation and forest degradation (see chapter 3).

5.2.2 Vehicle fleet and fuels

Outside South Africa, SSA currently has almost no vehicle manufacturing industry.[26] Instead, the vast majority of vehicles are imported into the region, often second-hand (IEA, 2014). The age, design, and condition of vehicles (scooters, motorcycles, cars, buses and trucks) influence the quantity of fuel consumed and GHG emissions produced. Due to the age of SSA's vehicle fleet, its fuel efficiency is significantly lower than in other regions of the world. Fuel-economy standards set by supplier countries do improve efficiency in SSA but only after a significant time lag. The IEA (2014) projects that by 2040 fuel efficiency of new vehicles will increase by over 20% in the region to 7.2 litres per 100 km. However, average fleet efficiency will still be lower than that in the EU today.

Beyond improving the fuel efficiency of vehicles, GHG emissions could also be reduced by altering the type of fuel used. Given the region's large gas reserves, compressed natural gas (CNG) could offer a lower-emission transport fuel. CNG is a well-established technology in Asia and South America. In Africa, CNG is already being used in Dar es Salaam, where the Tanzanian government aims to increase consumption of domestically produced natural gas (IEA, 2014).

Hybrid electric and pure electric vehicles are improving rapidly but their price remains out of reach for mass markets in developing countries. These technologies are also hindered by the current low-levels of power generation in SSA and the unreliability of the electricity grid (see chapter 4). Nonetheless, given the vast potential for renewable electricity generation in the region, electric cars could offer a low-carbon transport option in the longer-term. However, without any domestic manufacturing of automobiles, these technologies would most likely need to enter regional markets through technology transfer.

Another category of alternative fuels, of which SSA governments could have more influence in developing, is biofuels. Biofuels are liquid fuels (ethanol or biodiesel) converted from biomass that can be blended with gasoline or diesel. Conventional ICEs can generally run on a 20% blend of biofuels, however, modified ICEs or flex-fuel vehicles, common in Brazil, can accommodate greater blends or pure ethanol (Gee & McMeekin, 2011). A number of SSA countries, including Malawi, Ethiopia and Kenya are already mixing ethanol with transport fuel on a smaller scale (IEA, 2014; Ethco, 2015).

Biofuels are commonly divided into the first, second and third generations. The first uses fermentable sugars or oil extracted from feedstocks like sugar cane and palm oil; the second uses cellulose, which in some circumstances is derived

26 See chapter 8 for a description of Honda's and General Motors' fledgling auto manufacturing operations in Nigeria and Kenya.

from biomass waste; and the third uses biomass produced industrially through algae bioreactors (Carey, 2011b). Thus far, only first generation biofuels have been widely commercialised. The latter two categories are in the early stages of development and may offer long-term opportunities.

The climate impact of biofuels depends on the type and source of the feedstock. Measuring their net emissions requires a lifecycle analysis, because although GHGs are released during the production (fertilising, harvesting and refining) and in the burning of biofuels, growing the feedstock removes carbon dioxide from the atmosphere. It is for this reason that replacing fossil fuels with biofuels can theoretically reduce GHG emissions. Nonetheless, production of the feedstocks can require significant land area, leading to deforestation and sometimes cancelling out any gains in emission reductions (Lapola et al., 2010; Searchinger et al., 2008). Furthermore, greater demands on agricultural land could lead to higher food prices – a consideration that is particularly relevant in a region like SSA where 30% of the population already suffers from chronic malnutrition (Hickman et al., 2011). Feedstocks that can be grown on degraded land, such as jatropha, could negate some of the impacts on food prices but have yet to be proven commercially viable (GGBP Initative, 2014).

5.2.3 Urban design

The design of cities is highly influential on the climate impact of transportation. Low-density cities planned around transport via personal vehicles (scooters, motorcycles and cars) have the highest emissions. Differences in city design and density are a major reason for the average US urban dweller using 24 more times energy than the average Chinese urban dweller (Carey, 2011a). Higher density cities with co-located residential, commercial and public buildings that bring people and their jobs and services closer together, limit the use of private vehicles and encourage people to walk or cycle can lead to significant reductions in or avoidance of GHG emissions (Centre for Liveable Cities and Urban Land Institute, 2013). Mixed-use zones are also more easily supplied with efficient energy, water and sanitation infrastructure. Furthermore, simple investment in pavement can encourage pedestrian mobility over more polluting (and less healthy) modes of transportation.

5.2.4 Mass transportation systems

In much of SSA, government organised bus and rail systems (where they existed) declined in the latter decades of the 20th Century, owing to the burgeoning cost of subsidies, poor maintenance and mismanagement (Kumar, 2011). In urban areas, informal mini-buses and motorcycle taxes have taken their place. Between 1995 and 2007, commercial moto-taxis increased from 5,000 to 40,000 in Kampala and from 10,000 to 200,000 in Lagos (Kumar, 2011).

Despite challenges with implementation, the potential economic, social, and environmental benefits of government-organised mass transport infrastructure are large. Affordable urban transit systems can increase mobility of labour forces, particularly lower-income households. Well-designed regional transport systems can promote export-orientated trade, opening markets for agriculture and other industries. Reduced automobile use through all forms of mass transportation can improve local air quality and health.

The development of mass transit systems can also significantly reduce GHG emissions by reducing the number of automobile trips, both regionally and within cities. SSA's transport infrastructure deficit leads to high levels of congestion in urban areas, despite low rates of car ownership. This in turn creates further constraints on economic productivity (IEA, 2014).

Buses, mini-buses and coaches are the most common mass transport systems for inter- and intra-city travel in SSA. Existing bus systems are largely informal and unregulated, leading to frequent delays (IEA, 2014), although a bus rapid transit system is operational in Lagos. Others are being constructed in Dar es Salaam and Kampala. Improving bus systems is a relatively inexpensive option for mass transport, as they utilise existing road networks. Commuter rail and metro systems are more expensive, but can greatly alleviate congestion, reduce emissions and offer a highly efficient method of transporting people. The city of Addis Ababa opened the first urban rail network in SSA in 2015, while a partially completed urban rail network in Lagos continues to suffer severe delays due to funding issues.

Intercity rail systems operating over greater distances offer an alternative to cars and commercial vehicles for transporting not only people but also important commodities to markets. Intercity rail systems in SSA are sparse and those that exist are aging, disjointed and poorly maintained (AfDB, 2011). There are a handful of projected rail network expansions. One rail line that is planned with China's support would run from the port of Mombasa to Nairobi in Kenya and then on to neighbouring states in East Africa (IEA, 2014). Rwanda, along with Tanzania, also plans to develop a rail link between Dar es Salaam and Kigali, supported by the African Development Bank (Carey, 2011b). Nigeria has plans to further expand its internal intercity rail (Business Day, 2015).

Finally, navigable waterways in SSA, compared with other regions of the world, are relatively few in number. The Atlantic side of the continent offers more options than the Indian Ocean side (Balek, 1977). Where available, waterways offer additional low-cost and low-carbon options of transporting cargo and people.

5.3 Enabling low-carbon transitions in the transport sector

New and improved road networks can be critical to opening up access to markets for farmers and promoting economic growth. It is important that expansions are planned in an integrated way, taking into account the impacts that roads have on ecosystem services. For this reason, representatives from the transport sector should collaborate closely with those from the agriculture and forestry sectors in the development of integrated land-use plans (see Transition 4). Other transitions in the transport sector are necessary to reduce emissions from vehicles rather than land-use.

Transition 9: Remove fossil fuel subsidies for consumption

To increase efficiency in the transport sector (and other sectors with high levels of consumption subsidies), fossil fuel subsidies must be reformed. With global oil prices currently relatively low, it is an ideal time to reform consumption subsidies, particularly in oil importing countries (Whitley & van der Burg, forthcoming). The experience of Nigeria and Ghana with fossil fuel subsidy reform is discussed in Box 4. There is some indication that reform of fossil fuel subsidies, and subsequent higher energy prices would also shift resources to the development of low-carbon and efficient technologies (World Bank, 2014). For fossil fuel consumption subsidies, a primary aim is to level the playing field for efficiency investments and the development of alternative fuels and energy sources.

Of course, removing fossil fuel subsidies for consumption can have important consequences for economic growth and poverty reduction – both good and bad. While the higher costs of fuel may hurt certain parts of the economy, the removal of subsidies can end a significant strain on public finances, freeing up funds for underfinanced progressive policies like education and health care. Lessons from previous reform efforts in a number of countries, including those in SSA, provide the following principles for effective reform in order to minimise the negative impacts and enhance the benefits (Whitley & van der Burg, forthcoming).

Whole-of-government approach: The role of energy in the balance of the economy and the significant impact of subsidies on wider economic, environmental and social objectives justifies a whole-of-government approach to any reform process. In practice, this requires high-level political and bureaucratic leadership from central government agencies, such as the Treasury or Ministry of Finance, to ensure that any process is broad in scope and planning and brings all relevant players to the table.

Research and analysis: Research should be undertaken before, during and after reform. It should look into several areas including the scope and nature of fossil fuel subsidies, policy objectives of existing subsidies, potential domestic impacts of subsidy removal (economic, social and environmental), key attributes of relevant institutions and decision-making processes and the 'winners' and 'losers' of subsidy reform. Information and findings should feed directly into communication and consultation processes and should provide the necessary evidence to support cross-government collaboration and mobilise resources.

Consultation and communication (before, during and after reform): A large-scale, transparent and extensive information campaign should be undertaken to explain the relevance of the reform to the majority of the population. Communication could be vital to offsetting myths about subsidies, correcting information asymmetries, building coalitions of support for reform, improving participation in collective efforts and neutralizing those more resistant to change.

Mobilising upfront resources (before and during reform): While subsidy reform can provide significant fiscal space and additional government revenue, often dwarfing any upfront costs, positive impacts on government budgets are only felt after subsidies have been reformed. Upfront resources are important to cover the costs of analysis, communication, consultation, complementary measures and institutional reforms required in advance of wider subsidy reform processes.

Complementary measures (for households and sectors): Complementary measures for efficient and visible reallocation of resources to groups most impacted by reform (sectors, households and those within government) increases the likelihood of success and sustainability of reform processes. These complementary measures include social protection programmes for poor and vulnerable households as well as retraining and employment subsidies for workers in affected (high-carbon) and emerging (low-carbon) sub-sectors.

Careful timing, phasing-in and linking to wider reform: The best approach is to set ambitious endpoints and to complement these with slow, credible and pre-specified timeframes for phasing out subsidies. This avoids disruptive sharp increases in prices, which can lead to social unrest, and allows time for planning and implementation of consultation, communication and complementary measures. The sequencing of reforms is also important. It may be easier to start by introducing performance standards or fiscal incentives for low-carbon investments, progressively transforming the economic system into a more efficient one. After this, subsidies on goods mainly consumed by wealthier segments of the population (like gasoline) may be targeted before those consumed by lower-income groups (like diesel and kerosene).

Transition 10. Shift to a low-carbon automobile fleet and fuels

With little control over the design of vehicles, the main options available to governments in SSA to increase fuel efficiency of its fleet are somewhat limited. Nonetheless, there are options for regulating the efficiency of incoming vehicles. For example, Nigeria has adopted EU 2 emissions standards,[27] and Angola, Botswana, and Kenya have implemented import restrictions based on vehicle age (IEA, 2014).

Box 4: Reform of subsidies to fossil fuel consumption in Nigeria and Angola

Nigeria is the largest oil producer in SSA and as with many oil producing countries, it provides significant subsidies to the consumption of fossil fuels. Nigeria's subsidies to fossil fuel consumption of gas and oil – through maximum prices for kerosene, gasoline and diesel – had an average subsidisation rate of 28.8% and were estimated by the IEA to be $6.6 billion in 2013 (about 1.3% of Nigeria's GDP). The benefits from these subsidies are largely captured by high-income households consuming more energy products, not by low-income households. Nigeria undertook efforts to reform electricity subsidies, starting in 2008 (through a 15 year roadmap for cost-reflective tariffs), and gasoline subsidies, starting in 2011. Only six weeks after the announcement of the gasoline subsidy, in January 2012, the government raised the price of gasoline to full cost-recovery level – leading to a 117% price increase. For most Nigerians, the implementation of the reforms came as a surprise and led to protests across the country and threats of strikes by unions. In response, the government scaled back the price increase from 117% to 49% by mid-January 2012, meaning that the country's subsidies to gasoline were reduced significantly but not completely eliminated.

Angola is the second-largest oil producer in SSA. In 2014, Angola's spending on fossil fuel subsidies was higher than the country's spending on health and education combined and represented 3.7% of its GDP. In 2015, the Angolan government embarked on a campaign to reduce its fossil fuel subsidies. As a first step, the International Monetary Fund (IMF) conducted research into the distribution of subsidies across sectors, stakeholders and the possible impacts of reform. Using this research, IMF presented a strategy for reform based on the phasing of reform efforts with frontloaded reduction of subsidies for fuel products consumed by richer households (gasoline). This was later followed by a reform strategy for those fuel products consumed by poorer households (kerosene). The strategy prioritises strengthening existing social welfare programs and implementing a cash transfer program scheme. Both recommendations have been adopted by the Angolan government, which has underlined the significance of timing and of linking fossil fuel subsidy reform to larger macroeconomic or social initiatives.

Source: Whitley and van der Burg, forthcoming.

Fiscal policies can also be used to promote a more efficient stock. Vehicle excise duties and fuel taxes can shift consumer behaviour towards fuel efficiency. Revenues from these taxes are commonly used to fund road maintenance or public transit. Subsidy schemes can be used to further incentivise the purchase of efficient vehicles or to promote scrapping and recycling of aging inefficient vehicles. Box 5 describes one such subsidy programme in Egypt, which although not located in SSA, provides an interesting case study that could be applied in the region.

In the medium-term, SSA should aim to shift its vehicle fleet to alternative fuels. When promoting a fuel shift, governments will have more influence initially in switching captured fleets of vehicles, such as buses or taxes, rather than private ones. CNG offers a lower carbon option that is already attractive in countries with a domestic supply of natural gas. Continued innovation in electric and hybrid-electric vehicles should eventually bring their price down to affordable levels. SSA will need to invest in its electricity grid now to facilitate their entrance (see chapter 4). Given the region's growing and affordable labour force, it should also invest in building up the skill-base in engineering necessary to attract investment in the manufacturing of these future growth technologies in the medium- to long-term (see chapter 8).

There are a few initiatives in place to promote biofuel production in SSA. For example, Ethiopia's National Biofuels Policy promotes ethanol biofuels for cooking and for blending with gasoline for transportation (IEA, 2014). Likewise, the governments of Mali and Burkina Faso are facilitating foreign and domestic investment and providing technical support to farmers' cooperatives to develop Jatropha production for biodiesel (GGBP Initative, 2014). Further research should be conducted into the potential GHG emission reductions from biofuels and the social and environmental consequences of their production, before SSA governments implement any policies to promote them.

Shifting to a low-carbon automobile fleet and fuels would likely have marginal benefits for economic growth through efficiency gains, however the benefits would accrue primarily to the higher income segments of the population that can afford vehicles.

Transition 11. Implement higher density multi-use urban plans

As discussed in chapter 1, urban populations are projected to grow rapidly in SSA in the coming decades. To avoid lock-in to patterns of urban development that lead to high levels of GHG emissions, proactive urban planning is therefore of paramount importance (NCE, 2015). For

27 The Euro 2 emission standards were adopted by the EU in 1996. They limit nitrogen oxides, carbon monoxide and total hydrocarbon emissions of all vehicles.

Box 5: The Egypt Vehicle Scrapping and Recycling Programme

In order to accelerate the turnover of mass transport vehicles to newer, less carbon-intensive vehicles, Egypt implemented a Vehicle Scrapping and Recycling Program in 2010. The program provides vouchers of up to EGP 5,000 (US$840) to owners of taxis, microbuses, trailer trucks and buses who voluntarily surrender their vehicles for managed scrapping and recycling. The vouchers can then be used as a down payment for loans to purchase newer, more efficient vehicles from participating dealers. The Vehicle Scrapping and Recycling Program is complementary to a larger Urban Transport Development Program, which has seen a law established rendering owners of mass transport vehicles aged over 20 years ineligible for renewal of their operating licences.

The Urban Transport and Development Program received $150 million in financing from the International Bank of Reconstruction and Development of the World Bank and an additional $100 million in credit from the Clean Technology Fund (CTF).

instance, regulations on minimum density for urban residential units can encourage high-density construction, reducing urban sprawl (CDKN, 2014). Zoning to co-locate residential and commercial areas, with good connections via public transport corridors, can significantly reduce or avoid GHG emissions from private vehicle use.

Beyond these climate benefits, well-designed urban plans are needed to pre-empt the formation and growth of slums, and ensure that growing urban populations are adequately provided with housing, water, sanitation, transport, and energy infrastructure. Urban planning therefore has substantial benefits for both economic growth and poverty reduction.

Cross-ministerial coordination within SSA countries is needed to ensure urban planning processes are integrated across sectors. The policy and institutional governance requirements to achieve effective spatial planning are beyond the mandate of one ministry or government authority and indeed beyond one level of government. A national whole-of-government approach to urbanisation needs to be complemented by parallel action on governance, finance and capacity at sub-national and local levels (NCE 2015).

Transition 12. Promote mass transportation systems

As with urban planning, investments in large-scale transport systems are liable to lock-in particular development pathways over others. While the expansion of road networks is vital to the economic growth of the region, it risks an excessive focus on road development at the expense of mass transport systems. This could lock-in a GHG emission-intensive transport sector that remains overly reliant on automobiles. It is also important that alternatives to roads are considered, particularly intercity rail, urban rail and metro systems: 'Any such investment should be carefully considered to ensure maximum utilisation, often by matching the highest density occupancy to the location of transport nodes' (Carey, 2011a, p. 10).

As well-designed mass-transport systems enhance the mobility of goods and people, they offer significant benefits for economic growth. Low-income populations, in particular, benefit from mass transport systems given their frequent inability to afford private automobiles.

A central barrier to larger investments in mass transportation infrastructure is access to finance (NCE, 2015). For example, according to the AfDB (2011), restoring existing rail systems would require a one-time investment of $3 billion. New systems would be more expensive. The planned rail line between Dar es Salaam and Kigali would cost an estimated $10 billion (Carey, 2011b).

International development partners will need to provide technical assistance and financial support for the cost of transport infrastructure. Both development finance and climate finance could prove instrumental to governments securing the necessary capital to build metro systems and intercity rail lines. Box 6 provides a discussion of Lagos' efforts to construct an urban rail network. Governments could also explore options to partner with private sector

Box 6: Urban rail in Lagos

Lagos is currently constructing what will become only the second light rail network in SSA (after Addis Ababa's newly opened one). When finished, the Lagos Metropolitan Area Transport Authority (LAMATA, 2015) expects the blue line (the first to begin construction) to carry an estimated 400,000 passengers daily and 700,000 once fully operational. The Lagos rail network will be powered by electricity, primarily from natural gas sources. LAMATA's 30-year Strategic Transport Master Plan sees the entire urban rail network consisting of seven railway lines planned along high commuter demand corridors integrated with the city's bus rapid transit system.

Construction of the blue line began in 2009 and completion was expected by 2011 at a cost of $1.2 billion. Funding was to come entirely from the Lagos State Government (Railway Technology, 2015). However, the project continues to experience delays due to funding issues. Nonetheless, the contractor, China Civil Engineering Construction Corporation (CCECC), had completed a portion of the overhead rail tracks by 2012. The newspaper Business Day (2015) estimated that less than half of the construction project had been completed at the beginning of this year.

6. Extractives

SSA has considerable fossil fuel reserves – oil, natural gas and coal – and mineral stocks – copper, cobalt, uranium, gold, diamonds, etc. Around 7% of the world's conventional oil resources and 6% of the world's gas resources are in SSA (IEA, 2014). In 2011, the region produced 22% of the world's gold, 58% cobalt, 7% copper, 95% platinum group metals[28] and 18% uranium (Banerjee et al., 2014). It is also becoming an important region for coal production, with increasing foreign investment in production infrastructure following recent discoveries in Nigeria, Mozambique and Zimbabwe (IEA, 2014). Given the relatively low regional demand, a large portion of fossil fuels produced in SSA are consumed in other parts of the world, most notably Europe, America and (increasingly) China (UNECA, 2011a).

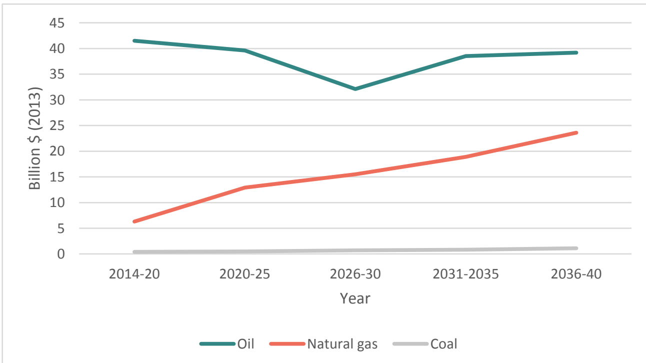
It is expected that production of fossil fuels in the region will expand to new countries. SSA accounted for nearly 30% of global oil and gas discoveries made from 2009 to 2014 (IEA, 2014). On coal, discoveries in Nigeria, Mozambique, Zimbabwe, Botswana, Tanzania, Zambia, Swaziland and Malawi are attracting investment by multinational companies keen to start production and export in the next decade (IEA, 2014). SSA is therefore likely to continue to play a significant role in the world energy market (UNECA, 2011a) (see Figure 19).

Mining is among the most important sectors to SSA's economy, according to its contribution to exports, revenues and GDP (Banerjee et al., 2014). Between 2000 and 2011, petroleum and mineral resources accounted for an average of more than two-thirds of exports across the region (Altenburg & Melia, 2014). For the major oil and gas producing countries in SSA, revenue from these fossil fuels accounts for 50-80% of government revenues (UNECA, 2011a). In Nigeria, for example, petroleum represents over 90% of total exports revenue, while oil and gas accounts for about 35% of GDP (OPEC, 2014). Mineral exports are also important to many countries' economies; in Zambia, for instance, copper contributes about 80% to the country's export earnings (Brülhart, Dihel & Kukenova, 2015).

Despite the significant contributions to export revenues, SSA's export of fossil fuels has had a variety of negative impacts. Countries specializing in export of fossil fuels and minerals are vulnerable to highly volatile prices (Brülhart et al., 2015). For example, Zambia's dependence on copper means that when prices fall, as they did in the 1970s and in 2008, so too do government revenues. Zambia has thus struggled to maintain macroeconomic stability (Christopher, Collier & Gondwe, 2014). Similarly, the region is a significant exporter of crude oil, but a net importer of refined oil products, due to SSA's limited oil refining capacity. Therefore, despite an increase in crude oil output from 2000 to 2012, SSA's oil product imports doubled over the same period (IEA, 2014). The region is left vulnerable to supply disruptions and to high import price volatility, and its ability to benefit from the increased value of refined oil products is limited (AfDB, 2013).

While extractives sectors may be important to many SSA countries' GDP, historically, African governments (among others) have a poor track record in managing their mining, mineral and fossil fuel resources to achieve sustained and inclusive economic growth. Against the objective of low-carbon development, the contribution of the sector to economic development and poverty reduction are important criteria to consider alongside the sector's GHG emissions. The short-term 'boom and bust' revenues characterizing the extractives sector have resulted in poor long-term macroeconomic planning in countries overly dependent on mining and mineral revenues, known as the 'resource

Figure 19: Average annual investments in fossil fuels in SSA (excl. RSA) in IEA's New Policies Scenario, 2014 – 2040*



Source: IEA, 2014.

** Investments for oil, gas, and coal include production, transformation and transportation. The New Policies Scenario projections is based on the continuation of existing policies and measures and their implementation and also takes into account prospective technology development and investments.*

28 Ruthenium, rhodium, palladium, osmium, iridium, and platinum. These metals are used for industrial applications and for jewellery.

Box 7: Botswana – avoiding the resource curse

Botswana is one of the world's largest producers of diamonds. It has famously been able to harness the wealth generated from this resource to support GDP growth and socioeconomic development for several decades. There are three policy areas that Botswana successively steered to achieve this growth and to avoid the resource curse. First, Botswana did not rely only on resource extraction for its revenue, instead diversifying its economy to also focus on development of its manufacturing and agriculture sectors. Efforts to create a business-friendly environment and ensure stability of the financial sector ensured long-term development of these high employment-creating and value-added sectors (Government of Botswana, 2009). This reduced reliance in the longer term on the country's non-renewable diamond resources, which provide more limited employment opportunities.

Second, Botswana developed a sustainable fiscal policy, including formal and informal fiscal rules to prevent excessive spending, based around the Sustainable Budget Index (SBI) – defined as the ratio of non-education, non-health recurrent expenditure to non-mining revenue. An SBI ratio of no greater than 1 is the aim, to ensure that all mineral revenues are invested productively or saved rather than being used to boost consumption. In addition, the Stock and Treasury Bills Act requires the government's total domestic debt guarantees to be less than 20% of GDP. Botswana also invested its windfall diamond revenues, spending only against projects identified in its National Development Plans, according to the law.

Finally, Botswana developed a culture of good governance, with strong institutions responsible for resource management. Botswana has a National Integrity System: 'laws, institutions and practices that maintain accountability and integrity of public, private and civil society organisations' (Transparency International, 2005, p. 3). Some of these mechanisms include an independent judiciary, freedom of expression, a strong civil society and the introduction of a parliamentary Public Accounts Committee responsible for scrutinising public service expenditures. Botswana's experience shows that resource management policies will only be as successful as the transparency, accountability and stability of the governance system that implements and enforces them. The Extractive Industries Transparency Initiative can be a helpful tool for governments to adopt good governance of the extractives sector (Extractive Industries Transparency Initiative, 2015).

curse' (Ximena-Meijia & Castel, 2012). In most countries, revenues from commodity exports have not been used to make strategic investments to grow other sectors of the economy that can reduce dependence on extractives, such as manufacturing and services (see chapter 8)(Altenburg & Melia, 2014). Moreover, rent-seeking behaviour, as well as corruption, has meant that in many countries macro-level growth has not translated into broader inclusive growth, nor poverty reduction. In addition, extractive industries are not generally labour intensive, create limited jobs (mining, oil and gas industries employ less than 1% of the region's workforce) and create limited links between foreign and local enterprises (UNCTAD, 2014; Altenburg & Melia, 2014).

However, the extractives industry does have the potential to generate economic and social development. This can be at lower environmental and social cost than historically, if strong and well-enforced policy and institutional measures are put in place (see e.g. Holden, 2013; Veit, Excell & Zomer, 2011; Morris, Kaplinsky & Kaplan, 2012). Botswana's policy approach to the management of its diamond resources, discussed in Box 7, reveals the macroeconomic and fiscal management tools that can be adopted to translate mineral revenues into social and economic development. Section 6.3 discusses the policy options available to reduce the environmental impact of the sector.

6.1 Extractive sector GHG emissions and projections

Many of the GHG emissions associated with the extractives sector are downstream emissions, particularly in electricity generation (see chapter 4) and transportation (see chapter 5). The major sources of direct emissions from the extractives industry are:

- fugitive emissions, and
- energy use in production (which is becoming more energy-intensive)

6.1.1 Fugitive emissions

Fugitive emissions from oil, gas and coal mining operations represent 7.3% of total GHG emissions in SSA (calculated using data from FAO, 2015; WRI, 2015; IEA, 2014) (see Figure 4). Fugitive emissions result from the liberation of stored GHGs (CO_2, CH_4, N_2O) during mining of oil, gas and coal. Traditionally, methane from coal mining has been flared, emitting significant GHGs. Methane and nitrous oxide also escape through oil and gas production via leaking equipment, natural gas transmission, distribution lines and storage facilities. In Nigeria, methane emissions from oil and natural gas in 2010 were 25.8MMtCO_2-e (over those of the Ukraine and India and just below Mexico and Indonesia). Mitigation of these fugitive emissions therefore presents a significant opportunity to reduce GHG emissions from the extractives industry (see Section 6.2.1 for a discussion of the technologies available).

6.1.2 Energy use in production of fossil fuels and minerals

Through the processes required to produce fossil fuels and minerals, the extractives sector is a major producer of GHG emissions in SSA (CDKN, 2014). In Botswana and Namibia, for instance, emissions from energy used in mining and quarrying account for 80% of national emissions from industrial energy use, and in Zimbabwe for 18.6% (IPCC 2012). Most of this energy comes from the direct consumption of fossil fuels to power heavy machinery used for excavation and the vehicles used for transport. While electricity accounts for only a small part of industry's total energy demand, extractive industries still also consume an overwhelming proportion of the power produced in many SSA countries (Banerjee et al., 2014) (see Figure 20). As will be discussed in section 6.2.1, renewable energy therefore provides a key opportunity for reducing GHG emissions from the extractives sector.

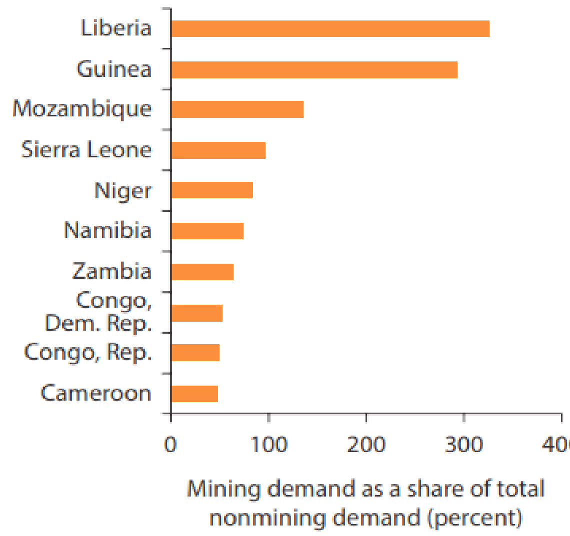
Fossil fuel extraction and production is becoming progressively more energy and emissions intensive. BP has stated that 'it is likely that the carbon intensity of our upstream (production) operations will continue to trend upwards as we move farther into more technically-challenging and potentially more energy-intensive areas' (BP, 2013). The Carbon Disclosure Project has found that major oil and gas companies (Exxon Mobil and Shell) are emitting more GHG emissions, despite producing less oil and natural gas (Bast, Makhijani, Pickard & Whitley, 2014). In SSA, both Nigeria and Angola buck this trend, with plentiful resources leading to a forecast of steadily increasing production. However, in Sudan, South Sudan, Equatorial Guinea, Gabon, Cameroon, Chad, Congo and Mauritania production is forecast to decrease due to natural decline in mature fields (EIA, 2013).

6.1.3 Future 'lock-in' and associated GHG emission projections

There is a risk that a cheap supply of fossil fuels from domestic production, combined with the development of fossil fuel-intensive infrastructure, such as coal-fired power plants and heavy manufacturing industries, will lock SSA countries into a path of increased fossil fuel supply. This 'lock-in' would result in high carbon energy use and substantial future GHG emissions, particularly for electricity generation and transport (see chapters 4 and 5). In the IEA's New Policy Scenario, oil demand in SSA increases from 147 to 251 Mtoe and accounts for 19% of total energy demand in 2040. Demand for natural gas grows by around 140% from 2012 to 2040. Coal demand increases from a relatively small amount to 63 Mtoe but its share in the energy mix remains very low at 5% (IEA, 2014). If the region were to pursue a low-carbon development path, these projections could be shifted downwards.

Even with reduced regional demand, the high percentage of SSA's mineral resources and fossil fuels that are exported means global demand is likely to play a major role in

Figure 20: Mining demand as a percentage of total non-mining demand for electricity, 2020



Source: Banerjee et al., 2014, p. 6.

shaping the future of its extractive industries. Globally, 42% of the world's electricity was from coal-fired power in 2010. The level of dependency on coal for electricity generation is even higher in developing or emerging economies such as China (79%), India (69%), Poland (90%), South Africa (93%) and Kazakhstan (70%) (UNECA, 2011a).

However, tighter restrictions on GHG emissions are emerging, indicating a global trend away from fossil fuel-intensive economies that may impact on the future of SSA's fossil fuel industry. For instance, there is increasing pressure on investors to divest from fossil fuel stocks. This is driven by the global carbon budget required to stay within a 2°C temperature increase, otherwise known as 'unburnable carbon.' This 'unburnable carbon' is increasingly making investment in fossil fuels both a climate and a financial consideration (see chapter 1 and Figure 21). For example, in mid-2015, the Norwegian Parliament voted in favour of the country's huge oil fund (the world's largest sovereign wealth fund) to divest from companies deriving 30% or more of their business from mining or burning coal. As one of the top ten investors in the global coal industry worldwide, it is expected that Norway's move may spark similar divestment in other major investment funds (Carrington, 2015).

In this context, a key question for SSA nations is whether and how to expand their natural gas production and demand. As flagged in chapter 4, natural gas could serve as a 'cleaner' alternative to coal or oil due to its much lower CO_2 emissions per unit of energy. Some governments in SSA are therefore beginning to regulate for greater domestic use of natural gas, particularly Mozambique and Tanzania, following their recent discoveries of offshore natural gas reserves. However, despite its potential as a bridging fuel, 34% of SSA's gas reserves must stay in the ground to meet the 2°C global temperature increase target, according to recent research by University College London (McGlade & Ekins, 2015).

As another example, in 2014, China introduced new regulations on 'dirty' coal: from 1 January 2015, imported coal must not have an ash content higher than 20% or sulphur content above 3%. These standards will impact 'dirty' global coal exporters significantly. For instance, Australian coal typically has an ash content above 20% and its producers are therefore expecting to reduce exports to China by 40% (Milman, 2014). The majority of Southern Africa's coal deposits also have a high ash content, above China's 20% limit, requiring sub-Saharan countries to either introduce a high-cost washing process to improve the quality of the coal or face a restricted export market (Cairncross, 2001).

SSA should consider the extent to which it develops its extractive industries against this growing trend away from unrestricted fossil fuel production and consumption.

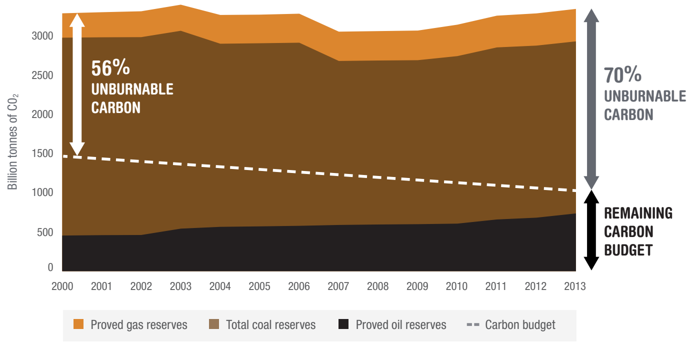
6.2 Key assets and processes in the extractives sector

The greatest opportunities to reduce emissions from fossil fuel consumption may involve a structural transformation of the economy away from extractive-based economies. Nonetheless, acknowledging that the extractives sector is vitally important to many SSA countries' economies, this section identifies the assets and processes that can be managed within the extractives industries to reduce GHG emissions: (1) the energy consuming technologies and processes of extractives operations; and (2) the fuels used by the extractives sector.

6.2.1 Energy consuming technologies and processes in extractives operations

The processes used in the extractives industry can be highly energy intensive, including the use of drills and heavy machinery for excavation, mining operations and mineral preparation and separation (IPCC 2012). Transportation is another major source of GHG emissions from the extractives sector, given that minerals and fossil fuels, as well as waste products, must often be hauled over long distances. Upgrading to newer and more efficient technologies offers an opportunity to reduce GHG emissions in the mining and quarrying process and fossil fuel production processes, often producing a net economic benefit during the lifetime of a project. However, energy efficiency upgrades frequently require significant investment resulting in potentially lengthy pay-back periods (Cantore, 2011).

Figure 21: The carbon content of fossil fuel reserves in comparison to the carbon budget, 2007-2013



Source: Bast et al, 2014, p. 13.

There are many options for improving the efficiency of mining and other extractive operations. Some technological examples include adopting process software to optimise operations (more efficient than human-directed operations). For operations requiring drills, water rock drills consume less energy than compressed air drills. Improvements in engine design features, such as adjustable speed drives for operations with differing load requirements, and optimally-programmed systems, can also increase efficiency (Bourgouin, 2014).

Alongside technical upgrades, process efficiencies can reduce GHG emissions. To reduce fugitive emissions along the supply chain of the oil and gas industries (e.g. from leakage or loss during transmission), methane and nitrous oxide gases can be captured and used for fuel gas. There are a number of readily available practices and technologies that can modernise older facilities for this purpose.[29] Capture and use of these fugitive emissions represent a cost-effective means of avoiding product losses (GMI 2011).

Capturing and using methane from oil and coal operations, rather than flaring it, presents an equally significant opportunity. The IEA estimates that 28 billion cubic feet (bcm) of natural gas was flared in SSA in 2012 alone, equivalent to an increase in SSA's electricity supply by around 35% had the gas been captured and used in a gas-fired power plant (IEA, 2014). The feasibility of capturing methane is dependent on whether it can be used by the mine itself (to generate electric power, for co-firing in boilers, to assist with coal drying or as vehicle fuel, among other uses) or its proximity to an end user or pipeline and the quality of gas extracted (GMI, 2011).

29 For example, natural gas-driven pneumatic devices are used in many operations to regulate modalities such as temperature and pressure. When these modalities exceed set limits, the devices, by design, vent natural gas. Devices set to vent a large volume of natural gas can be retrofitted to lower volumes, significantly reducing methane emissions. Storage devices for crude oil also vent methane but can be retrofitted with a recovery unit that captures the methane instead.

6.2.2 Fuels used by the extractives sector

Switching from diesel-powered machinery to low-carbon energy sources is an important GHG mitigation strategy for the extractives industry (Bourgouin 2014). A recent study by Navigant Research found that less than 0.1% of electricity consumed by the extractives industry in 2013 globally was generated from renewable energy sources. However, they forecast that, due to government regulations and growing international pressure for a more sustainable mining sector, renewable energy technologies will supply 5%-8% of the world's mining industry power consumption by 2022 (Navigant Research, 2013). For SSA, financial and technical capacity challenges will need to be overcome in order to achieve this level of deployment (Boyse, Causevic, Duwe & Orthofer, 2014).

The off-grid nature of many mining sites, which can be located in remote areas away from energy infrastructure, makes them well-suited to renewable energy power supply. In fact, a database collated by THEnergy demonstrates that solar and wind technologies can be the most competitive option at remote mining sites, in comparison with diesel power (THEnergy, 2015). As well as being more viable financially, installing renewable energy-generating assets can improve security of electricity supply to mining sites, which would no longer need to rely on diesel generators or insecure supply from the grid (Global Cleantech Center, 2014).

6.3 Policies to achieve low-carbon development for extractives

Many of the opportunities to reduce emissions from the extractives sector involve steps to reduce demand for fossil fuels. These 'demand-side' opportunities are discussed in the energy (electricity), transport and manufacturing chapters. This section focuses on the 'supply-side' opportunities, i.e. policies that aim to manage and reduce the energy used by the extractive industries themselves.

Transition 13: Strengthen the use of energy efficient processes and technologies in the extractives sector

There are a number of barriers to the adoption of energy efficient technologies in the extractives industries. Primarily, where significant fossil fuel subsidies reduce end-use energy prices, there may be fewer economic incentives to adopt new energy-efficient technologies (UNDP, 2000; Whitley & van der Burg, forthcoming). Evidence shows that countries where energy prices are much lower than their costs are characterized by very high consumption per capita and low energy efficiency (Whitley & van der Burg, forthcoming). In SSA, high capital and operating costs have also contributed to limit uptake of energy efficiency technologies. To overcome these barriers, economic incentives, including tax rebates,[30] tax credits and grants, can mitigate or reduce the upfront costs of efficient technologies. Reforming investment incentives also provides an opportunity to attract those investors using the best available technologies. In addition, fossil fuel subsidies must be reformed to improve the economic viability of energy efficiency innovations (Sayeh, 2014). Fossil fuel subsidy reform is reviewed in more detail in Transition 9.

Regulatory tools can also improve uptake of efficiency standards. Industry-wide standards for the emissions-intensity of mining products and processes can bring the industry up to a minimum level and in line with international standards (Cole, 2011). Measuring and reporting requirements for mining companies are important complements to energy efficiency standards, providing the ability to collect data and review companies' compliance with regulatory standards. Over time, reports allow the creation of an inventory of energy consumption and GHG emissions, providing governments with the information needed to tailor emission-intensive standards to different industries (Cole, 2011). This includes the need to increase the requirements over time, to ensure continuous improvement. While large mining and other extractives operators will have the resources to comply with reporting measures, it is important to consider the specific needs of artisanal miners with fewer human and financial resources, which could act as a barrier to the successful implementation of this regulatory tool.

Targets for improved energy efficiency across different extractive sectors are also a proven regulatory tool. In South Africa, for example, mining and industrial companies signed up to a Voluntary Energy Efficiency Accord with the Government, including Eskom, Sasol, BHP Billiton, Anglo American, AngloGold Ashanti, Anglo Platinum, Xstrata (DME, 2008). The target was a final energy demand reduction of 15%, and initial results of the Accord show that the individual electricity demand reduction achieved by the companies ranges from 38% to 2.5% (DME, 2008). Voluntary targets can often be used as a stepping stone towards compulsory energy efficiency targets, allowing companies to learn and plan for change.

There are numerous promising voluntary initiatives to promote the capture and use of fugitive gas from oil operations. Nigeria, Angola, Congo, Gabon and Cameroon are members of the Global Gas Flaring Reduction Partnership, 'an initiative that supports national efforts to use currently flared gas by promoting effective regulatory frameworks and tackling the constraints on gas utilisation' (IEA, 2014, p. 116). Gabon, in particular, has introduced penalties for those extractive operations that continue to flare gas, although enforcement remains a challenge. In Congo, similar requirements to reduce gas flaring have resulted in reductions of approximately 40% between 2005 and 2014 and captured gas is being used to power two plants (IEA, 2014). Competitive pricing, too, can

30 A partial retroactive refund to those who have paid too much for tax, rent, or a utility.

increase the market-value and incentivise the capture and supply of natural gas.

Finally, a lack of regional experience and expertise limit the ability of SSA-owned companies to implement best practice technologies and practices. Significant public investment and resources must also be dedicated to R&D and technology transfer for efficient alternatives. Supporting the capacity of SSA to develop and use the best available technologies could have considerable impacts on overall GHG emissions from the industry.

Transition 14: Switch to lower carbon and renewable energy sources to power mining and quarrying

In the extractives industry, renewable energy generation assets continue to be viewed as 'non-core' investments, despite the business case for them (explained in the assets and processes section above). Indeed, power generation in general is not a core business of mines, and financing renewable energy systems on a mine's balance sheet can be an obstacle for companies unfamiliar with this cost. A particular hurdle is often the higher upfront costs of renewables compared with diesel. Lack of awareness may also limit investment in on-site renewable energy generation, with companies citing ongoing concerns over the dependency of the technologies (Energy and Mines, 2015).

Governments can support development of renewable energy in the extractives sector by setting a clear and strategic policy framework that creates a stable business environment for renewable energy investments. This can range from command-and-control regulations, such as a mandate for a certain percentage of electricity coming from on-site renewable energy generation, through to market-based mechanisms, such as tax breaks for imports of renewable energy equipment and information campaigns for mining companies and employees. The regulatory tools examined in Transition 13 apply equally to the uptake of renewable energy technologies.

Regarding the expansion of natural gas production and domestic demand, as a cleaner fossil fuel alternative, there are a number of policy considerations to be taken into account surrounding institutional structure and regulatory framework (African Progress Panel, 2013). The World Bank argues that natural gas could be used to power large-scale industrial projects, such as aluminium mines and fossil fuel mines, generating fewer GHG emissions than alternative fossil fuels (Banerjee et al., 2014). In addition, new gas developments could be a source of fiscal revenue for governments such as Tanzania and Mozambique, with IEA projections expecting 'a cumulative $115 billion over the period to 2040 in Mozambique and about $35 billion in Tanzania' (IEA, 2014, p. 156). If managed effectively, it is possible these revenues could support development of a low-carbon transition, including, for example, the expansion of renewable energy (Greene & Lemma, 2015).

Increased domestic production of any fossil fuels, including natural gas, must be considered alongside incentives for renewables and energy efficiency measures. Some fear that increased motivation for domestic use of natural gas will push the adoption of these fuels and technologies further into the future (Ellis, Lemma, Mutimba & Wanyoike, 2013).

Transition 15: Reduce the use of fossil fuels

Domestically, SSA countries have strategic choices to make about the resource intensity of their economies, requiring analysis of long-term and short-term implications for energy costs and competitiveness (Ellis, 2013). Given the relative infancy of many SSA economies and the nascent stage of energy and industrial infrastructure, SSA is well-positioned to aspire to low-resource-intense economies built on long-term investments in low-carbon infrastructure. Economy-wide structural change to high value-added industries, such as manufacturing and services, will also have an important role in diversifying mining and mineral-rich countries' economies.

The elimination of subsidies to fossil fuel industries and re-distribution to renewable energy industries is an economic policy tool with the potential to prevent dependence on fossil fuels and promote a less resource-intensive economy. Fossil fuel subsidies are currently provided in a number of SSA countries and are particularly high in oil exporting countries. Although based on incomplete data, (see Box 8) estimates of fossil fuel subsidies, excluding subsidies to electricity in SSA in 2011 were:

- IMF pre-tax estimates: $7.9 billion
- IMF post-tax estimates (including failure to price externalities): $35.5 billion

Additional public support is provided to fossil fuel production in SSA through international development finance, government-owned banks, and export credit.[31] Oil Change International's Shift the Subsidies database, which tracks global public finance to the development of coal, gas, and oil, lists 64 public investments in fossil fuel in SSA between 2008 and 2014 worth approximately $2.8 billion.[32] Bast et al. (2014) further found that nine of the G20 countries are providing support for fossil fuel exploration in SSA countries, either through their public financial institutions or through their state-owned enterprises (SOEs) (see Table 5).

The recent fall in global oil, gas and coal prices provides an opportune moment for reform to fossil fuel subsidies and continued price volatility can send a strong signal that governments should also reduce production subsidies.

31 As they are state-owned entities, a portion of this would be considered a subsidy under the WTO definition (see Box 8).

Box 8: Incomplete data on fossil fuel subsidies in SSA

Research on fossil fuel subsidies in SSA has been limited to consumption subsidies by the IEA (for 4 countries: Ghana, Nigeria, Gabon and Angola) and IMF (for all of SSA).*

Although the IMF energy subsidy inventory appears to be comprehensive, it should be reviewed with caution. The IMF provides 'pre-tax' estimates of subsidies to consumption of petroleum products (gasoline, diesel and kerosene) for all SSA countries, based on the price gap approach.** Parallel information on subsidies to consumption of coal and natural gas, however, is limited to 3 countries (Nigeria, Angola and South Africa). In addition, while the IMF post-tax estimates cover all SSA countries (for petroleum products, natural gas and coal), they combine tax breaks for fossil fuels – included in the definition of subsidies under the WTO*** – and the cost of negative externalities (climate change, local pollution, traffic congestion), which are not normally defined as subsidies.

** As the price-gap method is the primary approach used to calculate the subsidies in Sub-Saharan Africa, it is difficult to confirm if these are subsidies to consumption, or production, or both.*

*** Where an energy product is traded internationally, the benchmark for calculating the price gap is that international price.*

**** The agreed definition of subsidies under the WTO - https://www.wto.org/english/res_e/booksp_e/anrep_e/wtr06-2b_e.pdf (see page 53)*

Table 5: G20 International Public Finance and SOEs Investments in Fossil Fuel Exploration in SSA

G20 nation	Recipient country
Brazil	Angola, Benin, Gabon, Namibia, Nigeria, Tanzania
Canada	Gabon
China	Chad, Equatorial Guinea, Gabon
India	Gabon
Italy	Mozambique
Japan	Democratic Republic of Congo, Ghana
South Africa	Equatorial Guinea, Ghana, Namibia
United Kingdom	Ghana, Guinea, Nigeria, Uganda, West Africa
United States	Nigeria

Source: Bast et. al., 2014.

However, a number of entrenched interests and policy justifications render the reform of fossil fuel subsidies challenging. For one, the benefits of fossil fuel subsidies are often concentrated among specific actors, while costs are spread across the general population (Commander, 2012). The influence of those with special interests can be significant and their lobbying power can obstruct reform efforts. Recent studies show that subsidies more often benefit the middle and upper classes than the poor (Fay et al., 2015; IMF, 2013).

Despite the challenges of fossil fuel reform, a number of SSA governments have undertaken subsidy reform efforts in recent years. For now, however, these have been focused on consumption subsidies. The lessons for reform are often equally applicable to production subsidies (see Transition 9).

32 This estimate includes a subset of projects in the database, which are either investments in fossil fuel production or (in countries where the majority of electricity is generated through fossil fuels) in transmission and distribution. (http://shiftthesubsidies.org/).

7. Construction

The construction sector is very active in a number of SSA countries and is expected to have the second highest growth rate globally (after emerging economies in Asia) by 2025 (Global Construction Perspectives & Oxford Economics, 2013). Although it has traditionally been focused on the development of infrastructure to support the extractives sector (in East Africa, for instance, four out of every ten large construction projects are related to resource-related transport (KPMG, 2014)), broader infrastructure spending is starting to increase. This is driven by growing populations and nascent urbanisation that are increasing demand for real estate projects, retail shopping centres and mixed-use developments (Ebohon & Rwelamila, 2002; KPMG, 2014). Nigeria, for example, has a forecasted national population growth rate of 2.5% per annum between 2012 and 2025, requiring an estimated 1.5 million new homes a year (Global Construction Perspectives & Oxford Economics, 2013). In Ghana, growing private consumption expenditure has catalysed an urban housing and infrastructure development boom, and construction is now the largest sub-sector within manufacturing and industry (AfDB, 2013; KPMG, 2014).

However, many Least Developed Countries (LDCs) in SSA are not experiencing the same rapid growth of new construction as Lower-Middle Income Countries (LMICs) and Middle Income Countries (MICs) (IPCC, 2014). This could see LDCs held back behind their more developed neighbours, particularly as the construction sector is estimated to provide 5-10% of employment at the national level and generate 5-15% of GDP (UNEP, 2006). As with the manufacturing sector, the construction sector has relatively high labour productivity and could be instrumental in achieving structural change to transform SSA countries' economies (AfDB, 2013).

The current dynamism of the construction industry makes it particularly important to focus on low-carbon options today. This should be done before more energy-intensive buildings, transport, energy or other infrastructure that lock-in unsustainable patterns are built. This chapter focusses on buildings and building materials, while other chapters focus on construction of infrastructure for relevant sectors such as energy, and transport, etc.

7.1 Construction sector GHG emissions and projections

Buildings are responsible for more than one third of total energy use and associated GHG emissions worldwide, when their full lifecycle (material extraction, construction, use and demolition) is taken into account (UNEP, 2006). The GHGs emitted in the production of construction materials can contribute up to 25% of a building's lifetime carbon footprint (Construction Industry Council, 2012). Low-carbon construction materials therefore play a large role in minimising GHG emissions in the construction sector. The energy required to operate buildings – lighting and heating predominantly – is the primary source of GHG emissions from the construction sector in urban SSA. In fact, energy used in buildings is estimated at 56% of the total national electricity consumption (Kitio, 2013). Residential buildings use the vast majority of final thermal energy consumption (IPCC, 2014), making the discussion of biomass earlier in this report equally important here.

Globally, changes in construction methods are expected to account for a ~29% reduction in GHG emissions in the residential and commercial buildings sector by 2020. With the rapid economic growth and urbanisation of SSA, CO_2 emissions from the building sector are – conversely – expected to increase at the rate of 2.4% between 2004 and 2030 (IPCC, 2007b).

As buildings are long-lived, action to incentivise the uptake of best available appliances, equipment and systems is fundamental to ensuring SSA's progress from the outset along a pathway to low-carbon economic growth (see Figure 22). 'With buildings in some countries lasting well over 100 years and [being] expensive to retrofit, urgent action is needed to ensure that high-performance building envelopes rapidly gain market share and quickly become the standard for all new construction globally' (IEA, 2013, p. 4).

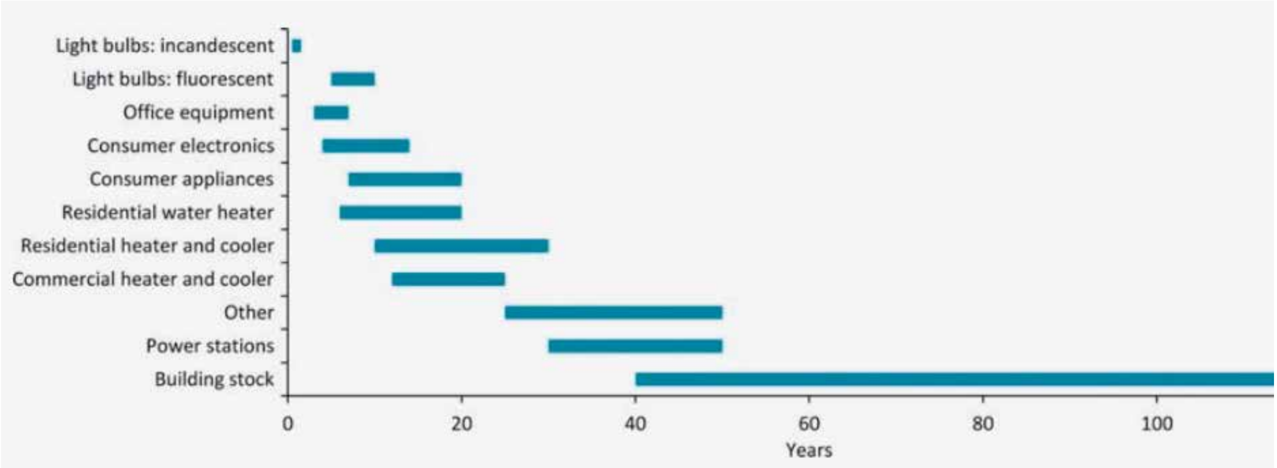
7.2 Key assets and processes in the construction sector

GHG emissions can be reduced along the entirety of the construction sector value chain, from planning (see chapter 5), to materials and end use. The most important assets and processes to consider in the transition to a low-carbon construction sector are therefore (1) the building materials and their application; and (2) the operation of the buildings once constructed. This section outlines the opportunities to reduce emission across these assets and processes.

7.2.1 Construction materials

Cement and steel are among the most popular construction materials but their production is very GHG-intensive (see chapter 8). In contrast, the use of more traditional materials, such as earth / clay bricks, local timber, straw, stone/rock and thatch can often have much lower

Figure 22: Economic life spans of energy-consuming equipment and infrastructure



Source: IEA 2013, p. 28.

embodied energy[33] but require different design and skills to take each material's specific characteristics into account (Ejiga, Paul & Osasona, 2012). Although not applicable to all aspects of construction (i.e. transport or energy infrastructure), some architects are seeking to use traditional building materials for residential houses in SSA. Compressed earth blocks are one example, where traditional adobe bricks are mixed with small amounts of cement or limestone as a less energy-intensive alternative to cement blocks (Ejiga et al., 2012).

The energy expended to produce construction materials varies greatly, particularly when comparing new, reused and recycled materials. Using reused or recycled materials can greatly reduce the embodied energy of building materials. Reusing entire buildings by retrofitting, rather than demolishing and constructing from new, almost always results in lower energy use and GHG emissions. Prefabricated materials are particularly appropriate for reuse if they are originally designed and constructed with a subsequent use in mind (Rauland & Newman, 2015), currently not often the case. Different new materials also have different levels of embodied energy: for instance, 'wood-based wall systems entail 10-20% less embodied energy than traditional concrete systems and concrete-framed buildings entail less embodied energy than steel-framed buildings' (IPCC, 2014, p. 694). If building materials are made by factories using renewable energy sources, this also reduces their embodied energy (Rauland & Newman, 2015).

Where materials are produced can have a big impact on lifecycle emissions of construction materials (Rauland & Newman, 2015). Large-scale, centralised production of building materials necessitates transportation of raw materials and end products over potentially long distances. Where there is potential to extract and manufacture building materials locally (more often the case with 'traditional' materials), this can contribute to reducing GHG emissions and increasing the positive impact of the construction sector on local economies. Local-level production of building materials can facilitate a more balanced distribution of wealth and employment across regions (du Plessis, 2002).

Several new building materials and techniques have been developed to improve energy efficiency in the operation of buildings. This includes products combining two elements into one, reducing the quantity of materials needed, such as house cladding that includes a weather-resistant barrier or tinted glass windows integrating solar PV technology (The Economist, 2015). Other examples of efficiency improvements include new insulation materials and techniques, high-reflectivity building materials and multiple glazing. Many of these materials and techniques are already commercially available in SSA (Goswami, Dasgupta & Nanda, 2009). While these materials may carry greater embodied energy than conventional materials, due to more complicated manufacturing processes, the total lifecycle energy use of low-energy buildings that adopt these energy efficient materials remains lower than conventional buildings (IPCC, 2014).

7.2.2 Building operations

Reducing buildings' consumption of energy can be achieved through a variety of proven and accessible methods. These include improved energy management systems (air-conditioning, ventilation and cooling systems, heating, water heating, lighting), use of high-efficiency appliances and use of alternative energy sources, such as solar water heaters and passive solar design (IPCC, 2007b). R&D is ongoing, and could be further promoted to produce

33 Embodied energy is the energy consumed by all of the processes associated with the production of a building.

cheaper varieties of these technologies and appliances on a large scale (Goswami, Dasgupta & Nanda, 2009).

The potential for savings in energy consumption is highest for new buildings, where 75% less consumption can be achieved through effective design and operation (IPCC, 2007b). Cost savings from reduced utility bills can substantially offset costs of higher-performance construction techniques and energy efficient equipment. Cost savings are around 35-50% compared with standard buildings (and even 50-80% with more advanced approaches). It is also important to consider retrofitting existing buildings, which can routinely achieve 25-70% savings in total energy use (IPCC, 2014). High density development in urban areas can further reduce energy intensity of buildings per capita (CDKN, 2014).

Finally, the placement and orientation of the building can have a big impact on energy use, particularly for heating and cooling (IEA, 2013). Clustering buildings together to achieve 'self-shading' (as in many traditional communities), or shading using plants or roller blinds, curtains or overhangs are techniques already being used in SSA to reduce the need for air-conditioning or fans (Goswami, Dasgupta & Nanda, 2009).

The fragmented and disjointed nature of planning in SSA is a major barrier to the uptake of new construction materials and energy efficiency improvements. This discrepancy spans the different stakeholders involved throughout a building's life – architects, engineers, building systems operators, occupants, etc. (UNEP, 2006). The choice of building material, for example, is likely to be determined by the engineer, who has no stake in the ultimate efficiency of the building's operation, given that the building owners or occupants will pay the bills. Integrated planning involving all of these stakeholders is necessary to achieve a lifecycle approach to construction industry regulation, incorporating tools and instruments to reduce energy use at each stage. 'In many cases the issue is not the lack of resources, but the lack of coordination to manage them in a more efficient way' (du Plessis, 2002, p. 17).

7.3 Low-carbon transitions in the construction sector

Low-carbon productive capacity in the construction sector requires a transition towards integrated and coordinated urban planning (see chapter 5), fewer carbon-intensive building materials and techniques and reduced energy used, via energy efficiency gains.

In many sub-Saharan countries, there are no clear-cut policies or specific legislation to support sustainable construction and urban planning (du Plessis, 2002). However, the arrangement, planning and permitting of the construction sector has great implications for its GHG emissions. As mentioned in Transition 11, national land-use planning and zoning, via cross-ministerial coordination, is a primary method of improving the regulation of and links between different players in the construction sector (see chapter 5).

Transition 16: Reduce emissions from construction materials and methods

Increasing global fuel prices combined with stricter GHG mitigation policies may raise the price of energy-intensive materials, creating a business case for materials with lower embodied energy. However, in the meantime, regulations are needed to incentivise their use.

Slow uptake of more efficient building materials and techniques is founded on limited information and skills in SSA leading to potential resistance among construction stakeholders to adopting more sustainable materials and practices. A carbon labelling programme for construction materials can provide information on the GHG footprint of different building materials, promoting the use of materials with lower embodied energy. Labelling schemes could be based on those of other countries, such as the UK's Carbon Trust, the China Energy Label and Energy Star in the US (CIC 2012). International standards could also be emulated, such as the ISO 14067: Greenhouse gases (carbon footprint of products), requirements and guidelines for quantification and communication (ISO, 2013) or the LEED (Leadership in Energy and Environmental Design) certification programme. Awareness-raising campaigns for all relevant stakeholders should accompany the introduction of labelling schemes to ensure building owners, as well as engineers and construction companies, can make informed decisions on materials. Lack of information (and options) on the carbon footprint of different materials is a barrier to low-carbon choices at the consumer or building owner level.

To complement these information instruments, regulations can introduce mandates for the use of low-carbon construction materials in certain types of new or retrofitted buildings. Further information on mandates is provided in Box 9.

Economic incentives are important for steering construction projects to use best practice methods or energy-saving materials, particularly where initial costs are higher than conventional alternatives. Tax exemptions, grants or funding schemes can provide important support for the initial adoption of low-carbon construction materials (CIC, 2012). Through preferential procurement policies, such as tender evaluation criteria related to the carbon footprint of construction materials, governments can 'lead by example' in adopting sustainable construction practices (du Plessis, 2002). Procurement processes in some countries are linked to BREEAM (Building Research Establishment Environmental Assessment Method) or LEED certification programmes, with all government procurement required to achieve a minimum standard (e.g. 'silver' LEED certification) (Canadian Green Building Council, 2013).

Transition 17: Reduce emissions from buildings

As discussed earlier, reducing energy consumption in buildings is one of the largest and most promising opportunities to achieve low-carbon infrastructure.

Moreover, improving energy efficiency in buildings would likely provide some benefits for economic growth through efficiency gains, however the benefits would accrue primarily to the higher income segments of the population that can afford efficient materials and technologies. This transition includes primarily (1) improving building efficiency and (2) switching to renewable energy generation within buildings (see also chapter 4), as well as changing behaviour (IPCC, 2007b). Possible policy options to achieve these transitions are explored below.

As with construction materials, limited information and skills surrounding energy efficiency measures have limited uptake in SSA. Mandatory, often government-subsidized energy audits promote the uptake of energy efficiency measures in existing buildings. They provide detailed and tailored information on current energy performance and identify areas of potential energy savings that will save money through reduced energy payments (Kitio, 2013; UNEP, 2007). This provision of information is key to raising awareness among SSA builders and owners, and to motivating the uptake of energy efficiency measures. Inspections or follow-up audits confirming the adoption of audit recommendations are particularly important to the success of these types of programmes.

For new buildings or retrofits of existing buildings, a UNEP study found building codes to be the most effective regulatory instrument in achieving improved energy efficiency. Mandatory building codes specifically are necessary to overcome the split incentives of the construction sector (between costs to builders and architects vs. those to owners and tenants) (IPCC, 2007a). Reforms to national building codes, based on sustainability criteria including minimum energy performance or renewable energy use, can spur installation of energy efficient and renewable energy technologies. An example is the requirement for solar water heating of public buildings in Kenya (see Box 9) (Martinat et al., 2011). Additional incentives can motivate exceedance of the building code and may include permits for larger site locations or reduced tax rates for more efficient building designs (UNEP, 2009).

Energy efficiency and renewable energy building standards are most effective when regularly updated against international standards, given the rapid technological innovation in these sectors (UNEP, 2009). There are a number of international standards assessing the environmental impact of buildings; BREEAM and LEED are two of the most dominant. Both use a points system based on sustainability criteria that attract points when adhered to by the building (Rauland & Newman, 2015).

SSA tends to suffer from limited enforcement of existing standards in the construction sector, rendering regulation ineffective and leading to ad hoc construction (Ahmed, Hatira & Valva, 2014). The success of building codes is highly dependent on enforcement and transparency in construction. To improve enforcement, capacities should be strengthened within existing planning and zoning rules and building permit approvals, as part of any new building code introduction. While it can be much easier to monitor new buildings (through the permit approval process) than existing buildings (where renovations can be more easily undertaken without approval), it will take longer to see the impact of policies on GHG emissions if only focusing on new buildings (UNEP, 2009).

Voluntary building code schemes, such as the Green Star Building Rating System in Ghana, can be particularly useful in the SSA context. They allow a transformation to more efficient building practices over time, often transforming into mandatory codes after a few years. This allows stakeholders time to adapt their behaviours and processes to meet new requirements.

Energy efficient technologies and upgrades, as well as generation of renewable energy in buildings' systems, may

Box 9: Legal mandates for building standards and energy audits in Kenya

The Kenyan Government has enacted regulations of the Energy Act 2006 to enhance use of solar thermal energy technologies within new buildings and to establish compulsory energy audits.

The Energy (Solar Water Heating) Regulations 2012 require all buildings with hot water requirements of a capacity exceeding 100 litres per day to install and use solar heating systems. Moreover, any new buildings and extensions or alterations of premises must incorporate solar water heating systems. The solar equipment must be of a high quality and all materials must meet the Kenya Standards, as established in the Standards Act. The regulations also require that businesses installing solar hot water systems are licensed by the Energy Regulatory Commission (ERC). As a result, specific solar courses are already appearing in Kenya at higher education centres such as Strathmore University's Centre for Energy Research (Strathmore University, 2014). This is particularly important in Kenya where solar technology skills and expertise are primarily brought in from outside the country.

Three-yearly energy audits are compulsory for factories, commercial buildings, institutional buildings and local authorities within Kenya. The organisation undergoing review must demonstrate that it has undertaken at least 50% of the recommendations outlined in the energy audit during the subsequent inspection by the ERC. The Energy Act 2006 also establishes an institutional framework for the licensing of energy auditors. As a result, organisations such as the Kenya Association of Manufacturers (KAM), the Centre for Energy Efficiency and Conservation (CEEC) and the Kenya National Cleaner Production Centre (KNCPC) are undertaking audits and promoting the adoption of innovative tools for energy management.

involve higher upfront costs than construction stakeholders are able or willing to pay. Therefore, fiscal incentives to drive down the costs of low-carbon options are an important complement to building codes and mandates.

As SSA consumers' incomes increase, use of electricity also increases. In buildings, this becomes particularly apparent through growing numbers of appliances, which lead growth in building energy consumption in OECD countries (UNEP, 2009). Energy efficient appliances can be promoted through appliance standards combined with mandatory labelling programmes for energy-using products. These can include lighting, heating and cooling equipment, personal computers, televisions and white goods. Appliance standards are among the most cost-effective instruments in reducing energy consumption in the operation of buildings (UNEP, 2009), if accompanied by effective, informative consumer communication campaigns. In 2011, for example, Nigeria announced the implementation of minimum energy performance standards for appliances and industrial equipment as part of the GEF-UNDP energy efficiency programme (Federal Republic of Nigeria, 2013). To be most effective, standards need to be updated periodically to continue providing incentives for further improvement. To further promote energy efficient appliances, governments may reduce import tax or VAT on efficient equipment (UNEP, 2009). Mandated energy efficiency standards of appliances can also drive domestic markets for their manufacture and production (see chapter 8).

Finally, if energy prices reflect real costs, rather than subsidized prices, efficiency and renewable energy investments become more profitable. Therefore, a phase-out of subsidies for fossil fuel consumption is often an important precondition to the success of other energy efficiency policies. These include those in the construction sector (see chapter 5 for a further discussion of reform to fossil fuel consumption subsidies).

8. Manufacturing

SSA has a small and stagnant manufacturing sector. The sector contributes the same percentage to SSA's GDP today (about 8%), as it did in the 1970s (Dinh et al., 2012). The region's share of global manufacturing has decreased over the past 20 years, from 2 to 1%, in comparison to developing countries more generally where it doubled between 1992 and 2012 to almost 35% (UNIDO, 2013).

As explained in the introduction, SSA runs counter to the expected pattern of productivity-enhancing structural change that tends to accompany economic growth. (Altenburg & Melia, 2014). Increasing the share of manufacturing could provide much-needed high-productivity jobs to SSA's growing working-age population, in contrast to the low-productivity smallholder agricultural sector still employing 65% of SSA's workforce (Dinh et al., 2012; Garcia-Verdu, Thomas & Wakeman-Linn, 2012; Altenburg & Melia, 2014). SSA's underutilised labour force provides an opportunity for comparative advantage in labour-intensive forms of production. This could be a significant advantage if capital-intensive forms of production, such as extractives (see chapter 6), become less competitive through future increases in energy prices and tighter restrictions on GHG emissions (Ellis et al., 2013). Historically, governments have used industrial policy tools to facilitate structural transformation from resources (extractives and agriculture) towards manufacturing and service-based economic structures. This structural transformation towards manufacturing and services, and away from extractives, would be likely to have material GHG emissions implications for SSA (see Altenburg & Melia, 2014).

For the purposes of low-carbon development, it is useful to split manufacturing industries into light and heavy, as the former has a far lower carbon footprint than the latter (UNDP, 2000). Light manufacturing in SSA includes the production of food and beverages (as part of wider agri-business), apparel and textiles, some chemical products, wood products, fabricated metal products, furniture and leather products among others (see Table 6) (Dinh et al., 2012; Scott et al., 2014; Xiaoyang, 2014). The light manufacturing sector in SSA is characterised by many micro, small and medium enterprises (MSMEs) that often work in the informal sector and local markets (Wroblewski & Wolff, 2010). Out of the 11.3 million MSMEs in SSA, the light manufacturing sector MSMEs represent 23% (IFC, 2013).

Heavy manufacturing in SSA is dominated by cement and petrochemical industries in Nigeria and aluminium smelting in Mozambique, all of which are very energy intensive (IEA, 2014). It is dominated by a few large firms, many of which are foreign-owned (Wroblewski & Wolff, 2010).

SSA is projected to increase its global share of manufacturing, although the timeframe and speed remain debated. The recent increase in wage levels in Asia could push up to 85 million manufacturing jobs out of China alone (Lin, 2011; Wiggins & Keats, 2014) and the right skill base development could potentially make manufacturing in SSA more globally competitive (Garcia-Verdu, Alun & Wakeman-Linn, 2012). Growing trade with the BRICS could help to drive this growth, with BRICs potentially outsourcing low-value manufacturing to labour-intensive countries in SSA (Ellis et al., 2013). Regarding light manufacturing, domestic demand for textiles, garments, leather goods and processed agricultural products may also grow along with the middle class in a number of the larger African economies (McKinsey & Co., 2010).

Looking at heavy manufacturing, growth in oil and gas production in SSA (see chapter 5) is likely to catalyse growth in the petrochemical industry under a business-as-usual scenario. Increased urbanisation is set to spur increased cement, steel and aluminium production for use in construction (see chapter 7). Although SSA accounts for only a very small part of global demand for these metals, demand is increasing. Steel demand, for example, grew by 4.5% between 2000 and 2007 in Africa (UNECA, 2011b).

Table 6: Location of light manufacturing sectors in SSA

Light manufacturing sector	Primary producer countries
Apparel and textile industries	Burkina Faso, Botswana, Chad, Ethiopia, Ghana, Lesotho, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Swaziland, Tanzania, Zambia, and Zimbabwe
Leather industry	Ethiopia, Nigeria, Zimbabwe, Zambia, Tanzania, Kenya, and Uganda
Wood products	Democratic Republic of Congo, Congo, Cote d'Ivoire, Cameroon, Central African Republic, Ethiopia, Gabon, Ghana, Nigeria and Swaziland
Agri-business	Throughout SSA

Source: FAO, 2013b; Trademap, 2015.

8.1 Manufacturing sector GHG emissions and projections

Emissions from the manufacturing sector are predominantly from energy consumption – either directly at an industrial facility, or through the use of fossil fuel-based electricity (see chapter 4). Process-oriented GHG emissions from production of cement, chemicals and other metals and from waste also contribute to the manufacturing industries' total emissions (IEA, 2007).

Although emissions data is sparse for SSA, WRI's Climate Analysis Indicators Tool suggests GHGs from industrial processes and energy use by the manufacturing sector only contributed 1% of global GHG emissions in this sector (although for many countries, no emissions data is recorded). The majority of these emissions are in Nigeria, Kenya, Angola, Sudan, Ghana and Ethiopia (WRI, 2014b).

IPCC projections suggest that SSA's contribution to global manufacturing GHGs will rise, but remain dwarfed by emissions from developing Asia (see Figure 23). Historically, increases in population, value added per capita, energy intensity and emissions intensity were correlated with GHG emission increases from the manufacturing sector in developed countries (Blockstein & Wiegman, 2012).[34] This trend is expected to emerge in SSA in a business-as-usual scenario, particularly if electricity is emissions-intensive (IPCC, 2014). For example, the electricity for aluminium production in Mozambique – which is responsible for 45% of the electricity consumed in Mozambique (Tran, 2013) – comes predominantly from coal-based South African plants (Justiça Ambiental and International Rivers Network, 2006). If there is increased renewable electricity generation, however (as advocated in Section 4), a cross-sectoral win-win situation could be created: growth in manufacturing achieved with a lower climate impact.

8.2 Key assets and processes in the manufacturing sector

While manufacturing has clearly played an important role in structural transformations in industrialised countries across the globe, achieving this in light of low-carbon objectives is an additional challenge. Growth of a manufacturing sector in resource-rich countries may reduce macroeconomic reliance on extractive revenues (see Box 7) and could support a less resource-intensive economy. This may particularly be the case if light manufacturing (and services) could be promoted to achieve a structural transformation without traditional reliance on heavy manufacturing industries. A detailed analysis of these structural transformation questions is beyond the scope of this paper but should be considered alongside sector-based strategies for low-carbon development.

This section aims to identify the technology options available for reducing GHG emissions to the extent possible, particularly from heavy manufacturing industries. In fact, it is useful to consider light and heavy manufacturing as distinct industries. The most important assets and processes to manage in the manufacturing sector include (1) energy-intensive technologies and processes in heavy manufacturing, (2) fuels used in heavy and light manufacturing and (3) the product mix.

8.2.1 Technologies and processes (in heavy manufacturing)

Looking at heavy manufacturing, large investments in cement, petrochemicals, steel and aluminium could lock economies into emissions-intensive infrastructure for decades. The average lifespan of a plant is 20-30 years (McKinsey & Co., 2009) but can be longer than 60 years or more (IRENA, 2014). Historic data trends show that low-income countries' heavy manufacturing sectors have greater energy intensity (energy consumption to GDP ratio) than those in developed countries. This is because they tend to be dominated by more energy-intensive industries, energy efficiency is poor, technology is out-of-date and low-quality fuels are used (Scott, 2011). However, developing countries' comparative advantage in manufacturing is their large labour force.

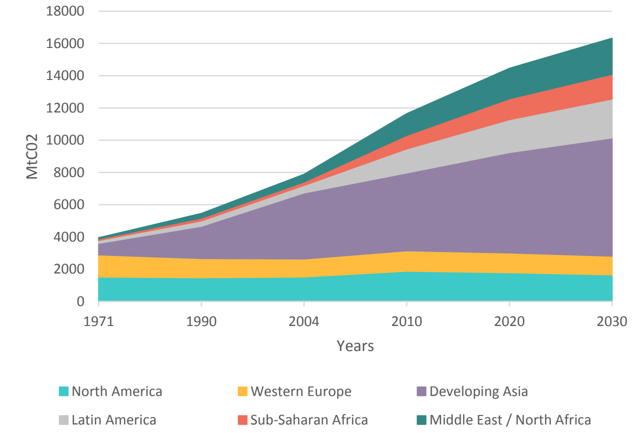
Recent improvements in energy efficiency have led to decreasing GHG emissions from the manufacturing sector in developed countries (UNIDO, 2013). If SSA can build these improvements in efficiency into its manufacturing sector as it expands, it can limit the growth of its GHG emissions from the commencement of industrialisation (IPCC, 2014). Greater efficiency (resulting in lower energy and production prices) can also be a key factor in heavy manufacturing industries' competitiveness (Cantore, 2011; UNIDO, 2013). Higher output can be achieved without requiring greater energy supply, particularly important in regions where electricity and energy supply can be constrained, as in many countries of SSA.

There are many opportunities to adopt energy-efficient technologies in heavy manufacturing (Carbon Trust, 2015). In the cement industry, for example, fuel emissions account for 40% of total GHG emissions and can be reduced through improving energy efficiency in clinker production. In the iron and steel sector, improved heat and energy recovery from process gases and waste streams, improved fuel delivery though coal injection and improved furnace design and process controls can all improve the industries' energy efficiency (Bourgouin, 2014).

Cogeneration, or combined heat and power, can improve energy efficiency across a range of manufacturing industries, including petro-chemicals, metal, oil refining,

34 In 2012, direct industrial greenhouse gas emissions accounted for approximately 20% of total US GHG emissions, making it the third largest contributor after the Electricity and Transportation sectors. If both direct and indirect emissions associated with electricity use are included, industry's share of total US GHG emissions in 2012 was 28%, making it the second largest contributor of any sector, just after transportation. (US EPA).

Figure 23: Industrial sector energy-related CO2 emissions (up to 2004) and projected emissions, based on SRES Scenarios (up to 2030)



Source: IPCC 2007, ch. 7.1.3.

pulp and paper, and food processing. Cogeneration combines technologies to concurrently generate electricity and heat more efficiently than two separate heat and power processes; cogeneration systems can reach efficiency levels of 80% (C2ES, 2011).

8.2.2 Fuels used in heavy and light manufacturing

Changing or substituting energy sources used to power and heat manufacturing processes and plants presents a second opportunity to decarbonise the SSA heavy manufacturing sector.

Biomass (from agricultural residue) offers the main renewable energy opportunity for heavy manufacturing. It can be used to produce process heat (via steam and direct heat), including very high temperatures. In the absence of low-cost energy storage, biomass is the primary source of renewable energy available as a continuous source for heat production and can therefore be more easily integrated into existing manufacturing plants and production processes (IRENA, 2014).[35] However, decomposition of certain agricultural residues improves the fertility of the soil and their removal for energy use could deplete important nutrients from agricultural lands. The choice of agricultural residues for biomass energy should therefore be based on their importance to soil health. Some residues such as cotton shells, risk husks, and coffee pruning do not decompose easily and could be prioritised, for example (Ravindranath & Rao, 2005).

Biomass waste streams from light manufacturing industries such as food, textile and wood processing can be used effectively to meet their energy demand (IRENA, 2014). Indeed, this renewable energy source holds a particular opportunity as the disposal of biomass waste by burning is a common practice (Whitley & Tumushabe, 2014). Taking the food industry as an example, 'in the African sugar industry, "optimising the bagasse by-product for co-generation facilities can meet all the required energy demand and provide electricity for export. In the dairy sector, larger facilities with feeding sheds may be able to meet all their fuel demand with biogas from manure"' (IRENA, 2014, p. 27) (see Box 10).

The cement industry, in particular, can reduce emissions through fuel switching. According to research by IRENA, up to 40% of fossil fuel use in the cement sector could be substituted with biomass (IRENA, 2014). For example, in Senegal, a fuel switching project using Jatropha plantations and biomass residues aims to substitute 40% of the coal burnt in kilns and expects to achieve GHG emission reductions of about 162,000 tCO2e per year. Furthermore, the wasted process heat produced during cement manufacturing can be recycled to produce electricity. The East Africa Portland Cement Company in Kenya is considering a waste heat recovery unit to generate its own electricity. Both of these projects are seeking approval under the Clean Development Mechanism (CDM) of the UN climate change convention.

For the light manufacturing industry, while MSMEs do not produce many GHGs, nor have high energy demand per plant,[36] they often have to rely on insecure electricity, with back-up diesel generators to manage power outages (Scott et al., 2014). Replacing back-up generators with renewable energy systems can provide a cheaper, and lower GHG-emitting solution (IRENA, 2014). This is especially so for high energy-intensity processes that make up a large proportion of total production costs (e.g. brick kilns, small grain and saw mills, textile factories and woodworking equipment). Nevertheless, according to a recent study by ODI (Scott et al., 2014), evidence of adoption of renewable energy technologies by SMEs remains very limited.

Fossil fuel subsidies reduce the uptake of renewable energies and thus undermine the competitiveness of these technologies (see chapters 5 and 6 and Transitions 9 and 15). There are two additional effects of subsidised energy on the manufacturing industry in SSA. First, under-pricing of energy has led to a cycle of under-investment in energy infrastructure, leading to poor maintenance and inadequate supply of electricity. This has a detrimental effect on the competitiveness and efficiency of manufacturing firms. As discussed earlier, firms in SSA are forced to spend considerable amounts to generate their own electricity, in order to deal with intermittent power supply and shortages.

Second, the development of large-scale heavy manufacturing in many SSA countries is predicated on 'cheap' energy for manufacturing consumers. Fossil fuel subsidies promote energy overconsumption and undermine efficiency (Whitley & van der Burg, forthcoming). However, governments keep electricity tariffs artificially low, in order to attract investment in heavy manufacturing. An example is aluminium-smelting industries in Cameroon and Ghana, where low, subsidized energy prices were offered as a temporary policy to attract energy intensive manufacturing. However, due to entrenched and politically-influential interest groups, these subsidies

Box 10: Biomass for thermal energy in Uganda's sugar manufacturing industry

The two largest biomass power projects in Uganda are bagasse co-generation projects linked to sugar production and manufacturing. Self-generation of thermal energy with biomass is particularly appropriate for sugar factories in Uganda as they have an abundant supply of free fuel (the by-products of sugar manufacturing). Sugar production needs substantial quantities of steam and electricity, thereby requiring high energy payments if using grid-connected sources of electricity. In addition, the economies of scale are substantial and 'a steam turbine/boiler that can export electricity to a utility is only marginally more costly than one that is sufficient only to meet the factory's own demand' (Whitley & Tumushabe, 2014, p. 39). Therefore, the factors that influenced the use of bagasse-generated energy to export to the grid included: having sufficiently large production of cane to provide a surplus; connection to the grid; and energy policy that provides stable prices to enable companies to take the decision to invest in a new boiler.

continued, locking in these extremely costly and highly GHG-emitting arrangements and reducing possible revenue from this heavy manufacturing industry (IMF, 2013). In Cameroon, the aluminium industry has contributed relatively little to the economy, providing fewer than 600 jobs and only contributing 2.8% of total government revenues between 2001 and 2006, before the cost of energy subsidies are deducted (Klemm, 2015).

8.2.3 Product mix (heavy to light, and low-carbon)

Light manufacturing industries are already less energy-intensive than heavy industries and contribute significantly to SSA's employment opportunities (IRENA, 2014). Policies to motivate a shift towards low-carbon products could also build a market for SSA light manufacturing industries. Such sectors are in a prime position to profit from expected growth in local and global consumer demand, due to growing awareness of climate change and increasing energy prices. However, knowledge, skills and awareness of technical requirements and markets for low-carbon products is low, particularly among MSMEs. Thus, workers' skills must be adapted and manufacturing MSMEs educated to take advantage of the changing demand.

Manufactured products that are more energy or water efficient in utilisation, as well as the equipment and infrastructure to produce them, can translate into labour demand and job creation in emerging green sectors (UNEP, 2015; UNIDO, 2013). Examples of such green products may include: waste-to-energy techniques that can be used to convert agricultural residues (and other forms of waste) into fuel products (such as briquettes); agri-processing based on climate-smart agriculture harvests (see chapter 2); power-saving light bulbs; biodegradable cleaning products; natural paints; certified products from sustainable forests such as paper, furniture and building materials (see chapter 3); energy storage and demand-side management technologies; manufacturing equipment for renewable energy such as wind turbines and solar panels (see chapter 4); and products to improve climate change adaptation or resilience (such as water storage tanks, drip irrigation systems, etc.) (Ellis, 2013; UNIDO and UNCTAD, 2011).

One example of the potential for the production of low-carbon products is the vehicle manufacturing industry. There is nascent interest in building a vehicle manufacturing and assembly industry in SSA. Honda, for example, has recently begun manufacturing motorcycles in Nigeria and Kenya (Kyodo, 2013), while General Motors leads a joint venture in Kenya manufacturing trucks and buses. Other international manufacturers are following suit (IEA, 2014). This could be an opportunity for SSA countries to negotiate a focus on production of hybrid and electric cars and motorbikes, over standard diesel or petrol vehicles.

8.3 Low-carbon transitions in the manufacturing sector

As the manufacturing industry grows in SSA, significant investments will take place. It is important that investment favours low-carbon productive growth over emissions-intensive investments that lock countries into unsustainable GHG emissions. For the manufacturing industry, this requires increasing the uptake of energy efficiency processes and renewable energy technology, and supporting the market for low-carbon products.

Transition 18: Increase the use of energy efficient processes and technologies and clean energy in heavy manufacturing

The adoption of energy efficient technologies in heavy manufacturing is hampered by a combination of factors. These include insufficient information available to manufacturers and financiers, energy consumption subsidies, the perceived risk in adopting new technologies and limited access to capital (Ellis, 2013). The policies available to overcome these barriers include:

- Regulatory tools, such as technical standards imposing GHG emission limits and energy efficiency standards

35 Ground source, geothermal heat pumps also provide a continuous source of thermal energy but uptake remains limited in sub-Saharan Africa to date.

36 Basic woodworking and construction equipment ranges in power from around 750-1200 W while the energy demand of agro-processing enterprises is frequently above 10 kW (Hogarth and Granoff, 2015).

Box 11: Growth of Nigeria's cement industry

Nigeria's cement industry provides a case study of the prospects for growth in heavy manufacturing, as well as new approaches for GHG emission reductions. Local Nigerian cement production was in decline from the 1980s to 2002. In 2002, a national backward integration policy (BIP) was introduced, requiring cement import licences to be allocated only to those showing proof of owning factories for domestic cement manufacturing (Mojekwu, Idowu & Sode, 2013). Before BIP, Nigeria's installed capacity of cement production was 4.03 million metric tonnes per annum (MMTPA) but it was producing only 2 MMTPA. Ten years after the implementation of the BIP, the country now produces 28 MMTPA with a total installed production capacity of 45 MMTPA. An additional 14 cement production plants of various capacities are under construction (Ohimain, 2014). This supply is matched by rising demand for cement, as well as rising GHG emissions.

The environmental regulations of the industry are light, and new plants are not always built to high standards of energy efficiency. Particularly high levels of sulphur dioxide (SO_2) are permitted in Nigeria (2000mg/Nm^3), compared to the industry best-practice in Germany of 50mg/Nm^3. The same trend can be seen for nitrogen oxide (NOx): most countries' national limits for this pollutant are in the region of 500-1000mg/Nm^3 but Nigeria has a limit of 1200Nm^3 for old plants. In a move towards more stringent environmental regulation, the standard decreases to 600-800Nm^3 for new plants (dependent on fuel) (Edwards, 2014).

Foreseeing a global GHG mitigation agreement and increases in energy prices, the extremely energy- and emissions-intensive cement industry in Nigeria will need more stringent regulation to avoid competitive disadvantage, particularly in international markets (Ellis et al., 2013). Implementation of low-carbon technologies and processes for the cement industry is already beginning in SSA and includes (1) energy efficiency, (2) waste heat recovery, (3) fuel switching with biomass and (4) clinker substitution with alternative raw materials.

Lafarge Cement – one of the largest multinational cement producers and owner of 14 cement facilities in SSA – is implementing a project at the Shagamu and Ewekoro cement plants in southwest Nigeria to manufacture and sell a new type of blended cement to gradually reduce clinker content. The chemical reaction during clinker processing is one of the most energy-intensive elements of the cement manufacturing process. The project to reduce the clinker content is expected to reduce emission reductions for these two plants by 1,324,140 tonnes CO_2 per year. Moreover, Lafarge is working with the Nigerian Government to introduce a new blended cement standard that could be used by other cement plants.

- Informational instruments, such as energy audits that identify energy saving opportunities

The regulatory tools with the widest impact are often industry-wide technical norms and standards that impose maximum emission limits, ideally in line with international standards (see Box 11). These regulations can push companies to adopt more efficient technologies, as well as fuel switching opportunities, and level the playing field between companies. Standards set to international requirements are particularly important for industries seeking export opportunities or those exposed to the price of imported inputs. Such industries are exposed to global price fluctuations, which can be moderated through reduced demand for energy. It is very likely that, over time, emphasis on environmental standards, carbon footprinting and associated certification down the manufacturing supply chain will increase (Ellis, 2013). If an industry does not meet international standards, access to markets will be reduced. These barriers may become manifest in border tax adjustments (see chapter 10) or other trade restrictions. If effectively communicated to manufacturing businesses, this business case provides an important financial incentive to adhere to sustainability standards.

Energy efficiency standards can be complemented with mandatory or voluntary energy audits and assessments to support manufacturing firms in identifying and adopting energy efficiency opportunities. As mentioned in chapter 7, audits should be accompanied by inspections or follow-up audits, to increase the likelihood of approach and technology adoption. Moreover, the adoption and adaptation of such technologies can be maximised through training and raising awareness of manufacturing enterprises (Ellis, 2013). Kenya provides a positive example of the impact of energy audits (see Box 9). More than 200 companies were audited between the adoption of the Energy Act in 2006 and 2013 with potential savings of over $100 million identified. The uptake of identified energy efficiency measures by businesses has been fairly high and the manufacturing industry has been particularly responsive. Some have already demonstrated considerable energy savings; for example Spin Knit Limited has reduced its fuel consumption by 41.29% and achieved a cumulative return on investment of over $40,000 (Ellis, 2013). Other instruments that can support adoption of efficient processes and equipment include well-designed fiscal policies, including tax exemptions or credits, and the use of financial instruments, such as grants, that can reduce the upfront costs of more efficient technologies.

Connecting economic activities can bring further value added and emissions reductions, by co-locating multiple elements of the value chain and lessening the distances between each step (raw materials, manufacturing, supply chains, market access and trade) (NCE 2014). Co-locating different types of manufacturing industries (in manufacturing 'clusters') can help mitigate emissions through innovative sharing processes: 'for example, the cement industry could use urban biomass waste in some of its products and urban areas could use industrial exhaust for heating' (CDKN, 2014, p. 59).

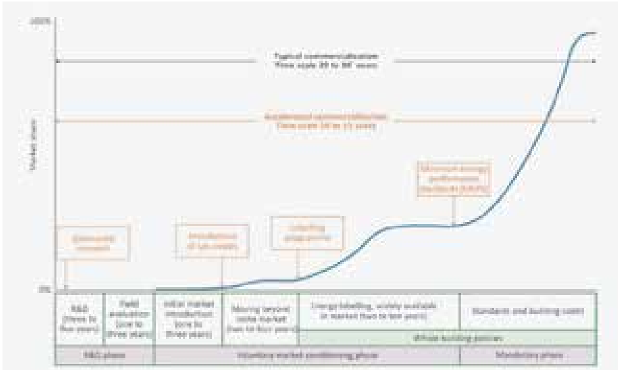
Transition 19: Drive growth in light manufacturing

Growth driven by light manufacturing promises to be lower-carbon than that driven by heavy industry. However, growth by light manufacturing enterprises is hampered by a lack of of access to markets, skilled labour and capital. Providing MSMEs in the light manufacturing sector with better access to financing sources has the potential to strengthen and accelerate growth in these highly-productive and low-carbon employers (AfDB, 2013). Policy changes or interventions focused on increasing access to capital include public financing, loan guarantees and information and demonstration programmes to provide domestic banks with information about the financial returns available from lower-carbon industries (Ellis, 2013).

Given the high degree of informal employment in MSME manufacturing firms, an additional challenge for SSA will be including these informal companies in the development and production of low-carbon products. Linking businesses in the informal sector to those in the formal sector can be promoted through manufacturing clusters, as above (McMillan, 2014). Such activity can also lead to knowledge transfer. Local content requirements and rules for (low-carbon) technology transfer from foreign direct investment can fast-track adoption by SSA manufacturers of more energy-efficient technologies and production processes (Ellis et al., 2013). The promotion of manufacturing clusters may need to be linked to supplier development programmes to ensure that local supply chains of a sufficient quality exist and can be tapped by foreign investments. Co-location of education institutions (technical/vocational colleges and business schools) and thus skilled labour should also be considered for the scale-up potential for MSMEs (Altenburg & Melia, 2014)

Clustering manufacturing companies can enable amalgamation of resources for investment in renewable energy technologies that can be shared. If strategically located by appropriate renewable energy sources, industrial parks can be important vehicles for renewable energy resource expansion (IRENA, 2014). Resources saved or generated through the removal of fuel subsidies could also be used to invest in these industrial parks, specifically in providing fiscal incentives for renewable energy power generation.

Figure 24: Tools to accelerate the low-carbon product commercialisation path



Source: IEA, 2013, p. 220.
** Note that this does not necessarily take into account conditions in many sub-sectors of the manufacturing sector in sub-Saharan African countries which involve significant levels of informal activity.*

Transition 20: Grow the market for low-carbon products

The adoption of nationwide standards for energy efficiency can drive markets in low-carbon products, such as lightbulbs, heating and cooling equipment, personal computers, televisions and white goods. Combined with mandatory labelling programmes and widespread information campaigns, the uptake of these products can be promoted to domestic consumers (see chapter 7) (see Figure 24). Equally, the demand for more fuel efficient cars can be promoted by introducing stricter fuel-economy standards (see chapter 5).

Domestically-produced low-carbon products will compete with similar products manufactured in other countries. Fiscal regulations to reduce the cost of such products, or requirements for local content in foreign investments relevant to these products and technologies, can improve domestic products' competitiveness (as long as they are in line with international trade rules, as discussed in chapter 10). For exports of manufactured products (whether low-carbon or not), SSA faces strong competition from international enterprises with more experience and established business partners. Therefore SSA governments will need to provide greater support, such as tax incentives, to exporting manufacturing firms. Special economic zones located near a seaport may also ease the costs and difficulties of export by providing good infrastructure and business-friendly regulations (Altenburg & Melia, 2014).

9. Risk of high carbon lock-in for each sector

Given the early stage of development of many of the above sectors in SSA nations, the risk of lock-in to high carbon pathways is a particularly important concern. Once polluting or resource-intensive infrastructure is built, green retrofits can often be costly or technically impossible to implement. It becomes more challenging to phase out such infrastructure before the end of its productive life cycle, creating a hard lock-in of polluting development pathways. Less tangibly, the institutions, technical knowledge, vested interests, cultural values and political lobbies surrounding incumbent industries create a soft lock-in of the status quo and, in turn, a disadvantage to innovative alternatives.

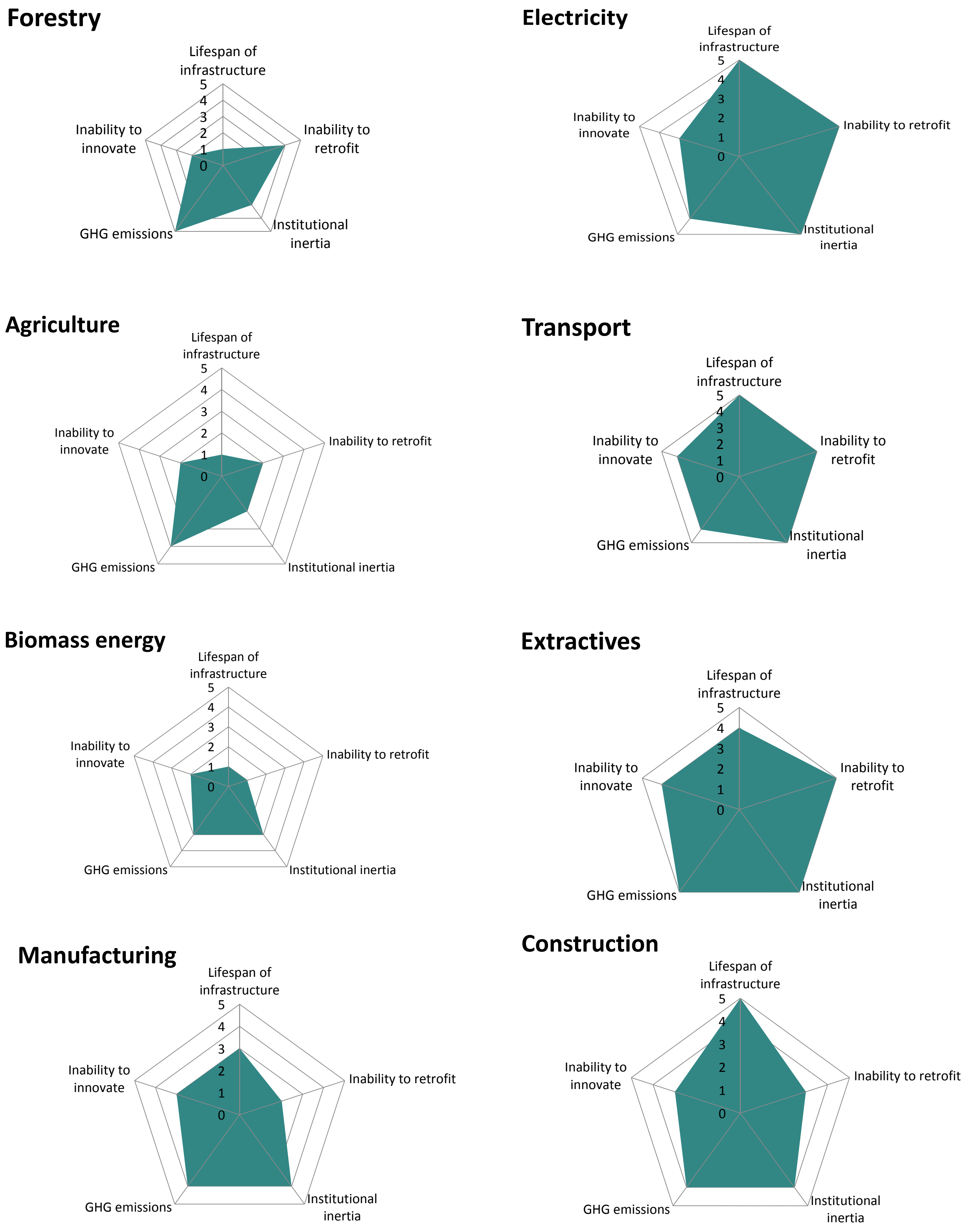
To assess the risk of lock-in to high carbon pathways in each sector, we developed a preliminary set of five criteria with scores of between zero and five, namely:

- **Lifespan of infrastructure –** How long will the infrastructure last?
- **Barriers to retrofitting infrastructure –** Can it be changed once it is built?
- **Institutional inertia –** Are there policies, vested interests, and established skill-sets that work to maintain the status quo?
- **GHG emissions –** How large are the sector's GHG emissions?
- **Barriers to innovation –** Within the sector, do there exist technological alternatives to high emitting technologies and practices, and the skill base and interest to apply those low-carbon options?

Beyond the in-depth analysis of each sector's GHG emissions discussed throughout the paper, scoring of the other criteria was based on the authors' previous experience rather than a detailed scientific method. Hence, scoring should be considered as indicative only. Further research would be required to develop a more robust method of scoring, particularly of institutional inertia and barriers to innovation.

Figure 25 presents the results of this explorative exercise. It indicates that the highest risk of lock-in exists in the energy (electricity), transport, extractives, construction and manufacturing sectors.

Figure 25: Risk of lock-in to high carbon pathways by sector



10. Role of international frameworks and finance

The sector-focused chapters above have outlined the key transitions required to build up low-carbon economic capacities and structures on a sector-by-sector basis. They have also defined the policies available to achieve each of those transitions. However, national-level transitions and policy choices sit within regional and international frameworks that will have important impacts on the success of SSA's low-carbon transitions.

This chapter outlines the range of regional and international frameworks and forms of support likely to shape low-carbon development in SSA. This is particularly important in light of SSA's ongoing dependence on donor financing and includes: the international climate change framework including technology transfer mechanisms; regional and international trade regimes and agreements (beyond the sector-specific regional cooperation identified in the previous chapters); and the existing public and private sources of capital and international finance mechanisms available to SSA countries.

10.1 United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is the primary international agreement on limiting climate change. Adopted in 1992, the Convention aims to stabilize greenhouse gas concentrations 'at a level that would prevent dangerous anthropogenic [human induced] interference with the climate system.' (UNFCCC, 1992). It is the UNFCCC that provides the international consensus and collaboration on which SSA relies to transition to a low-carbon development pathway alongside the rest of the world.

Climate change politics have shifted tremendously since the Kyoto Protocol was adopted in 1997, leading to changes in the architecture of the international climate change regime. A new structure has emerged, moving away from centrally-determined binding targets and timetables towards a decentralized approach, whereby Intended Nationally Determined Contributions (INDCs) are defined unilaterally by each sovereign state. The INDC structure allows for nuanced differentiation of commitments, based on countries' own interpretation of their capability and circumstances (economic, environmental, social, political, technological, etc.). INDCs are to be submitted to the UNFCCC in advance of the Paris climate policy negotiations in December 2015 and are meant to communicate national emission reductions plans.

There is also a shift away from requiring only developed countries to reduce GHG emissions, as was the case with the Kyoto Protocol, towards universal mitigation action. The agreement with country members of the UNFCCC at the 19th conference of the parties in 2011 requires countries: 'to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties' (UNFCCC, 2011). Nevertheless, developed countries will continue to have greater responsibility than developing and least developed countries to address climate change. This is due to countries' divergent levels of development and capacity and the differing intensity of their GHG emissions today, as well as historically (known as the principle of common but differentiated responsibility). Whether SSA countries will be bound to the mitigation and adaptation actions they propose in their INDCs remains to be seen (as opposed to developed countries who may need to adhere to different and more binding requirements) (Bodansky & Rajamani, 2015). In fact, the exact legal nature of INDCs has not yet been agreed and it remains unclear how prescriptive and binding they will be (van Asselt, 2014).

At a minimum, some form of review of INDCs is likely (whether by an independent international body or by a nationally designated body) and it is here that the international regime may provide the greatest policy support to SSA. The post-2015 international agreement, like the previous Kyoto Protocol, is likely to include modalities of centralized reporting and review. These will potentially include processes for independent review of INDCs before they are converted into final nationally determined contributions and for assessing countries' compliance with these contributions. Like the UNFCCC's current technical support and review of countries' Nationally Appropriate Mitigation Actions and National Adaptation Programmes of Action, review processes can support SSA in prioritizing and assessing their mitigation (and adaptation) activities and projects.

It is useful to note here that the UNFCCC structure is economy-wide, focused on the binary groupings of mitigation and adaptation. This is at odds with the sector-based structure of most domestic governance arrangements and institutions. It therefore poses a challenge to the effectiveness of the international regime in supporting national-level actions. This is particularly important for international climate finance, seen in section 10.4.

In more than half of the transitions detailed in chapters 2-8, adoption of low-carbon technologies is central to mitigating GHG emissions from future economic growth. The UNFCCC instructs all parties to promote and cooperate in developing, applying and transferring technologies, practices and processes that control, reduce or prevent emissions of GHGs (UNFCCC 1992, art 4.1 (c)). Developed countries are required to provide financial resources for the transfer of technology (UNFCCC 1992, art 4.3) and to 'take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly to developing countries' (UNFCCC 1992, art 4.5).

Thus far, developed countries have largely failed to provide effective transfer of low-carbon technologies in practice. Where they have, it has often been linked to promoting developed countries' own technologies and companies overseas (Ockwell, Haum, Mallet & Watson, 2010; Whitley, 2013c). While it is beyond the scope of this paper to assess the UNFCCC technology transfer mechanism in detail, barriers to its success have included: lack of political will on the part of donor countries; interest group lobbying; intellectual property rights (are low-carbon technologies public goods or commercially-in-confidence products?); lack of access to capital; substantial tariff barriers in recipient countries for imports of foreign technologies; and poor access to information in developing countries, resulting in weak foreign investment contracts that do not include technology transfer provisions (IPCC 2000).

In recognition of this failure, in 2010 the UNFCCC Conference of the Parties adopted the Technology Mechanism. This comprised the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN), with the objective of enhancing action on the development and transfer of technology (Cancun Agreement, 2010). The CTCN is particularly relevant to SSA as it provides direct operational support to developing countries that request assistance with the preparation and implementation of technology projects and strategies. The CTCN could be instrumental in helping SSA countries to develop scientific and technological capacities, to implement policies for R&D and innovation, to institutionalise technology needs assessment programmes within the national planning process,[37] and to identify and better use of existing domestic policies for technology transfer (such as FDI and procurement laws and policies) (ICTSD, 2012). Although it remains too early to tell conclusively, strong engagement by SSA policy-makers with the Technology Mechanism, and particularly the CTCN, could strengthen international technology transfer in favour of SSA's low-carbon transitions.

10.2 International trade policy

Low-carbon development in SSA will be shaped by global trade policy, which is itself changing and adapting to a carbon-constrained world (Keane, 2009). The World Trade Organisation (WTO) agreements provide the framework for global trade and commerce. The central premise of the WTO is free flow of trade. Measures to promote low-carbon transitions through domestic measures that restrict free trade can be interpreted as infringing international trade law. If carve-outs are not defined for 'climate clubs'[38] or an Environmental Goods Agreement (currently under negotiation) is not agreed, this could pose a barrier to low-carbon policy measures in SSA countries. The proposed Environmental Goods Agreement would lower barriers to market access for sustainable energy goods and services, including renewable energy and energy efficiency technologies (Sugathan, 2015).

As a result, while integration into global trade markets is seen as a necessary prerequisite for growth, international climate change mitigation policy is likely to result in shifts in comparative advantage. It may also bring about new export opportunities and risks, to which SSA will need to adapt to achieve low-carbon policy aims. For example:

- Ambitious emission reduction targets could create incentives for energy intensive industries to move to countries without or with only limited emissions reduction targets, such as many in SSA. Often termed 'carbon leakage', this situation leads to a possible trade-off between competitiveness and low-carbon growth. However, border tax adjustments are being considered in part by some developed countries to prevent this carbon leakage, which could have consequences for access to other export markets that were previously open to developing countries (Ellis, 2009) (see Box 12).
- Countries may implement new international standards that take the lifecycle of GHG emissions from production of goods into account (see Sections 4, 5, 6, 7 and 8 for discussions of sector-specific standards). This 'carbon footprinting' can potentially reduce access to markets for relatively energy-intensive products or products which are not certified. Efforts to improve

37 Since 2001, developing countries have developed Technology Needs Assessments (TNAs) for the UNFCCC. A TNA is a country-driven activity to identify and analyse the priority technology needs for mitigating and adapting to climate change and is the first step in understanding the needs for technology transfer (CTCN, 2015).

38 Climate clubs, or groupings of countries committed to more ambitious climate action than the international regime is able to agree, may be able to seek a general and permanent exception to the most-favoured nation principle under the WTO that permits trade benefits within climate clubs (Leycegui and Ramirez, 2015).

Box 12: Border tax adjustments

Given the reliance of many manufacturing sectors on foreign markets, it is important to consider the impact of a carbon-constrained future on exports. One proposal is the introduction of border tax adjustments; trade measures to 'level the playing field' between domestic producers, who are faced with costly climate change policies, and foreign producers, who are faced with fewer. The importing foreign producer would be required to pay costs equivalent to those imposed by climate policies on domestic producers. This type of trade measure could have detrimental effects on SSA countries exporting energy-intensive products, particularly in cases where a country's exports are highly concentrated in only a small number of commodities. For example, 80% of exports from Mozambique to the EU are energy-intensive (mostly aluminium but also iron, cement and paper) and 50.3% of exports from Zimbabwe to the US are also energy-intensive (mainly iron and steel but also paper and glass) (Brandi, 2010, pp. 1-3). It is important to note that border tax adjustments would be likely to include exemptions for low-income countries in the near-term. Moreover, countries with relatively low-carbon exports, which are frequently those with a supply of electricity from low-carbon sources, could experience a competitive advantage in markets with carbon border tax adjustments.

energy efficiency, including through the introduction of domestic standards or labelling adhering to international requirements, can ensure that SSA countries can take advantage of these new opportunities. At the least, such efforts will prevent their exclusion from markets (Ellis et al., 2013; Greene & Lemma, 2015).

10.3 Regional agreements

There are multiple levels of regional agreement within Africa pertaining to climate change and low-carbon development – both continent-wide and among smaller regional groups. At the African Union level, the Nairobi Declaration on the African Process to Combat Climate Change (the Nairobi Declaration) seeks to establish a comprehensive framework for climate change programmes across Africa (Scholtz & Verschuuren, 2015). This Declaration serves as the foundation for regional cooperation on climate change on the continent. At the sub-regional level, there are a number of regional economic communities aimed at the economic, social and cultural integration of member countries, namely: the Economic Community of West African States (ECOWAS); the Economic Community of Central African States (ECCAS); the Southern African Development Community (SADC); the East African Community (EAC); and the Common Market for East and Southern Africa (COMESA). Many of these regional economic communities also include climate change in their remit, with common policies dedicated to it, for example, the COMESA-EAC-SADC Climate Change Programme and the COMESA Climate Initiative. In fact, in an African Union Decision on Climate Change and Development, regional economic communities were expressly mandated to support member states' integration of climate change mitigation and adaptation measures into development strategies and programmes (AU, 2007).

While the mandate to address issues of climate change and low-carbon development may be firmly entrenched in the economic integration initiatives of the AU and regional economic communities, these same groups have been plagued historically by obstacles to achieving their aims. The ability of regional economic communities to move beyond written agreement to action has been reduced by several factors. These include overlapping membership, lack of effective coordination, lack of compatibility between national policies and regional objectives, and limited financial and human resources (Scholtz & Verschuuren, 2015). Until these barriers are addressed, regional groups may be unable to provide much support to the efforts of individual SSA governments to transform to low-carbon production.

Nonetheless, certain sectors lend themselves particularly to regional cooperation and build the case for strengthening regional bodies' ability to work together for low-carbon development aims. Existing electric power pools offer a significant opportunity to increase regional trade in electricity, with chances to exploit the enormous potential of renewable energy and hydropower resources, unencumbered by national energy demand (see chapter 4). Land-use planning also requires coordination at the regional level; watersheds, forests, national parks and animal habitats frequently cross country borders (see chapter 3). Mass transit systems, such as rail and bus networks, would benefit from regional cooperation and financing (see chapter 5). Manufacturing clusters could extend across national borders, with countries working collaboratively to provide preliminary energy and transport infrastructure to a priority group of industries (see chapter 8).

10.4 International finance for low-carbon development

There is widespread acceptance that significant increases in financial resources are needed to help countries shift to low-carbon development, both through mobilisation of additional funds and shifting of existing resources (UN High-level Advisory Group, 2010; UNFCCC, 2012). There is growing global recognition that a significant proportion of current funding for low-carbon development comes from private sector investment. There is also global acknowledgement of a critical role for public finance and public policy (domestic and international) in enabling greater investment in low-carbon development by the private sector (Buchner, Falconer, Hervé-Mignucci, Trabacchi & Brinkman, 2011; Mabey, 2012).

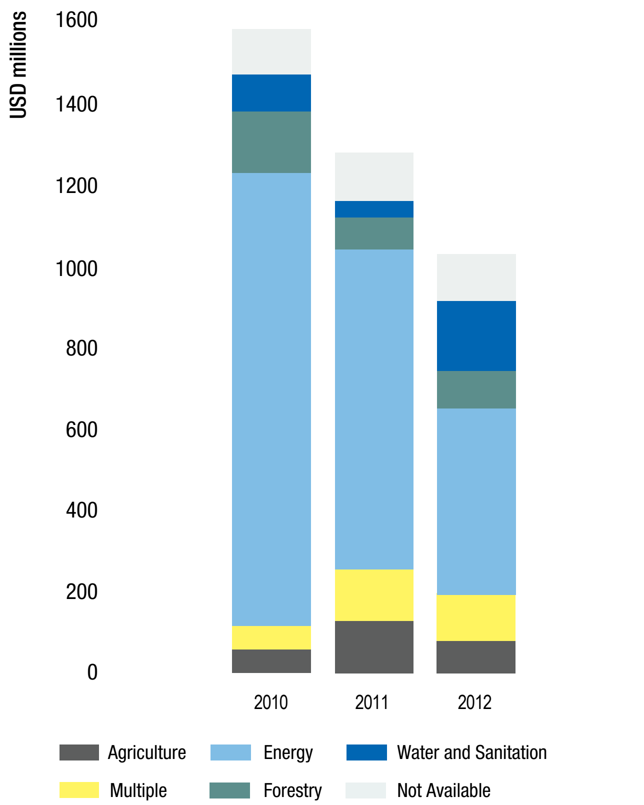
To address this financing gap, developed countries have committed to mobilising $100 billion annually. This is long-term climate finance from public and private sources to address the needs of developing countries by 2020 under the UNFCCC. However, despite this international commitment, there remains limited information available on public and private finance for low-carbon development in Africa. Without this information, it is difficult to understand to which low-carbon development transitions or sectors finance is currently being delivered, whether the level of climate finance is sufficient to achieve low-carbon aims, and which policy interventions are required to strengthen the finance architecture.

Research by ODI has begun to answer some of these questions. First, it is important to note that domestic finance makes up the majority (74%) of climate-relevant finance: it originates in the country in which it is used (Buchner et al., 2013). Even in SSA, the overwhelming majority of public expenditure on climate change is being funded domestically (Bird, 2014). For example, Ethiopia's national budgetary resources for climate change-relevant actions is estimated to be around $440 million per year, 14.5% of public expenditure from 2008-2011 (Eshetu et al., 2014). Therefore, policy changes or interventions should focus on increasing the impact of and access to these domestic sources of capital.

With regard to donor support for addressing climate change, international climate finance to SSA was $3.7 billion between 2010 and 2012 (11% of total) and the majority of support was focused on the energy sector (ODI, 2014) (see Figure 26), 14% of Joint Multilateral Development Bank (MDB) climate finance targets in SSA (incl. RSA) (EBRD, 2014).

The impact of domestic and international public finance depends largely on its ability to attract and mobilise additional domestic (and foreign) private finance to low-carbon development. Private investors in SSA may be incentivised to provide finance to low-carbon projects if the right enabling environment is in place, created by regulatory, economic and information instruments. Research by ODI has shown that public policy can most effectively mobilise private resources in SSA if a coherent package of such instruments is created around low-carbon objectives. This is opposed to isolated incentives within a broader environment unsupportive of low-carbon development. Innovative financing instruments, such as venture equity financing for businesses developing low-carbon technologies and local commercial debt to facilitate dissemination, will also be important considerations as

Figure 26: Fast-start climate finance to Africa by sector (US$ million)



Source: Whitley et al, 2014

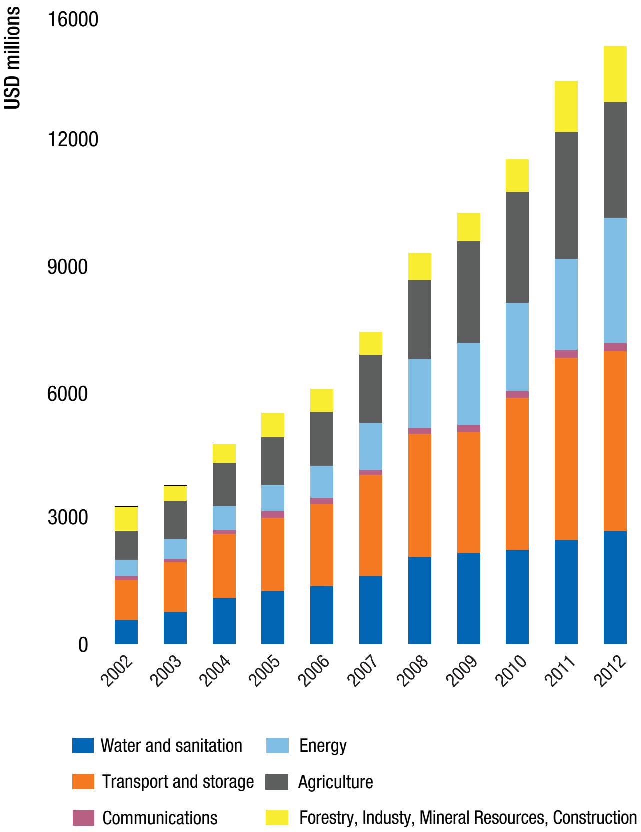
alternatives to more traditional project-level interventions. This is particularly so for smaller scale technologies (such as renewable energy systems or climate smart agriculture options)(Whitley et al, 2014).

ODI research into four donors (the US, the UK, Japan and Germany)s[39] from 2010-2012 identifies 16 interventions (projects and programmes) in all of Africa that have involved private co-financing (Whitley, 2013b). Public investment across these interventions has been almost $1.4 billion, although only $83.5 million in private co-financing is identified. The focus of support in SSA has been geothermal projects in Kenya and a number of investment funds. Investment by the private sector may be greater than this but details on transaction structures and participants are not readily available in the public domain.

While this information shows that some public and private international climate finance is reaching SSA through a variety of different channels, it is still insufficient and needs to be increased. In particular, a recent ODI report recommends a matched-funding approach to scale up international public finance for SSA (Bird, 2014).

39 This dataset can be reviewed by country, region and sector and includes over 70 donor interventions to mobilise private climate finance, representing US$8.5 billion (of which 20% comes from the private sector) (Whitley, 2013b). It excludes South–South investment, private finance mobilised by other donors and international and domestic finance relevant to climate mitigation or adaptation but not linked to donor activities.

Figure 27: ODA disbursed to Africa by climate-relevant sector (US$ million)



Source: Whitley et al, 2014

Following this approach, those countries that have an obligation to provide funding under the UNFCCC would grant public finance to the most vulnerable countries (including SSA states) equivalent to, at a minimum level, their published domestic public expenditure on climate change (Bird, 2014). Moreover, the ability of public funds to catalyse private co-financing is a continuing challenge. More information on how public finance has, to date, mobilised private support for low-carbon development is important in understanding what has worked in the past, to achieve significantly scaled-up investment in the future (Whitley, 2013b).

Which sectors and activities climate finance should cover is another important question for both donors and developing country governments. In the transition to a low-carbon economy, both donors and national decision-makers are facing tough choices about 'bridging' solutions, such as natural gas investments (see chapter 4). National governments in SSA are also grappling with a diversity of objectives, from poverty reduction, through basic resource provision (energy, water, food, etc.), to trade competitiveness and sustainability. If maintaining or upgrading a coal-fired power plant can achieve a number of these policy objectives, should international climate finance be withheld, because it is not a renewable energy source? These trade-offs are an important consideration for donors, who wish to remain credible and accepted by SSA governments but equally must adhere to minimum low-carbon requirements (Lütkenhorst, Altenburg, Pegels and Vidican, 2014)

Although potentially distinct from climate finance, related investment in carbon markets provides an indication of private support for low-carbon development in Africa. From 2003-2013, the UN-led portion of the carbon market attracted investment of over $215 billion to projects in developing countries. However, as is well known, little of this reached Africa. Almost 80% of registered Clean Development Mechanism (CDM) projects took place in four countries (India, China, Brazil and Mexico) with only 3% of projects (and volume of carbon credits) across Africa (UNEP DTU, 2014). The CDM is currently being reformed to simplify the administrative and financial burden for the least developed countries to attract and absorb climate finance (UNFCCC, 2015).

10.5 Investment trends

In addition to the above, a review of broader investment in the region provides some information on current trends in private climate finance and support to the sectors reviewed in this report (see also Appendix 1).

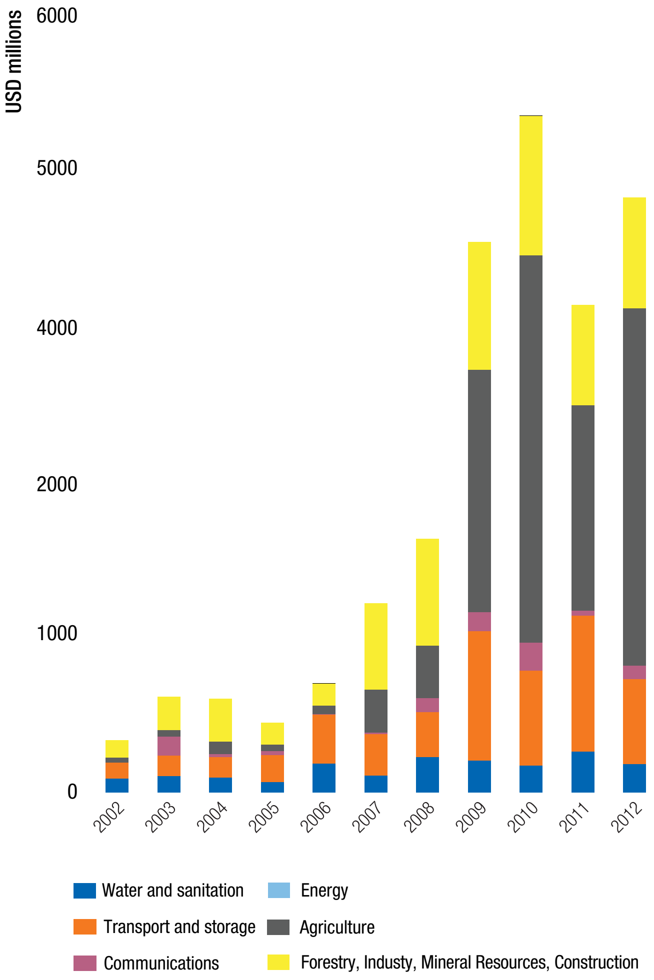
Grant-based and highly concessional support (Official Development Assistance - ODA) in SSA is tracked for the support provided by OECD countries. It is found to be focused on transport, energy, and water and sanitation (Figure 27). Contrastingly, less-concessional finance (with a grant element of less than 25%) and export-credits (Other Official Flows - OOF) focus on transport and agriculture, and the broad category 'forestry, industry, mineral resources and construction' (Figure 28). Wider investment is therefore primarily directed to activities in a small sub-set of sectors: predominantly energy and transport. This does not correlate with the large range of sectors requiring attention to achieve a low-carbon economy, nor does it correlate with some of the highest GHG-emitting sectors (such as agriculture, land-use and extractives)(Whitley et al, 2014).

A relatively new but very influential donor to SSA is China. Although data for China's support to SSA is not available from the World Bank and OECD data sets outlined above and in Appendix 1, it is currently the largest source of ODA and a major source of foreign direct investment (FDI) in the region. It also plays an important role in infrastructure development in many countries. Within SSA, Angola, Ethiopia, Zimbabwe, and Nigeria receive the greatest shares. Emerging oil and gas producers, Chad, Uganda, and Mozambique are also beneficiaries of Chinese FDI (IEA, 2014). China's support to SSA is only likely to increase with the recent establishment of the New

Development Bank (NDB – formerly referred to as the BRICS Development Bank), a multilateral development bank operated Brazil, Russia, India, China and South Africa.

China has turned to Africa for the primary resources needed to fuel its economic growth. As such, most ODA and FDI from China is unlikely to support low-carbon activities. Nevertheless, alongside the extractives sector, China has expanded its focus in SSA to include manufacturing industries. It has established a handful of special economic zones (SEZs) for Chinese manufacturing investors in the past 20 years. Following the model of Chinese SEZs, Ethiopia and Zambia have established their own economic zones for manufacturing. SEZs promise positive effects on Africa's economic transformation, with five Chinese SEZs creating around 20,000 jobs for Africans as of February 2015. However, local linkages remain limited, and this obstacle must be overcome before Chinese investments can lead to economy-wide transformational change (Tang, 2015).

Figure 28: Other Official Flows (non-concessional) to Africa by sector (US$ million)



Source: Whitley et al, 2014

11. Conclusion

In addition to grappling with significant social and economic challenges, SSA governments must join the global efforts to address the threat of dangerous climate change. This emerging responsibility for all governments to implement low-carbon policy will have specific implications for SSA.

Looking across the sectors, this report identified a series of 20 priority transitions that SSA governments can undertake to shift to a low-carbon development pathway (see Table 7).

A set of four criteria were used to rank the 20 transitions (see Table 8). Each was scored (from 1-5) based on whether the transition:

- Mitigates high levels of GHG emissions: the score is higher where the GHG emission sources linked to the transition are high and expected to grow.
- Avoids lock-in to GHG intensive activities (see chapter 9): the score is higher where government intervention is required now to avoid investments in high-carbon, slow-changing assets, including transport, electricity and building infrastructure.
- Increases productivity: the score is higher where the transition strengthens activities leading to higher productivity and contributes to economic development.
- Contributes to poverty reduction: the score is higher where the transition has the potential to contribute to reducing poverty, unemployment and inequality.

Many assumptions were made in assigning scores under each category, and the scores will vary significantly across different country contexts and depending on how the transition is implemented. Further research will be required to assign more robust scores, particularly under the poverty reduction category, which was not a central focus of this report. Until that research is completed, the results of this exercise should only be considered as indicative. Nonetheless, the exercise is useful in that it illustrates decision-making processes and criteria, beyond GHG emissions, that governments should use to prioritise sectors, interventions, and transitions within low-carbon development plans.

The analysis in the matrix below highlights seven high impact transitions (and groups of transitions) that we believe should be prioritised due to their contribution to low-carbon development, production, and poverty reduction in SSA (see Table 9). We have further categorised these transitions in terms of the types of policy tools most likely to support their development and the additional areas of focus needed to ensure that transitions can lead to 'win-wins' for economic development and climate.

Additional findings from our analysis are that the design and implementation of low-carbon policy in individual countries will need to be coordinated across many government agencies, ministries and departments. This is because the transitions cut across numerous sectors. Coordination at the central level by a government agency with broad responsibilities, such as the president's or prime minister's office, would help to identify the specific responsibilities of different government agencies (Kurukulasuriya, Schutte, Haywood & Rhodes, 2013). High-level political leadership would demonstrate the importance of low-carbon production to national objectives. This would need to be linked with internal incentives (within and across government) to lead to the changes in regulation, technology and behaviour required for low-carbon production (SDSN, 2014).

The 'championing' and 'incentivising' of low-carbon development must be supported by effective implementation across government. A common theme discussed in many of the low-carbon transitions is the need for institutional capacity building of government agencies and human resource development. This will include training in a variety of skills and competencies, ranging from land-use planning software, through low-carbon engineering, to finance.

Improving knowledge and engagement of private actors in low-carbon transitions will require communication and information campaigns to highlight that low-carbon objectives are in line with poverty reduction goals and improvements to quality of life. Increasing public understanding of the opportunities, direct and tangible benefits presented by low-carbon production can increase the likelihood of success.

In addition to the actions of individual governments, it is vital that international finance and other measures of support are provided. These will enhance the capacity of SSA governments to implement low-carbon policy. As demonstrated in chapter 10, while developed countries have agreed to take all practical steps to promote, facilitate and finance the transfer of environmentally sound technologies and knowledge, in practice they have largely failed at this task. In recognition of this failure, in 2010 the UNFCCC Conference of the Parties adopted the Technology Mechanism, including the Climate Technology Centre and Network (CTCN). This could be instrumental

Table 7: 20 transitions to support SSA countries in shifting to a low-carbon development pathway (and relevance across sectors)

Cross-sector transitions	Agriculture	Forestry	Energy	Transport	Extractives	Construction	Manufacturing
1. Reduce demand for agricultural land by intensifying production and reducing post-harvest waste	■			■			
2. Reduce emissions from livestock	■						
3. Diffuse climate-smart agriculture practices	■						
4. Integrate rural land-use planning	■	■	■	■	■		
5. Capture the value of forests' ecosystems services in public and private decision-making	■	■	■				
6. Formalise the charcoal industry, and promote efficient charcoal kilns and biomass cookstoves, and fuel switching		■	■				
7. Generate on-grid electricity from renewable sources and prevent lock-in of coal power			■				
8. Promote electricity access from off-grid and mini-grid systems in rural areas			■				
9. Remove subsidies to fossil fuel consumption			■		■	■	■
10. Shift to a low-carbon automobile fleet and fuels	■		■	■	■		
11. Implement higher density multi-use urban plans			■	■		■	
12. Promote mass transportation systems				■	■		
13. Strengthen the use of energy efficient processes and technologies in the extractives sector					■		
14. Switch to lower carbon fuel sources and renewable energy in the extractives sector			■		■		
15. Remove and avoid subsidies to fossil fuel production					■		
16. Reduce emissions from construction materials and methods						■	
17. Reduce emissions from building operations			■			■	
18. Increase use of energy efficient processes and technologies and clean energy in heavy manufacturing			■				■
19. Drive growth in light manufacturing			■				■
20. Develop low-carbon products	■	■	■	■		■	■

Each of the sector focused Chapters (2-8) provides individual recommendations for the specific transitions. This section navigates the synergies and trade-offs that exist between reducing GHG emissions, avoiding lock-in to high carbon development paths (see Chapter 9) and supporting inclusive economic growth.

in strengthening international technology transfer in favour of SSA's low-carbon transitions.

Current international flows of climate-related public and private finance are also inadequate and primarily directed toward high carbon activities in a small sub-set of sectors (energy and transport). To realise the 20 low-carbon transitions in this report, international financial and technical support will need to be scaled-up, and directed toward all of the sectors highlighted here.

Finally, international climate change policy is likely to result in shifts in comparative advantage and new trade opportunities and risks. SSA will need to adapt to these to achieve low-carbon policy aims. Border tax adjustments are being considered in part by some developed countries

Table 8: Scoring transitions according to their contribution to addressing climate change and supporting economic development (high 15+, medium 10+, low 5+)

Cross-sector transitions	High GHG reduction potential	Avoids lock-in to GHG intensive activities	Increases productivity	Contributes to poverty reduction	TOTAL (out of 20)
1. Reduce demand for agricultural land by intensifying production and reducing post-harvest waste	5	2	5	4	16
2. Reduce emissions from livestock	5	2	2	1	10
3. Diffuse climate-smart agriculture practices	3	2	3	2	10
4. Integrate rural land-use planning	5	3	3	4	15
5. Capture the value of forests' ecosystems services in public and private decision-making	4	3	2	2	11
6. Formalise the charcoal industry, and promote efficient charcoal kilns and biomass cookstoves, and fuel switching	2	2	2	4	10
7. Generate on-grid electricity from renewable sources and prevent lock-in of coal power	4	5	5	4	18
8. Promote electricity access from off-grid and mini-grid systems in rural areas	1	4	4	5	14
9. Remove subsidies to fossil fuel consumption	5	5	4	3	17
10. Shift to a low-carbon automobile fleet and fuels	4	4	3	1	12
11. Implement higher density multi-use urban plans	3	4	4	4	15
12. Promote mass transportation systems	3	5	4	4	16
13. Strengthen the use of energy efficient processes and technologies in the extractives sector	3	3	2	1	9
14. Switch to lower carbon fuel sources and renewable energy in the extractives sector	3	3	2	1	9
15. Remove and avoid subsidies for fossil fuel production	4	5	3	1	13
16. Reduce emissions from construction materials and methods	3	4	2	1	10
17. Reduce emissions from building operations	4	4	3	1	12
18. Increase use of energy efficient processes and technologies and clean energy in heavy manufacturing	4	5	4	1	14
19. Drive growth in light manufacturing	2	4	5	4	15
20. Develop low-carbon products	2	5	4	3	14

to prevent carbon leakage. These steps could have consequences for access to other export markets previously open to developing countries. In response, countries may need to implement new international standards taking into account the lifecycle of GHG emissions from goods production.

In the coming decades, SSA will experience rapid economic growth. Developing the necessary policies to transform SSA's infrastructure, natural and human resources in the near term, will play a large role in shaping SSA nations' growth going forward. It is crucial that SSA governments, development partners, civil society and the private sector all seize this opportunity to shift SSA's development along low-carbon pathways.

Table 9: Key considerations and interventions for priority low-carbon transactions

Transition	Key consideration(s) to ensure 'win-win'	Priority policy tools (see Figure 5)
Transition 1: Reduce demand for agricultural land by intensifying production	Ensure that productivity increases without converting forested land to cropland or pasture.	Regulatory and economic instruments and enforcement mechanisms to protect standing forests while increasing agricultural productivity. Economic and information instruments to promote practices and technologies that increase the intensity of agricultural production, such as irrigation and sustainable soil management techniques.
Transition 4: Integrate rural land-use planning	Ensure that land-use planning is undertaken in a manner that values ecosystem services (biodiversity, water, carbon) and is integrated across sectors.	Regulatory instruments to create long-term plans for land-use that take into account competing interests. Information and economic instruments (deployed within different levels of government) to set incentives that create buy-in for the valuation of ecosystem services and coordinate across sectors including forestry, transport, extractives, and agriculture.
Transition 7: Generate on-grid electricity from renewable sources and prevent lock-in of coal power	Ensure decision-makers have up-to date information on economic benefits of renewables as compared to fossil fuel power – in terms of lower (and falling costs) and security of supply.	Information instruments including technical support to develop national energy plans reflecting accurate costs of different energy sources, and to boost regional capacity for the development of energy technologies and projects. Economic instruments to de-risk investment in renewable energy technologies and secure finance for developers.
Transition 9: Remove subsidies to fossil fuel consumption	Ensure the costs of fossil fuel subsidies are widely communicated to decision-makers and the public.	Information instruments (including research, analysis and communication tools) to highlight the costs of subsidies to fossil fuel production and consumption. The decision to focus on economic, social, or environmental costs would depend on the subsidy type and current priorities (i.e. potential to address air pollution, the need for budget space to support education and health). Economic instruments to support the relevant complementary measures that should be implemented as part of reform.
Transitions 11 and 12: Implement higher density multi-use urban plans and promote mass transportation systems	Ensure urban infrastructure accommodate large increases in urban populations in a manner that incentivises mixed-use and high density.	Regulatory instruments to ensure high density urban plans are realised through enforceable and implementable zoning and planning regulations. Economic instruments (particularly public budget and public financial investments – domestic and international) to finance the development of mass transportation systems as part of high density urban planning, and well-linked to regional transport networks.
Transition 19: Drive growth in light manufacturing	Ensure growth of industries with high levels of added value and employment that are also low-carbon, such as light manufacturing.	Economic instruments including fiscal incentives to promote low-carbon business parks to support innovation, coordinate elements along the value chain and more easily supply clustered companies with energy and transport infrastructure. Information instruments to educate and train the skilled labour forces necessary to attract investment in low-carbon light manufacturing.

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Appendix 1: African countries included in international datasets

Dataset	PPI – World Bank	FDI – UNCTAD	ODA and OOF – OECD	FSF – ODI
Climate-relevant sectors covered	**Energy, Transport, Water and Sewerage (also by sub-sector)**	**None**	**Construction, Mineral Resources, Industry, Forestry, Agriculture, Energy, Communications, Transport and Storage, Water Supply and Sanitation (also by sub-sector)**	**Water and Sanitation, Energy, Forestry, Industry, Transport, Agriculture**
Algeria	x	x	x	x
Angola	x	x	x	x
Benin	x	x	x	x
Botswana	x	x	x	x
Burkina Faso	x	x	x	x
Burundi	x	x	x	x
Cameroon	x	x	x	x
Cape Verde	x	x	x	x
Central African Rep	x	x	x	
Chad	x	x	x	
Congo, Dem. Rep.	x	x	x	x
Congo (Zaire)	x	x	x	
Comoros		x	x	x
Djibouti	x	x	x	x
Egypt	x	x	x	x
Eritrea	x	x	x	x
Ethiopia	x	x	x	x
Equatorial Guinea		x	x	
Gabon	x	x	x	x
Gambia	x	x	x	x
Ghana	x	x	x	x
Guinea Bissau	x	x	x	
Guinea	x	x	x	
Côte d'Ivoire	x	x	x	x
Kenya	x	x	x	x
Lesotho	x	x	x	x
Liberia	x	x	x	x
Libya		x	x	
Madagascar	x	x	x	x
Malawi	x	x	x	x
Mali	x	x	x	x
Mauritania	x	x	x	x
Mauritius	x	x	x	x
Mayotte			x	
Morocco	x	x	x	x
Mozambique	x	x	x	x

Appendix 1: African countries included in international datasets (continued)

Dataset	PPI – World Bank	FDI – UNCTAD	ODA and OOF – OECD	FSF – ODI
Namibia	x	x	x	x
Niger	x	x	x	x
Nigeria	x	x	x	x
Rwanda	x	x	x	x
São Tomé and Principe	x	x	x	x
Senegal	x	x	x	x
Seychelles	x	x	x	x
Sierra Leone	x	x	x	
Somalia	x	x	x	x
South Africa	x	x	x	x
South Sudan	x	x	x	x
Sudan	x	x	x	x
St Helena			x	
Swaziland	x	x	x	
Tanzania	x		x	x
Togo	x	x	x	x
Tunisia	x	x	x	x
Uganda	x	x	x	x
Zambia	x	x	x	x
Zimbabwe	x	x	x	x

Note: x = available; not available.

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